Editorial

Cardiac Imaging in the Diagnosis of Coronary Artery Disease: A Comprehensive Overview of Various 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]. A variety of imaging modalities is used in the diagnosis of coronary artery disease including coronary CT angiography, cardiac MRI, SPECT, PET and integrated SPECT/CT and PET/CT [3]. To improve early diagnosis and patient management, it is of paramount importance to have an overview of the role of different cardiac imaging modalities. This special issue in the Current Medical Imaging Reviews will give particular attention to contributions describing the state of the art, advantages and disadvantages, current limitations and future directions of the use of medical imaging modalities in the diagnosis of CAD.

There are five review papers that have been contributed by researchers from different fields dealing with various medical imaging modalities in relation to their roles in the cardiac imaging [4-8]. The first paper by Sun et al focused on a hot topic, coronary CT angiography in the diagnosis of CAD [4]. Authors in this article provide an overview of the diagnostic and predictive value of coronary CT angiography in CAD with citation of more than 100 relevant references in this area. The first part of the article summarises the diagnostic performance of coronary CT angiography in CAD with use of retrospectively ECG-gated and prospectively ECG-triggered protocols. In particular, prospectively ECG-triggered coronary CT angiography has been discussed in detail with regard to the image quality, diagnostic value and radiation dose [9-12].

Prognostic value of coronary CT angiography in CAD represents the second highlight of the paper. Coronary calcium scoring is regarded as a strong indicator for prediction of cardiovascular events, and this is supported by a recent study showing that coronary calcium scoring is significantly related with CAD and prevalence of cardiac events, although a zero calcium score cannot exclude the presence of significant CAD [13]. Coronary CT angiography plays an important role in providing prognostic information for predicting adverse cardiac events and mortality in patients with known or suspected CAD. Discussion on this aspect is well supported by prospective studies conducted at single and multicentre trials, as well as two meta-analyses. Furthermore, coronary CT angiography is able to predict atherosclerosis by demonstrating the relationship between left coronary angulation and subsequent dimensional changes [14, 15]. The last part of the paper focuses on the radiation dose and dose-reduction strategies. As indicated in this section, tremendous progress has been made to reduce the radiation dose associated with coronary CT angiography with dose levels similar to or even lower than that of invasive coronary angiography. Further technical developments, especially improvement in temporal resolution and implementation of low-dose protocol will enable coronary CT angiography to become an effective alternative to invasive coronary angiography [16, 17].

The second paper by Lee deals with quantitative analysis in cardiac imaging [5]. This review article discusses an interesting topic about quantitative analysis in cardiovascular imaging with a focus on cardiac CT and MRI. The author reviews the feasibility of performing quantitative analysis of cardiac morphology and cardiac function using CT and MRI in the aspects of mechanical function of the heart, myocardial signal and myocardial perfusion. Despite increasing applications of cardiac CT due to technological developments in multislice CT scanners, cardiac MRI is still the reference method for evaluation of left ventricular function as it demonstrates superiority over cardiac CT in the myocardial perfusion assessment [18].

Cardiac CT is widely used in the diagnosis of CAD, which is reflected in the quantitative evaluation of CAD by coronary calcium score and coronary lumen assessment. Coronary CT angiography allows for not only the assessment of degree of stenosis but also the plaque contents and its vulnerability [3, 19]. Another promising area that is discussed in this paper is the use of CT-derived fractional flow reserve (FFR_{CT}) to identify the culprit CAD [20, 21]. FFR_{CT} is a novel method that integrates anatomic and physiologic assessment of CAD, and it provides additional value to coronary CT angiography for identification of individuals with ischemic stenosis.

