3D-speckle-tracking echocardiography correlates with CMR diagnosis of acute myocarditis

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Abstract

Abstract Background: The diagnostic importance of three-dimensional (3D) speckle-tracking strain-imaging echocardiography in patients with acute myocarditis has not yet been assessed. The aim of this study was to test the sensitivity and specificity of 3D-speckle-tracking echocardiography as compared to CMR (cardiovascular magnetic resonance imaging) for the diagnosis of acute myocarditis. Methods and Results: 45 patients that were admitted to the Medical Clinic II of the University Hospital Bonn with clinically suspected myocarditis were enrolled in our study (71% male, mean age: 43.9 ± 16.3 years, peak troponin level: 1.38 ± 3.51 ng/ml). 3D full-volume echocardiographic images were obtained and offline speckle-tracking analysis of regional and global LV deformation was performed. All patients received CMR scans and myocarditis was diagnosed in 29 subjects. The 16 patients, in whom myocarditis was excluded by CMR, served as controls. Regional changes in myocardial texture and tissue edema (diagnosed by CMR) were significantly associated with regional impairment of circumferential, longitudinal, and radial strain, as well as regional 3D displacement and total 3D strain. The 3D diastolic strain index was not associated with pathological findings in the CMR. However, the 3D global longitudinal strain (GLS) outperformed well-known 2D parameters associated with myocarditis, such as LVEF and LVEDV. Conclusions: This is the first study examining the use of 3D-speckletracking echocardiography in patients with acute myocarditis. Global longitudinal strain was significantly associated with and impaired in patients with myocarditis. Therefore, 3D echocardiography could become a useful diagnostic tool in the primary diagnosis of myocarditis.

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Short title: 3D-Speckle-tracking in myocarditis

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Conflict of interest statement

There are no conflicts of interest to disclose

Highlights

- Regional changes in myocardial texture and tissue edema (diagnosed by CMR) were significantly associated with regional impairment of circumferential, longitudinal, and radial strain, as well as regional 3D displacement and total 3D strain.
- 3D global longitudinal strain (GLS) outperformed well-known 2D parameters associated with myocarditis, such as LVEF and LVEDV
- 3D-speckle-tracking echocardiography could become a useful diagnostic tool in the diagnosis of myocarditis

Abstract

Background: The diagnostic importance of three-dimensional (3D) speckle-tracking strain-imaging echocardiography in patients with acute myocarditis has not yet been assessed. The aim of this study was to test the sensitivity and specificity of 3D-speckle-tracking echocardiography as compared to CMR (cardiovascular magnetic resonance imaging) for the diagnosis of acute myocarditis.

Methods and Results: 45 patients that were admitted to the Medical Clinic II of the University Hospital Bonn with clinically suspected myocarditis were enrolled in our study (71% male, mean age: 43.9 ± 16.3 years, peak troponin level: 1.38 ± 3.51 ng/ml). 3D full-volume echocardiographic images were obtained and offline speckle-tracking analysis of regional and global LV deformation was performed. All patients received CMR scans and myocarditis was diagnosed in 29 subjects. The 16 patients, in whom myocarditis was excluded by CMR, served as controls. Regional changes in myocardial texture and tissue edema (diagnosed by CMR) were significantly associated with regional impairment of circumferential, longitudinal, and radial strain, as well as regional 3D displacement and total 3D strain. The 3D diastolic strain index was not associated with pathological findings in the CMR. However, the 3D global longitudinal strain (GLS) outperformed well-known 2D parameters associated with myocarditis, such as LVEF and LVEDV.

Conclusions: This is the first study examining the use of 3D-speckle-tracking echocardiography in patients with acute myocarditis. Global longitudinal strain was significantly associated with and impaired in patients with myocarditis. Therefore, 3D echocardiography could become a useful diagnostic tool in the primary diagnosis of myocarditis.

1 Introduction:

Myocarditis is an inflammatory disease of the heart muscle frequently resulting from viral infection and/or post viral immune-mediated responses. Its clinical manifestation can range from essentially asymptomatic presentations showing symptoms of myocardial infarction to severe illness, including cardiogenic shock due to chronic or acute heart failure (HF) (1). Due to this broad variety of presentations, the diagnosis of myocarditis cannot usually be made based on clinical findings. Myocarditis can result in dilated cardiomyopathy (DCM) and is currently the leading cause for heart transplantation.

