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REVIEW

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Hybrid Imaging in the Assessment of Myocardial Ischemia and Viability

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ABSTRACT

Myocardial ischemia results from a reduction in blood flow as a consequence of a coronary stenosis, which produces ischemia in the myocardial territories irrigated by the stenotic artery. Myocardial viability is a concept that derived from several studies in which it was observed that, even if revascularization occurred, an irreversible left ventricular contractile dysfunction remained. The terms "stunned" and "hibernating" myocardium have been traditionally associated with the viable myocardium, and many controversies still exist on the most appropriate method to assess the presence and extent of viable myocardium. During the last decades, many efforts have been made to identify the best method to determine the viability of the myocardial tissue. Due to the fact that none of the stand-alone imaging methods provide sufficient data about myocardial viability, new methods for the investigation of myocardial viability became necessary. Thus, the concept of hybrid imaging was developed, consisting in the association of different imaging techniques, finally resulting in a single image that offers all the details provided by the two isolated methods of diagnosis, therefore being more precise in regards to the identification of viable myocardium territory. This review aims to appraise the recent studies related to myocardial viability investigated with hybrid imaging.

Keywords: myocardial ischemia, hybrid imaging, viability, PET-CT, MRI

INTRODUCTION

According to World Health Organization (WHO) statistics from 2016, cardiovascular diseases are the principal cause of death worldwide.[1] Recent research published by Townsend *et al.* in 2014 highlighted that coronary heart disease (CHD) causes 1.8 million deaths in Europe.[2] Having such a huge negative impact on the economy and social development, CHD should be diagnosed in early stages. Due to improvements of imagistic diagnostic tools, patients with myocardial ischemia started to have access to superior diagnostic techniques, resulting in a better therapeutic approach. Nichols *et al.* showed in an epidemiological update regarding cardiovascular disease mortality, that there is a descending trend in mortality caused by CHD in almost all European countries.[3]

Myocardial ischemia represents a condition that occurs when aerobic metabolism changes into an anaerobic one. This can represent the first sign before the occurence of an acute myocardial infarction. The underlying pathogenetic mechanism involved in the progression of myocardial ischemia is the development of atherosclerosis, leading to coronary stenosis and a decreased blood supply in the affected territories, which finally causes contractile impairment. Myocardial ischemia can be diagnosed using several imaging methods, such as echocardiography with contrast enhancement or with dobutamine, conventional coronary angiography, computed tomography angiography, magnetic resonance imaging and nuclear imaging.

Myocardial viability is a term characterizing the myocardial tissue, without scars or with limited ones, which suffered from severe ischemia that produced significant contractility impairment, but has the possibility to recover its functional status after the blood flow is reestablished.[4] Several studies have investigated this concept, thus updating the approach of patients with myocardial infarction. In 2006, Tarakij *et al.*, in a study on 765 patients with severe impairment of left ventricular (LV) function, showed that patients who underwent early revascularization therapies (percutaneous coronary intervention – PCI or coronary artery bypass grafting – CABG) for extensive CAD, had significantly lower mortality rates during the 3-year follow-up.[5]

Moreover, clinicians should consider the assessment of myocardial viability for a better approach of CAD patients that can aid in the examination and establishing the indication of coronary revascularization. In the assessment of myocardial viability, positron emission tomography (PET) is considered the gold standard method for evaluating functional recovery after revascularization.[6]

MYOCARDIAL STUNNING AND HIBERNATION

The term "myocardial stunning" describes a viable myocardial tissue with contractile dysfunction following a severe abrupt ischemic injury, which recovers its function spontaneously, without the need for coronary revascularization.[7] Myocardial stunning results after repeated episodes of reversible myocardial ischemia associated with angina pectoris with or without ECG changes, after which the myocardial tissue remains non-functional in terms of contractility, but with normal blood flow.

