ISSN 1669-9106

ORIGINAL ARTICLE

MEDICINA (Buenos Aires) 2023; 83: 19-28

SUBCOSTAL RIGHT VENTRICULAR FREE WALL STRAIN IN PATIENTS WITH PULMONARY HYPERTENSION

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Abstract Right ventricular longitudinal strain (RVLS) is frequently used as a measure of right ventricular systolic function. Abnormal RV strain is associated with poor prognosis in patients with pulmonary hypertension (PH); however, the measure is not always easy to obtain in patients with poor apical acoustic windows. **Objective**: This study aims to analyze the RVLS and determine if there is a difference when measured from the apical and subcostal views. **Methods**: In this cross-sectional study, we analyzed 22 adult outpatients (≥ 18 years old), 81% female, mean age 49.9 ± 17.3 years, with a diagnosis of PH using right heart catheterization, followed from January 2016 to January 2020. **Results**: RVLS measured in the RV free wall from the apical views was -15% (-19% to -10%) and subcostal views -14.5% (-18% to -11%) were highly correlated (Person's r = 0.969, p < 0.0001). Segment by segment analysis did not show significant differences either: basal four-chamber vs. subcostal view was -16.5% (-21% to -11%) vs. -15.5% (-20% to -11%), p = 0.99, mid four-chamber view vs. subcotal view was -16.5% (-21% to -12%) vs. -16.5% (-20% to -11%), p = 0.87, apical four-chamber view vs. subcostal view was -12% (-18% to -8%) vs. -13.5% (-19% to -10%), p = 0.93. **Conclusion:** Subcostal RVLS free wall is a feasible and accurate alternative to conventional RVLS free wall from the apical view in patients with pulmonary hypertension and could be useful in patients with poor acoustic apical four-chamber windows.

Key words: pulmonary hypertension, apical right ventricular strain, subcostal right ventricular strain, speckle tracking echocardiography

Resumen ***Strain subcostal de la pared libre del ventriculo derecho en pacientes con hipertensión pulmonar***
El *strain* longitudinal del ventrículo derecho (SLVD) permite medir la función sistólica del ventrículo derecho (VD). La disminución del *strain* (deformación) del VD se asocia con mal pronóstico en pacientes con hipertensión pulmonar (HP), pero no siempre es fácil de obtener en pacientes con mala ventana acústica apical. **Objetivo:** Este estudio tiene como objetivo analizar el SLVD y determinar si las vistas apical y subcostal son comparables. **Métodos:** En este estudio transversal, se incluyeron 22 pacientes adultos ambulatorios (≥18 años), 81% mujeres, edad promedio 49.9 ± 17.3 años, con diagnóstico de HP mediante cateterismo cardíaco derecho, seguidos desde enero de 2016 hasta enero de 2020. Se midió la deformación de la pared libre del ventrículo derecho desde las vistas de cuatro cámaras apical y cuatro cámaras subcostal. **Resultados:** El SLVD medido en la pared libre del VD desde la vista apical fue -15% (-19% a -10%) vs. -14.5% (-18% a -11%) cuando se midió desde la vista subcostal (p = 0,99). El análisis segmento por segmento tampoco mostró diferencias significativas: el segmento basal apical vs. subcostal fue -16.5% (-21% a -11%) vs. -15.5% (-20% a -11%), p = 0.99, el segmento medio apical vs. la vista subcotal fue -16.5% (-21% a -12%) vs. a -16.5% (-20% a -11%), p = 0.87, el segmento apical vs. la vista subcostal fue -12% (-18% a -8%) frente a -13.5% (-19% a -10%), p = 0.93. **Conclusión:** En pacientes con HP, el SLVD obtenido en la pared libre subcostal es una alternativa útil en los casos con ventana acústica apical subóptima.

Palabras clave: hipertensión pulmonar, *strain* del ventrículo derecho, vista de cuatro cámaras apical, vista de cuatro cámaras subcostal

Received: 14-III-2022 Accepted: 26-VIII-2022

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KEY POINTS
Current knowledge

- Right ventricular longitudinal longitudinal strain is frequently used as a measure of right ventricular systolic function. Abnormal right ventricular (RV) strain values are associated with poor prognosis in patients with pulmonary hypertension; however, the measure is not always easy to obtain in patients with poor apical acoustic window.

Contribution of the article to current knowledge

- Our study shows that subcostal right ventricular free wall strain can be reliably measured, with good agreement with traditional apical RV strain. It is a feasible and accurate alternative to conventional right ventricular free wall strain from the apical view in patients with pulmonary hypertension and poor acoustic apical window.

