

## Original Article

# Correlation of Tricuspid Annular Plane Systolic Excursion (TAPSE), as a predictor of Right Ventricular Systolic Function with Left Ventricular Systolic Function

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DOI: <https://doi.org/10.3329/bccj.v12i1.72423>

## Abstract:

**Introduction:** Right Ventricular (RV) function is a strong predictor of outcome in many Cardiovascular Diseases, but its significance is often neglected. Right Ventricle (RV) dysfunction may be secondary to Left Ventricle (LV) dysfunction as a consequence of “Ventricular Interdependence. Tricuspid Annular Plane Systolic Excursion (TAPSE) is an Echocardiographic measure that allows us to assess Right Ventricular systolic function and it correlates well with reference techniques like Cardiac Magnetic Resonance Imaging. Echocardiographic recording of the Tricuspid Annular Plane Systolic Excursion (TAPSE) has been recommended for assessing Right Ventricular function in cardiac patients. As RV dysfunction is associated with high in-hospital morbidity and mortality, early reorganization of RV dysfunction is warranted in patients with or without LV dysfunction.

**Objective:** Our objective was to demonstrate the relationship of TAPSE, as a predictor of RV Systolic Function with Left Ventricular Systolic Function.

**Method:** This was a cross-sectional study in patients undergoing comprehensive Transthoracic Echocardiography for any indication. From April 2022 to March 2023 we prospectively enrolled 100 adult (from 30 to age 103years) of both sexes who presented to the Cardiology Clinic of LABAID Cardiac Hospital. We performed a complete Transthoracic Echocardiography study. Assessed LV systolic function by conventional method. We additionally measured TAPSE in 2-dimensional M-mode Echocardiograms from the apical 4-chamber view, positioning the cursor on the lateral Tricuspid Annulus near the free RV wall and aligning it as close as possible to the apex of the heart. The mean values were taken by at least 2 measurements for reducing inter-observer and intra-observer variability's. Values of TAPSE as a predictor of RV Systolic Function were correlated with Left Ventricular Systolic Function. Patients with confirmed congenital & Valvular heart disease were excluded.

**Results:** Mean TAPSE values were (19.15±3.87mm) irrespective of LVEF, with no significant differences between sexes, (18.45±3.801 mm) in male, (19.94±3.853 mm) in female (P=.056). TAPSE value was (22.00±1.581 mm) in person with normal LVEF & (16.77±2.455 mm) in person with reduced LVEF (P<.001). A statistically significant positive correlation of LVEF (r=.813) and significant negative correlation of EPSS (r=-.639) were observed with TAPSE (p<0.001). But no significant correlation of TAPSE was found between age (r=-.185), gender (r=-.192) & RVIDd (r=-.063) (p >0.05). Multivariate analysis confirmed these correlations and the interactions between variables. Graph of estimated population-based TAPSE values adjusted by LV function was provided.

**Conclusion:** We determined the values of TAPSE in patients with or without LV systolic dysfunction and assessed relationship of these values with LVEF. TAPSE is predictive of RV Systolic function & correlated significantly with LV systolic function. The TAPSE measurement is simple & reproducible. This observation could guide decision making in daily clinical practice.

**Keywords:** EPSS- E-Point Septal Separation, LVEF- Left Ventricular Ejection Function, TAPSE- Tricuspid Annular Plane Systolic Excursion.

## Introduction:

Trans-thoracic Echocardiography is the method of choice for the assessment of both Systolic & Diastolic function of Left Ventricle. RV dysfunction is an established predictor of morbidity and mortality in both cardiovascular and respiratory diseases, including heart failure (HF),<sup>1</sup> myocardial infarction,<sup>1</sup> primary pulmonary hypertension,<sup>2</sup> chronic obstructive pulmonary disease.<sup>3</sup> pulmonary embolism.<sup>4</sup> but its significance is often neglected. Little is known about the prognostic value of RV systolic function in the general population.

RV dysfunction may be secondary to LV dysfunction, as a consequence of “Ventricular Interdependence”. There is close anatomic association between the two ventricles, as they are encircled by common muscle fibers, share a common septal wall and are enclosed within a common pericardium. So forces are transmitted from one ventricle to the other ventricle through myocardium and pericardium, independent of neural, humoral, and circulatory effects

In addition, the RV is also directly affected by the downstream left ventricular (LV) filling pressure as a result of circulatory coupling and RV function is impaired in conditions of diastolic dysfunction, such as in HF with preserved ejection

fraction.<sup>5</sup> HF subjects with reduced EF but normal RV function have better prognosis compared to those with impaired RV systolic function.<sup>6</sup> Subjects with HF with preserved EF may also have RV dysfunction and this has been found to be associated with clinical and echocardiographic evidence of more advanced HF and is predictive of poorer outcomes.<sup>6</sup> Hence early recognition of RV dysfunction is warranted; but until today it remains a challenging task.

