Original Article

Analysis of risk factors in patients with acute myocardial infarction based on coronary imaging analysis

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Abstract

Objective: This paper uses coronary imaging to explore the risk factors of patients with acute myocardial infarction, and to analyse the effect of coronary imaging on the analysis of risk factors for patients with acute myocardial infarction.

Methods: This paper uses coronary imaging analysis to analyse the risk factors of patients with acute myocardial infarction.

Results: Single vessel disease is a leading disease in young AMI patients (34 cases, accounting for 54.0%), this mostly affects the left anterior descending artery (51 cases, accounting for 81.0%), followed by the right coronary artery (30 cases, accounting for 47.6%), in elderly patients with AMI the disease presents in three-vessels (77 cases, accounting for 55.8%), and the left main trunk is mostly affected in the elderly.

Conclusion: The risk factor analysis method of patients with acute myocardial infarction based on coronary imaging analysis has a good effect. [*Ethiop. J. Health Dev.* 2023; 37(1) 000-000]

Keywords: coronary artery imaging; acute myocardial infarction; risk factors; imaging analysis

Introduction

At present, the most commonly used methods to check for coronary heart disease include an electrocardiogram, myocardial enzyme spectrum, echocardiography, CT, magnetic resonance imaging, nuclear medicine myocardial perfusion imaging, coronary angiography, etc. The specificity of ECG is not high and its effect is limited; myocardial enzymes generally begin to increase several hours after myocardial infarction. CT, MRI and nuclear medicine myocardial perfusion imaging and other inspection methods are expensive, complicated and time-consuming, and CT Radioactive, radionuclide perfusion imaging agents, etc. have different degrees of damage to the patient's body, so these inspection methods are difficult to use repeatedly in the diagnosis, treatment and review of coronary heart disease over a period of time. Echocardiography is simple, convenient and cheap. The inspection period is short, the information provided is sufficient for diagnosis, there is no radiation or other known hazards and the inspection can be repeated many times. Echocadiography has become the routine method of inspection for the diagnosis of coronary heart disease. Although coronary angiography is the gold standard for diagnosing coronary heart disease, it is generally not the first choice because it is an invasive method. Coronary angiography can perform balloon dilation or stent implantation, recanalize stenotic arteries, and at the same time, it can perform interventional therapy on stenosis-related arteries.

Myocardial infarction is currently one of the most common causes of abnormal deaths in the urban population during the process of urbanization and population aging in China. The number of deaths exceeds one million every year, and it is still on the rise (1). For acute myocardial infarction, electrocardiography (ECG) is the most common and preferred non-invasive examination (2). When a patient's 12-lead ECG shows a deep and broad Q wave (pathological Q wave) and abnormal elevation or depression of the ST segment, it usually indicates myocardial infarction (3). However, in some 25% - 63% patients with a clear history of myocardial infarction and pathological Q waves in the ECG, the pathological Q waves may disappear within a period of time. The reason may be due to severe ischemia of the myocardium, which causes a large amount of potassium ions in the cell to transfer to the outside of the cell, causing the negative value of the cell membrane polarization to decrease, which leads to an increase in the triggering action potential threshold (4). This makes it difficult or impossible to conduct action potentials and exhibits a similar infarct performance. From an electrophysiological point of view, the myocardium has been "inactivated", so it exhibits pathological Q waves. However, due to the fact that the myocardial morphology and structure have not yet experienced "necrosis", and due to the development of current treatment methods such as antiplatelet, thrombolysis, and vascular interventional therapy, the patient's ischemia can be corrected in time and the Q wave disappears.

Recent studies have confirmed that the prerequisite for normal myocardial perfusion is to have a healthy and well-functioning microcirculation in addition to a large epicardial coronary artery without obstruction. In imaging, the entire coronary artery system is divided into four parts according to the size of the tube: epicardial (>500μm), pre-arterioles (100~500μm), arterioles (10~100μm) and myocardial capillaries (5~10μm). The small arteries and myocardial capillaries together constitute the coronary microcirculation network. However, coronary angiography, which is the "gold standard", can only demonstrate coronary blood vessels above 200μm, and is helpless for the detection of coronary microcirculation below 200μm.

