


EuroEcho 2019: highlights

Julien Magne ^{1,2*}, Tara Bharucha³, Maya Cikes⁴, Maurizio Galderisi⁵,
Suzanna Price⁶, Leyla Elif Sade⁷, Bogdan A. Popescu⁸, Bernard Cosyns⁹, and
Thor Edvardsen^{10,11,12}

¹CHU Limoges, Hôpital Dupuytren, Service Cardiologie, Limoges F-87042, France; ²INSERM U1094, Univ. Limoges, CHU Limoges, IRD, U1094, GEIST, 2, rue Marcland, 87000 Limoges, France; ³Department of Congenital Cardiology, University Hospital Southampton NHS Foundation Trust, Tremona Road, Southampton SO16 6YD, UK; ⁴Department of Cardiovascular Diseases, University of Zagreb School of Medicine, University Hospital Center Zagreb, Kispaticeva 12, 10000 Zagreb, Croatia; ⁵Department of Advanced Biomedical Sciences, Federico II University Hospital, via S. Pansini 5, 80131 Naples, Italy; ⁶Unit of Critical Care Medicine, Imperial College School of Medicine, Royal Brompton Hospital, Dovehouse Street, London SW3 6LY, UK; ⁷Department of Cardiology, University of Baskent, E Blok, 54. Sokak, Bahcelievler 06490, Ankara, Turkey; ⁸University of Medicine and Pharmacy "Carol Davila"—Eurocolab, Institute of Cardiovascular Diseases "Prof. Dr. C. C. Iliescu", Bucharest, Romania; ⁹Centrum voor Hart en Vaatziekten (CHVZ), Universitair Ziekenhuis Brussel, Vrij Universiteit van Brussel, Brussels, Belgium; ¹⁰Department of Cardiology, Center for Cardiological Innovation, Oslo University Hospital, Rikshospitalet, Oslo, Norway; ¹¹University of Oslo, Oslo, Norway; and ¹²Faculty of Medicine, University of Oslo, Oslo, Norway

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The annual meeting of the European Association of Cardiovascular Imaging, EuroEcho 2019, was held in Vienna, Austria, in December 2019. In this article, we present a summary of the 'Highlights' session.

Keywords

heart failure • heart valve disease • new technologies • congenital heart disease • acute cardiac care • prevention

Introduction

The 23rd annual scientific meeting of the European Association of Cardiovascular Imaging (EACVI), EuroEcho 2019, was held from 4 to 7 December in Vienna, Austria. The main themes were 'cardiomyopathies' and 'imaging in acute cardiac care'.

This year, the world leading congress on echocardiography, reached a total number of 4095 health care professionals coming from 95 countries.

Over 1639 abstracts and clinical cases were submitted and the scientific programme involved 387 international faculties from 44 countries in 233 scientific sessions. Furthermore, five studies were presented in the Late Breaking Trial session, newly launched this year.

Overall, 15 oral abstract sessions and 34 poster sessions were presented. The preferred topics regarding abstracts submission were 'Tissue Doppler, Speckle Tracking and Strain Imaging', 'Valve Diseases', 'Systolic and Diastolic Function', and 'Stress Echocardiography'.

The 'Highlights' session wrapped up the event with a summary of the most relevant abstracts presented throughout the congress on the last day of the meeting. A short report of this session is presented below.

Heart failure

The best abstracts dealing with heart failure (HF) included novelties such as artificial intelligence (AI), myocardial work (MW), shear wave propagation, vortex formation but also strain imaging, standard echo-Doppler, and multimodality imaging approach.

The AI was tested to assess both left ventricular (LV) systolic and diastolic function. Uejima *et al.*¹ performed a multiparametric assessment of diastolic function in 279 consecutive HF patients. The diastolic function was assessed according to a cluster analysis [based on unsupervised machine learning (ML) algorithm] compared to diastolic grading of current recommendations. The hospitalization for LV ejection fraction (EF) worsening was the primary endpoint and the combination cardiovascular (CV) death + HF hospitalization the secondary endpoint. The comparison of diastolic parameters [E/A , e' velocity, E/e' , left atrial (LA) volume index (LAVi), and tricuspid regurgitation (TR) velocity] showed similar trend between grading and clusters and both grading and cluster classification correlated with brain natriuretic peptide levels. However, during a follow-up of 2.6 ± 2.0 years (primary endpoint reached by 62 patients), cluster-based classification showed a superiority to predict HF-free survival and the combined endpoint of CV death + HF-free survival (Figure 1). The combination of MAGGIC score (an HF risk calculator

