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GENEL TIP DERGİSİ
The Journal of General Medicine

Received: 21 Oct 2025 | **Accepted:** 14 Jan 2026 | **Published:** 27 Mar 2026 **Genel Tıp Derg. Volume** 36(2026), 1-6

DOI: 10.54005/geneltip.1807952

ORIGINAL ARTICLE

Prognostic Value of TAPSE/sPAP Ratio, RV S′ Velocity, and RV S′/sPAP Ratio in Hospitalized Patients with COVID-19: A Retrospective Echocardiographic Analysis

Hastaneye Yatırılan COVID-19 Hastalarında TAPSE/sPAP Oranı, RV S′ Hızı ve RV S′/sPAP Oranının Prognostik Değeri: Retrospektif Bir Ekokardiyografik Analiz

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How to cite ?

Ülgen Kunak A. Kunak T. Prognostic Value of TAPSE/sPAP Ratio, RV S′ Velocity, and RV S′/sPAP Ratio in Hospitalized Patients with COVID-19: A Retrospective Echocardiographic Analysis. Genel Tıp Derg. 36 (2026), 1-6

ABSTRACT

Aim: This study aimed to evaluate the association between the tricuspid annular plane systolic excursion (TAPSE) to systolic pulmonary artery pressure (sPAP) ratio, right ventricular (RV) S′ velocity, RV S′/sPAP ratio, and adverse clinical outcomes in hospitalized COVID-19 patients.
Materials and Methods: A retrospective cohort of 100 adult patients hospitalized with laboratory-confirmed COVID-19 who underwent transthoracic echocardiography (TTE) was analyzed. Patients were classified into two groups according to clinical outcomes: adverse outcome (ICU admission, mechanical ventilation, ARDS, or in-hospital mortality) and favorable outcome. Echocardiographic parameters (TAPSE, sPAP, RV S′, TAPSE/sPAP, and RV S′/sPAP) were compared between groups, and receiver operating characteristic (ROC) curve analysis was performed to assess discriminative performance in this exploratory analysis.
Results: Thirty-two patients experienced adverse outcomes. The TAPSE/sPAP ratio (0.44 ± 0.18 vs. 0.55 ± 0.22, p = 0.006), RV S′ velocity (9.17 ± 2.1 cm/s vs. 10.54 ± 2.1 cm/s, p = 0.004), and RV S′/sPAP ratio (0.28 ± 0.10 vs. 0.33 ± 0.08, p = 0.008) were significantly lower in the adverse outcome group. ROC analysis showed fair discriminative performance for TAPSE/sPAP, RV S′, and RV S′/sPAP with AUCs of 0.686, 0.691, and 0.753, respectively.
Conclusion: TAPSE/sPAP, RV S′, and RV S′/sPAP are non-invasive echocardiographic markers associated with adverse outcomes in hospitalized COVID-19 patients. Their combined use may contribute to early risk stratification in an exploratory, hypothesis-generating context.

Keywords: COVID-19, echocardiography, prognosis, right ventricular function, RV S′/sPAP, TAPSE/sPAP.

ÖZ

Amaç: Bu çalışmanın amacı, hastanede yatan COVID-19 hastalarında triküspit anüler düzlem sistolik ekskursiyonunun (TAPSE) sistolik pulmoner arter basıncına (sPAP) oranı, sağ ventrikül (RV) S′ hızı ve RV S′/sPAP oranı ile olumsuz klinik sonlanımlar arasındaki ilişkiyi değerlendirmektir.
Gereç ve Yöntemler: Laboratuvar olarak doğrulanmış COVID-19 tanısı ile hastaneye yatırılan ve transtorasik ekokardiyografi (TTE) yapılan 100 erişkin hastadan oluşan retrospektif bir kohort analiz edilmiştir. Hastalar klinik sonuçlarına göre iki gruba ayrılmıştır: olumsuz sonuç (yoğun bakım ünitesine yatış, mekanik ventilasyon, akut solunum sıkıntısı sendromu [ARDS] veya hastane içi mortalite) ve olumlu sonuç. Ekokardiyografik parametreler (TAPSE, sPAP, RV S′, TAPSE/sPAP ve RV S′/sPAP) gruplar arasında karşılaştırılmış ve bu keşifsel analizde ayırt edici performansı değerlendirmek amacıyla alıcı işletim karakteristiği (ROC) eğrisi analizi yapılmıştır.
Bulgular: Otuz iki hastada olumsuz klinik sonlanım gözlenmiştir. TAPSE/sPAP oranı (0,44 ± 0,18'e karşı 0,55 ± 0,22; p = 0,006), RV S′ hızı (9,17 ± 2,1 cm/sn'ye karşı 10,54 ± 2,1 cm/sn; p = 0,004) ve RV S′/sPAP oranı (0,28 ± 0,10'a karşı 0,33 ± 0,08; p = 0,008) olumsuz sonuç grubunda anlamlı derecede daha düşük bulunmuştur. ROC analizi, TAPSE/sPAP, RV S′ ve RV S′/sPAP için sırasıyla 0,686, 0,691 ve 0,753 AUC değerleri ile orta düzeyde ayırt edici performans göstermiştir.
Sonuç: TAPSE/sPAP, RV S′ ve RV S′/sPAP, hastanede yatan COVID-19 hastalarında olumsuz klinik sonlanımlar ile ilişkili non-invaziv ekokardiyografik belirteçlerdir. Bu parametrelerin birlikte kullanımı, keşifsel ve hipotez oluşturmaya yönelik bir bağlamda erken risk sınıflandırılmasına katkı sağlayabilir.

