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Chapter 3

RIGHT VENTRICULAR LONGITUDINAL PEAK SYSTOLIC STRAIN MEASUREMENTS FROM THE SUBCOSTAL VIEW IN PATIENTS WITH SUSPECTED PULMONARY HYPERTENSION: A FEASIBILITY STUDY

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ABSTRACT

Background

The assessment of right ventricular (RV) function with two-dimensional echocardiography can be challenging in patients with pulmonary hypertension, especially in those with chronic pulmonary disease. The aim of the present study was to evaluate the feasibility of measuring RV longitudinal peak systolic strain (LPSS) in the echocardiographic subcostal view in patients with suspected pulmonary hypertension.

Methods

A total of 179 patients evaluated for pulmonary hypertension were included (85 with systemic disorder, 64 with pulmonary disease, and 30 with RV dilatation and dysfunction). Additionally, 30 normal controls were evaluated. The feasibility of RV LPSS speckle-tracking measurements in the apical four-chamber view and in the subcostal view was evaluated. Furthermore, the RV LPSS speckle-tracking measurements performed in these two echocardiographic views were compared.

Results

The feasibility of RV LPSS in the subcostal view was 95.3%, 92.2%, 93.3%, and 93.3% in patients with systemic disorder, with pulmonary disease, with RV dilatation and dysfunction, and controls, respectively. In comparison, the feasibility of RV LPSS in the apical four-chamber view was 92.9%, 82.8%, 90%, and 93.3% in each group, respectively. Bland-Altman analysis showed good agreement between measurements in both echocardiographic views (systemic disorder: mean bias, -0.14; pulmonary disease: mean bias, 0.28; RV dilatation and dysfunction: mean bias, 0.3; and normal controls: mean bias, -0.14).

Conclusions

The subcostal view provides a good alternative for RV strain assessment in patients who are evaluated for pulmonary hypertension. This measurement may be a valuable surrogate of RV function in patients with challenging apical windows.

INTRODUCTION

The performance of the right ventricle is an important prognostic marker in patients with pulmonary hypertension.[1,2] Therefore, reliable, highly feasible, and reproducible methods of right ventricular (RV) function assessment are of interest. Echocardiography is the most widely available imaging test to evaluate patients with pulmonary hypertension.[3-5] However, the assessment of RV function using two-dimensional echocardiography relies on geometric assumptions that may reduce the accuracy of this method.[6] In addition, some subgroups of patients with pulmonary hypertension, such as patients with chronic obstructive pulmonary disease, may not have appropriate apical acoustic windows to visualize the right ventricle.[7,8] In this group of patients, RV systolic function is often evaluated in the subcostal view, which may provide better image quality. However two-dimensional measurements in this view may not be comparable with measurements obtained from the apical view.[9]

Speckle-tracking echocardiography permits the angle-independent evaluation of myocardial strain. This methodology does not rely on geometric assumptions and has been shown to provide reliable information on ventricular performance.[10-14] In patients with pulmonary hypertension, the assessment of longitudinal strain of the right ventricle with speckle-tracking strain imaging may be a valid estimate of RV function.[15-17] RV longitudinal peak systolic strain (LPSS) measurements can be obtained from the apical and subcostal views. However, it remains unclear whether these two approaches provide comparable results. The purpose of the present study was to assess the feasibility of RV LPSS measurement in the subcostal view in a broad spectrum of patients who were referred for the evaluation of pulmonary hypertension.

METHODS

Patient and data collection

Patients who were referred to the outpatient clinic for diagnosis and treatment of suspected pulmonary hypertension between January 2005 and August 2011 were included. All patients were screened extensively according to the international guidelines for pulmonary hypertension.[5] On the basis of the results of the screening protocol, patients were categorized into one of the five different groups according to the Dana Point classification for pulmonary hypertension etiology[5]: group 1 consisted of patients with pulmonary arterial hypertension due to a primary disease process in the pulmonary arteries, group 2 of patients with pulmonary hypertension due to underlying left-heart disease, group 3 of patients with pulmonary hypertension secondary to pulmonary and/or hypoxic disease, group 4 of patients with pulmonary hypertension due to chronic thromboembolic disease, and group 5 of patients with pulmonary hypertension due to multifactorial mechanisms.[5] For the purpose of this study, only patients in group 1 (pulmonary arterial hypertension), group 2 (left-heart disease with established RV dilatation and dysfunction), and group 3 (pulmonary disease) were included. Patients with complex congenital heart disease or who had permanent atrial fibrillation were excluded. Additionally, patients were divided into two groups on the basis of a cut-off value of tricuspid annular plane systolic excursion (TAPSE) of ≤18 mm, as a parameter for RV dysfunction.[18]

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Furthermore, 30 controls without evidence of structural heart disease were selected from an echocardiographic database.[19] Control individuals who were referred for echocardiographic evaluation of known valvular heart disease, murmur, congestive heart failure, or cardiac transplantation were excluded. Therefore, the control group included subjects who were referred for atypical chest pain, palpitations, or syncope without murmurs and who showed normal echocardiographic results.