The last part of this paper focuses on quantitative analysis of cardiac blood flow and vascular wall. Cardiac MRI using phase-contrast MRI is a well-established technique providing high spatial and temporal resolution for an accurate and reliable quantification of the regional cardiac function by encoding the velocity in the phase information of the MR signal [22, 23]. This has been well discussed in this paper. Myocardial velocities are sensitive markers of myocardial contractility. Thus, phase-contrast MRI is able to reveal regional myocardial motion changes, acquire transmitral flow velocity and vortical pulmonary artery flow for assessment of left ventricular function and pulmonary arterial hypertension. In addition, phase-contrast MRI enables acquisition of a velocity profile, from which the computational fluid dynamics parameters such as wall shear stress and oscillation shear index can be derived and used for analysis of early atherosclerotic change [24-26].

The third paper by Rees and Nieto-Baltar provides an overview of the use of medication in cardiac CT imaging [6]. In the introduction section authors highlight the importance of heart rate control with the aim of achieving diagnostic images with less motion artifacts. Although the section of patient preparation and workup seems very general to clinicians or cardiologists, it is still necessary to obtain the patient's clinical history, in particular, the pharmacological history as most drugs that affect heart rate and coronary blood flow will lower blood pressure, which may lead to serious consequences such as fainting or cardiac arrhythmia [6].

Heart rate control by beta-blockers and Ivabradine comprises the main component of this paper. A detailed discussion has been provided with a focus on the pharmacological effects of these two drugs including half-life, doses administered and the potential side effects and contraindications. This section provides valuable sources of information for clinicians to perform cardiac CT examinations effectively with minimisation of complications associated with use of drugs [27, 28].

The last part of this paper is about use of drugs in cardiac CT perfusion imaging. Cardiac CT perfusion represents a new imaging technique with coronary vasodilatation being an essential component of the scanning protocol. Two main drugs including Adenosine and Dipyridamole are well described in terms of their pharmacological mechanisms and injection protocols. Furthermore, some new pharmacological stress agents such as Regadenoson are briefly discussed to provide guidance for centres dealing with CT perfusion imaging in cardiac patients.

The fourth paper by Aziz et al reviews the use of cardiac MRI in the imaging diagnosis of CAD with a focus on the left ventricular assessment, myocardial perfusion and viability with citation of more than 100 references [7]. The paper starts from an overview of technical details of cardiac MRI including technical aspects, pulse sequences and imaging protocols. Different sequences are presented with regard to their applications in perfusion imaging and coronary artery imaging. A number of imaging protocols are recommended for cardiac MRI corresponding to different cardiac conditions such as cardiomyopathy, valvular disease and arrhythmogenic ventricular dysplasia.

Left ventricular function assessment is the main strength of cardiac MRI, and this section has been discussed in detail with sufficient evidence confirming the superiority and high diagnostic value of cardiac MRI. As discussed in the paper, quantitative assessment of ventricular volume, ejection fraction and ventricular wall can be reliably achieved with cardiac MRI. Myocardial perfusion imaging represents another important area where cardiac MRI shows potential applications. Detection of myocardial ischemia and myocardial infarction, more recently, myocardial perfusion reserve can be quantified by cardiac MRI with high diagnostic accuracy when compared to SPECT and PET [7]. In addition, myocardial viability can be assessed by cardiac MRI using myocardial gadolinium enhancement. A detailed discussion has been contributed to this section in combination with authors' clinical experience.

The last part of this paper summarises the current research status of cardiac MRI including microvascular obstruction which can be reliably detected on cardiac MRI. High field MRI such as 3.0 T is briefly discussed with regard to its improved diagnostic performance when compared to the routinely used 1.5 T. The future developments of cardiac MRI such as hybrid PET/MRI are also highlighted.

The last paper by Sun et al discusses the cardiac nuclear medicine imaging with a focus on the diagnostic performance of SPECT and PET in the assessment of myocardial viability and perfusion [8]. This paper provides a comprehensive overview of the cardiac SPECT and PET with regard to their clinical applications in CAD with citation of more than 150 references. The article starts with a review of different radiopharmaceuticals that are used in nuclear cardiology including common and some new radiopharmaceuticals. Radiation dose associated with radiopharmaceuticals in cardiac nuclear imaging is briefly discussed in the second part, although more research is needed to focus on reduction of radiation exposure to patients undergoing cardiac nuclear imaging examinations.

