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Systolic right ventricular function assessment by pulsed wave tissue Doppler imaging of the tricuspid annulus

Prospective analysis in 258 individuals

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Summary

Background: Systolic right ventricular (RV) function is an important predictor in the course of various congenital and acquired heart diseases. So far, tricuspid annular motion velocity in systole as obtained by pulsed wave tissue Doppler imaging (TDI) has rarely been investigated for RV function assessment in a sizeable adult patient population.

Methods: 258 individuals were included in the study. Among them, there were 107 individuals without cardiovascular disease, 71 patients with predominant RV dysfunction, 40 patients with pulmonary artery hypertension, and 40 patients with predominant left ventricular dysfunction. The reference methods for RV systolic function assessment were biplane two-dimensional echocardiography and magnetic resonance imaging (MRI; n = 31) for the calculation of RV ejection fraction (EF). Lateral tricuspid valve annular motion velocities in systole (TV_{lat}, cm/s) were recorded using pulsed wave TDI from the apical 4-chamber view (long axis function).

Results: RV EF as determined by biplane echocardiography correlated significantly with respective values as assessed by MRI: $RVEF^{echo} = RV\ EF_{MRI} + 1.6$; $r^2 = 0.569$, $p < 0.0001$. Using the best TV_{lat} threshold of 12 cm/s, distinction between the group with RV dysfunction and the other groups was possible with 86% sensitivity and 83% specificity. There was a direct and significant correlation between TV_{lat} and RV ejection fraction ($p < 0.0001$). Using TV_{lat} thresholds of 12 and 9 cm/s, distinction between normal RV EF (>55%), moderately reduced (30–55%) and severely reduced RV EF (<30%) was possible with 84% sensitivity and 81% specificity, respectively with 83% sensitivity and 67% specificity.

Conclusion: Systolic long axis velocity measurement of the lateral tricuspid annulus is useful and accurate to assess RV systolic function in a broad patient population. Thresholds of 12 and 9 cm/s allow differentiation between normal, moderately reduced and severely reduced RV ejection fraction.

Key words: right ventricular function; Doppler imaging; tricuspid annulus; ejection fraction

Introduction

Systolic right ventricular (RV) function is an important predictor in the course of congenital as well as acquired heart diseases such as tetralogy of Fallot and transposition of the great arteries [1], or in pulmonary artery hypertension and RV infarction [2]. However, one of its widely used parameters, RV ejection fraction (EF), has been difficult to assess both with accuracy and ease. This is due to the complex geometrical shape of the RV rendering volume measurements by echocardiography prone to error. Moreover, the more precise respective determinations by magnetic resonance imaging (MRI) are not readily available and costly [3]. Traditionally, various geometrical models for gauging RV volumes and calculating EF by two-dimensional echocardiography have been employed [4], but also one–dimensional parameters such as the tricuspid annular motion excursion in systole or an index describing global myocardial performance have been used [5]. The advent of tissue Doppler imaging (TDI) has initiated the recording of myocardial contraction and relaxation velocities, and pulsed wave TDI can be employed to analyse the long axis function of both ventricles which is difficult to evaluate by conventional echocardiography [6]. So far, tricuspid annular motion velocity in systole has not been investigated for RV function assessment in a sizeable

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adult patient population. In particular, it has not been compared to both echocardiographic and MR data for characterising systolic RV function.

Therefore, the purpose of the present study was to test the accuracy of tricuspid annular motion velocity for systolic RV function assessment.

Methods

Study subjects

Patients were eligible for inclusion in the study if RV ejection fraction could be obtained by biplane echocardiography and if lateral tricuspid annular motion velocity during systole was measurable. 258 individuals were consecutively included in the study. Among them, 107 had no history of cardiovascular or pulmonary disease and a normal Doppler echocardiographic exam (normal group), 71 patients had predominant systolic RV dysfunction as judged visually by echocardiography (group: RV dysfunction), 40 patients had pulmonary artery hypertension without systolic dysfunction of either ventricle (ie, RV-right atrial pressure gradient by Doppler >30 mm Hg; group: PAHT), and 40 patients had predominant systolic left ventricular (LV) dysfunction (ie, LV EF by echocardiography <50%; group: LV dysfunction). The study protocol was approved by the local ethics committee (Cantonal Ethic Commission of Berne, Switzerland), and all subjects provided written informed consent to participate in the study before inclusion.