As part of the departmental protocol, complete transthoracic echocardiography was performed, including assessment of RV function with two-dimensional speckle-tracking strain analysis. RV LPSS was measured in the apical four-chamber and subcostal views. The feasibility of RV LPSS measurements in the apical four-chamber and subcostal views was evaluated in the group of patients with pulmonary disease, in the group of patients with systemic disorder, in the group of patients with RV dilatation and dysfunction, and in normal controls. Finally, the agreement between RV LPSS measured in the apical four-chamber view and in the subcostal view was evaluated in the overall population and for each group of patients.

Echocardiography

Echocardiography was performed using a commercially available system (Vivid 7 and E9, GE-Vingmed Ultrasound AS, Horten, Norway). Images were obtained in the parasternal and apical views with the patient in the left lateral decubitus position and in the subcostal view with the patient in the supine position using a 3.5 MHz transducer. Standard two-dimensional, color, pulsed and continuous wave Doppler data were acquired and saved in regular cine loop format. Using dedicated software, the images were analysed offline (EchoPac 111.0.00, GE–Vingmed Ultrasound AS). First, left ventricular end-systolic volume and end-diastolic volume were measured in the apical two- and four-chamber views and LV ejection fraction was derived according to biplane Simpson's method.[6] Thereafter, RV dimensions were assessed by measuring RV end-diastolic area (RVEDA) and RV end-systolic area (RVESA) in the apical four-chamber view.[6] RV function was evaluated by calculating the fractional area change (FAC) and measuring TAPSE. TAPSE was measured in the apical four-chamber views by aligning the M-mode cursor along the movement of the lateral tricuspid annulus.[6] Valve disease was evaluated according to the current guidelines.[6, 20] Systolic pulmonary arterial pressure was estimated by calculating the systolic pressure gradient between the right ventricle and the right atrium by the maximum velocity of the tricuspid regurgitant jet using the modified Bernoulli equation and adding right atrial pressure. Right atrial pressure was estimated according to the diameter and inspiratory collapse of the vena cava inferior.[4]

Strain analysis by speckle-tracking echocardiography

RV LPSS was measured in the apical four-chamber and subcostal views using speckle-tracking analysis.[21] As previously described, speckle-tracking echocardiography enables the angle-independent evaluation of myocardial strain by tracking frame to frame the movement of the speckles, or natural acoustic markers, within the myocardium on two-dimensional grayscale images.[11] Longitudinal strain is defined as the percentage of shortening of the region of interest relative to the original length and is conventionally presented as a negative value. Only images with frame rates > 40 frames/sec were selected for reliable analysis. The endocardial border of the RV free wall was manually traced at an end-systolic frame, and the software displayed automatically a region of interest including the myocardial wall. This region of interest can be manually adjusted to the thickness of the myocardium to ensure adequate tracking. Peak systolic strain was measured in the basal, midventricular, and apical segments of the RV free wall in both the apical four-chamber and subcostal views and averaged to obtain RV LPSS (Figure 1). Segments of poor quality were noted as not feasible in either the apical four-chamber or the subcostal view or in both views. Patients with nonfeasible analyses were excluded from further analysis.