There are two methods for clinically diagnosing the state of coronary microcirculation: qualitative

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diagnosis and quantitative diagnosis. Qualitative diagnosis has strong subjective dependence, poor reproducibility, and it is not easy to establish a unified diagnostic standard, so the value of quantitative diagnosis is higher. There are many parameters that can be used to quantitatively diagnose the state of coronary microcirculation. The myocardium's uptake of oxygen in the blood is close to the maximum at rest. For example, when the demand for oxygen demand in the myocardium increases during exercise or pressure, the myocardium can only increase the MBF to achieve the additional oxygen demand of the myocardium. This ability to increase the MBF by increasing the coronary blood flow from the resting state to the congested state when the oxygen requirement increases or the coronary arteries are dilated due to neurohumoral factors and the introduction of drugs is called coronary artery blood flow reserve (CFR). There are currently two methods for invasive determination of CFR. One is to use the Doppler guide wire to measure the average peak of velocity (APV) at rest and under pressure respectively, and to reflect the change in MBF through the change of APV, in order to calculate the CFRDoppl. The second is by adding a temperature sensor with a measurement accuracy of 0.02 degrees Celsius to the tip of the pressure wire. When injecting warm normal saline into the coronary artery, because the temperature sensor can sense the temperature difference between blood and normal saline, the time for warm normal saline to leave the guiding catheter to the tip of the guide wire can be calculated by calculating the Transit mean time (Tmn). Moreover, this method separately records the Tmn at rest and under pressure, and calculates the CFRthermo by reflecting the change of MBF through the change of Tmn. However, because this method is invasive, its clinical application is limited.

With the accumulation of nearly 30 years of experience in non-invasive measurement of MBF, currently available clinical methods for the non-invasive measurement of MBF include: positron emission tomography (PET/CT), single photon emission computed tomography (SPECT), CT myocardial perfusion imaging (CT-MPI), MRI myocardial perfusion imaging (MRI-MPI), and myocardial contrast echocardiography (MCE). Among them, PET/CT has become an alternative non-invasive quantitative measurement of MBF and is considered as the "gold standard". However, PET/CT is affected greatly by the heart beat and the breathing movements, and is very expensive. It is also affected by the tracer hemodynamic model and the quantitative calculation process is complicated. Secondly, it has radioisotope damage, so it cannot be used as a routine examination in clinical work. Echocardiography has naturally become the best choice for clinical routine imaging examinations due to its safety, convenience, low cost, and the benefits of bedside performance. With the continuous development of technologies related to contrast-enhanced ultrasound and ultrasound microbubble contrast agents, a technology called myocardial contrast-enhanced ultrasound (MCE) has gradually developed. It uses low mechanical index real-time ultrasound imaging, quantitative measurements of MBF and combined stress ultrasound quantitative coronary flow reserves (CFR) to quantitatively evaluate the functional status of coronary microcirculation, but whether its conclusions are accurate and reliable requires further investigation.

The main purpose of this study was to investigate the risk factors and coronary imaging characteristics of patients with acute myocardial infarction (AMI).

Related work

Coronary atherosclerotic heart disease is a heart disease caused by various damage factors that cause coronary artery stenosis, occlusion, or functional changes (spasm) resulting in insufficient blood supply or even necrosis of the myocardium. Coronary heart disease is the number one killer of human health in the world. With the improvement of medical standards, the mortality rate of CHD in the world has declined in the past 40 years , but among people over 35 years old, the deaths caused by CHD still account for 1/3 or more of the total deaths [5], and this trend has decreased since 1990. The downward trend of coronary heart disease may be related to changes in risk factors and to the improvement of treatment measures. Changes in risk factors, including decreased smoking prevalence (attributable ratio of 12%), decreased systolic blood pressure (attributed ratio of 20%), total cholesterol decrease (attributed ratio of 24%), and a decrease in physical inactivity (attributed ratio of 5%) may also be the reason behind the steady decline of CHD in 35 year olds (6). The improvement of treatment measures includes initial treatment of acute coronary syndrome, secondary prevention of coronary heart disease, revascularization of chronic angina pectoris, and medical treatment of heart failure. The reason for the decreasing trend of coronary heart disease since 1990, is the increase in body mass index and the increase in the prevalence of diabetes, both of which work together to increase the number of deaths by 18%. Worldwide, due to the differences in economic and health development, in developing countries, coronary heart disease is still a major disease that seriously affects the lives of people (7).