Aside from conventional Doppler echocardiography [7], all individuals underwent echocardiographic examination focusing on the RV with mono- and biplane determination of RV EF (primary endpoint), and with TDI of the lateral free wall (TV_{lat}; test variable) and the septal wall (TV_{sept}) tricuspid annular long axis motion in systole. In 31 individuals, cardiac MRI with particular focus on RV volume and EF measurement was performed (independent reference method).

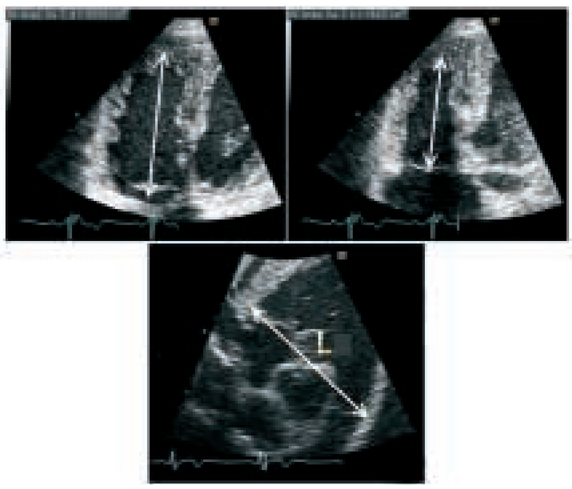


Figure 1

Two-dimensional echocardiographic images for the assessment of mono- and/or biplane right ventricular ejection fraction taken from the apical 4-chamber view (upper panels; diastole: left, systole: right), and from the subcostal view (lower panel). Abbreviations: L = long axis; RV = right ventricular.

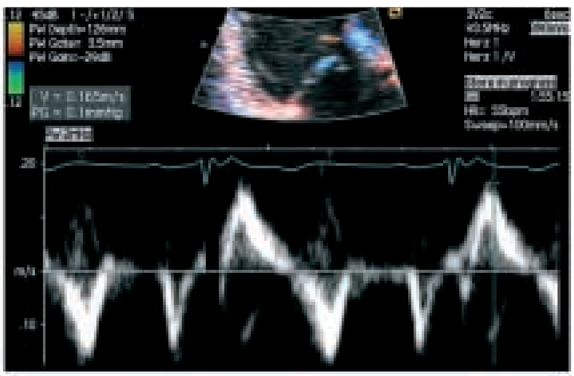


Figure 2

Recording of lateral tricuspid annular motion velocity (TV_{lat}) using pulsed wave tissue Doppler imaging in an individual of the normal group. Systolic lateral tricuspid annular velocity amounts to 16.5 cm/s.

Doppler echocardiography

Transthoracic Doppler echocardiography was performed using an Acuson Sequoia C 256 (Acuson Corporation, a Siemens company, Mountain View, CA, USA) with a 3.5 MHz transducer including second harmonic and tissue Doppler imaging technology. Subjects were examined in supine, left-lateral position. They underwent conventional M-mode and two-dimensional echocardiography from a left parasternal and apical window. M-mode measurements of the LV were obtained during end-systole and end-diastole. The measurements included septal and posterior wall thickness and LV and left atrial cavity diameter according to the leading edge method. LV mass was calculated according to the cube formula using end-diastolic values of septal and posterior wall thickness and LV cavity dimension. LV volume measurements for the calculation of LV EF were carried out in biplane projection from apical four- and two-chamber views. LV volumes were computed using the biapical Simpson rule. The systolic tricuspid-regurgitation pressure gradient between the RV and the right atrium was calculated by the simplified Bernoulli equation. Mitral annular motion velocity during systole was determined using TDI with the pulsed-wave sample volume placed at the septal, lateral, inferior and anterior mitral annulus from the apical four- and two-chamber view, respectively. For data analysis, spatially averaged values were considered.