The complex geometry of the right ventricle (RV) makes systolic function evaluation difficult. The thick trabeculae in the endocardial surface and muscular elongated outflow tract—located in a different plane to that of the inflow tract—prevent us from adopting the theoretical volumetric models that can be applied in the left ventricle.<sup>7, 8, 9, 10, 11</sup> interventions. Right ventricular ejection fraction (RVEF) derived from Cardiac Magnetic Resonance Imaging (MRI) remains the gold standard for functional RV assessment. Hence, in daily clinical practice, we need a means to reliably, reproducibly measure RV systolic function.<sup>12, 13</sup>

Several parameters have been suggested for Echocardiographic evaluation of the RV. TAPSE is an Echocardiographic parameter that estimates RV systolic function adequately and correlates well with reference techniques like Cardiac Magnetic Resonance Imaging.<sup>14</sup> Recommendations for Echocardiographic evaluation of RV and TAPSE values in the adult population can be found in the literature.<sup>15, 16</sup>

### Objective:

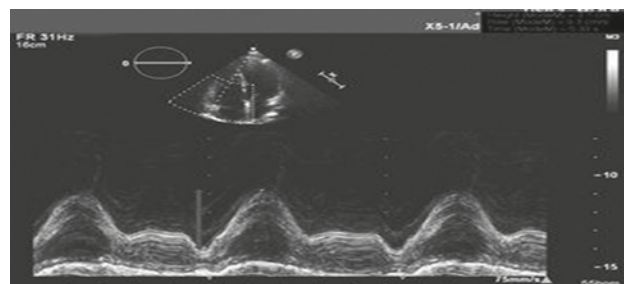
Our objective was to determine the values of TAPSE in adult population with or without LV systolic dysfunction, to evaluate the relationship of TAPSE, as a predictor of RV Systolic Function with Left Ventricular Systolic function & to demonstrate Co-existence of RV & LV systolic dysfunction.

### Material & Methods:

This was a cross-sectional study in patients undergoing comprehensive Transthoracic Echocardiography for any indication. From April 2022 to March 2023, we prospectively enrolled 100 adult (from 30 to age 103 years) of both sexes who had been referred to the Cardiology service of LABAID Cardiac Hospital for routine health check up. We performed a

complete Trans-thoracic Echocardiography study. M-mode and 2D Echocardiograms were recorded on a Vivid™ E 95 with cSound™ ultrasound system (GE Medical System) with M5sc-D (GE) multifrequency transducer. We followed a standard protocol and evaluated Left Ventricular Systolic function. A normal Left Ventricular Ejection Fraction (LVEF) typically considered  $\geq 50\%$ . An LVEF between 40% and 49% was considered Heart Failure with a midrange ejection fraction (HFmrEF), an LVEF < 40% was classified as HFrEF, and an LVEF  $\leq 30\%$  was defined as AHF. In addition to routine Echocardiographic measurements, EPSS was measured by M-mode in the Para-sternal Long Axis view (PLAX) of the Heart. We additionally measured TAPSE in 2-dimensional M-mode Echocardiograms from the apical 4-chamber view, positioning the cursor on the lateral Tricuspid annulus near the free RV wall and aligning it as close as possible to the apex of the Heart (Figure 1). To prevent systematic errors in obtaining or interpreting the Echocardiograms, 2 different Cardiologists performed the Echocardiograms and the mean values were taken by at least 2 measurements for reducing inter-observer and intra-observer variability's. Tricuspid Annular Plane Systolic Excursion (TAPSE) is a recognized predictor of RV systolic function. Different values of TAPSE were correlated with different levels of LVEF to evaluate Co-existence of RV & LV systolic dysfunction. We excluded patients with Congenital & Valvular Heart Disease.

This study was approved by the local institutional ethics committee and conducted in accordance with the Declaration of Helsinki.



**Figure 1:** Standard technique for measuring Tricuspid Annular plane Systolic Excursion using Two-dimensional M-mode Echocardiography.

