Research Square

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Prognostic value of left atrial strain in patients with Tetralogy of Fallot

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Abstract

PURPOSE:

To demonstrate prognostic utility of left atrial strain(LAS) in adult patients with repaired Tetralogy of Fallot(rTOF).

METHODS:

Adults patients with rTOF were prospectively enrolled in this study between years 2011-2015. Left atrium(LA) phasic functions were assessed using 2D speckle tracking echocardiography(2D-STE). Association of LA strain(LAS) with primary(any cardiovascular event) and secondary(death, heart failure or arrhythmia) composite endpoints was assessed using Cox regression analysis.

RESULTS:

Hundred-and-twelve rTOF patients, in whom LAS was feasible and were in sinus rhythm, were included in the final analysis (age 33±10 years, 68[61%] male). Median duration of follow-up was 8.6[4.2-9.7] years in the study group. Primary composite endpoint was reached in 48 patients (mean event-free survival time: 7.2[6.6-7.9] years), and secondary composite endpoint was reached in 22 patients (mean event-free survival time: 8.7[8.1-9.2] years). LAS-r was defined as tertile groups(1^{st} tertile<33 %,2^{nd} tertile=33-44%,3^{rd} tertile>44%). Decreasing tertiles of LAS-r was associated with primary and secondary composite endpoints in Kaplan-Meier analysis(p=0.02 and 0.002, respectively). In univariable Cox-regression, both decreasing LAS-r and LAS-r tertiles were associated with primary and secondary composite endpoints. Adjusted by initial repair age and NT-proBNP quartiles, increased LAS-r was associated with significantly decreased occurrence of experiencing any events(HR=0.97,CI:0.93-0.99,p=0.037]). Decreasing LAS-r was still associated with primary endpoint when adjusted by left atrium volume index(LAVImax) (HR=0.96,CI:0.03-0.99,p=0.01),left ventricle global longitudinal strain(LV-GLS)(0.95,95%CI:0.92-0.98,p=0.002) or right ventricle free wall longitudinal strain (RV-FWLS)(0.96,95%CI:0.93-0.99,p=0.04).

CONCLUSION:

Assessment of LA mechanics with the use of STE has incremental utility in determination of mortality and morbidity in rTOF, and may be implemented in clinical practice.

Introduction

Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart disease, comprising approximately 10% of all congenital heart defects.[1] Due to advances in surgical techniques, majority of the patients survive to adulthood. Still, many patients have residual defects, mostly residual pulmonary regurgitation and pulmonary homograft stenosis. Long-term follow up of the patients is complicated with arrhythmias, heart failure and cardiovascular mortality.[2] Prognostication of patients with repaired TOF(rTOF) is a hot topic in the field of adult congenital heart disease. Improvement in risk stratification of

the patients might result in better timing of reinterventions and bring survival patterns of the patients closer to healthy adult population.

Currently prognostication of the patients is based on electrocardiographic and basic echocardiographic parameters, such left and right ventricle ejection fraction, age, late gadolinum enhancement in cardiac magnetic resonance imaging, peak oxygen consumption in cardiopulmonary exercise testing and blood biomarkers.[3, 4] In recent years, speckle tracking echocardiography has come to fore in determination of prognosis. Previously, left ventricle global longitudinal strain(LV-GLS) and right ventricle free wall longitudinal strain(RV-FWLS) has been shown to independently predict heart failure or mortality in rTOF.[5]

Left atrial strain is a new STE biomarker that has been shown to have prognostic implications in patients with heart failure,[6] cryptogenic stroke,[7] and patients undergoing catheter ablation for atrial fibrillation.[8] LA reservoir strain has been demonstrated to be superior to LA volumes in determination of diastolic dysfunction, and proposed as a new biomarker for this purpose.[9] There are several studies investigating changes in left atrial strain and left atrial phasic functions with STE in rTOF compared with healthy controls.[10] However, prognostic role of LAS in rTOF hasn't been demonstrated yet. In the current study, we sought to evaluate the prognostic utility of this novel biomarker in patients with rTOF.