Hibernating myocardium represents a different type of viable myocardium, which recovers its contractile function after a successful revascularization. In opposition with myocardial stunning, a hibernating myocardium requires an intervention to improve its function, either through pharmacological therapy or by coronary revascularization. It is important to differentiate between a hibernating and an irreversible ischemic myocardium. The first one will recover after revascularization, and the patient with hibernating myocardium will benefit from the coronary intervention, which will lead to a significant improvement in left ventricular function.[8]

COMPUTED TOMOGRAPHY ANGIOGRAPHY IN THE ASSESSMENT OF MYOCARDIAL VIABILITY AND ISCHEMIA

Being more widely available and more often used due to lower costs, delayed contrast-enhancement multi-slice spiral computed tomography (MSCT) can assess myocardial viability, providing information about the anatomy of the coronary vessels, together with details on their functionality.[9]

The main limitation of this technique comes from the radiation exposure that must be taken into consideration. One of the features that characterize an infarcted territory, as seen in cardiac MSCT, is low contrast enhancement after the arterial phase, which shows a deficient coronary perfusion. Yamauch *et al.* showed the benefits of using perfusion computed tomography angiography in the assessment of the myocardial ischemia in stable patients. They performed a study on 2,878 symptomatic patients with suspected coronary artery disease and concluded that the patients who underwent perfusion computed tomography angiography had a better prognosis compared with those who underwent direct percutaneous coronary intervention.[10]

In an attempt to assess the accuracy of MSCT for the assessment of myocardial ischemia and viability, many studies found that MSCT has a sensitivity of 95–97% and a specificity of 93–98% in detecting the coronary artery stenosis associated with myocardial ischemia. An important limitation of this noninvasive diagnostic procedure is that in case of lesions with a high degree of calcification, the stenosis can be overestimated.[11–14]

Albert *et al.* studied the accuracy of MSCT in detecting myocardial necrosis and viability after myocardial infarction in 10 dogs and 7 pigs. They produced a myocardial infarction by performing a balloon occlusion in one of the coronary arteries, which was followed by percutaneous revascularization. Their results showed that myocardial ischemia and the extension of the myocardial infarction can be accurately analyzed by MSCT, leading to a precise diagnosis.[15]

By combining the images obtained via CT (that offer data on the anatomy of the coronary tree) with PET image acquisitions (that indicate the functionality of the myocardial tissue), the resulted fusion images can improve the decision-making process on the need for revascularization.

MAGNETIC RESONANCE IMAGING (MRI) DISTINGUISHES VIABLE MYOCARDIUM FROM INFARCTED MYOCARDIAL TISSUE

MRI is a valuable diagnostic tool in the assessment of myocardial injuries. Being a noninvasive method without many limitations, it can differentiate the viable myocardium from scar tissue. Therefore, it represents an important imaging technique that leads to an accurate diagnosis.[16] Furthermore, MRI can help in investigating the need of coronary revascularization in ischemic territories, and to predict whether the restoration of the blood flow will lead to functional recovery of the affected myocardial tissue. Currently, there are three techniques used for the assessment of myocardial viability and ischemia based on magnetic resonance: resting MRI, dobutamine MRI and contrast-enhanced MRI. In a report, Schinkel *et al.* stated that a myocardium with a measured thickness of less than 6 mm indicates a scar tissue that will probably not recover after the restoration of blood supply in the afferent territory. That means that the myocardial wall thickness assessed by MRI can be a predictive factor for the outcome of patients following a myocardial infarction.[6]

Wellnhofer *et al.* conducted a prospective blind study on 29 patients with coronary artery disease, in which they assessed myocardial viability and the functional recovery after revascularization by performing dobutamine-MRI and contrast-enhanced MRI. They found that low-dose dobutamine MRI has a better predictive capacity for myocardial recovery compared to contrast-enhanced MRI and is not dependent on the depth of the scar. Similar results were obtained by Motoyasu *et al.* in their research.[17,18] Contrariwise, Van Hoe *et al.* did not find any advantages for stress MRI over contrast-enhanced MRI in the assessment of viable myocardium, and they stated that the dobutamine stress test associated with MRI should not be integrated in the protocol for the evaluation of myocardial viability, as it offers no additional information.[19]