Anahtar Kelimeler: COVID-19, ekokardiyografi, prognoz, sağ ventrikül fonksiyonu, TAPSE/sPAP, RV S′/sPAP

Peer-Review: Double anonymized - Two External
Plagiarism Checks: Yes - intihal.net
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Introduction

Coronavirus disease 2019 (COVID-19), caused by SARS-CoV-2, has emerged as a global health crisis affecting multiple organ systems. While respiratory failure remains the dominant clinical manifestation, cardiovascular complications, particularly right ventricular (RV) dysfunction have been increasingly recognized as major determinants of poor outcomes in severe and critically ill patients [1].

The RV is particularly vulnerable to acute increases in afterload due to its thin wall and limited contractile reserve. In COVID-19, several mechanisms such as pulmonary vascular inflammation, microthrombosis, hypoxia-induced vasoconstriction, and elevated intrathoracic pressure during mechanical ventilation can raise pulmonary vascular resistance, resulting in RV strain and failure [2]. Previous studies have demonstrated that RV dysfunction is common in severe COVID-19 and is independently associated with higher mortality, irrespective of left ventricular function [3].

Transthoracic echocardiography (TTE) is a practical, bedside imaging modality for assessing RV performance. Conventional indices such as tricuspid annular plane systolic excursion (TAPSE) and tissue Doppler-derived systolic velocity of the tricuspid annulus (RV S′) are widely used to evaluate RV systolic function. Recently, the ratio of TAPSE to systolic pulmonary artery pressure (TAPSE/sPAP) has gained interest as a non-invasive measure of RV–pulmonary arterial (PA) coupling, reflecting the relationship between RV contractility and afterload [4]. A lower ratio indicates ventriculo-arterial uncoupling, which has been linked to adverse outcomes and increased mortality in COVID-19 [5].

Although the prognostic role of RV S′ in COVID-19 has been less extensively studied, emerging evidence suggests that reduced RV S′ may precede overt RV dilatation or failure, offering additional insight particularly when interpreted alongside coupling indices such as TAPSE/sPAP [6].

Given this background, the present study aimed to investigate the prognostic significance of the TAPSE/sPAP ratio, RV S′ velocity, and RV S′/sPAP ratio in hospitalized COVID-19 patients, focusing on their association with adverse clinical outcomes using comparative and ROC curve analyses. We hypothesized that lower values of these indices would be associated with worse clinical outcomes and that their combined assessment could improve early risk stratification.

Materials and Methods

This retrospective, observational study was conducted at a tertiary care hospital. Adult patients (≥18 years) hospitalized with laboratory-confirmed COVID-19 between 2020 and 2021 were included. SARS-CoV-2 infection was confirmed by reverse transcription polymerase chain reaction (RT-PCR).

Patients were eligible if they underwent transthoracic echocardiography (TTE) during hospitalization for clinical assessment and had complete echocardiographic data available, particularly regarding right heart function. TTE was performed based on clinical indications such as respiratory deterioration, hemodynamic instability, or suspicion of cardiac involvement. Therefore, the study population represents hospitalized COVID-19 patients who underwent clinically indicated echocardiography rather than an unselected hospitalized cohort. All examinations were obtained during the index hospitalization and reflected routine clinical care rather than a predefined research protocol. The exact timing of echocardiography relative to hospital admission was not standardized and could not be uniformly retrieved due to the retrospective nature of the study.

