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The year 2018 in the European Heart Journal – Cardiovascular Imaging. Part I

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Manuscript

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Abstract

The European Heart Journal – Cardiovascular Imaging has become one of the leading multimodality cardiovascular imaging journal since it was launched in 2012. The impact factor is an impressive 8.366 and it is now established as one of the top 10 cardiovascular journals. The journal is the most important cardiovascular imaging journal in Europe.

The most important studies from 2018 will be highlighted in 2 reports. Part I of the review will focus on studies about myocardial function and risk prediction, myocardial ischaemia, and emerging techniques in cardiovascular imaging, while Part II will focus on valvular heart disease, heart failure, cardiomyopathies, and congenital heart disease.

European Heart Journal – Cardiovascular Imaging has successfully consolidated as a multimodality journal during its first 7 years. The journal is now in the top 10 of all cardiovascular journals according to the recent 2017 impact factor ratings. It has now an important role as a significant resource for cardiologists, specialists in all imaging modalities, and other physicians working in the field of cardiovascular imaging. The tradition of highlighting the most important studies that were published in the last year is continued.[1,2] In two articles, we will summarize the most important papers from the journal in 2018. Part I will focus on myocardial function and risk prediction, myocardial ischaemia, and emerging techniques in cardiovascular imaging.

Recommendations and expert consensus documents from the European Association of Cardiovascular Imaging

One important assignment of European Heart Journal – Cardiovascular Imaging is to publish position papers, recommendations and expert consensus papers from the European Association of Cardiovascular Imaging (EACVI). The journal published 6 recommendations and expert consensus papers in the field of multimodality imaging.[3–8] These papers are commented on in more detail elsewhere in the two documents.

Myocardial function and risk prediction

Hong and coworkers investigated 21 patients with invasive left ventricular (LV) pressure measurements and simultaneous echocardiography at rest and during submaximal supine bicycle exercise. LV apical back-rotation parameters by speckle-tracking echocardiography at rest and during 50 W of exercise were compared. Lack of decrease in minimal LV pressure during exercise, a manifestation of impaired LV suction in early diastole, was linked with impaired LV

apical back rotation during exercise. Dynamic changes in LV apical back rotation during exercise can be used as a non-invasive parameter of diastolic suction during exercise.[9] This paper was commented on by Dr. Smiseth, emphasizing that untwisting velocity may help to identify patients with severely impaired diastolic function during exercise. However, the small size of the study essentially demonstrated a mechanistic principle.[10]

Bergerot and coauthors explored diastolic function changes over time in 310 patients with type 2 diabetes without overt heart disease to identify predictive factors of diastolic function deterioration. Diastolic function was assessed by echocardiography at baseline and 3-year follow-up. Age, retinopathy, and increase in blood pressure over time were associated with an increased risk of diastolic function deterioration in type 2 diabetes patients.[11]

Lee et al investigated the longitudinal relation between changes in body mass index (BMI) and LV diastolic function. They retrospectively identified 165 asymptomatic individuals with preserved LV ejection fraction, who underwent repeated health check-ups (median interval: 365 days). They showed an association between changes in BMI and LV diastolic function. A decrease in BMI corresponded to a significant decrease in left atrial (LA) volume index and a significant increase in Doppler imaging peak diastolic (*e′*) velocity.[12]

Hubert et al investigated if atrial remodelling occurring at early stage might predict atrial fibrillation (AF) in veteran athletes. Twenty-seven male endurance veteran athletes with documented paroxysmal AF were retrospectively enrolled and compared with 30 control endurance athletes without documented AF, with similar training level, age, and cardiovascular risk factors. All subjects underwent echocardiography, to evaluate the left and right atrial anatomical and functional remodelling assessed by two-dimensional (2D) strain. Atrial function was strongly associated with paroxysmal AF and was proposed to identify male endurance veteran athletes at risk to develop AF.[13]