Klein *et al.* compared contrast enhancement MRI with PET in 31 patients with known CAD and showed that MRI hyperenhancement can better assess the scar tissue in comparison with PET, which is considered the best method in evaluating myocardial viability and can be a good predictor for functional recovery.[20]

STRESS ECHOCARDIOGRAPHY USED FOR EVALUATING THE VIABLE MYOCARDIUM

Using echocardiography with the administration of dobutamine, the contractile reserve of the myocardial tissue can be determined, thus enabling the evaluation of the functional recovery of the myocardium after revascularization. Low-dose dobutamine infusion associated with ultrasound can identify the viable myocardium with contractile dysfunction and can reveal myocardial ischemia by increasing the dose of dobutamine, leading to an increased need for oxygen.[21]

This method is limited due to the fact that it requires an experimented operator, thus being preferred to be used in association with other imaging techniques. Wang *et al.* combined in their myocardial viability study the low-dose dobutamine echocardiography with speckle-tracking echocardiography and with delayed enhancement MRI in 35 patients who had previously suffered an acute myocardial infarction. They observed that by using this association, the sensitivity and specificity in detecting the viable myocardium was increased considerably, but due to the small size of the study sample, their results were not representative.[22]

NUCLEAR IMAGING FOR MYOCARDIAL ISCHEMIA AND VIABILITY ASSESSMENT

PET-FDG has an increased value in the evaluation of myocardial viability,[23] with a 92% sensitivity in evaluating myocardial viability.[6] Even if it has a high diagnostic value, it is not frequently used due to its increased costs and reduced availability.

HYBRID IMAGING FOR THE ASSESSMENT OF MYOCARDIAL VIABILITY

Hybrid imaging represents the association of two different imaging technologies into a single examination, which is able to provide all the details that would be obtained separately by each of the two techniques, in a single step. Examples of hybrid imagistic methods are: MRI/PET, PET/CT, MR/SPECT, ultrasound/MR, or ultrasound/CT. The advantages of using such models are related to the high diagnostic accuracy and the reduced exposure to radiations. This new imaging technology represents an upgrade in the diagnostic precision of myocardial ischemia by providing more information in regards to the possibility of coronary revascularization and the functional recovery of the myocardial tissue after restoring the blood flow.

Masuda *et al*. recently published a study on 12 patients, in which they assessed myocardial viability using a new technique consisting of the integration of two different imaging methods: cardiac MRI and PET. They found a positive correlation between cardiac wall thickness and fluorodeoxyglucose (FDG) uptake with the patients' outcome.[24]

Hybrid imaging accomplished by the association of CT and MRI with PET can be used for the assessment of the extension of viable myocardium after acute coronary syndromes. The result provided by this kind of hybrid imaging is a single scan and a single fusion image that allows the clinician to evaluate the morphology and functionality of the myocardial tissue, being a valuable predictor for functional recovery after revascularization in patients with previous myocardial infarction. This hybrid method can also be used for the examination of patients with sarcoidosis, with reduced left ventricular ejection fraction or other cardiomyopathies.[25,26]

Hybrid imaging tools may improve the outcome of coronary patients by evaluating cardiovascular risks, and they can also decrease the costs of further investigations. The technique can be used for the identification of patients with viable myocardium, as established with the use of noninvasive imaging tools. This is particularly important because these patients will truly benefit from revascularization and should undergo percutaneous coronary intervention.[27,28]

CONCLUSIONS

Hybrid imaging represents the future of imaging methods in investigating myocardial ischemia and viability. Further research is required to illustrate the real advantages of these techniques in providing more complex information for the selection of patients who will truly benefit from revascularization procedures.

CONFLICT OF INTEREST

Nothing to declare.

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