Materials And Methods

Study population

Clinically stable rTOF patients who are followed up on an outpatient basis between years 2011 and 2015 were included in this prospective observational study. Patients under 18 years old were excluded. The study was conducted in accordance with the Declaration of Helsinki and local ethical committee approval was obtained priorly. Written informed consent was obtained from the participants, and the participants who cannot understand and sign the informed consent form was excluded.

Data collection

In addition to medical history, physical examination, 12-lead electrocardiogram, venous blood sampling and routine 2-dimensional transthoracic echocardiogram, speckle tracking echocardiographic analysis was performed. Follow-up data was acquired through yearly appointments and review of electronic medical records. Referring hospitals were contacted when necessary.

Echocardiographic Acquisition

An iE33 or EPIQ7 ultrasound system (Philips Medical Systems, Best, the Netherlands) with a transthoracic broadband X5-1 matrix transducer (composed of 3040 elements with 1–5 MHz) was used to obtain two-dimensional greyscale harmonic images in the left lateral decubitus position. Standardized sequential segmental analysis protocol, that was described previously, was utilized.[11] Routine echocardiographic

assessment was performed in accordance with contemporary guidelines.[12] Acquisitions were obtained with the focus on LA with a frame rate > 60 Hz, for volume and strain analyis of the LA.

Speckle tracking analysis

STE analysis of the acquired data was performed on a vendor-neutral software (Image Arena version 4.6 TomTec Imaging Systems, Unterschleissheim, Germany). Firstly mitral lateral and medial anulus and LA apex were marked on a point and click basis. The end-diastolic frame was tagged at the R-wave and end-systolic frame was tagged at one frame before the mitral valve opening. The software traced and tracked automatically the LA endocardium throughout the cardiac cycle. Manual corrections were made as needed. Quality of the endocardial delineation and quality of the tracking were graded as “poor”, “moderate” or “good”. When either or both of these two was poor, LAS was termed “infeasible”. LAS analysis was performed in accordance with the previous consensus document by European Society of Cardiology.[13] The definitions of LA strain, strain rate and volume are summarized in Supplementary table 1. Normative ranges for LA-S[13], LV-GLS[14], LV-SRe[15], and RV-FWLS[16] were extracted from the studies conducted in the same hospital.

Definition and assessment of endpoints

The following endpoints were recorded: death, heart failure requiring treatment, hospitalization, arrhythmia, percutaneous intervention and surgical intervention. Two composite endpoints were defined for this study: primary composite endpoint was defined as occurence of any cardiovascular event, and secondary composite endpoint was defined as occurence of death, heart failure or arrhythmia.

Event free survival was defined as the duration from the time of enrollment in the study to occurence of the first endpoint. When any of the predefined endpoints was not reached, the patient was cencored at the time of last contact, or at the time of closure of the follow-up. The caretakers and the researchers in this project were blinded to the STE measurements. The patients were treated in accordance with the contemporary guidelines, independent of the study protocol.

Statistical analysis

Continuous variables were initially assessed for distribution, using histograms and Shapiro-Wilk test. The data were presented as mean ± SD when normal distribution was met, and median (interquartile range) when not. The study population was divided into three tertile groups based on the LAS-r value. One-way ANOVA test was used for assessing the significance of difference in continuous variables between groups when homogeneity of variances was met, and Kruskal-Wallis test otherwise. Categorical data were presented as frequencies and percentages. Pearson’s Chi Square test -or Fisher’s exact test when a cell has a frequency less than 5- was used to assess difference between LAS-r tertile groups with regard to categorical variables.

