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Research paper

Nursing evaluation during treatment with helmet continuous positive airway pressure in patients with respiratory failure due to COVID-19 pneumonia: A case series

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ABSTRACT

Background: During COVID-19 outbreak, with the increasing number of patients presenting with acute respiratory failure, a large use of non invasive positive pressure ventilation was done in the emergency departments and medical wards despite the lack of recommendations.
Objectives: This study describes the clinical characteristics of patients presenting to the hospital with acute respiratory failure due to COVID-19 related pneumonia undergoing treatment with helmet continuous positive airway pressure (CPAP) with a strict nursing evaluation and monitoring.
Methods: A case series study enrolling adult patients admitted to an emergency department of an Italian hospital with acute respiratory failure due to COVID-19 pneumonia from March 18th to April 18th, 2020, was conducted. Only patients who strictly followed a local CPAP protocol were enrolled.
Results: A total of 52 patients were included in this study. Thirty-eight patients (73%) were judged eligible for endotracheal intubation (ETI). Eighteen (34.6%) were intubated. Sixteen (30.8%) patients died: seven (38.9%) and nine (26.5%) in the eligible-for-ETI and non eligible-for-ETI group, respectively. The median hospital length of stay was different in the ETI and non-ETI group: 26 days (interquartile range [IQR]: 16–37) vs 15 days [IQR 9–17] ($p = 0.005$). The median invasive mechanical ventilation time was 11 days [IQR 7–21] with an ICU length of stay of 14.5 days [IQR 10–28]. During the CPAP trial, among patients eligible for ETI variations over time for positive end-expiratory pressure ($p = 0.003$) and respiratory rate ($p = 0.059$) were found between intubated and non-intubated patients.
Conclusions: A short closed monitored CPAP trial could be considered for acute respiratory failure due to COVID-19 pneumonia before considering ETI. A progressive positive end-expiratory pressure titration should target reduction in a patient's respiratory rate. More studies are needed to evaluate the efficacy and predictors of failure of CPAP and non-invasive positive pressure ventilation in patients with acute respiratory failure due to COVID-19 pneumonia.

1. Introduction

With the exponential rise in the number of patients with coronavirus disease 2019 (COVID-19), hospitals have had to face an increasing number of patients presenting with hypoxemic respiratory failure, with a demand of mechanical support and endotracheal intubation (ETI) higher than normal, often exceeding available resources. Fifteen percent of patients with COVID-19 develop severe respiratory failure, with a rate highly dependent on the patient's age and comorbidities such as obesity, diabetes mellitus, hypertension, and chronic pulmonary disease.[1] Estimated overall case fatality varies from 1.4% in patients younger than 60 y to 4.5% in those aged 60 y and older.[2] Patients with COVID-19 pneumonia present an atypical form of acute respiratory distress syndrome (ARDS). The first phases of the disease are characterised by a severe hypoxaemia associated with preserved lung compliance ("silent" hypoxemia).[3,4] The severe

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hypoxaemia is likely due to the loss of hypoxic pulmonary vasoconstriction, with a remarkable hyperperfusion of gasless tissue, and impaired regulation of pulmonary blood flow, with ventilation/perfusion (VA/Q) mismatch. Positive end-expiratory pressure (PEEP) and prone positioning can improve oxygenation through recruitment of collapsed areas and redistribution of pulmonary perfusion, improving the VA/Q ratio. In many patients, the disease stabilises at this first stage, whereas in others, about 20–30%, it may worsen to a clinical picture similar to ARDS, with bilateral CT consolidations and low compliance.[5] Evidence on noninvasive positive pressure ventilation (NIPPV) in acute respiratory failure (ARF) due to viral pneumonia is lacking, and its use is still of uncertain benefit.[6,7] Data from observational studies on the use of NIPPV in influenza A (H1N1) viral pneumonia showed a variable successful rate between 40.7% and 48%.[8–10] Some studies reported an increased ICU mortality in patients who failed NIPPV trial compared with early invasive mechanical ventilation (IMV), whereas NIPPV success resulted in shorter hospital stay. A high rate of NIPPV failure (92.4%) was reported in critically ill patients with the Middle East respiratory syndrome.[1,8,9] Owing to the lack of randomised controlled trials, no recommendations are offered on NIPPV use in these patients, but according to data from observational studies, a cautious NIPPV trial in selected patients and in a protected environment and experienced centres can be tried.

