

Right Ventricular Function Across Different Respiratory Support Strategies in Severe Community-Acquired Pneumonia

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Abstract

Background:

Right ventricular (RV) dysfunction is increasingly recognized in acute respiratory failure. Hypoxaemia, hypercapnia, acidosis, pulmonary vascular involvement and positive-pressure respiratory support may increase pulmonary vascular resistance (PVR) and RV afterload, thereby impairing RV performance. However, the haemodynamic effects of non-invasive respiratory support strategies in severe community-acquired pneumonia (CAP) outside the ICU remain insufficiently characterized.

Objectives:

To assess, in patients with severe CAP (Pneumonia Severity Index - PSI - IV and V): (1) the association between oxygenation mode and RV systolic performance (Tricuspid Annular Plane Systolic Excursion - TAPSE, and lateral Tissue Doppler imaging - TDI) and (2) the relationship between oxygenation mode and Length of hospital stay (LOS).

Methods:

Single-centre prospective observational study with consecutive enrolment of adult patients with severe CAP (PSI IV-V, according to ATS/IDSA - American Thoracic Society/Infectious Diseases Society of America - severity criteria) hospitalized in an internal medicine ward. The initial respiratory support strategy was selected in the emergency setting among NIV-PSV [Pressure Support Ventilation], HFNC, and Venturi Mask according to the patient's gas-exchange and acid-base profile; complete transthoracic echocardiography was then performed on ward admission while patients remained on the initially assigned device and settings, before any ward-driven modification of respiratory settings. The diagnostic etiological work-up comprised blood and sputum samples for cultures and multiplex nasopharyngeal viral/atypical PCR assays.

Results:

A total of 70 patients were enrolled (NIV = 21, HFNC = 22, Venturi mask = 27). All patients had bilateral multilobar consolidations and pleural effusions. The predominant etiology was viral/atypical bacteria: human metapneumovirus A/B (30%), rhinovirus (30%), HPIV - Human parainfluenza virus - (20%), *Mycoplasma pneumoniae* (20%). RV systolic parameters significantly varied between oxygenation modalities ($p < 0.001$). Patients on NIV showed the worst RV performance (TAPSE 1.16 ± 0.19 cm; TDI 6.02 ± 0.73 cm/s), while patients on a Venturi mask had better RV systolic performance (TAPSE 1.74 ± 0.33 cm; TDI 10.12 ± 2.28 cm/s). LOS was considerably longer in NIV and HFNC patients than in Venturi mask patients (28.4 ± 3.0 vs 27.4 ± 2.9 vs 14.7 ± 3.7 days; $p < 0.001$). In multivariate linear regression

analysis, age and pattern of respiratory support (NIV/HFNC vs Venturi) were both independently associated with prolonged LOS.

Conclusions:

In this cohort, pressure-generating respiratory support modalities were associated with poorer RV systolic indices and longer hospitalization. Because the study specifically evaluated RV systolic function - and not RV failure or RV-pulmonary artery uncoupling - and because echocardiography was performed after respiratory support had already been selected and started, these findings should be interpreted as hypothesis-generating associations that may reflect both underlying disease severity and support-related haemodynamic effects.

INTRODUCTION

Severe community-acquired pneumonia (CAP) remains one of the leading causes of acute respiratory failure and hospital admission in adult patients, and it is still associated with substantial morbidity and mortality [1, 2]. In internal medicine wards, where severe CAP is frequently managed outside the ICU, the interaction between respiratory failure, ventilatory support, and cardiovascular function is clinically relevant but still incompletely characterized.

Right ventricular (RV) dysfunction has been increasingly recognized as an important component of acute respiratory failure, and several studies have shown that RV dysfunction or RV failure is associated with worse outcomes in this setting [3–5]. Hypoxaemia, hypercapnia, acidosis, pulmonary vascular involvement, and sepsis-related cardiopulmonary interactions may all increase pulmonary vascular resistance (PVR) and RV afterload, thereby impairing RV performance [3, 4]. Positive-pressure respiratory support may further contribute to this burden through increased intrathoracic pressure, reduced venous return, alveolar overdistension, and further rises in PVR [6, 7].

Driving pressure is conceptually distinct from PEEP and has been associated with mortality in ARDS, but this construct was not specifically linked to RV strain in the landmark study by Amato et al. [8]. However, although the prognostic relevance of RV dysfunction in acute respiratory failure is increasingly acknowledged, the specific impact of pressure-generating respiratory support on RV performance remains less clearly defined. In particular, the potential contribution of PEEP-related RV burden to clinical outcome in respiratory disease is still a relatively underexplored field.

