Introducing TAPSE-slope and Assessing Inter-observer Variability of Its Timing Measurements

Farnoosh Larti[1], Mansoureh Nik[1], Roya Sattarzadeh[1], Babak geraiely[1], and Maryam Mehrpouya[1]

[1]Tehran University of Medical Sciences

November 9, 2022

Abstract

Purpose: Introducing tricuspid annular systolic excursion (TAPSE)-slope and assessing inter-observer variability of its timing measurements **Methods:** We performed comprehensive Doppler echocardiographic examinations on 84 healthy subjects (mean age: 36.3 years, range: 30-50 years, 51 women, 33 men). In color-coded M-mode tracing of right ventricle's free wall, peak systolic excursion was defined. TAPSE and time from initial QRS to peak systole in color-coded M-mode were measured, and TAPSE-slope was calculated based on this formula: TAPSE slope=TAPSE/TAPSE-t. For the evaluation of inter-observer variability, two other cardiologists measured TAPSE-t in offline mode separately. **Results:** The average (SD) of the "TAPSE-slope" was 7.0(1.0) cm/sec, the average (SD) TAPSE was 2.42(0.3) cm, and an average TAPSE-t of 343(27.6) msec. A significant difference was seen in TAPSE-slope between men and women (P value=0.001). No significant difference was detected in TAPSE-slope in people younger than 40 years old compared with participants older than 40 years. Intra-class correlation coefficient value of the TAPSE-t measurement was 0.886, showing excellent agreement between three different raters. **Conclusion:** TAPSE-slope may have added value compared to TAPSE alone for the assessment of right ventricular systolic function.

Introducing TAPSE-slope and Assessing Inter-observer Variability of its Timing Measurements

Mansoureh Nik tab[1] MD, Roya Sattarzadeh Badkoubeh[1] MD, Babak Geraiely[1] MD, Maryam Mehrpouya[1] MD, Farnoosh Larti[1*] MD

1-Department of Cardiology, Imam Khomeini Hospital Complex, Tehran University of Medical Sciences, Tehran, Iran

*Name and complete address for correspondence:

Farnoosh Larti, Email: Farnooshlarti@gmail.com, Postal code: 1419733141, Cardiology Department, Imam Khomeini Hospital Complex, Keshavarz Boulevard, Tehran, Iran, telephone number: +989188319061, +9861192647.

ORCID ID:0000-0001-7939-9306

Data availability statement: The data of this study is available for further analysis

Funding statement: No funding was received for this study

Patient consent statement: All the patients had informed consent regarding the research process

Conflict of interest disclosure: No conflict of interest was present to be disclosed

Ethics approval statement: The study process was approved by the Ethics Committee of the Tehran University of Medical Sciences

Purpose: Introducing tricuspid annular systolic excursion (TAPSE)-slope and assessing inter-observer variability of its timing measurements

Methods: We performed comprehensive Doppler echocardiographic examinations on 84 healthy subjects (mean age: 36.3 years, range: 30-50 years, 51 women, 33 men). In color-coded M-mode tracing of right ventricle's free wall, peak systolic excursion was defined. TAPSE and time from initial QRS to peak systole in color-coded M-mode were measured, and TAPSE-slope was calculated based on this formula: TAPSE slope=TAPSE/TAPSE-t. For the evaluation of inter-observer variability, two other cardiologists measured TAPSE-t in offline mode separately.

Results: The average (SD) of the "TAPSE-slope" was 7.0(1.0) cm/sec, the average (SD) TAPSE was 2.42(0.3) cm, and an average TAPSE-t of 343(27.6) msec. A significant difference was seen in TAPSE-slope between men and women (P value=0.001). No significant difference was detected in TAPSE-slope in people younger than 40 years old compared with participants older than 40 years. Intra-class correlation coefficient value of the TAPSE-t measurement was 0.886, showing excellent agreement between three different raters.

Conclusion: TAPSE-slope may have added value compared to TAPSE alone for the assessment of right ventricular systolic function.

KEYWORDS: Right ventricle, Right ventricular systolic function, Echocardiography, TAPSE-slope, TAPSE, Inter-observer variability, Color M-Mode

Introducing TAPSE-slope and Assessing Inter-observer Variability of Its Timing Measurements

Introduction

The right ventricle (RV) has a significant role in morbidity and mortality of cardiac diseases, but due to its complex anatomy, evaluation of RV function is not so easy and has always been a challenge in echocardiography. In the latest "Recommendations For Cardiac Chamber Quantification"[1] , measurement of at least one of the following indices: Fractional area change (FAC), the peak systolic velocity of lateral tricuspid annulus wave by tissue Doppler imaging (S'), Tricuspid annular plane systolic excursion (TAPSE), and RV index of myocardial performance (RIMP) has been recommended. Measurement of TAPSE is a practical and straight forward method reflecting longitudinal RV function. Although this parameter is load dependent, multiple studies have shown its utility in various clinical situations such as pulmonary embolism[2,3], pulmonary hypertension[2], chronic obstructive pulmonary disease[3] and post cardiac surgery [4].

