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Cardiac Imaging Modalities in the Diagnosis of Coronary Artery Disease

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Abstract

Coronary artery disease is the leading cause of death in advanced countries. Early detection and diagnosis of coronary artery disease plays an important role in the identification of disease severity and prediction of disease outcome, consequently improving patient management. Diagnosis and management of coronary artery disease is increasingly dependent on less-invasive imaging modalities, including coronary CT angiography, cardiac magnetic resonance imaging, cardiac radionuclide imaging such as SPECT and PET modalities. Rapid developments of these imaging modalities have significantly improved the diagnostic performance of each imaging technique with high diagnostic accuracy achieved in both diagnostic and prognostic value in coronary artery disease. This editorial provides an overview of the diagnostic applications of a variety of less-invasive imaging modalities in the diagnosis of coronary artery disease. This special issue of “Arteriosclerotic Vascular Disease: Part II” in the journal of Clinical and Experimental Cardiology will give particular attention to contributions focusing on the clinical applications of these imaging modalities in the arteriosclerotic vascular disease, in particular, coronary artery disease.

Keywords: Coronary artery disease; Arteriosclerotic vascular disease; Diagnostic value; Imaging modalities

Coronary artery disease (CAD) is the leading cause of death in advanced countries and its prevalence is increasing among developing countries [1,2]. Various less-invasive imaging modalities are increasingly used in the diagnosis of CAD including coronary CT angiography, cardiac magnetic resonance imaging (MRI), and cardiac single photon emission computed tomography (SPECT), positron emission tomography (PET) and integrated SPECT/CT and PET/CT [3]. To improve early diagnosis and patient management, it is essential to have an overview of the diagnostic value of different imaging modalities in CAD. This editorial provides an overview of the diagnostic performance of these imaging modalities in CAD, with a focus on the advantages, limitations and future directions of the use of each imaging modality in the diagnosis of CAD.

Coronary CT angiography represents the most rapidly developed imaging modality in cardiac imaging with evolution from single slice CT to multislice CT, from early generation of 4- and 16-slice CT to 64- and 320-slice CT scanners, demonstrating excellent visualization of coronary anatomy and assessment of coronary artery disease [4-6]. In summary, diagnostic sensitivity of coronary CT angiography has been significantly improved with 64- or more slice CT scanners when compared to the early generations of 4- and 16-slice scanners, while, the negative predictive value remains consistently high (>90%), regardless of the type of CT scanners [7-11]. This indicates the main role of coronary CT angiography is to rule out significant CAD, thus reducing the need for invasive coronary angiography. The prime indication of coronary CT angiography is to diagnose patients with a low and intermediate probability of CAD as a simple non-invasive testing, while patients with a high probability of CAD will benefit from invasive coronary angiography [12].

In addition to the diagnostic value, coronary CT angiography allows for characterization of plaque components (calcified versus non-calcified plaques and shows potential prognostic value of disease extent and cardiac events [13,14]. Studies based on single center and multicenter clinical trials have shown that coronary CT angiography provides incremental prognostic value over clinical risk analysis in predicting major adverse cardiac events with absence of CAD leading to event free survival period, while presence of plaques associated with increased risk of cardiac events [15-19].

Radiation dose associated with coronary CT angiography is the main concern of this technique in cardiac imaging, and this has increased substantially over the last decade with the development of multislice CT scanners and widespread use of cardiac CT in routine clinical practice. This has raised a serious concern and it is a hot topic of debate in the literature. Various dose-saving strategies have been proposed and recommended in the past few years to lower radiation exposure to patients undergoing coronary CT angiography with tremendous progress having been achieved. Effective dose reduction has been accomplished by employing techniques with a radiation dose of less than 10 mSv to as low as 1 mSv in some studies [11,20,21], although much effort is still required to ensure that coronary CT angiography is safely performed in imaging patients with suspected coronary artery disease.

MRI provides excellent soft tissue contrast, with inherent 3D capabilities, and acquisition of images in any anatomical plane. Furthermore, MRI does not expose the patient to ionizing radiation, thus, the usefulness of MRI has been investigated widely. However, the diagnostic accuracy of cardiac MRI in CAD varies widely according to the literature, with sensitivity ranging from 38% to 83%, and specificity ranging from 57% to 95% due to variable scanning protocols used in the studies [22]. Recent technical developments in MRI, especially with the emergence of 3.0 T MR imaging system have been shown to be a promising technique for performing cardiac MRI, with significant improvement of diagnostic value for detection of CAD [23,24]. Despite these advantages, cardiac MRI is still limited in the visualization of distal coronary segments due to inferior spatial resolution, thus, it is

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not as widely used as coronary CT angiography in the diagnosis of CAD.

