

## Review

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## Magnetic Resonance Imaging of the Heart is a Robust Method for Diagnosing Myocardial Lesions with Low Availability in Emergency Cardiology Departments

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**ABSTRACT** This article discusses the problem of underuse, low availability of modern imaging techniques such as magnetic resonance imaging of the heart (MRI). This technique is characterized by high accuracy and uniqueness in the diagnosis of myocardial lesions of various genesis. The widespread introduction of this technique in emergency cardiology departments can improve the accuracy of diagnosis and the effectiveness of patient therapy. Despite the high costs of implementation and current use, modern diagnostic methods can save healthcare resources by reducing hospital stays and improving treatment outcomes.

**Keywords:** myocardial infarction, myocarditis, cardiomyopathy, pulmonary embolism, COVID-19, cardiac magnetic resonance imaging

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ACS — acute coronary syndrome

CHD — ischemic heart disease

CHF — chronic heart failure

CT — computed tomography

ECG — electrocardiography

EchoCG — echocardiography

MINOCA — myocardial infarction with non-obstructive coronary arteries

MRI — magnetic resonance imaging

PE — pulmonary embolism

RVC — regional vascular center

### RELEVANCE

The program of vascular centers/departments has been currently underway in Russia for over 10 years. In implementing the initial goals and objectives, cardiology departments have evolved significantly since then. A wider coverage of the population with modern medical care was achieved, approaches to patient routing between primary departments and

regional vascular centers (RVC) changed. Most patients with acute coronary syndrome (ACS) have access to modern, including invasive, methods of treating coronary heart disease (CHD). Moreover, there is a large list of emergency nosologies, such as pulmonary embolism, cardiac arrhythmia, chronic heart failure (CHF) of various origins, which are also treated in emergency cardiology departments.

In our view, the cardiology community needs to actively discuss the problem of underuse and low availability of cardiac magnetic resonance imaging (MRI), especially in the regions. This article aims to highlight the informative value of the method, its potential benefit for achieving cardiology service targets, and its economic feasibility, despite its high cost.

MRI equipment is not a standard feature of primary emergency cardiology departments. In accordance with the current procedure for providing medical care to patients with cardiovascular diseases, MRI scanners are installed in RVCs [1]. Unfortunately, the equipment does not always include software for cardiac examination. This software is often expensive, requiring additional significant financial investments. Besides, RVCs usually concentrate patients with ACS who are subject to invasive methods of examination and treatment. A significant number of patients requiring active diagnostic search using modern non-invasive imaging are concentrated in primary emergency cardiology departments, where the availability of cardiac MRI is extremely low.

The possible use of the method is reflected in the existing standards of care for patients with ACS and is included in the existing tariffs. In particular, in the current standards of care for patients with acute myocardial infarction with ST segment elevation and ACS without ST segment elevation of the electrocardiogram (ECG), the average rates of providing “magnetic resonance imaging of the heart and main vessels” service are 0.05 and 0.058, that is, in 5% and 5.8% of ACS cases, respectively [2, 3].

In actual clinical practice, the frequency of using this method is much lower. We analyzed the frequency of MRI use and the structure of diseases among those hospitalized over 3 years in the emergency cardiology department (primary department, without the possibility of using invasive X-ray surgical methods of diagnosis and treatment) (Figure).

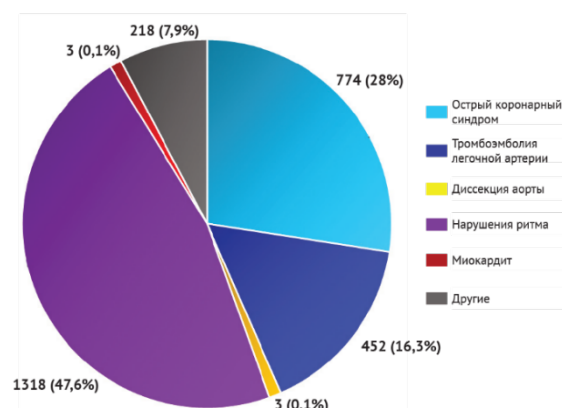


Figure. Structure of diseases (final diagnoses) among patients hospitalized in the emergency cardiology department for the period of 2020–2022

