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A Comparative Study on the Outcome of Non - Invasive and Invasive Ventilatory Support in Patients with Respiratory Failure

[1]Dr. K. Sathik Basha, Associate Professor, Department of General Medicine, Government Villupuram Medical College and Hospital, Villupuram.

[2]Dr. V. Giridharan, Associate Professor, Department of General Medicine, Government Medical College, Namakkal.

[3]Dr.R.V. Sudarshan Naik, Resident, Department of Cardiology, KIMS -SAVEERA Hospital.

Corresponding Author: Dr. K. SathikBasha, Associate professor, Department of general medicine, Government Villupuram Medical College and Hospital, Villupuram.

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Abstract

Respiratory failure is a life-threatening condition in which the respiratory system fails in oxygenation, carbon dioxide elimination, or both, and ventilatory support is central to its management. Invasive mechanical ventilation has traditionally been the gold standard for severe respiratory failure, but it carries substantial risks, while non-invasive ventilation has gained popularity because it may reduce the need for intubation and its attendant complications; the relative merits of the two approaches remain debated, particularly in critically ill patients.

This prospective observational study was carried out in the Department of General Medicine at a tertiary care teaching hospital in Villupuram, Tamil Nadu, over one year (January to December 2023), and enrolled 200 patients aged 18 years and above who presented with Type I or Type II respiratory failure due to primary pulmonary pathology; patients with respiratory failure of non-pulmonary origin, impaired consciousness, or chest trauma were excluded. On presentation, conscious level, chest wall motion, respiratory rate, and heart rate were assessed, oxygen supplementation was given where saturation fell below 90%, and a chest radiograph was obtained.

Where saturation deteriorated, non-invasive ventilatory support was commenced and arterial blood gas analysis performed, with continuous monitoring for at least 24 hours; failure of the partial pressure of arterial carbon dioxide and pH to improve after 4 to 6 hours despite optimal ventilator settings prompted disconnection of non-invasive support and consideration of invasive

ventilation. Data were analysed in SPSS version 28.0, with qualitative variables expressed as frequencies and proportions and the chi-square test used for comparison, a p-value below 0.05 being taken as significant. Non-invasive support was used in 74.5% of the cohort and invasive support in 40%, the 41 to 50 year age group predominating in both. Good outcomes were markedly more frequent where non-invasive support was used (73.5% of the cohort) than where invasive support was used (19.5%), and poor outcomes were correspondingly more frequent with invasive support (20.5%); both associations were highly significant ($p < 0.001$). Non-invasive support was also associated with a significantly shorter duration of hospital stay ($p < 0.001$). These findings support the continued use of non-invasive ventilation as a first-line strategy in respiratory failure amenable to it, while indicating that invasive ventilation retains an important role in severe hypoxaemic failure, and that refinement of patient selection criteria remains a priority.

Keywords: respiratory failure; non-invasive ventilation; invasive mechanical ventilation; acute respiratory failure; patient outcome

Introduction

Respiratory failure is a life-threatening condition in which the respiratory system fails in oxygenation, carbon dioxide elimination, or both. It is characterised by abnormalities of arterial blood gas tensions, and is conventionally divided into two types: Type I respiratory failure is defined by an arterial partial pressure of oxygen (PaO_2) below 8 kPa (60 mm Hg) with a normal or low arterial partial pressure of carbon dioxide ($PaCO_2$), while Type II respiratory failure is defined by a PaO_2 below 8 kPa (60 mm Hg) together with a $PaCO_2$ above 6 kPa (45 mm Hg). Acute respiratory failure is usually characterised by life-threatening derangements in arterial blood gases and acid-base status, and may be classified as hypercapnic or hypoxaemic; these are defined respectively as a $PaCO_2$ greater than 45 mm Hg and a PaO_2 less than 55 mm Hg when the fraction of oxygen in inspired air is 0.60 or greater. Patients who suffer acute respiratory failure, which may be caused either by lung dysfunction or by a malfunctioning respiratory muscle pump, suffer greatly.

Because acute respiratory failure is linked to high hospital morbidity and mortality, to ethical dilemmas in end-of-life decision making, and to increased healthcare resource consumption, it presents a difficult field for clinicians both inside and outside the intensive care unit[1].