The application of a PEEP during ARF secondary to pneumonia has been demonstrated to improve arterial oxygenation by increasing functional residual capacity, to shift the tidal volume to a more compliant part of the pressure–volume curve and to reduce the work of breathing.[1,8,9] Furthermore, it recruits nonaerated alveoli in dependent pulmonary regions, stabilises the airways, and reduces the heterogeneity of lung volume distribution.[11] During the COVID-19 pandemic, NIPPV with helmet continuous positive airway pressure (CPAP) was largely used to support patients with ARF in emergency departments (EDs) and medical wards, to manage the large number of affected patients. Improved tolerability of the helmet and a reduced room contamination compared with oronasal masks may improve clinical management of patients and also increase the safety of healthcare workers.[12] Despite the relative simplicity of setting up a helmet CPAP, the need for attentive and careful monitoring of the respiratory and haemodynamic response to the application of PEEP should be part of the standard operating procedures of the unit. Extensive use of NIPPV has been used to support patients with COVID-19–related respiratory failure, despite the lack of evidence. A progressive PEEP titration targeting the patient's SpO_2 improvement and respiratory rate (RR) reduction with a close medical and nursing monitoring of the patient's clinical response is mandatory in the ED to identify patients likely to respond to CPAP treatment. The aim of this study was to describe the clinical characteristics of patients presenting to the ED with ARF due to COVID-19–related pneumonia undergoing treatment with helmet CPAP with a strict nursing evaluation and monitoring.

2. Methods

2.1. Study design, setting, and ethics approval

This was a retrospective case series study enrolling adult patients admitted to the ED from March 18th to April 18th, 2020, with ARF due COVID-19 pneumonia. The study was approved by the local ethical committee. Owing to retrospective and deidentified data collection, the need for informed consent was waived.

2.2. Participants

Patients admitted to the ED with ARF due to COVID-19 pneumonia treated with helmet CPAP were included in the study. Diagnosis of COVID-19 pneumonia was made if typical computed tomography (CT) scan patterns were present (ground-glass opacities, crazy-paving pattern, consolidations) and a SARS-CoV2 infection was confirmed by positive real-time reverse transcriptase–polymerase chain reaction assay of nasopharyngeal swab.[13]

2.2.1. Inclusion and exclusion criteria

The inclusion criteria were as follows: age 18 years or older, diagnosis of COVID-19–related pneumonia, a preserved state of consciousness[14] (Kelly score 1 or 2) and stable haemodynamics, SpO_2 level <94%, and RR ≥ 28, despite 5-L/min oxygen administration through a nasal cannula or face mask. In accordance with the local protocol, all these patients started a trial of helmet CPAP (Fig. 1).

Exclusion criteria were as follows: the achievement and maintenance of a $SpO_2 \geq 94\%$ and RR < 28 with standard O_2 support (5 L/min of O_2 administered with a nasal cannula or face mask); the need for immediate ETI for cardiovascular arrest, impaired and ineffective respiratory mechanics (e.g., agonic breathing and thoracic-abdominal dyskinesia); haemodynamic instability or severe arrhythmias; altered state of consciousness (Kelly score ≥3); contraindications to CPAP (severe bleeding of the upper digestive tract, vomiting, inability to protect the airways; recent surgery on