**Statistical Analysis:** Numerical data obtained from the study were analyzed and significance of difference was estimated by using statistical method. The statistical data were analyzed using IBM SPSS 25.0. The continuous data were expressed as frequency, the mean  $\pm$  standard deviation, and the categorical data were expressed as percentages. Significance of difference between groups was evaluated by unpaired student t test. Graphical representation, Correlation test & Pearson correlation coefficient were used to measure the relationship between TAPSE & other variables. Stepwise simple & multiple linear regression analysis were used to estimate the relation between different variables and TAPSE and also to identify best predictor of TAPSE. Probability values ( $P < 0.05$ ) were considered statistically significant in the analyses.

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**Results:**

Echocardiographic tracings of sufficient quality for analysis were obtained in all patients.

Fig 2 showed sexes and age distribution of study patients. In total, 100 patients were enrolled in the study. We examined 53 male (53%) and 47 female (47%). Age range was 30 to 103 yrs, majority of the cases (>60%) were in between 41-to 70 yrs of age. Mean age was 58.7 ± SD 11.66 yrs, Male and Female ratio was 1.1: 1. Majority of male patient were in between 51-70 yrs of age and majority of female patient were in between 61 to 70 yrs of age.

Table I showed Distribution of Echocardiography parameters. The LVEF ranged from 20% to 68% (mean±SD 47.14±15.77%), the EPSS ranged from 4 to 28 mm (mean ±SD 9.26±5.60mm), the LVIDd ranged from 30 to 72 mm (mean ±SD 50.43±8.97mm), LVIDs ranged from 12mm to 62 mm (mean ± SD 34.77±12.32mm). TAPSE ranged from 12 to 25 mm (mean ±SD =19.15± 3.878mm) , RV Dimension ranged from 17 to 34 mm (mean ±SD =24.28± 3.975mm).

Table II showed mean TAPSE value in the study population in relation to gender. TAPSE value was 19.94±3.853mm (mean ± SD ) in female & 18.45± 3.801 mm (mean ± SD ) in male. There was only a small gender difference but correlation is insignificant (r=.192 P=.056)

Table III showed correlation of TAPSE value to different variables. TAPSE declined with increasing age but the correlation with age was not significant (r=-.185 , P=.065). Correlation with RVIDd was negative but not significant (r =-.063, P=.533). Very significant positive correlations of TAPSE was found with LVEF (r =.813, P<.001) & significant negative correlation of TAPSE was found with EPSS (r = -.639, P<.001).

Table IV showed that an LVEF > 50% is evidence of TAPSE >20 mm, (P<.001). Of note, LVEF <40% correlates with decreased TAPSE value with an estimated TAPSE of <17 mm. (P<.001) suggestive of reduced RV systolic function.

Table V showed Pearson Correlation between different variables & TAPSE. A statistically significant negative correlation of EPSS (r= -.639) and very significant positive

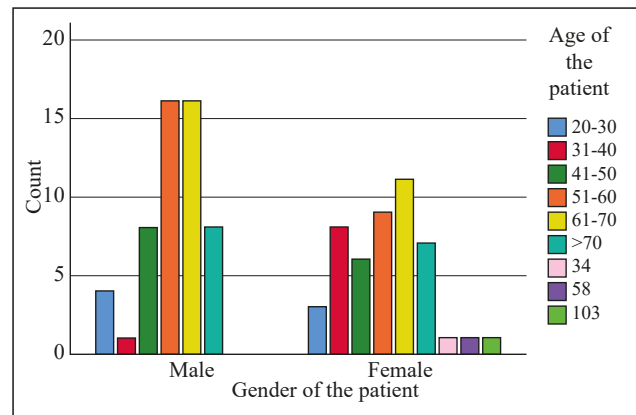
correlation of LVEF (r=.813) were observed with TAPSE (p<0.001). But no significant correlation of TAPSE was found with age (r=-.185), gender (r=.192) & RVIDd (r= -.063) (p >0.05). In the analysis, LVEF presented the best positive correlations with TAPSE values (r=0.813; P<.001)

Table VI showed Simple Linear Regression analysis. In linear regression analysis with all of the variables only LVEF & EPSS were significant predictor of TAPSE. Most important determinant of TAPSE was LVEF (R=.813, p<0.001).