Specific RV measurements: Two-dimensional echocardiography-derived RV volumes were determined using a mono- and biplane area/length method (figure 1; [4, 8, 9]) as well as the method according to Simpson's rule. Using the monoplane area/length method, RV volumes were obtained from the apical 4–chamber view as follows: $3/8\ \pi\ (\text{RV area})^2/L$, whereby L corresponds to the long axis of the RV (figure 1). The biplane area/length method employed RV area measurements taken from the apical 4-chamber view, and RV length determinations obtained from a subcostal or parasternal view (figure 1): RV volume = $\frac{2}{3}$ RV area × L. RV EF was calculated as the difference between diastolic and systolic RV volume divided by diastolic RV volume. For data analysis, the average among the three methods was used. Pulsed wave TDI of the systolic tricuspid annular motion (cm/s) at the lateral free wall (TV_{lat}) and at the septal wall (TV_{sept}) was obtained from the apical 4-chamber view using a pulsed wave Doppler sampling gate of 2–4 mm and a sweep of 100–150 mm/s (figure 2; [10]). The average of 3 TDI signals from different cardiac cycles was employed for data analysis.

Cardiac magnetic resonance imaging

Study individuals were examined in supine position using a 1.5 T whole body clinical MRI system (Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany), with a phased array cardiac coil placed around their chest. Cardiac synchronization was obtained from 3 electrodes placed on the left anterior hemithorax. The cardiac short axis was determined from three scout images: a mid-ventricular axial view, a cine breath-hold vertical long axis, and a cine breath-hold horizontal long axis. The basal short axis slice was positioned beyond the level of the mitral valve plane, and the ventricles were imaged from the base towards the apex during short end-expiratory breath-holds using contiguous short axis slices in 8 mm increments. Complete coverage of the ventricles with the short axis acquisitions was confirmed on long-axis views. A cine steady state free precession technique (TR/TE/flip 24/1.5/65; slice thickness 8mm; temporal resolution 25 ms) was used.

MR image analysis was done off-line in random order by an experienced observer blinded to clinical data and echocardiographic results. Image analysis was carried out on a dedicated workstation using commercially available software (Argus version VA50C, 2002, Siemens Medical Solutions, Erlangen, Germany). RV volumes were determined according to the modified Simpson's rule (disk summation, no geometrical assumption).

Statistical analysis

For comparison between groups of continuous demographic and Doppler echocardiographic variables a factorial analysis of variance (ANOVA) followed by Scheffé's test was used. Linear regression analysis was carried out for the detection of statistically relevant correlations between tricuspid annular TDI values and RV ejection fraction. Receiver operating characteristic (ROC) analysis was performed with TV_{lat} as the test variable and RV EF as the state variable. Multiple regression analysis was used to determine variables independently associated with RV EF; the variables entered in the model were: age, heart rate, blood pressure, body surface area, LV mass index, LV EF, systolic trans-tricuspid pressure gradient, systolic lateral and septal triscuspid as well as mitral annular motion velocity. Statistical significance was defined at a p-value <0.05.

Results

Study subjects characteristics

Individuals in the normal group were younger than patients from the other groups, and the oldest patient group was the one with PAHT (table 1). Male gender predominance was less pronounced in the normal and PAHT groups than in the other two groups. Basic hemodynamic variables and the presence of atrial fibrillation differed between the groups (table 1). Primary diagnoses of the study individuals are listed on table 1. Among the patient groups, the most frequent diagnoses were coronary artery disease, dilated cardiomyopathy, secondary and primary pulmonary artery hypertension, followed by valvular heart disease and the remaining items. By definition, individuals in the normal group were in accordance with the diagnosis "normal cardiovascular system", and patients in the PAHT group in predominant agreement with that of "primary PAHT" or "secondary PAHT". In the RV dysfunction group, diagnoses were more evenly distributed than in the other groups, whereas the diagnoses "coronary artery disease" and "dilated cardiomyopathy" were predominant in the LV dysfunction group.