The difference of composite endpoints between LAS-r tertile groups was assessed using the Kaplan Meier curves. Log-rank test was used for the assessment of significance of the difference when the

hazards were proportional. When proportional hazards assumption was not met, Peto-Peto Prentice test was utilized. The association of baseline characteristics, as well as STE parameters with composite endpoints was assessed with Cox proportional hazards method. Variables that showed p-values < .10 in the univariable analyses and which didn't have more than mild level of significant correlation with LAS-r were included in subsequent multivariable analyses. An event frequency of at least 10 per variable in the multivariable models was ensured.

Tests were considered statistically significant when two-sided p-values were smaller than 0.05. Statistical analysis was performed using R software and IBM SPSS Statistics.

Results

Study population

Hundred-and-twelve rTOF patients, in whom LAS was feasible and were in sinus rhythm, were included in the final analysis (age 33±10 years old, 68[61%] male). The overall feasibility of the LAS measurements was 87.4%. Twenty-three patients (15.2%) were excluded due to poor image quality or poor tracking, while 22 patients (14.6%) were excluded due to a baseline rhythm other than sinus.

Baseline characteristics of the study patients are summarized in Table 1. Patients in the lower LAS-r tertiles were significantly older(36±11 vs 31±9 vs 32±9y, p=0.034), had a larger initial repair age (4[2-9] vs 2[1-5] vs 2[1-5]y, p=0.036), and had greater proportion of Waterston shunt as the initial repair(21% vs 5% vs 6%, p=0.030). Cardiac medication use was also significantly higher in the lower LAS-r tertiles(37% vs 3% vs 3%, p<0.001).

Distribution of baseline electrocardiographic, echocardiographic and laboratory parameters in the study group is demonstrated in Table 2. QRS duration was significantly higher in the lowest tertile group(155±29 vs 127±32 vs 133±28ms,p<0.001). LVEF (52±8 vs 54±5 vs 56±5%,p=0.034), and E' amplitude was lower in lower tertiles(8±3 vs 9±3 vs 9±2cm/s,p=0.042).

Left atrial volume and function

Distribution of LA, LV and RV STE parameters among LAS-r tertiles is demonstrated in Table 4. All the LAS and LASR values were decreased in lower tertiles. LV-GLS and LV-Sre were significantly lower in lower tertiles, however RV-FWLS didn't differ significantly(LV-GLS:-16.8±3.5 vs -18.3±2.8 vs -18.4±2.8%, p=0.005;LV-SRe: 0.7±0.2 vs 0.8±0.2 vs 0.8±0.2,p=0.009;RV-FWLS:-14.9±4.3 vs -16.5±3.4 vs -16.5±3.3,p=0.14).

Follow-up and assessment of endpoints

Overview of the events observed during follow-up are summarized in Supplemental table-2. Median duration of follow-up was 8.6[4.2-9.7] years in the study group. During follow-up, 98 events occurred. 33 patients underwent surgical or transcatheter intervention. 18 patients had an arrhythmia episode, and 8 patients had a heart failure episode requiring treatment. 37 patients were hospitalized during follow-up. There were two deaths: 1 due to viral pneumonia, the other due to sudden cardiac death. The primary composite endpoint of any event was observed in 48 patients (mean event-free survival time: 7.2[6.6-7.9] years), while the secondary composite endpoint of death, heart failure or arrhythmia was observed in 22 patients (mean event-free survival time: 8.7[8.1-9.2] years).

Baseline clinical and echocardiographic predictors of prognosis

Baseline characteristics associated with composite endpoints are shown in Supplemental Figure 1. In univariable Cox regression, age, age at repair, QRS duration, e' wave, AV peak velocity, AR of more than moderate degree, TR peak velocity and increasing tertile of NT-proBNP were associated with primary and secondary endpoints. RV end-diastolic annulus diameter and TR of more than moderate degree was associated with primary, while E/e' ratio was associated with secondary composite endpoints.