* Corresponding author. Tel: +33 5 19 76 19 18. E-mail: julien.magne@unilim.fr

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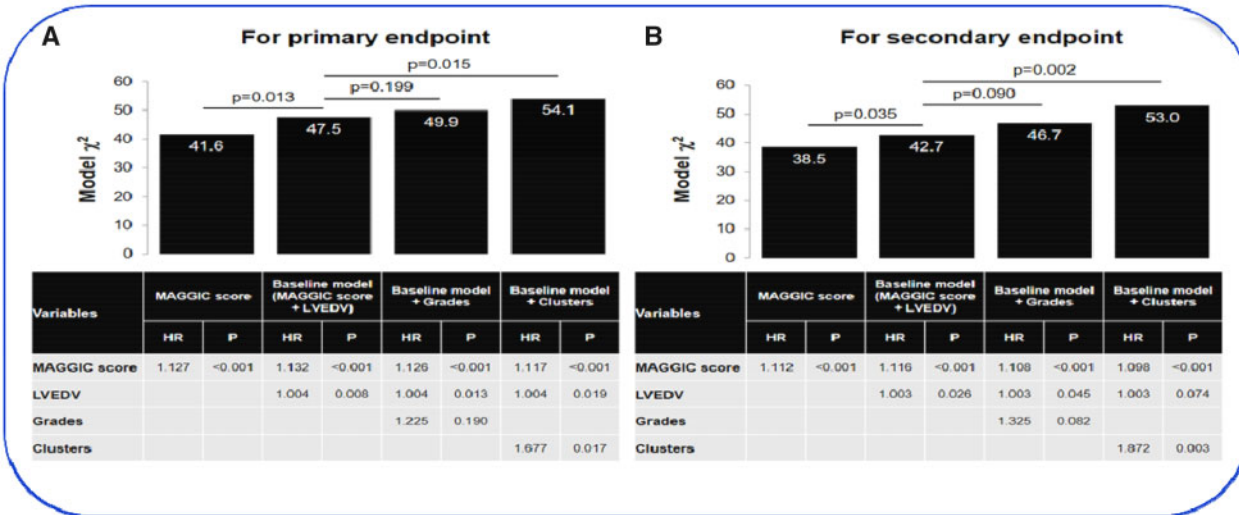
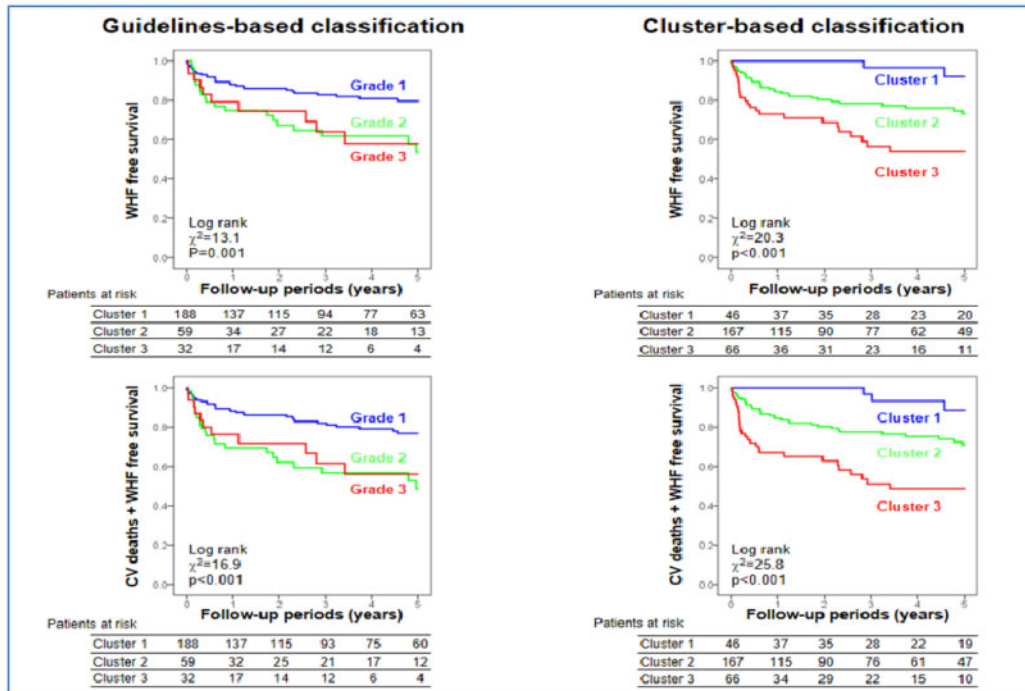


Figure 1 Clinical outcomes by grading and cluster (top) and Cox proportional hazard models (bottom, A, primary end-point and B, secondary end-point). Modified from Sanchez-Martinez et al.³⁵ LVEDV, left ventricular end-diastolic volume.

including 13 clinical variables, risk factors, and treatment) and cluster analysis showed an additional value in comparison with MAGGIC score + grading classification in predicting primary and secondary endpoints (Figure 1). The authors conclude that AI presents an incremental value in comparison with current recommendations for predicting HF decompensation. Popoff et al.² evaluated accuracy and reproducibility of an AI-based semi-automated tool to compute LV volumes and EF, in comparison with manual contouring, using cardiac magnetic resonance (CMR) as reference in a two-centre retrospective study ($n = 114$ patients in sinus rhythm). LV segmentation using U-Net convolutional network on the frames selected by three

observers. The authors showed improved accuracy (vs. CMR) and higher reproducibility of AI.

The impact of MW acute redistribution after cardiac resynchronization therapy (CRT) on LV reverse remodelling ($\Delta\%$ LV end-systolic volume) was evaluated by Duchenne et al.³ in 135 HF patients referred for CRT (four European centres). Before CRT, MW showed clear differences among LV walls. The CRT caused an acute redistribution of MW, with most increase in the septum and most decrease laterally and induced a more homogeneous MW distribution. After 1-year follow-up, acute MW redistribution ($\Delta\%$ changes) was positively related to $\Delta\%$ LV end-systolic

volume. The authors conclude that regional loading modification is the mode of action of CRT.

Hubert *et al.*⁴ evaluated a novel semi-automatic tool for the assessment of volume–strain loops in 17 patients with cardiac amyloidosis compared with 18 healthy controls and 18 patients with HF with preserved EF. The volume–strain area better correlated with average e' of the mitral annulus ($r = 0.65$, $P < 0.001$) than all the other indices, thus demonstrating to be a very promising tool to assess semi-automatically diastolic function.

Novel sudden cardiac death (= sudden cardiac arrest or an appropriate intracardiac defibrillator (ICD) intervention) predictors such as global longitudinal strain (GLS), LV average strain, and LAVi (instead of LA dimension) were tested in 252 patients with hypertrophic cardiomyopathy by Adamczak *et al.*⁵ By using Cox's proportional hazard analysis, the models with the novel parameters was highly significant ($P = 0.00094$), whereas the model including the standard parameters was marginally significant ($P = 0.04385$) in predicting ICD implantation during an average follow-up of 3.8 years. The new predictors could be taken into account when considering ICD implantation.