This issue is especially relevant outside the ICU, where NIV, HFNC, and Venturi Mask are frequently used, yet their differential association with RV performance has not been systematically assessed in patients with severe CAP. Among studies specifically addressing non-invasive ventilation, Lazzeri et al. showed that RV-pulmonary circulation uncoupling, assessed by the TAPSE/sPAP ratio, independently predicted NIV failure in COVID-related ARDS [9]. More broadly, echocardiographic RV parameters have shown prognostic value in CAP and acute respiratory failure populations [10, 11], while the updated Global ARDS

definition and contemporary reviews support the haemodynamic relevance of HFNC and NIV in non-ICU respiratory care [12–15].

In the present study, we deliberately focused on RV systolic function rather than RV failure or RV-pulmonary artery uncoupling, because TAPSE and lateral tissue Doppler systolic velocity were the prespecified and systematically acquired echocardiographic variables in our ward-based protocol. These parameters are simple, reproducible bedside markers of longitudinal RV systolic performance, although they do not fully characterize RV geometry, systemic venous congestion, or load-contractility coupling.

Accordingly, the aim of this study was to assess the association between respiratory support strategy and RV systolic performance, as well as their relationship with clinical outcome, in patients with severe CAP admitted to an internal medicine ward. We hypothesised that pressure-generating ventilation patterns (NIV and HFNC) would be associated with greater RV systolic impairment and more extended hospitalisation than Venturi Mask, which provides oxygenation without a positive intrathoracic pressure.

MATERIALS AND METHODS

Study population

This single-centre prospective observational study consecutively enrolled adult patients admitted to the Internal Medicine Department of S. Elia Hospital (Caltanissetta, Italy) between April 2024 and October 2025. The inclusion criterion was severe community-acquired pneumonia, defined as PSI class IV-V according to ATS/IDSA criteria for severe CAP [1, 2]. All patients had acute symptom onset within 7 days, chest imaging showing bilateral multilobar consolidations and concomitant pleural effusion, and acute hypoxemic respiratory failure requiring high-concentration oxygen or non-invasive respiratory support.

In accordance with the Berlin and global definitions of ARDS [12], all patients met the temporal and radiographic diagnostic criteria for ARDS. Since the Venturi mask does not deliver PEEP, only the NIV and HFNC groups met the PEEP-dependent component of the Berlin/global definition; however, the entire population showed ARDS-like pathophysiology typical of severe CAP.

Exclusion criteria

Patients with diseases that independently influence RV load/function were excluded: COPD (Chronic Obstructive Pulmonary Disease), ILD (Interstitial Lung Disease), pulmonary embolism or CTEPH (Chronic Thromboembolic Pulmonary Hypertension), previous pulmonary hypertension, significant left heart valve disease, congenital heart disease, and severe tricuspid regurgitation.

Respiratory support

Initial settings within each respiratory support modality were standardized [13–15], but the choice among Venturi Mask, HFNC, and NIV was made in the emergency setting according to the patient's gas-exchange and acid-base profile at presentation (Fig. 1):

- NIV: PSV mode (PS – pressure support – 10 cmH₂O, PEEP 5 cmH₂O) for hypercapnic acidosis
- HFNC: flow 80 L/min, FiO₂ 90%
- Venturi Mask: FiO₂ 60%, 12 L/min

HFNC was used according to the American College of Physicians evidence report as a non-invasive respiratory support option in acute respiratory failure, particularly when conventional low-flow oxygen therapy was insufficient to maintain adequate oxygen saturation [15].

Patients remained on the same respiratory support device during transfer from the emergency department to the Internal Medicine ward.

Echocardiography

Complete transthoracic echocardiography was performed on ward admission after the respiratory support modality had already been selected and initiated in the emergency setting, while the patient was still receiving the initial device and settings, and before the ward team introduced any substantial modification of flow, FiO₂, PEEP, or pressure support (Fig. 1). Thus, echocardiographic measurements reflected the haemodynamic condition under the respiratory support modality initially assigned in the emergency setting. RV function was assessed through TAPSE and lateral TDI following ESC recommendations. Because RV chamber dimensions, PASP, and venous congestion markers were not systematically acquired as prespecified variables in all patients, RV dilatation, RV failure, and RV-PA uncoupling were not formally adjudicated in the present analysis.

Microbiological testing

A nasopharyngeal screening using multiplex PCR was performed for respiratory viruses and *Mycoplasma pneumoniae*. Etiology is reported in Table 1.

Table 1

Anthropometric, clinical, radiological, echocardiographic and laboratory characteristics of the study population (mean $\pm$ SD or n, %).