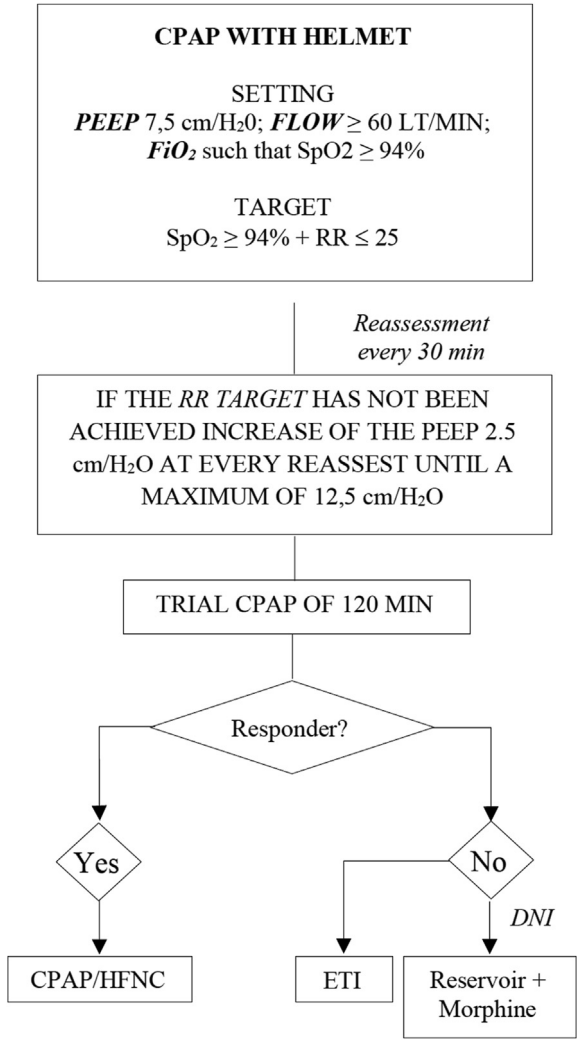

Fig. 1. *Local protocol for helmet CPAP trial.* Abbreviations: CPAP, continuous positive airway pressure; DNI, Do-Not-Intubate; ETI, endotracheal intubation; FiO_2, fraction of inspired oxygen; HFNC, high-flow nasal cannula; PEEP, positive end-expiratory pressure; RR, respiratory rate; SpO_2, peripheral oxygen saturation.

the skull or oesophagus; trauma and craniofacial burns; undrained pneumothorax). Patients with symptoms and radiological imaging suggestive for COVID-19 pneumonia but no microbiological confirmation were also excluded. All patients were followed up from the day of hospital admission to the day of hospital discharge or death.

2.2.2. CPAP local protocol

CPAP was delivered through helmet and high-flow-generating devices as the first choice. According to the local operative flow-chart, initial settings were a PEEP of 7.5 cm/H_2O, a flow $\geq$60 L/min, and an FiO_2 titrated to reach an $SpO_2 \geq 94\%$ and an RR $\leq$ 25 breaths per minute. PEEP was increase by 2.5 cm/H_2O up to a maximum of 12.5 cm/H_2O in case of failure to reach the RR established target. The CPAP trial lasted 120 min (Fig. 1). Alternatively, in patients with risk of muscular exhaustion (e.g., history of chronic obstructive pulmonary disease, neuromuscular disease), a trial of Bi-PAP was started with a face mask.[15]

If an $SpO_2 \geq 94\%$ and an RR $\leq$ 25 min were reached after the 120-min trial, CPAP treatment was continued alternating with a high-flow nasal cannula, maintaining continuous vital signs monitoring. In case of failure to reach the established targets after 120 min of the CPAP trial, patients were evaluated for early ETI if they were candidates for the ICU. In patients with a Do-Not-Intubate (DNI) order, the choice to continue helmet CPAP or shift to standard O_2 therapy and start palliative care depended on clinician evaluation.[15]

2.3. Data collection

Demographics, comorbidities, time from symptoms onset, arterial blood gases, and clinical and laboratory findings on admission were recorded. SpO_2, RR, PEEP, FiO_2 and body temperature were recorded before the CPAP trial was started and then every 30 min, until the end of the trial (t0 - t30 – t60 – t90 – t120). ETI was performed according to clinical judgment of the ICU specialist. Patients not considered eligible for ETI due to their age and comorbidity and the severity of the disease received a DNI order after the evaluation by an ICU specialist in consultation with the emergency physician. Data on time from the beginning of the CPAP trial to ETI together with data on duration of NIPPV (intended as cycles of CPAP or Bi-PAP longer than 6 h for day) or of IMV were collected. Pharmacological treatment was also recorded.