Most patients with ACS hospitalized in the primary department in accordance with the routing and recommendations at different times were transferred to the RVC for invasive diagnosis and treatment. In a significant number of patients, obstructive coronary artery disease was not detected. Among all 774 patients with ACS, the MRI technique was used in 3 cases (0.4%), which is an order of magnitude lower than the figures proposed by the standard. Unavailability unreasonably limits the use of the method. It is necessary to emphasize the low prevalence of myocarditis in the structure of diseases - 0.1% among all hospitalized in the emergency cardiology department. Moreover, among the 3 established cases, in 2 cases the diagnosis was established using MRI of the heart. This indicates the high efficiency of the technique in detecting myocarditis, which is always a difficult diagnostic task.

The need to achieve modern goals to reduce cardiovascular mortality, increasing comorbidity of patients, the impact of the novel coronavirus pandemic create new challenges for cardiologists. Implementation of more sophisticated screening protocols is required.

# REVIEW OF DATA ON THE USE OF CARDIAC MRI IN THE DIAGNOSIS OF MYOCARDIAL LESIONS OF VARIOUS ETIOLOGIES

Magnetic resonance imaging is a modern and constantly improving method of visualization. When used in cardiology, this technique allows for a detailed assessment of the structural features of the heart chambers and vessels, and for examining intracardiac hemodynamics and functional indicators of the heart. Indications for the examination may include diagnostics of congenital heart defects, aortic disease, pericardial and myocardial lesions of various origins, and heart tumors.

The technique can be actively used and is capable of significantly improving the level of diagnostics in emergency cardiology departments. Most patients admitted to emergency cardiology departments experience chest pain and/or dyspnea. The causes may be both cardiac and non-cardiac [4]. Among cardiac causes, the most common are ACS, cardiomyopathy, myocarditis, and pericarditis. Possible non-cardiac causes include aortic dissection, pulmonary embolism (PE), esophagitis, inflammatory lung disease, and thoracic dorsopathy. Questioning, and physical examination in combination with ECG, echocardiography (EchoCG), laboratory tests (determination of the blood level of troponin, D-dimer, NT-proBNP), if necessary, computed tomography (CT) angiography of the lungs and aorta allows us to establish a diagnosis in most patients. The equipment is available in emergency cardiology departments according to equipment standards. Selective coronary angiography in the RVC makes it possible to determine the presence of changes in the coronary arteries.

The need for differential diagnosis of such complex cardiac problems as myocarditis, cardiomyopathy, myocardial infarction with non-obstructive coronary arteries (MINOCA) and takotsubo cardiomyopathy may require additional imaging methods. In these cases, cardiac MRI is particularly informative, including with the use of contrast agents. The possibility of using additional methods is considered in the Fourth Universal Definition of Myocardial Infarction [5], and current

recommendations of the Ministry of Health of the Russian Federation for the diagnosis and management of ACS [6]. The need to conduct a complex diagnostic search has become especially relevant in the context of the COVID-19 pandemic, since this disease is associated with the risk of myocardial damage of both ischemic and non-ischemic origin.