Prevention

Clerc *et al.*⁶ investigated the predictive value of coronary artery calcium score (CACS) for predicting myocardial ischaemia in 927 consecutive patients without known coronary artery disease, who underwent 82Rb positron emission tomography myocardial perfusion imaging and multi-slice computerized tomography. The proportion of ischaemia, expressed as summed difference score ≥ 4 , increased in relation with CACS. The CACS was a better associated with ischaemia than combined clinical and electrocardiogram data (area under curve = 0.82 vs. 0.69; $P < 0.001$). A CACS < 100 AU had high sensitivity (81%) and negative predictive value (94%) to exclude ischaemia, whereas CACS > 1000 AU had high specificity (94%) but moderate positive predictive value (60%) to identify ischaemia, underlining the need for additional testing after positive CACS.

Regarding atherosclerosis, Matangi *et al.*⁷ performed screening by carotid ultrasound in 1683 consecutive patients to estimate the proportion and severity of carotid disease in patients referred for stress echocardiography. Patients had no diabetes, statin treatment, or prior history of any CV disease. Plaque scoring was performed according to Rotterdam method.⁸ A brief carotid using echocardiographic screening prior to stress echocardiography identified a significant proportion of patients (68% males, 52% females) having high risk for CV events who might benefit from guidelines based CV disease prevention therapies including aspirin and statins, regardless of induced wall motion abnormalities and/or ischaemia.

Important data came from the ARIC-NCS (Atherosclerosis Risk in Communities Neurocognitive Study) sub-study regarding stroke prevention. Bianco *et al.*⁹ demonstrated the association between age-related LA remodelling and ischaemic stroke in the elderly with normal sinus rhythm, preserved LV ejection fraction (LVEF) and no valvular heart disease. Three subgroups were studied as follow: (i) no cerebral infarcts on CMR ($n = 315$), (ii) CMR-diagnosed subclinical infarcts ($n = 58$), and (iii) clinically diagnosed stroke ($n = 34$). Among investigated echocardiographic parameters, they found that E/e' divided by LA GLS, as a surrogate of LA stiffness, was an independent

risk factor for overall cerebral infarcts [odds ratio (OR) 1.92, $P = 0.005$] and stroke (OR 2.30, $P = 0.009$), while LA GLS, was an independent marker for subclinical cerebral infarct (OR 1.0, $P = 0.014$). These results have important clinical implications for empiric anticoagulation to prevent both recurrent subclinical cerebral infarcts and stroke before the development of atrial fibrillation among elderly.

Taha *et al.*¹⁰ explored echocardiographic mechanical dysfunction in phospholamban R14del mutation carriers. In all, 120 mutation carriers and 60 control subjects were studied. Phospholamban (PLN) R14del carriers were classified as: pre-symptomatic (no ventricular arrhythmias, LVEF $\geq 50\%$), arrhythmic with LVEF $\geq 50\%$, and structurally abnormal (LVEF $< 50\%$). GLS was reduced in pre-symptomatic stage that could be further differentiated from concealed stage by means of GLS (Figure 2A). Patients with arrhythmias or structural abnormalities had both increased mechanical dispersion and low GLS. Future studies should aim to investigate the therapeutic and prognostic value of these measurements.

Loncaric *et al.*¹¹ used ML tool to explore hypertensive patient profiles based on full myocardial deformation and Doppler traces. ML goes beyond the limited number of standard echocardiographic parameters by capturing and integrating the complex and complete information from blood pool and tissue characteristics throughout the cardiac cycle and represents the individual on an output space where patients are grouped based on the similarity of their cardiac function. Individual clinical data, velocity, and deformation patterns can be extracted and compared between positions in the output space (Figure 2B). New patients can be projected into the existing space to aid in clinical interpretation. This futuristic model is promising to refine risk assessment and patient management in a cohort with well-regulated blood pressure.

Heart valve diseases

In contrast with past years, aortic stenosis is no longer the most frequently investigated heart valve diseases and tricuspid valve is no longer the 'forgotten valve'.

Previtero *et al.*¹² studied the prognostic value threshold of semi-quantitative (i.e. vena contracta) and quantitative [i.e. regurgitant volume, effective regurgitant orifice area (EROA), and regurgitant fraction (RF)] echocardiographic parameters of functional TR assessment. In this single centre, retrospective study involving 296 patients, they identified new cut-off values, slightly lower than those reported in current guidelines. They also underlined the crucial value of RF in risk stratification of functional mitral regurgitation (MR), related to its less dependency to loading conditions.

In a prospective multicentre study,¹³ the right ventricular (RV) geometry and function, as well as tricuspid annulus size, of 100 patients with various TR severity (from mild to torrential) were analysed. The EROA of TR was independently associated with right atrial size and tricuspid tethering area but not with RV function parameters. Of note, the vast majority of patients, regardless of TR severity, exhibited tricuspid annulus dilatation (> 40 mm).

The prognostic implication of bivalvular functional regurgitation (i.e. concomitant presence of both functional MR and TR) has been investigated by Heitzinger *et al.*¹⁴ This context remains challenging to treat and manage, and only limited data are available. Among the