Rehman et al assessed whether resting right ventricular (RV) function assessed by Global RV longitudinal strain (RVLS) and RV fractional area change (FAC) was associated with exercise performance in pulmonary arterial hypertension (PAH) and in chronic thromboembolic pulmonary hypertension (CTEPH). They prospectively recruited 46 consecutive patients with PAH and 42 patients with CTEPH who were referred for cardio-pulmonary exercise testing and transthoracic echocardiography. In PAH, resting RV function was associated with exercise performance and could therefore make a significant contribution to non-invasive assessment in PAH patients. This association was not found in CTEPH, suggesting a disconnection between resting RV function and exercise performance, with implications for the use of exercise measurements as a prognostic marker and clinical/research endpoint in CTEPH.[14]

Chowdhury et al assessed the validity of echocardiographic indices of LV systolic function via direct comparison to a novel composite measure of contractility derived from pressure–volume loop (PVL) analysis. Children with normal loading conditions undergoing routine left heart catheterization were prospectively enrolled. Pressure–volume loops were obtained via conductance catheters and systolic function was measured by speckle-tracking echocardiography. A composite invasive composite contractility index (ICCI) was developed using data reduction strategies to combine four measures of contractility derived from PVL analysis. Speckle-tracking derived longitudinal strain was associated the invasive composite contractility index in children with normal loading conditions and they concluded that longitudinal measures of deformation appeared to accurately assess LV contractility in children.[15]

The EACVI/ASE/Industry Task Force to standardize deformation imaging prepared a consensus document to standardize definitions and techniques for using two-dimensional (2D) speckle tracking echocardiography (STE) to assess left atrial, right ventricular, and right atrial myocardial deformation. The document aimed to represent a step forward in the collaboration

between the scientific societies and the industry since technical specifications of the software packages designed to post-process echocardiographic datasets have been agreed and shared before their actual development. The consensus aimed for more clinically oriented software packages which will be better tailored to clinical needs and will allow industry to save time and resources in their development.[7]

Co-workers from the NORRE study (Normal Reference Ranges for Echocardiography) obtained the normal ranges for echocardiographic measurements of LA function from a large group of healthy volunteers accounting for age and gender. A total of 371 healthy subjects were enrolled at 22 collaborating institutions. Left atrial data sets were analysed with a vendor-independent software package allowing homogeneous measurements irrespective of the echocardiographic equipment used to acquire data sets. The presented data highlight the importance of age-specific reference values for LA functions.[16]

Semi-supine bicycle ergometry stress echocardiography was used to evaluate RV systolic and diastolic reserve in 39 paediatric heart transplantation (HTx) recipients and 23 controls. Colour tissue Doppler imaging (TDI) peak systolic (s') and e' velocities, myocardial acceleration during isovolumic contraction (IVA), and RV free wall longitudinal strain were measured at incremental heart rates. RV systolic and diastolic functional response to exercise was preserved with a normal increase in TDI velocities and strain values with increasing heart rate. There was a blunted IVA response possibly indicating a mildly decreased RV contractile response which requires further investigation.[17]

Almeida et al evaluated the impact of the recent 2016 American Society of Echocardiography (ASE)/European Association of Cardiovascular Imaging (EACVI) recommendations in the prevalence and grades of diastolic dysfunction compared with the 2009 guidelines and the Canberra Study Criteria. A population-based cohort of a total of 1000

individuals, aged ≥45 years, were evaluated retrospectively. Diastolic function was assessed by transthoracic echocardiography. The application of the new 2016 ASE/EACVI recommendations resulted in a much lower prevalence of diastolic dysfunction and the concordance between the classifications was poor. The updated algorithm seemed to be able to diagnose only the most advanced cases.[18]

The study was commented on by Drs. Edvardsen and Smiseth. They pointed out that the recommendations in the recent EACVI/ASE guideline suggesting echocardiographic indices of LV diastolic function to be used to identify patients with elevated LV filling pressure have been confirmed in two large multicentre validation studies. This represents a major step forward in echocardiographic evaluation of diastolic function. The issue of optimal combination of diastolic function indices to grade diastolic function and to differentiate between normal and abnormal diastolic function needs further elaboration. They concluded that rather than more expert opinions, there is need for studies which relate different filling patterns and more novel classification schemes to clinical outcome.[19]

