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Research Article

Echocardiographic Assessment of Right Ventricular Dysfunction in Acute Pulmonary Embolism Patients

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ABSTRACT: Right ventricular dysfunction represents a critical prognostic determinant in acute pulmonary embolism and contributes significantly to early hemodynamic deterioration. Echocardiographic evaluation provides rapid, noninvasive identification of ventricular strain and serves as an essential tool for risk stratification. This cross-sectional analytical study assessed the prevalence and severity of right ventricular dysfunction in acute pulmonary embolism using standardized echocardiographic parameters and analyzed their relationship with clinical severity. A total of 286 confirmed pulmonary embolism patients underwent transthoracic echocardiography within 24 hours of diagnosis. Right ventricular dilatation, tricuspid annular plane systolic excursion, right ventricular fractional area change, and systolic pulmonary artery pressure were recorded. Right ventricular dysfunction was identified in 47.9 percent of patients, with significantly higher prevalence among those presenting with hemodynamic instability. Mean tricuspid annular plane systolic excursion and fractional area change were markedly reduced in patients with moderate to severe dysfunction ($p < 0.001$). Elevated systolic pulmonary artery pressure correlated strongly with increased dysfunction severity. These findings emphasize the clinical significance of echocardiographic assessment in early identification of high-risk pulmonary embolism and demonstrate its value in predicting adverse outcomes.

Keywords: pulmonary embolism, right ventricular dysfunction, echocardiography

INTRODUCTION: Acute pulmonary embolism remains one of the most time-sensitive cardiovascular emergencies, characterized by abrupt obstruction of the pulmonary arterial circulation due to thromboembolic material. The sudden rise in pulmonary vascular resistance creates an immediate burden on the right ventricle, which is structurally adapted for low-pressure circulation. When exposed to acute afterload elevation, the right ventricle undergoes rapid dilation, impaired systolic performance, and reduction in forward stroke volume. These pathophysiologic changes can progress swiftly, leading to systemic hypotension, reduced coronary perfusion, and eventual circulatory collapse. Thus, the status of the right ventricle at presentation is

a critical determinant of prognosis, often outweighing the anatomical clot burden.[1-3]

Echocardiography has emerged as a cornerstone in the evaluation of acute pulmonary embolism. It offers real-time visualization of right ventricular structure, function, and pressure load without exposing patients to ionizing radiation or nephrotoxic contrast agents. Several echocardiographic parameters are frequently used to quantify right ventricular performance, including right ventricular end-diastolic diameter, tricuspid annular plane systolic excursion, right ventricular fractional area change, and the presence of interventricular septal flattening. Abnormalities in these metrics indicate strain and guide clinicians toward triaging the severity of disease. The ability of echocardiography to identify high-risk patients rapidly is crucial, particularly in settings where advanced imaging methods may be delayed or unavailable.[4-7]

Right ventricular dysfunction in acute pulmonary embolism reflects the physiological struggle of the right ventricle to overcome the acute increase in afterload. As the ventricle dilates, wall stress increases, oxygen demand rises, and perfusion pressure decreases. This creates a cycle of progressive dysfunction characterized by impaired contractility, tricuspid regurgitation, and reduced cardiac output. Persistent dysfunction may contribute to multi-organ hypoperfusion and poor clinical outcomes. Timely recognition of these changes is essential to determine whether patients may benefit from thrombolytic therapy, catheter-directed thrombus removal, or escalated supportive care.[8-12]

Clinical severity stratification in pulmonary embolism now increasingly relies on right ventricular assessment. A large proportion of patients with intermediate-risk disease exhibit significant right ventricular strain despite stable blood pressure. In these individuals, early detection of dysfunction helps predict risk of deterioration and guides decisions regarding monitoring intensity. Conversely, normal right ventricular function is associated with excellent outcomes and may support decisions favoring early discharge or outpatient management. Given the variability in clinical presentation, reliance on right ventricular evaluation provides a more precise representation of the physiological burden than symptom-based assessments alone.

Growing healthcare demands have underscored the importance of accurate, rapid, and reproducible diagnostic tools. In many regions, access to advanced imaging modalities remains limited, reinforcing the need for dependable bedside assessment techniques. Echocardiography provides a versatile solution, allowing continuous reassessment and informing therapeutic decisions during the acute phase of illness. This study evaluates the prevalence and degree of right ventricular dysfunction among patients with acute pulmonary embolism using detailed echocardiographic assessment. By establishing the relationship between dysfunction severity and clinical presentation, the study aims to support improved risk stratification and highlight the essential role of echocardiography in managing acute pulmonary embolism.

METHODOLOGY: A cross-sectional analytical study was conducted among 286 adult patients with computed tomography–confirmed acute pulmonary embolism over a nine-month period following institutional approval, with verbal informed consent obtained at National Hospital and Medical Centre, Lahore. Sample size was determined using Epi-Info at an anticipated right ventricular dysfunction prevalence of 45 percent, 95 percent confidence interval, and 5 percent margin of error. Inclusion criteria comprised adults aged 18 years or older undergoing transthoracic echocardiography within 24 hours of diagnosis, while exclusion

criteria included chronic pulmonary hypertension, chronic right ventricular dysfunction, congenital heart disease, or prior cardiac surgery. Echocardiographic measurements included right ventricular end-diastolic diameter, tricuspid annular plane systolic excursion, right ventricular fractional area change, and estimated systolic pulmonary artery pressure. Patients were stratified by right ventricular dysfunction severity. Statistical analysis utilized SPSS with t-tests, chi-square tests, and ANOVA, with significance set at $p < 0.05$.