The diagnostic accuracy of clinical history, physical examination, electrocardiography, and serology are generally not adequate for an accurate diagnosis of myocarditis. Furthermore, the findings during acute myocarditis in conventional echocardiography are not specific (2). Endomyocardial biopsy, with further immunohistochemical and biochemical workup, remains the most widely accepted standard technique, however, it may not be appropriate for many patients, especially those with less severe disease. For the noninvasive imaging techniques, cardiac magnetic resonance imaging (CMR) has become the most important diagnostic tool for myocarditis (3).

Consensus CMR criteria for myocarditis (including visualization of edema with cellular swelling and using early and late enhancement methods) has standardized CMR protocols for assessing myocarditis (3, 4). Echocardiography is currently recommended in the initial diagnostic evaluation of all patients with suspected myocarditis (5). Echocardiography in myocarditis is typically performed to visualize the associated functional abnormalities, such as wall thickness and pericardial effusion. However, many patients with less severe cases of myocarditis present with a normal echocardiogram or unspecific echocardiographic findings, which diminishes the diagnostic value of this technique, owing to poor specificity and high variability (2).

Two-dimensional speckle-tracking echocardiography can quantitatively measure myocardial mechanics (strain and strain rate) in longitudinal, radial, and circumferential directions (6-8). In many clinical settings, such as cardiomyopathy or coronary artery disease, a decrease in the longitudinal strain shown by two-dimensional speckle-tracking echocardiography has been found to indicate left-ventricular dysfunction before the occurrence of changes in left-ventricular ejection fraction (9, 10). Hsiao *et al.* demonstrated in acute myocarditis that left-ventricular strain and strain rate may be promising diagnostic and prognostic tools, even in patients with preserved left-ventricular ejection fraction (11). However, the diagnostic importance of a novel technique, three-dimensional (3D) speckle-tracking strain imaging echocardiography, in patients with acute myocarditis has not yet been assessed. The aim of this study was to test the sensitivity and specificity of 3D-speckle-tracking echocardiography versus CMR in the diagnosis of acute myocarditis.

2 Methods

We analyzed acquired data sets of 45 patients with suspected acute myocarditis in this observational study. Inclusion criteria were (a) clinical symptoms compatible with a diagnosis of acute myocarditis, such as fever, viral prodromes, chest pain, palpitations, or dyspnea within six weeks of admission, (b) evidence of structural or functional abnormalities by echocardiography or evidence of myocardial damage as indicated by an elevation of at least one biomarker (troponin I level > 0.1 ng/ml or creatine kinase MB fraction 0.5-3.6 μ g/l), and (c) absence of evidence of coronary artery disease by coronary angiography. The exclusion criteria were previous heart surgery, known coronary artery disease (CAD), severe valvular disease, and a poor echocardiographic window. Controls were individuals with no history of cardiovascular disease who had normal echocardiography and no signs of acute myocarditis via CMR.

2.1 Two-dimensional transthoracic echocardiography

Each patient underwent standardized two-dimensional (2D) transthoracic echocardiography for the determination of left- and right-ventricular functional parameters and dimensions, according to the recommendations of the American Society of Echocardiography, using a commercially available ultrasound scanner (Vivid 7, General Electric Medical Health, Waukesha, Wisconsin, USA) with a 2.5 MHz phased-array transducer (12, 13). Echocardiographic views, including apical four- and two-chamber views (4CV, 2CV) and parasternal (long- and short-axis views), with the patient in the left lateral decubitus position, were obtained in twodimensional, three-dimensional, and color tissue Doppler imaging (TDI) modes. The 2D ejection fraction (EF) was calculated by using Simpson's rule from the 4CV image. The E/e' ratio was determined by measuring the TDI-derived systolic and diastolic velocities of the septal mitral valve annulus, according to the recommendations of the American Society of Echocardiography.

2.2 Three-dimensional speckle-tracking analysis

A 3D full-volume data set of the ventricle was obtained with gated (five beats) acquisition and stored on an echocardiographic imaging server (XCELERA, Philips Medical Systems, Koninklijke N.V.). Offline 3D ST analyses of the gray-scale images obtained by 3D echocardiography were performed with commerciallyavailable software (TomTec Imaging Systems GmbH, Unterschleissheim, Germany). Sector size and depth were optimized to obtain the highest possible volume rates, reaching 17 to 20 frames/sec in the contrast 3D full-volume mode. The best real-time 3D echocardiography (3DE) dataset was selected and analyzed offline by an experienced investigator who was blinded to the results of the CMR and 2DE measurements.