In Table VII by combining different variables in stepwise multiple linear regression analysis an attempt for predicting TAPSE was done. When other variables were included with the variable LVEF into multiple linear regression analysis the resultant correlation coefficient was ((R=.818, P <.001). So it was observed that contribution of other variables is very insignificant & LVEF was the best independent predictor of TAPSE (R=.813, P<.001).

Scatter plot in fig 3 showed the relationships of TAPSE with LVEF indicating their sample distribution. Plots showed TAPSE is directly proportionate to LVEF

Fig 4 showed measurement of LVEF In the image 4a, EPSS in the image 4b & TAPSE in the image 4c. LVEF is ~44%, EPSS is ~12 mm & TAPSE is ~15 mm indicating both LV & RV systolic dysfunction.



**Fig 2:** Age and sex distribution of the study patients

**Table I: Distribution of Echocardiography parameters**

Echocardiographic Parameters	N	Minimum	Maximum	Mean	Std Deviation
Left Ventricle Diastolic Dimension ( mm)	100	30	72	50.43	8.976
Left Ventricle Systolic Dimension ( mm)	100	12	62	34.77	12.321
Left Ventricular Ejection Fraction (%)	100	20	68	47.14	15.777
E Point Septal Separation (mm)	100	4	28	9.26	5.601
Tricuspid Annular Plane Systolic Excursion (mm)	100	12	25	19.15	3.878
Right Ventricle Dimension(mm)	100	17	34	24.28	3.975

Data presented as Mean± SD

**Table II : Correlation of mean TAPSE value with gender**

Gender	N	Mean TAPSE (mm)	SD	Correlation (r value )	Sig (P value)
Male	53	18.45	3.801	.192	.056
Female	47	19.94	3.853		

P value reached from Paired sample t test,\*p- value significant at <0.05.

**Table III: Correlation of mean TAPSE with different variables**

	Mean	SD	N	Correlation ( r value)	Sig ( p value)
TAPSE	19.15mm	3.878	100		
Pair -1 Age	58 yrs	11.663	100	-.185	.065
Pair -2 RVIDd	24.28 mm	3.975	100	-.063	.533
Pair -3 LVEF	47.14 %	15.777	100	.813	.000
Pair -4 EPSS	9.26 mm	5.601	100	-.639	.000

P value reached from Paired sample t test , p- value significant at<0.05.

**Table IV: Prediction of TAPSE in respect of LVEF**

LVEF (%)	TAPSE (mm)	Std Deviation	N	P value
55	22	1.581	5	.000 <sup>s</sup>
35	16	2.455	13	.000 <sup>s</sup>

\*P value reached from unpaired student t test, S = significant, P 0<.01

**Table V: Pearson Correlation between different variables & TAPSE**

Variable vs. TAPSE	Pearson Correlation Co-efficient ( r value) (N=100)	Sig (P value)
EPSS (mm)	-.639**	.000 <sup>s</sup>
LVEF (%)	.813**	.000 <sup>s</sup>
Age (in yrs)	-.185	.065
Gender	.192	.056
RVIDd (mm)	-.063	.533

P value reached from Correlation test. \*\*. Correlation is significant at the 0.01 level (2-tailed). S =significant

**Table VI: Simple Linear Regression analysis.**

Simple Linear Regression analysis	R value	R Square	P value
LVEF (%)	.813	.662	.000 <sup>s</sup>
EPSS (mm)	.639	.408	.000 <sup>s</sup>
Gender	.192	.037	.056
Age (in yrs )	.185	.034	.065
RVIDd (mm)	.063	.004	.533

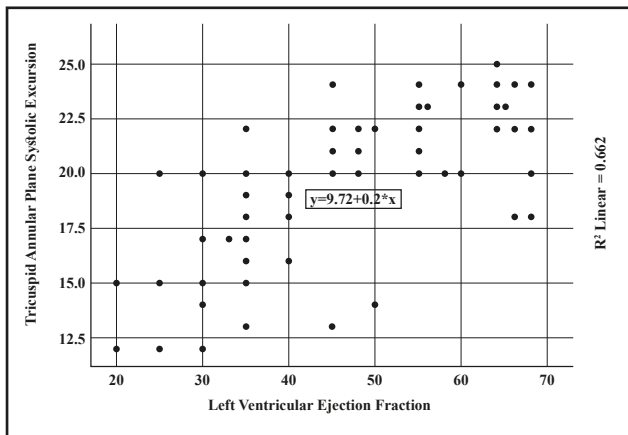
Dependent Variable: TAPSE, Predictor: LVEF, EPSS, Age, Gender & RVIDd. P value derived from Pearson correlation, S= significant, \*\*. Correlation is significant at the 0.01 level (2-tailed).