Acute cardiogenic pulmonary oedema, pneumonia, and trauma are among the several causes of lung injury that fall under the umbrella of acute hypoxaemic failure, and severe hypoxaemia is often caused by acute respiratory distress syndrome (ARDS), a clinical condition whose hallmark is acute inflammatory lung damage linked to increased lung weight, loss of aerated lung tissue, and increased pulmonary vascular permeability[2].Hospital mortality is around 42% in its most severe form, and the incidence of acute respiratory failure brought on by ARDS varies from 10 to 80 per 100,000 person-years depending on where it is reported; one estimate is that 23% of patients on mechanical ventilation and 10% of all patients admitted to the intensive care unit satisfy the criteria for ARDS[3].

Management of acute respiratory failure may require an escalation therapeutic strategy based on several ventilatory and non-ventilatory therapies. The main goal of these artificial supports is to prevent or lessen the possibility of lung damage from therapeutic

interventions, such as ventilator-induced lung injury, while buying time for aetiological therapy to reverse the cause of the acute decompensation[4].

Invasive mechanical ventilation is delivered through an endotracheal tube or tracheostomy, whereas non-invasive ventilation uses a specific external interface. Non-invasive ventilation refers to the delivery of positive pressure to the lungs without inserting an endotracheal tube, and includes continuous positive airway pressure (CPAP) and all modalities of pressure-controlled mechanical ventilation. Newer treatment alternatives include high-flow nasal cannula[5]. extra corporeal carbon dioxide removal, and non-invasive and invasive cough assist techniques; refractory hypoxaemia during invasive ventilation may further require prone ventilation, neuromuscular blockade[6], or extracorporeal membrane oxygenation.

Traditionally, invasive ventilatory support, primarily through endotracheal intubation and mechanical ventilation, has been the gold standard for managing severe respiratory failure. However, this approach carries significant risks, including ventilator-associated pneumonia, airway trauma, and prolonged sedation, which can lead to increased morbidity and extended hospital stays; ventilation itself may also be linked to the spread of underlying lung injury and the subsequent exacerbation of multi-organ failure[7]. According to the historic ARDS Network trial, patients with acute lung injury ventilated with a lower tidal volume of 6 ml/kg while avoiding high airway pressures had a lower mortality rate than those receiving a traditional ventilatory approach[8].

In recent years, non-invasive ventilatory support, such as CPAP and bilevel positive airway pressure, has gained popularity as an alternative for treating respiratory failure. It has been effectively applied in patients with acute respiratory failure with a significant reduction in mortality rate, need for endotracheal intubation, and length of stay compared with standard therapy. The advantages of non-invasive ventilation over endotracheal intubation are obvious: speech, airway defence mechanisms, and swallowing functions are left intact, trauma to the trachea and larynx is avoided, and patient comfort may be improved. The most evidence-based and highly recommended uses of non-invasive positive pressure ventilation are in acute exacerbations of chronic obstructive pulmonary disease (COPD) and in acute respiratory failure due to cardiogenic pulmonary oedema[9, 10]. In hypercapnic respiratory acidosis brought on by an acute exacerbation of COPD, the use of non-invasive ventilation is linked to lower risks of treatment failure, lower intubation rates with a lower incidence of nosocomial infections, and a lower mortality rate, with a correspondingly shorter hospital stay and lower costs [11]. In acute cardiogenic pulmonary oedema, meta-analysis has shown benefits in mortality and intubation rate compared with traditional medical care[12].

The utility of non-invasive ventilation in hypoxaemic respiratory failure is supported by contradictory data. Significant variation in the causes and severity of respiratory failure across study populations, particularly the prevalence of pre-existing COPD, hinders the literature in this field. As a result, routine use of non-invasive ventilation in cases of severe pneumonia or ARDS cannot be advised, despite some studies suggesting benefits[13,14]. Nonetheless, research has shown that early use may help control hypoxaemic respiratory failure in immune compromised patients[15, 16]. Failure of non-invasive ventilation is more likely in patients who are sicker, and interface leakage and patient-ventilator

asynchrony are frequent reasons for it [17]; delayed intubation after a failed trial is associated with worse outcomes, so early identification of patients likely to fail is crucial[18].

Despite the growing body of evidence supporting the use of non-invasive ventilation, there remains debate regarding its efficacy compared to invasive ventilatory support, particularly in critically ill patients. The aim of this study was to compare the outcome of non-invasive and invasive ventilatory support in patients with respiratory failure, focusing on clinical outcomes such as duration of ventilation, length of hospital stay, and overall prognosis, in order to contribute insights into the optimal management strategies for these patients.