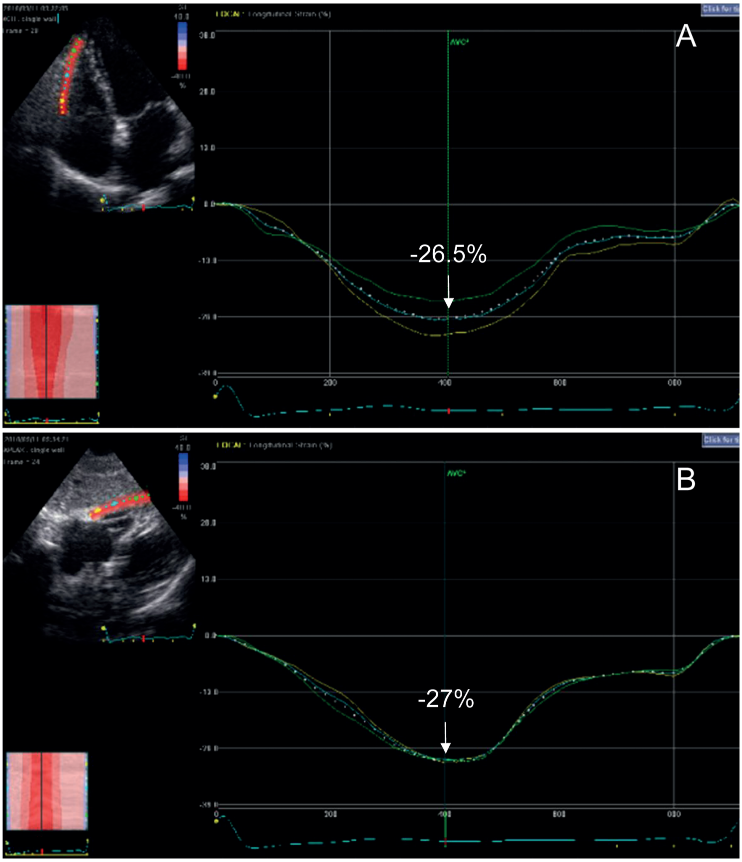

Figure 1. RV longitudinal strain assessment by speckle-tracking echocardiography. Assessment of RV LPSS of the free wall in the apical four-chamber view (A) and in the subcostal view (B). The value of RV LPSS in the apical four-chamber view and in the subcostal views were -26.5% and -27% respectively.

Statistical analysis

All continuous data are presented as mean ± SD. Categorical data are presented as frequencies or percentages. The feasibility of RV LPSS measurement was compared between the two echocardiographic views (apical four-chamber and subcostal) in all four patient groups using χ^2 tests. Differences in baseline clinical and echocardiographic characteristics between the four groups were compared using analysis of one-way variance. Post hoc analyses were performed using Bonferroni's correction for multiple comparisons. Correlation between RV LPSS measurements in the apical four-chamber and subcostal views was calculated using intraclass correlation coefficients. Bland-Altman analysis was used to evaluate the agreement between RV LPSS measurements in the apical four-chamber and subcostal views for all patient groups.[22] Conventional parameters to assess RV performance, including TAPSE and RV dimensions (RVEDA and RVESA), were correlated with RV LPSS, measured in the apical four-chamber and subcostal views, using Pearson's correlation. Multivariate logistic regression analysis was performed to detect the accuracy of RV LPSS to diagnose RV dysfunction, defined as TAPSE ≤ 18 mm.[18] In a series of nested models, parameters of RV function (RVEDA and FAC) were entered individually in a stepwise fashion. Furthermore, the incremental value of RV LPSS over RV FAC to detect RV dysfunction was established by calculating the change in global χ^2 values. Finally, 15 patients were randomly selected to test the intraobserver and interobserver reproducibility of RV LPSS measurements in the apical four-chamber and subcostal views. Two independent observers measured RV LPSS in the apical four-chamber and in the subcostal views in a blinded manner. For intraobserver reproducibility, the measurements were performed by the same observer with a 1-month interval. Bland-Altman analyses were performed.[22] In addition, the coefficient of variation and the intraclass correlation coefficient were calculated.[10] All analyses were performed using SPSS version 17.0 for Windows (SPSS, Inc., Chicago, IL).

RESULTS

Clinical and echocardiographic characteristics

A total of 179 patients were included in this evaluation: 85 patients had underlying systemic disorder, 64 had underlying pulmonary disease associated with pulmonary hypertension, and 30 showed left-sided heart disease and RV dilatation and dysfunction. In addition, 30 normal controls were included. Table 1 summarizes the clinical and echocardiographic characteristics of the four subgroups. As expected, left ventricular function was significantly reduced in the group of patients with RV dilatation ans dysfunction compared with the other patient groups. By definition, RV function assessed by TAPSE and RV FAC was depressed in the group of patients with RV dilatation and dysfunction. The estimated systolic pulmonary artery pressure was >50 mm Hg in 16 (19%), 20 (31%), 18 (60%) patients with systemic disorder, pulmonary disease and patients with RV dilatation and dysfunction, respectively. Control individuals did not show pulmonary hypertension. The systolic pressure gradient between the right ventricle and the right atrium was measurable in 90.9% of the total population. In 9.1% no significant tricuspid regurgitation was measurable. Additionally, in 82.8% of the total population mild to moderate tricuspid regurgitation was present, while 8.1% of the population had severe tricuspid regurgitation.