Park et al investigated the association between alcohol consumption and LV functional and structural abnormality. Study participants were 49 714 Korean adults undergoing echocardiogram during a health check-up program and they were stratified into 6 groups according to alcohol consumption. Increased alcohol intake had adverse effect on LV function and structure. Potential favourable effect of light alcohol intake was not observed.[20]

Gorter et al studied the value of echocardiographic right-sided characterization for the discrimination between pre- vs. post-capillary pulmonary hypertension in heart failure with preserved ejection fraction (HFpEF), using invasive haemodynamics as gold standard. A total of 102 consecutive HFpEF patients with simultaneous right heart catheterization and echocardiography were identified. Abnormal right ventricular-vascular coupling identified

patients with HFpEF and additional pre-capillary pulmonary hypertension and predicted poor outcome in HFpEF.[21]

Saito et al investigated the prognostic value of LV and RV deformation in 103 patients with systemic sclerosis and 103 age- and gender-matched controls. Speckle tracking LV strain parameters including global longitudinal strain (GLS) and global circumferential strain (GCS), and tricuspid annular peak systolic velocity (Ts′) were measured. Subjects were followed for a median of 3.4 years for heart failure-specific admission or death. RV dysfunction was associated with adverse outcome, independent of and incremental to clinical and LV deformation parameters. LV dysfunction appeared to have less prognostic relevance than RV dysfunction.[22]

Risum et al investigated the importance of RV function for prediction of sudden cardiac death (SCD) or malignant ventricular arrhythmias (VAs) after acute myocardial infarction in 790 prospectively included patients with acute MI. All patients had 2D strain echocardiography performed to evaluate right ventricular (RV) free wall strain (RVS) and RV mechanical dispersion (MD). RVS, but not RV MD, was significantly and independently related to SCD/VA in patients with acute MI. Furthermore, RVS was shown to be superior to TAPSE.[23]

Fung et al examined 129 patients of which 73 had hypertension with dobutamine echocardiography. LV ejection fraction (LVEF), global longitudinal strain (GLS), circumferential, and radial strain were measured at rest and at low-dose dobutamine. Compared with controls, hypertensive patients had impaired LV GLS at rest and impaired contractile reserve despite normal LVEF. Impaired contractile reserve correlated with LV wall thickness but independent of prevailing blood pressure.[24]

Hilbert and colleagues provided further important evidence of the feasibility - with regards to safety and diagnostic image quality - for performing CMR in patients with cardiac implantable electronic devices.[25] Device type and location were the main determinants of image

quality with implantable cardioverter defibrillators demonstrating the largest impact. Post-contrast spoiled gradient echo sequences were of higher quality in such patients compared with the steady state free precession (SSFP) cine imaging for assessment of cardiac volumes and function.

Differentiation of normal from pathological cardiac remodelling still remains challenging clinically despite years of research and progress. Claessen and colleagues reported the potential for exercise CMR to address the problem of differentiating athlete's hearts from pathological LV dilatation and mildly reduced LV systolic function.[26] The LV ejection fraction change due to exercise was dampened in dilated cardiomyopathy patients and endurance athletes with myocardial fibrosis when compared to endurance athletes without myocardial fibrosis.

CMR has the ability to provide information that can lead to change in management in 70% of patients with thalassaemia major due to its ability to determine chamber sizes and function, myocardial fibrosis and myocardial iron overload determined by T2* measurements. In addition, as shown by Pepe and colleagues, myocardial fibrosis, myocardial iron overload and ventricular dysfunction were independent predictors of heart failure in thalassaemia major patients.[27]

Ischaemic heart disease

Ischaemic heart disease remains an important subject for imagers and multimodality imaging is frequently needed.[28,29] Echocardiography remains clinically significant and important prognostic markers can be reported just after and during the follow-up of patients treated for an acute myocardial infarction.[30] (Figure 1)