Association of LA speckle tracking parameters with prognosis

Univariable analysis showing association of speckle tracking parameters with prognosis is shown in Supplemental Figure 2. In univariable cox regression, increased LAS-r was associated with primary and secondary composite endpoints. In Kaplan-Meier analysis, decreasing tertile of LAS-r was associated with decreased event free survival from primary and secondary composite endpoints (mean survival=5.9[4.7-7.1] vs 7.8[6.8-8.8] vs 7.9[6.8-9]years,p=0.020 for primary; 7.2[6-8.5] vs 9[8.3-9.7] vs 9.7[9.1-10.2]years,p=0.002 for secondary composite endpoints) (Figure 1A and 1B, respectively).

When adjusted by initial repair age and NT-proBNP quartiles, increased LAS-r was associated with significantly decreased occurrence of any events(HR=0.97,CI:0.93-0.99,p=0.037]). When adjusted by baseline echocardiographic parameters e' wave, RVEDD, TRV, TR of at least moderate degree, AV peak velocity, and AR of at least moderate degree, and increasing LAS-r was associated with decreasing occurrence of primary composite endpoint(HR=0.95,CI:0.91-0.99,p=0.016). In a third model, when adjusted by LAVImax, increased LAS-r was associated with decreased occurrence of primary composite endpoint(HR=0.96,CI:0.03-0.99,p=0.01). LAS-r was significantly associated with primary endpoint when also adjusted by LV-GLS(0.95,95%CI:0.92-0.98,p=0.002) or RV-FWLS(0.96,95%CI:0.93-0.99,p=0.04).

Discussion

The current study demonstrates that decreased LAS-r is associated with mortality and morbidity in adult patients with rTOF, when adjusted by baseline clinical, laboratory and echocardiographic parameters.

Left atrium mechanics

Feasibility of LAS was on the lower side of the range reported in previous literature in healthy individuals.[17] Main causes of decreased feasibility were poor tracking and LA foreshortening, which is observed to be associated with right chamber enlargement in majority of the cases. 3D-STE techniques might yield improved feasibility, even though it is not reported in the single study on TOF patients using this technique for LA strain analysis.[18]

In our study, LAS-r based stratification of the study cohort revealed worse baseline clinical status as well as LV and LA mechanical functions in decreasing tertiles of LAS-r. In contrast, LVEF was within normal limits in all three tertiles. In the majority of the studies that compared healthy controls and patients with TOF with regard to LA phasic functions,[18–22] although LAS-r was decreased compared with controls, changes in the remaining LAS/LASR parameters varied significantly. In the current study we were able to demonstrate cross-sectionally that patients show varying degrees of LA dysfunction, or supranormal LA functions, depending on the stage of the disease. We think that patients with intact LA functions(due to earlier stage of disease or less LA scar) but impaired RV hemodynamics and resultant LV diastolic dysfunction compensate this hemodynamic load by augmenting LA mechanical function. With progression of the disease, LA dysfunction add up, and all LA phasic functions become impaired.

Prognostic role of left atrium phasic functions

Long-term follow-up of patients with rTOF is set back with heart failure, ventricular arrhythmias and sudden cardiac death. Risk stratification and timely interventions as needed are extremely important. The role of STE in prognostication of rTOF is demonstrated. In a study by van Grootel et al, RV-FWLS was associated with primary endpoint of heart failure or death, previously.[5] However, the prognostic role of LAS and LASR in rTOF hasn't been studied up to now.

In one large cohort, Baggen et al. demonstrated LAVImax and LAVImin, along with several LA-phasic function parameters, to be associated with cardiovascular events and heart failure with the use of 2D-TTE.[23] In the current study, we demonstrated using STE that LAS-r was associated with endpoints when adjusted by LAVImax, LV-GLS or RV-FWLS which points out the independent role of this parameter in prognostication of rTOF.