The pathophysiological difference between the two is that the pathological basis of STEMI, the thrombosis, completely blocks the coronary blood vessels, while the NSTEMI is that the thrombosis does not completely block the coronary arteries or microembolism. Non-ST-segment elevation myocardial infarction mostly has a chronic progressive onset, prone to recurrent angina pectoris, re-infarction rate and the long-term mortality rate (8). The treatment principle of NSTEMI is antithrombotic but not thrombolysis, because the coronary thrombus in NSTEMI is mostly platelet-rich white thrombus. Thrombolytic drugs have no beneficial effect on platelet thrombosis, but will activate platelets, aggravate the progression of thrombosis, and cause vascular occlusion (9). The

treatment of NSTEMI is mainly drug therapy, and some patients whose symptoms are not well controlled by drugs need interventional therapy. Studies have found that early interventional therapy may be more beneficial for middle-high-risk patients (10). The difference between UA and NSTEMI is whether the ischemia is severe enough to cause sufficient myocardial damage.

In the initial evaluation of patients with ischemic chest pain, UA and NSTEMI are usually difficult to distinguish, because the detection of myocardial damage markers after MI is delayed. It takes 4-6 hours for the myocardial damage markers to be released into the blood at detectable levels. Sometimes it may take 12 hours for patients to detect an increase in troponin (Tn). Non-ST-segment elevation myocardial infarction (NSTEMI), the clinical manifestations are often atypical, or chest pain symptoms are mild, manifested as shoulder, back or left upper limb pain, and some patients even suffer from irritability, chest tightness, sweating, nausea, vomiting, abdominal pain, etc. Symptoms are the chief complaint. Because the clinical symptoms are mild or atypical, the ECG has no specific manifestations, and the early myocardial injury markers have not yet increased (11).

The ECG changes of non-ST-segment elevation myocardial infarction may be related to the following pathological factors: the location of the infarction, the type of thrombus, the degree of affected vessel occlusion, time, autolysis, and collateral compensation. Studies have found that (12) the infarcts of STEMI patients are mostly located at the proximal end of the blood vessel. The descending artery and right coronary artery are common in the past, while the infarcts of NSTEMI are mostly located at the distal end of the blood vessel. These findings are consistent with other research in the field. The reasons for the analysis may be the following two aspects: 1. The NSTEMI lesion is mainly the former descending branch and the distal end of the circumflex branch, which is close to the apex of the heart, and the collateral circulation is abundant. In myocardial infarction, the ECG does not appear with a ST-segment elevation; Secondly, the standard 18-lead ECG is not sensitive to the detection of distal vascular lesions (13). ST-segments and/or T-wave changes usually persist in NSTEMI patients, but are mostly transient changes in UA patients. The number of ST-segment depression and the degree of depression are positively correlated with the severity of ischemia, which can indicate Prognosis. With the acceleration of population aging, the incidence of non-ST-segment elevation myocardial infarction is increasing annually. The reasons may be due to the chronic disease course, mild symptoms, accompanying multiple diseases, non-specific ECG performance, etc. Not enough information is available about the disease and it often goes undiagnosed. Although non-ST-segment elevation myocardial infarction is relatively mild, it has the characteristics of a high reinfarction rate, high long-term mortality, common three-vessel disease of the coronary artery, and more commonly collateral circulation (14).

Materials and methods

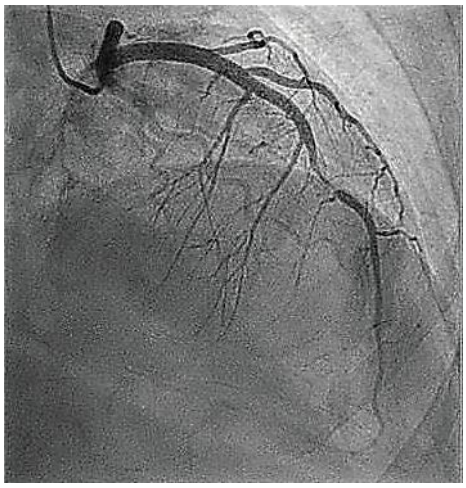
This research utilizes young patients as participants for this research.