Variable	N	Mean	SD
Age (years)	70	76.6	12.91
Systolic BP (mmHg)	70	132.36	17.72
Diastolic BP (mmHg)	70	70.87	10.68
Heart rate (bpm)	70	92.79	21.37
Height (cm)	70	172.21	8.68
Weight (kg)	70	79.09	16.33
BMI (kg/m ²)	70	26.83	6.20
Left atrial area (cm ²)	70	26.17	5.86
TAPSE (cm)	70	1.46	0.37
E/E' ratio	70	18.32	5.80
Lateral TDI (cm/s)	70	8.15	2.29
Left ventricular EF (%)	70	59.19	5.52
Total cholesterol (mg/dL)	70	248.13	35.29
LDL (mg/dL)	70	156.10	30.83
HDL (mg/dL)	70	46.13	7.26
Triglycerides (mg/dL)	70	178.57	43.79
Fasting glucose (mg/dL)	70	156.57	60.19
HbA1c (%)	70	6.68	1.43
NT-proBNP (pg/mL)	70	14861.39	24784.03
GFR (CKD-EPI mL/min/1.73m ²)	70	61.78	22.86
PCT (ng/mL)	70	9.17	31.77
CRP (mg/L)	70	117.78	84.57
Length of stay (days)	70	22.8	7.26
Documented viral infection, n (%)	70	56	80%
Mean $\pm$ SD unless otherwise specified. Viral and atypical etiologies based on multiplex nasopharyngeal PCR. All patients exhibited bilateral multilobar consolidations with concomitant pleural effusion.			

Variable	N	Mean	SD
– Human metapneumovirus A/B	–	21	30%
– Rhinovirus	–	21	30%
– Parainfluenza virus (HPIV)	–	14	20%
Mycoplasma pneumoniae, n (%)	–	14	20%
Radiology: bilateral multilobar consolidations, n (%)	70	70	100%
Pleural effusion, n (%)	70	70	100%
Mean ± SD unless otherwise specified. Viral and atypical etiologies based on multiplex nasopharyngeal PCR. All patients exhibited bilateral multilobar consolidations with concomitant pleural effusion.			

Antibiotic therapy

Empirical treatment closely followed ATS/IDSA guidelines [1, 2]: intravenous β -lactams + macrolide (clarithromycin/azithromycin) or respiratory fluoroquinolones. Antibiotic coverage for MRSA - Methicillin-resistant *Staphylococcus Aureus* - (vancomycin/linezolid) or *Pseudomonas Aeruginosa* was added when appropriate.

Corticosteroid therapy

All patients, at the time of enrolment, received corticosteroid therapy (40 mg intravenous methylprednisolone) for five days, followed by 25 mg oral prednisone with gradual reduction of the posology until withdrawal (using a specific tapering strategy) [16].

Statistical analysis

Continuous variables were analyzed using Analysis of Variance - ANOVA - or Kruskal-Wallis, as appropriate; categorical ones using χ^2 /Fisher's exact test. Spearman's correlation was used to test associations between RV function indices and LOS. A multivariate linear regression analysis included LOS as the outcome and TAPSE, age, PSI class, CRP (C-reactive protein), and oxygenation pattern as predictors.

RESULTS

Seventy patients with severe CAP (PSI IV–V) were included (NIV = 21, HFNC = 22, Venturi = 27). Baseline anthropometric, clinical and echocardiographic features are reported in Table 1.

All patients had bilateral multilobar consolidations with pleural effusions, suggesting severe parenchymal involvement. Pneumonias were caused mainly by viruses and “atypical” bacteria: human

metapneumovirus A/B (30%), rhinovirus (30%), HPIV (20%) and *Mycoplasma pneumoniae* (20%). Blood and sputum cultures were negative.

Right Ventricular (RV) Function

RV systolic function was significantly different between the different oxygenation modalities (Table 2, Figs. 2–3). In particular, while non-invasive ventilation (NIV) resulted in the mode which mainly affected the RV systolic function (TAPSE 1.16 ± 0.19 cm; TDI 6.02 ± 0.73 cm/s), the Venturi mask was correlated to the lowest impairment (TAPSE 1.74 ± 0.33 cm; TDI 10.12 ± 2.28 cm/s; $p < 0.001$ for both TAPSE and TDI), HFNC was in the middle. We also observed a significant correlation between TAPSE and TDI ($\rho = 0.805$, $p < 0.05$).

Table 2

TAPSE, lateral tricuspid annular systolic velocity (TDI) and Length of hospital stay (LOS) according to oxygenation modality (mean $\pm$ SD).

Modality	N	TAPSE (cm)	SD TAPSE	TDI (cm/s)	SD TDI	LOS (days)
HFNC	22	1.40	0.29	7.76	0.72	27.41
NIV	21	1.16	0.19	6.02	0.73	28.43
Venturi Mask	27	1.74	0.33	10.12	2.28	14.67
Values reported as mean $\pm$ SD. NIV = Non-invasive ventilation; HFNC = High-flow nasal cannula; LOS = Length of hospital stay.						

Length of Stay (LOS)

NIV (28.4 ± 3.0 days) and HFNC (27.4 ± 2.9 days) were associated with a significantly more extended hospitalisation than Venturi mask (14.7 ± 3.7 days; $p < 0.001$). (Table 2, Fig. 4). There was also an inverse correlation between LOS and TAPSE and TDI (Table 3, $\rho = -0.55$ and -0.614 , respectively).

Table 3

Spearman correlation matrix between TAPSE, lateral TDI and Length of stay (LOS).