2.3 Cardiovascular magnetic resonance imaging

All patients received CMR-scans within 72h of admission in accordance to our site-specific SOP. All examinations were performed on a 1.5 Tesla system (Intera 1.5 T; Philips Healthcare, Best, The Netherlands). A 32-channel torso coil with digital interface was used for signal reception. ECG-gated steady-state free precession cine images were obtained, including short axis (SA), vertical long axis (VLA), horizontal long axis (HLA), and left-ventricular outflow track (LVOT) stacks. The left ventricle was fully covered in the SA stack. Edema-sensitive black blood T2-weighted short-tau inversion recovery (STIR) sequences were performed in SA and transverse orientations. Early gadolinium enhancement was assessed using transverse free-breathing fast-spin echo T1-weighted images, which were acquired in three identical slices taken both before and after intravenous injection of a double-dose bolus of 0.2 mmol/kg of body weight of gadobutrol (Gadovist, Bayer Healthcare, Leverkusen, Germany) using the body coil for signal reception. Late gadolinium enhancement (LGE) imaging was achieved by segmented inversion recovery gradient-echo sequences in SA, VLA, and HLA orientations. The optimal inversion time was determined by using the Look-Locker technique.

2.4 Statistical Analysis

We used the Kolmogorov-Smirnov test to examine the normal distribution of continuous variables. Continuous data were expressed as mean values \pm standard deviation. Two-tailed p-values were calculated and were considered to be significant if they ranged below 0.05. For comparison between two groups, we used the Student t test for paired samples. To evaluate the results, in particular their predictive diagnostic value, and to enable a comparison between the results obtained from the cardiac MRI with the results from the speckle-tracking analysis and the control group, we used the following parameters and methods:

To analyze the collected data and its predictive value, we used receiver operating characteristic (ROC) curves and the Youden index (J). The resulting values ranged between 0 and 1, with values near 0 indicating only low diagnostic value and values near 1 showing very good diagnostic value. For ROC curves, the corresponding areas under the curve (AUC) and their 95% confidence intervals (CIs) were calculated.

3 Results

The study design is depicted in Figure 1. A total of 45 patients with clinically suspected myocarditis who met the inclusion criteria were enrolled in the study. Initially, conventional two-dimensional echocardiography and 3D full-volume echocardiographic images were obtained with offline speckle-tracking analysis of regional and global LV deformation. All patients were subjected to CMR scans, and myocarditis was diagnosed in 29 of the subjects (age 47.7 \pm 17, male 72%). There were 16 patients in whom myocarditis was excluded by CMR, and these patients then served as controls for the study (age 40.4 \pm 15.6, male 63 %). The initial clinical characteristics of the patients are shown in Table 1. Body weight, blood pressure, and smoking rates were similar in both groups. The peak troponin and peak CK-MB levels were elevated in patients with myocarditis without reaching significance (peak troponin 2.15 \pm 5.44 ng/ml vs 0.61 \pm 1.58 ng/ml (p=0.28), CK-MB 20.6 \pm 51.3 µg/l vs 20.4 \pm 63.6 µg/l (p=0.17)). The inflammation status of the patients was detected by measuring the peak leukocytes and peak hsCRP levels and did not differ between the two groups.

The two-dimensional and 3D-echocardiograms were performed within 24 hours after admission to our clinic. The main conventional echocardiographic findings are shown in Table 2. In patients with myocarditis LVEF was significantly reduced ($44.4\pm3.2 \%$ vs. $54.3\pm4.2 (p=0.03)$). In addition, this was associated with significantly higher LVEDP ($159.3\pm14.3 mmHg$ vs. $118.8\pm14.4 mmHg (p=0.02)$), higher E/A ratios (1.9 ± 0.22 vs. $1.05\pm0.09 (p=0.03)$), and elevated septal E/e' ratios ($12.76\pm1.9 vs. 4.9\pm0.67 (p=0.004$). There was no difference in IVSd, systolic PAP, or TAPSE measurements between the two groups. Furthermore, no difference was detected in the primary ECG findings (Table 2).

Regional changes in myocardial texture and tissue edema, as diagnosed by CMR, were significantly associated with regional impairment of circumferential, longitudinal, and radial strain as well as regional 3D displacement and total 3D strain (Figure 2). The 3D diastolic strain index was not associated with pathological findings in the CMR (Figure 2). 3D global longitudinal strain (GLS) out-performed the well-known 2D parameters associated with myocarditis, such as LVEF and LVEDV (Figure 3). The predictive value of 3D-GLS was confirmed by ROC curve analysis, which demonstrated an area under the curve (AUC) of 0.71 (95% confidence interval 0.53 to 0.83, p=0.019, Figure 3). Global torsion and twist were not associated with myocarditis in our collective (Figure 3).