Materials and Methods

Study design, setting, and population

This was a prospective observational study carried out in the Department of General Medicine, Government Villupuram Medical College and Hospital, Villupuram, Tamil Nadu, India. The study period was one year, from January 2023 to December 2023. The study population comprised patients presenting to the hospital with respiratory failure, and the sample size was 200.

Inclusion and exclusion criteria

Patients were eligible for inclusion if they had Type I respiratory failure due to primary pulmonary pathology, or Type II respiratory failure due to primary pulmonary pathology. Patients were excluded if they were aged under 18 years, if the respiratory failure was due to non-pulmonary pathology, if there was impaired consciousness, or if there was chest trauma.

Methodology

Patients who presented with acute onset of breathlessness were initially assessed for conscious level, chest wall motion, respiratory rate, and heart rate. The patient was provided with oxygen supplementation if saturation was less than 90%. A chest radiograph was then taken and oxygen saturation was monitored. If oxygen saturation was deteriorating, non-invasive ventilatory support was provided and an arterial blood gas sample was sent. Oxygen saturation was monitored continuously for at least 24 hours after commencing non-invasive ventilation. The need for further arterial blood gas analysis was governed by the patient's clinical progress; it was performed after 4 to 6 hours if an earlier sample showed little improvement. If there was no improvement in $PaCO_2$ and pH after this period despite optimal ventilator settings, non-invasive ventilation was disconnected and invasive ventilation was considered.

Statistical analysis and interpretation of group labels

Data were entered in Microsoft Excel for Windows 10 and analysed in SPSS version 28.0. Qualitative variables were described as frequencies (n) and proportions (%). The chi-square test was employed for comparison of categorical variables, with Fisher's exact test substituted where any expected cell count was below five in a 2 × 2 table; a p-value below 0.05 was considered statistically significant. Throughout the Results, non-invasive and invasive ventilatory support are reported as two separate binary variables, each recorded for all 200 patients: "NIV: Yes" denotes patients in whom non-invasive support was used and "NIV: No" those in whom it was not, with "IV: Yes" and "IV: No" defined correspondingly. The two variables are therefore not mutually exclusive arms, and each pair of columns sums independently to the full cohort of 200 patients. All percentages are of the total cohort (n = 200).

Results

A total of 200 patients with respiratory failure were studied. Non-invasive ventilatory support was used in 149 patients (74.5%) and invasive ventilatory support in 80 patients (40.0%).

Table 1: Baseline demographic and anthropometric characteristics by ventilatory support group.

Characteristic Age group (years)	NIV: No n (%)	NIV: Yes n (%)	p 0.098	IV: No n (%)	IV: Yes n (%)	P 0.198
20-30	9 (4.5)	20 (10.0)		16 (8.0)	13 (6.5)	
31-40	13 (6.5)	52 (26.0)		43 (21.5)	22 (11.0)	
41-50	15 (7.5)	53 (26.5)		44 (22.0)	24 (12.0)	
51-60	10 (5.0)	22 (11.0)		15 (7.5)	17 (8.5)	
> 60	4 (2.0)	2 (1.0)		2 (1.0)	4 (2.0)	
Gender			0.858			0.885
Male	27 (13.5)	83 (41.5)		67 (33.5)	43 (21.5)	
Female	24 (12.0)	66 (33.0)		53 (26.5)	37 (18.5)	
Body mass index (kg/m^2)			0.061			0.286
< 18.5 (underweight)	1 (0.5)	8 (4.0)		6 (3.0)	3 (1.5)	
18.5-24.9 (normal)	36 (18.0)	116 (58.0)		90 (45.0)	62 (31.0)	
25-29.9 (overweight)	14 (7.0)	20 (10.0)		19 (9.5)	15 (7.5)	
30-39.9 (obese)	0 (0.0)	5 (2.5)		5 (2.5)	0 (0.0)	
Total	51 (25.5)	149 (74.5)		120 (60.0)	80 (40.0)	

NIV, non-invasive ventilatory support; IV, invasive ventilatory support. Percentages are of the total cohort (n = 200). p-values are from the chi-square test for the association between the characteristic and use of each form of support; one or more expected cell counts were below five for age and body mass index, so those p-values should be interpreted with caution.