Variable 1	Variable 2	Spearman ρ	p-value
TAPSE	TDI	0.805	< 0.05
TAPSE	LOS	-0.55	< 0.05
TDI	LOS	-0.614	< 0.05
ρ = Spearman's rank correlation coefficient; p-values reflect statistical significance.			

Multivariable Analysis

A multivariable linear regression model (LOS as outcome; predictors: TAPSE, age, PSI class, CRP, oxygenation modality) is reported in Table 4. Age was independently associated with a longer LOS (beta

= 0.13, 95% CI 0.06–0.20, $p < 0.05$).

Table 4
Multivariable linear regression model evaluating predictors of Length of hospital stay (LOS).

Predictor	β coefficient	95% CI	p-value
TAPSE (per 1 cm increase)	-0.27	-3.16 to 2.61	> 0.05
Age (per year)	0.13	0.06 to 0.20	< 0.05
PSI class V (vs IV)	-1.14	-2.99 to 0.70	> 0.05
CRP (per 1 mg/L)	0.00	-0.01 to 0.01	> 0.05
NIV (vs Venturi Mask)	13.40	10.30 to 16.50	< 0.05
HFNC (vs Venturi Mask)	12.02	9.61 to 14.44	< 0.05
Dependent variable = length of hospital stay (LOS). Multivariable linear regression adjusted for TAPSE, age, PSI class, CRP, and oxygenation modality. Venturi Mask used as reference category.			

Both NIV (beta = 13.40, 95% CI 10.30–16.50, $p < 0.05$) and HFNC (beta = 12.02, 95% CI 9.61–14.44, $p < 0.05$) showed a firm association with prolonged LOS compared with Venturi Mask. In addition, TAPSE, PSI class and CRP did not result as significant predictors ($p > 0.05$).

Therefore, in the multivariable model, PSI class was not associated with LOS, whereas NIV and HFNC remained independently associated with longer hospitalization than Venturi mask.

DISCUSSION

This study reports a statistically significant association between respiratory support pathway, hospitalization length, and RV systolic function in patients with severe community-acquired pneumonia managed in an Internal Medicine ward.

NIV, in PSV mode, was associated with worse RV systolic indices and longer hospitalization; Venturi mask showed the opposite pattern, while HFNC displayed intermediate values [6, 7, 13, 14].

These findings should be interpreted within the broader framework of heart-lung interaction. Positive airway pressure can increase transpulmonary pressure, reduce venous return, and raise PVR, thereby increasing RV afterload [6, 7]. However, our study explored only one dimension of the RV response, namely longitudinal RV systolic function assessed by TAPSE and lateral TDI. We did not measure composite RV-PA coupling indices such as TAPSE/PASP, nor did we define RV failure, which generally requires integration of RV dilatation with systolic impairment and the clinical/hemodynamic consequences of inadequate forward flow [3, 4, 5, 9]. Accordingly, any mechanistic interpretation should remain cautious and limited to RV systolic performance rather than broader constructs of RV dysfunction.

Several reports have already shown that RV dysfunction or RV failure is associated with worse outcomes in acute respiratory failure and pneumonia [4, 5, 9, 10, 11]. In particular, TAPSE/PASP has been associated with survival in COVID-19 ARDS and with NIV failure in a dedicated COVID-ARDS cohort [5, 9], while echocardiographic RV parameters have shown prognostic value in CAP populations [10, 11]. Our data extend this field to a non-ICU internal medicine cohort, but specifically at the level of RV systolic performance rather than RV failure or RV-PA uncoupling, and without establishing a causal effect of the respiratory support modality itself.

An alternative interpretation must also be considered. The worse TAPSE and TDI observed in the NIV and HFNC groups may partly reflect greater underlying cardiorespiratory severity rather than a purely device-mediated haemodynamic effect. Severe hypoxaemia, hypercapnia, pulmonary vascular involvement and sepsis-related myocardial dysfunction may all depress RV performance independently of respiratory support. Moreover, PSI captures oxygenation only in a simplified way and does not directly account for sepsis-induced myocardial dysfunction. This point is especially relevant because echocardiography was performed after the emergency-setting respiratory support had already been selected and started, not before modality allocation. Therefore, confounding by indication is plausible, and the observed association between support modality and RV systolic impairment should not be interpreted as evidence of causality.

The significant inverse correlation between RV systolic values and LOS suggests that patients with poorer RV systolic performance may experience a slower recovery. In multivariable analysis, NIV and HFNC remained independently associated with longer LOS even after adjustment for TAPSE, PSI class, CRP, and age; however, this association should still be interpreted cautiously in light of the observational design and the likelihood of residual confounding.

In univariate analysis, TAPSE and TDI correlated with LOS, but TAPSE was no longer significant in the adjusted model, likely reflecting collinearity with respiratory support modality and the limited sample size. These results suggest that respiratory support pattern may identify a clinically relevant severity/hemodynamic phenotype not fully explained by PSI alone, rather than proving an adverse effect of the device per se.

