ORIGINAL RESEARCH

Diagnostic Value of cTnl, NT-pro BNP, and Combined Tests in Acute Myocardial Infarction Patients

Junhui Shi, BM; Wei Wang, BM; Yongfang Sun, BM; Minzhi Zhou, BM; Jiang Liu, BM

ABSTRACT

Objective • Acute myocardial infarction (AMI) is characterized by heart damage resulting from blocked blood flow. Prompt diagnosis is vital for timely treatment and saving lives. This study aimed to evaluate the diagnostic value of cTnl, NT-pro BNP, and a combined test in AMI patients.

Methods • In this study, a retrospective observational design was employed, and we selected 221 patients with AMI admitted to our hospital within a 3-year period as the research subjects and included them in the AMI group. Additionally, 200 patients from the control group, who visited our hospital for physical examinations, were selected to compare the expressions of cardiac Troponin I (cTnl) and N-Terminal pro-B-type Natriuretic Peptide (NT-pro BNP) between the two groups. Receiver Operating Characteristic (ROC) curves were constructed to analyze the diagnostic value of cTnl combined with NT-pro BNP for AMI. Furthermore, AMI patients were categorized into four groups based on the New York Heart Association (NYHA) classification (grades I, II, III, and IV). The differences in cTnl, NT-pro BNP, and Left Ventricular Ejection Fraction (LVEF) were compared among the AMI patients with different cardiac function grades to analyze their correlation and diagnostic value in assessing the severity of AMI-related cardiac insufficiency.

Results • The levels of cTnl and NT-pro BNP in AMI patients were significantly higher than those in the control group, and their combined detection effectively facilitated the diagnosis of AMI occurrence. Moreover, cTnl and NT-pro BNP concentrations increased with the severity of cardiac dysfunction (NYHA grades) and showed a notable negative correlation with LVEF. Furthermore, the combined testing of cTnl and NT-pro BNP demonstrated significant value in evaluating the severity of AMI in patients.

Conclusions • The combined detection of cTnl and NT-pro BNP holds considerable application value in diagnosing AMI occurrence and assessing its severity. (*Altern Ther Health Med.* 2023;29(7):412-417).

Jiang Liu, BM, Attending Doctor; **Junhui Shi, BM**, Attending Doctor; **Wei Wang, BM**, Associate Chief Nurse; **Yongfang Sun, BM**, Supervisor Nurse; **Minzhi Zhou, BM**, Supervisor Nurse; Department of Cardiovascular Medicine, Zhejiang Xinan International Hospital, Jiaxing, China.

Corresponding author: Jiang Liu, BM
E-mail: lj13306732066@163.com

INTRODUCTION

Acute Myocardial Infarction (AMI) is a critical medical condition characterized by the acute blockage of a coronary artery and subsequent necrosis of the heart muscle due to inadequate blood supply. It falls under the category of acute coronary syndrome.[1] The incidence of AMI has been steadily increasing since 2002, with a notable surge in rural areas. In some years, the occurrence of AMI in rural regions has surpassed that in urban areas. For instance, in 2016, the mortality rate from AMI was 58.69 per 100 000 individuals in urban areas, while it reached 74.72 per 100 000 in rural areas.[2]

Current clinical studies have demonstrated that coronary atherosclerosis is the prevailing cause of AMI, with smoking history, diabetes, dyslipidemia, and other related independent risk factors significantly contributing to the occurrence of AMI.[3] These factors can lead to the obstruction of blood supply to the heart, resulting in myocardial necrosis. The affected myocardium continues to function with increasing oxygen consumption, creating an imbalance between oxygen supply and demand, ultimately leading to myocardial necrosis.[4]

The primary symptoms experienced by AMI patients include a sudden onset of pressing pain or a suffocating feeling in the precardiac area, lasting for more than 30 minutes, often accompanied by a sense of impending death.[5] In some cases, patients may report fatigue, chest discomfort, palpitations, shortness of breath, irritability, and precardiac pain, common symptoms of coronary heart disease, several days before the actual onset.[6] In some cases, a few patients may not experience pain but instead present with symptoms such as chest tightness, shortness of breath, dyspnea, cough, and other signs of heart failure at the onset.[7] There are also instances where patients may exhibit shock symptoms, including blurred consciousness, pale skin, cold limbs, generalized sweating, and decreased blood pressure.[6,7] As AMI occurs, various clinical indicators, including heart rate and blood pressure, also undergo varying degrees of change.