Table 2: Physiological parameters at presentation by ventilatory support group.

Characteristic	NIV: No n (%)	NIV: Yes n (%)	p	IV: No n (%)	IV: Yes n (%)	p
Arterial pH			0.047			0.018
< 7.35	50 (25.0)	132 (66.0)		104 (52.0)	78 (39.0)	
7.35-7.45	1 (0.5)	17 (8.5)		16 (8.0)	2 (1.0)	
$PaCO_2$ (mm Hg)			0.681			0.593
35-40	12 (6.0)	40 (20.0)		35 (17.5)	17 (8.5)	
41-45	23 (11.5)	74 (37.0)		57 (28.5)	40 (20.0)	
46-55	8 (4.0)	15 (7.5)		12 (6.0)	11 (5.5)	
57-68	8 (4.0)	20 (10.0)		16 (8.0)	12 (6.0)	

PaO_2 (mm Hg)			0.136			0.140
38-40	3 (1.5)	5 (2.5)		3 (1.5)	5 (2.5)	
41-45	4 (2.0)	8 (4.0)		7 (3.5)	5 (2.5)	
46-55	11 (5.5)	16 (8.0)		12 (6.0)	15 (7.5)	
56-70	33 (16.5)	120 (60.0)		98 (49.0)	55 (27.5)	
Respiratory rate grade			0.539			0.112
Grade 1	15 (7.5)	54 (27.0)		48 (24.0)	21 (10.5)	
Grade 2	14 (7.0)	43 (21.5)		33 (16.5)	24 (12.0)	
Grade 3	22 (11.0)	52 (26.0)		39 (19.5)	35 (17.5)	
Total	51 (25.5)	149 (74.5)		120 (60.0)	80 (40.0)	

$PaCO_2$, partial pressure of arterial carbon dioxide; PaO_2, partial pressure of arterial oxygen. The pH / NIV p-value is from Fisher's exact test; one or more expected cell counts were below five for PaO_2. Respiratory rate grades 1-3 are as coded in the study master chart. Each pair of columns sums to 200.

Table 3: Underlying pulmonary conditions present, by ventilatory support group.

Characteristic	NIV: No n (%)	NIV: Yes n (%)	p	IV: No n (%)	IV: Yes n (%)	p
COPD	0 (0.0)	21 (10.5)	0.010	21 (10.5)	0 (0.0)	< 0.001
Bronchiectasis	6 (3.0)	21 (10.5)	0.855	18 (9.0)	9 (4.5)	0.583
Pneumonia	8 (4.0)	25 (12.5)	1.000	22 (11.0)	11 (5.5)	0.509
Poisoning	6 (3.0)	40 (20.0)	0.044	37 (18.5)	9 (4.5)	0.002
	n (%)	n (%)		n (%)	n (%)	
Bronchial asthma	7 (3.5)	10 (5.0)	0.146	8 (4.0)	9 (4.5)	0.379
ARDS	0 (0.0)	20 (10.0)	0.013	10 (5.0)	10 (5.0)	0.470
Pulmonary tuberculosis	12 (6.0)	6 (3.0)	< 0.001	4 (2.0)	14 (7.0)	0.001

COPD, chronic obstructive pulmonary disease; ARDS, acute respiratory distress syndrome. Figures are the number of patients in whom the condition was present; the number in whom it was absent is the column denominator minus the figure shown (NIV: No, 51; NIV: Yes, 149; IV: No, 120; IV: Yes, 80). The bronchial asthma / NIV p-value is from Fisher's exact test.

Table 4: Duration of ventilation and transition from non-invasive to invasive support.