Left atrium plays an important role in regulation of LV filling, via reservoir, conduit and booster pump functions. Conventionally, LA diameters and volumes are used to determine LA phasic functions. Novel STE allowed LAS to be measured. LAS-r corresponds to the LA stretch during LA filling. In addition to it's role in improving LV diastolic function assessment,[9] it has been shown to have implications in prognostication of patients with heart failure with preserved ejection fraction.[24] The current study demonstrated that this novel parameter could also have a role in assessing prognosis in patients with rTOF.

Limitations of the Study

Limited feasibility of LA-STE, caused by alterations in chamber sizes that result in difficulties bringing LA in the imaging sector, is an important limitation. MR or CT based strain imaging, or alternatively 3D-STE, could potentially overcome this limitation. Additionally, the number of variables that could be added in multivariable cox regression models is limited by observed event numbers. Larger cohorts with longer follow-up durations might solve this problem.

Conclusion

LA-STE analysis is present in majority of the modern echocardiography machines, with off-line and on-line analysis options. Although variability is still a concern, added clinical value is ascertained by accumulating evidence. This study demonstrated the prognostic utility of LAS in patients with rTOF. Lower tertiles of LAS-r, a comprehensively studied marker of diastolic functions was associated with increased morbidity and mortality in rTOF patients. Results from this study support potential clinical value of LAS in prognostication in patients with rTOF.

Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Ferit Onur Mutluer, Daniel J. Bowen, Roderick W. J. van Grootel, Isabella Kardys, Jolien W. Roos-Hesselink and Annemien E. van den Bosch. The first draft of the manuscript was written by Ferit Onur Mutluer and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Erasmus Medical Center, Rotterdam (EMC 05-01-43-01-05).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent to publish

No individual person's data has been presented in any of the figures or tables in this publication.

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None to declare.

DISCLOSURE

The authors have no relevant financial or non-financial interests to disclose.

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Tables

Table 1. Baseline characteristics of the study cohort

	All patients n=112	1st tertile (<33%) n=38	2nd tertile (33-45%) n=38	3rd tertile (>45%) n=36	p-value
Age, years	33±10	36±11	31±9	32±9	0.034
Sex, male n (%)	68(61)	25(66)	21(55)	22(61)	0.64
NYHA class II-III, n (%)	11(10)	6(16)	2(5)	3(8)	0.27
Body mass index, kg/m2	24.1±3.7	24.2±3.8	23.6±3.0	24.4±4.3	0.59
Body surface area, m2	1.86±0.20	1.86±0.20	1.84±0.20	1.89±0.20	0.51
Systolic blood pressure, mmHg	125±14	128±14	124±16	122±13	0.22
O2 saturation <90%, n (%)	1(1)	1(3)	0(0)	0(0)	0.38
Cardiac medication, n (%)	16(14)	14(37)	1(3)	1(3)	<0.001
ACE-inhibitor or ARB	8(7)	8(21)	0(0)	0(0)	<0.001
Beta blocker	6(5)	5(13)	0(0)	1(3)	0.028
Anti-arrhythmic	2(2)	2(5)	0(0)	0(0)	0.14
Aspirin	3(3)	2(5)	0(0)	1(3)	0.36
Anticoagulants	8(7)	7(18)	0(0)	1(3)	0.004
Associated lesions, n (%)	32(29)	10(26)	12(32)	10(28)	0.88
Atrial septal defect	16(14)	6(16)	7(18)	3(8)	0.37
Patent ductus arteriosus	10(9)	3(8)	3(8)	4(11)	0.63
Aortic valve stenosis	9(8)	3(8)	2(5)	4(11)	0.62
Surgical characteristics					
Age at repair, years	2(1-6)	4(2-9)	2(1-5)	2(1-5)	0.036
Prior aortopulmonary shunt, n (%)	38(33)	13(34)	14(37)	11(31)	0.75
Blalock shunt	26(23)	5(13)	12(32)	9(25)	0.22
Waterston shunt	12(11)	8(21)	2(5)	2(6)	0.030
Other shunt	1(1)	1(3)	0(0)	0(0)	0.23
Transannular patch used, n (%)	59(53)	18(47)	22(58)	19(53)	0.63
Re-intervention, n (%)	57(51)	22(58)	17(45)	18(50)	0.49

