ORIGINAL ARTICLE

RIGHT VENTRICULAR FUNCTION ON ROUTINE ECHOCARDIOGRAPHY AS A PREDICTOR OF SHORT-TERM OUTCOMES IN ACUTE HEART FAILURE ADMISSIONS IN A RESOURCE-LIMITED TERTIARY CARE HOSPITAL IN PAKISTAN

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Background: Acute heart failure (AHF) is associated with high short-term morbidity and mortality. While left ventricular function is routinely evaluated, right ventricular dysfunction has emerged as an important determinant of outcomes. Simple echocardiographic parameters such as tricuspid annular plane systolic excursion (TAPSE) and right ventricular fractional area change (FAC) may provide useful prognostic information in patients hospitalized with AHF. The objective of this study was to evaluate right ventricular function using TAPSE and FAC and evaluate their association with short-term clinical outcomes in patients with acute heart failure. **Methods:** This prospective observational study included 120 patients admitted with acute heart failure at a tertiary care Cardiology Unit. Transthoracic echocardiography within 24 hours assessed left ventricular ejection fraction (LVEF), TAPSE, FAC, and pulmonary artery systolic pressure. Right ventricular dysfunction was defined as TAPSE <16 mm or FAC <35%. Patients were monitored during hospitalization for short-term outcomes including ICU admission, inotropic support, mechanical ventilation, worsening renal function, prolonged hospital stay, and in-hospital mortality. **Results:** The mean age of patients was 54.62±8.15 years and 65.8% were male. Reduced TAPSE and FAC were observed in 46.7% patients. ICU admission, need for inotropic support, and mechanical ventilation were significantly more frequent in patients with reduced TAPSE and FAC ($p \leq 0.01$). Prolonged hospital stay was significantly associated with reduced FAC ($p < 0.05$). Echocardiographic differences between survivors and non-survivors were not statistically significant. **Conclusion:** RV dysfunction is associated with adverse short-term outcomes in AHF and may aid in early risk stratification.

Keywords: Acute heart failure, echocardiography, fractional area change, right ventricular function, TAPSE

Pak J Physiol 2029;22(1):46–51, **DOI:** https://doi.org/10.69656/pjp.v22i1.1942

INTRODUCTION

Acute heart failure (AHF) represents a complex clinical syndrome characterized by the rapid onset or worsening of symptoms and signs of cardiac dysfunction, leading to urgent hospital admission and high short-term morbidity and mortality.[1] While left ventricular (LV) dysfunction has traditionally been the primary focus in heart failure assessment, growing evidence highlights the prognostic importance of right ventricular (RV) function.[2] The right ventricle plays a critical role in maintaining effective pulmonary circulation and overall cardiac output, particularly under conditions of increased haemodynamic stress.[3] Simple echocardiographic indices such as tricuspid annular plane systolic excursion (TAPSE) and fractional area change (FAC), obtained during routine transthoracic echocardiography, offer practical means for assessing RV systolic performance.[4]

Heart failure remains a major global health burden, affecting more than 64 million individuals worldwide and accounting for substantial healthcare utilization. Acute decompensated episodes are among the leading causes of hospitalization in adults over 65 years of age and are associated with high early readmission and mortality rates. In low- and middle-income countries, including South Asia, the burden of AHF is increasing due to population aging, rising prevalence of hypertension, ischemic heart disease, and limited access to advanced heart failure therapies.[5] The aetiology of acute heart failure is heterogeneous and includes ischemic heart disease, hypertensive crises, cardiomyopathies, valvular heart disease, and arrhythmias.[6] Common precipitants include myocardial ischemia, uncontrolled blood pressure, infection, non-adherence to medication, and renal dysfunction. Several risk factors contribute to adverse outcomes in AHF, including advanced age, diabetes mellitus, chronic kidney disease, pulmonary hypertension, and pre-existing right ventricular dysfunction. Importantly, conditions that increase pulmonary vascular resistance or RV afterload disproportionately affect right ventricular performance and may worsen short-term prognosis.[7]

From a pathophysiological perspective, RV dysfunction in AHF results from complex interactions between pressure overload, volume overload, myocardial ischemia, and ventricular interdependence.