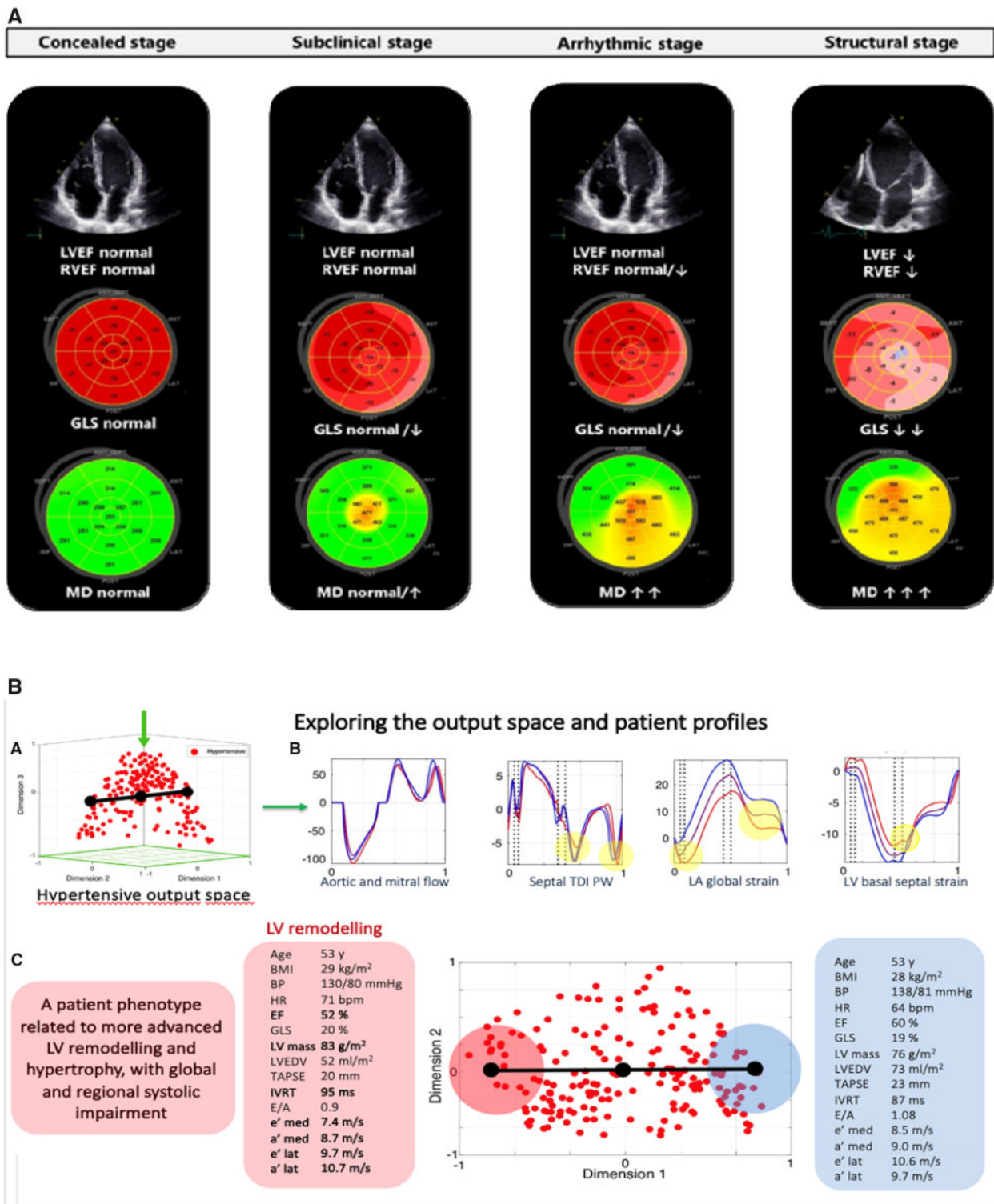


Figure 2 (A) Classification of PLN (Phospholamban) mutation (R14del) carriers on the basis of deformation characteristics. Pre-symptomatic stage is differentiated from concealed stage by means of decreased GLS and mechanical dispersion. LVEF, left ventricular ejection fraction; RVEF, right ventricular ejection fraction. (B) Exploration of the hypertensive output space and patient profiles from the output space. (A) Hypertensive output space, (B) extraction of individual measurements, and (C) exploration of individual patient profiles. Modified from Sanchez-Martinez et al.³⁵ LA, left atrial; LV, left ventricular; PW, pulsed wave; TDI, tissue Doppler imaging.

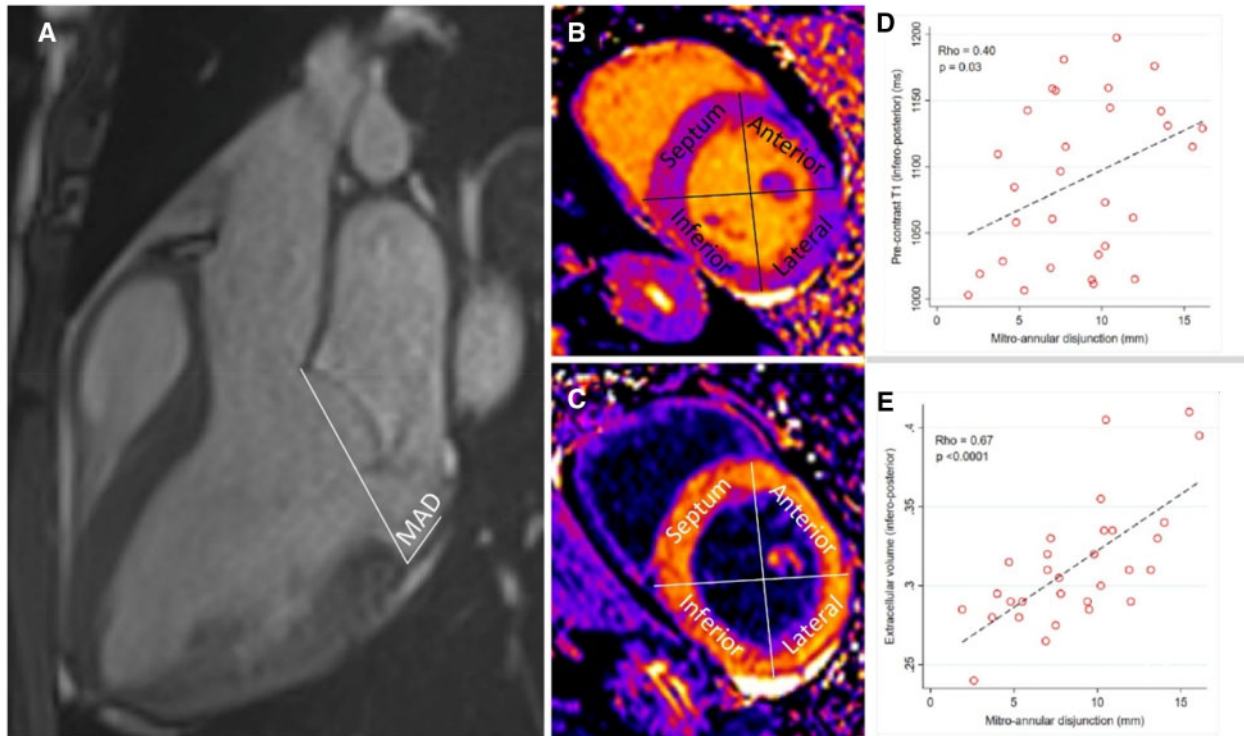


Figure 3 Myocardial ECV by T1 mapping-CMR in mitral valve prolapse with mitral-annulus disjunction. The three-chamber view (A) show MAD (between 7.1 and 12.3 mm); pre contrast T1 mapping (B) and after contrast T1 mapping (C) divided into four segments to evaluate the ECV. Relation between mitro-annular disjunction and pre contrast T1 mapping (D). Relationship between MAD and ECV (E). Modified from Sanchez-Martinez *et al.*³⁵

