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Effects of Noninvasive Mechanical Ventilation in COVID-19 Patients

COVID-19 Hastalarında Noninvazif Mekanik Ventilasyonun Etkileri

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ABSTRACT

The aim of this study was to examine the results of NIMV applied with a full face mask in COVID-19 patients.

A descriptive and cross-sectional study. The study was conducted in the 1st level COVID-19 Intensive Care Unit of a university training and research hospital between August 15 and November 15, 2021. The study included 31 critical care patients who agreed to participate in the study and met the sampling criteria. The data was collected by the third researcher using the questionnaire based on the literature.

The mean age of patients was 68.90±9.97 (41-82) years. In the measurements before NIMV, after the first application and after 24-h, a statistically significant difference was found between measurements in terms of SpO_2 scores ($p<0.001$). In venous blood gas measurements before and 24-h after NIMV, a statistically significant difference was found between the measurements in terms of PCO_2 scores ($p<0.05$).

The study findings showed that NIMV was effective in terms of SpO_2 and venous PCO_2 scores in COVID-19 patients. It can be used as an effective option in the management of acute hypoxemic respiratory failure in COVID-19 patients.

Keywords: COVID-19, noninvasive mechanical ventilation, critical care, patient

ÖZ

Bu çalışmanın amacı, COVID-19 hastalarında tam yüz maskesi ile uygulanan NIMV sonuçlarının incelenmesidir.

Tanımlayıcı ve kesitsel bir çalışmadır. Bu çalışma bir üniversite eğitim ve araştırma hastanesinin 1. basamak COVID-19 Yoğun Bakım Ünitesinde 15 Ağustos-15 Kasım 2021 tarihleri arasında yapıldı. Araştırmanın örneklemini araştırmaya katılmayı kabul eden ve örneklem kriterlerine uyan 31 yoğun bakım hastası oluşturdu. Veriler literatür doğrultusunda hazırlanan anket kullanılarak üçüncü araştırmacı tarafından toplandı.

Bulgular: Hastaların yaş ortalaması 68.90±9.97 (41-82) idi. NIMV öncesi, ilk uygulama sonrası ve 24 saat sonra yapılan ölçümlerde SpO_2 skorları açısından ölçümler arasında istatistiksel olarak anlamlı fark bulundu ($p<0.001$). NIMV öncesi ve 24 saat sonra venöz kan gazı ölçümlerinde PCO_2 skorları açısından ölçümler arasında istatistiksel olarak anlamlı fark bulundu ($p<0.05$).

Çalışma bulguları, NIMV'nin COVID-19 hastalarında SpO_2 ve venöz PCO_2 skorları açısından etkili olduğunu göstermiştir. COVID-19 hastalarında akut hipoksemik solunum yetmezliğinin tedavisinde etkili bir seçenek olarak kullanılabilir.

Anahtar Kelimeler: COVID-19, noninvazif mekanik ventilasyon, yoğun bakım, hasta

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INTRODUCTION

A new coronavirus called SARS-COV-2, which started in Wuhan, China in December 2019 and has a high transmission rate, caused the disease and spread all over the world. The most feared aspect of this disease is that it is highly contagious, causes pneumonia in 20% of patients, and also requires critical care and mechanical ventilation support (MV) in approximately 5-10% of these patients.[1]

Patients in COVID-19 disease are monitorized in the intensive care unit (ICU).[2] According to the COVID-19 guide of the Ministry of Health in Turkey dated April 14, 2020; dyspnea and respiratory distress, respiratory rate ≥28/min, SpO_2 <93% and PaO_2/FiO_2 <300 despite nasal oxygen support of 5 liters/min and above, PaO_2 <60 mmHg, with clinical worsening, bilateral infiltrates on chest X-ray or tomography, or involvement in multiple lobules or an increase in their infiltrates compared to previous imaging findings require ICU admission. The patients with hypotension or vasopressor requirement, skin perfusion disorders, lactate >4 mmol/L, ≥2 units increase in SOFA score, elevated cardiac enzymes (Troponin) or arrhythmia, macrophage activation syndrome (MAS) also admitted to the ICU.[3]

Of the patients admitted to the ICU and developing COVID-19 pneumonia, 14% received oxygen therapy due to severe respiratory failure and 5% received MV.[4] A respiratory rate >30/min, SpO_2 <93% in room air, and a heart rate >120/min indicate that respiratory failure is progressing and an increase in respiratory workload.[5] These patients may require oxygen therapy, high flow nasal oxygen (HNFO), noninvasive mechanical ventilation (NIMV) or invasive mechanical ventilation (IMV).[6]