Conventional Doppler echocardiographic data

The following parameters shown on table 2 were different between the study groups: LV end-diastolic septal and posterior wall thickness, LV end-diastolic diameter, left atrial and aortic root diameter, LV mass index and ejection fraction, as well as systolic trans-tricuspid pressure gradient (obtained in 47 individuals of the normal group, in 61 patients with RV dysfunction, in all patients with PAHT, and in 30 patients with LV dysfunc-

Table 1

Study subjects characteristics.

	Normal	RV dysfunction	PAHT	LV dysfunction
Number	107	71	40	40
Age (years)	43 ± 16	57 ± 19	65 ± 19	57 ± 15
Men (%)	56 (52)	51 (72)	21 (53)	35 (88)
Heart rate (beats per minute)	70 ± 12	77 ± 16	77 ± 17	75 ± 16
Blood pressure (mm Hg)	126/75	118/74	132/73	126/73
Atrial fibrillation (%)	0	10 (14)	5 (13)	4 (10)
Primary diagnosis				
Normal CV system	107			
Primary PAHT		5	15	
Secondary PAHT		3	18	
Cor pulmonale		8		
RV cardiomyopathy		8		
Pulmonary embolism		4	1	
Coronary artery disease		15		19
Dilated cardiomyopathy		15	1	16
Valvular heart disease		5	3	2
Hypertensive heart disease		2	1	3
Congenital heart disease		6	1	

Abbreviations: LV = left ventricular; PAHT = pulmonary artery hypertension; RV = right ventricular

Table 2

Conventional Doppler echocardiographic data

	Normal	RV dysfunction	PAHT	LV dysfunction
Number	107	71	40	40
Height (cm)	171 ± 10	171 ± 7	168 ± 9	172 ± 7
Weight (kg)	70 ± 15	72 ± 14	65 ± 13	73 ± 12
Body surface area (m^2)	1.81 ± 0.22	1.8 ± 0.19	1.74 ± 0.2	1.85 ± 0.87
LV ED septal thickness (mm)	10 ± 2	12 ± 3	12 ± 3	12 ± 4
LV ED posterior wall thickness (mm)	9 ± 2	10 ± 2	11 ± 4	11 ± 4
LV ED diameter (mm)	48 ± 5	54 ± 11	48 ± 6	58 ± 11
Left atrial diameter (mm)	37 ± 6	48 ± 12	43 ± 10	45 ± 6
LV mass index (g/m^2)	91 ± 22	136 ± 59	115 ± 35	157 ± 53
LV ejection fraction (%)	67 ± 4	47 ± 17	65 ± 8	40 ± 11
Systolic ΔP RV-RA (mm Hg)	20 ± 7 (n = 47)	43 ± 22 (n = 61)	45 ± 12 (n = 40)	29 ± 8 (n = 30)

Abbreviations: ΔP = pressure gradient; LV = left ventricular; PAHT = pulmonary artery hypertension; RA = right atrium; RV = right ventricular/rventricle

Table 3

Systolic right ventricular function data

	Normal	RV dysfunction	PAHT dysfunction	LV	P
Number	107	71	40	40	
RV ejection fraction, echocardiographic (%)	67 ± 4	38 ± 13	66 ± 6	68 ± 6	<0.0001
Magnetic resonance imaging (MRI) exam (n = 31; %)	11 (10)	12 (17)	2 (5)	6 (15)	0.25
RV ejection fraction, MRI (n = 31; %)	63 ± 5	43 ± 13	56 ± 13	58 ± 12	0.001
Lateral tricuspid annular motion velocity (cm/s)	16 ± 3	10 ± 2	16 ± 4	14 ± 4	<0.0001
Septal tricuspid annular motion velocity (cm/s)	10 ± 2	7 ± 2	9 ± 3	8 ± 3	<0.0001
Systolic mitral annular motion velocity (cm/s)	10 ± 2	8 ± 3	9 ± 2	8 ± 2	<0.0001