Selection criteria: Patients who meet the diagnostic criteria for AMI established by the Cardiovascular Branch of the Chinese Medical Association. . This research included patients with complete coronary angiography data, who were enrolled at the hospital from April 2019 to September 2021. Exclusion criteria: (1) Renal insufficiency (increased blood creatinine more than 1 times the upper limit of normal); (2) Incomplete case data; (3) AMI patients aged 45-74 years.

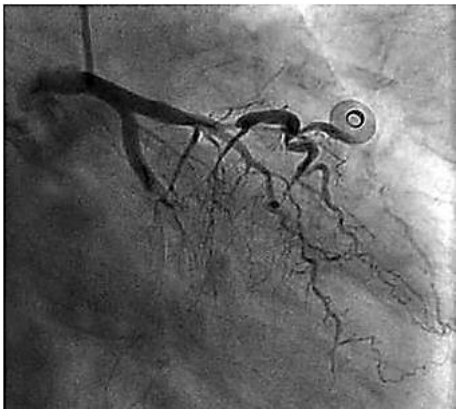
Diagnostic criteria for the study included the following observations: A family history of coronary heart disease was considered a first-generation immediate relative (father <55 years old, mother <65 years old) with coronary heart disease; a family history of heart disease was a first-generation immediate relative (father <55 years old, mother <65 years old) with coronary heart disease ; Hypertension is the resting systolic blood pressure ≥140mmHg or diastolic blood pressure ≥90mmHg (measured at least twice); Diabetes refers to the symptoms of diabetes + random blood glucose ≥ 11.1 mmol/L, or fasting blood glucose ≥ 7.0 mmol/L, and the 2-h blood glucose in the oral glucose tolerance test ≥ 11.1.trgnol/L (at least 2 times); Body mass index (BMI)=weight/height (kg/m2), ≥28 means obesity; drinkers calculate drinking index (drinking index=g/day×number of drinking years)>150 means alcoholism; the diagnostic criteria for dyslipidemia are based on the guidelines for the prevention and treatment of dyslipidemia in adults, The diagnostic criteria for dyslipidemia are total cholesterol ≥ 5.2 mmol/L, that is, greater than 200 mg/dL; low-density lipoprotein cholesterol ≥ 3.4 mmol/L, that is, greater than 130 mg/L; 40mg/dL; triglyceride ≥1.7mmol/L, that is, greater than 200mg/dL. (16).

Coronary angiography methods and judgment criteria: Both groups of patients had undertaken coronary angiography (CAG) via the Judkins method. Any one of the left main trunk, left anterior descending branch, left circumflex branch and right coronary artery with luminal stenosis ≥50% is judged to be a meaningful lesion. When the disease only involves the above-mentioned blood vessel, it is a single-vessel disease. When the lesion involves any two branches, it is a double-vessel disease. When the disease involves any three branches, it is a three-vessel disease. CAG is performed on an optional schedule within 30 days after the occurrence of acute AMI(16).

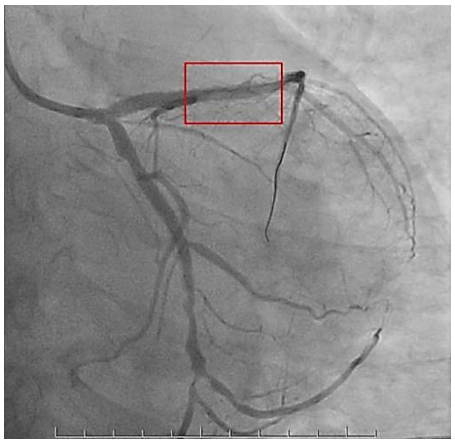
(a) Case 1(vascular blockage)



(b) (Coronary occlusion)



(c) Case 3 (vascular stenosis)



(d) Case 4(thrombus)

Figure 1. **Cases of coronary artery imaging**

From the findings in the figure, it can be seen that the method proposed in this paper can clearly identify the pathological characteristics of patients with acute myocardial infarction.