Right ventricular (RV) systolic dysfunction is a strong predictor of mortality in patients with PH[1, 2]. Several functional parameters have been derived from two-dimensional RV assessment, but all have inherent strengths and weaknesses[3]. In patients with PH, with conditions such as chronic obstructive pulmonary disease, apical acoustic window are often suboptimal.

Speckle-tracking echocardiography (STE) allows to quantify RV systolic function without geometric assumptions[4-6]. RV longitudinal strain (RVLS) measurements can be obtained from both the apical and subcostal views; however we don´t know whether these two approaches are truly comparable. Hence, the aim of this study was to compare Right Ventricular Longitudinal Peak Systolic Strains (RV LPSS) obtained from both echocardiographic views.

Material and methods

This cross-sectional study analyzed 22 adult outpatients (≥18 years old), 81% female, mean age 49.9 ± 17.3 years, with a diagnosis of PH. According to the guidelines published by the European Society of Cardiology in 2015[7], PH was defined as a mean pulmonary artery pressure ≥ 25 mmHg in the right heart catheterization. The population was followed at Dr. Cosme Argerich Hospital from January 2016 to January 2020, and they were compared to a control group of 22 age- and sex-matched healthy subjects.

The control group was recruited by invitation from hospital staff (mean age 49 ± 15 years) without any history of cardiovascular disease and normal clinical examination, chest X-ray, electrocardiogram, and two-dimensional echocardiography.

The Research Ethics Committee of the Hospital Dr. Cosme Argerich approved this study.

All patients involved in this study provided written informed consent authorizing the use and disclosure of their protected health information.

According to the current clinical classification of pulmonary hypertension (PH) into five groups, based upon etiology and mechanism[7-8], the most frequent causes of PH (Table 1) was included in Group I (Pulmonary Arterial Hypertension): Eisenmengers's disease due to Congenital heart disease: 36.4%, Idiopathic: 18.2%, Connective tissue disease: 9.1%, HIV: 4.5%, Hereditary: 4.5%, portopulmonary hypertension: 4.5%), Group II (PH due to left side heart disease): 13.6%, Group III (PH due to chronic lung disease): COPD: 4.5% and Group V (PH due to multifactorial mechanism): Gaucher disease: 4.5%. None patient was in Group IV (PH due to chronic pulmonary thromboembolism).

All patients had been treated with PH-specific drugs (Table 1), including intravenous/inhaled prostacyclin analogues (Iloprost: one patient intravenous and two patients inhaled, treprostinil: two patients), endothelin receptor antagonists (ERA: Bosentán: three patients, Ambrisentán: three patients), and phosphodiesterase 5-inhibitors (PDE-5: Sildenafil: eleven patients), either as a single drug or combined in concordance with current guidelines recommendations[7].

All patients at the time of the study had to have a diagnosis of PH confirmed by right heart catheterization and defined as mean pulmonary artery pressure ≥ 25 mmHg.

Patients were excluded from the study for any of the following: age less than 18 years, irregular heart rhythm, prolonged QRS duration, aortic or mitral regurgitation more significant than mild, coronary heart disease, RV outflow tract obstruction, RV pacing and RV myocardial infarction.

Patients with these comorbidities were excluded to avoid any possible influence on the results of RV strain measurement.

All two-dimensional echocardiogram was performed using a commercially available Vivid 7 ultrasound system (General Electric Medical Systems, Milwaukee, WI) with a phased array 3.5 MHz transducer. Three cardiac cycles were recorded and saved in cine loop format in the machine's hard drive to be analyzed offline later by two independent observers. For measuring left and right ventricular parameter the following views were used: left parasternal (long- and short axis), apical 4-chamber views, including RV focused apical view according to the guidelines of the American Society of Echocardiography (ASE)[8], with the patient in left decubitus position. The subcostal four-chamber view were obtained with the patient in the supine position.

The following parameters were measured using M-mode and two-dimensional echocardiography: left ventricular (LV) diameter and end-diastolic volume, LV diameter, and end-systolic volume, LV ejection fraction, right ventricular (RV) basal diameter, RV dimensions (end-systolic and end-diastolic areas), RV fractional area change (RV FAC), tricuspid annular plane systolic excursion (TAPSE), Pulmonary artery systolic pressure (PASP) and mean right atrial pressure[3]. In addition, the LV ejection fraction (EF) was estimated using Simpson's method, and LV dysfunction was defined as a value below 55%.

All patients were examined using second-harmonic, adjusting the sector size for adequate frame rate and optimal RV border visualization.