Exclusion criteria included known significant structural heart disease (e.g., moderate-to-severe valvular disease or congenital heart defects), acute pulmonary embolism, acute myocardial infarction, known heart failure with reduced or preserved ejection fraction, poor echocardiographic image quality, or incomplete clinical/echocardiographic data.

Because strict infection control and isolation protocols limited echocardiographic examinations during the pandemic, most analyses were conducted retrospectively from digitally stored images acquired during routine clinical care. All images were reviewed by two experienced cardiologists blinded to clinical outcomes.

Echocardiographic evaluations were performed according to the guidelines of the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI) [7].

• TAPSE was measured in M-mode from the apical four-chamber view.

• RV S′ velocity was obtained by tissue Doppler imaging at the lateral tricuspid annulus.

• sPAP was estimated using the modified Bernoulli equation from the peak velocity of the tricuspid regurgitation jet, adjusted for right atrial pressure.

• RV–PA coupling was assessed using the TAPSE/sPAP and RV S′/sPAP ratios.

• Additional parameters included right atrial (RA) and right ventricular (RV) diameters and left ventricular ejection fraction (LVEF) calculated by the biplane Simpson's method.

Patients were categorized into two outcome groups:

1. Adverse outcome group: ICU admission, mechanical ventilation, ARDS, or in-hospital mortality.

2. Favorable outcome group: none of the above complications.

Statistical Analysis

Normality of continuous variables was assessed using visual methods (histograms and Q–Q plots) and analytically using the Shapiro–Wilk test. Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range, IQR)

as appropriate. Comparisons between groups were performed using independent-samples t-tests or Mann–Whitney U tests for continuous variables and χ^2 or Fisher's exact tests for categorical variables.

The predictive value of echocardiographic parameters (TAPSE/sPAP, RV S′, RV S′/sPAP) for adverse outcomes was evaluated using ROC curve analysis. Areas under the curve (AUCs) with 95% confidence intervals (CIs) were calculated, and optimal cutoff values were determined using the Youden index.

Due to the relatively limited sample size and the potential for collinearity among closely related right ventricular echocardiographic parameters (e.g., TAPSE/sPAP, RV S′, and RV S′/sPAP), multivariable regression analysis was not performed. Therefore, the analyses were exploratory and focused on univariable associations.

All analyses were two-tailed, and p-values <0.05 were considered statistically significant.

The study was approved by the Institutional Review Board of Akdeniz University (Approval Number: KAEK-535, Date: 22.07.2020) and conducted in accordance with the Declaration of Helsinki. As the analysis was retrospective and anonymized, written informed consent was waived.

Results

A total of 100 hospitalized patients with confirmed COVID-19 were included. Among them, 32 (32%) experienced adverse outcomes, while 68 (68%) had favorable outcomes. The composite adverse outcome included ICU admission, mechanical ventilation, ARDS, and in-hospital mortality.

Baseline demographic, clinical, and laboratory characteristics are summarized in Table 1. There were no significant differences between the groups in terms of age (58.32 ± 21.55 vs. 56.69 ± 20.29 years, p = 0.64) or heart rate (87.91 ± 13.94 vs. 89.97 ± 16.11 beats/min, p = 0.48). The mean hospital stay was slightly longer in the adverse outcome group (11.25 ± 3.68 days) compared with the favorable outcome group (10.07 ± 4.25 days), but this difference was not statistically significant (p = 0.16).

Table 1. Baseline Characteristics of the Study Population

Variable	Favorable Outcome (n = 68)	Adverse Outcome (n = 32)	p-value
Age (years)	58.32 ± 21.55	56.69 ± 20.29	0.64
Length of hospital stay (days)	10.07 ± 4.25	11.25 ± 3.68	0.16
Heart rate (beats/min)	87.91 ± 13.94	89.97 ± 16.11	0.48
Neutrophil count (×10³/L)	4630 ± 2782	4599 ± 2397	0.94
Lymphocyte count (×10³/L)	1718 ± 919	1611 ± 971	0.61
CRP (mg/L)	11 (7-30)	28.2 (9.8-123)	0.005
Hypertension, n (%)	31 (45.6)	15 (46.9)	0.90
Diabetes mellitus, n (%)	20 (29.4)	9 (28.1)	0.91
COPD, n (%)	6 (8.8)	7 (21.9)	0.07
Obesity, n (%)	10 (14.7)	10 (31.3)	0.065
Smoking, n (%)	45 (66.2)	27 (84.4)	0.059
CKD, n (%)	4 (5.9)	2 (6.3)	0.94
Malignancy, n (%)	3 (4.4)	1 (3.1)	0.78
Atrial fibrillation, n (%)	5 (7.4)	2 (6.3)	0.84