There are two types of NIMV. These are CPAP and BIPAP (Bi-Level Positive Airway Pressure).[6] High flow nasal oxygen therapy (HFNO) differs in that, like CPAP, it involves the use of a nasal cannula to provide positive pressure to the airways.[7] CPAP is the preferred form of non-invasive ventilatory support in the management of the hypoxemic COVID-19 patient, with the evidence supporting the use of HFNO is still being debated, with conflicting guidance emerging.[6]

NIMV has become frequently used in patients with hypoxemic respiratory failure, although its success is low.[8-10] Therefore, NIMV can be applied to provide respiratory support to patients with active COVID-19 infection. There is increasing evidence that with improved CPAP equipment, it can benefit patients in the early stages of the disease process and completely reduce the need for IMV.[6] However, there are opinions that NIMV may increase transmission through droplets in viral infections.[10] For this reason, full face mask is preferred instead of nasal or oronasal mask to minimize particle dispersion in NIMV application. In addition, it has been suggested that helmet mask use is the most appropriate mask for administering NIMV to patients with COVID-19.[11-13] Due to the risk of aerosol formation, NIMV should be applied in negative pressure rooms if possible, and if this is not possible, in single rooms and full compliance with personal protective equipment.[2,10,14] However, continuous positive airway pressure (CPAP) application through a full face mask improves oxygenation and prevents intubation.[15,16] This study aimed to examine the results of NIMV applied with a full face mask in COVID-19 patients in the ICU.

MATERIAL AND METHOD

Design and setting

This descriptive and cross-sectional study was carried out in the 1st level COVID-19 intensive care unit of a university hospital in Turkey, between August and November 2021.

Sample

The study included 31 critical care patients. The inclusion criteria for the study were patients with SpO_2 <93% despite nasal oxygen support of 5 liters/min and had with respiratory distress symptoms (dyspnea, tachypnea). Patients who needed emergency endotracheal intubation and had <60 min NIMV duration and had impaired hemodynamic status (vasopressor support, cardiac rhythm disturbances) were excluded from the study.

Data collection

The data questionnaire form consisted of 3 parts. In the first part, the descriptive characteristics of the patients (age, gender, smoking, presence of comorbidity, etc.) were included. The second part included physiological parameters such as body temperature, systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), respiration rate (RR), oxygen saturation (SpO_2) and level of consciousness (Glasgow Coma Scale). The third part included variables such as venous blood gas and ventilator parameters. Arterial blood gas results could not be specified because the patient was followed up by venous blood gas monitoring in the ICU where the research was conducted. These parameters were recorded from the nurse observation forms.

Data analysis

The data analysis was performed using SPSS Statistics software for Microsoft Windows XP. version 21. The descriptive statistics were used for sample characteristics. The differences between measurements were analysed using RM-ANOVA and t-test for dependent samples.

Ethical aspects and conflict of interest

This study was approved by the ethics committee (date: 14.04.2021, number: 2021/3). All participants were informed about study and confidentiality.

Study limitations

This study has several limitations. The principal limitation of our study is that it is a single center study with a relatively small number of patients. Therefore, this study might not be generalizable to other centers. This study is purely descriptive, and all enrolled patients were being treated with NIMV; hence, it is not possible to draw conclusions regarding the superiority or inferiority of NIMV to other forms of support (e.g, standard oxygen therapy or IMV). Third, the follow-up periods of this study were 24-h, and so further research is needed to identify long-term effects of NIMV.

RESULTS AND DISCUSSION

The mean age of patients was 68.90±9.97 (41-82) years. Of the 31 patients in the study, 51.6% were male, 16.1% were current smoker, 61.3% had hypertension and 45.2% had diabetes mellitus when their comorbid diseases were examined. The length of stay of the patients in the ICU was determined as 5.96 ± 3.85 days (Table 1).