Currently, the diagnosis of AMI patients involves three main stages. Firstly, upon the patient's arrival at the hospital, vital signs such as blood pressure and heart rate are tested, and blood samples are collected for laboratory analysis. If the medical history and ECG provide a precise diagnosis, prompt treatment can be initiated. However, in cases where the diagnosis is uncertain, the ECG should be regularly reviewed every 30-60 minutes to monitor the condition until the laboratory examination report is completed. Dynamic observation of cardiac markers can aid in determining AMI presence.[8] Therefore, the assessment of laboratory indicators holds paramount importance in identifying AMI.

This study examines the expression of cTnl and NT-pro BNP in the serum of AMI patients, laying a theoretical foundation for establishing effective and accurate criteria for the clinical diagnosis of AMI.

PATIENTS AND METHODS

Study Design and Patients Selection

A retrospective collection of research subjects involved 221 patients diagnosed with AMI in our hospital between January 2020 and June 2022. These patients were included in the AMI group, while a control group of 200 individuals who visited the hospital for physical examinations was also selected. The study adhered to clinical ethics guidelines, ensuring the confidentiality of patient information. The inclusion criteria encompassed patients aged ≥ 18 years with a diagnosis of AMI,[9] including non-ST elevation myocardial infarction and ST elevation myocardial infarction, as per the 2017 European Society of Cardiology (ESC) clinical practice guidelinesfor the diagnosis and management of patients with AMI. Patients with congenital heart disease, malignant tumors, mental disorders, and immune dysfunction were excluded from the study.

cTnl and NT-pro BNP Detection

In patients with AMI, 3 ml of venous blood was drawn immediately after admission. For the control group, 3 ml of fasting venous blood was taken in the morning, and all samples were put into anticoagulant tubes. The serum levels of cTnl (Ortho Clinical Diagnostics, 6802301) and NT-pro BNP (Beijing Hotgen Biotech Co., Ltd, D22090221) were quantitatively measured using a chemiluminescence immunoassay system and respective kits according to the manufacturer's protocol.

Left Ventricular Ejection Fraction (LVEF) Detection

Left Ventricular Ejection Fraction (LVEF) was measured using a Color Doppler ultrasound diagnostic instrument (manufacturer: GE; Model: Vivid 7) equipped with an S5-1 probe operating at a frequency of 1.0~5.0 MHz. All subjects were positioned in the left decubitus position during the measurement of LVEF.

NYHA Classification

The grading criteria for cardiac function, as per the New York Heart Association (NYHA) classification, are as follows[10]: (1) Grade I: Patients with grade I have no restrictions in daily life, and ordinary activities do not cause symptoms such as dyspnea or angina; (2) Grade II: Patients in grade II experience slight limitations in physical activity, and they may not exhibit symptoms at rest. However, when performing ordinary activities, they might experience symptoms like dyspnea and angina pectoris; (3) Grade III: Patients with grade III experience significant limitations in daily activities, and they may encounter dyspnea even with minor daily tasks; (4) Grade IV: Patients in grade IV are unable to engage in any physical activity and suffer from heart failure symptoms such as dyspnea and angina pectoris even when at rest. These symptoms worsen after exercise.

The specific grading criteria are summarized in Table 1. Among the 221 patients included in this study, 45 cases were classified as grade I, 68 cases as grade II, 71 cases as grade III, and 37 cases as grade IV.

Statistical Analysis

Data analysis was conducted using Statistical Product and Service Solutions (SPSS) 25.0 statistical software (IBM, Armonk, NY, USA). Measurement data conforming to a normal distribution were expressed as ($\bar{x} \pm s$) mean ± standard deviation. The independent sample t test was utilized to compare data between groups, while one-way analysis of variance (ANOVA) was performed for multiple group comparisons. Descriptive statistical data analysis was conducted using percentages, and the χ^2 test was applied for categorical variables. Pearson correlation coefficient was calculated to assess correlations, and the diagnostic value was assessed using ROC (Receiver Operating Characteristic) analysis. Statistical significance was set at $P < .05$.