2.4. Statistical analysis

No statistical sample size calculation was performed a priori, and sample size was equal to the number of patients treated with helmet CPAP during the study period. Sociodemographic variables and clinical data were reported as absolute and relative frequencies for categorical variables, while for numerical ones, the mean and the corresponding standard deviation (SD) or median and interquartile range (IQR) were reported, as appropriate. The percentage of subjects who required invasive mechanical ventilation and died were calculated with their 95% confidence interval (95% CI). To explore the risk factors associated with ETI, the χ^2 test or Fisher's exact test and the student or Mann–Whitney U test were used to compare the sociodemographic and clinical variables with the use of IMV. To better understand the time trend of parameters related to the use of CPAP (FiO_2, PEEP, RR, and SpO_2), graphical representations were done using mixed models, which take into account for repeated measures within subjects. The same models, adding as covariate the use of ETI, were also performed to evaluate if significant changes between groups were observed. Survival curves were plotted using the Kaplan–Meier method and compared between patients with vs without ETI using the log-rank test. A two-sided α of less than 0.05 was considered statistically significant. Statistical analyses were performed using the SAS software (version 9.4).

3. Results

In the period from 18, March, 2020, to 18, April, 2020, a total of 52 patients met the study inclusion criteria. The median age was 62.5 years (IQR, 50–72.50 years), and 40 (76.9%) were male. The most commonly self-reported symptoms at illness onset were fever followed by dyspnoea and cough. Thirty-eight (73%) patients had at least one comorbidity, with hypertension, obesity, and cardiomyopathy being the most prevalent. The median waiting time from the first ED evaluation to the beginning of CPAP treatment was 118 min [IQR, 79–216], with a minimum of 9 min to a maximum of 911 min. Eleven subjects (21.15%) received morphine in the first 2 h of the CPAP trial.

Thirty-eight (73%) were judged eligible for ETI, of which 18 were intubated (34.62%; 95% CI, 21.68–47.55) (Fig. 2). No differences in demographics, clinical features, and laboratory findings were found between subjects undergoing ETI compared with the others, except for P/F ratio (103 vs 214, $p = 0.03$) (Table 1). For these 18 patients, the median time lapse between hospital admission and ETI was 2 days [IQR, 1–6] with a range from a minimum of 1 to a maximum of 30 days.

The CPAP-related parameters (PEEP, FiO_2, RR, and SpO_2) and their variation over time analysed for patients eligible for ETI are shown in Fig. 3. Considering the models with ETI as a covariate, changes between the two groups were found for PEEP ($p = 0.003$) and RR ($p = 0.059$). No significant changes were found for FiO_2 ($p = 0.245$) and SpO_2 ($p = 0.076$).

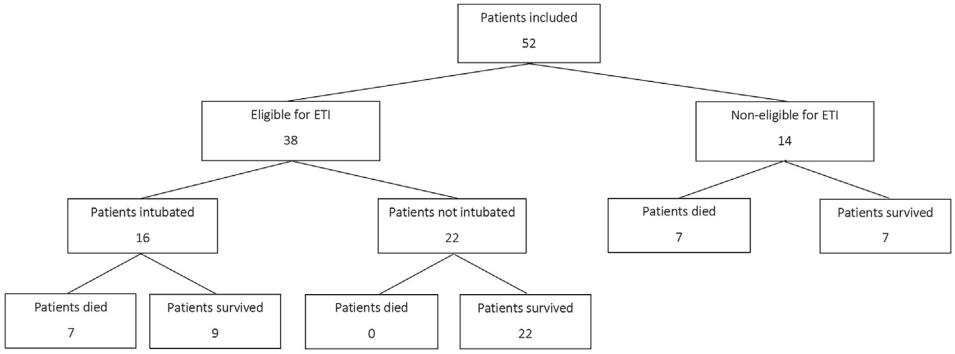

Fig. 2. *Flow diagram of case series.* Abbreviations: ETI, endotracheal intubation.

A total of 16 (30.8%; 95% CI, 18.22–43.31%) subjects died: seven (38.9%) and nine (26.5%) in the eligible-for-ETI and noneligible-for-ETI group, respectively. Considering only patients eligible for ETI, ETI patients had significant higher mortality rate than the others (N = 7, 38.9% *vs* N = 0; p = 0.002).

The median length of stay in hospital was different in subjects with and without ETI: 26 days [IQR, 16–37] vs 15 days [IQR, 9–17], respectively (p = 0.005). The median CPAP time was 4.50 days [1–7], ranging from 1 to 14 days. The median IMV time was 11 days [IQR, 7–21] with an ICU length of stay of 14.5 days [IQR, 10–28].