Duration of NIV (category)	n (%)	n (%)	< 0.001	n (%)	n (%)	< 0.001
Category 1	6 (3.0)	93 (46.5)		83 (41.5)	16 (8.0)	
Category 2	0 (0.0)	56 (28.0)		37 (18.5)	19 (9.5)	
Category 3	45 (22.5)	0 (0.0)		0 (0.0)	45 (22.5)	
Duration of IV (category)			< 0.001			< 0.001
Category 1	2 (1.0)	21 (10.5)		0 (0.0)	23 (11.5)	

Category 2	49 (24.5)	8 (4.0)		0 (0.0)	57 (28.5)	
Category 3	0 (0.0)	120 (60.0)		120 (60.0)	0 (0.0)	
NIV to IV transition			0.027			< 0.001
Nil	35 (17.5)	70 (35.0)		66 (33.0)	39 (19.5)	
No	12 (6.0)	56 (28.0)		54 (27.0)	14 (7.0)	
Yes	4 (2.0)	23 (11.5)		0 (0.0)	27 (13.5)	
Total	51 (25.5)	149 (74.5)		120 (60.0)	80 (40.0)	

Duration categories 1-3 are as coded in the study master chart. "NIV to IV transition" records whether a patient commenced on non-invasive support was subsequently escalated to invasive ventilation; "Nil" denotes patients for whom the transition was not applicable. Each pair of columns sums to 200.

Table 5: Duration of hospital stay and clinical outcome by ventilatory support group.

Characteristic Duration of hospital stay	NIV: Non (%)	NIV: Yes n (%)	P <0.001	IV: Non (%)	IV: Yes n (%)	P < 0.001
< 2 days	4 (2.0)	27 (13.5)		27 (13.5)	4 (2.0)	
3-5 days	13 (6.5)	90 (45.0)		87 (43.5)	16 (8.0)	
> 5 days	34 (17.0)	32 (16.0)		6 (3.0)	60 (30.0)	
Outcome			< 0.001			< 0.001
Good	12 (6.0)	147 (73.5)		120 (60.0)	39 (19.5)	
Poor	39 (19.5)	2 (1.0)		0 (0.0)	41 (20.5)	
Total	51 (25.5)	149 (74.5)		120 (60.0)	80 (40.0)	

Percentages are of the total cohort (n = 200). Each pair of columns sums to 200.

Non-invasive methods were used in 74.5% of cases, the majority of whom were in the 41-50 year age group (26.5%); invasive procedures were involved in 40% of cases, and the largest age group receiving invasive procedures was also 41-50 years (12.0%). Neither age nor gender nor body mass index was significantly associated with the form of support used. Among males 75.5% received non-invasive support and among females 73.3% did so, while 39.1% of males and 41.1% of females underwent invasive ventilation.

Where non-invasive support was not used, 2.0% of cases had a hospital stay of less than 2 days, 6.5% a stay of 3 to 5 days, and 17.0% a stay greater than 5 days; where it was used, the corresponding figures were 13.5%, 45.0%, and 16.0%. Where invasive support was not used, 13.5% had a stay of less than 2 days, 43.5% a stay of 3 to 5 days, and 3.0% a stay greater than 5 days; where it was used, the figures were 2.0%, 8.0%, and 30.0% respectively. Both associations were highly significant ($p < 0.001$).

Where non-invasive support was not used, a good outcome was achieved by only 12 patients (6.0% of the total) while 39 patients (19.5%) had a poor outcome. Where non-invasive support was used, a good outcome was achieved by 147 patients (73.5%) and only 2 patients (1.0%) had a poor outcome. Where invasive support was not used, a good outcome was seen in 120 patients (60.0%) and there were no poor outcomes.

Where invasive support was used, 39 patients (19.5%) had a good outcome and 41 patients (20.5%) experienced a poor outcome. Non-invasive methods therefore showed a much better rate of good outcome (73.5%) than invasive methods (19.5%), and the poor outcome rate was much higher where invasive methods were used (20.5%) than where the non-invasive approach was used; both associations were highly significant ($p < 0.001$). Patients with ARDS were more commonly managed with non-invasive methods (10.0% of the cohort) than with invasive procedures (5.0%).

Discussion

The analysis shows that the age group 41-50 years is the most common demographic for both non-invasive and invasive procedures, representing 26.5% of non-invasive cases and 12% of invasive cases, although in the present cohort this difference did not reach statistical significance ($p = 0.098$). This trend may reflect a higher prevalence of respiratory and related conditions in this age group, necessitating medical interventions. Research by Smith et al. also indicated that middle-aged adults aged 40 to 60 years have a higher incidence of requiring respiratory interventions due to the increasing prevalence of COPD and asthma in this age bracket [19].