Abbreviations: LV = left ventricular; PAHT = pulmonary artery hypertension; RV = right ventricular

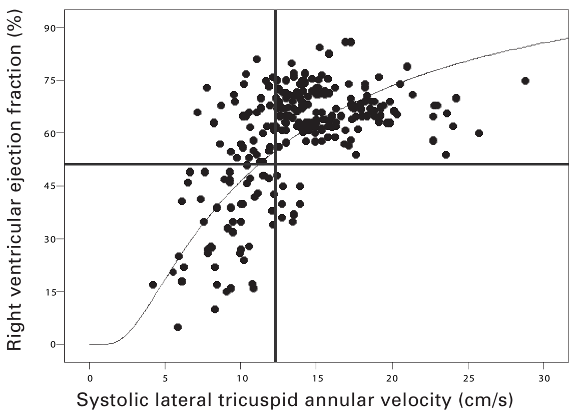


Figure 3

Correlation in all study patients between systolic lateral tricuspid annular velocity (TV_{lat}, horizontal axis) as obtained by pulsed wave tissue Doppler imaging, and right ventricular ejection fraction as determined by two-dimensional echocardiography (vertical axis). The thick lines mark the thresholds of 12 cm/s TV_{lat} and 55% RV ejection fraction.

tion). Mainly, the differences were due the comparison between groups without and with cardiovascular disease.

Systolic right ventricular function data

By definition, RV EF's determined by echocardiography as well as by MRI were significantly lower in the RV dysfunction than in the other groups (table 3). RV EF measured by echocardiography and by MRI correlated linearly and significantly (p <0.0001): $RV\ EF_{echo} = RV\ EF_{MRI} + 1.6$; $r^2 = 0.569$, standard error of estimate = 9.1%. TV_{lat} as well as TV_{sept} was highest in the normal and PAHT group, and lowest in the RV dysfunction group; the respective values were intermediate in the LV dysfunction group (table 3). For comparison, systolic septal mitral annular velocity was low in both RV and LV dysfunction groups. There was a direct and significant correlation between TV_{lat} and RV EF (figure 3). The best curve fit describing the relation was a sigma function, whereby b0 = 4.76, b1 = –9.20, $r^2 = 0.428$, p = 0.0001. In the specific study groups, there was a direct curvilinear relation between TV_{lat} and RV EF only in patients with systolic RV dysfunction and in those with systolic LV dysfunction (figure 4). ROC analysis curves for RV EF thresholds of 55% and of 30% are shown on figure 5. Using TV_{lat} thresholds of 12 and 9 cm/s, distinction between normal RV EF (>55%), moderately reduced (30–55%) and severely reduced RV EF (<30%) was possible with 84% sensitivity and 81% specificity, respectively with 83% sensitivity and 67% specificity (figure 6).

By multiple regression analysis, TV_{lat} (p = 0.0001), and systolic trans-tricuspid pressure gradient (inverse relation; p = 0.0003) were the only variables independently associated with RV EF.

Figure 4

Correlation between systolic lateral tricuspid annular velocity (horizontal axis) as obtained by pulsed wave tissue Doppler imaging, and right ventricular ejection fraction as determined by two-dimensional echocardiography (vertical axis) according to study groups. Upper left panel: normal group (p = not significant); upper right panel: RV dysfunction group (r^2 = 0.225, p = 0.0001); lower left panel: PAHT group (p = not significant); lower right panel: LV dysfunction group (r^2 = 0.190, p = 0.0003). Abbreviations: LV = left ventricular; PAHT = pulmonary artery hypertension; RV = right ventricular.