4. Discussion

To our knowledge, this is the first reported case series study of patients with ARF due to COVID-19 describing a strict nursing evaluation and monitoring during a standardised CPAP trial in the ED and subsequent patients' outcomes.

Fifty-two patients were included in the study. The population enrolled was similar in terms of comorbidities and clinical features to other studies populations of patients with COVID-19 described in literature.[1,16] Median time from symptoms onset and hospital admission was 7 days [IQR, 5–10], whereas only 1 [0–3] from dyspnoea onset. Delayed hospital presentation was in part due to the attempt to manage patients at home. The late appearance of dyspnoea might be due to the typical normal pulmonary compliance in the first phases of the disease and the initial "silent hypoxia".[3,4] All patients had severe or moderate ARF, and most started CPAP treatment within 3 h of hospital admission; few started CPAP later owing to progressive worsening of respiratory failure during ED observation. Seventy-three percent were eligible for ETI. The ETI

Table 1
Demographics, clinical features, laboratory findings, and treatments stratified as for endotracheal intubation (ETI) and non-ETI groups.

Variable	All (N = 52)	ETI (N = 18)	Non-ETI (N = 34)	p-values
Gender				
Female, mean (SD)	12 (23.08)	4 (22.22)	8 (23.53)	0.999
Male, mean (SD)	40 (76.92)	14 (77.78)	26 (76.47)	
Age (years)				
Median [IQR]	62.50 [50–72.50]	57 [51–67]	66 [48–75]	0.265
Comorbidities				
None, number (%)	14 (26.92)	5 (27.78)	9 (26.47)	0.919
At least one, number (%)	38 (73.08)	13 (72.22)	25 (73.53)	
Hypertension, *number (%)*	23 (44.23)	8 (44.44)	15 (44.12)	
Obesity, *number (%)*	14 (26.92)	7 (38.89)	7 (20.59)	
Cardiomyopathy, *number (%)*	9 (17.31)	1 (5.56)	8 (23.53)	
Diabetes, *number (%)*	8 (15.38)	4 (22.22)	4 (11.76)	
Lung disease, *number (%)*	8 (15.38)	1 (5.56)	7 (20.59)	
Vasculopathy, *number (%)*	5 (9.62)	1 (5.56)	4 (11.76)	
Immunosuppression, *number (%)*	4 (7.69)	1 (5.56)	3 (8.82)	
Rheumatoid arthritis, *number (%)*	3 (5.77)	0 (0.00)	3 (8.82)	
Chronic renal failure, *number (%)*	2 (3.85)	0 (0.00)	2 (5.88)	
Malignancy, *number (%)*	1 (1.92)	0 (0.00)	1 (2.94)	
