EDITORIAL

Cardiac stress-perfusion MRI: ready for primetime?

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Can you practice cardiology in 2021 without access to cardiac magnetic resonance imaging (CMR)? A silly question, perhaps, but there are authorities who would answer in the affirmative[1]. Comparison with echocardiography (ECHO, Table 1) is most natural, because the imaging planes are the same and at least some of the images look very similar. Is CMR just an expensive „ECHO plus"?

Table 1. Comparative features of echocardiography and cardiac MRI

Feature	ECHO	CMR
Portability	+++	-
Affordable price	+++	-
Complexity of physics theory involved	+	+++
Complexity of examination	+	+++
Complexity of interpretation	++	+++
Operator-dependence of image quality	+++	++
Availability and access	+++	+
Contraindicated in renal failure	-	++
Signal-to-noise ratio^	+	+++
Reproducibility	+	+++
Patient factors effect on image quality	+++	+
Versatility	+++	+++
Spatial resolution (mm)	0.5-2	1-2
Temporal resolution (ms)	10-50	20-50
Foreshortening, missing the apex of the heart*	++	-
Geometric assumptions for volume/EF measurement*	++	-
Assessment of valve stenosis	+++	++
Assessment of valve regurgitation	++	+++
Accuracy for detection of myocardial ischaemia#	++	+++
Accuracy for detection of myocardial viability**	++	+++
LV Volumes and EF	++	+++
RV Volumes and EF	+	+++
Extracardiac structures	+/-	+++
Assessment of cardiac masses	++	+++
Tissue characterisation	+/-	+++

^ - significantly improved with the use of ultrasound contrast agents
* - only for 2D echo, not for 3D echo
# - dobutamine/vasodilator/exercise stress
** - low-dose dobutamine stress echo; LGE for CMR

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A major attraction of CMR is its excellent reproducibility, better than that of ECHO, which has been extensively proven and which can massively reduce calculated sample sizes necessary to demonstrate clinically meaningful changes in LV dimensions and ejection fraction by CMR vs. ECHO[2]. Due to its excellent signal-to-noise ratio, CMR has rapidly become the gold standard for cardiac chamber and ejection fraction measurement[3], and CMR is also clearly superior to ECHO for the assessment of RV structure and function[4,5]. A truly unique feature of CMR is its ability to perform *in-vivo* myocardial tissue characterisation and provide, effectively, a non-invasive myocardial biopsy, and thus allow assessment of viability, replacement fibrosis, iron overload, myocardial oedema/inflammation or tumours[6]. Flow imaging allows valve assessment in a manner similar to, but more reproducible than, ECHO[7]. Parametric techniques such as T1 mapping[8] hold promise for imaging of interstitial fibrosis and for the detection of an expanded extracellular myocardial compartment, while tensor vector imaging[9] visualises the microstructure of the myocardium, with potentially fundamental clinical implications, yet to be fulfilled.

CMR has an excellent track record for the detection of inducible myocardial ischaemia. Most centres use a 4 to 6-minute adenosine intravenous infusion and image the myocardial distribution of gadolinium at maximum coronary artery vasodilation[10]. Dobutamine stress CMR, where inducible ischaemia is inferred from transient wall motion abnormalities at peak stress, is also available, but, being technically more demanding, is not widely used[11]. Also the safety profile of vasodilator stress is superior to that of dobutamine, particularly considering the logistics of the patient being stressed inside the MRI scanner.

There is an unresolved „tension" between advocates of perfusion vs. anatomical imaging for the assessment of coronary artery disease. Over several decades, in the USA, SPECT has been the leading method for ischaemia detection, due to its robustness, wide availability[12]. However, there is increasing concern about radiation exposure associated with nuclear cardiac techniques[13], relatively low spatial resolution, as well as a shift towards anatomical techniques, as evidenced by the recommendation from NICE to use CTCA as the first test in patients with chest pain and low to moderate pre-test probability of CAD[14].

In multiple direct comparisons and meta-analyses, stress perfusion CMR consistently comes top of the list for sensitivity and specificity in the detection of myocardial ischaemia[15,16]. It is radiation-free, non-invasive, repeatable, offers extensive anatomical and functional assessment of the heart beyond perfusion assessment, and has better spatial resolution than SPECT[17]. Why then is it the least-adopted[18] ischaemia test?

Undoubtedly, cost, limited availability and relative scarcity of training opportunities have a major part to play, although limited data suggest cost-effectiveness[19]. Whilst the significance of inducible myocardial ischaemia itself is now being questioned[20], there is increased recognition that ischemia imaging will continue to play a major role in cardiovascular medicine[21].

In this issue of the „Review" Onciul et al. present their pioneering experience with CMR and stress-perfusion CMR in a large academic centre in Romania[22]. They are to be commended for taking the time and trouble to document their practice in comprehensive detail, in a context where CMR is still in its infancy. A simple Google search[23] reveals that out of 10 MRI imaging centres in Bucharest only 2 offer CMR. This ratio is not specific to Bucharest – in Wales, out of 15 major hospitals with cardiology departments, only 5 offer CMR[24] – CMR is still a minority pursuit.

In the era of personalised, quantitative medicine, with its emphasis on genetic markers of disease and on big data, as illustrated by the UK Biobank project for instance[25], CMR is an essential piece of the complex puzzle of progress and discovery in cardiology[26], and the data presented by Onciul et al. represent an important contribution to the wider adoption of a still underused imaging modality.

Conflict of interest: none declared.