Feasibility of RV longitudinal strain measurements in the apical four-chamber and subcostal views

In the total study population of 209 individuals, the measurement of RV LPSS was feasible in the apical four-chamber view in 187 individuals (89.5%) and in the subcostal view in 196 individuals (93.8%). The percentages of feasibility of RV LPSS measurement in the apical four-chamber view and

Table 1. Patient characteristics

Clinical characteristics	Systemic disorder (n=85)	Pulmonary disease (n=64)	LV disease with RV dysfunction (n=30)	Normal controls (n=30)	p-value
Mean age (yrs)	53 ± 14	63 ± 11	64 ± 10	53 ± 12	<0.001
Men (%)	23 (27)	35 (55)	22 (73)	10 (33)	<0.001
BSA (m^2)	1.82 ± 0.2	1.86 ± 0.2	1.92 ± 0.2	1.86 ± 0.2	0.2
NYHA functional class	1.93 ± 0.8	2.44 ± 0.6	2.73 ± 0.58	1.00 ± 0.19	<0.001
Echocardiography					
Left ventricle					
LVEDV (ml)	94 ± 25	95 ±24	144 ±87	106 ± 28	<0.001
LVESV (ml)	42 ± 15	43 ± 13	99 ± 75	41 ± 14	<0.001
LVEF (%)	56 ± 8	55 ± 7	38 ± 14	62 ± 7	<0.001
Right ventricle					
RVEDA (cm^2)	19 ± 6	20 ± 6	29 ± 5	16 ± 3	<0.001
RVESA (cm^2)	12 ± 5	13 ± 4	21 ± 5	10 ± 2	<0.001
RVD 1 (cm)	3.8 ± 0.7	3.8 ± 0.7	5.1 ± 0.6	3.0 ± 0.3	<0.001
RVD 2 (cm)	2.6 ± 0.8	2.6 ± 0.6	3.4 ± 0.7	2.1 ± 0.1	<0.001
RVD 3 (cm)	7.1 ± 0.9	7.3 ± 0.9	8.1 ± 1.1	7.2 ± 0.8	<0.001
TAPSE (mm)	19 ± 4	19 ± 4	12 ± 2	23 ± 3	<0.001
RV FAC (%)	38 ± 10	37 ± 8	29 ± 10	37 ± 9	<0.001
Estimated SPAP (mm Hg)	39 ± 19	46 ± 16	59 ± 20	21 ± 5	<0.001
Estimated SPAP > 50 mm Hg (n, %)	16 (19)	20 (31)	18 (60)	-	<0.001

BSA, Body surface area; LV, left ventricular; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; NYHA, New York Heart Association; RVD 1, tricuspid annular diameter; RVD 2, mid-RV diameter; RVD 3, base-to-apex diameter; SPAP, systolic pulmonary arterial pressure.
Data are expressed as mean ± SD or as number (percentage).

subcostal view are presented in Figure 2 for all patient groups. There were no significant differences in the feasibility of RV LPSS measurement between the apical four-chamber view and the subcostal view in the systemic disorder group (P = 0.26), the pulmonary disease group (P = 0.58), the RV dysfunction group (P = 1.00), or the normal control group (P = 1.00) (Figure 2).

Correlation and agreement between RV longitudinal strain measured in the apical four-chamber view and subcostal view

In the patient group with underlying systemic disorder, RV LPSS in the apical four-chamber view and in the subcostal view was -22.56 ± 7.07% and -22.42 ± 6.97% (p=0.304), respectively. In the group of patients with pulmonary disease, RV LPSS was -19.72 ± 6.08% in the apical four-chamber view and -19.99 ± 6.06% in the subcostal view (p=0.087). Among patients with RV dilatation and dysfunction, RV LPSS was -14.74 ± 4.87% in the apical four-chamber view and -15.04 ± 4.96% in the subcostal view (p=0.145). In the normal control group, RV LPSS was -25.86 ± 4.17% and -25.72 ± 4.16% for the apical four-chamber and subcostal views (p=0.431), respectively (Table 2).