1021 patients with HF and reduced EF studied, 32% have bivalvular function regurgitation. During a maximal follow-up of 5 years, 433 patients died, and as expected, bivalvular function regurgitation was associated with markedly reduced survival, significantly lower than isolated severe functional regurgitation. Furthermore, the authors also found that moderate bivalvular functional regurgitation is associated with higher risk of mortality than isolated severe functional MR or TR, or even similar risk that severe functional MR and moderate TR or vice-versa.

Mitral annular disjunction (MAD) associated with mitral valve prolapse has been studied using CMR by Pavon *et al.*¹⁵ They purposely aimed to investigate the relationship between MAD and the presence of interstitial fibrosis, in the basal inferior LV wall (Figure 3). A group of 33 patients with both MAD and regurgitant mitral valve prolapse was compared to 22 patients with regurgitant prolapse without MAD. The MAD size and interstitial fibrosis, as assessed as extracellular volume (ECV) derived from T1 mapping, were measured using CMR. The ECV was statistically higher in MAD patients than in those without MAD, in anterior, septal, inferior, and lateral wall. It was also reported a significant correlation between ECV of the basal inferior wall and MAD size. This finding emphasize the potential role of interstitial LV fibrosis in the arrhythmogenic abnormalities frequently associated with MAD.

Similarly, the prognostic values of the presence of late gadolinium enhancement (LGE) derived from CMR were tested by Bouttier *et al.*¹⁶ in 237 patients with mitral valve prolapse with or without MR.

The presence of LGE was observed in 41% of patients and 32% had LGE in the myocardial wall, 4% in the papillary muscle tip and 5% on both locations. The LGE was only associated with age and LV mass in multivariate analysis. Nevertheless, moderate to severe MR and the presence of LGE were both independently associated with event-free survival (i.e. composite endpoint of CV death, HF, new onset of atrial fibrillation or arterial embolism). These results suggest that CMR may be an additional prognostic tool in patients with mitral valve prolapse.

Acute cardiac care

A major focus of the congress related to the acute and critical care setting, with numerous abstracts relating to acute myocardial infarction (MI) and risk stratification, and evaluating novel applications of existing/emerging techniques to optimize and individualize patient care.

Trifunovic *et al.*¹⁷ reported part of the PREDICT-VT study, aiming to test whether deformation imaging based on speckle tracking was superior to conventional echocardiography when predicting outcome (i.e. total mortality, hospitalization for HF and New York Heart Association >III) in patients who had undergone percutaneous coronary intervention (PCI) post-ST-elevation acute myocardial infarction (STEMI). A total of 264 patients were included, with follow-up at 1 year. With well-defined cut-off values, peak systolic

longitudinal strain, radial strain rate during atrial contraction, and peak systolic circumferential strain (endocardial layer) were superior to standard parameters (including EF and tricuspid annular plane systolic excursion) and predicting outcome.

In a study presented by Backhaus *et al.*,¹⁸ the interplay of infarct territory-related myocardial mechanics and prognosis post-MI were explored. Here, 795 STEMI and 440 non-STEMI patients underwent CMR 3 days (interquartile range 2–4 days) post-PCI. Primary clinical endpoint was the occurrence of major adverse cardiovascular events (MACE) within 1 year. The LV and LA deformation were analysed using standard parameters, including those of LA reservoir, conduit, and booster pump function. Unsurprisingly, lesion related to left anterior descending (LAD) and left circumflex were associated with higher rate of MACE than right coronary artery lesion. However, LAD risk assessment was most significant using LA strain, suggesting the importance of LA function post-MI. In a separate study with the same group of patients, the impact of right atrial function was also analysed. Schuster *et al.*¹⁹ presented data demonstrating that with RVEF <61.3%, impairment of all three elements of right atrial function were associated with a significant increase in MACE. De Campos *et al.*²⁰ presented further data relating to the impact of right heart function on outcomes post-MI. Numerous variables (physiological, biological, and echocardiographic) were studied post-MI in 303 patients with follow-up at short- and long-term (i.e. 1 year and 73 months). Even modest evaluation of pulmonary artery pressure was associated