Result

The incidence of severe smoking, alcohol abuse, obesity, family history of coronary heart disease, increased triglycerides and decreased high-density lipoprotein in the youth group was higher than that of the elderly group, as indicated in Table 1(18):

Table 1: **Comparison of risk factors between the two groups**

	Youth group (%)	Elderly group (%)	P
Heavy smoking	82.6	34.9	<0.05
Alcoholism	44.4	13.9	<0.05
Obesity	46.1	26.9	<0.05
Family history of coronary heart disease	30.3	10.2	<0.05
Hypertension	17.6	59.5	<0.05
Diabetes	12.8	45.0	<0.05
Increased triglycerides	31.8	18.2	<0.05
Decreased HDL	38.2	13.1	<0.05
Increased LDL	22.3	26.2	<0.05

Table 1 details the relevant influencing factors of acute myocardial infarction in young people, which verifies the innovation of this study and reflects the effectiveness of this study method.

The details are shown in Table 2 (19). In coronary angiography, single-vessel disease accounts for 54.1%, double-vessel disease accounts for 31.8%, three-vessel disease accounts for 12.8%, normal coronary angiography accounts for 1.8%, and no left main artery disease was found. In coronary angiography in the elderly group, single-vessel disease accounts for 11.8%, double-vessel disease accounts for 32.7%, three-vessel disease accounts for 55.9%, and left main artery disease accounts for 12.4%. The single vessel disease in the young group is more than that in the old group (54.1 and 11.7%, $P<0.05$), the three-vessel disease in the elderly group is more than in the young group (55.9% and 12.8%, $P<0.05$), and the left main artery disease is more involved in the elderly group than in the young group ($P<0.05$), and the difference was statistically significant. The coronary arteries of the youth are slightly more normal than the elderly group, and the two-vessel disease is slightly less than that of the elderly group, but there is no significant difference ($P>0.05$).

Table 2: **Comparison of diseased blood vessels in the two groups**

Location	Youth group (%)	Elderly group (%)	P
Left main stem	0	12.4	<0.05
Left anterior descending branch	81.1	87.1	>0.05
Right coronary artery	47.7	59.5	>0.05
Left circumflex	33.4	52.3	<0.05
Simple lesions	54.1	11.7	<0.05
Double Vessel Disease	31.7	32.7	>0.05
Three-vessel disease	12.7	55.9	<0.05
Normal	1.7	0	>0.05

Analysis and discussion

The main risk factors for young AMI patients are family history of coronary heart disease, heavy smoking, obesity, alcoholism, increased triglyceride, and decreased high-density lipoprotein; coronary imaging features are mostly single-vessel disease, and left anterior descending artery disease, which is the most common.

In recent years, due to the rapid development of China's socio-economic level, people's quality of life is improving annually. Compared with the past few decades, people's lifestyles have undergone great changes at this stage. People's daily intake of high-fat and high-calorie foods has increased significantly. Moreover, people's sports activities have decreased significantly, while social competition and people's work pressure have increased. These factors have led to the increasing incidence of coronary heart disease in China in recent years, and this is a clear trend for the younger generation. Acute myocardial infarction is a very common type of coronary heart disease, and it is one of the most common clinical acute and severe diseases. Acute myocardial infarction can cause cardiac arrest, arrhythmia, and even sudden death in patients. Therefore, it has a high fatality and disability rate, which causes great harm to human health.

The effective treatment of acute myocardial infarction and the improvement of its clinical prognosis is particularly important. At present, the focus of acute myocardial infarction treatment, has been on how to promptly and fully open the occluded artery, so as to rescue the ischemic myocardial cells quickly and effectively, to minimize the occurrence of the myocardial infarction area and to prevent cardiac insufficiency. In the past, the treatment of acute myocardial infarction was mainly through intravenous thrombolytic therapy, but due to thrombolytic therapy, complications such as bleeding are more likely to occur and the effect is slow. Therefore, it has been replaced by coronary interventions (18).

In recent years, selective coronary intervention has gradually become the main treatment method for acute myocardial infarction (19). Research and analysis have confirmed that emergency coronary intervention can significantly reduce the mortality of patients with acute myocardial infarction, and its safety is significantly better than thrombolytic therapy.

