MODERATED POSTER SESSION 3

Right ventricle in normal conditions and under pressure

Friday 9 December 2011, 08:30-12:30

Location: Moderated Poster Area

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Gender difference in right ventricular diastolic function in normal subjects.

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Background: Normative Doppler values and determinants for gender difference of right ventricular diastolic function in healthy subjects have not been fully elucidated. The purpose of this study is to verify the difference of right ventricular diastolic function between men and women at each age.

Method: One hundred sixty nine male and 221 female in healthy subject, aged 20 to 90, were examined by both tricuspid inflow velocity and tricuspid annulus velocity by tissue Doppler imaging. All subjects were divided into 7 groups as 20s, 30s, 40s, 50s, 60s, 70s, 80s depend on their age.

Results: The tricuspid E velocity was significantly decreased with age (p<0.0001). The tricuspid A velocity was significantly increased with age (p<0.0001). But both E and A velocity were no differences significantly in all generation between men and women (Table). Ratio of tricuspid E and A velocity (E/A) was significantly decreased with age. But no differences were observed in ratio of E/A in all generation between men and women. (20s: 2.0 ± 0.6 vs 2.3 ± 0.6 , 30s: 1.9 ± 0.5 vs 2.1 ± 0.5 , 40s: 1.6 ± 0.4 vs 1.9 ± 0.5 , 50s: 1.3 ± 0.3 vs 1.5 ± 0.4 , 60s: 1.2 ± 0.2 vs 1.2 ± 0.3 , 70s: 1.1 ± 0.3 vs 1.1 ± 0.3 , 80s: 1.2 ± 0.3 vs 1.2 ± 0.3 , total: 1.4 ± 0.5 vs 1.5 ± 0.6). Early diastole velocity of tricuspid annulus (Ea) by tissue Doppler method was significantly decreased with age. But Ea was no differences significantly in all generation between men and women (Table).

Conclusion: Our results provide the normative Doppler values of right ventricular diastolic function for age decades. There was no difference significantly of right ventricular diastolic function between men and women.

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Echocardiographic assessment of right ventricular dimensions in male elite athletes: time to re-evaluate the limits of normality?

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Purpose: Arrhythmogenic right ventricular cardiomyopathy (ARVC) is the cause of sudden death in a significant proportion of young athletes, particularly in the Mediterranean region. Several studies have demonstrated right ventricular (RV) enlargement as a result of systematic training. The use of transthoracic echo (TTE) to differentiate ARVC from physiological RV enlargement is an essential component of cardiovascular assessment in athletes. International criteria for RV quantification are derived from studies of non-athletes, lack indexing for body surface area (BSA), and do not

distinguish between male and female subjects. We aim to establish TTE RV upper reference limits (URLs) for male elite athletes (EA), with indexing for BSA.

Methods: TTE was performed in 167 healthy, male EA after prior evaluation of personal and family history, and 12-lead ECG. EA from 11 different sporting disciplines were included (73% competing at international level). Mean age was 21.8 years. Five standard RV measurements were made in each case, and compared with ESC reference values. Proposed URLs for EA were calculated as (mean + 2 standard deviations of the mean), and indexed for BSA.

Results: Image quality was sufficient for a total of 712 RV measurements: 72% of these exceeded ESC URLs (Table 1). Mean values for all 5 RV dimensions in EA were greater than ESC URLs.

Conclusions: RV dimensions in male EA are considerably greater than current ESC reference values for the general population, which should not be used as markers of pathology in athletes. We propose novel, BSA-indexed URLs for RV dimensions in male EA, and advocate similar studies in female athletes.

Table 1 RV dimensions in male EA.

	PESC Reference Values URL (mm)	Elite Athletes (EA)	Elite Athletes (EA)				
		Values > ESC URL (%)	Mean (mm)	Proposed URL (mm/ m²)			
RVOT1	≤ 29	65.6	31.9	≤ 22			
RVOT2	≤ 23	54.3	24.4	≤ 17			
RVD1	≤ 28	100.0	43.0	≤ 27			
RVD2	≤ 33	57.4	33.7	≤ 23			
RVD3	≤ 79	77.0	86.1	≤ 57			

RVOT1/2 = right ventricular outflow tract (aortic valve/pulmonary valve levels, parasternal short axis view); RVD1/2/3 = right ventricular diameter (basal/mid-ventricular/base to apex, apical 4-chamber view); URL = upper reference limit.