TAPSE was measured in the apical four-chamber view by aligning the M-mode cursor through the lateral tricuspid annulus, calculating the total excursion of the tricuspid annulus from its highest position until its lowest descent during ventricular systole. A TAPSE < 16 mm indicates RV systolic dysfunction[8].

RV FAC was calculated according to the ASE formula[3] as: (RV end-diastolic area -RV end systolic area)/RV end-diastolic area) x 100. RV FAC < 35% indicates RV systolic dysfunction.

Pulmonary artery systolic pressure (PASP) was calculated from the tricuspid regurgitation jet's peak velocity, using the modified Bernoulli equation plus right atrial pressure estimated by the inferior vena cava size and collapsibility[3].

Standard, a commercially available software (EchoPac PC, Version 108.1.5; GE Medical System), was used to obtain two-dimensional STE, by a single experienced reader (OP), and the analysis was confirmed by a separate experienced reader (TFC). We use STE to evaluate the RVLS.

RVLS is defined as the percentage of shortening of the region of interest (ROI) relative to the original length and is conventionally presented as a negative value. The only images with a frame rate between 40 to 80 frames/sec were selected for reliable analysis.

The endocardial border of the RV free wall was manually traced out at an end-systolic, and the software displayed automatically an ROI, including the myocardial wall. This ROI can be manually adjusted to the thickness of the RV myocardium to ensure adequate tracking, and segments were excluded because of suboptimal visualization or if unable to be satisfactorily tracked.

For the lateral RV strain assessment, the images were obtained from the apical 4-chamber RV dedicated view focusing on the lateral wall[8] and from the four-chamber subcostal view. The frame rate used in 4-chamber RV dedicated view focusing on the free wall was higher (probably narrower interrogation sector) vs. subcostal (wider attempting to include apex to base RV, resulting in lower frame rate).

Peak systolic strain was measured in the basal, midventricular, and apical segments of the RV free wall (obtained from the apical four-chamber and subcostal view), and averaged to obtain RVLS (Figs. 1 and 2).

TABLE 1.– *Demographic and clinical data of patients with PH and control subjects*

Demographic Data	Patients with PH n = 22	Normal Controls n = 22	p-value
Women, n (%)	18 (81.8%)	17 (81.0%)	0.94
Age (years)	49.9 ± 17.3	49 ± 15.0	0.86
Weight (Kg)	65.2 ± 14.8	70.7 ± 14.5	0.23
Height (m)	1.60 ± 7.1	1.62 ± 6.2	0.24
Body mass index (kg/m^2)	25.8 ± 5.3	25.1 ± 3.1	0.89
Heart rate (bpm)	76 ± 13	70 ± 9	0.23
Systolic blood pressure (mmHg)	119 ± 11	118 ± 14	0.25
Diastolic blood pressure (mmHg)	70 ± 8	71 ± 9	0.23
PH etiology, n (%)			
Group I			
Congenital heart disease	8 (36.4)		
Idiopathic	4 (18.2)		
Connective tissue disease	2 (9.1)		
HIV	1 (4.5)		
Hereditary	1 (4.5)		
Portopulmonary hypertension	1 (4.5)		
Group II			
Left side heart disease	3 (13.6)		
Group III			
COPD	1 (4.5)		
Group IV			
None	0		
Group V			
Gaucher disease	1 (4.5)		
PH-specific therapy			
Prostaciclins (Iloprost, Treprostinil)	5		
ERAs (Bosentan, Ambrisentan)	6		
PDE-5 Inhibitors (Sildenafil)	11		
NYHA functional class			
I: n (%)	2 (9)	(100)	
II: n (%)	6 (27.3)	(0)	
III: n (%)	11 (50)	(0)	
IV: n (%)	3 (13.7)	(0)	
6MWD (m)	347 (420-310)	554 (564-550)	0.0001

PH: pulmonary arterial hypertension; NYHA: New York Heart Association; 6MWD: 6-minute walking distance; m: meters; COPD: chronic obstructive pulmonary disease; HIV: Human immunodeficiency virus; ERAs: endothelin receptor antagonists; PDE-5: phosphodiesterase-5

Group I: pulmonary arterial hypertension; Group II: PH due to left side heart disease; Group III: PH due to significant lung diseases; Group IV: Chronic Thromboembolic PH; Group V: PH with unclear and/or multifactorial mechanism;

Data are expressed as mean ± SD or median and interquartile range or as number (percentage)

We analyze the RV free wall separately, excluding the ventricular septum, and synchronize the analysis with the time of the pulmonary valve's opening and closure (Fig. 1 and 3).