Strain data are encouraged by several studies despite the fact that we miss strong evidence that might change the treatment. Twist, torsion, and strain have been reported as more reduced in

heart failure patients compared to controls. Torsion and twist are significantly lower in patients with non-ischaeic compared to ischaeic cardiomyopathies, despite similar volumetric dimensions, circumferential and longitudinal strain parameters, and LVEF. These torsion and rotation patterns could be considered more carefully in future studies for best characterizing the LV dysfunction according to the aetiology[31,32]. The additive value of strain data in diabetic patients has been reported and will probably be recommended in the future for the assessment of the myocardium of diabetic patients[33–35].

Among patients with ST-segment elevation myocardial infarction (STEMI), the presence of chronic obstructive pulmonary disease (COPD) has been independently associated with higher mortality when compared with patients without COPD. LV systolic function is a known prognostic factor after ST-segment elevation myocardial infarction but impaired LV GLS is independently associated with worse long-term survival in STEMI patients. 143 patients with an acute myocardial infarction were retrospectively included, and 66 (46%) patients died and 70 (49%) patients reached the combined endpoint after a median follow-up of 68 months. Patients with LV GLS >-14.4% (more impaired) showed higher cumulative event rates of all-cause mortality.[36]

The consequences of myocardial infarction on mitral valve apparatus are important to consider and a proper understanding of the relationship between the injured myocardium and the mitral valve apparatus might impact the management of the patient.[37 38 39] Mechanisms of chronic ischaemic mitral regurgitation (IMR) are well-characterized by apically tethered leaflet caused by papillary muscles (PMs) displacement and adynamic mitral apparatus.[39] But, using 3D echocardiography of patients with first MI, it has been provided insights into unique 3D dynamics of the mitral apparatus in acute IMR.[40] Mitral plasticity is a compensatory mechanism that allows the mitral valve to increase its total area and generate a larger coaptation zone, and

therefore, decrease and potentially prevent ischaemic mitral regurgitation. This is affected by the post MI remodelling, but it has also been shown that clinical features have to be considered. Authors found that longer time-duration of diabetes mellitus and higher haemoglobin levels were independently associated with development of mitral plasticity.[39] This is fascinating and might impact our clinical management.

Coronary computed tomography angiography (CTA) with its excellent sensitivity and negative predictive value is a reliable non-invasive imaging tool to rule out obstructive coronary artery disease. Advancements in image reconstruction algorithms, detector architecture, and post-processing tools further increased the ability to assess coronary atherosclerotic plaques and provide important prognostic information. The mismatch between coronary artery stenosis grade and ischaemia is well known, and it is reflected by the limited specificity and positive predictive value of coronary CTA to identify haemodynamically relevant coronary lesions. Different methods have been introduced to overcome this clinically important limitation. The two main and most robust approaches to add functional dimension to this anatomical imaging technique are the computed tomography (CT)-based simulation of fractional flow reserve (FFR) and CT perfusion imaging (CTP). These techniques are complementary to anatomical CT imaging and are able to enhance the diagnostic performance by increasing positive predictive value and specificity and consequently reducing unnecessary downstream testing.

Detecting ischaemia is crucial to guide clinical decision making particularly among patients with at least moderate stenosis (above 50%). The simulation of FFR is based on conventionally acquired coronary CTA images, however, its use is still limited mainly due to the associated high costs and the necessity to send whole CT data sets to an offsite location to perform the computer intense haemodynamic simulations. CTP requires pharmacologic stressor

agents and additional imaging either using static or dynamic acquisition protocols. However its results are instantly available for the referring physicians.