RESULTS

Comparison of Baseline Data between AMI Group and Control Group

The baseline data revealed that the AMI group had a significantly higher number of patients with a smoking history, drinking history, diabetes, and hypertension compared to the control group. This finding is consistent with current clinical studies on factors influencing the incidence of AMI. However, the two groups exhibited no significant differences in other baseline data, demonstrating a certain degree of comparability ($P > .05$). Refer to Table 1 for detailed results.

Table 1. Comparison of Baseline Data between the AMI Group and Control Group

Variable	AMI Group (n = 221)	Control Group (n = 200)	t/χ^2	*P* value
Age(years)	61.64 ± 8.00	62.17 ± 7.56	-0.699	.485
Gender			0.113	.736
Man	146(66.06)	129(64.50)		
Woman	75(33.94)	71(35.50)		
BMI(kg/m^2)	22.68 ± 1.39	22.51 ± 1.41	1.211	.227
Degree of education			1.330	.514
Primary School and below	165(74.66)	154(77.00)		
Middle School to High School	43(19.46)	39(19.50)		
University or above	13(5.88)	7(3.50)		
Smoking n(%)	156(70.59)	110(55.00)	10.967	.001
Drinking n(%)	165(74.66)	128(64.00)	5.639	.018
Diabetes n(%)	131(59.28)	98(49.00)	4.469	.035
Hypertension n(%)	143(64.71)	104(52.00)	6.990	.008
Family History n(%)	85(38.46)	61(30.50)	2.938	.087

Note: Values are presented as mean ± standard deviation for continuous variables and n (%) for categorical variables. *t* tests were used for continuous variables, and χ^2 tests were used for categorical variables to assess the significance between the AMI and control groups. $P < .05$ was considered statistically significant.

Table 2. Diagnostic Performance of cTnl and NT-pro BNP in AMI

Biomarker	AUC	95%CI	Sensibility (%)	Specificity (%)	Cutoff Value
cTnl	0.617	0.568~0.663	61.09	65.50	> 3.35 ng/ml
NT-pro BNP	0.598	0.550~0.645	66.06	60.50	> 518.56 pg/ml
Combined diagnosis	0.896	0.862~0.923	85.79	92.50	--
$Z/P_{\text{cTnl \& Combined Diagnosis}}$	10.121 / <.001				
$Z/P_{\text{NT-pro BNP \& Combined Diagnosis}}$	11.032 / <.001				

Note: AUC: Area Under the Curve: CI: Confidence Interval; Z/P: *Z* statistic/*P* value. Sensibility and specificity are presented as percentages. Cutoff values represent the threshold for diagnostic classification. Combined Diagnosis refers to the combined detection of cTnl and NT-pro BNP for diagnosing AMI. Z/P values are calculated to compare combined diagnosis with individual biomarkers, where Z represents the Z statistic, and *P* represents the corresponding *P* value.

Comparison of Serum Levels of cTnl and NT-pro BNP between AMI Group and Control Group

Upon analysis, the AMI group exhibited significantly higher expressions of cTnl and NT-pro BNP, with values of (5.01 ± 2.03) ng/ml and (730.17 ± 268.81) pg/ml, respectively, compared to the control group, where the corresponding values were (0.02 ± 0.01) ng/ml and (71.79 ± 23.29) pg/ml, as depicted in Figure 1.

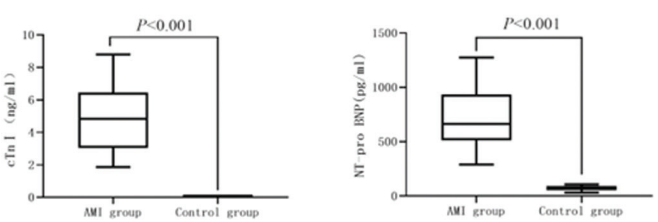
The Diagnostic Value of Combined cTnl and NT-pro BNP Detection for AMI

The diagnostic efficacy is presented in Table 2. The findings demonstrate that the combined detection of cTnl and NT-pro BNP in diagnosing AMI exhibits significantly higher efficacy than a single diagnosis, with increased sensitivity and specificity, as illustrated in Figure 2.