Myocardial blood flow is mainly located in the capillaries, accounting for 90% of the blood flow. Coronary angiography is the gold standard for diagnosing CAD (20). Although it can assess whether there is coronary stenosis and its severity, it can only display vessels with a diameter of more than 100um in the epicardial coronary artery, but not micro vessels with a diameter of less than 100um. Some patients do not have obvious epicardial coronary stenosis, but due to the dysfunction of the small blood vessels of 100~200um that regulate coronary blood flow, it can still cause pain in the precordial area, which is called "microvascular angina". Studies have found that even if the arteries associated with epicardial infarction are opened, the microcirculation structure and function are destroyed, and there will still be low or no reflow. This indicates that the integrity of myocardial microcirculation may be more important than the patency of the epicardial coronary artery.

The hemodynamic of ultrasound microbubbles are similar to that of red blood cells, and are evenly distributed in the myocardium like red blood cells, so MCE can reflect the myocardial microcirculation. MCE can qualitatively diagnose coronary heart disease, combined with drugs or exercise load, etc., and can also qualitatively evaluate the area of myocardial infarction following myocardial infarction, myocardial viability, as well as predict the recovery of cardiac function. In the qualitative assessment of myocardial perfusion using MCE, the

sensitivity is 66% when the degree of myocardial infarction is less than 50%, and the sensitivity is 84% when the degree of myocardial infarction is more than 50% (21).

Acute myocardial infarction (AMI) is caused by a sudden stenosis or occlusion of the coronary arteries, which causes acute and persistent ischemia and hypoxia in the blood supply area of the diseased coronary arteries, which causes local myocardial necrosis. The disease is mostly sudden and has high fatality and high disability rates. Acute myocardial infarction is divided into two categories according to the electrocardiogram: The two are different in pathogenesis, so there are corresponding differences in treatment strategies. This results in the complete blockage of the vascular lumen and there is less collateral circulation, which causes rapid transmural myocardial necrosis.

Acute non-ST-segment elevation myocardial infarction (NSTEMI) has many pathogeneses. Coronary artery stenosis is very severe, and the lumen has not been completely occluded. Once there is an increase in myocardial oxygen consumption, the oxygen supply and demand will be out of balance, which leads to prolonged ischemia and hypoxia in the myocardium and then leads to the necrosis of myocardial cells. Acute thrombosis exists in the coronary artery lumen, but the lumen is not completely blocked, and this type of thrombus is usually mainly white thrombosis. Long-term severe coronary artery stenosis or chronic occlusive disease promotes the formation and establishment of collateral circulation. Moreover, part of the myocardial blood supply depends on the collateral circulation. Once the myocardial supply and demand are out of balance, subendocardial non-transmural myocardial injury and necrosis will occur (21).

At present, smoking, alcohol abuse, hypertension, diabetes, hyperlipidemia, obesity, and a family history of coronary heart disease are recognized as traditional risk factors for CHD, but their effects on AMI patients of different ages vary. A large number of smoking releases increased vasoconstrictor factors and decreased vasodilator factors (such as NO), which can cause coronary artery spasm, easily lead to in situ thrombosis, and make arteriosclerotic plaques unstable and easy to rupture.

In this study, the proportion of young AMI patients who smoked reached 82.5%, which was significantly higher than that of the elderly group. The youth AMI group had higher alcohol consumption rates than the elderly group, and they all drank a lot, suggesting that long-term heavy drinking is one of the important risk factors for AMI in young people. Obesity was higher in the youth group than in the elderly group, indicating that the high BMI value was related to AMI. The rates of increased triglycerides and decreased high-density lipoprotein were higher in the youth group than in the elderly group. The rate of family history of early-onset cardiovascular disease was relatively higher in the youth group.