Pneumonias in our cohort were mainly caused by viruses and atypical bacteria, highlighting the importance of appropriate antimicrobial stewardship [17], and this distribution was consistent with contemporary CAP epidemiology [18].

Overall, our study supports the clinical relevance of early RV-focused echocardiography in Internal Medicine patients with severe CAP and acute respiratory failure. Bedside assessment of RV systolic performance may help identify patients with a more vulnerable haemodynamic profile under noninvasive respiratory support, while awaiting studies specifically addressing RV failure, RV-PA uncoupling, and causal treatment effects.

Study Limitations

This is a single-centre prospective observational study with a modest sample size. Echocardiography was performed by one operator, enhancing internal consistency but limiting generalizability. The initial respiratory support modality was selected in the emergency setting on clinical grounds, and echocardiography was performed only after support had already been initiated in the ward setting; therefore, baseline pre-support RV assessment was unavailable and confounding by indication cannot be excluded. RV chamber dimensions, PASP, and markers of systemic venous congestion were not systematically collected in all patients; therefore RV dilatation, RV failure, and RV-PA uncoupling could not be formally assessed. Blood and sputum culture yield was low, and nasopharyngeal PCR may underestimate bacterial co-infection. The multivariable analysis was exploratory because of the sample size.

CONCLUSIONS

In severe CAP, the pathway of oxygenation was associated with RV systolic indices and LOS. Specifically, pressure-generating modalities (NIV and HFNC) were associated with poorer RV systolic performance and longer hospitalization compared with Venturi mask, independent of PSI class in the adjusted model. Because this study assessed RV systolic function only - and not RV failure or RV-PA uncoupling - and because echocardiography was performed after the initial respiratory support decision, these findings should be considered hypothesis-generating and potentially influenced by confounding by indication and underlying disease severity. Early RV-focused echocardiography may nevertheless be clinically useful for identifying a more vulnerable haemodynamic profile during noninvasive respiratory support.

Abbreviations

ARDS

acute respiratory distress syndrome

ATS/IDSA

American Thoracic Society/Infectious Diseases Society of America

CAP

community-acquired pneumonia

CRP

C-reactive protein

HFNC

high-flow nasal cannula

LOS

length of stay

NIV

non-invasive ventilation

PEEP

positive end-expiratory pressure

PSI

Pneumonia Severity Index
PVR
pulmonary vascular resistance
RV
right ventricle/right ventricular
TAPSE
tricuspid annular plane systolic excursion
TDI
tissue Doppler imaging.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki. According to Italian national regulations, formal approval by an Institutional Review Board or Ethics Committee was not required because this was a non-interventional, observational study based exclusively on data collected during routine clinical care. All participants provided written informed consent for participation in the study and for the use of their anonymized clinical data for research purposes. Reference legislation: Italian Ministerial Decree 8 February 2013 and subsequent updates.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request, subject to institutional approval and applicable data protection regulations.

Competing interests

The authors declare that they have no competing interests.

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This research received no external funding.

Authors' contributions

CDM conceived the study, collected the data, performed the echocardiographic examinations, and drafted the manuscript. GP, MD, RLN, SF, GG, GV, SR, and VDC contributed to patient enrolment, clinical

data collection, and critical revision of the manuscript. NC and AT supervised the study design, interpretation of the results, and manuscript revision. All authors read and approved the final manuscript.