Symptoms				
Dyspnoea, *number (%)*	49 (94.23)	18 (100.00)	31 (91.18)	
Fever, *number (%)*	48 (92.31)	17 (94.44)	31 (91.18)	
Cough, *number (%)*	22 (42.31)	9 (50.00)	13 (28.24)	
Asthenia and/or myalgia, *number (%)*	6 (11.54)	3 (16.67)	3 (8.82)	
Gastrointestinal, *number (%)*	5 (9.62)	2 (11.11)	3 (8.82)	
Time from symptoms onset to hospital admission, days, *median [IQR]*	7 [5–10]	8 [4–10]	7 [5–10]	0.855
Time from dyspnoea onset to hospital admission, days, N = 49, *median [IQR]*	1 [0–3]	0.50 [0–3]	1 [0–4]	0.759
Treatment in hospital				
None, number (%)	7 (13.46)	4 (22.22)	3 (8.82)	0.218
At least one, number (%)	45 (86.54)	14 (77.78)	31 (91.18)	
Hydroxychloroquine, *number (%)*	40 (76.92)	12 (66.67)	28 (82.35)	
Steroid, *number (%)*	28 (53.85)	10 (55.56)	18 (52.94)	
Kaletra, *number (%)*	24 (46.15)	11 (61.11)	13 (38.24)	
Azithromycin, *number (%)*	19 (36.54)	1 (5.56)	18 (52.94)	
Tocilizumab, *number (%)*	9 (17.31)	5 (27.78)	4 (11.76)	
Morphine, *number (%)*	11 (21.15)	2 (11.11)	9 (26.47)	
Laboratory findings				
C-reactive protein, g/dL, *mean (SD)*	12.75 (7.7–18.8)	13.85 (9.3–17)	10.15 (7.1–19.3)	0.545
White blood cells, cell/L^{-1}, *mean (SD)*	8.55 (6.6–10.23)	8.25 (6.66–10.15)	8.55 (6.59–10.78)	0.870
Lymphocytes, cell/L^{-1}, *mean (SD)*	4.8 (0.9–12.85)	2.58 (0.71–12.9)	5.3 (0.99–12.5)	0.637
Platelets, cell/L^{-1}, *mean (SD)*[1]	220 (188.5–264)	233 (201–316)	215 (172–254)	0.062
Creatinine, mg/dL, *mean (SD)*	0.91 (0.77–1.22)	0.87 (0.77–1.17)	1.01 (0.77–1.34)	0.322
Total bilirubin, mg/dL, *mean (SD)*	0.59 (0.46–0.78)	0.67 (0.47–0.78)	0.56 (0.42–0.76)	0.672
INR, *mean (SD)*	1.21 (1.13–1.28)	1.17 (1.13–1.24)	1.22 (1.13–1.29)	0.429
aPTT ratio, *mean (SD)*	1.15 (1.05–1.27)	1.15 (1.05–1.36)	1.15 (1.05–1.26)	0.923
pH, *mean (SD)*	7.47 (7.44–7.5)	7.48 (7.44–7.5)	7.47 (7.43–7.5)	0.403
pCO_2, mmHg, *mean (SD)*	31 (29–36)	30.8 (29–33)	33 (29–36)	0.325
pO_2, mmHg, *mean (SD)*	67.9 (52.5–83.85)	70 (53–79)	65 (52–92)	0.965
FiO_2, *mean (SD)*	0.65 (0.21–0.8)	0.8 (0.21–0.8)	0.45 (0.21–0.8)	0.140
PaO_2/FiO_2 ratio, *mean (SD)*	143.5 (86–252.19)	103.38 (85–147)	214 (101–290)	0.030
SpO_2, %, *mean (SD)*	94 (89–96)	94.8 (89–96)	92 (89–97)	0.922