TAPSE measures the longitudinal movement of the tricuspid annulus during systole, but we think measuring the velocity of this excursion utilizing "TAPSE-slope" may add to its value. TAPSE less than 17 mm is associated with RV systolic dysfunction; nevertheless, categorizing RV systolic dysfunction as mild, moderate, and severe based on TAPSE measure is not mentioned in the available guidelines and nor is it routinely performed in clinical practice. In this study, we measured normal values of "TAPSE-slope". As this was a new index, we also calculated the inter-observer variability of TAPSE-t measurements.

Study Participants and Methods

We included 84 healthy subjects, aged between 30 and 50, in our study. After an announcement in our hospital, this group was recruited from medical students, medical residents, and clinical and non-clinical hospital personnel. Each person signed a detailed written informed consent before enrollment in the investigation. The study was in accordance with the Declaration of Helsinki. After comprehensive history taking and physical examination, an electrocardiography (ECG) was acquired and detailed echocardiography was performed based on the latest guidelines for performing a comprehensive transthoracic echocardiographic examination in adults[1]. Exclusion criteria were any of the coronary artery disease risk factors including : diabetes, hyperlipidemia, hypertension, cigarette smoking), history of cardiac or pulmonary diseases, any signs or symptoms in favor of cardiac, pulmonary, or thyroid diseases, ECG abnormalities (including bradycardia, tachycardia, axis deviation or bundle branch blocks and any ST-T changes) or any echocardiographic

abnormalities in chamber sizes or function and cardiac valves. Participants with mild valvular regurgitations in echocardiography were not excluded.

Echocardiography was done in the left lateral decubitus position with the "Vivid S5 GE" vendor. All echocardiographic measurements were done in offline mode by an expert echocardiography fellowship. In the RV-focused view, the M-mode cursor was aligned with the lateral tricuspid annulus. The distance between early systole and end-systolic excursion of RV free wall was measured in centimeters (cm). Color-coded M-mode was used to better delineate the peak systole of the RV free wall. Systolic time (TAPSE-t) was also measured in the exact tracing by measuring the time from the initial QRS to the maximum systolic excursion (Figure A, B)

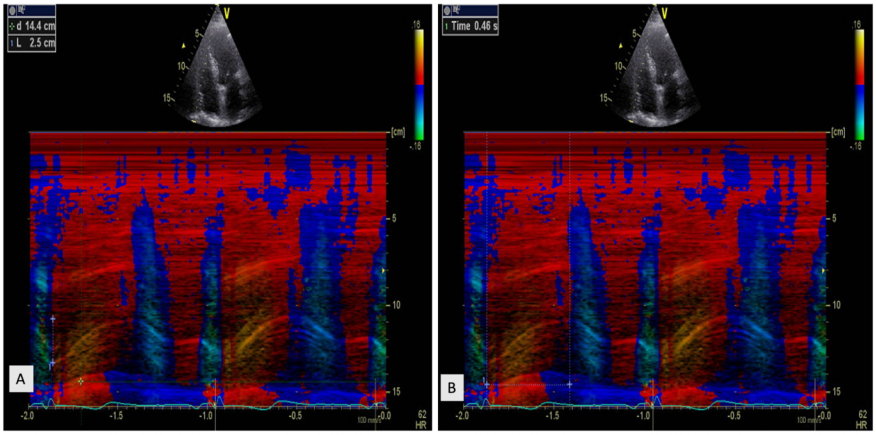

Figure 1. Measurement of TAPSE(A) and TAPSE-t from color-coded M-mode image of the RV free wall in RV-focused view

As we could not directly measure the TAPSE slope with our echocardiography machine, *TAPSE* and *TAPSE-t* were measured from color-coded M-mode tracing of the lateral tricuspid annulus. Then TAPSE-slope (cm/sec) was calculated based on the following formula:

*TAPSE-slope(cm/sec) = TAPSE (cm) *1000/ TAPSE-t (msec)*

As this is a new index, we also evaluated the inter-observer variability of TAPSE-t measurements. To assess this, two other cardiologists also performed offline measurements of TAPSE-t.

Results

IBM SPSS statistics 24 package was used for data analysis. All values were expressed as mean (SD).

A total of 84 healthy subjects (51 women and 33 men) aged 30-50 were included. The mean age of participants was 36.3 (5.4) years old. The body surface area (BSA) was 1.76(0.20) Kg/m^2. The mean heart rate of the study population was 77.5 (11) beats per minute.