Figure 3A shows the correlation between RV LPSS measurements obtained from the apical four-chamber and subcostal views observed in the group of patients with systemic disorder (r=0.987,

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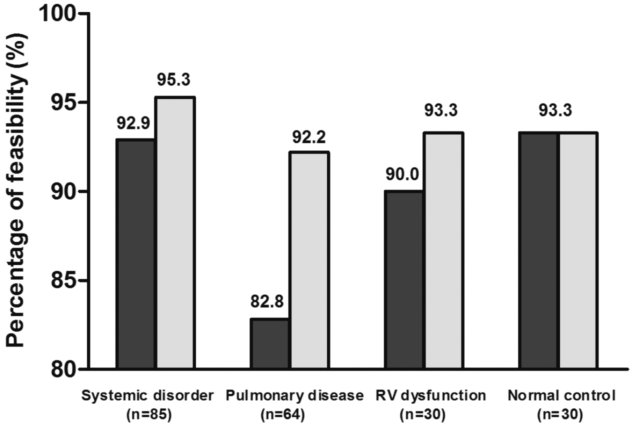

Figure 2. Feasibility of RV LPSS assessment in the apical four-chamber and the subcostal views. Percentage of feasibility of RV LPSS measurements in apical four-chamber view (black bars) and subcostal view (light grey bars) for patients with systemic disorder (n=85), patients with pulmonary disease (n=64), patients with RV dysfunction (n=30) and controls (n=30).

Table 2. Right ventricular strain analysis

	RV LPSS apical four-chamber view (%)	RV LPSS Subcostal view (%)	p-value
Systemic disorder	-22.56 ± 7.07	-22.42 ± 6.97	0.304
Pulmonary disease	-19.72 ± 6.08	-19.99 ± 6.06	0.087
RV dilatation and dysfunction	-14.74 ± 4.87	-15.04 ± 4.96	0.145
Normal control	-25.86 ± 4.17	-25.72 ± 4.16	0.431

p<0.001). In addition, the Bland-Altman analysis showed good agreement between measurements in both echocardiographic views with no significant underestimation or overestimation and tight limits of agreement in this group of patients (mean bias -0.14, 95% limits of agreement: -2.4% to 2.2%; Figure 3B). In the patient group with underlying pulmonary disease, the correlation between RV LPSS measurements in the apical four-chamber view and in the subcostal view was 0.987 (p<0.001), with good measurement agreement between both echocardiographic views (Figure 3C and 3D). There was no significant underestimation or overestimation and the mean bias was 0.28 (95% limits of agreement, –1.93% – 2.46%). The correlation between RV LPSS measurements in the apical four-chamber and subcostal views in the group of patients with RV dilatation and dysfunction was 0.977 (p<0.001) (Figure 3E). Figure 3F shows good agreement between both echocardiographic views with a mean bias of 0.30 (95% limits of agreement; -1.70% – 2.3%). There was no significant underestimation or overestimation observed in this patient group. In the normal control group correlation between RV LPSS measured in the apical four-chamber view and in the subcostal view was also good (r=0.973, p<0.001; Figure 3G). Additionally, Bland-Altman analysis demonstrated a mean bias of -0.14 with good agreement (95% limits of agreement: -1.96% to 1.68%; Figure 3H).