The main focus of this paper is on the myocardial viability and myocardial perfusion imaging by cardiac SPECT and PET. Although cardiac SPECT is regarded as the standard method for both cardiac viability and perfusion assessment, it is being challenged by the rapid developments and increasing applications of cardiac PET [29-31]. This has been discussed in detail in each individual section with support of relevant recent references. Hybrid imaging modalities such as SPECT/CT, PET/CT and PET/MRI are also discussed regarding their diagnostic value in cardiac imaging, although further research on multicentre trials is required to validate these integrated imaging protocols.

In summary, these five excellent review papers contributed by researchers with a wealth of knowledge in different research fields provide readers with valuable sources of information on the cardiac imaging modalities in the diagnosis of coronary artery disease. This special issue delivers both educational and teaching message to clinicians with research interests in cardiac imaging. Also, it can be used as a valuable source of references for researchers to conduct more advanced studies in cardiac imaging.

REFERENCES

[1] Lloyd-Jones D, Adams RJ, Brown TM, *et al.* Executive summary: heart disease and stoke statistics 2010 update: A report from the American Heart Association. Circulation 2010; 121: 948-954.
[2] Gaziano TA, Bitton A, Anand S, *et al.* Growing epidemic of coronary heart disease in low-and middle-income countries. Curr Probl Cardiol 2010; 35: 72-115.
[3] Sun Z, Cao Y, Li HF. Multislice computed tomography angiography in the diagnosis of coronary artery disease. J Geriatr Cardiol 2011; 8: 104-113.
[4] Sun Z, Wang WL, Hsieh IC, Liu YC, Wen MS. Coronary CT angiography in the diagnosis of coronary artery disease. Curr Med Imaging Rev 2013.
[5] Lee J. Quantitative analysis in cardiovascular imaging: current status. Curr Med Imaging Rev 2013.
[6] Rees M, Nieto-Baltar B. Use of medication in coronary imaging by CT. Curr Med Imaging Rev 2013.
[7] Abdul Aziz Y, Fadzli F, Azman R, *et al.* State of the Heart: cardiac magnetic resonance imaging in coronary artery disease. Curr Med Imaging Rev 2013.
[8] Sun Z, AbAziz A, Khairuddin Md Yusof A. Cardiac nuclear imaging: current status and future directions. Curr Med Imaging Rev 2013.
[9] Sun Z, Ng KH. Diagnostic value of coronary CT angiography with prospective ECG-gating in the diagnosis of coronary artery disease: A systematic review and meta-analysis. Int J Cardiovasc Imaging 2012; 28: 2109-2119.

[10] Sun Z, Ng KH. Prospective versus retrospective ECG-gated multislice CT coronary angiography: a systematic review of radiation dose and diagnostic accuracy. Eur J Radiol 2012; 81: e94-e100.

[11] Xu L, Yang L, Zhang Z, *et al.* Low-dose adaptive sequential scan for dual-source CT coronary angiography in patients with high heart rate: comparison with retrospective ECG gating. Eur J Radiol 2010; 76: 183-7.

[12] Sabarudin A, Sun Z, Ng KH. Radiation dose in coronary CT angiography associated with prospective ECG-triggering technique: comparisons with different CT generations. Radiat Prot Dosim 2013; 154: 301-7.

[13] Liu YC, Sun Z, Tsay PK, *et al.* Significance of coronary calcification for prediction of coronary artery disease and cardiac events based on 64-slice coronary computed tomography angiography. Biomed Res Int 2013; 2013: 472347.

[14] Sun Z, Cao Y. Multislice CT angiography assessment of left coronary artery: correlation between bifurcation angle, dimensions and development of coronary artery disease. Eur J Radiol 2011; 79: e90-e95.