Abbreviations: aPPT ratio, activated partial thromboplastin time; FiO_2, fraction of inspired oxygen; INR, international normalised ratio; IQR, interquartile range; $PaCO_2$, arterial carbondioxide; PaO_2, arterial oxygen; SD, standard deviation; SpO_2, peripheral oxygen saturation.

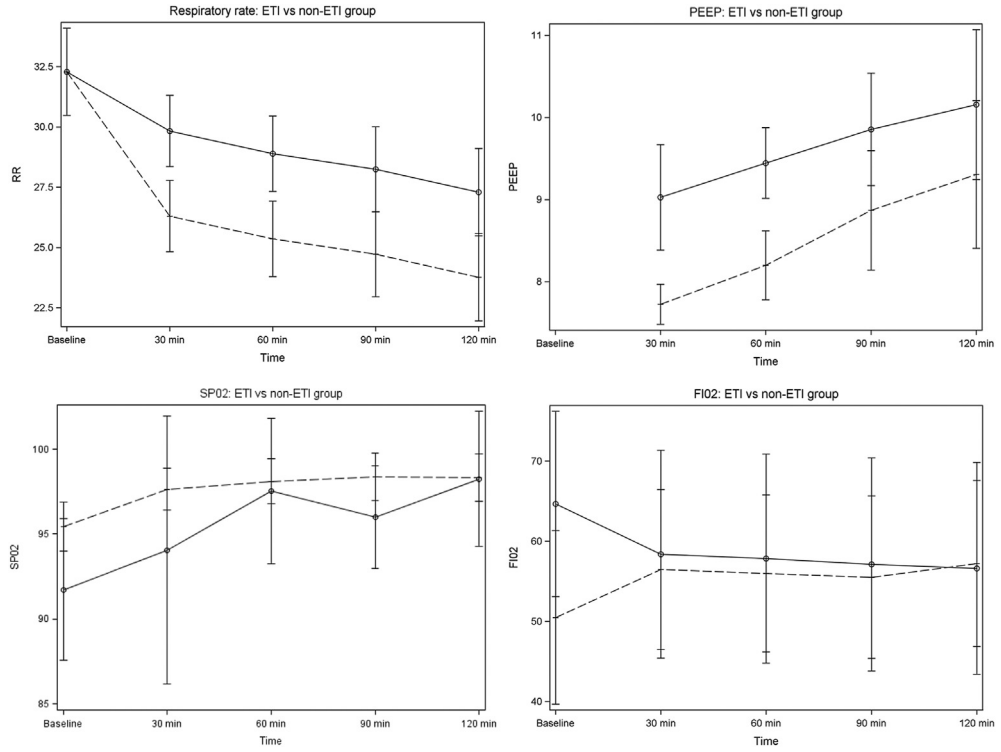

Fig. 3. *Respiratory rate, PEEP, SpO_2, and FiO_2 values over time in endotracheal intubation (ETI, solid line) and non-ETI patients (dash line).* Abbreviations: ETI, endotracheal intubation; FiO_2, fraction of inspired oxygen; PEEP, positive end-expiratory pressure; SpO_2, peripheral oxygen saturation.

rate was 34.6%, concordant to other case series even if still few data on NIPPV failure in these patients are available.[17] Patients who were intubated had a lower P/F ratio than those treated only with NIPPV. ETI was performed with a median time lapse of 2 days. When ETI was not performed immediately after the CPAP trial, the delay was never due to the CPAP treatment prolongation but to a subsequent worsening of respiratory failure or to a lack of resources available. General mortality was 30.7% with no significant differences between ETI and non-ETI patients. All patients eligible for ETI but treated only with CPAP survived. The mortality rate was similar to other study populations even if a comparison is not easy owing to differences in disease severity among different studies groups.[1–17] A significant difference in the median length of hospital stay hospital resulted between ETI and non-ETI patients, 26 days [IQR, 16–37] vs 15 days [IQR, 9–17], respectively ($p = 0.005$), certainly due, in addition to initial patients' severity, to complications related to IMV and ICU stay. We decided to evaluate CPAP-related parameters and their variation on time only in patients eligible for ETI to assess whether an early RR improvement with a step-up PEEP titration could be useful in identifying *PEEP responder* patients treatable without IMV. Patients with an early respiratory rate improvement likely have a prevalent hypoxic stimulus on respiratory drive, which is reduced by correcting hypoxia through alveolar recruitment and oxygenation. We found that non-ETI patients, while using a lower mean PEEP, had a sharper and faster decline in RR after starting the CPAP trial. We think that a nursing evaluation and close monitoring of respiratory parameters, in particular RR, should be done when a CPAP trial is started, to identify patients likely to respond (or not) to CPAP treatment. Our study has some limitations owing to its retrospective and single-centre study design. The results must be considered cautiously owing to the small sample of patients evaluated. On the other hand, its strength and novelty lie on the application of a local protocol for the use of helmet CPAP to treat patients with COVID-19 and a strict nursing evaluation and monitoring in the first hours of CPAP treatment. We standardised the initial approach to patients with COVID-19 presenting with ARF to the ED, proposing a progressive up titration of PEEP to increase SpO_2 and lower RR.

5. Conclusions

A first short closed monitored CPAP trial, with a strict nursing evaluation and monitoring, could be considered for ARF due to COVID-19 pneumonia before considering ETI. A progressive PEEP titration should target a patient's SpO_2 improvement and RR reduction. A rapid RR decrease could help to identify patients likely to respond to CPAP treatment. More studies are needed to evaluate the efficacy and predictors of failure of CPAP and NIPPV in patients with ARF due to COVID-19 pneumonia.

Consent to participate

Informed consent was waived owing to the retrospective and observational nature of the study according to the Italian law on observational studies.

Availability of data and material

The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Conflict of Interest

None.

CRediT authorship contribution statement

DP, NC and LA: Conceptualisation, Methodology; CA: Software and Data curation; PD and NC: Original draft preparation; PD, AM, FP and RE: Visualisation, Investigation; PD, NC and LA, Supervision; CA: Software, Validation; All Authors: Writing-Reviewing and Editing.

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