More than two re-interventions	4(4)	2(5)	1(3)	1(3)	0.56
Surgical, n (%)	63(56)	21(55)	1(47)	24(67)	0.33
Pulmonary valve replacement	48(43)	18(47)	17(45)	13(36)	0.33
Residual VSD repair	16(14)	10(26)	2(5)	4(11)	0.06
Catheter-based, n (%)	15(13)	5(13)	4(11)	6(17)	0.67
Pulmonary valve balloon dilatation	7(6)	2(5)	2(5)	3(8)	0.59
Pulmonary valve replacement	4(4)	2(5)	2(5)	0(0)	0.23
Ablation	2(2)	1(3)	0(0)	1(3)	0.98

NYHA: New York Heart Association, ACE: angiotensin converting enzyme, ARB: angiotensin receptor blocker, VSD: ventricular septal defect

Table 2. Baseline electrocardiography, echocardiography and laboratory results of the study cohort.

	All patients n=112	1st tertile (<33.2 %) n=38	2nd tertile (33.2-44.6%) n=38	3rd tertile (>44.6%) n=36	p-value
Electrocardiography					
Heart rate, beats/min	75±13	76±13	73±13	77±13	0.45
QRS duration, ms†	139±32	155±29	127±32	133±28	<0.001
QRS duration >120 ms, n (%)*	74(66)	34(90)	20(53)	20(56)	<0.001
RBBB	67(73)	30(79)	18(62)	19(78)	<0.001
LBBB	1(1)	1(3)	0(0)	0(0)	0.29
Other	6(5)	3(8)	2(7)	1(4)	0.55
Echocardiography					
LV end diastolic volume, mL/m^2	59±14	63(15)	59±14	54±11	0.026
LV ejection fraction, %	54±6	52±8	54±5	56±5	0.034
E' wave, cm/s	8±3	8±3	9±3	9±2	0.042
E/E'-ratio	10.5±3.5	11.2±4.4	10.0±3.3	10.2±2.5	0.33
RV end-diastolic annulus, mm	45±7	47±7	43±7	46±8	0.12
TAPSE, mm	18±4	18±5	18±4	19±4	0.37
RV fractional area change, %	40±10	38±12	41±9	43±8	0.19
Valvular function					
AV peak velocity, m/s	1.05(0.91-1.20)	1.02(0.87-1.20)	1.07(0.97-1.20)	1.05(0.95-1.20)	0.50
AR ≥ moderate, n (%)	5(5)	2(5)	3(8)	0(0)	0.28
PV peak velocity, m/s	2.20±0.73	2.01±0.83	2.24±0.70	2.21±0.64	0.35
PR ≥ moderate, n (%)	43(38)	12(32)	15(40)	16(44)	0.25
TR peak	2.84±0.59	2.90±0.66	2.83±0.52	2.79±0.58	0.78

velocity, m/s					
MR ≥ moderate, n (%)	1(1)	0(0)	1(3)	0(0)	0.98
Laboratory results					
Hemoglobin, g/dl	14.7±1.6	14.6±1.7	14.8±1.5	14.5±1.4	0.72
Creatinine, mg/dl	0.86±0.14	0.84±0.15	0.85±0.11	0.88±0.17	0.44
NT-proBNP, pg/ml	118(51-232)	141(78-288)	120(50-260)	75(46-141)	0.13

RBBB: right bundle branch block, LBBB, left bundle branch block, LV: left ventricle, RV: right ventricle, AV: aortic valve, AR: aortic regurgitation, PV: pulmonary valve, PR: pulmonary regurgitation, TR: tricuspid regurgitation, MR: mitral regurgitation

Table 3. Distribution of speckle tracking echocardiography parameters in the study cohort