The use of delayed contrasting of the myocardium with gadolinium (late contrast enhancement, LCE) allows us to expand the capabilities of MRI in cardiology. Gadolinium and its derivatives are extracellular contrast agents that are structurally inert and cannot penetrate the intact membrane of cardiomyocytes. In the intact myocardium, the cells are tightly adjacent to each other, and the intracellular space makes up the bulk of the tissue. In such cases, the main part of the contrast agent remains in the vascular bed of the myocardium, and is quickly excreted by the kidneys. In acute myocardial injury, the integrity of cell membranes is disrupted, the contrast accumulates in necrotic and scar tissue and is excreted longer. In the early phase of contrasting, hypervascularization in active inflammation foci or microvascular obstruction foci (first minutes of gadolinium administration) can be detected, and in the late phase - delayed contrasting (tens of minutes) - necrosis and fibrosis zones are visible [7]. Magnetic resonance imaging is not a single technique, it consists of several technologies, programs (pulse sequence technologies), the combination of which ultimately allows assessing tissue changes specific to the corresponding pathology and providing the necessary level of diagnostics. MRI results can be influenced by the experience and knowledge of the specialists performing the examination.

Magnetic resonance imaging helps detect characteristic myocardial changes of various etiologies. The diagnosis of MINOCA, established according to the Fourth Universal Definition [5], may require MRI after coronary angiography. The examination should be performed as early as possible (up to 7 days after the onset), since in case of a small lesion, a delay in examination will not allow changes

to be detected in some patients. Magnetic resonance imaging makes it possible to detect characteristic signs of inflammation, edema and scar formation in the affected area. Late contrast enhancement allows us to see the typical pattern of the lesion: contrast accumulation subendocardially or transmurally. This is typical for ischemic etiology of the lesion and is due to the direction of blood supply to the myocardium from the epicardium to the endocardium. Subendocardial areas are more vulnerable to ischemia. The absence of contrast enhancement may be due to microvascular dysfunction or non-coronary etiology [4]. In a significant proportion of patients with a primary diagnosis of MINOCA, MRI reveals other diseases. One prospective study showed that among 87% of patients with MINOCA, 37% had acute myocarditis, 27% had stress cardiomyopathy (takotsubo), 21% had acute MI, 1% had atypical hypertrophy, and 2% had dilated cardiomyopathy [8].

Takotsubo cardiomyopathy (stress cardiomyopathy) accounts for 1–2% of patients with acute myocardial lesions [9]. It may have a similar picture to MINOCA. This form of cardiomyopathy is characterized by the absence of late gadolinium accumulation during MRI. Signs of edema and contraction disturbances (ballooning) are detected, localized in the apical and middle zones of the left ventricle with dyskinesia in the anterior wall. Research shows that the use of MRI allows establishing an appropriate diagnosis in 74–84% of cases [8].

Myocarditis is a difficult diagnostic problem. The true incidence of its development is unknown. The clinical course may vary from subclinical to fulminant with the development of severe acute heart failure and life-threatening rhythm disturbances. According to studies, it can cause up to 12% of sudden cardiac deaths among young patients; myocarditis is responsible for 0.5–4% of cases of CHF and 9% of cases of dilated cardiomyopathy [10]. Despite the fact that histological examination is the "gold standard" of its diagnosis, endomyocardial biopsy is rarely performed [11]. Most often, the diagnosis is based on ECG signs, increased troponin

levels in the blood, and echocardiography data. Since 2009, MRI criteria for myocarditis have been used (Lake Louise Criteria): edema, hyperemia, and necrosis or fibrosis detected with late contrast enhancement [12]. MRI also allows us to determine the localization of the process different from ischemic myocardial lesions [8]. It is believed that the MRI technique is most sensitive in the acute period (the first two weeks of the disease); subsequently, inflammatory changes may not be determined, significant fibrous changes are detected. In the chronic phase, myocardial biopsy becomes more important [13]. MRI in myocarditis may have prognostic value. In a prospective study of 203 patients with histologically confirmed myocarditis, late contrast enhancement was associated with a 12.8-fold increase in the risk of death. MRI changes were associated with left ventricular dilation and decreased left ventricular ejection fraction [14]. In another study, late contrast enhancement had additional prognostic value when the ejection fraction was greater than 40%. In patients with a low fraction, the prognosis was worse, but the contrast enhancement index did not have an additional negative effect on it [15]. A large meta-analysis involving 2328 patients with myocarditis showed that late contrast enhancement during MRI and anterior septal localization of the inflammatory process are independent unfavorable prognostic factors [16].