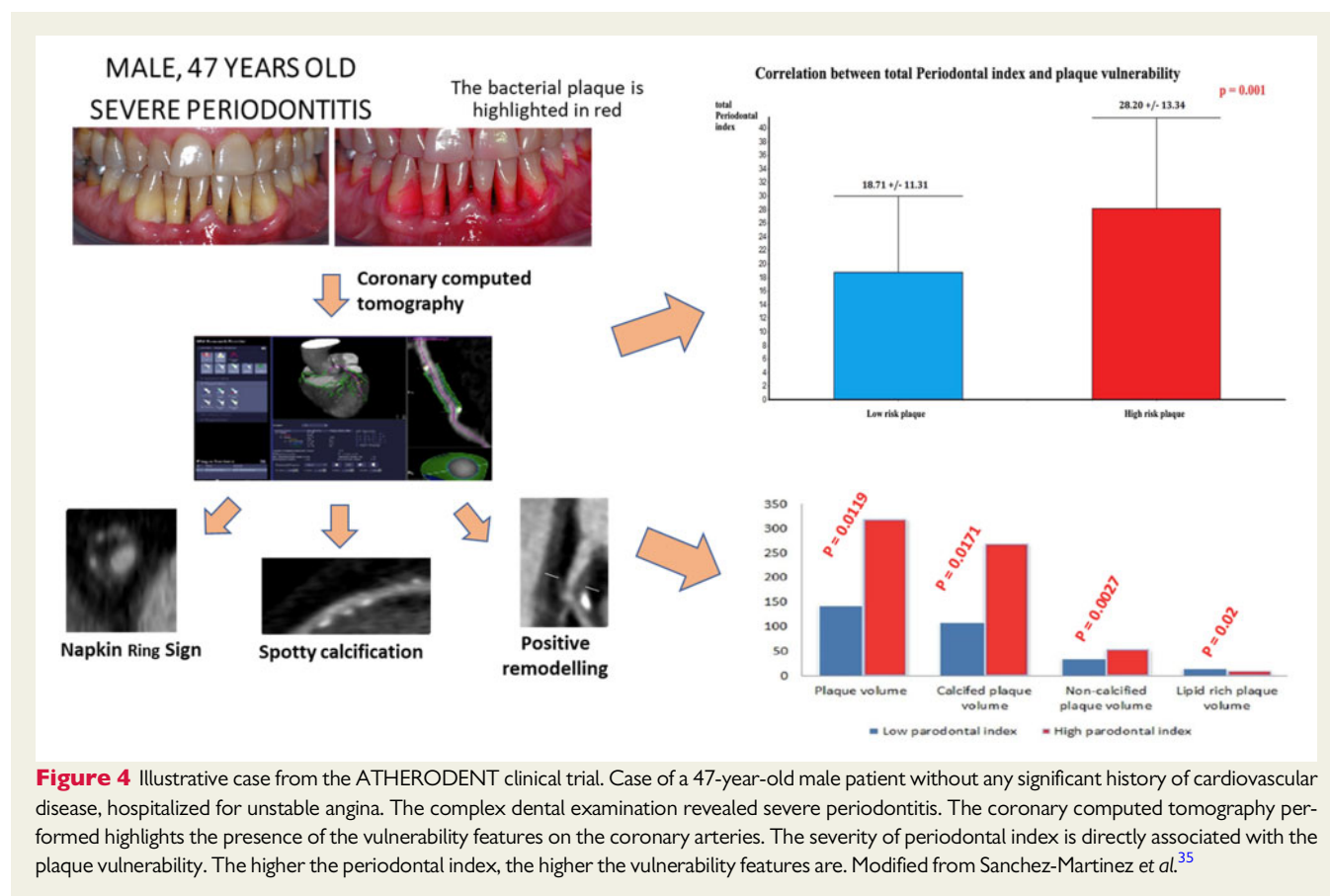
with a significantly increased mortality, again highlighting the importance of the right heart in outcome prediction.

A study presented by Karagiannis *et al.*,²¹ addressed imaging and quantitative estimation of thrombus burden in patients with STEMI with the use of micro-computed tomography. In this methodological study, micro-computed tomography of aspirated thrombus was studied in 3D models, looking at volume, density, and calcification. A striking finding was that those with a family history of ischaemic heart disease had higher density thrombus, suggesting a potential genetic contribution to the type of thrombus in different patient populations.

Rodean *et al.*,²² presented results from the ATHERODENT study, aiming to evaluate the association between coronary plaque vulnerability and periodontal disease in patients with unstable angina. In this study, 52 patients with unstable angina were underwent (in addition to standard investigations and interventions) complete dental examination (periodontal index), coronary computed tomography angiography, carotid ultrasound, and measurement of abdomen and neck circumference (Figure 4). Findings demonstrated that a high periodontal index was associated with an increased calcium score, plaque volume (calcified, non-calcified and lipid-rich), and increased plaque vulnerability.

Congenital heart disease

In congenital heart disease, the right ventricle is often abnormal, either anatomically or because it is subjected to abnormal pressure or



volume loading conditions. Many of our current clinical conundrums relate to assessment of the pathological RV, and imaging parameters which relate to functional/clinical status are increasingly useful.

Avesani *et al.*²³ used echocardiography and CMR to investigate which parameters correlate best with functional exercise capacity in children with repaired tetralogy of Fallot (TOF), who very commonly have significant pulmonary regurgitation (PR). CMR is the gold standard method to assess PR and RV size and function, but CMR has a number of drawbacks in children, such as the requirement for general anaesthesia in younger patients; echocardiography is a much more attractive tool in this population. A number of echocardiographic parameters were studied, but most showed disappointing correlation with CMR, although RV end-diastolic area indexed correlated well with CMR volumes. Right atrial strain, as an indicator of RV diastolic function, was the best determinant of peak VO_2 in young patients and could be a useful addition to the routine follow-up echocardiogram in young patients with repaired TOF.

Akazawa *et al.*²⁴ assessed the effect of electromechanical dyssynchrony (EMD) on RV dysfunction and exercise capacity in unoperated patients with Ebstein's malformation. The EMD within the functional RV was determined by the presence of a septal flash or difference in time to peak shortening between the RV basal segment and apical septum (Figure 5). They found that intra-functional RV delay correlated with RV GLS and RV fractional area change, and also with CMR-derived measures of RV function/area, as well as peak VO_2 . Ostenfeld *et al.*²⁵ also investigated exercise capacity in relation to imaging

markers in Ebstein patients but focused on adults having undergone tricuspid repair/replacement surgery. Using CMR, they demonstrated an increase in cardiac index which continued at 5 years following surgery, as did improvement in VO_2 . However, a decline in RVEF may mitigate potential benefits with regards to incidence of MACE, and therefore longer-term follow-up is required to determine whether there is any lasting alteration to the natural history in this condition.