Abbreviations:

CAD	Coronary artery disease
CMR	Cardiac magnetic resonance
CTCA	Computer tomographic coronary angiography
ECHO	Echocardiography
LGE	Late gadolinium enhancement
LV	Left ventricle
MRI	Magnetic resonance imaging
NICE	National Institute for Clinical Excellence (UK)
SPECT	Single-photon emission computer tomography

References

1. Kilner P. Personal communication to the author, 22 Oct 2012.
2. Grothues F, Smith GC, Moon JCC, Collins P, Klein HU, Pennell DJ. Comparison of interstudy reproducibility of cardiovascular magnetic

resonance with two-dimensional echocardiography in normal subjects and in patients with heart failure or left ventricular hypertrophy. Am J Cardiol 2002; 90: 29-34.
3. Pennell DJ. Cardiovascular magnetic resonance: twenty-first century solutions in cardiology. Clinical Medicine 2003; 3: 273-8.
4. Geva T. MRI Is the Preferred Method for Evaluating Right Ventricular Size and Function in Patients with Congenital Heart Disease. Circ Cardiovasc Imaging. 2014 7: 190–197.
5. Te Riele ASJM, Tandri H, Sanborn DM, Bluemke DA. Noninvasive Multimodality Imaging in ARVD/C. JACC Cardiovasc Imaging. 2015; 8: 597–611.
6. Karamitsos TD, Arvanitaki A, Karvounis H, Neubauer S, Ferreira VM. State-of-the-Art Review: Myocardial Tissue Characterization and Fibrosis by Imaging. JACC: Cardiovascular Imaging. 2020. 13: 1221-1234.
7. Gulsin GS, A. Singh A, McCann GP. Cardiovascular magnetic resonance in the evaluation of heart valve disease BMC Med Imaging. 2017; 17: 67.
8. Taylor AJ, Salerno M, Dharmakumar R, Jerosch-Herold M. State-of-the-Art Paper. T1 Mapping: Basic Techniques and Clinical Applications. JACC: Cardiovasc Imag 2016; 9: 67-81.
9. Khalique Z, Ferreira PF, Scott AD, Nielles-Vallespin S, Firmin DN, Pennell DJ. State-of-the-Art Review: Diffusion Tensor Cardiovascular Magnetic Resonance Imaging: A Clinical Perspective JACC: Cardiovasc Imag 2020; 13: 1235-55.
10. Hamon M, Fau G, Née G, Ehtisham J, Morello R, Hamon M. Meta-analysis of the diagnostic performance of stress perfusion cardiovascular magnetic resonance for detection of coronary artery disease. J Cardiovasc Magn Reson. 2010;12:29–38.
11. Charoenpanichkit, C., Hundley, W.G. The 20 year evolution of dobutamine stress cardiovascular magnetic resonance. J Cardiovasc Magn Reson 2010. 12, 59.
12. Abbott BG, Case JA, Dorbala S et al. Contemporary Cardiac SPECT Imaging—Innovations and Best Practices: An Information Statement from the American Society of Nuclear Cardiology. Circulation: Cardiovasc. Imag. 2018; 11: e000020.
13. Einstein A. Effects of Radiation Exposure From Cardiac Imaging: How Good Are the Data? J Am Coll Cardiol. 2012; 59: 553–565.
14. https://www.nice.org.uk/sharedlearning/ct-coronary-angiography
15. Danad I., Szymonifka J., Twisk J.W.R. et al. Diagnostic performance of cardiac imaging methods to diagnose ischaemia-causing coronary artery disease when directly compared with fractional flow reserve as a reference standard: a meta-analysis. Eur. Heart J. 2017; 38: 991-998.
16. Siontis GCM, Mavridis D, Greenwood JP et al. Outcomes of non-invasive diagnostic modalities for the detection of coronary artery disease: network meta-analysis of diagnostic randomised controlled trials. BMJ 2018;360:k452.
17. Jivan A, Lee DC. Is stress perfusion CMR ready for prime time? https://www.acc.org/latest-in-cardiology/articles/2017/12/08/10/32/is-stress-cmr-ready-for-prime-time Accessed online 30/01/2021.
18. Asher A, Ghelani R, Thornton G et al. UK perspective on the changing landscape of non-invasive cardiac testing. Open Heart. 2019; 6: e001186
19. Francis, Sanjeev F, Cohen J, Olchanski N et al. Stress CMR myocardial perfusion imaging (CMR-MPI) is cost-effective compared to nuclear SPECT: a retrospective cost-effectiveness analysis. J Cardiovasc Magn Reson. 2012, 14 (Suppl 1): 03.
20. Maron DJ, Hochman JS, Reynolds HR et al. Initial Invasive or Conservative Strategy for Stable Coronary Disease. N Engl J Med 2020; 382:1395-1407.
21. Shaw L, Kwong R, Nagel E et al. Cardiac Imaging in the Post-ISCHEMIA Trial Era: A Multisociety Viewpoint. JACC Cardiovasc Imaging. 2020;13:1815-1833.
22. Onciul S, Popa O, Nicolaesu R et al. Stress perfusion CMR – a report of an initial Romanian Experience. Romanian J Cardiol 2021, 31: 1-11.
23. Google search performed on 30/01/2021, using the key words "rezonanță magnetică nucleară" and "București" (nuclear magnetic resonance and Bucharest).
24. https://www.wales.nhs.uk/ourservices/directory/Hospitals accessed on 30/01/2021, for list of major hospitals. The figure of only 5 hospitals which offer CMR comes from the author's knowledge of the service structure in Wales.
25. https://www.ukbiobank.ac.uk/ accessed online on 29/01/2021.
26. Petersen, S.E., Matthews, P.M., Francis, J.M. et al. UK Biobank's cardiovascular magnetic resonance protocol. J Cardiovasc Magn Reson 2015; 18: 8.