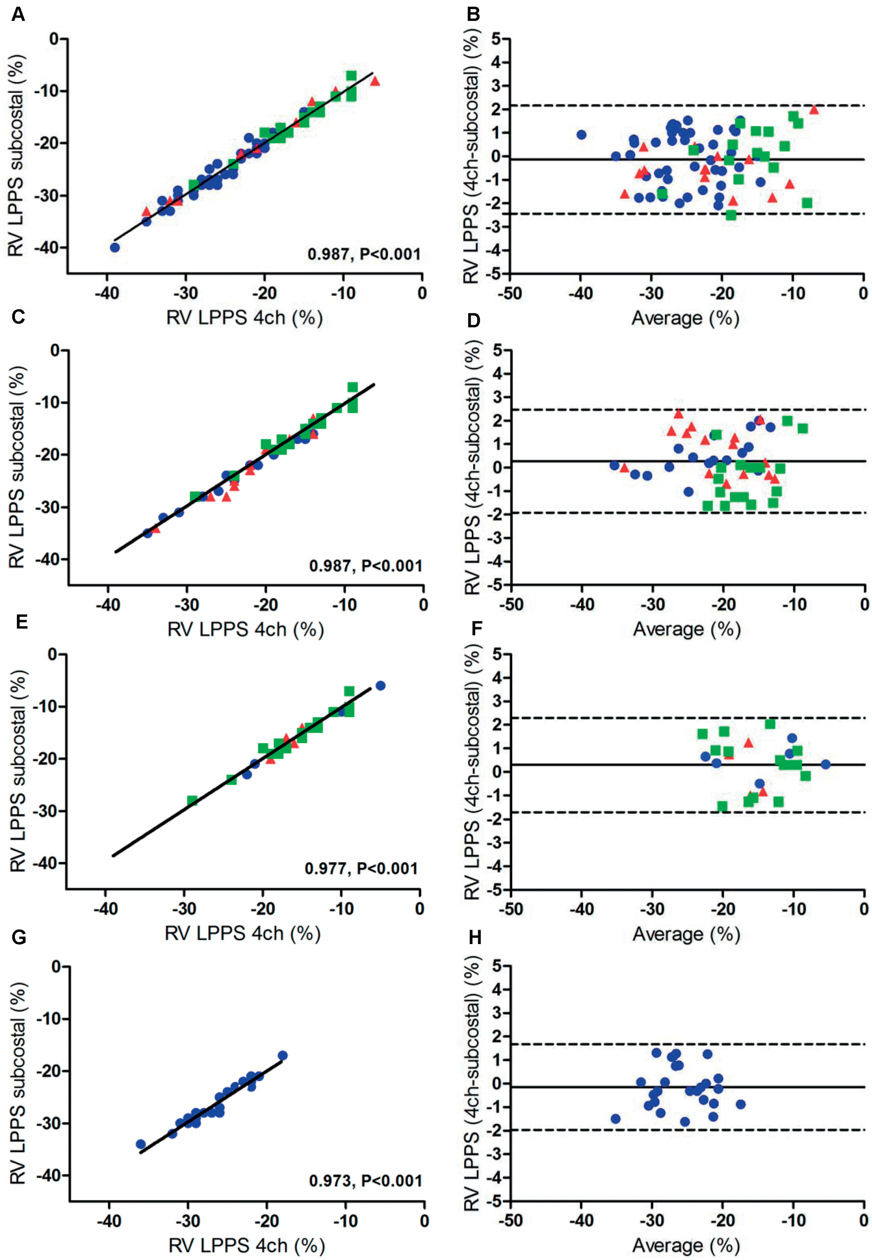

Figure 3. RV LPSS assessment in the apical four-chamber and subcostal views in the four study groups (pulmonary disease, systemic disorder, RV dysfunction and normal controls). The scatterplots show the correlation between RV LPSS measured in the apical four-chamber view and RV LPSS measured in the subcostal view in the group of patients with systemic disorder (A and B), patients with pulmonary disease (C and D), patients with RV dysfunction and dilatation (E and F) and normal controls (G and H). The Bland-Altman plots show the agreement between RV LPSS measured in the apical four-chamber and subcostal views. Patients with estimated pulmonary pressures of ≤ 36 mm Hg are represented by blue dots, those with estimated pulmonary pressures of 37 to 50 mm Hg by red triangles and those with estimated pressures > 50 mm Hg by green squares.

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There were modest but significant correlations between RV LPSS measured in the apical four-chamber view and TAPSE (r=-0.43, p=<0.001) and between RV LPSS measured in the apical four-chamber view and RV dimensions (RVEDA, r=0.56, p<0.001; RVESA, r=0.58, p<0.001). Furthermore, there were modest correlations between RV LPSS measured in the subcostal view and TAPSE (r=-0.47, p<0.001) and between RV LPSS measured in the subcostal view and RVEDA (r=0.61, p<0.001) and RVESA and (r=0.62, p<0.001). Multivariable logistic regression analyses demonstrated that RV LPSS measured in the apical four-chamber view and in the subcostal view provided significant diagnostic information on RV dysfunction (OR 1.06, 95% confidence interval [CI] 1.00 – 1.12, p=0.004; and odds ratio, 1.08, 95% CI 1.02 – 1.15, p=0.009, respectively). In addition, on the basis of significant increment in global χ^2 values, RV LPSS was superior to RV FAC to predict RV dysfunction, defined by TAPSE ≤ 18 mm.[18] (Table 3).