	Reference range	All patients n=112	p-value	1st tertile (<33.2 %) n=38	2nd tertile (33.2-44.6%) n=38	3rd tertile (>44.6%) n=36	p-value
Volumes							
$LAVI_{max}$ (ml/m2)	34±9.2	26.2±11.3	<0.001	30.1±15.1	24.9±9.1	23.6±7.1	0.32
$LAVI_{min}$ (ml/m2)	12.8±5.5	9.9±7.2	<0.001	14.5±10.1	8.2±3.3	6.7±2.7	<0.001
LA TEV (ml/m2)	21.9±6.1	30.4±12.8	<0.001	28.7±14.3	30.6±13.1	32.0±10.8	0.54
LA TEF(%)	63±11	63.6±12.0	0.69	53.1±11.1	66.4±9.5	71.6±6.1	<0.001
LA PEV (ml/m2)	14.0±5.7	19.9±9.9	<0.001	18.8±11.4	20.8±10.2	20.3±8.0	0.67
LA PEF (%)	43.3±13.5	41.6±13.4	0.34	34.5±11.5	44.6±14.5	45.5±11.4	<0.001
LA AEV (ml/m2)	7.7±3.3	5.4±3.7	<0.001	4.8±4.9	5.4±2.8	6.1±2.8	0.36
LA AEF (%)	38.0±9.3	22.2±11.6	<0.001	18.6±13.9	22.0±10.2	26.0±9.3	0.023
Strain							
LAS-r, %	36.3±1.1	38.6±9.9	0.012	27.5±5.3	39.1±3.2	49.7±3.4	-
LAS-cd, %	-18.1 ± 8.7	-23.8±7.2	<0.001	-17.0±4.2	-25.3±4.7	-29.2±6.2	<0.001
LAS-ct, %	-14.9 ± 6.0	15.0±6.5	0.90	-10.7±4.4	-13.7±4.9	-20.5±6.0	<0.001
Strain rate							
LASR-r, 1/s	1.02 ± 0.30	1.10±0.32	0.05	0.83±0.19	1.12±0.25	1.39±0.22	<0.001
LASR-cd, 1/s	-0.73 ± 0.31	-1.00±0.33	<0.001	-0.74±0.20	-1.10±0.24	-1.16±0.37	<0.001
LASR-ct, 1/s	-0.72 ± 0.26	-0.83±0.39	0.011	-0.66±0.40	-0.74±0.28	0.76-9.82	<0.001
LV and RV strain							
LV GLS,%	-20.4±2.2	-17.9±3.1	<0.001	-16.8±3.5	-18.3±2.8	-18.4±2.8	0.005

LV SRe,1/s	1.11±0.24	0.79±0.22	<0.001	0.7±0.2	0.8±0.2	0.8±0.2	0.009
RV FWLS, %	-26.5±4.5	-16.0±3.7	<0.001	-14.9±4.3	-16.5±3.4	-16.5±3.3	0.14

LA: left atrium, LAVI: left atrium volume index, EV: ejection volume, EF: ejection fraction, P: passive, A: active, LAS: left atrium strain, LASR: left atrium strain rate, r: reservoir, cd: conduit, ct: contraction, AGLS: average global longitudinal strain, SRe: early diastolic strain rate, FWLS: free wall longitudinal strain