4 Discussion

3D echocardiography has been widely used in clinical settings since its introduction in commercially available 3D-*speckle* tracking systems. 3D-speckle-tracking has not been regarded as a routine tool for analysis of cardiac function, despite its various advantages compared to two-dimensional (2D) imaging (16). 3D-speckletracking is a novel echocardiographic technique that allows digital tracking and quantification of myocardial deformation as a function of time. The deformation can be assessed as three orthogonal strain values: radial strain (RS), longitudinal strain (LS), and circumferential strain (CS). Strain and strain-rate imaging can assess both circumferential deformation (a negative value in systole, as the circumference of the LV decreases) and radial deformation (a positive value in systole, as the LV wall thickness increases) (17).

Acute myocarditis is characterized by inflammatory myocardial damage that can result in severe leftventricular wall motion abnormalities (1). However, the myocardial damage is mainly circumscribed to the subepicardial layers, whether or not it is associated with any wall motion abnormality. Previous echocardiographical studies of patients with myocarditis have shown a variety of findings (18).

In addition to systolic function, regional wall motion abnormalities, diastolic dysfunction, and changes in echocardiographic image texture have been reported (2, 6, 19-21). In this study, routine parameters such LVEDP and septal E/e' ratio are significantly elevated due to acute inflammatory left-ventricular damage. Furthermore, LVEF was significantly reduced in patients with acute myocarditis.

The most important result of this study is that 3D global longitudinal strain (GLS) outperformed the wellknown 2D parameters associated with myocarditis such as LVEF and LVEDV (2). A GLS assessment using automated speckle-tracking echocardiography is a technique for detecting and quantifying subtle disturbances in the LV systolic function (22). GLS reflects the longitudinal contraction of the myocardium, and its accuracy has been validated against tagged CMR (23). In the general population and patients with heart failure, GLS was shown to be a superior predictor of cardiac events and all-cause mortality compared to LVEF (24, 25). Furthermore, it has also been shown that GLS is a robust prognostic marker following myocardial infarction as well as in patients with cardiomyopathy and aortic stenosis (26-28).

The second relevant finding is that regional changes in myocardial texture and tissue edema, as diagnosed by CMR, were significantly associated with regional impairment of circumferential, longitudinal, and radial strain as well as regional 3D displacement and total 3D strain. Our results also showed that radial strain had the highest accuracy in detecting the segmental myocardial defects that are induced by acute myocarditis. Radial strain represents radially-directed myocardial deformation toward the center of the LV cavity, and thus indicates the degree of LV thickening and thinning motions during the cardiac cycle. Radial strain values are obtained by 3D-speckle-tracking echocardiographic analysis of both basal and apical LV short-axis views. Routinely, echocardiography is the first imaging technique used in a clinical setting. Especially in patients with angina and normal LV size and function, the findings are mostly normal, which leads to poor diagnostic accuracy. The gold standard for noninvasive diagnosis of myocarditis is cardiac magnetic resonance imaging (CMR). CMR or invasive diagnostics, such as myocardial biopsy, are often not feasible in the setting of an acute presentation. It has been shown that 2D echocardiography with strain imaging can help with differential diagnosis and lead to an optimal treatment path for the patient (10, 29).

A representative case (shown in Figure 4) demonstrates that decreased myocardial 3D radial strain, as assessed by 3D-speckle tracking, is associated with the CMR findings. However, the major pitfalls of 3D-speckle-tracking are its dependency on image quality and its ability to define the endocardial and epicardial boundaries by random noise and relatively low temporal resolution.

2D echocardiography has generally played only a minor role in confirming the diagnosis of acute myocarditis. The underlying reasons are the apparently normal findings that it gives and a lack of specific features for less severe forms of myocarditis.

The advent of novel echocardiographic modalities, such as strain echocardiography, has dramatically expanded the scope of echocardiography, which can provide an accurate bedside assessment of regional contractility and can identify global longitudinal myocardial dysfunction derived from edema in acute myocarditis. Interestingly, a decrease in myocardial GLS, as assessed by the 3D-speckle-tracking technique, in the absence of wall-motion abnormalities, may represent a useful additional diagnostic finding in acute regional myocarditis.