Table 3. Logistic regression multivariable models with RV FAC, RVEDA and RV LPSS (measured in apical four-chamber view or in subcostal view) to predict RV dysfunction (TAPSE ≤ 18 mm)

Model	OR	95% CI	p-value	χ^2	Significance from previous model
RVEDA (model 1)	1.15	1.09 – 1.22	<0.001	34.11	<0.001
Model 1 + RV FAC (model 2)	0.99	0.96 – 1.03	0.7	34.24	0.7
Model 2 + RV LPSS measured in apical four-chamber view	1.06	1.00 – 1.12	0.051	38.61	0.004
Model 2 + RV LPSS measured in subcostal view	1.08	1.02 – 1.15	0.01	41.75	0.009

Intraobserver and interobserver reproducibility

Fifteen patients were randomly identified for assessment of the interobserver and intraobserver reproducibility. According to Bland–Altman analysis, intraobserver reproducibility was good, with mean differences of -0.59 ± 3.17% and 0.44 ± 2.15% and coefficient of variation of 5.4% and 4.9% for RV LPSS measured in the apical four-chamber view and in the subcostal view, respectively. Additionally, the intraclass correlation coefficients for intraobserver variability for RV LPSS measured in the apical four-chamber view and in the subcostal view were 0.89 (95% CI, 0.73 – 0.96) and 0.97 (95% CI, 0.92 – 0.99), respectively. Interobserver variability was also good with mean differences of -0.23 ± 2.21 for RV LPSS measured in the apical four-chamber view and -0.69 ± 3.88 for RV LPSS measured in the subcostal view. The coefficients of variation were 9.6% in the apical four-chamber view and 5.6% in the subcostal view. The inter-observer variability assessed by the intraclass correlation coefficient was 0.95 (95% CI, 0.88 – 0.98) for the apical four-chamber view and 0.89 (95% CI 0.74 – 0.96) for the subcostal view.

DISCUSSION

The present study demonstrated that the measurement of RV LPSS in the subcostal view is feasible and comparable to the measurement of RV LPSS measured in the apical four-chamber view.

Importantly, the measurement of RV LPSS in the subcostal view improved the feasibility of RV systolic function assessment in patients with challenging acoustic windows.

RV functional assessment with speckle-tracking echocardiography

RV function is the strongest prognostic determinant of patients with pulmonary hypertension.[1,23] Timely and accurate detection of RV dysfunction is therefore of clinical importance. Echocardiography is a widely available noninvasive imaging technique to assess patients with pulmonary hypertension. Several two-dimensional echocardiographic variables, such as TAPSE, have been evaluated as prognostic markers to risk-stratify patients with pulmonary hypertension.[2] However, TAPSE is measurable only in specific views of the right ventricle, and the assumption that the lateral tricuspid annulus represents global RV function is a limitation. Other parameters, such as RV FAC and RV volumes, rely on geometric assumptions and are less reproducible than TAPSE.[24] Even so, TAPSE can be reliably measured only in the apical four-chamber view, and when this view is not sufficient (e.g., in patients with pulmonary disease), alternative measurements are needed.

Two-dimensional speckle-tracking imaging is a promising new echocardiographic technique that allows the angle-independent evaluation of RV systolic function. A number of studies have evaluated the feasibility of RV function assessment using two-dimensional speckle-tracking echocardiography in different populations.[15-17,25] Patients with pulmonary hypertension showed significantly more impaired RV LPSS compared with normal controls.[16,17] In this study, we demonstrated a modest but significant correlation between RV LPSS and RV dimensions and TAPSE. Furthermore, this study showed the incremental prognostic accuracy of RV LPSS, measured in the apical four-chamber view or in the subcostal view, in addition to other parameters for the detection of RV dysfunction. In previous studies evaluating longitudinal strain in patients with pulmonary hypertension, RV LPSS was assessed only in the standard apical four-chamber view, and patients with insufficient image quality, precluding reliable analysis of RV LPSS with two-dimensional speckle-tracking imaging, were excluded. The reported feasibility of measuring RV LPSS in the apical four-chamber view ranges from 75% to 93%.[16,25] In addition, patients with pulmonary hypertension secondary to pulmonary disease (i.e., chronic obstructive pulmonary disease), including those with challenging echocardiographic windows, were underrepresented in those studies. Therefore, in a significant number of patients with pulmonary hypertension, the assessment of RV function remains challenging. The present evaluation included a high percentage of patients with pulmonary disease. In this patient group, the feasibility of RV LPSS measurement with two-dimensional speckle-tracking imaging in the apical four-chamber view was 82.8%, compared with the 92.9%, 90%, and 93.3% feasibility in patients with systemic disorders, those with RV dilatation and dysfunction, and normal controls, respectively. The technical characteristics of two-dimensional speckle-tracking imaging overcome the limitations of other techniques, such as tissue Doppler–derived strain, and permit the assessment of RV LPSS from other feasible acoustic windows, such as the subcostal view. Although the feasibility of RV LPSS measurements was comparable between the two echocardiographic views in patients with pulmonary disease, there seemed to be a trend toward higher feasibility in the subcostal view than in the apical four-chamber view (Figure 2). The subcostal view may therefore be more advantageous than the apical four-chamber view in this subpopulation.