To compare the diagnostic performance of a reduced-order computed tomography-derived fractional flow reserve (CT-FFR) technique derived from luminal deformation and static CT stress myocardial perfusion (CTP), Ihdayhid and colleagues prospectively enrolled 46 patients (84 vessels) with suspected coronary artery disease from a single institution planned for elective coronary angiography. They underwent research indicated invasive FFR and 320-detector CT coronary angiography (CTA) and static CTP.[41] The authors demonstrated that in patients with suspected coronary artery disease, a reduced-order CT-FFR technique can identify lesion specific ischaemia with high accuracy compared with FFR; and is superior to CTA and static CTP assessed visually and quantitatively, in a per-vessel and per-patient analysis. Based on this selected cohort of patients, CT-FFR had superior incremental diagnostic value when added to CTA for identifying functionally significant stenosis as assessed by FFR when compared with CTP. Importantly, the benefit of CT-FFR was delivered using a standard desktop computer from a single widened acquisition CTA, without the need for additional medications and with reduced contrast and radiation exposure compared with CTP. (Figure 2)

However, larger prospective studies in an intermediate risk population will be required to further assess the real-world feasibility of this CT-FFR technique.

Another important study, that underlined the big effort around these themes, was published by Pontone et al. [42]. Aim of this study was to further elucidate the ability of static stress CTP to increase diagnostic performance when compared with coronary CTA using on one hand the visual assessment of ischaeia and on the other hand the calculation of transmural perfusion ratio (TPR). The investigators enrolled 88 symptomatic patients with high pre-test probability who were referred for invasive angiography and FFR measurement. The prevalence of obstructive

CAD and functionally significant CAD were 71% and 48%, respectively. The Authors concluded that adding cCTA to CTP with either qualitative or quantitative evaluation has good accuracy for detecting functionally significant CAD. However, TPR evaluation is associated with a trend towards lower specificity, positive predictive, and diagnostic accuracy when compared with cCTA plus CTP with qualitative evaluation and is more time consuming. Thus, a protocol integrating anatomy and functional assessment using the latest-generation scanner is feasible, and provides fast and simple qualitative evaluation of myocardial perfusion allowing reliable detection of functionally significant CAD.

Finally, the use of CT-FFR can be an effective to technique for the rule out of patients with typical angina pectoris. To assess the use of downstream coronary angiography (ICA) and short-term safety of frontline CTA with CT-FFR testing in stable patients with typical angina pectoris, 774 patients referred to non-emergent ICA or coronary CTA at Aarhus University Hospital on a suspicion of CAD were enrolled and downstream testing and treatment within 3 months and adverse events ≥ 90 days were registered. [43] In the high- vs. low-intermediate-risk group, ICA was cancelled in 75% vs. 91%. Coronary revascularization was performed more frequently in high-risk than in low-intermediate-risk patients, 76% vs. 52% (P = 0.03). Serious clinical events occurred in four patients, but not in any patients with cancelled ICA by coronary CTA with selective CT-FFR testing. The authors concluded that frontline coronary CTA with selective CT-FFR testing in stable patients with typical angina pectoris in real-world practice is associated with a high rate of safe cancellation of planned ICAs.

Coronary CT can be used also to examine the association between coronary artery calcium score (CACS) and risk of future AF, and to estimate the predictive accuracy of CACS for AF development in patients undergoing non-contrast cardiac computed tomography (nCCT).

In the study published by Vinter et al, a Danish registry-based cohort study, 27 962 patients were followed until 2016 (median 2.9 years).[44] The authors concluded that a high CACS was associated with a high risk of AF and that the relationship between the two parameters was such that an individual's risk of AF increased as the CACS increased, even after multivariable adjustment. They also demonstrated that CACS had moderate predictive accuracy with respect to identifying individuals at risk for developing AF within one year after nCCT. CACS combined with knowledge regarding other AF risk factors may help clinicians to identify patients at high risk for AF, which may facilitate both disease prevention and earlier treatment of patients who most likely develop AF and thus reduce their risk of stroke.

The role of myocardial perfusion scintigraphy (MPS) in the evaluation of patient with known or suspected CAD is well known. However, there are some points that need to be underlined or clarified.

Single-photon emission computed tomography (SPECT) is widely used for the assessment of coronary artery disease and for decision-making regarding revascularization, even if concerns about possible false negative findings exist.