Even though our sample size was small, we believe that the findings can be applied to patients with clinically suspected myocarditis. The 3D-speckle-tracking investigator was blinded to the results of the CMR. Nevertheless, further prospective studies on a larger collective with subdivision into different entities and follow-ups are required to confirm our results.

5 Conclusions

This is the first study investigating 3D-speckle-tracking echocardiography in patients with acute myocarditis. Global parameters, such as longitudinal strain, were significantly associated with the prevalence of myocarditis. 3D radial strain allows the diagnosis of regional wall mechanics, and, therefore, this new imaging modality could become a useful diagnostic tool in the diagnosis of myocarditis. A definitive diagnosis would still be based on clinical presentation and noninvasive diagnostic testing, such as CMR.

Authors' contributions

PRG, SZ, AZ, UB, JK, CH and VT acquired the Echo data, AI analyzed the cardiac MRI data, PRG, SZ, AZ, CH, GN and VT analyzed the data and wrote the manuscript.

Figures and legends

Figure 1: Study design. 45 patients with suspected acute myocarditis were included in this observational study. Each patient underwent standardized two-dimensional transthoracic echocardiography and a 3D full-volume data set of the ventricle was obtained by using commercially available software (TomTec Imaging Systems GmbH). All patients received cardiac MRI-scans and myocarditis was diagnosed in 29 subjects. 16 patients without myocarditis according to the CMR scan served as controls.

Figure 2: Correlation of CMR findings with the regional changes detected in the 3D-speckletracking. Regional changes in myocardial texture and tissue edema, as diagnosed by CMR, were significantly associated with regional impairment of circumferential, longitudinal, and radial strain as well as regional 3D displacement and total 3D strain. The 3D diastolic strain index was not associated with pathological findings in the CMR. Green: significantly associated (p[?]0.05); red: no significant association (p>0.05).

Figure 3: Assessment of the association of global 3D- and 2D parameters with acute myocarditis. Receiver operating characteristic curves for 3D-global longitudinal strain (GLS), LVEF, and LVEDV. GLS out-performed the well-known 2D parameters associated with myocarditis, LVEF and LVEDV. Global torsion and twist were not associated with myocarditis in our collective.

Figure 4: Example of the significant correlation of 3D radial-strain parameters with CMR findings in a patient with myocarditis. In the short axis stack view (left box) of the whole left ventricle, late enhancement of the anterior and lateral areas was detected in CMR. White arrows indicate the myocardial damage (hyperenhancement areas) that involve the subepicardial layers. This was significantly correlated with impairment in the 3D radial strain (right box) within the same area. RV: right ventricle, LV: left ventricle.

Tables

		Myocarditis	Controls			
	All $(n=45)$	(n=29)	(n=16)	Р	Р	
Age	43.9 ± 16.3	47.4±17.0	$40.4{\pm}15.6$	$40.4{\pm}15.6$	0.18 0.37	0.18 0.37
(years)	71/29%	72/28%	63/37%	63/37%	$0.78 \ 0.28$	$0.78 \ 0.28$
Sex	(39/16)	(21/8)	(10/6)	(10/6)	$0.45 \ 0.17$	$0.45 \ 0.17$
(male/female)	85.7 ± 17.5	90.3 ± 22.9	81.1 ± 12.1	81.1 ± 12.1	$0.81 \ 0.49$	$0.81 \ 0.49$
Body-	$175.95{\pm}12.25$	175.1 ± 11.9	$176.8 {\pm} 12.6$	$176.8 {\pm} 12.6$	$0.71 \ 0.41$	$0.71 \ 0.41$
weight	$1.38 {\pm} 3.51$	2.15 ± 5.44	$0.61{\pm}1.58$	$0.61{\pm}1.58$	$0.77 \ 0.09$	$0.77 \ 0.09$
(kg)	$185.15{\pm}242.45$	218.4 ± 331.7	$151.9{\pm}153.2$	$151.9{\pm}153.2$	0.24 0.44	$0.24 \ 0.44$
Height	20.5 ± 35.8	20.6 ± 51.3	$2.4{\pm}2.3$	$2.4{\pm}2.3$	0.01	0.01
(cm) Peak	$35.4{\pm}56.6$	$39.5 {\pm} 49.6$	$31.3 {\pm} 63.6$	$31.3 {\pm} 63.6$		
Troponin I	$9.72 {\pm} 3.94$	10.13 ± 3.55	$9.3 {\pm} 4.33$	$9.3 {\pm} 4.33$		
$(\mu g/l)$	$133.2 {\pm} 29.8$	131.2 ± 24.5	$135.1 {\pm} 35.0$	$135.1 {\pm} 35.0$		
Peak CK	$79{\pm}11.7$ 3	81.3 ± 16.2	$76.7 {\pm} 7.2$ 0	76.7 ± 7.2 0		
(U/l)	(5.5%) 13	3(10,3%)	$(0\%) \ 3$	$(0\%) \ 3$		
Peak	(23.6%)	8 (27,6%)	(18,7%) 6	(18,7%) 6		
CK-MB	20(36.4%)	10 (34,5%)	(37,5%) 3	(37,5%) 3		
$(\mu g/l)$	11 (20%)	6 (20,7%)	(18,75%) 7	(18,75%) 7		
Peak	38(69.1%)	23 (79,3%)	(43,75%)	(43,75%)		
hsCRP						
(mg/ml)						
Peak Leu-						
cocytes						
(G/l) SBP						
(mmHg)						
DBP						
(mmHg)						
Diabetes						
(n, %) Hy-						
pertension						
(n, %)						
Dyslipi-						
demia (n,						
%)						
Smoking						
(n, %) An-						
giography						
(n, %)						