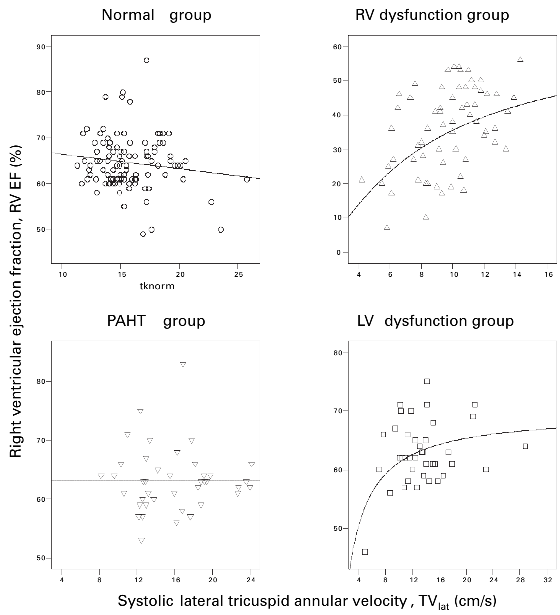


Figure 5

Receiver operating characteristic (ROC) analysis curves for the distinction using lateral tricuspid annular velocity (TV_{lat}) between normal and abnormal RV ejection fraction (RV EF <55%; left panel; area under the ROC curve = 0.896, 95% confidence interval = 0.850–0.942), and between moderately and severely reduced RV ejection fraction (RV EF<30%; right panel; area under the ROC curve = 0.805, 95% confidence interval = 0.700–0.910).

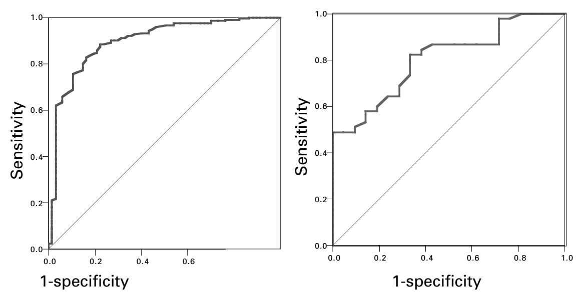
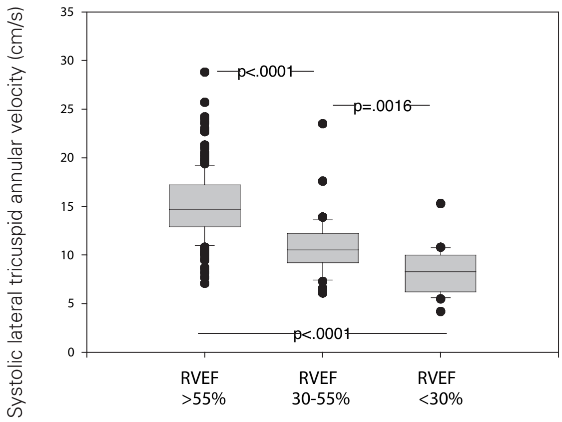


Figure 6

Systolic lateral tricuspid annular velocities (vertical axis) in tertile groups of right ventricular ejection fraction (RVEF; horizontal axis). Bar graphs indicate mean values and 75% confidence intervals, error bars show 90% confidence limits, and beyond those, individual values are depicted.



Discussion

In an extensive adult patient population, this study demonstrates that TDI of the systolic lateral tricuspid annular long axis velocity (TV_{lat}) is accurate to characterise systolic RV function independent of most, pathophysiologically meaningful co-factors. A velocity of 12 and 9 cm/s differentiates among normal and moderately reduced RV ejection fraction, respectively between moderately and severely impaired RV EF.

RV systolic function parameters

For both ventricles, systolic function of the myocardium reflects the interaction between myocardial preload, afterload and contractility [11]. The clinical measure of preload is end-diastolic wall stress, that of afterload is systolic ventricular wall stress, and contractility is described by the maximal rise of ventricular pressure or the velocity of contractile element shortening during isovolumic contraction. Since systolic function is not a synonym for contractility [11], the widespread use of spatial ventricular one- to three-dimensional fractional ejection changes (fractional shortening, fractional area change and ejection fraction) is justified, although they are influenced by myocardial preload, afterload and contractility. The basis of all spatial fractional ejection changes are ventricular length and area measurements providing the parameters for volume calculations by means of various geometric functions approximating the ventricular shape. It is notorious that in case of the RV, such approximations reflect the actual ventricular profile less accurate than for the LV [12]. However, a recent echocardiographic study in a very small population of 11 individuals has documented precise RV volume determination using an ellipsoidal shell model in comparison with multislice MRI-obtained volumes [9]. Considering the mentioned limitations of echocardiographic RV volume measurements, respective summed multislice, MRI-determined values were obtained in our study for the first time in order to have a quality control of the echo-derived reference parameter. RV EF measured by the two methods were practically identical over the entire range of values.