[15] Cademartiri F, La Grutta L, Malago R, *et al.* Assessment of left main coronary artery atherosclerotic burden using 64-slice CT coronary angiography: correlation between dimensions and presence of plaques. Radiol Med 2009; 113: 358-69.

[16] Sun Z, Choo GH, Ng KH. Coronary CT angiography: current status and continuing challenges. Br J Radiol 2012; 85: 495-510.

[17] Xu L, Zhang Z. Coronary CT angiography with low radiation dose. Int J Cardiovasc Imaging 2010; 26: 17-25.

[18] Kim YJ, Kim RJ. The role of cardiac MR in new-onset heart failure. Curr Cardiol Rep 2011;13:185-93.

[19] Sun Z, Faridah Y, Ng KH. Coronary CT angiography: How should physicians use it widely and when do physicians request it appropriately? Eur J Radiol 2012; 81: e684-e687.

[20] Min JK, Leipsic J, Pencina MJ, *et al.* Diagnostic accuracy of fractional flow reserve from anatomic CT angiography. JAMA 2012; 308: 1237-45.

[21] Yoon YE, Choi JH, Kim JH, *et al.* Noninvasive diagnosis of ischemic-causing coronary stenosis using CT angiography: diagnostic value of transluminal attenuation gradient and fractional flow reserve computed from coronary CT angiography compared to invasively measured fractional flow reserve. J Am Coll Cardiol Img 2012; 5: 1088-96.

[22] Wong KL, Sun Z, Worthley SG, Mazumdar J, Abbott D. Medical image diagnostics based on computer-aided flow analysis using magnetic resonance images. Comput Med Imaging Graph 2012; 36: 527-41.

[23] Wong KL, Sun Z, Tu J. Medical imaging and computer-aided flow analysis of a heart with an atrial septal defect. J Mech Med Bio 2012; 12: 5.

[24] Chaichana T, Sun Z, Jewkes J. Computational fluid dynamic analysis of the effect of plaques in the left coronary artery. Comput Math Meth Med 2012; 2012: 504367.

[25] Chaichana T, Sun Z, Jewkes J. Computation of haemodynamics in the left coronary artery with variable angulations. J Biomech 2011; 44: 1869-1878.

[26] Chaichana T, Sun Z, Jewkes. Haemodynamic analysis of the effect of different types of plaque at the left coronary artery. Comput Med Imaging Graph 2013; 37: 197-206.

[27] Pichler P, Pichler-Cetin E, Vertesich M, *et al.* Ivabradine versus metoprolol for heart rate reduction before coronary computed tomography. Am J Cardiol 2012;109(2):163-73.

[28] Guaricci AI, Schuijf JD, Cademartiri F, *et al*. Incremental value and safety of oral ivabradine for heart rate reduction in computed tomography coronary angiography. Int J Cardiol 2012;156(1):28-33.

[29] Sato A, Nozato T, Hikita H, *et al.* Incremental value of combining 64-slice computed tomography angiography with stress nuclear myocardial perfusion imaging to improve noninvasive detection of coronary artery disease. J Nucl Cardiol 2010;17:19-26.

[30] Kajander S, Joutsiniemi E, Saraste M, *et al.* Cardiac positron emission tomography/computed tomography imaging accurately detects anatomically and functionally significant coronary artery disease. Circulation 2010;122:603-613.

[31] Gaemperli O, Bengel FM, Kaufmann PA. Cardiac hybrid imaging. Eur Heart J 2011; 32: 2100-8.

Zhonghua Sun
Associate Professor
Discipline of Medical Imaging,
Department of Imaging and Applied Physics,
Curtin University of Technology,
GPO Box, U1987, Perth,
Western Australia 6845,
Australia
Tel: +61-8-9266 7509
Fax: +61-8-9266 2377
E-mail: z.sun@curtin.edu.au