Acute elevations in left-sided filling pressures can transmit backward into the pulmonary circulation, increasing RV afterload and impairing RV systolic function.[8] The interventricular septum and pericardial constraint further link LV and RV performance, such that LV failure can precipitate or exacerbate RV dysfunction. Impaired RV contractility leads to reduced forward flow, systemic venous congestion, hepatic and renal dysfunction, and diminished response to standard therapies.[9]

Current management of AHF focuses on haemodynamic stabilization, relief of congestion, optimization of preload and afterload, and treatment of underlying precipitants. Although guideline- directed medical therapy primarily targets LV dysfunction, recognition of RV impairment has important therapeutic implications, particularly regarding fluid management, use of diuretics, vasodilators, and inotropic support.[10]

Existing literature increasingly supports the prognostic value of RV dysfunction in both chronic and acute heart failure; however, its routine integration into risk stratification remains inconsistent. Variability in measurement techniques, patient populations, and outcome definitions has led to ongoing debate regarding the optimal parameters and thresholds for RV assessment. In this context, easily accessible echocardiographic markers such as TAPSE and FAC continue to attract attention for their potential role in identifying high-risk patients during acute heart failure admissions and informing early clinical decision-making. The objective of this study was to evaluate right ventricular function using TAPSE and FAC and evaluate their association with short-term clinical outcomes in patients with acute heart failure.

MATERIAL AND METHODS

After obtaining a formal approval from the Institution Research and Ethical Board (IREB), this prospective observational study was conducted in the Department of Cardiology of a tertiary care teaching hospital, Peshawar. A total of 120 consecutive patients admitted with a diagnosis of acute heart failure (AHF) were enrolled during the study period from Apr to Sep 2025. Acute heart failure was defined as new-onset or worsening signs and symptoms of heart failure requiring hospital admission, based on clinical evaluation supported by laboratory and radiological findings.

Patients aged 18 years or older of either gender were included in the study. Patients with congenital heart disease, significant primary pulmonary disease, poor echocardiographic window, prior cardiac surgery affecting right ventricular geometry, or haemodynamic instability precluding echocardiographic assessment were excluded.

After obtaining informed written consent, detailed demographic and clinical data were recorded at the time of admission. These included age, gender, and co-morbid conditions such as hypertension, diabetes mellitus, ischemic heart disease, and chronic kidney disease, along with vital signs and baseline laboratory investigations.

All patients underwent routine transthoracic echocardiography (TTE) within 24 hours of admission using a standardized protocol. Right ventricular systolic function was assessed using tricuspid annular plane systolic excursion (TAPSE) measured in the apical four-chamber view with M-mode, and right ventricular fractional area change (FAC) calculated by tracing the right ventricular endocardial borders in systole and diastole. Reduced right ventricular function was defined according to guideline-recommended cut-off values (TAPSE <16 mm and FAC <35%). Left ventricular ejection fraction (LVEF) and other relevant echocardiographic parameters were also recorded.

Patients were managed according to standard hospital protocols for acute heart failure, and treating physicians were blinded to the study-specific analysis. Short-term clinical outcomes were recorded during hospitalization, including in-hospital mortality, intensive care unit (ICU) admission, requirement of inotropic support, mechanical ventilation, worsening renal function, and length of hospital stay. Patients were followed until hospital discharge or death.

The sample size was calculated using calculator.net, sample size calculator for proportion estimation, assuming an expected adverse outcome frequency of 30%, a 95% confidence level, and an 8% margin of error. The minimum calculated sample size was 126 patients; however, 120 consecutive eligible patients were included in the final analysis.

Data were analysed using SPSS-29. Continuous variables were expressed as Mean±SD, while categorical variables were presented as frequencies and percentages. Associations between categorical variables were analysed using the Chi-square test while independent sample *t*-test was used for comparison of continuous variables between groups, and $p \leq 0.05$ was considered statistically significant.

RESULTS

The study included a total of 120 patients with acute heart failure. The mean age of the participants was 54.62±8.15 years. The majority of patients were younger than 60 years, accounting for 87 (72.5%) cases. Male patients were 79 (65.8%) and 41 (34.2%) were females. Hypertension was present in 98 (81.7%) patients. Diabetes mellitus was observed in 31 (25.8%) patients. Ischemic heart disease was documented in 44 (36.7%) participants. Chronic kidney disease was present in a smaller proportion of patients, affecting 14 (11.7%) patients. (Table-1).