As a non-volumetric ventricular parameter, tricuspid annular peak systolic excursion (TAPSE) has provided an alternative for estimating global systolic RV function, whereby EF has been found to be approximated by 3 times TAPSE in mm as obtained from the apical 4-chamber view [5]. The one-dimensionality of TAPSE characterising RV long axis function is at the same time its advantage and limitation, since sources of measurement error introduced by echocardiographic RV area determination are prevented, but on the other hand, global function is extrapolated from a single variable for regional systolic RV function. Using M-mode echocardiography of the lateral annulus, TAPSE can be obtained with optimal precision thanks to the high image resolution inherent in this method. Furthermore, by utilising also the temporal dimension of M-mode echocardiography, systolic tricuspid annular motion velocity in the long axis can be acquired even without software capabilities for TDI [13].

Determinants of RV ejection fraction

Since the tricuspid valve moves toward the RV apex during ventricular systole as lengthwise shortening of both the interventricular septum and RV free wall, it is intuitively evident that TAPSE or TAPSE per time must be related to RV EF. Theoretically, the monoplane area/length method employed for the two-dimensional echo measurement of RV volume and calculation of EF contains the RV long axis length in diastole and systole, and hence TAPSE in its equation, and thus, must be associated with RV ejection fraction. For that reason, the average RV EF determined from two projections with RV long and short axis directions was used as the reference variable in this study. Aside from such considerations, it is imaginable that factors such as body surface area of the individual, tethering of the septal tricuspid but also mitral annulus (and thus LV function), the degree of LV myocardial mass, the presence of pulmonary artery hypertension or atrial fibrillation and other factors influence TAPSE or TAPSE per time, and thus indirectly RV EF. Therefore, a multivariate regression analysis was performed in our study for the determination of factors independently influencing RV EF. Aside from the Doppler estimate of pulmonary artery pressure, TV_{lat} was the only independent variable determining RV EF. That pulmonary artery pressure was inversely associated with RV EF is entirely expected, and just confirms the notion that EF is afterload-dependent. Since it is only above 40 mm Hg that pulmonary artery pressures impacts on TV_{lat} (data not shown), it affects the relationship between TV_{lat} and RV EF especially in patients with pure PAHT in whom the former cannot be used for RV function assessment (figure 4C).

As outlined above and even directly confirmed in the present study, RV EF and thus RV systolic long axis function is load-dependent, the fact of which is often considered as a basic drawback [12]. However, because the clinically employed “gold standard” for RV function is not myocardial contractility, and since even inotropy is not load-independent [14], the argument of disadvantageous pre- and afterload influence practically only counts in the presence of pure PAHT.

TDI parameters for RV systolic function determination

Yet analysing tricuspid annular long axis motion in systole, a parameter for the characterisation of myocardial *contractility* has even been documented to exist: acceleration during isovolumic contraction by TDI (ie, the first of 2 systolic velocity peaks) [15]. In the experimental pig model, it has been shown to be independent of pre- and afterload alterations, to respond to inotropic drugs, and to reflect the force-frequency relation of the RV. So far, the clinical feasibility of RV free wall acceleration during isovolumic contraction for systolic function assessment has not been studied.