Comparison of cTnl, NT-pro BNP, and LVEF Levels in AMI Patients with Different Cardiac Function Grades

The results indicated a gradual increase in cTnl and NT-pro BNP expressions in AMI patients with the increase of cardiac function grade, while LVEF demonstrated a downward trend with the increase of cardiac function grade, as depicted in Table 3 and Figure 3.

Figure 1. Comparison of Serum cTnl and NT-pro BNP Levels between AMI Group and Control Group

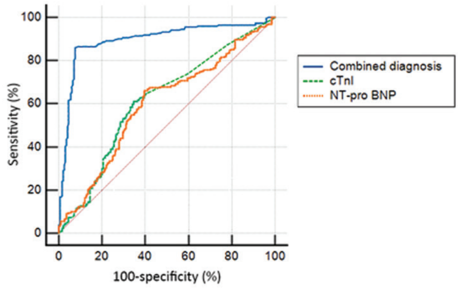


Note: The figure compares serum cardiac Troponin I (cTnl) and N-Terminal pro-B-type Natriuretic Peptide (NT-pro BNP) levels between the AMI and control groups. The data are depicted in ng/ml for cTnl and pg/ml for NT-pro BNP.

Correlation between cTnl, NT-pro BNP, and LVEF

Pearson correlation analysis revealed a significant negative correlation between cTnl and NT-pro BNP expression and LVEF ($P < .05$). This finding further confirms that higher cTnl and NT-pro BNP expression levels are associated with more severe impairment of cardiac function in AMI patients, as illustrated in Figure 4.

Figure 2. Combined Diagnostic Efficacy Diagram



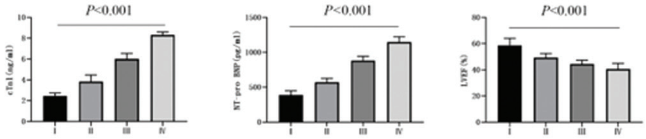
Note: The figure displays the diagnostic efficacy of the combined detection of cardiac Troponin I (cTnl) and N-Terminal pro-B-type Natriuretic Peptide (NT-pro BNP) for AMI. The diagram provides insights into the sensitivity and specificity of the combined diagnosis, which is represented as the area under the curve (AUC) of the receiver operating characteristic (ROC) curve. The higher AUC value indicates improved diagnostic accuracy.

Table 3. Cardiac Biomarker Levels and LVEF in AMI Patients with Different Cardiac Function Grades

Grade	n	cTnl (ng/ml)	NT-pro BNP (pg/ml)	LVEF (%)
I	45	2.47 ± 0.28	286.64 ± 61.23	58.80 ± 5.32
II	68	3.84 ± 0.62	572.73 ± 54.68	49.45 ± 3.04
III	71	6.01 ± 0.53	881.16 ± 61.26	44.45 ± 2.89
IV	37	8.32 ± 0.28	1147.59 ± 75.99	40.65 ± 4.30
F		1202.577	1303.376	192.171
P value		<.001	<.001	<.001

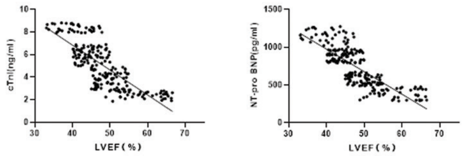
Note: cTnl: cardiac Troponin I; NT-pro BNP: N-Terminal pro-B-type Natriuretic Peptide; LVEF: Left Ventricular Ejection Fraction. Data are presented as mean ± standard deviation for cTnl, NT-pro BNP, and LVEF levels in AMI patients with different cardiac function grades (I, II, III, IV). The statistical significance of differences among groups is indicated by the F and *P* values obtained from one-way analysis of variance (ANOVA), where *F* represents the *F* statistic and *P* represents the corresponding *P* value.

Figure 3. Comparison of cTnl, NT-pro BNP, and LVEF Levels in Each Cardiac Function Grade Group.



Note: The figure illustrates the comparison of cardiac Troponin I (cTnl), N-Terminal pro-B-type Natriuretic Peptide (NT-pro BNP), and Left Ventricular Ejection Fraction (LVEF) levels among different cardiac function grade groups (Grade I, Grade II, Grade III, and Grade IV) in AMI patients. The data are presented in ng/ml for cTnl, pg/ml for NT-pro BNP, and as a percentage for LVEF.