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Prominent contribution of free wall to supernormal right ventricular contractility of competitive athletes: a speckle tracking and real-time three-dimensional echocardiography

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Purpose: To assess determinants of supernormal right ventricular (RV) contractility in competitive athletes by combining real-time 3-D echo (RT3DE) and Speckle Tracking Echocardiography (STE).

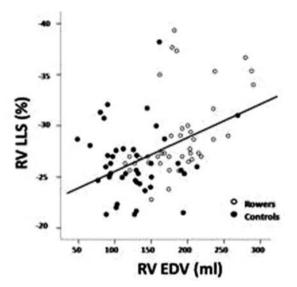
Doppler parameters in each generations. Abstract 50075 Table

		20s	30s	40s	50s	60s	70s	80s	total
E-velocity	Male	58.7 ± 15.3	49.3 ± 11.5	47.6 ± 9.7	46.5 ± 9.5	42.0 ± 8.6	41.6 ± 10.1	40.3 ± 8.2	45.2 ± 11.2
	Female	59.4 + 9.4	52.1 + 11.9	49.9 + 9.2	46.9 + 10.2	40.9 + 8.1	40.1 + 9.2	42.1 + 10.5	45.8 + 11.6
	p-value	NS	NS	NS	NS	NS	NS	NS	NS
A-velocity	Male	29.2 ± 5.4	26.6 ± 7.4	31.3 ± 5.4	36.0 ± 8.4	36.4 ± 7.4	38.3 ± 10.5	36.5 ± 9.6	34.5 ± 9.1
	Female	25.0 ± 7.0	27.5 ± 6.1	28.1 ± 6.1	32.8 ± 8.3	36.8 ± 9.6	39.3 ± 10.6	36.1 ± 5.6	33.9 ± 9.8
	p-value	NS	NS	NS	NS	NS	NS	NS	NS
Ea	Male	12.0 ± 2.6	12.4 ± 3.0	9.6 ± 2.6	9.2 ± 2.3	8.7 ± 2.4	7.6 ± 2.0	7.1 ± 2.6	9.2 ± 2.9
	Female	14.1 ± 3.3	13.5 ± 2.8	10.7 ± 3.7	10.3 ± 2.3	7.8 ± 2.1	7.4 ± 1.9	7.8 ± 2.2	9.7 ± 3.5
	p-value	NS	NS	NS	NS	NS	NS	NS	NS

Methods: RV function was compared in 43 healthy controls and 40 top-level rowers by standard echo-Doppler, RT3DE and STE. RV internal diameters, tricuspid annular plane systolic excursion (TAPSE), tricuspid inflow E/A ratio and pulsed Tissue Doppler of lateral tricuspid annulus were determined. RT3DE RV volumes were estimated off-line and both ejection fraction (EF) and stroke volume (SV) derived. STE provided estimate of RV global longitudinal strain (GLS) (6 segments), septal longitudinal strain (average of 3 septal regions, SLS) and lateral longitudinal strain (average of 3 lateral regions, LLS).

Results: The 2 groups were comparable for age, body mass index and blood pressure while heart rate (HR) was lower in rowers (p < 0.0001). RV diameters were significantly larger and TAPSE, E/A ratio, and Tissue Doppler derived s' and e' velocities higher in rowers. RT3DE RV end-diastolic volume (EDV) and end-systolic volume were greater in rowers (both p < 0.0001), without differences of EF. STE derived GLS (p < 0.005) and LLS (p < 0.001), but not SLS, were higher in rowers. In the pooled population LLS was related to EDV (r = 0.42) (Figure) and SV (r = 0.39) (both p < 0.0001). Both these relations remained significant after adjusting for HR (r = 0.35, p < 0.001 and r = 0.33, p < 0.002 respectively).

Conclusions: The combination of RT3DE and STE allows to increase the knowledge of RV contractility in athletes. By the Frank-Starling mechanism the preload increase (EDV) exerts its maximal influence on the longitudinal lateral fibers, whose effect induces in its turn the increase of SV.