Yokota et al aimed to assess the prevalence of stenoses which are both functionally and anatomically significant in 133 patients referred for invasive FFR measurements following a normal SPECT, because of persistent complaints.[45] If FFR <0.75 was used, only 7.5% of the patients had both anatomically and functionally significant stenoses. In patients with normal SPECT who undergo FFR measurements because of persistent complaints, the prevalence of stenoses which are of both anatomically and functionally significant is low. This suggests that the prevalence of false-negative SPECT is (very) low.

The Dan-NICAD trial, an open label, parallel, head to head, randomized controlled diagnostic accuracy trial of CMR and myocardial perfusion scintigraphy showed disappointing

diagnostic accuracy for both techniques. In this work by Nissen and colleagues these functional tests were performed in patients at low to intermediate risk of obstructive coronary artery disease following a positive coronary CT angiography.[46] These patients may represent a particular challenge to perfusion techniques and further research to better understand the underlying mechanisms is needed.

In order to increase the sensitivity of SPECT, the appropriate choice of stress modality, especially in difficult population, is mandatory. To this end, Gimelli and colleagues compared the impact of exercise stress test versus vasodilator test in patients with diabetes mellitus, matched with a control group.[47] In patients with DM exercise stress SPECT had a lower accuracy than vasodilator-stress (AUC 0.70 vs. 0.89, $P < 0.001$), because of a lower specificity (45% vs. 69%), while in the control group the accuracy of MPS was similar regardless of the stress-protocol adopted. So, even if the accuracy of MPS in patients with DM is elevated, a reduced specificity can be expected in the case of exercise stress MPS, because of an impaired exercise capacity.

Finally, nuclear cardiology can be used for the evaluation not only of contractile reserve, but also of chronotropic response in patients with reduced left ventricular ejection fraction. [48] Tamarappoo et al evaluated, by Rubidium-82 gated PET, the independent prognostic value of inadequate heart rate reserve and ejection fraction in response to pharmacologic stress in a high-risk group of 461 patients with reduced resting LVEF. The Authors concluded that resting heart rate, inadequate heart rate reserve and ejection fraction were prognostically important in predicting all cause of death after accounting for clinically important risk factors. The relative importance these variables in affecting all cause of death were dependent upon age. A significant inadequate heart rate reserve was relatively more important than reduced ejection fraction reserve for improved survival among young patients, with the exception of older patients.

Emerging techniques

In the field of echocardiography new techniques have been recently developed and some older ones proved their clinical utility in new clinical settings.

Myocardial work (estimated by pressure-strain loops) was studied for the identification of responders to cardiac resynchronization therapy (CRT). Galli et al have assessed 97 patients with symptomatic heart failure (ejection fraction: 27 ± 6%, QRS duration 164 ± 18 ms) undergoing CRT. Patients with higher myocardial work (>1057 mmHg%) exhibited a favourable response to CRT, predicting a >15% reduction in left ventricular (LV) end-systolic volume at 6 months follow up in both ischaemic and non-ischaemic aetiology. [49]

In patients with acute coronary syndrome (ACS) layer-specific and global longitudinal strain (GLS) provide prognostic information regarding the risk of heart failure or cardiovascular death. Skaarup et al have studied 465 ACS patients treated by PCI, with a median follow-up time of 4.6 years. Endomyocardial GLS (12% vs 17%), global longitudinal strain (11% vs 14%), and epimyocardial GLS (9% vs. 13%) were all significantly reduced in patients with an adverse outcome. GLS and epimyocardial GLS provided incremental prognostic information when added to all other significant predictors in this setting. [50]

The echocardiographic-fluoroscopic fusion imaging is a new imaging system that facilitates catheters and device navigation during catheter-based structural heart disease interventions. The advantages and limitations of this novel imaging system during mitral valve transcatheter interventions are discussed in a comprehensive review by Faletra et al. [51]