Table 1: Baseline clinical characteristics. Groups are divided with regard to the findings from CMR. Data are expressed as median or as percentage. CK: creatine kinase, CK-MB: muscle-brain type creatine kinase, hsCRP: high sensitivity C-reactive protein, SBP: systolic blood pressure, DBP: diastolic blood pressure

		Myocarditis	Controls	
	All $(n=45)$	(n=29)	(n=16)	P
LVEF (%)	$49.4{\pm}3.7$	$44.4{\pm}3.2$	$54.3 {\pm} 4.2$	0.03 0.02 0.08
LVEDV (ml)	$135.6 {\pm} 14.4$	$159.3{\pm}14.3$	111.8 ± 14.4	$0.22 \ 0.56 \ 0.08$
LV length	$8.7 {\pm} 0.3$	$8.9{\pm}0.2$	$8.4{\pm}0.3$	$0.03 \ 0.10 \ 0.004$
(cm) IVSd E	$1.2{\pm}0.07$	$1.2{\pm}0.04$	$1.1{\pm}0.09$	$0.99 \ 0.08 \ 0.77$
wave (m/sec)	$0.86 {\pm} 0.06$	$0.83 {\pm} 0.05$	$0.88 {\pm} 0.07$	$0.45 \ 0.93 \ 0.68$
A wave	$0.87 {\pm} 0.05$	$0.55 {\pm} 0.04$	$0.69 {\pm} 0.05$	0.88
(m/sec) E/A	$1.48 {\pm} 0.16$	$1.9 {\pm} 0.22$	$1.05 {\pm} 0.09$	
ratio Septal e'	$0.26 {\pm} 0.06$	$0.19{\pm}0.04$	$0.33 {\pm} 0.08$	
(cm/sec)	$8.83 {\pm} 1.33$	$12.76{\pm}1.9$	$4.9 {\pm} 0.76$	
Septal E/e'	$16.75 {\pm} 2.85$	16.7 ± 2.1	$16.8 {\pm} 3.6$	
ratio sPAP	$2.05{\pm}0.1$ 28	$1.89{\pm}0.1$ 18	$2.2{\pm}0.1\ 10$	
(mmHg)	$(62.2)\ 1\ (2.2)\ 7$	$(62.1) \ 1 \ (3.45)$	$(62.5) \ 0 \ (0) \ 2$	
TAPSE (cm)	(15.6) 4 (8.89)	5(17.2) 3	$(12.5)\ 1\ (6.25)$	
Primary	5(11.1)	(10.34) 3	2(12.5)	
ECG		(10.34)		
findings				
Normal n $(\%)$				
ST-segment				
elev. (%)				
T-wave				
changes $(\%)$				
RBBB (%)				
LBBB (%)				

Table 2: Conventional echocardiographic characteristics and primary ECG findings. LV, left ventricle; LVEF, left-ventricular ejection fraction; LVEDV, left-ventricular end-diastolic volume; IVSd, interventricular septum diameter; E, early; A, atrial; sPAP, systolic pulmonary arterial pressure; TAPSE, tricuspid annular plane systolic excursion; RBBB, right bundle branch block; LBBB, left bundle branch block. Data are expressed as the median or as a percentage.

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