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Figures

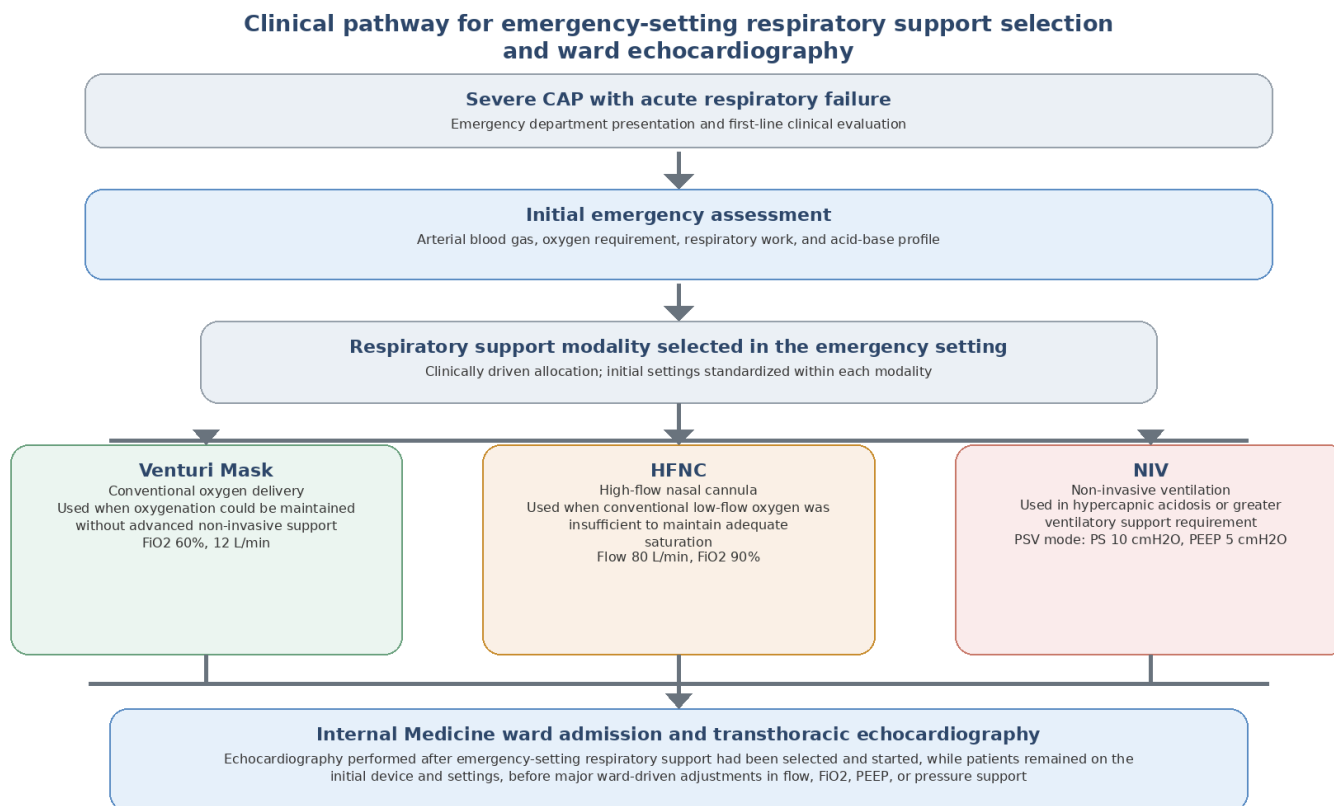


Figure 1

Emergency-setting selection of respiratory support modality and subsequent ward transthoracic echocardiography.

Respiratory support modality was selected in the emergency setting according to the patient's gas-exchange and acid-base profile. Transthoracic echocardiography was then performed after ward admission while the patient remained on the initially selected device and settings, before any major ward-driven modification in flow, FiO2, PEEP, or pressure support.

