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TOPIC HIGHLIGHT

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Contribution of cardiovascular magnetic resonance in the evaluation of coronary arteries

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Abstract

Cardiovascular magnetic resonance (CMR) allows the nonradiating assessment of coronary arteries; to achieve better image quality cardiorespiratory artefacts should be corrected. Coronary MRA (CMRA) at the moment is indicated only for the detection of abnormal coronary origin, coronary artery ectasia and/or aneurysms (class Ⅰ indication) and coronary bypass grafts (class Ⅱ indication). CMRA utilisation for coronary artery disease is not yet part of clinical routine. However, the lack of radiation is of special value for the coronary artery evaluation in children and women. CMRA can assess the proximal part of coronary arteries in almost all cases. The best results have been observed in the evaluation of the left anterior descending and the right coronary artery, while the left circumflex, which is located far away from the coil elements, is frequently imaged with reduced quality, compared to the other two. Different studies detected an increase in wall thickness of the coronaries in patients with type Ⅰ diabetes and abnormal renal function. Additionally, the non-contrast enhanced T1-weighed images detected the presence of thrombus in acute myocardial infarction. New techniques using delayed gadolinium enhanced imaging promise the direct visualization of inflamed plaques in the coronary arteries. The major advantage of CMR is the potential of an integrated protocol offering assessment of coronary artery anatomy, cardiac function, inflammation and stress perfusion-fibrosis in the same study, providing an individualized clinical profile of patients with heart disease.

Key words: Coronary angiography; Coronary venous system; Gadolinium; Magnetic resonance imaging

Core tip: Cardiovascular magnetic resonance (CMR) allows the non-radiating assessment of coronary arteries. At the moment it is indicated only to detection of abnormal coronary artery origin, ectasia and/or aneurysms (class Ⅰ indication) and coronary artery bypass grafts (class Ⅱ indication). The utilisation of coronary MRA (CMRA) for coronary artery disease diagnosis is not at the moment part of clinical routine. However, due to lack of radiation is particularly useful for children and women. A combined CMR protocol, including CMRA and stress perfusion-fibrosis evaluation may offer a non-invasive assessment of cardiovascular profile in high risk patients.

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INTRODUCTION

Coronary artery disease (CAD) with its sequelae including myocardial infarction and heart failure, is the main cause of increased mortality in our days[1,2]. The usual way for CAD assessment is the use of invasive coronary angiography; however, the high incidence of CAD and

the queries of invasive assessment necessitate the use of a noninvasive evaluation of coronaries[3,4].

Cardiovascular magnetic resonance (CMR) can provide a combined approach including coronary arteries, cardiac function and stress myocardial perfusion-fibrosis evaluation. Coronary magnetic resonance angiography (CMRA) has been already used for assessment of coronary anatomy and vessels' wall, providing useful information in CAD[5-7].

In this review we provide an update of clinical applications of CMRA, discussing the current limitations and the challenges for future applications.

INDICATIONS FOR CMRA

The clinical indications of CMRA are at the moment limited only to the detection of abnormal origin of coronary arteries, coronary ectasia and/or aneurysms (class I indication) and coronary bypass grafts (CABG) evaluation (class II indication). The routine application of CMRA for diagnosis of CAD is not at the moment part of clinical practice[8,9].

CORONARY VESSELS ABNORMALITIES AND ANEURYSMS (CLASS I INDICATION)

CMRA assesses precisely the abnormal coronary arteries and the location and dimensions of coronary aneurysms. The larger caliber and the proximal location of the coronary artery aneurysms (CAA) facilitate their imaging. The most important benefit of CMRA is the absence of ionizing radiation, which is of special clinical value for children and women[8,10]. Clinical entities, characterized by ectatic or aneurysmatic coronaries, include Kawasaki disease, autoimmune vasculitis and coronary artery ectasia[11,12].

KAWASAKI DISEASE AND OTHER AUTOIMMUNE VASCULITIS

In Kawasaki disease, CMR can diagnose lesions both in acute and chronic phase. During the acute phase, a complete evaluation of the coronary anatomy, left and right ventricular function, myocardial inflammation and myocardial fibrosis either due to inflammatory process or due to myocardial infarction is essential.

The presence of CAA needs serial evaluation for patients' risk stratification. Although transthoracic echocardiography is usually sufficient in young children, the visualization of the coronary arteries becomes progressively more difficult as children grow up. According to previous publications, coronary magnetic resonance, using navigator techniques, has an excellent correlation with X-ray coronary angiography using both Pearson coefficient and Bland-Altman analysis and can be used as a reliable alternative for KD patients[13,14]. Recently, the application of free-breathing techniques in children with KD using the whole-heart approach detected successfully not only the abnormalities of coronary lumen, but also the abnormally thickened vessel wall and improved risk stratification and monitoring of therapy[15]. In parallel with coronary assessment, during the same examination, an evaluation of function and wall motion of both ventricles can be also performed using the standard SSFP sequence[16]. However, only anatomic evaluation is not sufficient to successfully risk stratify KD patients. Previous studies in patients with atherosclerotic coronary artery disease proved that maybe a severe anatomic lesion could not provoke severe myocardial ischemia and in contrary, a marginal coronary lesion can induce significant myocardial ischemia[17]. Magnetic resonance (MR) first-pass myocardial perfusion imaging during hyperaemia, due to the vasodilating agent adenosine, demonstrates a high diagnostic performance of MR perfusion imaging for the detection of anatomically defined coronary artery stenoses[18].