CRP: C-reactive protein; COPD: Chronic obstructive pulmonary disease; CKD: Chronic kidney disease

Although comorbidities such as hypertension, diabetes, and coronary artery disease showed no significant association with outcomes, obesity (31.3% vs. 14.7%, p = 0.065), COPD (21.9% vs. 8.8%, p = 0.07), and smoking (84.4% vs. 66.2%, p = 0.059) tended to be more prevalent in the adverse outcome group.

Echocardiographic parameters are presented in Table 2. Patients with adverse outcomes demonstrated significantly reduced RV functional indices. The TAPSE/sPAP ratio was markedly lower in the adverse outcome group (0.44 ± 0.18 vs. 0.55 ± 0.22, p = 0.006), as was RV S′ velocity (9.17 ± 2.1 cm/s vs. 10.54 ± 2.1 cm/s, p = 0.004).

Table 2. Echocardiographic Parameters According to Outcome

Variable	Favorable Outcome (mean ± SD)	Adverse Outcome (mean ± SD)	p-value
TAPSE/sPAP ratio	0.55 ± 0.22	0.44 ± 0.18	0.006
RV S′ (cm/s)	10.54 ± 2.1	9.17 ± 2.1	0.004
RV S′/sPAP ratio	0.33 ± 0.08	0.28 ± 0.10	0.008
TAPSE (mm)	17.85 ± 3.96	17.11 ± 2.65	0.743
sPAP (mmHg)	34.98 ± 9.2	36.09 ± 8.5	0.567
RA diameter (cm)	3.46 ± 0.64	3.65 ± 0.63	0.166
LVEF (%)	55.8 ± 8.9	56.9 ± 9.4	0.547

TAPSE: Tricuspid annular plane systolic excursion; sPAP: Systolic pulmonary artery pressure; RV S′: Right ventricular systolic velocity; LVEF: Left ventricular ejection fraction; RA: Right atrium

Similarly, the RV S′/sPAP ratio was significantly lower among patients with adverse outcomes (0.28 ± 0.10 vs. 0.33 ± 0.08, p = 0.008). Other echocardiographic parameters, including TAPSE, sPAP, RA diameter, and LVEF did not differ significantly between groups (p > 0.05 for all).

ROC curve analysis demonstrated fair to good discriminative power for all three indices (Figure 1–3). The AUC for RV S′ velocity was 0.691 (95% CI 0.576–0.806, p = 0.002) with an optimal cutoff of 7.0 cm/s. The TAPSE/sPAP ratio yielded an AUC of 0.686 (95% CI 0.567–0.805, p = 0.002) with an optimal cutoff value of 0.445 (sensitivity 95.6%, specificity 65.6%). Notably, the RV S′/sPAP ratio demonstrated the highest discriminative performance among the examined indices, with an AUC of 0.753 (95% CI 0.65–0.86, p < 0.001) and an optimal cutoff of 0.305.

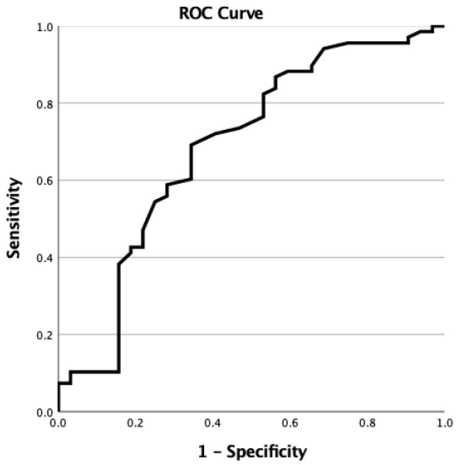

Figure 1. Receiver operating characteristic (ROC) curve of TAPSE/sPAP ratio for predicting adverse clinical outcomes in hospitalized COVID-19 patients. The area under the curve (AUC) was 0.686 (95% CI 0.567–0.805, p = 0.002). The optimal cutoff was 0.445 with a sensitivity of 95.6% and specificity of 65.6%.