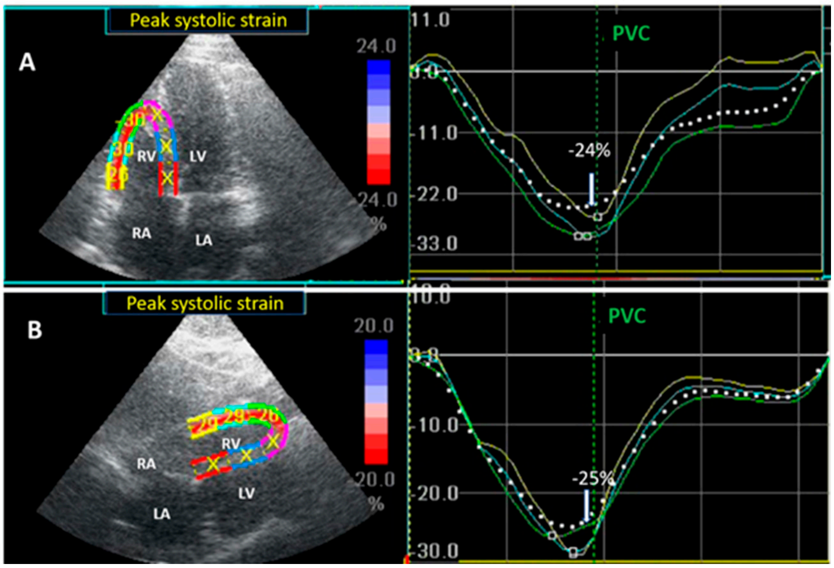
RVLS is depicted with a negative curve and a peak close to the pulmonary closure. These RVLS curves represent the maximum longitudinal myocardial shortening during contraction in the three segments of the lateral from 4-chamber and subcostal views.

Segments for which the automated acquisition of strain failed were corrected manually. Segments for which the acquisition of strain failed again were excluded.

In accordance with Muraru et al[9] the predefined cutoff for RV systolic dysfunction was a RVLS less than −23% (−22.5% for men and −23.3% for women)

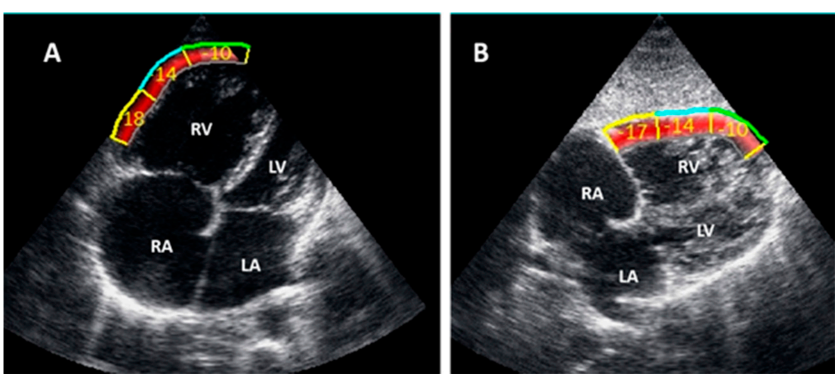
Quantitative data with a normal distribution were expressed as mean ± standard deviation, and data with a non-Gaussian

Fig. 1.– RVLS free wall assessment by speckle tracking echocardiography in a normal subject. A: RVLS in the Apical four-chamber view (-24%). B: RVLS in the subcostal view (-25%). Note the good correlation between both views.



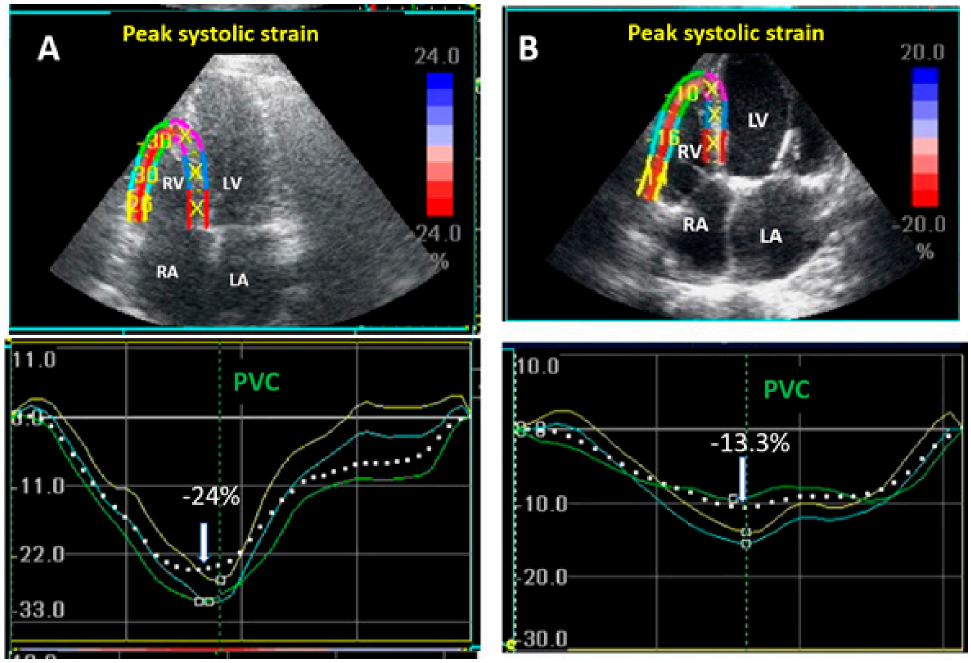
RVLS: right ventricular longitudinal strain; PVC: pulmonic valve closure; RA: right atrium; RV: right ventricle; LA: left atrium; LV: left ventricle