Relation between RV EDV and RV LLS

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Regional adaptation of the right ventricle in athletes: insights from myocardial deformation imaging.

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Purpose: Despite that left ventricular (LV) remodeling in chronic endurance exercise is well described, adaptation of the right ventricle (RV) is less studied. Our aim was to evaluate global and regional RV dimensions and function in athletes, assessing if adaptation corresponds to what is observed in other states of volume overload, namely homogeneously increased regional myocardial strain.

Table 1 All dimensions were indexed by body surface area

	Healthy volunteers	Athletes	Р
LV end-diastolic volume [ml/m2]	55 ± 8	67 ± 10	0.00
LV end-systolic volume [ml/m2]	22 ± 4	28 ± 5	0.00
Interventricular septum [mm/m2]	4.7 ± 0.5	5.3 ± 0.6	0.00
Posterior wall [mm/m2]	4.6 ± 0.5	5.2 ± 0.5	0.00
LV ejection fraction [%]	60 ± 3	59 ± 3	n.s.
Right atrium volume [ml/m2]	20 ± 5	25 ± 6	0.01
RV mid-cavity diameter [mm/m2]	16 ± 1	17 ± 2	n.s.
RV longitudinal diameter [mm/m2]	37 ± 2	39 ± 4	0.03
Total RVED area [cm2/m2]	11 ± 1	12 ± 1	0.00
Total RV fractional change area [%]	36 ± 6	37 ± 6	n.s.
RV global strain [%]	-28 ± 3.2	-27 ± 2.9	n.s.
RV inlet strain [%]	-25 ± 3.9	-22 ± 3.7	0.007
RV apex strain [%]	-31.6 ± 5.2	-32.2 ± 5.4	n.s.

Methods: Sedentary volunteers (n=25) and elite athletes (n=65) were prospectively enrolled. Conventional echocardiographic parameters and 2D echo derived strain (2DSE) were calculated in two RV free wall segments (inlet and apex).

Results: Flow in the RV and LV outflow tracts (table 1) were significantly increased in athletes as compared to healthy volunteers (RV VTI 14 ± 2 cm vs 22 ± 3 cm, and LV VTI 15 ± 3 vs 21 ± 3 , volunteers vs athletes respectively,p<0.001 for both). In 39 athletes (60%), but only in 5 volunteers (20%), there was an exaggerated strain gradient between the inlet and the apex regions of the RV.

Conclusions: Adaptation of the RV to chronic exercise shows not only global dilatation, as induced by volume overload, but additionally results in regional deformation changes as would be observed in chronic pressure overload. The interplay of volume and pressure in the RV and the observed (regional) remodeling in some athletes warrant further investigation.

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Early right ventricular systolic dysfunction in patients with COPD without pulmonary hypertension

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Background: The aim of this study was to assess right ventricular (RV) systolic function in patients with chronic obstructive pulmonary disease (COPD) without pulmonary hypertension (PH) by isovolumetric acceleration (IVA), tricuspidal annular systolic excursion (TAPSE) and tissue velocity imaging (TVI) as early indexes for detection of RV systolic dysfunction in COPD patients with normal resting pulmonary artery pressure (mPAP).

Methods: 36 patients with COPD and mPAP<25mmHg, aged 65.0 years (61.5-70.0), weight 72.0 kg (62.5-79.0), height 170.5 cm (164.0-176.5) and BMI 24.6 (22.0-26.9) [median (25%-75% percentiles] and 17 healthy matched controls with normal estimated non invasive systolic pulmonary artery pressure (sPAP) were included. Systolic function was measured by standard TTE including measurements of IVA, TAPSE and TVI. RV images were obtained at end-expiration from a modified apical four-chamber view to optimize RV visualization. Three consecutive cycles were recorded with a frame rate greater than 150 fps for offline analysis. The region of interest (ROI) for TVI was placed at basal RV free wall. All the COPD patients underwent standard right heart catheterization (RHC) for mean pulmonary artery pressure (mPAP) evaluation, and PH was defined as mPAP rest ≥ 25 mmHg. Controls were evaluated for PH as determined by transtricuspid conventional Doppler echocardiography and estimation of sPAP according to the continuous equation.