In patients with myocardial infarction, MRI may theoretically be an ideal examination method. It helps not only evaluate the blood supply to the myocardium and contractility disorders, but also differentiate the acute process from cicatricial changes in the myocardium, when the patient is already outside the diagnostic window for the troponin level in the blood. Magnetic resonance imaging at rest and stress methods can be used in the presence of chest pain and suspected ACS. In practice of emergency departments, given the availability of other methods, the use of MRI in patients with confirmed myocardial infarction is limited. The technique is used for precise assessment of the extent of damage, including for scientific purposes

when studying various therapy methods. Magnetic resonance imaging allows us to identify complications of myocardial infarction (aneurysm, left ventricular thrombus, myocardial hematoma), and can be used to assess the presence and course of the no-reflow phenomenon [7].

In 2020, the results of the multicenter SPINS trial were published [18]. In the research, MRI was used in 2,349 patients with suspected coronary artery disease. The patients were dynamically observed for several years with a median of 5.4 years. MRI revealed signs of previous, timely undiagnosed myocardial infarction in 347 patients (15%). This was comparable with a group of 358 patients (15%) in whom the diagnosis of AMI was established in a timely manner. Ischemia, reduced left ventricular ejection fraction, and signs of previous myocardial infarction were independent predictors of adverse outcomes (cardiovascular, overall mortality, myocardial infarction, rhythm disturbances, heart failure). Patients with undiagnosed heart attacks were twice as likely to be hospitalized for heart failure and were less likely to receive treatment in accordance with current guidelines.

In PE, MRI can be used as an alternative to CT when X-ray examination methods are undesirable (for example, in pregnant women) or in the presence of contraindications for iodine-containing contrast agents. Magnetic resonance imaging is informative even without the use of contrast, but it has limitations in identifying segmental and subsegmental lesions [17].

## CONCLUSION

Modern non-invasive imaging methods - computed tomography and magnetic resonance imaging, are increasingly used in clinical practice. For objective reasons, the number of studies grows by 5-10% every year. At the 2022 Society of Cardiovascular Computed Tomography (SCCT) Annual Scientific Meeting, it was reported that in the pandemic year of 2020, the number of CT and MRI procedures increased by 29% and 26%, respectively. Radiation methods occupy leading positions in

diagnostics of emergency departments, in patients experiencing chest pain. The availability of imaging allows the implementation of a universal strategy of “one stop shopclinic” (“key examinations in one place”) in emergency cardiology, where modern CT and MRI scanners, in combination with laboratories and sufficiently qualified personnel, can provide an accurate diagnosis in a significant proportion of patients with chest pain without the need for invasive diagnostics [19]. This can speed up the correct diagnosis and thus save lives. Such tactics allow saving health care resources by reducing the length of hospital stays.

Like any method, MRI has limitations in use. It is not advisable to use MRI with contrast agents in patients with a glomerular filtration rate of less than 30 ml/min/1.73 m<sup>2</sup> due to the risk of developing systemic fibrosis. The method requires highly qualified personnel. Experience in using this method among doctors of diagnostic radiology departments is insufficient. The training of the physician performing cardiac MRI requires a separate discussion. Moreover, there is an insufficient number of hours of relevant training in residency programs, primary retraining of radiologists; as a result, additional improvement is usually required in the conditions of experienced centers that perform a large volume of research, and conduct a comprehensive examination of patients, and not just MRI.

The emerging challenges in modern cardiology, achieving a reduction in mortality from cardiovascular diseases require further investment and the introduction of modern visualization. In this regard, the cardiac MRI technique should be used on a larger scale - in emergency cardiology departments, including primary vascular departments/centers.

In general, in order to improve the quality of medical care and implement the idea of creating highly qualified centers in each region of this country, further development of cardiac care with wider implementation of expensive modern imaging techniques is of absolute necessity.

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