Fig. 2.–.RVLS free wall obtained from a patient with pulmonary hypertension, showing the impairment of myocardial strain: A: RVLS in the Apical four-chamber view: -14%. B: RVLS in the subcostal view: -13.66. Note the good correlation between both views.



RVLS: right ventricular longitudinal strain; RA: right atrium; RV: right ventricle; LV: left ventricle; LA: left atrium

Fig. 3.– Assessment of RVLS free wall. A: Normal subject (-24%). B: Patient with pulmonary hypertension (-13.3%)



RVLS: right ventricular longitudinal strain; PVC: pulmonary valve closure; RA: right atrium; RV: right ventricle; LA: left atrium; LV: left ventricle

distribution were expressed as a median and interquartile interval.

To compare quantitative variables with a normal distribution, Student's t-test for paired data was used; for variables with non-normal distribution, either Wilcoxon or Signed Rank's test were used. All p values < 0.05 were considered to be statistically significant.

Categorical variables were described as number and percent; continuous variables were expressed as mean and standard deviation (SD) or median and interquartile interval (IQI) according to their distribution. To establish the distribution of quantitative variables, we used asymmetry analysis (skewness) and Kurtosis, and the Shapiro-Wilk test.

Comparison of continuous variables between groups was performed with the t-test, or non-parametric tests (Wilcoxon or Signed Rank test) according to their distribution.

The intraclass correlation coefficient (ICC) was used to determine inter- and intraobserver reproducibility for RVLS from data for ten randomly selected patients using an identical cine loop for each view.

In patients with PH, Pearson'correlation was performed to evaluate the degree of agreement between RV LPSS measurements in the apical and subcostal views.

The methods used to evaluate the agreement between the two variables were simple linear regression and the Bland & Altman concordance test.

A p-value < 0.05 was considered significant. All analyses were performed with Epi-info 2000 v. 3.5.1 and Statistics 7.0 software.

Results

In the present study, four patients with poor acoustic window were excluded because of inadequate tracking of two or more segments of the RV. These patients could not be measured RV strain with the RV focused view but could be evaluated with the subcostal view.

A total of 22 patients with a diagnosis of PH had adequate apical and subcostal views, and these patients were included and analyzed.

The clinical and demographic characteristics data of the 22 patients diagnosis with PH and 22 control subjects are described in Table 1. This population's demographic is similar in age and sex. Body mass index, heart rate, systolic blood pressure, and diastolic blood pressure were similar in both groups. Two patients (9%) with PH were in NYHA functional class I, six patients (27.3%) in class II, 11 patients (50%) in class III, and three patients (13.7%) in class IV.

Table 2 summarizes the echocardiographic variables of both groups. There were no differences in LV dimensions between both groups. As expected, LV ejection fraction was significantly lower in patients with PH compared with the control group (p < 0.0002).

Patients with PH exhibited anatomic and functional impairment of the RV echocardiographic parameters. All echocardiographic-derived parameters (RV basal diameter, TAPSE, and RV FAC) were significantly different between patients with PH and controls, consistent with RV dilatation and RV systolic dysfunction.

When patients with PH were compared to normal subjects, they exhibited, RV basal dilation (46.7 ± 7.1 mm vs. 28.6 ± 3.9 mm, p < 0.0001), decreased TAPSE (18.8 ± 6.7 mm vs. 26.4 ± 2.5 mm, p < 0.0001), decreased RV fractional area change (19.0 ± 8.0% vs. 44.3 ± 7.4%, p < 0.0001), increased pulmonary artery systolic pressure (73.8 ± 24.2 mmHg vs. 20.3 ± 2.1 mmHg, p < 0.006), and increased mean right atrial pressure (14.3 ± 4.4 mmHg vs. 5.0 ± 0 mmHg, p < 0.0001).