Figure 4. Correlation Analysis between cTnl, NT-pro BNP, and LVEF



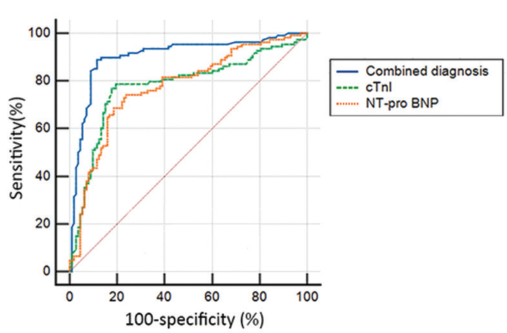
Note: The figure presents a correlation analysis between cardiac Troponin I (cTnl), N-Terminal pro-B-type Natriuretic Peptide (NT-pro BNP), and Left Ventricular Ejection Fraction (LVEF) in AMI patients. The analysis is based on the Pearson correlation coefficient, which measures the strength and direction of linear relationships between variables.

Table 4. Diagnostic Performance of cTnl and NT-pro BNP in Assessing AMI Severity

Biomarker	AUC	95%CI	Sensibility (%)	Specificity (%)	Cutoff Value
cTnl	0.777	0.717~0.830	78.70	80.53	> 4.48
NT-pro BNP	0.773	0.712~0.826	74.07	76.11	>621.88
Combined Diagnosis	0.905	0.858~0.940	88.89	88.50	--
$Z/P_{\text{cTnl \& Combined}}$	4.135 / <.001				
$Z/P_{\text{NT-pro BNP \& Combined}}$	4.271 / <.001				

Note: AUC: Area Under the Curve; CI: Confidence Interval; *Z*/*P*: *Z* statistic/*P* value. Sensibility and specificity are presented as percentages. Cutoff values represent the threshold for diagnostic classification. Combined Diagnosis refers to the combined detection of cTnl and NT-pro BNP for assessing AMI severity. *Z*/*P* values are calculated to compare combined diagnosis with individual biomarkers, where *Z* represents the *Z* statistic, and *P* represents the corresponding *P* value.

Figure 5. Efficacy of cTnl and NT-pro BNP Combined Test in Evaluating AMI Severity.



Note: The figure depicts the diagnostic efficacy of the combined detection of cardiac Troponin I (cTnl) and N-Terminal pro-B-type Natriuretic Peptide (NT-pro BNP) for assessing the severity of acute myocardial infarction (AMI). The diagram illustrates the diagnostic performance of the combined test, which is represented as the area under the curve (AUC) of the receiver operating characteristic (ROC) curve. A higher AUC value indicates improved diagnostic accuracy.

Diagnostic Value of cTnl and NT-pro BNP in Assessing the Severity of AMI

The diagnostic efficacy is presented in Table 4 and Figure 5. The results demonstrate that the combined detection of cTnl and NT-pro BNP can accurately and effectively evaluate the severity of AMI in patients.

DISCUSSION

AMI refers to myocardial necrosis caused by acute and prolonged ischemia and hypoxia in the coronary arteries, clinically characterized by severe and persistent retrosternal pain that is not fully relieved by rest and nitrates. It is accompanied by increased serum myocardial enzyme activity and progressive electrocardiogram changes and may be complicated by arrhythmia, shock, or heart failure, often posing a life-threatening condition.[11]

In recent years, the incidence of AMI has been on the rise due to changes in lifestyle and diet patterns, making it the most common cause of sudden death in young and middle-aged individuals. Once the blood vessel is blocked, myocardial tissue necrotizes after approximately 30 minutes, with complete necrosis occurring within 6 to 8 hours. During this critical period, the early opening of blocked blood vessels becomes crucial, as it can significantly impact the amount of viable myocardial tissue and patient outcomes.[12]