Results: There were no significant differences in age, weight, height or BMI between the groups. IVA, TAPSE and TVI were significantly reduced in the patient group compared to controls (p<0.05), respectively from 3.2 m/s2 (2.9-3.7) to 1.8 m/s2 (1.6-2.1), 2.8 mm (2.7-3.0) to 2.3 mm (2.1-2.4) and 11.5 cm/s (10.8-12.8) to 8.8 cm/s (8.1-9.9). Conclusion: This study shows that systolic RV function is reduced in COPD patients despite normal mPAP at rest. It is therefore important to evaluate systolic RV function also in COPD patients without established PH, for early detection of right ventricular systolic impairment.

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Reliability of right ventricular myocardial isovolumic relaxation time as a predictor of pulmonary hypertension

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Background: Traditional echocardiographic methods used for evaluation of pulmonary hypertension (PH) have several limitations. Right ventricular (RV) isovolumic relaxation time (IVRT)) is sensitive to changes in pulmonary artery systolic pressure (PASP). Plasma endothelin-1 (ET-1) levels are elevated patients with PH & correlates with PH severity.

Objectives: To test hypothesis of measurement of Pulsed-wave Doppler tissue imaging (PWDTI)-derived RV myocardial IVRT as a valid predictor of PASP against invasively measured PASP & correlate this with ET-1 levels.

Patients & Methods: The study included 94 patients with PH with different cardiac pathologies & 30 healthy subjects as a control group. Conventional echocardiography with DTI & assessment of plasma level of ET-1 were performed just before invasive measurement of PASP. Tricuspid annular motion at RV free wall was assessed by M-mode echocardiography & PWDTI. Blood pool-derived IVRT & PWDTI-derived IVRT were estimated & corrected for heart rate (IVRTc).

Results: Echo-derived PASP, RV Tei index and ET-1 levels were significantly higher in patients than controls $(69.57\pm23.06\ \text{mm}\ \text{Hg}\ \text{vs}.18.6\pm4.26\ \text{mm}\ \text{Hg},1.19\pm0.42\ \text{vs}.0.43\pm0.12,6.9\pm0.99\ \text{pg/ml}\ \text{vs}.1.45\pm0.46\ \text{pg/ml}, \text{ respectively},\ p<0.001\ \text{ for all}).$ Tricuspid annular plane systolic excursion was significantly lower in patients than controls $(17.76\pm6.17\ \text{mm}\ \text{vs}.27.9\pm6.04\ \text{mm},\ p<0.05).$ Myocardial PWDTI-derived IVRTC, myocardial PWDTI-derived IVRTC (non corrected)& blood pool-derived IVRTc were significantly higher in patients than controls $(90.51\pm31.77\ \text{ms}\ \text{vs}.\ 23.63\pm4.73\ \text{ms},85.87\pm29.19\ \text{ms}\ \text{vs}.\ 18.49\pm3.45\ \text{ms},\ 82.33\pm22.13\ \text{ms}\ \text{vs}.\ 15.11\pm5.09\ \text{ms},\ \text{respectively},\ p<0.001\ \text{for all}).$ Strong positive correlations found between invasively measured PASP & each of myocardial PWDTI-derived IVRTC (r = .82),myocardial PWDTI-derived IVRTC (r = .79),blood pool-derived IVRTC (r = .67),RV Tei index (r = .61), ET-1 level (r = .78) also between PWDTI-derived IVRTC & ET-1 levels (r = .75), P<0.001\ \text{for all correlations}. The cutoff point of RV myocardial IVRT is 65 ms & for

Abstract 50864 Table

	PAP	S Tr	MPI Tr	RV-GS	LV-GS	Nt-ProBNP
PPH (n=15)	81.6 <u>+</u> 25.0	11.9 ± 3.3	0.29 ± 0.06	-14.8 <u>+</u> 5.2	-17.2 <u>+</u> 2.6	639 ± 549
PVH (n=5)	98.6 ± 19.4	9.0 ± 2.7	0.44 ± 0.14	-11.0 ± 2.9	-12.5 <u>+</u> 4.1	2170 ± 1470
P value	0.05	0.02	0.027	NS	0.034	0.042

RV myocardial IVRTc is 70 ms, for prediction of PASP >40 mmHg,with 93% & 96% sensitivity,90 % & 94% specificity, respectively.