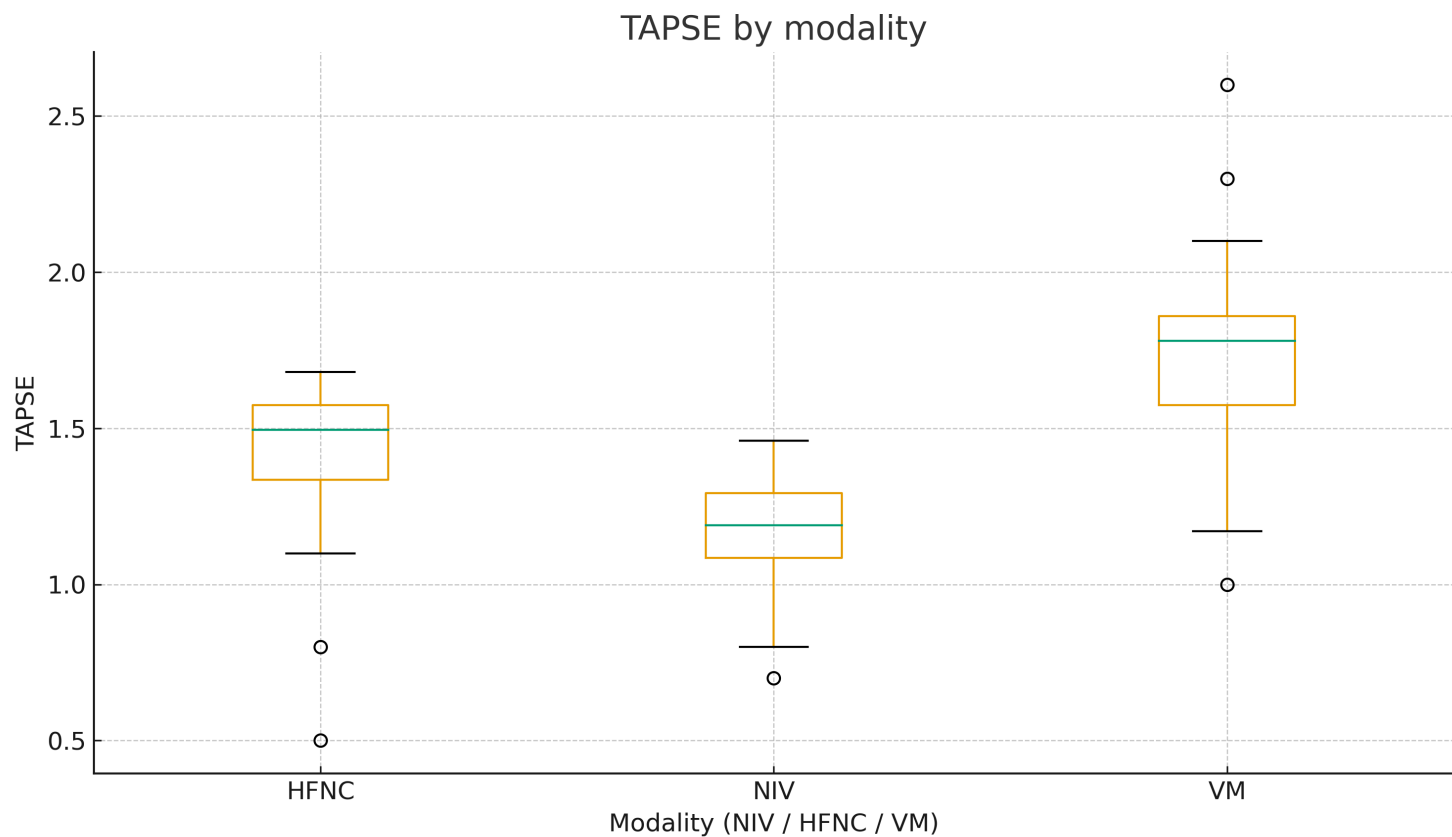


Figure 2

Distribution of TAPSE across oxygenation modalities.

Distribution of TAPSE across oxygenation modalities (NIV, HFNC, VM). NIV shows significantly lower TAPSE values, indicating worse right ventricular function.

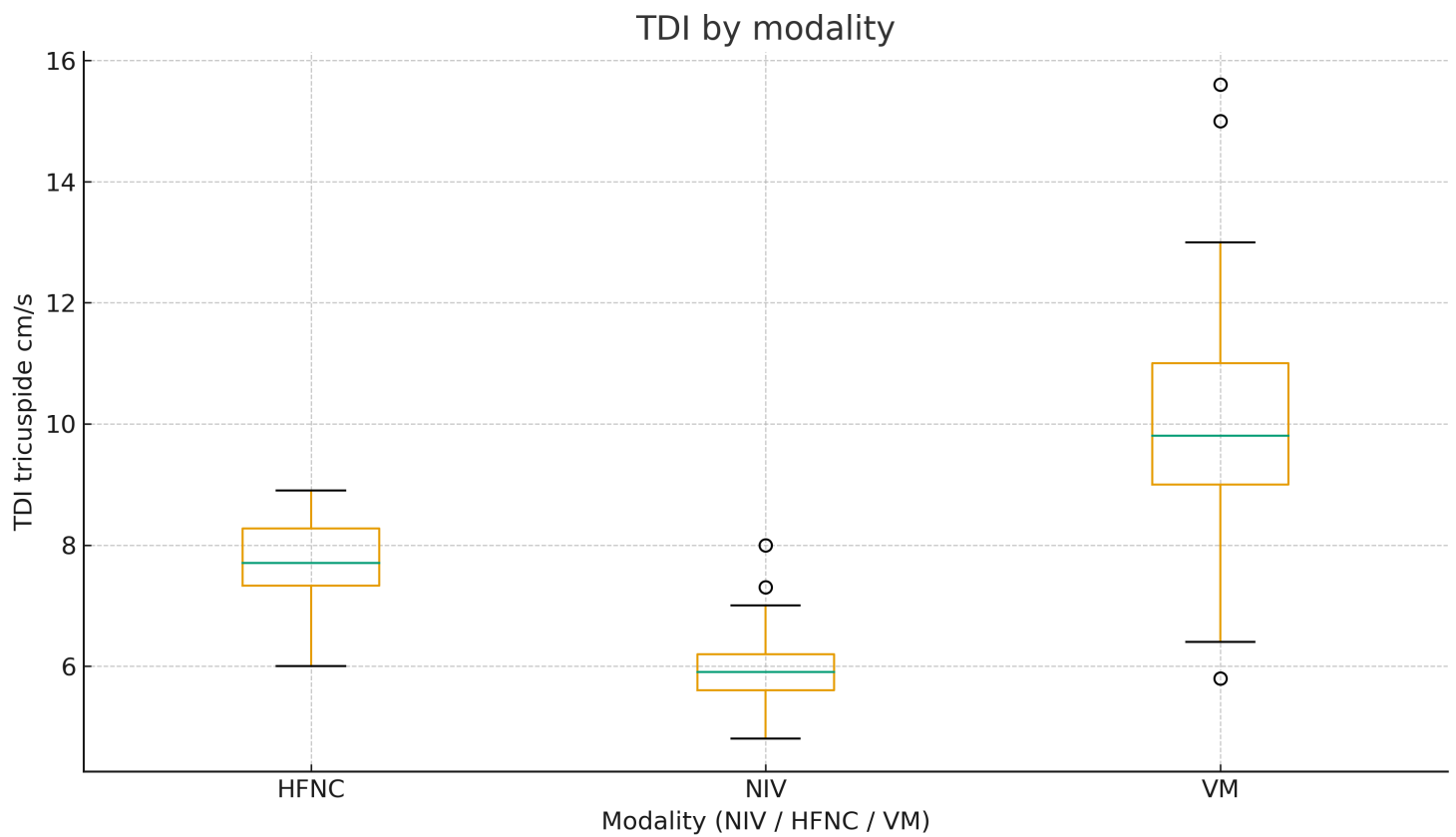


Figure 3

Distribution of lateral TDI across oxygenation modalities.