Patients in whom the right ventricle is the systemic ventricle suffer from early HF. Surkova *et al.*^{26,27} investigated both the prevalence of MR and systolic dysfunction in the subpulmonary LV in a mixed group comprising patients who had undergone atrial switch operations (Mustard/Senning) and patients with congenitally corrected transposition of the great arteries. They found that non-systemic MR was associated with LV dilatation and systolic dysfunction, raised brain natriuretic peptide levels and HF symptoms. Patients with atrial switch procedures were particularly likely to have severe HF if MR was significant. Dysfunction of the subpulmonary LV was independently associated with HF in these patients, and more likely to predict functional class than systemic RV function. These findings highlight the importance of LV/RV interaction in these patients and remind us that assessment of the function of both ventricles is informative in their follow-up.

Patients with Fontan (single ventricle) circulation also suffer early HF, and diastolic function in this group is especially important but difficult to assess. Cordeiro Rato Mesquita Da Silva *et al.*²⁸ aimed to characterize the relationship between atrial strain and exercise

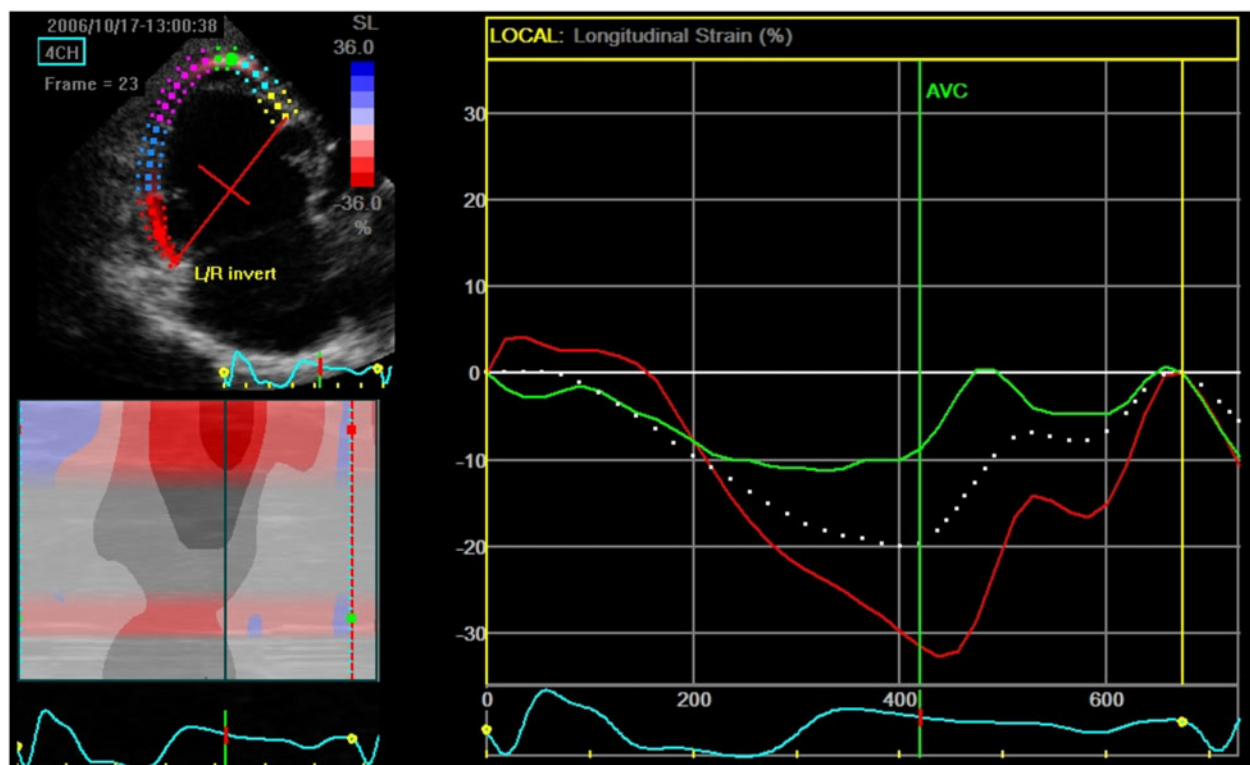
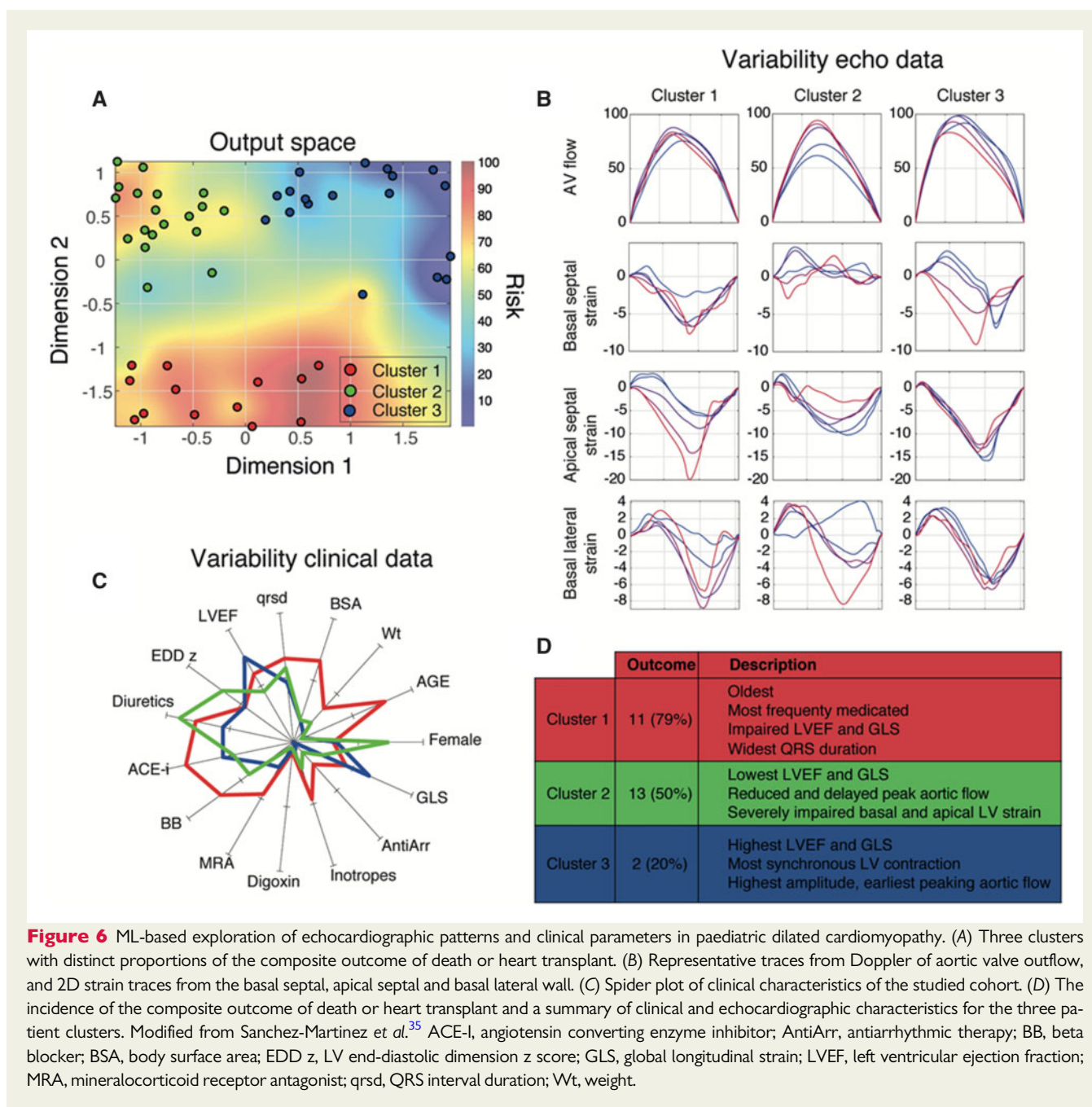