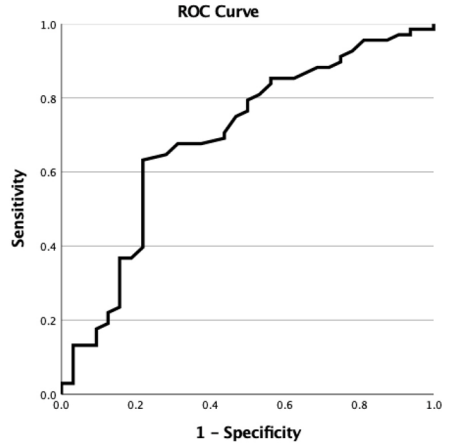

Figure 2. ROC curve of RV S' velocity for predicting adverse clinical outcomes in hospitalized COVID-19 patients. The AUC was 0.691 (95% CI 0.576–0.806, p = 0.002), with an optimal cutoff of 7.0 cm/s, corresponding toa sensitivity of 95.6% and a specificity of 65.6%.

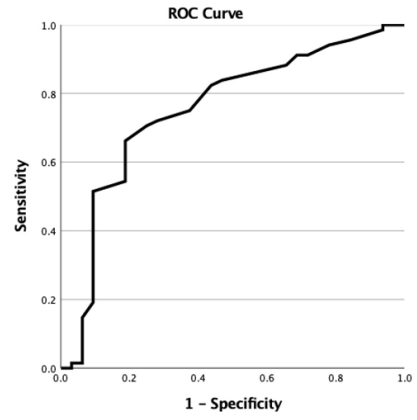

Figure 3. ROC curve of RV S'/sPAP ratio for predicting adverse clinical outcomes in hospitalized COVID-19 patients. The AUC was 0.753 (95% CI 0.65–0.86, p < 0.001). The optimal cutoff was 0.305, with a sensitivity of 70.6% and specificity of 75.0%, demonstrating superior discriminative performance compared with TAPSE/sPAP and RV S' alone.

Discussion

In this retrospective study of 100 hospitalized COVID-19 patients, we demonstrated that right ventricular functional impairment, particularly as reflected by reduced TAPSE/sPAP ratio and RV S' velocity was associated with adverse clinical outcomes in hospitalized COVID-19 patients who underwent clinically indicated echocardiography. All three indices, TAPSE/sPAP, RV S', and RV S'/sPAP showed significant associations with adverse outcomes, underscoring their complementary value in assessing RV–PA coupling and highlighting their potential relevance in clinical risk assessment.

RV–PA coupling represents the relationship between RV contractility and afterload, typically expressed by the ratio of end-systolic to arterial elastance (Ees/Ea). Under physiological conditions, this ratio remains within the range of 1.5–2.0, reflecting efficient energy transfer between the ventricle and pulmonary circulation [8,9]. When RV–PA coupling deteriorates ("uncoupling"), the RV fails to compensate for increased afterload, leading to dilation, functional impairment, and eventual right heart failure. The TAPSE/sPAP ratio has been validated as a non-invasive surrogate of RV–PA coupling in various cardiopulmonary disorders and critical illnesses [10].

In our study cohort, both TAPSE/sPAP and RV S' values were significantly lower in patients with adverse outcomes, confirming RV systolic dysfunction as an important prognostic determinant in COVID-19. ROC analysis identified cutoff values with fair discriminative ability, characterized by high sensitivity but moderate specificity, suggesting potential utility for risk enrichment or screening rather than definitive prognostication. These findings, consistent with previous reports, indicate that while these indices are highly sensitive in identifying high-risk patients, they should be interpreted alongside clinical and laboratory parameters given their moderate discriminative performance (AUC ≈ 0.69).

COVID-19 exerts multiple hemodynamic and inflammatory insults on the RV. Pulmonary endothelial inflammation, thrombotic microangiopathy, and hypoxia-induced vasoconstriction collectively increase pulmonary vascular resistance, while mechanical ventilation and high intrathoracic pressures further exacerbate RV afterload [11,12]. Lazzeri et al. reported a high incidence of RV dilation and dysfunction in COVID-19-related ARDS, closely linked to mortality and ventilatory dependence [13]. Similarly, our findings reinforce that RV impairment in COVID-19 reflects the interplay of pulmonary vascular injury and hemodynamic stress.

Although the optimal TAPSE/sPAP cutoff in our cohort was higher (0.445), previously reported thresholds such as <0.31 by D'Alto et al. [4] were derived from critically ill ARDS populations, which may explain the observed differences. In line with this, Tsolaki et al. observed progressive RV dysfunction in mechanically ventilated COVID-19 patients, with declining TAPSE/sPAP and increasing RV dilation correlating with mortality [14].