According to the findings of this study, the expressions of cTnl and NT-pro BNP in the serum of AMI patients were markedly higher than those observed in the control group. Cardiac Troponin I (cTnI), a myocardial-specific protein molecule responsible for maintaining the contraction and relaxation of myocardial fibers, can be released into the bloodstream when myocardial cells are damaged. As a result, cTnI is widely utilized in diagnosing acute myocardial injury diseases. Therefore, serum cTnI levels increase during myocardial injury or stimulation.[13] Similarly, NT-pro BNP, a cardiac neurohormone synthesized and secreted by the heart, shows a significant increase in its expression in the serum of AMI patients. It occurs when the ventricle is filled or when myocardial fibers are stimulated, leading to the secretion of a considerable amount of NT-pro BNP.[14]

Furthermore, the 221 AMI patients were divided into four groups based on different degrees of cardiac function. The comparison of LVEF, cTnl, and NT-pro BNP revealed a gradual increase in the levels of cTnl and NT-pro BNP in AMI patients with an increase in cardiac function grade. Conversely, LVEF demonstrated a progressive downward trend. The Pearson correlation analysis further validated a significant negative correlation between cTnl, NT-pro BNP, and LVEF.[15]

This analysis suggests that LVEF serves as an essential indicator for evaluating left ventricular function. In AMI patients, arrhythmia can lead to uneven myocardial echo and left ventricular thrombosis, resulting in significantly reduced LVEF. As the severity of AMI increases, arrhythmia symptoms worsen, leading to lower LVEF performance.[14,15] Conversely, cTnl and NT-pro BNP are released in large quantities when cardiomyocytes and myocardial fibers are damaged. Consequently, their expression levels increase in the blood. Therefore, a drop in LVEF in AMI patients indicates varying degrees of cardiomyocyte and fiber damage, further promoting the secretion of large amounts of cTnl and NT-pro BNP into the bloodstream, creating a negative correlation.[14]

Given the highly significant differences observed in cTnl and NT-pro BNP levels among AMI patients and those with varying degrees of cardiac function, this study further reinforces the clinical applicability of combined cTnl and NT-pro BNP detection by constructing ROC curves. The results demonstrated that the combined detection of cTnl and NT-pro BNP offers an effective classification method for assessing AMI and an efficient tool for evaluating the disease severity in AMI patients.

The study suggests that using cTnl and NT-pro BNP in clinical practice can provide reliable indicators for diagnosing AMI and evaluating the patient's condition.

Study Limitations

The current study has a few limitations that should be acknowledged. Firstly, the study design was retrospective, which may introduce bias and limit the ability to establish causal relationships. Additionally, the sample size was relatively small, which might impact the generalizability of the findings. Moreover, the study only included patients from a single hospital, which may not fully represent the broader population. The exclusion of patients with certain medical conditions could also limit the study's applicability to patients with comorbidities. Furthermore, the use of specific laboratory kits and equipment may have influenced the results and limited the comparability with other studies. Despite these limitations, the study provides valuable insights into the diagnostic value of cTnl and NT-pro BNP in AMI patients, and further research with larger and more diverse populations is warranted to validate these findings.

CONCLUSION

In conclusion, this study demonstrates the significant diagnostic value of combined cTnl and NT-pro BNP detection in AMI patients. Compared to the control group, the elevated expressions of cTnl and NT-pro BNP in AMI patients highlight their potential as valuable biomarkers for diagnosing AMI. Furthermore, the correlation between cTnl, NT-pro BNP, and LVEF reaffirms their role in assessing the severity of cardiac dysfunction in AMI patients. The findings underscore the clinical utility of cTnl and NT-pro BNP in aiding AMI diagnosis and also provide a reference for the auxiliary assessment of AMI severity. These biomarkers can serve as reliable indicators for healthcare professionals in the timely and accurate identification of AMI, contributing to improved patient outcomes and effective treatment strategies. However, the single-center approach also warrants caution in generalizing the results to broader populations.

DATA AVAILABILITY

The simulation experiment data used to support the findings of this study are available from the corresponding author upon request.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

AUTHORS' CONTRIBUTIONS

JL and JS designed the study and performed the experiments, JS and WW collected the data, YS and MZ analyzed the data, and JL prepared the manuscript. All authors read and approved the final manuscript.