Global RVLS of the right ventricle's free wall was decreased in patients with PH: -14.1% ± 8.9% vs. -27.9% ± 3.5% in control subjects (p < 0.0001).

Global RVLS measured in the RV free wall from the apical four-chamber view (Table 3) was -15% (-19% to -10%) vs. -14.5% (-18% to -11%) when measured from the subcostal view (p=0.99). Segment by segment analysis did not show significant differences either: basal four-chamber was -16.5% (-21% to -11%) vs. -15.5% (-20% to -11%) from the subcostal view (p = 0.99), mid four-chamber was -16.5% (-21% to -12%) vs. 16.5% (-20% to -12%) (p = 0.59), apical four-chamber view was -12% (-18% to -8%) vs. -13.5% (-19% to -10%) from the subcostal view (p = 0.93).

This study aimed to compare RVLS obtained from apical and subcostal views in patients with PH.

The evaluation of Figure 1 was made on a normal subject, with a good correlation in of between RVLS obtained

TABLE 2.– *Echocardiographic variables of patients with PH and control subjects*

Variable	Patients with PH n = 22	Controls n = 22	p-value
LVDD (mm)	45.8 ± 8.4	48.8 ± 4.1	0.19
LVSD (mm)	27.7 ± 9.4	28.5 ± 4.7	0.75
LV Ejection Fraction	58.0 ± 11.0	67.3 ± 1.9	< 0.0002
RV basal diameter (mm)	46.7 ± 7.1	28.6 ± 3.9	< 0.0001
TAPSE (mm)	18.8 ± 6.7	26.4 ± 2.5	< 0.0001
RV FAC	19.0 ± 8.0	44.3 ± 7.4	< 0.0001
PASP (mmHg)	73.8 ± 24.2	20.3 ± 2.1	< 0.0001
Mean RA Pressure (mmHg)	14.3 ± 4.4	5.0 ± 0	< 0.0001
Apical free wall RVLS	-14.1 ± 8.9	-27.9 % ± 3.5	< 0.0001

PH: pulmonary hypertension; LVDD: left ventricular diastolic diameter; LVSD: left ventricular systolic diameter; TAPSE: tricuspid annular plane systolic excursion; RV: right ventricle; LV: left ventricle; RA: right atrial; FAC: fractional area change; PASP: pulmonary artery systolic pressure; RVLS: right ventricular longitudinal strain

Data are expressed as mean and ± SD

TABLE 3.– *Measurements of the right ventricle longitudinal strain from subcostal view and four-chamber view in patients with pulmonary hypertension*

Variables	Apical 4-chamber view n = 22	Subcostal view n = 22	p-value
Global RV free wall longitudinal strain (%)	-15 (-19 to -10)	-14.5 (-18 to -11)	= 0.99
Basal segment of RV longitudinal strain (%)	-16.5 (-21 to-11)	-15.5 (-20 to -11)	= 0.99
Mid segment of RV longitudinal strain (%)	-16.5 (-21 to -12)	-16.5 (-20 to -12)	= 0.59
Apical segment of RV longitudinal strain (%)	-12 (-18 to -8)	-13.5 (-19 to -10)	= 0.93

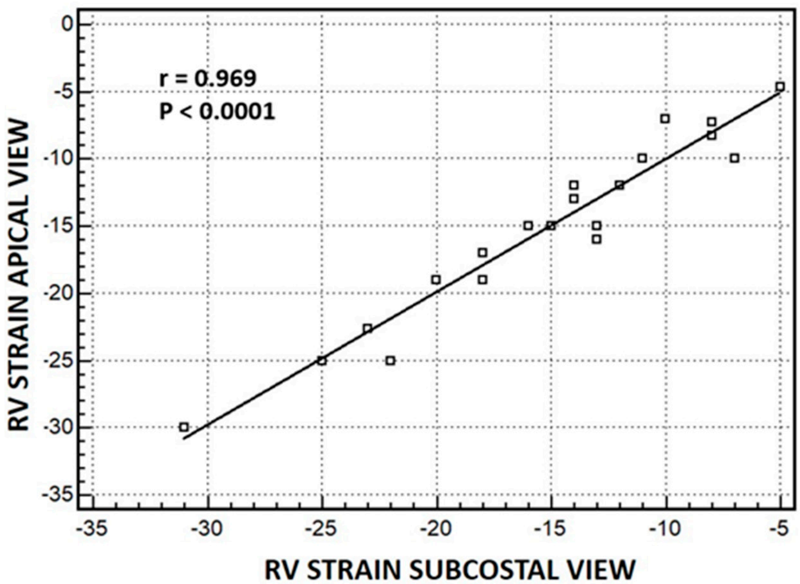
RV: right ventricle

Data are expressed as median and interquartile range from apical and subcostal views. In controls subjets, we only perform RVLS from the 4-chamber view, but we do not use the subcostal view in this population.