Noninvasive evaluation for obstructive CAD is performed by gatekeeper tests that offer physiologic information of coronary stenosis (physiologic imaging) or the degree of stenosis (anatomic imaging). Coronary CT angiography serves as an excellent anatomic gatekeeper as it has a very high negative predictive value, while stress perfusion cardiac MRI is a regarded as a physiologic gatekeeper. Stress perfusion cardiac MRI has been proved to be a robust and accurate diagnostic test for CAD when invasive coronary angiography is used as the reference standard [25-28]. Several systematic reviews and meta-analyses have shown that the sensitivity and specificity of stress perfusion MRI ranged from 89% to 91% and 76% to 81%, using invasive coronary angiography as the reference standard [26-28]. Desai and Jha recently conducted a meta-analysis of 12 studies regarding the cardiac stress perfusion MRI in the diagnosis of flow-limiting obstructive CAD using fractional flow reserve measured at invasive coronary angiography as the reference standard [29]. Their analysis shows that cardiac stress perfusion MRI has a sensitivity of 89.1% and 87.7% and a specificity of 84.9% and 88.6% on a patient-based and on a coronary territory-based analysis, respectively. Thus, cardiac stress perfusion MRI is an accurate test for the detection of flow-limiting stenosis.

Myocardial perfusion imaging (MPI) with stress gated SPECT has been widely used in the diagnosis of CAD and is a well-documented non-invasive method for risk stratification with high diagnostic accuracy when compared to coronary CT angiography [30,31]. The presence of ischemia could be used to classify the patients as having CAD and candidates for receiving aggressive medical therapy and management. Coronary CT angiography has limited accuracy for identifying the physiologic significance of perfusion defects in patients with intermediate or high pre-test likelihood of CAD when compared to MPI SPECT [32]. Thus, MPI SPECT offers additional functional information in the evaluation of coronary stenosis.MPI SPECT can be used as the gatekeeper to invasive coronary angiography. Bateman et al. showed that referral to invasive coronary angiography was 3.5%, 9%, and 60%, respectively, corresponding to normal to mild, moderately abnormal and severely abnormal perfusion scans [33]. A negative SPECT imaging has been confirmed to serve as an excellent prognostic indicator with an annual cardiac event rate of <1% for the general population, while an increasing cardiac events are associated with increasing severity of both fixed and reversible perfusion defects, regardless of the presence of non-obstructive coronary disease [34-36].

Cardiac PET imaging is another well-established tool for the evaluation of ischemia, blood flow quantification, myocardial viability and perfusion [37,38]. Cardiac PET utilizing ^{18}F-FDG is considered the most sensitive modality for detecting hibernating viable myocardium and predicting left ventricular functional recovery post-coronary revascularization. PET has higher spatial and temporal resolution than SPECT due to more robust methods of attenuation correction, thus, PET allows quantification of resting and hyperemic regional myocardial perfusion. When PET was integrated into clinical patient management, a significant reduction in cardiac events was observed in patients with ^{18}F-FDG PET-assisted management, according to randomized controlled trials [39,40]. PET images provide incremental prognostic information to the clinical and angiographic findings with regard to event-free survival. An increased extent and severity of perfusion defects with stress PET were reported to be associated with increased frequency of adverse cardiac events, thus, this indicates PET can be used to predict cardiac mortality [41,42].

Cardiac PET is not yet as widely available as SPECT imaging. Furthermore, experience in image interpretation and operation may vary widely. Cardiac PET will continue to play a key role in the investigation of myocardial viability and perfusion contributing more to available data.

Integrated SPECT/PET-multislice CT has huge potential for cardiac imaging. The incremental value of hybrid imaging lies in accurate spatial co-localization of myocardial perfusion defects and anatomic coronary arteries. This combined technology allows detection and quantification of the burden of calcified and non-calcified plaques, quantification of vascular activity and endothelial health, identification of flow-limiting coronary stenosis, and potentially identification of high-risk plaques in the coronary artery tree [43]. Combined SPECT/CT and PET/CT systems are today well established in clinical routine imagingwith promising results reported [44-48], although more multicentre trials are needed to validate the diagnostic value of the hybrid imaging modalities. Combined PET/MRI represents another new integrated protocol, however, it is only limited to a few clinical centers for preclinical cardiac imaging with a focus on animal experiments [49,50].

In summary, this editorial briefly reviews the diagnostic applications of these less-invasive imaging modalities including coronary CT angiography, cardiac MRI, cardiac SPECT and cardiac PET in coronary artery disease. Advantages and limitations of each imaging modality in the detection of coronary artery disease are also highlighted. Researchers are encouraged to contribute both original and review papers to this special issue with the aim of delivering both educational and teaching message to clinicians with research interests in cardiac imaging.

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