Other autoimmune vasculitis that can potentially develop coronary aneurysms include polyarteritis nodosa, microscopic polyangiitis and Wegener granulomatosis[19]. In these diseases the application of coronary MRA with simultaneous assessment of myocardial oedema-fibrosis may reveal disease activity and pathophysiology of heart lesion noninvasively and without radiation[20].

CORONARY ARTERY ECTASIA

Coronary artery ectasia (CAE) represents a form of atherosclerosis, detected in 3%-8% of subjects during X-ray coronary angiography. Sluggish blood flow is produced within the ectatic segments, leading to chest pain in effort and myocardial infarction, independently of the significance of coexisting stenosis. CAE is the dilatation of an artery 1.5 times greater than the normal coronary artery and is assessed in 5% of angiographic and in 0.22%-1.4% of autopsy cases[21-24]. It may involve the entire vessel or be localized in a specific part of the vessel. If it involves the entire vessel, it is called "ectasia". It is due to atherosclerosis in > 50% of cases. Ectasia coexists with coronary artery disease in the majority of patients. Only 10%-20% of CAE coexist with systemic diseases[25,26], such as scleroderma[27,28], Ehlers-Danlos syndrome[29], different types of antineutrophil cytoplasmic antibody (ANCA)-related vasculitis[19] (Figure 1A), syphilitic aortitis[30] and Kawasaki disease[14] (Figure 1B). In some patients, CAE has a congenital origin[31]. The differentiation between congenital and acquired coronary aneurysms is rather difficult. Acquired CAE should also be differentiated from aneurysms due to different coronary procedures.

The correct follow up of ectatic vessels demands repeated angiograms and CMRA offers an excellent alternative for the evaluation of the initial part of left main, left anterior descending and right coronary arteries[32]. CMRA has been already proved a valuable clinical tool for diagnosis of abnormal coronary origin, and is in some cases superior to X-ray coronary angiography; however, it is still under investigation for the assessment of the CAD[32]. Our group proved that CMRA is equal

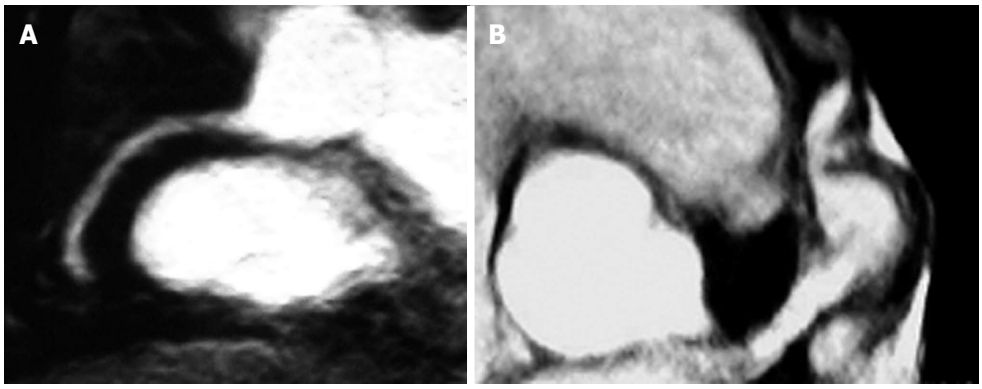

Figure 1 Magnetic resonance angiography. A: Ectatic coronaries in a patient with polyarteritis nodosa, assessed by MRA; B: Aneurysmatic coronaries in a patient with Kawasaki disease, assessed by MRA. MRA: Magnetic resonance angiography.

to quantitative coronary angiography for evaluation of ecstatic/aneurysmatic disease. Furthermore, it is a non-invasive, nonradiating technique[4]. Compared with CT, CMRA does not need use of a contrast agent. CMRA can also give additional data about, vessels' blood flow and stress perfusion-fibrosis pattern[33].

CORONARY BYPASS-GRAFTS (CLASS II INDICATION)

Bypass grafts can be assessed very well by coronary MRA, because they are relatively immobile and have larger diameter compared to coronary arteries. Different imaging ways have been already used, including spin echo[34-37] and gradient echo techniques. The application of contrast agents for better imaging of the blood signal[38,39]. increased the sensitivity to 95%.

However, metallic clips in grafts constitute the commonest limitation of coronary bypass MRA. Coronary MRA can be used at some special centers to detect lesions in bypass grafts[8].

CORONARY MAGNETIC RESONANCE ANGIOGRAPHY FOR ASSESSMENT OF CAD

Coronary MRA assesses the initial part of the coronary arteries in almost 100% of patients, with excellent results acquired for the left anterior descending (LAD) and the right coronary artery (RCA); the left circumflex (LCX), due to its peculiar way, is at a increased distance from the cardiac coil, and therefore its visualization is of inferior quality. According top revious studies, the imaged length for LAD is 50 mm, for RCA is 80 mm and for LCX is 40 mm[40-47]. An excellent agreement between the proximal parts of coronary arteries measured by MRA and by invasive angiography was assessed by previous studies[48].