In patients with PH, simple linear regression (Fig. 4) and Bland & Altman concordance test (Fig. 5), showed good correlation between apical and subcostal views measurements of RVLS (r = 0.969; p < 0.0001, and 95% Limits of agreement = -3.13 to 3.14 respectively).

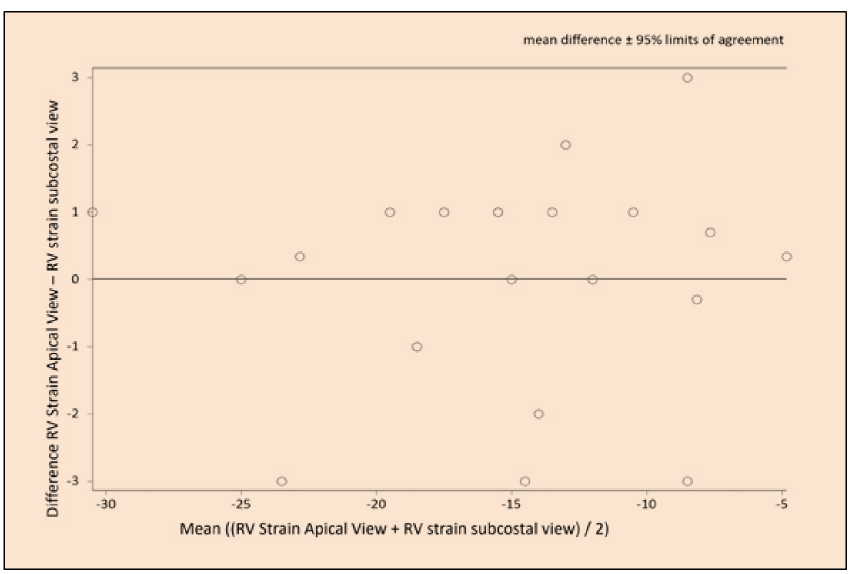
The intraclass correlation coefficient (ICC) for intraobserver reproducibility for RVLS measured in the

Fig. 4.– Linear regression plot between RVLS measured in the apical and subcostal view. *r* = correlation coefficient by Pearson



RVLS: right ventricular longitudinal strain

Fig. 5.– Agreement Bland & Altman.



In patients with PH, the Bland-Altman plot show agreement between RV strain measured in the apical and subcostal view (95% Limits of agreement = -3.13 to 3.14) apical four-chamber view and subcostal view were 0.90 (95% CI, 0.75-0.95), and 0.95 (95% CI, 0.90-0.97), respectively. The corresponding ICC for interobserver reproducibility was 0.94 (95% CI 0.87-0.97) for the apical four-chamber view and 0.88 (95% CI, 0.73-0.95) for the subcostal view.

Discussion

In patients with PH, the present study has shown an excellent correlation between the apical four-chamber view and the subcostal view for the measurement of global and regional RV LPSS ($r = 0.969$, $p < 0.0001$). The crucial finding in this study is that the measurement of RVLS in the subcostal view allows to assess RV function in patients with poor apical echocardiographic window.

The RV systolic dysfunction is a strong predictor of mortality in PH. However, the assessment of RV systolic function, using two-dimensional echocardiography, entails several disadvantages.

While TAPSE is a robust and highly reproducible measure of RV systolic function, it is obtained only in specific views of the RV; additionally, it is angle-dependent and may be overestimated in patients with PH and apical clockwise rotation. TAPSE assumes that the longitudinal motion of the basal segment of the RV free wall represents the function of a complex RV geometry.

Other parameters are less reproducible than TAPSE, such as the RV FAC calculated from a single apical four-chamber view, which is obtained by tracing the RV endocardium both in systole and diastole from the annulus. Care must be taken to trace the free wall, excluding the trabeculations[3]. The RV FAC is dependent on the imaging plane, thus causing considerable inter and intraobserver variability in patients with suboptimal endocardial definition and limited by its assumptions regarding complex RV geometry. Both methods are reliable only when measured in the apical four-chamber view, and when such view is not available, an alternative measurement is required.