Quantitative myocardial perfusion evaluated with positron emission tomography in the form of stress myocardial blood flow and myocardial flow reserve (MFR) is a prognostic factor for the development of major adverse cardiovascular outcomes (MACE) in populations with

known or suspected coronary artery disease. Eight studies (n = 6804) were analysed in a systematic review. The pooling instance demonstrated that MFR significantly associates with the development of MACEs (HR: 1.92 [1.29, 2.84]; P = 0.001). Myocardial flow reserve seems to outperform stress myocardial blood flow as an independent prognostic factor. [52]

Optical frequency domain imaging (OFDI) is a new method used to assess fibroatheromas with the goal to identify coronary lesions precursors of acute events. In 49 patients, OFDI was performed following treatment of culprit lesion and at 6-month follow-up in patients with STEMI. Non-culprit fibroatheromas located in the infarct related artery of patients with acute coronary syndromes had a volumetric reduction of the fibrous cap at 6-month follow-up, and 27% of the lesions changed their phenotype over time. Quantitative fibrous cap assessment was able to differentiate high-risk lesions that became thick cap fibroatheromas.[53]

In another study, Shimokado et al. showed that short wavelength (1700 nm) infra-red optical coherence tomography accurately identified lipid tissue in coronary autopsy specimens with a positive predictive value and a negative predictive value of 97% and 74%, respectively. This new technique increases the possibility of identifying histopathological features of coronary plaques at risk for rupture.[54]

Cao and colleagues derived central circulation transit time from first pass perfusion cardiovascular magnetic resonance (CMR) images. This transit time was determined as the time delay between the peaks of signal intensity curves normalised to the cardiac cycle length. The transit time between the right atrium and the ascending aorta was considered to be the global transit time, and regional transit times were between the right atrium and pulmonary artery or the pulmonary artery and left atrium, and the left atrium and ascending aorta. Prolongation of global and regional transit times were observed in patients with heart failure and reduced ejection fraction and patients with heart failure and preserved ejection fraction. Thus, determination of

transit times is feasible using first pass perfusion CMR and may be an important biomarker in heart failure.[55]

In some way similar to the transit times by Cao and colleagues was a method developed and described by Ricci and colleagues. Similar, as it also used first pass perfusion CMR and time delays between peaks of signal intensity curves. Ricci and colleagues called their biomarker pulmonary blood volume index (PBVI). PBVI equals the right ventricular stroke volume and the pulmonary transit time normalised by the body surface area. The pulmonary transit time is the time delay between the peak of the signal intensity curves in the right ventricle and the left atrium. This marker was determined in a cohort of chronic heart failure patients and healthy controls and PBVI was found to be higher in heart failure and was additionally found to be an independent predictor of a composite cardiovascular endpoint. [56]

In another MRI study Schäfer et al. showed that reduced vortices assessed by four-dimensional flow CMR in the LV of patients with mild-to-moderate chronic obstructive pulmonary disease is a potential marker of early LV diastolic dysfunction and precede more obvious mechanical changes such as stiffening and dilatation. Reduced LV vortices appear to be driven by COPD-induced changes in lung tissue and parallel RV dysfunction. [57]

Hybrid positron emission tomography–magnetic resonance (PET/MR) imaging is a novel imaging modality with emerging applications for cardiovascular disease. It aims at combining the high-spatial resolution morphological and functional assessment afforded by MRI with the ability of PET for quantification of metabolism, perfusion, and inflammation. An overview of PET-MR technology and the clinical cardiovascular applications of PET and MRI performed separately and with hybrid PET-MR are presented in a comprehensive review by Nazir et al. [58]

Wicks and colleagues reported the complementary information provided by CMR and 18F-flurodeoxyglucose (FDG)-positron emission tomography to diagnose cardiac sarcoidosis. In

particular patients with late gadolinium enhancement and FDG uptake were at increased risk of adverse events.[59]

Figure legends

Figure 1. Scar in the infero-latero basal segment involving the papillary muscle and inducing a severe tethering on the posterior mitral leaflet (A); severe secondary mitral regurgitation (B); consequences on the longitudinal strain with a dyskinesia localized in the segment of the inferior papillary muscle (C).