Beyond TAPSE and TAPSE/sPAP, tissue Doppler-derived RV S' velocity has emerged as a sensitive marker of early RV contractile impairment. Szekely et al. and Li et al. both found that echocardiographic parameters reflecting RV systolic function including TAPSE, RV S', and RV longitudinal strain were more predictive of adverse outcomes than traditional left-sided indices [3,15]. Dandel et al. further suggested that RV systolic impairment may precede structural changes, highlighting the role of early tissue Doppler assessment in detecting subclinical dysfunction [16].

In our analysis, the novel RV S'/sPAP ratio demonstrated the highest discriminative ability (AUC = 0.753, 95% CI 0.65–0.86, $p < 0.001$). However, given the limited sample size and potential collinearity with other RV–PA coupling indices such as TAPSE/sPAP, these findings should be interpreted as associative and hypothesis-generating rather than independently predictive. This parameter may nonetheless represent a promising adjunct marker for RV–PA uncoupling in future studies with larger cohorts.

Comorbidities such as obesity, COPD, and smoking history showed borderline associations with adverse outcomes, suggesting additive stress on RV performance. These findings support the notion that preexisting cardiopulmonary compromise may amplify COVID-19–related RV dysfunction, warranting closer monitoring in these subgroups.

From a practical standpoint, RV S' measurement offers a quick, reproducible, and resource-efficient assessment of RV function, especially beneficial in emergency and resource-limited settings. Incorporating TAPSE/sPAP and RV S' parameters into early echocardiographic screening could facilitate timely risk stratification and guide escalation of care in hospitalized COVID-19 patients.

Several studies outside the COVID-19 context further support these findings. Anastasiou et al. demonstrated that lower TAPSE/sPAP ratios predicted all-cause mortality and heart failure hospitalization [17], while Bosch et al. reported that impaired RV–arterial coupling was independently associated with adverse outcomes in patients with left-sided heart failure [18]. Warpechowski et al. emphasized that echocardiographic indices, particularly TAPSE/sPAP, can serve as early predictors of ICU admission, mechanical ventilation, and mortality in COVID-19 [6]. Collectively, these studies reinforce the utility of RV–PA coupling indices as non-invasive, clinically actionable prognostic markers.

From a clinical perspective, bedside assessment of TAPSE/sPAP and RV S' may provide practical information for early risk stratification in hospitalized COVID-19 patients. Reduced values of these parameters could prompt closer monitoring, earlier escalation of respiratory or hemodynamic support, and timely consideration for intensive care referral. Given their simplicity and feasibility, these measures may complement clinical and laboratory findings in daily decision-making, particularly in resource-limited settings.

This study has several limitations. Its retrospective, single-center design limits generalizability and may introduce selection bias. The relatively small sample size restricted the scope of statistical analyses and precluded multivariable regression modeling, particularly given potential collinearity among closely related right ventricular parameters such as TAPSE/sPAP, RV S', and RV S'/sPAP. Advanced echocardiographic techniques, including right ventricular strain analysis and three-dimensional imaging, were not available and may have provided additional insights into RV mechanics. Furthermore, echocardiographic examinations were performed according to clinical indications at varying time points during hospitalization, which may have introduced timing-related variability. Variability in the timing of echocardiography may have influenced RV functional parameters due to dynamic changes in loading conditions, disease severity, and therapeutic interventions such as ventilation or fluid management. Therefore, these echocardiographic indices should be interpreted as context-dependent markers rather than fixed prognostic measurements, and prospective studies with larger cohorts are warranted to confirm these findings.

Conclusion

The TAPSE/sPAP ratio, RV S' velocity, and RV S'/sPAP ratio are simple, non-invasive echocardiographic indices that provide valuable insights into right ventricular–pulmonary arterial interaction in COVID-19. These readily obtainable bedside parameters may help identify patients at higher risk of clinical deterioration and support risk stratification and informed clinical decision-making when interpreted in the appropriate clinical context. Integrating these measures into standard echocardiographic assessments may enhance prognostic evaluation and clinical management in patients with COVID-19–related cardiopulmonary involvement. Prospective, large-scale studies are warranted to validate these findings and further clarify their clinical utility.

Conflict of interest

The authors have no conflict of interest to declare.

Financial support

The authors declared that this study has received no financial support.

Acknowledgement

N.A.

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