Figure 5 EMD in the functional right ventricle in a patient with Ebstein's malformation, demonstrating difference in time to peak shortening between the RV basal segment (red line) and apical septum (green line). Modified from Sanchez-Martinez *et al.*³⁵



capacity. They found that atrial strain parameters are strongly correlated with VO_2 in Fontan patients, and this may be a useful addition to their clinical assessment, especially given the heterogeneity of anatomy in this group, and lack of standardized parameters for assessment of ventricular function.

New technologies

A number of abstracts focused on new technologies and different tasks by which they can support clinical decision-making: from image acquisition,²⁹ feature extraction^{31–34} to data interpretation.³⁵

Langet et al.²⁹ evaluated AI-assisted TTE: 40 novices performed apical four-chamber acquisitions: initial standard TTE, AI-assisted TTE, and repetition standard TTE. An apical four-chamber acquisition was also performed by an expert. A significant contribution of AI-assisted vs. initial TTE was found in matching reference performance over time, associated with improved clinical use suitability, suggesting that AI-assisted TTE can assess and improve novices' skills, and support acquisition standardization.

Nordal et al.³⁰ aimed to automatize perioperative monitoring of LV function by TOE detection of mitral annular plane systolic excursion (MAPSE). Convolutional neural networks were trained in a supervised manner to predict the location of two landmarks on

the mitral annulus and automatically track MAPSE in B-mode. The detector was able to adequately track vertical movement of the landmarks, providing a fast calculation of MAPSE and eliminating intraobserver variability.

Wheeler *et al.*³¹ compared the accuracy of a virtual reality (VR) 3D linear measurement system to clinical imaging software, using multiplane reformatting and volume-rendered views. Experts performed VR measurements by selecting two points in the volume rendering on a calibration phantom, and anatomically meaningful measurements, using a VR system and two commercial systems. Distance measurement bias of the VR system was lower than a commercial application's, providing evidence for clinical acceptability of the VR tool.

In a prospective multicentre study ($n = 200$), Aalen *et al.*³² used regional work by pressure-strain analysis before and 7 ± 1 months after CRT to determine whether combined assessment of septal function and viability (by LGE CMR) identified CRT responders. Septal work was improved in CRT responders. The difference between work in the LV lateral wall and septum provided good prediction of CRT response while septal scar predicted non-response; combining these parameters improved the prediction of CRT response.

Petrescu *et al.*³³ prospectively studied 22 heart transplant recipients to investigate if natural shear wave velocities increase with the degree of diffuse myocardial fibrosis. Shear wave elastography was performed at 1100 ± 250 frames/s, measuring shear wave propagation velocity at mitral and aortic valve closure from M-mode acceleration maps. Pulmonary capillary wedge pressure was measured invasively, CMR (native T1, ECV) quantified diffuse myocardial fibrosis. End-diastolic and end-systolic shear wave velocities correlated with CMR-defined fibrosis, while end-diastolic shear wave velocities correlated with pulmonary capillary wedge pressure.

Papadacci *et al.*³⁴ studied semiautomatic evaluation of cardiac Doppler indices within a single heartbeat by 4D ultrafast echocardiography (5200 volumes/s). Four-dimensional colour-flow and tissue Doppler imaging were computed from single heartbeats; spectral Dopplers were derived at each voxel, automatically detecting the LV outflow tract, mitral inflow, and basal inferoseptum. Doppler indices from Doppler and tissue velocity spectra were compared to standard 2D echocardiography indices: 4D ultrafast echocardiography was able to quantify major Doppler indices from a single heartbeat acquisition.

Sanchez-Martinez *et al.*³⁵ studied 50 children with dilated cardiomyopathy using unsupervised ML. The input consisted of longitudinal strain traces, LV outflow Doppler patterns, and clinical parameters. According to similarities in these descriptors, three distinct clusters (Figure 6) were created with significantly different risk of death or heart transplantation. This suggests that ML-based approaches can be useful to explore the combination of regional and global echocardiographic and clinical parameters in association to outcomes.

Conflict of interest: none declared.

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