Table 1 demonstrates the minimum, maximum, and mean values of echocardiographic variables in study participants. The independent sample T-test detected a significant difference in the mean TAPSE-slope between men and women (P value=0.001).

Table 1. Descriptive statistics of TAPSE, TAPSE-t, TAPSE-slope

	Minimum	maximum	mean	Std. Deviation
TAPSE*(cm)	1.8	3.1	2.42	0.3
TAPSE-t$^+$(msec)	270	400	343	27.68

	Minimum	maximum	mean	Std. Deviation
TAPSE-slope^{++}(cm/sec)	5.0	10	7.0	1.0
TAPSE-slope in men(cm/sec)	5.0	10	7.3	1.0
TAPSE-slope in women(cm/sec)	5.0	9.0	6.9	0.9

* Distance between early systole and end diastole of color-coded M-mode tracing of the lateral tricuspid annulus

+ Time from initial QRS to the maximum systolic excursion in color-coded M-mode tracing of the lateral tricuspid annulus

++ TAPSE-slope(cm/s) = TAPSE (cm) *1000/ TAPSE-t (msec).

For reliability analysis, we calculated the inter-class correlation coefficient (ICC) between 84 TAPSE-t readings by two other cardiologists. In IBM SPSS statistics 24, ICC type C was calculated between these three raters, which was 0.886 (95% CI: 0.82-0.92). Grouped scatter plot of three times TAPSE-t measurement by three raters is shown in figure 2.

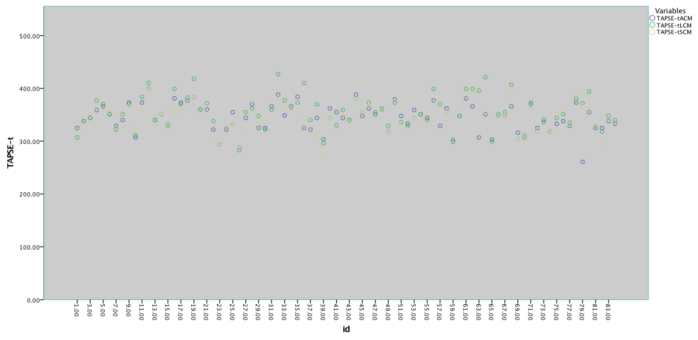

Figure 2. Grouped scatter plot of TAPSE-t measurements by three different raters

Discussion

The "TAPSE-slope" index was proposed and measured in 84 healthy persons. In our study group, TAPSE-slope was 7.0±1.0, TAPSE-slope was 7.3±1.0 in men, and TAPSE-slope was 6.9±0.9 in women. A significant difference (P value=0.001) was observed between the mean TAPSE-slope in men and women.

Slope signifies the ratio of the longitudinal systolic movement to the time change. In other words, it shows an object's acceleration. Neither height nor time alone determines slope, but a combination of these parameters.

TAPSE-t actually shows the systolic interval (SI) [5]that consists of isovolumic contraction time (IVCT) and ejection time (ET). In the left ventricle (LV), systolic interval and diastolic interval (DI) and their ratio not only depend on heart rate (HR) but also depend on diurnal variations[6], Valsalva maneuver[7], and medications[8]. Also, multiple studies have shown that LVET increases from infancy to childhood independent of the heart rate [9,10]. In older people, LVET also becomes prolonged [11]. In systolic heart failure, IVCT is prolonged and LVET shortens, but the SI does not change significantly [12]. In a study on diabetic patients, autonomic neuropathy increased the ratio of SI to DI[13]. Theoretically, SI and change in the ratio of SI to DI may also apply to the right ventricle, and these parameters may also change in RV systolic dysfunction.

Evaluation of RV function is crucial in the management of cardiac diseases. As measuring tricuspid systolic excursion (TAPSE) is an essential part of evaluating RV systolic function. When TAPSE is measured, changes in SI, IVCT, or ET are not considered. We hypothesized that evaluating the *rate* of this systolic excursion

may also be beneficial and should be considered. As mentioned above, two people with similar heart rates may have different systolic intervals. In equal systolic intervals, higher TAPSE-slope reflects better RV function. Still, in different systolic intervals, the rate of acceleration of RV free wall may give us better information regarding RV function.

As this was a new index, "reliability analysis" for TAPSE-t measurements was also done, and Intra class correlation (ICC) between the three cardiologists was 0.886 (95% CI: 0.827-0.925). According to Cicchetti's classification [14] values between 0.75-1.00 show excellent inter-rater agreement. In 2010 [15] Pinedo et al. showed excellent inter-observer ICC for TAPSE measurements of about 0.79. They measured Intra and inter-observer variability of different indices of RV function in 30 patients with isolated mitral valvulopathy who were candidates for heart surgery. TAPSE-slope was not measured in this study.