Figure 2 Coronary artery disease with positive CT-FFR and CTP. Forty-two-year-old man with increasing exertional chest pains and suspected coronary artery disease. CTA demonstrated moderate to severe stenosis (x) in the proximal LAD artery with further moderate disease in the mid-vessel (y) (A). Invasive coronary angiography (B) demonstrated moderate 40–50% stenosis in the proximal (x) and mid-segment (y) of the LAD. Invasive FFR was functionally significant at 0.75 in the distal vessel. CT-FFR (C) was functionally significant at 0.77 in the distal vessel. Visually assessed CTP identified perfusion defects in the anterior wall indicating LAD territory ischaemia (D). Transmural perfusion polar plot (E, F) demonstrating TPR values and abnormal perfusion in anterior wall. Orange colour indicates TPR values <0.94 and blue colour indicates TPR values >0.99. CT-FFR, CT-derived fractional flow reserve; CTA, CT coronary angiogram; CTP, CT stress myocardial perfusion imaging; FFR, fractional flow reserve; LAD, left anterior descending; TPR, transmural perfusion ratio. From Ihdayhid et al. [41]

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Figure 1

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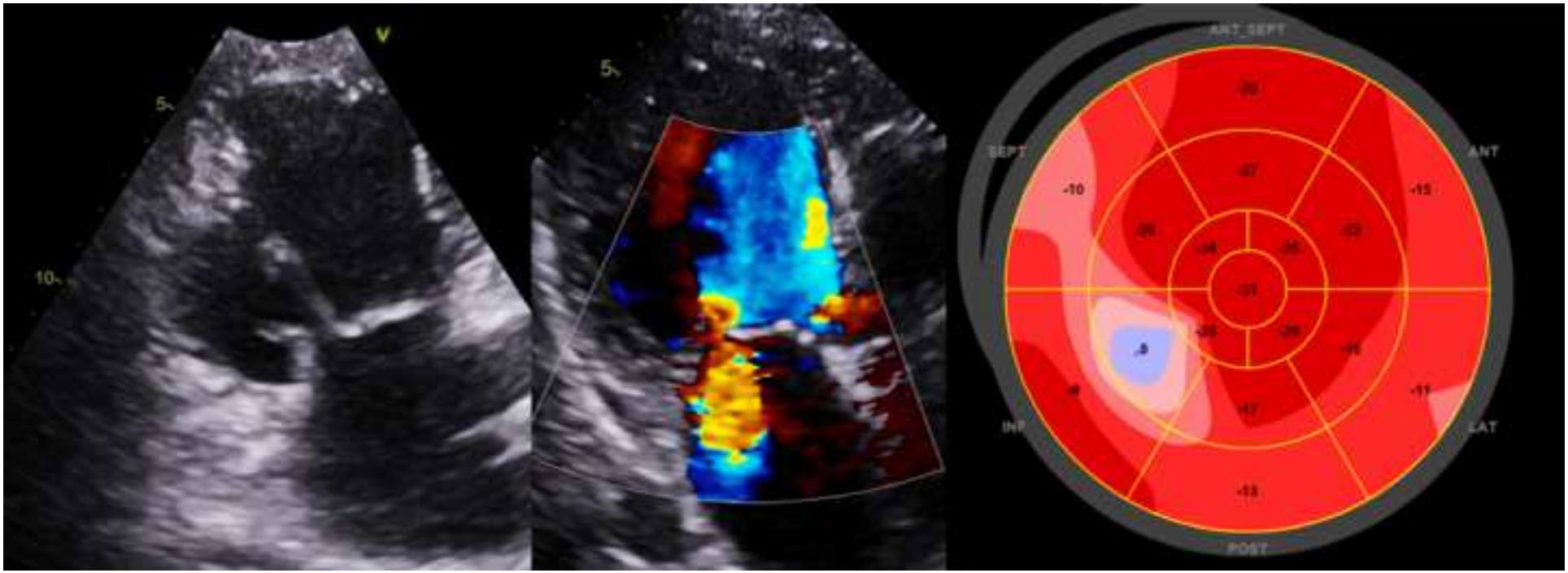

Figure 2

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