Echocardiographic assessment at the time of admission demonstrated a mean left ventricular ejection fraction of 36.22±4.07%. The mean tricuspid annular plane systolic excursion was 17.71±3.92 mm, with more than half of the patients (64, 53.3%) showing TAPSE values greater than 16 mm, while reduced TAPSE of <16 mm was observed in 56 (46.7%) patients. The mean right ventricular fractional area change was 34.90±6.76%, with 64 (53.3%) patients having FAC values above 35% and 56 (46.7%) demonstrating FAC below 35%. Pulmonary artery systolic pressure was elevated, with a mean value of 49.78±7.64 mmHg across the study population. (Table-2).

In-hospital mortality was observed in 14 (11.7%) patients. Admission to the intensive care unit was required in 38 (31.7%) patients. Inotropic support was needed in 44 (36.7%) cases. Mechanical ventilation was instituted in 26 (21.7%) patients. Worsening renal function during hospitalization occurred in 38 (31.7%) patients. Prolonged hospital stay of more than seven days was noted in 60 (50.0%) patients, with an equal proportion discharged within 7 days. (Table-3).

Among patients who did not require ICU admission, 52 (63.4%) had TAPSE >16 mm, while 30 (36.6%) had TAPSE <16 mm. In contrast, ICU admission was more frequent among patients with reduced TAPSE, with 26 (68.4%) having TAPSE below 16 mm compared to 12 (31.6%) with TAPSE above 16 mm. Regarding inotropic support, the majority (65.8%) of patients who did not require inotropes had TAPSE >16 mm 50, whereas those (30, 68.2%) requiring inotropic support more commonly exhibited reduced TAPSE. Eighteen (69.2%) patients who required mechanical ventilation predominantly had TAPSE <16 mm, compared to those (8, 30.8%) with preserved TAPSE. A higher proportion of patients (22, 57.9%) developing renal deterioration had TAPSE <16 mm, although this association did not reach statistical significance. (Table-4).

Among patients who did not require ICU admission, 52 (63.4%) had FAC values >35%, while 30 (36.6%) had FAC <35%. Conversely, ICU admission was more common in patients with reduced FAC, with 26 (68.4%) exhibiting FAC <35% compared to 12 (31.6%) with FAC >35%. Regarding inotropic support, most patients (50, 65.8%) who did not require inotropes had FAC values >35%, and those requiring inotropic support (30, 68.2%) predominantly had reduced FAC.

Patients requiring ventilatory support more frequently (18, 69.2%) had FAC <35% compared to those (8, 30.8%) with preserved FAC. A higher proportion (22, 57.9%) of patients developing renal deterioration had FAC values <35%, although this association was not statistically significant. Prolonged hospital stay of >7 days was more frequently (34, 56.7%) observed among patients with reduced FAC compared to those (26, 43.3%) with FAC >35%. (Table-5).

Survivors (36.48±4.12%) had a higher mean left ventricular ejection fraction compared to non-survivors (34.21±3.17%), with the difference reaching borderline statistical significance. The mean tricuspid annular plane systolic excursion (17.95±3.93 mm) was also greater among survivors than non-survivors (15.86±3.35 mm), although this difference did not achieve statistical significance. Survivors demonstrated a higher mean right ventricular fractional area change (35.24±6.68%) compared to non-survivors (32.36±7.09%), without a statistically significant difference between the two groups. (Table-6).

Table-1: Demographic and baseline clinical characteristics of study participants (n=120)

Variable	Category	n (%)
Age	<60 years	87 (72.5)
	>60 years	33 (27.5)
Gender	Male	79 (65.8)
	Female	41 (34.2)
Hypertension (HTN)	Yes	98 (81.7)
	No	22 (18.3)
Diabetes Mellitus (DM)	Yes	31 (25.8)
	No	89 (74.2)
Ischemic Heart Disease (IHD)	Yes	44 (36.7)
	No	76 (63.3)
Chronic Kidney Disease (CKD)	Yes	14 (11.7)
	No	106 (88.3)

Table-2: Echocardiographic characteristics of study participants at admission (n=120)

Parameter	Mean±SD/ n (%)
Left ventricular ejection fraction (%)	36.22±4.07
TAPSE (mm)	17.71±3.92
>16 mm	64 (53.3)
<16 mm	56 (46.7)
Right ventricular FAC (%)	34.90±6.76
>35%	64 (53.3)
<35%	56 (46.7)
Pulmonary artery systolic pressure (PASP mmHg)	49.78±7.64