Conclusion: PWDTI-derived RV myocardial IVRTc measured at the tricuspid annulus of RV free wall correlates very strongly with both invasively measured PASP & ET-1 levels therefore, can be used to predict PASP. It can be used as a complementary echocardiographic method for prediction of PASP or as an alternative method when tricuspid requirgitation is non recordable or difficult to measure.

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Comparison of three dimensional strain of the right ventricular free wall with pulmonary arterial pressures

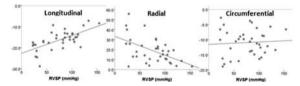
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Purpose: Studies have demonstrated a moderate correlative link between longitudinal right ventricular (RV) strain and RV systolic pressure (RVSP), using two-dimensional strain methodology. We sought to establish whether this relationship would hold true for longitudinal (LS), radial (RS) and circumferential (CS) strain vectors when tracked utilising three-dimensional speckle tracking (3DST) software.

Methods: N=28 patients with pulmonary hypertension (PHT) and N=8 healthy volunteers (20-85 years, RVSP 23-154mmHg) with satisfactory imaging for 3DST and measurable tricuspid regurgitation were assessed. RV end-diastolic pressures (RVEDP) were obtained in a subset of N=22 patients with PHT and N=5 healthy volunteers (RVEDP 7-41mmHg). In addition to standard 2D and Doppler studies, a 3D full volume capture of the RV was acquired and analysed for RS, LS and CS.

Results: RS (r= -0.522, p= 0.001) and LS (r= 0.657, p< 0.001), but not CS (r= 0.064, p= 0.711) decreased with increasing RVSP. For increasing RVEDP, LS was the only strain vector which demonstrated a significant decrease (r= 0.600, p= 0.001). RS demonstrated a weak tendency for reduced strain with increasing RVEDP (r= -0.375, p= 0.054), whilst CS did not reveal a relationship (r= 0.052, p= 0.796). **Conclusion:** There were moderate correlative associations between RVSP and both RS and LS, and a moderate correlation between LS and RVEDP.



Strain (%) vs RVSP (mmHg)

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Load Influence in pulmonary hypertension. Left and right ventricle 2D-Strain evaluation.

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Introduction: Right ventricle (RV) pressure and/or volume overload causes left ventricle (LV) deformation.

Objective: Assessment of RV and LV wall deformation in pulmonary arterial hypertension (PAH) patients accordingly to pressure or volume overload conditions.

Methods: 20 patients, age 65.4 \pm 13.5, with PAH on specific therapy, median Nt-ProBNP 730, TAPSE 21.0 \pm 5.7, RV ejection fraction 36.7 \pm 18.4%, pulmonary artery pressure (PAP) 85.9 \pm 15mmHg. Patients grouped in 2 groups accordingly to pressure overload (PPH, n=15) or volume overload (VPH) including patients with more than moderate tricuspid regurgitation. RV and LV longitudinal global strain (GS), tricuspid annulus TDI S waves recorded and MPI calculated. Nt-ProBNP characterised the neurohormonal activation. Between groups comparisons achieved with Mann-Whitney non-parametric test.

Results (see table): Patients with PVH had significantly: (1) higher PAP (p=0.05), Nt-Pro-BNP (p=0.042) and tricuspid MPI (n=0.027); (2) worst RV systolic function with decreased S-Tr (p=0.02), however with no change in RV-GS; (3) worst LV systolic function with lower LV-GS (0.034).

Conclusion: Volume overload is associated with greater neurohormonal activation, lower tricuspid S wave, but does not alter the longitudinal RV strain compared with the pressure overloaded RV. However LV longitudinal strain is decreased.

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Usefulness of pulmonary vascular resistance over pulmonary artery pressure to predict right ventricular remodeling and functional tricuspid regurgitation

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Background: Pulmonary artery pressure depends on pulmonary vascular resistance (PVR) and cardiac flow, and its elevation does not always correlate properly with increasing degrees of right ventricular (RV) remodeling or functional tricuspid regurgitation (TR). We evaluated whether a non-invasive measure of PVR is better than systolic pulmonary artery pressure (sPAP) to predict RV dilatation, RV dysfunction and degree of TR.