**Table VII: Stepwise Multiple linear regression analysis:**

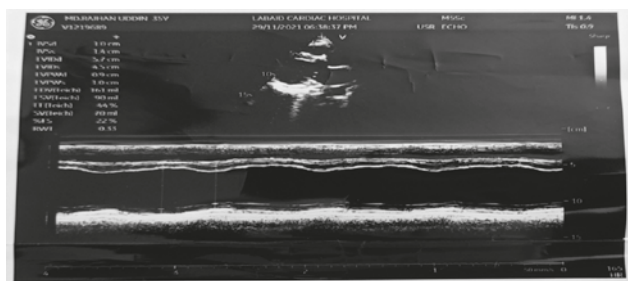
Stepwise Multiple Linear regression analysis	R value	R square	P value
LVEF	.813	.662	.000 <sup>s</sup>
LVEF+EPSS	.814	.662	.000 <sup>s</sup>
LVEF+EPSS+Age	.816	.667	.000 <sup>s</sup>
LVEF+EPSS+Age+ Gender	.817	.667	.000 <sup>s</sup>
LVEF+EPSS+Age+ Gender +RVIDd	.818	.669	.000 <sup>s</sup>

P value derived from Pearson correlation, S= significant, \*\*. Correlation is significant at the 0.01 level (2-tailed). A). Dependent Variable: TAPSE B) Predictors: (Constant), LVEF, EPSS, Age, Gender & RVIDd

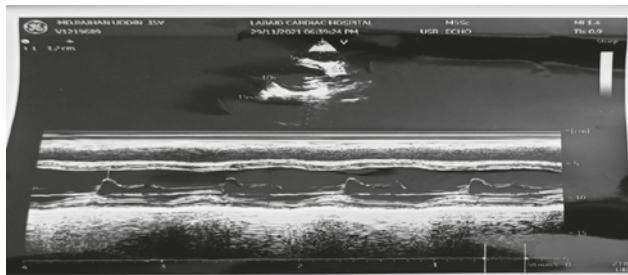




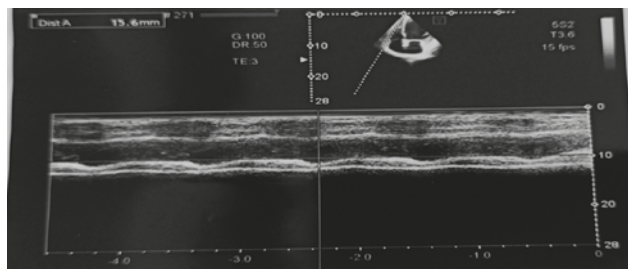
**Fig 3:** Scatter plot (BIVAR) = LVEF with TAPSE



**Fig 4a**



**Fig 4b**



**Fig 4c**

Fig 4 : Measurement of LVEF In the image above ( Fig 4a ) , EPSS in the image middle (Fig 4b) & TAPSE in the image below (Fig 4c). LVEF is ~44%, EPSS is ~12 mm & TAPSE is ~15 mm indicating both LV & RV systolic dysfunction.

**Discussion**

Cardiovascular disease remains a leading cause of death. Right ventricular (RV) function is a strong predictor of outcome in many cardiovascular diseases, but its significance is often neglected. The right ventricle (RV) has often been coined “the forgotten chamber.”<sup>17</sup>

LV systolic function is a significant determinant of RV systolic function through mechanical inter-ventricular dependence.<sup>18</sup> RV function worsens with increasing severity of LV dysfunction and this may result from the concept of ventricular interdependence.<sup>19</sup>

This study showed that RV systolic dysfunction is common in subjects with LV systolic dysfunction. We investigated RV systolic function using Echocardiographic parameter TAPSE, which is most routinely used to assess RV function in Echocardiographic studies. This may be because of TAPSE's simplicity, ease of measurement, and good reproducibility.<sup>20</sup> It does not require state-of-the art image quality or high-frame rate conditions for optimal measurement,<sup>20</sup> as is the case for other measures of RV systolic function, such as 2-dimensional speckle tracking of the RV free wall.<sup>20</sup> In addition, it can often be hard to acquire high-quality images of the entire RV free wall, whereas imaging only the RV base and Tricuspid annular plane is much more feasible. Despite its simplicity, TAPSE has been found to correlate well with RV Ejection Fraction determined by Radionucleotide Angiography<sup>20, 21</sup>

Kjaergaard et al<sup>22</sup> studied RV function in HF subjects using TAPSE and found that although TAPSE is reduced with LV dysfunction in HF , the absolute reduction is small and seemed to be of minor importance in the clinical utilization of TAPSE as a measure of RV systolic function or as a prognostic factor.