Table-3: Short-term clinical outcomes of study participants during hospital Stay (n=120)

Outcome	Category	n (%)
In-hospital mortality	Yes	14 (11.7)
	No	106 (88.3)
ICU admission	Yes	38 (31.7)
	No	82 (68.3)
Inotropic support	Yes	44 (36.7)
	No	76 (63.3)
Mechanical ventilation	Yes	26 (21.7)
	No	94 (78.3)
Worsening renal function (WRF)	Yes	38 (31.7)
	No	82 (68.3)
Prolonged hospital stays (>7 days)	Yes	60 (50.0)
	No	60 (50.0)

Table-4: Association of tricuspid annular plane systolic excursion (TAPSE) with short-term clinical outcomes (n=120)

Outcome		TAPSE >16 mm n (%)	TAPSE <16 mm n (%)	*p*
ICU admission	No	52 (63.4)	30 (36.6)	0.001
	Yes	12 (31.6)	26 (68.4)	
Inotropic support	No	50 (65.8)	26 (34.2)	<0.001
	Yes	14 (31.8)	30 (68.2)	
Mechanical ventilation	No	56 (59.6)	38 (40.4)	0.009
	Yes	8 (30.8)	18 (69.2)	
Worsening renal function (WRF)	No	48 (58.5)	34 (41.5)	0.093
	Yes	16 (42.1)	22 (57.9)	

Table-5: Association of right ventricular fractional area change with short-term clinical outcomes [n (%)]

Outcome		FAC >35%	FAC <35%	*p*
ICU admission	No	52 (63.4)	30 (36.6)	0.001
	Yes	12 (31.6)	26 (68.4)	
Inotropic support	No	50 (65.8)	26 (34.2)	<0.001
	Yes	14 (31.8)	30 (68.2)	
Mechanical ventilation	No	56 (59.6)	38 (40.4)	0.009
	Yes	8 (30.8)	18 (69.2)	
Worsening renal function (WRF)	No	48 (58.5)	34 (41.5)	0.093
	Yes	16 (42.1)	22 (57.9)	
Prolonged hospital stay (>7 days)	No	38 (63.3)	22 (36.7)	0.028
	Yes	26 (43.3)	34 (56.7)	

Table-6: Comparison of echocardiographic parameters according to survival status (Mean±SD)

Parameter	Survivors (n=106)	Non-survivors (n=14)	*p*
LVEF (%)	36.48±4.12	34.21±3.17	0.050
TAPSE (mm)	17.95±3.93	15.86±3.35	0.060
FAC (%)	35.24±6.68	32.36±7.09	0.135

DISCUSSION

Traditionally, assessment and prognostication in heart failure have focused primarily on left ventricular systolic function. However, growing evidence indicates that right ventricular dysfunction plays a critical role in determining clinical outcomes, particularly during acute decompensation.[11] Right ventricular impairment contributes to systemic congestion, renal dysfunction, and poor response to therapy. Routine transthoracic echocardiography allows rapid bedside assessment of right ventricular function using simple parameters.[12] Tricuspid annular plane systolic excursion and right ventricular fractional area change are practical, reproducible indices that may help identify high-risk patients early during acute heart failure admissions.

The present study demonstrates that right ventricular dysfunction assessed by routine echocardiographic parameters is closely associated with adverse short-term outcomes in patients admitted with acute heart failure, and these findings are largely concordant with previously published international and regional literature. In our cohort, reduced TAPSE and reduced FAC were present in 46.7% of patients, indicating a high burden of right ventricular involvement during acute decompensation. Patients with reduced TAPSE had significantly higher rates of ICU admission, inotropic support, and mechanical ventilation, while a similar pattern was observed for FAC, underscoring the clinical relevance of RV systolic impairment in the acute setting.