Table 1. Descriptive Characteristics of Patients (n=31)

Characteristics	n	%
Age, years (mean ± SD)	68.90 ± 9.97	(range: 41-82)
The length of ICU, days (mean ± SD)	5.96 ± 3.85	(range: 2-20)
Gender		
Female	15	48.4
Male	16	51.6
Current smoker		
Yes	5	16.1
No	26	83.9
Comorbidity		
Hypertension	19	61.3
Diabetes Mellitus	14	45.2
Congestive heart failure	4	12.9
COPD*	3	9.7
Hepatic disease	1	3.2
Asthma	0	-
Cerebrovascular disease	0	-
Chronic renal failure	0	-

COPD: Chronic obstructive pulmonary disease

In the measurements before NIMV, after the first application and after 24-h, there was a statistically significant difference ($p<0.001$) between measurements in terms of SpO_2 scores while there was no statistically significant difference between the other measurements in terms of body temperature, SBP, DBP, MAP, HR, and RR ($p>0.05$) (Table 2).

Table 2. Physiological Parameters of Participants

Outcomes	Before NIMV	After the first NIMV	After 24-h	RM-ANOVA, F (*p*)
	Mean±SD	Mean±SD	Mean±SD	
Temperature, ^{0}C	36.53±0.32	36.54±0.39	36.62±0.29	F=.813; p=.448
SBP, mmHg	128.06±17.10	126.12±18.89	131.06±22.19	F=1.455; p=.242
DBP, mmHg	74.45±15.19	75.54±12.64	74.96±15.55	F=.099; p=.906
MAP, mmHg	76.19±14.30	75.74±12.76	80.25±14.78	F=2.142; p=.126
HR, beats/min	91.61±20.98	94.25±20.94	95.51±19.84	F=3.207; p=.051
RR, breaths/min	26.38±4.71	25.32±6.22	27.93±10.68	F=1.396; p=.256
SpO_2, %	79.74±8.19	90.64±5.43	82.03±7.31	F=88.647; p=.000*
				(1-2) (1-3) (2-3)
				.000 .015 .000
GKS	13.22±2.20	16.64±18.36	12.77±2.56	F=1.220; p=.303

*SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure; HR: Heart rate; RR: Respiration rate; SpO_2: Oxygen saturation; GKS: Glaskow coma scale; *p<0.001*

Venous blood gas measurements and ventilator parameters before and 24-h after NIMV, there was a statistically significant difference ($p<0.05$) between the measurements in terms of PCO_2 and FiO_2 scores while there was no statistical difference between the measurements in terms of pH, PO_2, SO_2 scores ($p>0.05$) (Table 3).

Table 3. Venous Blood Gas and Ventilator Parameters of Participants

Outcomes	Before NIMV	After 24-h	Test
	Mean±SD	Mean±SD	
Venous pH	7.28±0.66	7.34 ±0.37	t= -.434; p=.668
Venous PO_2, mmHg	46.22±.16.37	46.32 ±24.43	t= -.031; p=.976
Venous PCO_2, mmHg	49.57±.19.09	44.79 ±18.31	t= 3.115; p=.004*
Venous SO_2, %	60.40±.22.45	65.04 ±22.46	t= -1.378; p=.178
FiO_2, %	93.22±.16.61	75.00±21.56	t= 5.177; p=.000*
PEEP, cm H_2O	6.25±0.92	6.32 ±0.97	t= -1.000; p=.325

*PO_2: Venous partial pressure of oxygen; PCO_2: Venous partial pressure of carbon dioxide; SO_2: Venous oxygen saturation; FiO_2: Fraction of inspired oxygen; PEEP: Positive end expiratory pressure; *p<0.05*

A meta-analysis study before pandemic period demonstrated that NIMV reduced endotracheal intubation rates and hospital mortality in patients with respiratory failure with acute hypoxemia and hypercapnia, excluding COPD and cardiogenic pulmonary edema.[17] However, the use of NIMV in COVID-19 disease remains contentious, with evidence for and against still being gathered, analysed and disseminated.[6] NIMV can be applied in selected patient populations and where access to high-flow nasal cannulae is limited.[2] In this study, the physiological parameters. venous blood gas and ventilator parameters of COVID-19 patients who underwent NIMV were examined.