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None

REFERENCES

1. Kapur NK, Thayer KL, Zweck E. Cardiogenic Shock in the Setting of Acute Myocardial Infarction. *Methodist DeBakey Cardiovasc J*. 2020;16(1):16-21. doi:10.14797/mdcj-16-1-16
2. DeFilippis AP, Chapman AR, Mills NL, et al. Assessment and Treatment of Patients With Type 2 Myocardial Infarction and Acute Nonischemic Myocardial Injury. *Circulation*. 2019;140(20):1661-1678. doi:10.1161/CIRCULATIONAHA.119.040631
3. Zeymer U, Bueno H, Granger CB, et al. Acute Cardiovascular Care Association position statement for the diagnosis and treatment of patients with acute myocardial infarction complicated by cardiogenic shock: A document of the Acute Cardiovascular Care Association of the European Society of Cardiology. *Eur Heart J Acute Cardiovasc Care*. 2020;9(2):183-197. doi:10.1177/2048872619894254
4. Elbadawi A, Elgendy IY, Omer M, et al. Outcomes of Acute Myocardial Infarction in Patients with Familial Hypercholesteremia. *Am J Med*. 2021;134(8):992-1001.e4. doi:10.1016/j.amjmed.2021.03.013
5. Femia G, French JK, Juergens C, Leung D, Lo S. Right ventricular myocardial infarction: pathophysiology, clinical implications and management. *Rev Cardiovasc Med*. 2021;22(4):1229-1240. doi:10.31083/j.rcm2204131
6. Tehrani BN, Basir MB, Kapur NK. Acute myocardial infarction and cardiogenic shock: should we unload the ventricle before percutaneous coronary intervention? *Prog Cardiovasc Dis*. 2020;63(5):607-622. doi:10.1016/j.pcad.2020.09.001
7. Lemor A, Ya'qoub L, Basir MB. Mechanical Circulatory Support in Acute Myocardial Infarction and Cardiogenic Shock. *Interv Cardiol Clin*. 2021;10(2):169-184. doi:10.1016/j.iccl.2020.12.005
8. Mizutani Y, Ishikawa T, Nakahara S, Taguchi I. Treatment of Young Women with Acute Myocardial Infarction. *Intern Med*. 2021;60(2):159-160. doi:10.2169/internalmedicine.5883-20
9. Lang IM. What is new in the 2017 ESC clinical practice guidelines : management of acute myocardial infarction in patients presenting with ST-segment elevation. *Wien Klin Wochenschr*. 2018;130(13-14):421-426. doi:10.1007/s00508-018-1333-0
10. Bredy C, Ministeri M, Kempny A, et al. New York Heart Association (NYHA) classification in adults with congenital heart disease: relation to objective measures of exercise and outcome. *Eur Heart J-Qual Car*. 2018;4(1):51-58. doi:10.1093/ehjqcco/qcx031
11. Josiassen J, Møller JE, Holmvang L, Hassager C. Interventional treatment of acute myocardial infarction-related cardiogenic shock. *Curr Opin Crit Care*. 2021;27(4):433-439. doi:10.1097/MCC.0000000000000835
12. Occhipinti G, Bucciarelli-Ducci C, Capodanno D. Diagnostic pathways in myocardial infarction with non-obstructive coronary artery disease (MINOCA). *Eur Heart J Acute Cardiovasc Care*. 2021;10(7):813-822. doi:10.1093/ehjacc/zuab049
13. Fan J, Ma J, Xia N, Sun L, Li B, Liu H. Clinical Value of Combined Detection of CK-MB, MYO, cTnI and Plasma NT-proBNP in Diagnosis of Acute Myocardial Infarction. *Clin Lab*. 2017;63(3):427-433. doi:10.7754/Clin.Lab.2016.160533
14. Celebi S, Celebi OO, Cetin S, et al. The Usefulness of Admission Plasma NT-pro BNP Level to Predict Left Ventricular Aneurysm Formation after Acute ST-Segment Elevation Myocardial Infarction. *Arq Bras Cardiol*. 2019;113(6):1129-1137. doi:10.5935/abc.20190226
15. Inandiklioglu N, Demir V, Celik Y, Demirtas M; Leukocyte telomere length and lipid parameters in patients with myocardial infarction with non-obstructive coronary arteries. *Cell Mol Biol*. 2021;67(6):346-352. doi: 10.14715/cmb/2021.67.6.45