These findings align well with the study by Naseem *et al*[13] who demonstrated that RV–pulmonary arterial uncoupling, assessed using the TAPSE/PASP ratio, was a strong independent predictor of in-hospital mortality in acute heart failure. Their reported univariate odds ratio and multivariable odds ratio emphasize the prognostic significance of RV dysfunction beyond conventional LV parameters. Although our study did not evaluate TAPSE/PASP as a composite index, reduced TAPSE alone was associated with a higher frequency of critical care needs, suggesting that even simple RV indices capture clinically meaningful haemodynamic compromise.[13]

The MRAHF cohort reported by Berrill *et al*[14] demonstrated that TAPSE <17 mm and FAC <35% were associated with worse long-term outcomes. While their primary endpoints focused on 2-year mortality and major adverse events, the consistency of risk associated with guideline-defined TAPSE and FAC threshold support our observation that these parameters are clinically relevant even in short-term in-hospital phase. Moreover, their multivariable analysis showing RV FAC as an independent predictor reinforces the role of FAC as a robust marker of RV systolic performance.[14]

The association between RV dysfunction and mortality has also been demonstrated in non-AHF populations. Zornoff *et al*[15] reported that in patients with LV dysfunction following myocardial infarction, each 5% reduction in RV FAC increased the odds of cardiovascular mortality by 16%. Although our study showed only borderline or non-significant differences in mean TAPSE and FAC between survivors and non-survivors, the numerical trends toward lower RV indices among non-survivors are directionally consistent with these findings and may reflect limited statistical power due to the relatively small number of deaths.

Importantly, our results regarding worsening renal function and length of stay are supported by the study of Genedi *et al*[16] who reported a significant correlation between TAPSE<16 mm and adverse in-hospital outcomes, including WRF and prolonged hospitalization. In our cohort, both reduced TAPSE and reduced FAC were associated with higher proportions of WRF (although statistical significance was not consistently achieved) suggesting that venous congestion and impaired forward flow related to RV dysfunction may contribute to renal impairment during acute heart failure.

Our findings are consistent with those reported by Antit *et al*[17] who demonstrated that reduced RV FAC was a strong predictor of adverse outcomes in acute

heart failure, with reported sensitivity of approximately 80% and specificity of 83% for composite poor outcomes. The study by Siddiqui *et al*[18] evaluating right ventricular involvement in inferior myocardial infarction showed RV dysfunction in nearly half of patients using FAC and TAPSE, supporting the high prevalence of RV impairment observed in our cohort. Javed *et al*[19] reported a significant positive correlation between TAPSE and right ventricular function aligning with our observation that reduced TAPSE was associated with increased ICU admission, inotropic support, and mechanical ventilation.

Evidence from regional and Pakistani studies further supports the prognostic importance of RV assessment. Khan *et al*[20] found that lower TAPSE values were associated with worse postoperative outcomes and longer hospital stay in patients undergoing rheumatic valve surgery, highlighting the impact of RV dysfunction on short-term recovery. Data from AFIC/NIHD and other local series have shown that impaired TAPSE and FAC correlate with in-hospital adverse events in conditions characterized by acute RV load, such as pulmonary embolism. Studies in myocardial infarction populations have also shown that RV involvement assessed by FAC and TAPSE is common and clinically meaningful, with significant correlations between TAPSE and RV function and a high prevalence of RV dysfunction ranging from approximately 40 to 50%. Brohi *et al*[21] reported a high prevalence of RV dysfunction in ischemic heart disease patients, with significantly lower TAPSE values with RV dysfunction, reinforcing the link between RV impairment and disease severity.

STUDY LIMITATIONS

This study was conducted at a single centre, which may limit the generalizability of the findings. The sample size was relatively modest, and advanced echocardiographic techniques such as three-dimensional imaging or strain analysis were not evaluated. Long-term outcomes after hospital discharge were also not assessed.

CONCLUSION

Right ventricular dysfunction assessed by TAPSE and FAC on routine echocardiography is associated with adverse short-term clinical outcomes in patients with acute heart failure. These simple echocardiographic parameters provide valuable prognostic information at the time of admission. Incorporating routine ventricular assessment may improve early risk stratification and clinical decision-making in acute heart failure.

ACKNOWLEDGEMENT

We sincerely acknowledge the support and guidance of our mentors, colleagues, and the staff of the participating hospital for their valuable assistance throughout this study.

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Received: 13 Mar 2026 **Reviewed:** 26 Mar 2026 **Accepted:** 31 Mar 2026

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Authors approved the draft and are accountable in ensuring that questions related to accuracy or integrity of the work are duly investigated and resolved.
MM: Concept, study design, manuscript drafting and data analysis **SA:** Data interpretation and supervision of study
SU: Assisted in study design, data collection and data interpretation **MA:** Data collection, data entry and statistical analysis

Conflict of Interest: No conflict of interest is declared, **Funding:** None received from any agency