Unfortunately, the resolution of CMRA remains lower compared with invasive coronary angiography and does not allow the evaluation of stenosis in small coronary arteries. This is the reason of the low specificity documented in a recent international multicenter study[4]; however, CMRA was shown to have a high sensitivity (92%) for the detection of CAD and its diagnostic performance was ameliorated. In a subanalysis of left main or three vessel disease, a sensitivity of 100% and a negative predictive value of 100% was documented. These findings were also supported by smaller single-center studies[40,49-57].

Recently, a meta-analysis compared coronary MRA and multi-slice computed tomography (CT) for assessment of significant CAD[34]. CT was more accurate than MRA and therefore CT was suggested as the preferred non-invasive alternative to X-ray coronary angiography. However, the superiority of CMRA is that it can offer more data about the patient, including cardiac anatomy, function, inflammation, stress perfusion and fibrosis evaluation.

Recently, a multicenter study showed that whole-heart CMRA at 1.5 T can detect significant CAD with high sensitivity (88%) and moderate specificity (72%). Additionally, a negative predictive value (NPV) of 88% indicates that this technique can effectively be used to exclude the presence of significant CAD[58]. We should mention that this NPV reported by this trial is identical to the NPV of the CORE-64 CTA multicenter study[59]. Proving the value of CMRA to rule out CAD in patients with low pre-test probability (< 20%)[60].

Finally, in a direct comparison between CMRA and CTA no significant difference was proved for the detection of CAD between 3 T MR and 64-slice CTA[61]. A comparison between coronary MRA, CTA and invasive coronary angiography (CA) is shown in Table 1.

CORONARY VESSEL WALL ASSESSMENT

The initial CMR images of the coronary vessel wall were taken using fast spin echo techniques[62,63]. A double inversion recovery preparation was used to take black-blood images improving the contrast between blood and vessel wall[64]. Recently, the double inversion recovery prepulse has been combined with fast gradient echo[65], spiral[66]

Table 1 Comparison between invasive coronary coronary angiography, CTA and magnetic resonance angiography

	CA	CTA	MRA
Noninvasive	No	Yes	Yes
Radiation	Yes	Yes	No
Nephrotoxicity	Yes	Yes	No
Accuracy	+++	++	+
Negative predictive value	+++	+++	++
Cost	High	High	High
Calcium detection	±	+	-
Anomalous coronaries	+++	+++	+++
Ectasia/aneurysm	+++	+++	+++
Graft assessment	+++	+++	+++
CAD evaluation	+++	++	+
Plaque evaluation	+++	±	±

CA: Coronary angiography; MRA: Magnetic resonance angiography; CAD: Coronary artery disease; CTA: Computed tomography coronary angiography.

and radial acquisitions[67].

Various studies documented the capability of vessel wall imaging to detect remodeling of coronary arteries in CAD and increased vessel wall thickness in type I diabetes with abnormal renal function[68,69]. It was also documented by Jansen *et al*[70] that non-contrast enhanced T1-weighed MR visualized thrombus in acute myocardial infarction.

Recently, new techniques using delayed gadolinium enhancement facilitated the direct assessment of inflamed plaques in the coronary arteries. Clinically used contrast agents showed non-specific uptake in plaques of patients with chronic angina[71]. Acute coronary syndromes[72] and systemic lupus erythematosus[73]. The contrast enhancement by CMR, assessed in patients with stable angina, was associated with calcified or mixed plaques on MSCT, while in ACS it was transient, probably due to inflammatory process.

New contrast agents have been already used in animals and their accumulation in blood was associated with increased endothelial permeability and/or increased neovascularization[74]. Additionally, increased accumulation of iron-oxide particles (USPIO) was indicative of increased endothelial permeability and vessel wall inflammation, due to intraplaque macrophages[75,76].

Such molecules have been used as targets for new molecular contrast agents that allowed the assessment of inflammatory indexes, such as intercellular adhesion molecule-1 (ICAM-1), vascular adhesion molecule-1 (VCAM-1) or matrix metalloproteinase (MMP)[77,78]. Furthrmore, thrombi labeling using a fibrin-specific contrast agent[79,80] and evaluation of extracellular matrix remodelling, using targeting elastin is a new promising molecular imaging technique[81,82] for early detection of plaque vulnerability[83].

CONCLUSION

CMR is a non-invasive, non-radiating technique for evaluation of coronary arteries and coronary wall. Its major advantage is the potential of a combined protocol, including coronary arteries, cardiac anatomy, function, inflammation and stress perfusion-fibrosis in the same study in CAD and/or heart failure.

CMRA current indications include: (1) assessment of abnormal coronary arteries, coronary ectasia and/or aneurysm (class I indication); and (2) coronary bypass grafts (class II indication). In the future, it may be used to exclude CAD in selected patients. However, further improvements are needed to support its use for routine assessment of high risk populations.

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