Current guidelines define the normal range of RV systolic function determined by TAPSE in the general population as a mean±SD of 24±3.5 mm<sup>23</sup> and abnormal RV systolic function is defined as TAPSE <17 mm.<sup>23</sup> In our study mean value of TAPSE was 22±1.581 mm in person with normal LVEF (P<.001) & 16 ±2.455 mm in person with reduced LVEF (P<.001). In the study, decreasing LV systolic function was significantly associated with decreasing RV systolic function, as determined by TAPSE. It was found that TAPSE has very significant positive correlation with calculated LVEF (r=.813, p<.001). LVEF > 50% was evidence of TAPSE >20 mm, (P<.001). Of note, LVEF <40% correlates with decreased TAPSE value with an estimated TAPSE of <17 mm. (P<.001) suggestive of reduced RV systolic function.

Several studies<sup>24, 25</sup> have reported positive correlations between Echocardiographic variables of RV systolic function with LVEF and LV chamber dimensions. Guglin et al<sup>25</sup> noted that RV systolic dysfunction correlated positively with LVEDD in HF subjects. Karaye et al<sup>26</sup> also reported that LVEF was the best correlate of TAPSE and RV S'; however, this was in a cohort of hypertensive subjects without features of HF. In this study, subjects with reduced EF had the highest prevalence of RV systolic dysfunction (61.9% and 63% by TAPSE and RV MPI, respectively). This observation was also reported in studies by de Groote et al<sup>27</sup> (52%) and by Puwanant et al<sup>28</sup> (63%–76%).

In our study linear regression analysis with all of the variables showed only LVEF & EPSS were significant predictor of TAPSE. Most important determinant of TAPSE was LVEF (R=.813, p<.001). In other study, the relationship between

TAPSE and age was positive. On the other hand, relation between TAPSE and HR was linear and negative. Although not all studies have found HR has a clear influence of on tricuspid annular plane movement.<sup>29</sup> In our study we found TAPSE declined with increasing age but the correlation with age was not significant (  $r = -.185$ ,  $P = .065$ ). And we did not correlate HR with TAPSE. Right ventricular systolic function, as assessed by TAPSE, has important prognostic value in chronic heart failure patients. It is correlated to both systolic LV function and physical performance of the patients. TAPSE was correlated significantly with LVEF ( $r = 0.36$ ;  $P = 0.049$ ) and with distance walked in the 6MWT ( $r = 0.43$ ;  $P = 0.02$ ).<sup>30</sup>

Measuring TAPSE as a parameter to evaluate RV systolic function was reproducible. In our study, we found good concordance for TAPSE<sup>31</sup>, in the line with published recommendations<sup>32</sup> and in parallel with other studies conducted in different circumstances.<sup>33</sup> The same conclusion about reproducibility has been reached by other methods.<sup>34</sup> Moreover, in contrast to other less readily available MRI (Magnetic Resonance Imaging) or more invasive diagnostic Right Heart Catheterization techniques, this method is accessible in any Echocardiography laboratory. Future large scale studies will probably needed to determine the clinical role of TAPSE measurement in adults.

### Study Limitations

A limitation of the present study is the number of patients.

### Conclusion:

We determined the values of TAPSE in adult population with or without LV systolic dysfunction and assessed relationship of these values with LVEF. TAPSE as a well recognized predictor of RV Systolic Function correlated highly significantly with LV systolic function. It was directly proportional to LV systolic function. This study moreover demonstrated that in patients with LV systolic dysfunction there was also RV dysfunction, as predicted by TAPSE. Co-existence of RV & LV systolic dysfunction may explain 'ventricular interdependence'. TAPSE is a simple, sensitive, reproducible & non-geometric Echocardiographic parameter. It may provide novel diagnostic & prognostic information about the risk of CVD to guide therapeutic decision making. It can act as accurate parameter with less variability to detect RV dysfunction at an early stage so as to reduce morbidity and mortality in these patients.

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