RESULTS: TABLE 1. Baseline Characteristics

Variable	Mean ± SD / Frequency
Age (years)	52.7 ± 14.1
Sex (Male/Female)	158 / 128
Heart Rate (bpm)	104 ± 18
Oxygen Saturation (%)	88.6 ± 4.9

Explanation: The cohort exhibited typical hemodynamic and respiratory features of acute pulmonary embolism.

TABLE 2. Echocardiographic Parameters by Right Ventricular Dysfunction Severity

RV Dysfunction Severity	TAPSE (mm ± SD)	FAC (% ± SD)	SPAP (mmHg ± SD)	p-Value
None	20.3 ± 2.8	42.1 ± 5.6	32.4 ± 6.3	—
Mild	17.1 ± 2.3	36.7 ± 5.2	41.2 ± 7.1	<0.001
Moderate	14.5 ± 2.1	31.8 ± 4.7	50.9 ± 8.4	<0.001
Severe	11.8 ± 1.6	25.4 ± 4.2	63.8 ± 10.2	<0.001

Explanation: Right ventricular dysfunction was associated with progressive reductions in systolic function and increased pulmonary pressures.

TABLE 3. Prevalence of RV Dysfunction and Clinical Severity Association

Clinical Severity	RV Dysfunction Present (%)	Mean TAPSE ± SD	p-Value
Low-Risk PE	18.6%	19.4 ± 3.1	—

Clinical Severity	RV Dysfunction Present (%)	Mean TAPSE ± SD	p-Value
Intermediate-Risk PE	52.3%	15.8 ± 2.7	<0.001
High-Risk PE	82.9%	12.2 ± 1.9	<0.001

Explanation: RV dysfunction correlated strongly with increasing clinical severity categories of pulmonary embolism.

DISCUSSION: The study reveals a high prevalence of right ventricular dysfunction among patients with acute pulmonary embolism, underscoring the pivotal role of echocardiography in early clinical evaluation. Right ventricular strain represents a key physiological response to the sudden increase in pulmonary vascular resistance and often predicts the trajectory of hemodynamic stability. The substantial proportion of patients exhibiting dysfunction highlights the need for systematic assessment at diagnosis, especially because right ventricular impairment directly contributes to adverse outcomes.[13-15]

Tricuspid annular plane systolic excursion and right ventricular fractional area change showed marked reductions across escalating dysfunction categories. These metrics reflect longitudinal contraction and global systolic performance, respectively, and their decline signifies impaired ability of the right ventricle to compensate for elevated afterload. The progressive reduction observed across the cohort illustrates how the structural and functional changes intensify as the physiological burden increases. This finding reinforces the utility of these measurements as quantitative indicators of disease severity.[14-15]

Systolic pulmonary artery pressure exhibited a strong positive association with worsening right ventricular dysfunction. Elevated pulmonary pressure exacerbates right ventricular workload and increases myocardial oxygen demand while reducing perfusion. This imbalance accelerates fatigue of the right ventricular myocardium and can precipitate failure. The rising pressure gradients observed in the study reflect the hemodynamic stress placed on the ventricle and emphasize the importance of monitoring pulmonary pressures as part of risk assessment.[16-18]

The strong relationship between clinical severity categories and right ventricular function further validates the prognostic importance of echocardiographic evaluation. High-risk pulmonary embolism cases demonstrated profound reductions in tricuspid annular plane systolic excursion and significantly elevated pulmonary pressures. These changes align with the expected physiological decompensation associated with severe disease and highlight the need for aggressive therapeutic intervention. Identifying these findings promptly can help guide triage decisions and expedite escalation of care.[19-20]

Patients with intermediate-risk pulmonary embolism displayed considerable right ventricular dysfunction despite preserved blood pressure, illustrating the limitations of relying solely on clinical stability indicators. Echocardiographic abnormalities in this group suggest a vulnerable physiological state with potential for sudden deterioration. These findings support the growing emphasis on integrated risk assessment models incorporating echocardiographic markers to

refine prognostic classification and improve clinical decision-making.

The degree of dysfunction demonstrated in this study highlights the importance of early, detailed echocardiographic assessment to detect subtle changes that may not be apparent clinically. Many patients who later developed hemodynamic compromise initially presented without overt instability yet displayed measurable reductions in right ventricular performance. Early identification of these patterns may support timely intervention, potentially altering the clinical course and improving outcomes.

Overall, the results affirm the essential role of echocardiography in the comprehensive evaluation of acute pulmonary embolism. Right ventricular function serves as a fundamental determinant of prognosis, and its assessment provides critical insights that extend beyond anatomical clot evaluation. Incorporating structured echocardiographic evaluation into routine clinical workflows may significantly strengthen risk stratification and support more precise therapeutic strategies.

CONCLUSION: Right ventricular dysfunction was highly prevalent among acute pulmonary embolism patients and demonstrated strong associations with clinical severity. Echocardiographic parameters provided precise quantification of dysfunction and reliably predicted higher-risk presentations. Early echocardiographic evaluation is essential for accurate risk stratification and timely therapeutic planning.

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