Distribution of lateral TDI across oxygenation modalities. NIV is associated with the lowest TDI values and the highest degree of RV systolic dysfunction.

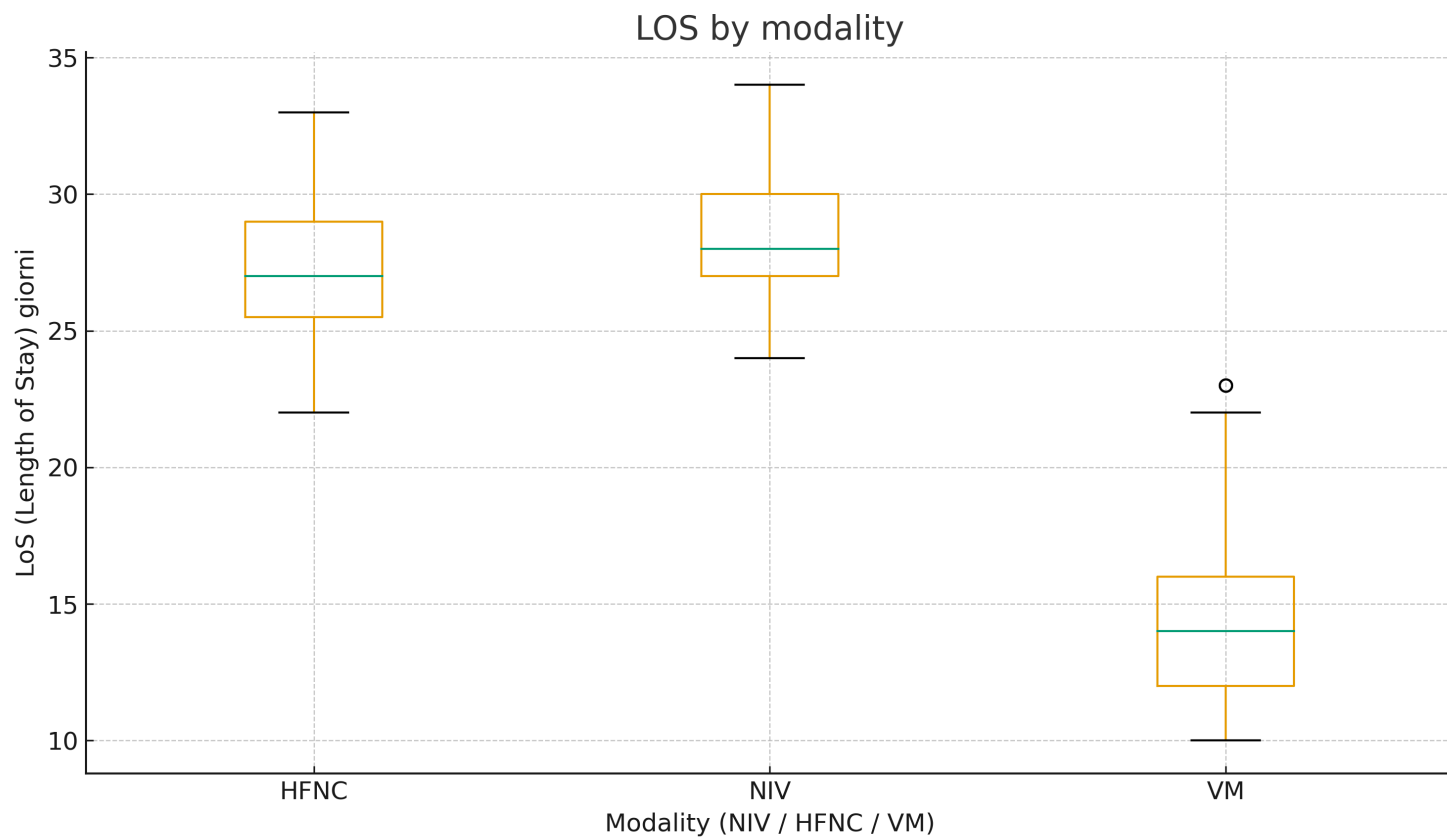


Figure 4

Length of Stay across oxygenation modalities.

Length of hospital stay (LOS) according to oxygenation modality. NIV and HFNC are associated with longer LOS compared with VM.