Aside from the measurement of acceleration during isovolumic contraction, there are two other approaches of pulsed TDI measurements for systolic ventricular function characterisation: calculation of strain rate and strain taken from local spatial velocity gradients [16], and direct examination of myocardial velocity data as performed in the present study. The principal advantage of strain rate and strain against velocity measurements is that overall heart motion, cardiac rotation, and contraction in adjacent segments is accounted for with strain imaging. However, there has been, so far, no systematic investigation testing strain and strain rate, as well as systolic RV free wall velocity for the characterisation of systolic RV function. In a control population of 40 normal individuals, Kowalski et al. studied RV segmental systolic velocity, strain rate and strain, whereby the obvious difference between the longitudinal basal lateral free wall velocity of 9.7 ± 2.3 cm/s as compared with the respective value among normal subjects in our study of 16 ± 3 cm/s is noteworthy [17]. Aside from the mentioned advantages of strain rate and strain versus velocity imaging, it appears to be difficult using current technology to obtain radial strain rate and strain values from the normal RV free wall, as the small computational distance of <6 mm in combination with near field artefacts renders post processing complicated [16]. Additionally, the conceptual drawback of one- instead of three-dimensional myocardial data information applies equally to myocardial strain rate and strain as well as to pure velocity imaging.

Analysis of systolic RV long axis function using pure velocity data has the principle advantage of practicability for the following reasons: an apical 4-chamber window is available in the vast majority of patients, tricuspid annular free wall velocity data can be obtained using a simple M-mode measurement even without TDI software [13], there is no data post processing required as with strain rate and strain imaging. Limitations inherent in the method such as dependency of the velocity measurement on the angle of interrogation (ideally 0° relative to the velocity vector), and heart motion are minimised in the particular case of long axis function assessment from the apical 4-chamber view. This is due to the facts, that the direction of baso-apical tricuspid annular systolic motion is close to parallel to the Doppler beam, and that apical cyclic cardiac motion is minimal when compared to the base. Variability in the data obtained in this study illustrates that the stated details specific for the chosen image projection are not absolute, and that deviations from them constitute sources of TV_{lat} data overlap between the different RV ejection fraction groups. With regard to the specific TV_{lat} threshold value of 12 cm/s for the distinction between normal and impaired RV function in our investigation, the study by Oezdemir and coworkers using RV TDI has to be cited [18], because it found an identical cut-off with almost identical sensitivity and specificity of 81 and 82% for the diagnosis of RV myocardial infarction. In comparison, Miller et al. documented a rather low sensitivity of 59% (specificity: 94%) of TV_{lat} for detecting reduced RV ejection fraction, which may be related to the limited power of the study (RV ejection fraction values in 80 patients) [19].

Study limitations

Aside from the limitations alluded to above, it has to be mentioned that MRI data are available only in a small minority.

Conclusions

Systolic long axis velocity measurement of the free wall tricuspid annulus is useful and accurate to assess RV systolic function. Thresholds of 12 and 9 cm/s differentiate well between normal, moderately reduced and severely reduced RV EF.

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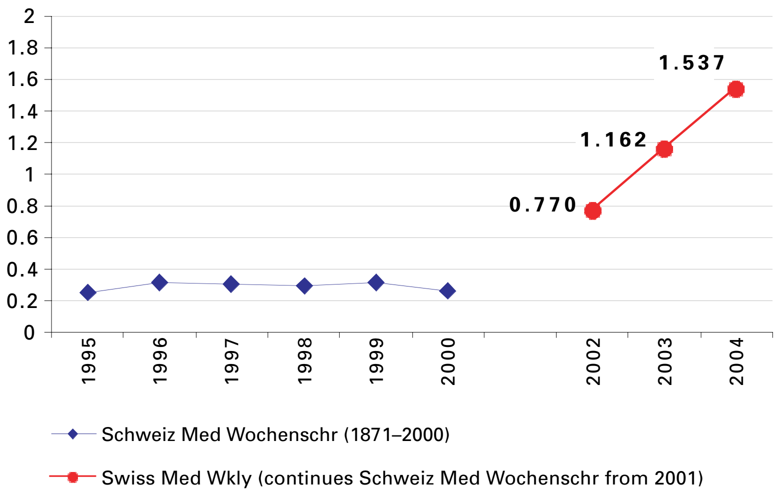

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