This study findings demonstrated that most of the COVID-19 infected critical care patients treated with NIMV were elderly and male patients. In addition, similar to our results, it was determined that the majority of the patients had at least one comorbidity such as hypertension, cardiovascular diseases and diabetes mellitus.[18-21]

COVID-19 is a multisystem disease that affects the respiratory system, cardiovascular system, renal and gastrointestinal system and even the central nervous system. Therefore, clinical and laboratory monitoring, which requires close monitoring of all systems, is of great importance during the critical care follow-up of these patients. Noninvasive or invasive arterial pressure, oxygen saturation, ECG, body temperature, and urine output should be monitored as standard monitoring parameters.[2] In this study, it was found to be statistically significant difference between the measurements in terms of SpO_2 scores and SpO_2 scores increased after NIMV considered in terms of physiological parameters. However, no statistically significant difference was found in other physiological parameters. SpO_2 score was reported that it should be above 90% and no higher than 96% in different guidelines. [4,22,23] Bellani et al. (2021) found that SpO_2 values were 94.6% in all patients after NIMV and 96.5% in patients in whom NIMV was successful.[20] The current study findings suggest that the use of NIMV in COVID-19 patients is feasible and can be considered as an effective way to improve oxygenation in patients who do not respond to conventional oxygen therapy. Continuous pulse oximetry should be followed in COVID-19 patients followed in the ICU, and vital and neurological signs should be monitored hourly. In addition, in cases where respiratory failure progresses, signs of respiratory failure (e.g, use of accessory respiratory muscles, mouth breathing, tachypnea and bradypnea) should be followed.[6]

Arterial blood gas measurement includes very valuable parameters in terms of providing appropriate respiratory support management in the patient.[2] However, since the patient was followed up by venous blood gas monitoring in the ICU where the research was conducted, the venous blood gas results were assessed in the measurements before and 24-h after the NIMV. In addition, studies concluded that there was a statistically high correlation between arterial and venous pH, PCO_2, HCO_3 scores, and venous and arterial

differences were around the 0 line.[24-26] The venous PCO_2 scores of patients were found to be significantly lower 24-h after NIMV in this study. Avdeev et al. (2021) found that the arterial PCO_2 scores were 37.9 mmHg (33.7–42.0) for all patients, 37.5 mmHg (33.6–41.4) in patients with NIMV-success, and 41.5 mmHg (34.5–46.3) in patients with NIMV-failure, however the authors reported that there was no statistical difference between the groups (p=0.276).[8] Contrary to our study findings, Menzella et al. (2021) stated that arterial PCO_2 scores increased statistically in the measurements after 72-h and 7 days (40.7±11.1, 39.9±5.8, respectively; p=0.006) in patients with NIMV.[27] Similarly, Bellani et al. (2021) reported that patients with NIMV-failure had lower $PaCO_2$ scores (36.6±7.2–37.9±6.6) associated with a higher incidence of dyspnea and accessory muscle use.[20] The authors concluded that these higher inspiratory efforts in patients were associated with respiratory impulse and work of breathing. However, the authors were unable to provide a clear conclusion as to the extent to which higher breathing work contributed to NIMV failure.[20] Studies have shown that the use of NIMV is significantly beneficial in patients with hypercapnia.[9,10,19,20] The findings of this study also suggest that these benefits are in the direction of NIV to improve hypercapnia.

As for recommendations on parameter settings, NHS (critical care) suggested that low-flow CPAP was suitable for patients with a lower oxygen requirement (fraction of inspired oxygen, FiO_2 <0.4).[28] In this study, FiO_2 scores were found to be as 75.00±21.56 24-h after the NIMV and statistically significant between measurements. Mukhtar et al. (2020) reported that the PaO_2/FiO_2 ratio was low [170 (112-224)] in patients treated with NIMV.[29] Menzella et al. (2021) in a study evaluating the effectiveness of NIMV found that the mean values (± standard deviation) of PEEP and FiO_2 were, respectively, 9.5 (±2.4), and 63.1 (±10.8).[27] Other studies have also shown that the FiO_2 scores in patients NIMV-success were statistically lower (61.2±8.6 vs 78.2±19.1; 50 (50–60) vs 60 (50–70)) compared to patients with NIMV-failure.[19-20] FiO_2 is the proportion of oxygen in the inspired air, and study findings suggest that NIMV improves FiO_2 scores.

CONCLUSION

The study findings demonstrated that NIMV was effective in terms of SpO_2 and venous PCO_2 scores in COVID-19 patients. The results demonstrated that SpO_2 scores were increased and venous PCO_2 scores were decreased 24-h after NIMV. In summary, the current study was shown that NIMV was feasible in patients with COVID-19 and it could be considered as a valuable option for the management in these patients. Due to the risk of aerosol formation, NIMV can be applied in negative pressure rooms if possible, and if this is not possible, in single rooms with maximum personal protective equipment. This study can be conducted in larger sample groups and by measuring arterial blood gas parameters.

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