The results of the study revealed that the main risk factors for AMI in young people are smoking, alcohol abuse, obesity, dyslipidemia and family history of coronary heart disease. Among them, the family history of coronary heart disease is a more important predictive value for young AMI. Therefore, patients with coronary heart disease in the family should pay more attention to preventing the occurrence of AMI. Moreover, quitting smoking, quitting alcohol, adjusting blood lipids, and controlling body weight are more important for preventing and treating the occurrence of AMI. The youth group is predominantly male, and there were only 2 females (3.2%). The traditional concept believes that due to the protective effect of estrogen on the cardiovascular system, women are not susceptible to coronary heart disease, and the age of onset of coronary heart disease in women is delayed by an average of 10 -20 years. The incidence of coronary heart disease in premenopausal women is significantly lower than that of men, and the incidence of coronary heart disease in postmenopausal women is gradually increasing. The results of this paper indicate that young AMI patients mainly have the single-vessel disease (34 cases accounted for 54.0%). Moreover, most of the branch vessels involved are the left anterior descending artery (51 cases accounted for 81.0%), followed by the right coronary artery (30 cases accounted for 47.6%). Elderly patients with AMI mostly have three-vessel diseases (77 cases account for 55.8%), and in the elderly diseases of the left main stem are more common than in young people. In young people with AMI with normal coronary arteries, the cause of AMI may be caused by coronary artery spasms and thrombosis in the coronary arteries.

References

1. Pasupathy, S., Tavella, R., Grover, S., Raman, B., Procter, N. E., Du, Y. T., ... & Beltrame, J. F. (2017). Early use of N-acetylcysteine with nitrate therapy in patients undergoing primary percutaneous coronary intervention for ST-segment–elevation myocardial infarction reduces myocardial infarct size (the NACIAM Trial [N-acetylcysteine in Acute Myocardial Infarction]). *Circulation*, *136*(10), 894-903.
2. Elbadawi, A., Elgendy, I. Y., Mahmoud, K., Barakat, A. F., Mentias, A., Mohamed, A. H., ... & Jneid, H. (2019). Temporal trends and outcomes of mechanical complications in patients with acute myocardial infarction. *JACC: Cardiovascular Interventions*, *12*(18), 1825-1836.
3. Hausenloy, D. J., Kharbanda, R. K., Møller, U. K., Ramlall, M., Aarøe, J., Butler, R., ... & Galván-Núñez, P. (2019). Effect of remote ischaemic conditioning on clinical outcomes in

patients with acute myocardial infarction (CONDI-2/ERIC-PPCI): a single-blind randomised controlled trial. *The Lancet*, *394*(10207), 1415-1424.