Recently, STE has been recommended as a superior method for the assessment of RV function, given its advantage of being angle-independent. Moreover, it can detect RV dysfunction more accurately and sensitively than TAPSE or RV FAC[6, 10].

Other authors have demonstrated that STE strain is simpler, more accurate, and faster than longitudinal strain assessed by cardiac magnetic resonance (CMR). The study concludes that STE is a good alternative to CMR, with a moderate degree of agreement[11].

Inclusion of the interventricular septum is another issue[12, 13]. Several authors showed that RVLS free wall correlated better than global RVLS with RV ejection fraction measured by CMR. In a recent recommendation published by the European Association of Cardiovascular Imaging (EACVI)/American Society of Echocardiography (ASE)/Industry Task Force to standardize deformation imaging, using RVLS free wall is the default method for measurement of RV strain[14]. However, this recommendation stated that including the interventricular septum in the analysis was an option for the users. In our study, we measured RVLS excluding interventricular septum[6]. The RVLS free wall values are more frequently negative than RVLS values. Anatomically, the RV and LV share an interventricular septum. The RV free wall is composed of predominantly the transverse fibers, and the LV is encircled by oblique fibers. The interventricular septum consists primarily of oblique fibers that extend into the RV outflow tract. Consequently, the LV actively contributes to about 80% of the flow and to 2/3 of the pressure generated by the RV during systole. Moreover, measuring strain only in the the RV free wall is difficult for some algorithms because of the strict differentiation required between RV free wall and the interventricular septum.

In previous studies evaluating RV function in patients with PH, RVLS was measured from the apical four-chamber view, and patients with poor apical acoustic windows were excluded. Many of these patients had PH secondary to chronic obstructive pulmonary disease and were therefore underrepresented in those studies. Feasibility of measuring RVLS in the apical four-chamber view has been reported to range between 75% and 93%[7]. Alternatively, measuring RVLS from the subcostal view may overcome this limitation.

An advantage of using STE to calculate RV systolic deformation is the lack of angle dependence, since speckles are traced in two directions along the myocardial wall, and not in the direction of the ultrasound beam[6, 15]. The algorithm used by EchoPAC PC, Version 203, does not take into account if the region of interest is parallel (4-chamber view) or perpendicular (subcostal view) to the transducer, so the workstation always measures the longitudinal shortening of the RV myocardial fibers from RV base to RV apex, regardless of the insonation angle.

Although prior studies have analyzed multiple RV views, they did not report results obtained from the subcostal approach[16]. A major strength of RVLS is its ability to assess the RV function without the limitations of other two-dimensional RV function parameters.

In agreement with Haeck et al.[17], we demonstrated that RV strain obtained from the subcostal and apical four-chamber views were similar, but our population was different from theirs, because they studied patients with suspected pulmonary hypertension, excluded patients with congenital heart disease and did not perform right heart catheterization. In our study, we included patients with confirmed PH, defined as a mean pulmonary arterial pressure ≥ 25 mmHg assessed by right heart catheterization, and the most frequent etiology of PH was congenital heart disease (36.4%).

In our study, the measurement of subcostal RVLS proved to be feasible and accurate, showing good correlation and agreement with the standard apical four-chamber view. In patients with PH, with a dilated RV and poor RV function, RVLS showed a good correlation between both echocardiographic views. Therefore, RVLS obtained from the subcostal view could be an alternative to conventional RV strain obtained from the apical view in patients with pulmonary hypertension and poor echocardiographic apical window.

There are several limitations to this study. First, it was performed at a single center, therefore, we cannot reach definitive conclusions but can only formulate a hypothesis that will require confirmation by future multicenter trials.

Also, the study included a small number of patients with a PH of various etiologies, who were assessed in a non-randomized manner. Hence, a larger study, including more patients with a single etiology of PH, would be required to validate our findings.

We compared RVLS from the apical and subcostal views in patients with PH, but we do not usually perform RVLS from the subcostal view in normal subjects. A control group was included in our study only to assess whether there were differences between the RVLS between both views.

The echocardiographic speckle-tracking technique is dependent on good image quality. However, this study has demonstrated that the technique has excellent interobserver and intraobserver correlations.

In conclusion, subcostal right ventricular free wall strain can be reliably measured, and has shown good agreement with traditional apical RV strain. Hence, it represents a feasible and accurate alternative to apical right ventricular strain in patients with pulmonary hypertension and a poor apical acoustic window.

Conflict of interest: None to declare

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