Conclusion

Using color-coded TAPSE to measure the time of systolic excursion of RV free wall and TAPSE-slope may better assess RV systolic function as the rate of systolic excursion has also been included in this index.

Limitations

As with TAPSE, TAPSE-slope will be load-dependent. Our study measured TAPSE-slope in a normal population, so we cannot provide cut-off values to differentiate normal and abnormal RV function.

Future Perspective

We are about to survey TAPSE-slope in CMR- proven RV systolic dysfunction to propose different values of this new index in different RV ejection fractions.

Acknowledgement

Many thanks to Dr P.Faryadresan for his thoughtful question that strikes measuring TAPSE-t.

References

1. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. 2015. doi:10.1016/j.echo.2014.10.003.

2. Guazzi M, Bandera F, Pelissero G, et al. Tricuspid annular plane systolic excursion and pulmonary arterial systolic pressure relationship in heart failure: an index of right ventricular contractile function and prognosis. *Am J Physiol Heart Circ Physiol* . 2013;305(9):H1373-81. doi:10.1152/ajpheart.00157.2013.

3. Caminiti G, Cardaci V, Conti V, et al. Right ventricular systolic dysfunction is related to exercise intolerance in patients with chronic obstructive pulmonary disease. *J Cardiopulm Rehabil Prev* . 2015;35(1):70-74. doi:10.1097/HCR.0000000000000086.

4. Sun X, Zhang H, Aike B, et al. Tricuspid annular plane systolic excursion (TAPSE) can predict the outcome of isolated tricuspid valve surgery in patients with previous cardiac surgery? *J Thorac Dis* . 2016;8(3):369-374. doi:10.21037/jtd.2016.02.38.

5. Cui W, Roberson DA, Chen Z, Madronero LF, Cuneo BF. Systolic and Diastolic Time Intervals Measured from Doppler Tissue Imaging: Normal Values and Z-score Tables, and Effects of Age, Heart Rate, and Body Surface Area. *J Am Soc Echocardiogr* . 2008;21(4):361-370. doi:10.1016/j.echo.2007.05.034.

6. Weissler A, Kamen A, ... RB-TA journal of, 1965 undefined. The effect of deslanoside on the duration of the phases of ventricular systole in man. *Elsevier* . http://www.sciencedirect.com/science/article/pii/0002914965904492. Accessed December 19, 2017.

7. Flessas A, Kumar S, Journal DS-AH, 1970 undefined. Effects of the Valsalva maneuver on the cardiac systolic intervals: beat-to-beat versus timed analysis. *Elsevier* . http://www.sciencedirect.com/science/article/pii/0002870370902012. Accessed December 19, 2017.

8. Boudoulas H, Rittgers S, Lewis R, Circulation CL-, 1979 undefined. Changes in diastolic time with various pharmacologic agents: implication for myocardial perfusion. *Am Hear Assoc* . http://circ.ahajournals.org/content/60/1/164.short. Accessed December 19, 2017.

9. Golde D, Circulation LB-, 1970 undefined. Systolic phases of the cardiac cycle in children. *Am Hear Assoc* . http://circ.ahajournals.org/content/42/6/1029.short. Accessed December 19, 2017.

10. Harris L, Weissler A, ... AM-TA journal of, 1964 undefined. Duration of the phases of mechanical systole in infants and children.*Elsevier* . http://www.sciencedirect.com/science/article/pii/0002914964900281. Accessed December 19, 2017.

11. Willems J, Roelandt J, Geest H De, Circulation HK-, 1970 undefined. The left ventricular ejection time in elderly subjects. *Am Hear Assoc* . http://circ.ahajournals.org/content/42/1/37.short. Accessed December 19, 2017.

12. Weissler A, Harris W, Circulation CS-, 1968 undefined. Systolic time intervals in heart failure in man. *Am Hear Assoc* . http://circ.ahajournals.org/content/37/2/149.short. Accessed December 19, 2017.

13. Imam MH, Karmakar CK, Jelinek HF, Palaniswami M, Khandoker AH. Analyzing Systolic-Diastolic Interval Interaction Characteristics in Diabetic Cardiac Autonomic Neuropathy Progression. *IEEE J Transl Eng Heal Med* . 2015;3:1900510. doi:10.1109/JTEHM.2015.2462339.

14. Cicchetti D V. Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology.*Psychol Assess* . 1994;6(4):284-290. doi:10.1037/1040-3590.6.4.284.

15. Pinedo M, Villacorta E, Tapia C, et al. Inter-and Intra-Observer Variability in the Echocardiographic Evaluation of Right Ventricular Function. *Rev Esp Cardiol* . 2010;63(7):802-809.