Figures

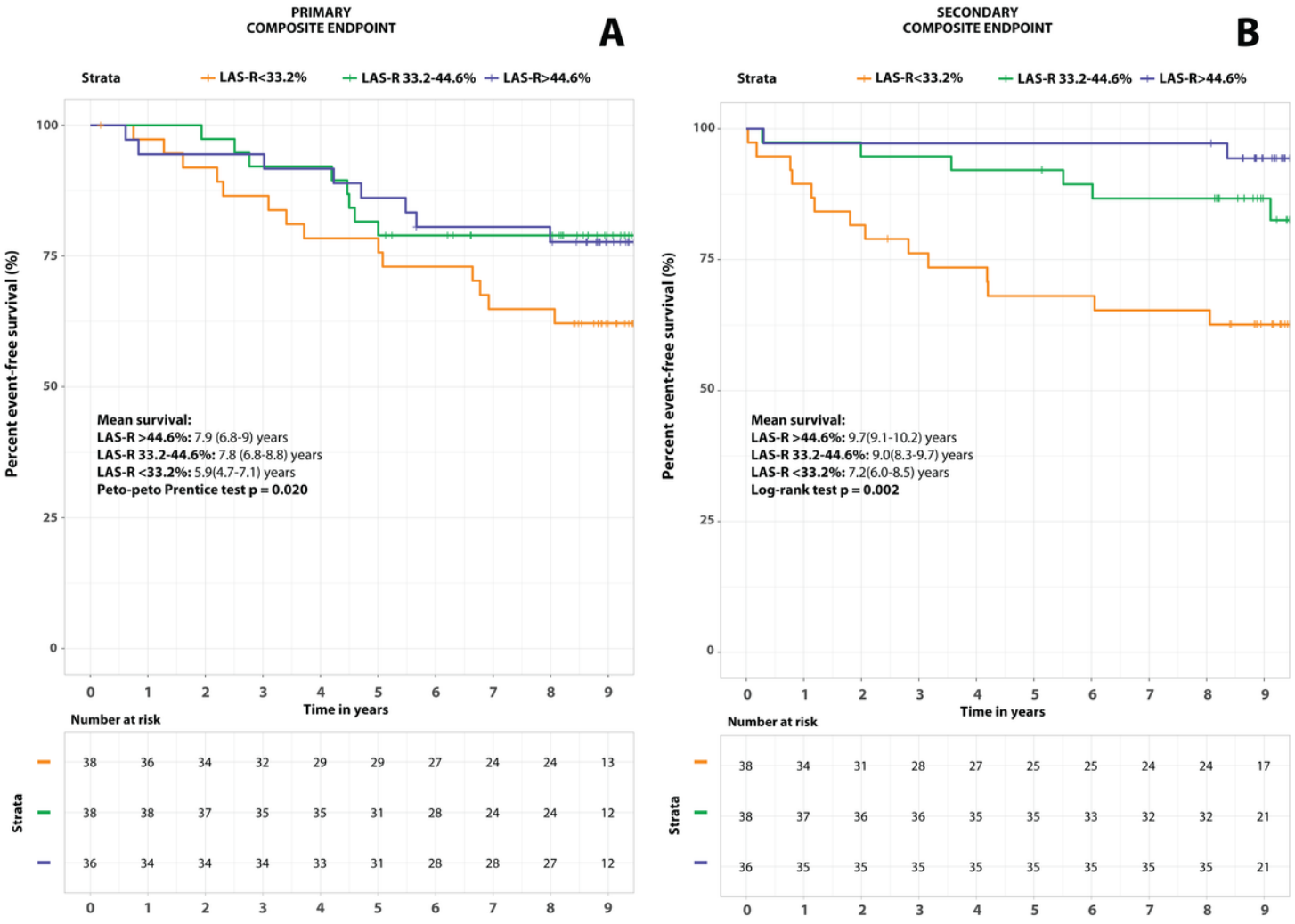


Figure 1

Percent primary (A) and secondary (B) composite outcome-free survival among tertiles of LAS-r. LAS-r 1st tertile <33.2%, 2nd tertile (33.2-44.6%) and 3rd tertile (>44.6%). Primary outcome: any cardiac adverse event, secondary outcome: death, heart failure or arrhythmia

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementalFigure1.png
- SupplementalFigure2.png
- Supplementaltable1.MeasurementofLAvolumestrainandstrainrateparameters.docx
- Supplementaltable2Overviewofeventsduringfollowup.docx