A higher percentage of both males (75.5%) and females (73.3%) underwent non-invasive procedures compared to invasive methods (39.1% in males and 41.1% in females), with no significant difference between the genders ($p = 0.858$). This could be attributed to the initial preference for less invasive options, especially in cases where the condition is manageable without surgical intervention. In similar studies, such as that conducted by Jones et al., non-invasive procedures were predominantly preferred for initial treatment in respiratory conditions, especially in stable cases where invasive measures are seen as a last resort due to their higher associated risks [20].

The distribution of non-invasive and invasive procedures across BMI categories shows that overweight and obese individuals are more likely to require invasive interventions, although this association did not reach significance in the present cohort ($p = 0.061$). This aligns with the understanding that higher BMI is associated with a greater risk of severe respiratory complications. A study by Brown et al. demonstrated that obesity significantly increases the likelihood of complications during respiratory infections, thus making invasive interventions more frequent among obese patients[21].

A significant portion of non-invasive procedures fell into the longest duration category (60.0%), compared to 40.0% for shorter durations, and for invasive procedures a similar pattern was observed, with longer durations being more common ($p < 0.001$). Additionally, non-invasive procedures generally resulted in shorter hospital stays, with 13.5% of non-invasive cases discharged in less than 2 days compared to only 2% of invasive cases ($p < 0.001$). This observation is consistent with findings from Lee et al., who reported that non-invasive ventilation often results in shorter hospital stays due to reduced risks of complications compared to invasive procedures, which are associated with longer recovery times [22].

The data indicate that non-invasive methods are associated with a higher rate of good outcomes (73.5%), compared to invasive methods where a considerable percentage (20.5%) had poor outcomes, and this was the strongest association observed in the study ($p < 0.001$). This difference can be attributed to the less traumatic nature of non-invasive methods and their reduced risk of

infection. Several studies, including those by Patel et al., have highlighted that non-invasive ventilation is associated with fewer complications and better overall outcomes in patients with moderate respiratory distress compared to those undergoing invasive mechanical ventilation, particularly in cases where the patient's condition can be managed without intubation [23]. Patients with ARDS were more commonly managed with non-invasive methods (10%) compared to invasive procedures (5%). However, invasive methods provided more definitive diagnoses for conditions like pulmonary tuberculosis and were preferred in more severe cases. Research by Wilson et al. indicated that non-invasive methods are increasingly used in managing ARDS patients to avoid the complications associated with mechanical ventilation, especially in settings where the patient's respiratory effort is deemed sufficient to prevent further decline [24].

Conclusions

The choice between non-invasive and invasive ventilatory support in patients with respiratory failure is influenced by the underlying cause of respiratory distress, the severity of the condition, and patient-specific factors. While non-invasive ventilation offers advantages such as reduced complications and shorter intensive care unit stays, its effectiveness is limited in severe hypoxaemic respiratory failure, where invasive ventilation may be more beneficial. The overall higher success rate of non-invasive methods, alongside a preference for these methods in both genders and across various BMI categories, supports their continued use as the first line of treatment for respiratory conditions. Future studies should focus on refining patient selection criteria for non-invasive ventilation and on optimising invasive ventilation strategies and patient selection for invasive procedures, so as to reduce associated complications and improve patient outcomes.

Ethics approval and consent to participate

All participants were provided with a study information sheet, and written informed consent was obtained from every participant before inclusion; consent documentation was available in both English and Tamil. Participation was voluntary, participants were free to withdraw at any time without any effect on their future treatment at the hospital, and the privacy and confidentiality of participants were maintained throughout. No personally identifiable information is shared in this publication.

List of abbreviations

ABG, arterial blood gas; ARDS, acute respiratory distress syndrome; ARF, acute respiratory failure; BiPAP, bilevel positive airway pressure; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CPAP, continuous positive airway pressure; ICU, intensive care unit; IV, invasive mechanical ventilation;

NIV, non-invasive ventilation; NPPV, noninvasive positive pressure ventilation; $PaCO_2$, partial pressure of arterial carbon dioxide; PaO_2, partial pressure of arterial oxygen; PTB, pulmonary tuberculosis; SpO_2, peripheral oxygen saturation.

Data Availability

The data supporting the findings of this study consist of the coded master chart of all 200 enrolled patients, together with the key defining each coded variable. These data are held by the Department of General Medicine, Government Villupuram Medical College and Hospital, Villupuram, Tamil Nadu, India, and are available from the corresponding author on reasonable

request. The data are not publicly deposited in order to protect participant confidentiality.

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