Methods: We prospectively analyzed consecutive stable patients with TR and a Doppler estimation of sPAP \geq 35 mmHg or any degree of RV dilatation or RV dysfunction. We excluded patients with organic TR, pacemaker leads, primary RV dilatation or dysfunction and intracardiac shunts. Non-invasive PVR was measured as the quotient between TR velocity and RV outflow tract flow (VTI).

Results: We included 255 patients, age 72,1 \pm 11,4 years-old, 52% women, 76,1% with type 2 pulmonary hypertension, and 38% in atrial fibrillation. Mean sPAP was 48,6 \pm 13,2 mmHg. RV dilatation was mild, moderate and severe in 35,7%, 15,3% and 2,0%, respectively. TR was graded in four categories: mild in 48,2% of patients, mild-moderate in 34,1%, moderate-severe in 15,3% and severe in 2,4%. RV systolic function was measured by TAPSE (mean 20,1 \pm 4,9mm). In univariate analysis, sPAP was associated with RV dilatation (r=0,62), degree of TR (r=0,55) and RV systolic function (r=-0,27) (all p<0,001). PVR was similarly associated with RV dilatation (r=0,59) and degree of TR (r=0,50), and had a stronger correlation with RV systolic function (r=-0,51) compared to sPAP (all p<0,001). In multivariate analysis, sPAP was an independent predictor of RV dilatation and TR severity, while PVR was an independent predictor of RV dilatation, TR severity and RV systolic function.

Conclusion: Non-invasive PVR measurement is superior to sPAP for the prediction of RV systolic dysfunction, but it does not confer additional value to predict RV dilatation or TR severity.

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Improvement of right ventricular function during specific drugs administration in patients with pulmonary arterial hypertension.

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Introduction: Dedicated drugs improve functional status and hemodynamic in patients with pulmonary hypertension. Drugs effect is today not reported on right ventricular function by echocardiography. This work aims to evaluate right ventricular function before and after pre and post administration of these drugs.

Methods: 20 symptomatic patients receiving the definition of pulmonary arterial hypertension (PAH) were treated by phosphodiesterase type 5 inhibitors (30%), endothelin receptor antagonists (20%) or both (50%). Echocardiographic analysis was performed before and after 4-6 months of treatment for right cavities area by planimetry, tricuspid free wall S velocity by tissue Doppler imaging, right ventricular longitudinal systolic 2D strain, peak tricuspid regurgitation velocity as well as conventional left ventricular

Results: Mean age was 53 ± 19 y. There were 8 men. At baseline, patients had elevated invasive mean pulmonary artery pressure $(38\pm12 \text{ mm Hg})$. All were at least in NYHA functional class 3 and had reduced 6-min walking test $(324\pm98 \text{ m})$. Echocardiographic findings after 4-6 of treatment are listed in table 1. Overall, the administration of dedicated drugs for PAH induced right ventricular cavities area reduction following pulmonary pressure decline, increased longitudinal right ventricular free wall displacement and deformation and positively enhanced left ventricular diastolic function.

Conclusion: In addition to functional class and hemodynamic improvement, this work reports for the first time non-invasive right ventricular function enhancement by echocardiography in patients receiving specific drugs for pulmonary arterial hypertension.

Parameters	baseline	4-6 months of treatment	р
RV diameter (mm)	33 ± 8	27 ± 10	0.004
RV area (cm ²)	20 ± 8	15 ± 7	0.02
RA area (cm ²)	22 ± 6	18 ± 8	0.016
Tricuspid S velocity(cm/s)	9 ± 3	10±3	0.01
RV free wall S 2D strain (%)	13 ± 7	16±6	0.04
TR velocity gradient (mm Hg)	52 ± 13	36 ± 4	0.02
Transmitral E/A ratio	0.75 + 0.44	0.92 + 0.58	0.02
LV ejection fraction (%)	70 ± 11	71 <u>±</u> 7	0.58

RV: right ventricle, RA: right atrium, S = systolic, LV: left ventricle.