RV performance assessment: apical versus subcostal echocardiographic view

Previous studies have evaluated the feasibility and accuracy of echocardiography to assess RV function from different views. Current guidelines advise using all available views in the assessment of RV function to acquire all complementary information that these additional views provide.[26] However, the different echocardiographic methodologies to assess RV function, such as TAPSE, may not be applicable in all echocardiographic views. The measurement of RV FAC in the apical four-chamber view or in the subcostal view may also vary considerably. Kaul et al.[27] compared in 30 individuals the accuracy of RV FAC measured in the echocardiographic apical four-chamber and subcostal views against radionuclide-determined RV ejection fraction. The investigators showed that RV FAC measured in the subcostal view had lower accuracy to estimate RV function compared with RV FAC derived from the apical four-chamber view. These results were confirmed by Danchin et al.,[9] who also found that the apical four-chamber view was more suitable to assess RV dimensions than the subcostal view. The geometric assumptions to derive RV areas and FAC may account for the different accuracies in RV systolic function assessment with echocardiography.[27] In a more recent study, Ostenfeld et al.[28] evaluated the feasibility of three-dimensional echocardiography to assess RV function in the apical four-chamber view and subcostal view. The investigators observed that the feasibility of the apical four-chamber view to visualize and evaluate the right ventricle was superior to the feasibility of the subcostal view. However, even in the apical four-chamber view, only 30% of patients had adequate views to assess RV function with three-dimensional echocardiography. The development of novel imaging techniques that permit the accurate assessment of RV function from unlimited views may overcome these limitations. RV LPSS measurement with two-dimensional speckle-tracking echocardiography may allow measurement of the longitudinal function of the right ventricle in different echocardiographic views and independent of the insonation angle. In the present study, the measurement of RV LPSS in the subcostal view had good feasibility in all patient groups, with good correlation and agreement with the standard apical four-chamber view, even when RV size was enlarged or function was depressed and in patients with challenging acoustic windows. This indicates that the subcostal view can also be used in the assessment of RV function, especially in those patients with poor acoustic windows in the apical four-chamber view. Whether the assessment of RV longitudinal function with speckle-tracking echocardiography needs to include the assessment of longitudinal shortening of the interventricular septum may be open to discussion. The interventricular septum has been proven to contribute to RV performance. However, to date, there is no agreement on how to evaluate RV function by means of two-dimensional speckle-tracking longitudinal strain. Although some research groups include the interventricular septum in the assessment of RV function,[17,29,30] other groups include only the RV free wall or analyze it separately from the interventricular septum.[31,32] The assessment of the interventricular septum may also introduce some biases, because it is also highly dependent on left ventricular function and hemodynamics. Therefore, we focused on the assessment of the RV free wall.

Limitations

To evaluate the correlation between RV LPSS measured in the apical four-chamber view and in the subcostal view, we could perform analyses only in patients with echocardiographic images that allowed reliable speckle-tracking analysis. This could have introduced selection bias in the study. In the present study, regional differences between the two echocardiographic views were not compared.[33] In certain patient populations, such as those with ischemic cardiomyopathy with prior infarction of the right ventricle, the presence of regional wall motion abnormalities of the right ventricle would have an influence on the present results. However, we did not include patients with prior RV myocardial infarction in this study. Also, there are few data on the additional value of assessment of regional dysfunction of the right ventricle in patients with pulmonary hypertension. Therefore, this was beyond the scope of the present study. Additional studies showing the relevance of regional assessment of RV strain and strain rate in patients with pulmonary hypertension are warranted.

Conclusions

The measurement of RV LPSS in the subcostal view is feasible and provides good agreement with RV LPSS measured in the apical four-chamber view. This measurement may be a valuable surrogate of RV systolic function in a subgroup of patients with pulmonary hypertension and poor acoustic apical four-chamber windows.

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