4. Aniwan, S., Pardi, D. S., Tremaine, W. J., & Loftus Jr, E. V. (2018). Increased risk of acute myocardial infarction and heart failure in patients with inflammatory bowel diseases. *Clinical Gastroenterology and Hepatology*, *16*(10), 1607-1615.
5. Lim, M., Wang, W., Liang, L., Han, Z. B., Li, Z., Geng, J., ... & Han, Z. (2018). Intravenous injection of allogeneic umbilical cord-derived multipotent mesenchymal stromal cells reduces the infarct area and ameliorates cardiac function in a porcine model of acute myocardial infarction. *Stem cell research & therapy*, *9*(1), 1-17.
6. Zhang, N., Yang, G., Gao, Z., Xu, C., Zhang, Y., Shi, R., ... & Firmin, D. (2019). Deep learning for diagnosis of chronic myocardial infarction on nonenhanced cardiac cine MRI. *Radiology*, *291*(3), 606-617.
7. McCartney, P. J., Eteiba, H., Maznyczka, A. M., McEntegart, M., Greenwood, J. P., Muir, D. F., ... & Berry, C. (2019). Effect of low-dose intracoronary alteplase during primary percutaneous coronary intervention on microvascular obstruction in patients with acute myocardial infarction: a randomized clinical trial. *Jama*, *321*(1), 56-68.
8. Maniwa, N., Fujino, M., Nakai, M., Nishimura, K., Miyamoto, Y., Kataoka, Y., ... & Yasuda, S. (2018). Anticoagulation combined with antiplatelet therapy in patients with left ventricular thrombus after first acute myocardial infarction. *European heart journal*, *39*(3), 201-208.
9. Boeddinghaus, J., Nestelberger, T., Twerenbold, R., Koechlin, L., Meier, M., Troester, V., ... & Rentsch, K. (2019). High-sensitivity cardiac troponin I assay for early diagnosis of acute myocardial infarction. *Clinical chemistry*, *65*(7), 893-904.
10. de Waha, S., Patel, M. R., Granger, C. B., Ohman, E. M., Maehara, A., Eitel, I., ... & Stone, G. W. (2017). Relationship between microvascular obstruction and adverse events following primary percutaneous coronary intervention for ST-segment elevation myocardial infarction: an individual patient data pooled analysis from seven randomized trials. *European heart journal*, *38*(47), 3502-3510.
11. Greenslade, J. H., Carlton, E. W., Van Hise, C., Cho, E., Hawkins, T., Parsonage, W. A., ... & Cullen, L. (2018). Diagnostic accuracy of a new high-sensitivity troponin I assay and five accelerated diagnostic pathways for ruling out acute myocardial infarction and acute coronary syndrome. *Annals of emergency medicine*, *71*(4), 439-451.
12. Mannil, M., von Spiczak, J., Manka, R., & Alkadhi, H. (2018). Texture analysis and machine learning for detecting myocardial infarction in noncontrast low-dose computed tomography: unveiling the invisible. *Investigative radiology*, *53*(6), 338-343.
13. Robbers, L. F., Nijveldt, R., Beek, A. M., Teunissen, P. F., Hollander, M. R., Biesbroek, P. S., ... & van Rossum, A. C. (2018). The influence of microvascular injury on native T1 and T2* relaxation values after acute myocardial infarction: implications for non-contrast-enhanced infarct assessment. *European radiology*, *28*(2), 824-832.
14. Badertscher, P., Boeddinghaus, J., Twerenbold, R., Nestelberger, T., Wildi, K., Wussler, D., ... & Geigy, N. (2018). Direct comparison of the 0/1h and 0/3h algorithms for early rule-out of acute myocardial infarction. *Circulation*, *137*(23), 2536-2538.
15. Arora, S., Stouffer, G. A., Kucharska-Newton, A. M., Qamar, A., Vaduganathan, M., Pandey, A., ... & Caughey, M. C. (2019). Twenty year trends and sex differences in young adults hospitalized with acute myocardial infarction: the ARIC Community Surveillance Study. *Circulation*, *139*(8), 1047-1056.
16. Thackeray, J. T., Hupe, H. C., Wang, Y., Bankstahl, J. P., Berding, G., Ross, T. L., ... & Bengel, F. M. (2018). Myocardial inflammation predicts remodeling and neuroinflammation after myocardial infarction. *Journal of the American College of Cardiology*, *71*(3), 263-275.
17. Eitel, I., Stiermaier, T., Lange, T., Rommel, K. P., Koschalka, A., Kowallick, J. T., ... & Schuster, A. (2018). Cardiac magnetic resonance myocardial feature tracking for optimized prediction of cardiovascular events following myocardial infarction. *JACC: Cardiovascular Imaging*, *11*(10), 1433-1444.
18. Doi, T., Kataoka, Y., Noguchi, T., Shibata, T., Nakashima, T., Kawakami, S., ... & Yasuda, S. (2017). Coronary artery ectasia predicts future cardiac events in patients with acute myocardial infarction. *Arteriosclerosis, thrombosis, and vascular biology*, *37*(12), 2350-2355.
19. Mahmud, E., Dauerman, H. L., Welt, F. G., Messenger, J. C., Rao, S. V., Grines, C., ... & Henry, T. D. (2020). Management of acute myocardial infarction during the COVID-19 pandemic: a position statement from the Society for Cardiovascular Angiography and Interventions (SCAI), the American College of Cardiology (ACC), and the American College of Emergency Physicians (ACEP). *Journal of the American College of Cardiology*, *76*(11), 1375-1384.
20. Gavara, J., Rodriguez-Palomares, J. F., Valente, F., Monmeneu, J. V., Lopez-Lereu, M. P., Bonanad, C., ... & Bodi, V. (2018). Prognostic value of strain by tissue tracking cardiac magnetic resonance after ST-segment elevation myocardial infarction. *JACC: Cardiovascular Imaging*, *11*(10), 1448-1457.
21. Fernández-Jiménez, R., Barreiro-Pérez, M., Martin-García, A., Sánchez-González, J.,

Agüero, J., Galán-Arriola, C., ... & Ibanez, B. (2017). Dynamic edematous response of the human heart to myocardial infarction: implications for assessing myocardial area at risk and salvage. *Circulation*, *136*(14), 1288-1300.