Comparison of helmet and facial mask during noninvasive ventilation in patients with acute exacerbation of chronic obstructive pulmonary disease: a randomized controlled study

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Background/aim: Noninvasive mechanical ventilation (NIMV) is an approach to prevent complications in acute respiratory failure. In this study we aimed to compare the efficacy of a full face mask and a helmet in chronic obstructive pulmonary disease (COPD).

Materials and methods: Fifty patients were divided randomly into 2 groups as full face mask (Group F) and helmet (Group H). Demographic data, forced expiratory volume at 1 s (FEV1), additional disease, hemodynamic parameters, respiratory rate, APACHE II score, peripheral O_2 saturation (SpO_2), arterial blood gases (ABG), patient tolerance scale (PTS) score, and fraction of inspired oxygen (FiO_2) were recorded. Parameters were recorded as follows: 20 min before the NIMV; every 30 min of NIMV until 120 min; 30 min, 24 h, and 48 h after NIMV; and prior to intensive care unit discharge.

Results: The SpO_2, PTS, ABG, complication rate, and APACHE II scores were not different between the groups (P > 0.05). The decrease in $PaCO_2$ was statistically significant at 60 min in Group F (P < 0.05), and there was no statistical difference in Group H (P < 0.05) according to initial $PaCO_2$ values.

Conclusion: Both masks are efficient in improving the patients' outcome in COPD, but the decrease in $PaCO_2$ in the helmet group was slower than in the full face mask group.

Key words: Chronic obstructive pulmonary disease, noninvasive mechanical ventilation, helmet, full face mask

1. Introduction

Chronic obstructive pulmonary disease (COPD) is a preventable disease characterized by partially reversible airway obstruction (1). Acute exacerbations are the most important cause of morbidity and mortality in COPD. Recurrent episodes (2 to 3 attacks per year) are frequently observed in the course of COPD. Hypoxic and hypercapnic respiratory failure may develop due to COPD exacerbation (2). Invasive mechanical ventilation (IMV) is an option for management of COPD exacerbation, but its complication rate is quite high. The main complications are ventilator-associated pneumonia and tracheal damage and stenosis because of the endotracheal tube (3). Noninvasive mechanical ventilation (NIMV) is another option for the treatment of COPD exacerbation. NIMV via nasal-facial mask or helmet is a choice of therapy for the treatment of acute COPD exacerbation (4). The advantages of NIMV are maintenance of airway protection mechanisms, the ability to swallow and speak, and a reduction in the sedation

requirement. Air leakage, improper mask position, and patient distress are the most important reasons for NIMV failure (5–7). Recently, the helmet has been introduced as an alternative interface for NIMV alongside full face and oro-nasal masks (8,9).

In this study we aimed to compare the efficacy and complication rates of a full face mask and a helmet in cases of COPD acute exacerbation.

2. Materials and method

After approval from the institutional review board and all patients, 50 COPD patients admitted to the respiratory intensive care unit (ICU) due to acute exacerbation of COPD between December 2011 and May 2012 were randomly included in this study. All patients were previously diagnosed with COPD according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria (10). In cases of COPD exacerbation, NIMV was routinely applied to the patients based on general criteria

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[respiratory rate (RR) of >25/min, $PaCO_2$ of >45 mmHg, and pH of <7.35]. COPD exacerbation was defined by the presence of the following criteria: increase in dyspnea, and increase in quantity and purulence of sputum (10). The COPD exacerbation treatments given to all patients were subcutaneous heparin, systemic steroids, bronchodilators, and, if necessary, antibiotics. Electrolyte abnormalities were also corrected.

Patients who had an IMV indication, unstable hemodynamic situation (systolic arterial pressure (SAP) of <90 mmHg and mean arterial pressure (MAP) of <50 mmHg), cooperation problems, neurologic disorders, facial trauma, facial surgery or deformity, pleural effusion, or malignant diseases were excluded from the study.

Age, sex, height, weight, body mass index (BMI), FEV1, presence of additional disease, heart rate (HR), MAP, SAP, diastolic arterial pressure (DAP), RR, Acute Physiology Assessment and Chronic Health Evaluation (APACHE) II score, peripheral O_2 saturation (SpO_2), arterial blood gases (ABG) measurements, and fraction of inspired oxygen (FiO_2) were recorded. We also recorded complications, intubation requirements, duration of ICU and hospital stay, and duration of treatment.

Patients were observed closely during the study period. Nasal oxygen was administered to the patients to keep their SpO_2 between 85% and 92% prior to study. NIMV was started with patients in a sitting position, and bilevel positive airway pressure was performed using a mechanical ventilator (Servo Maquet S; Getinge Group, USA). Initial NIMV modes were setup as FiO_2 0.4, positive end expiratory pressure (PEEP) 5–7 cmH_2O, pressure support (PS) 10 cmH_2O, and trigger –2 cmH_2O.

Patients were randomly divided into 2 groups as full face mask (Group F, n = 25) and helmet (Group H, n = 25) in the ICU. The NIMV was started using full a face mask (Respironic-S Facial Mask; Teleflex Medical, Ireland) in Group F and a helmet (CaStar; Starmed, Italy) in Group H. PS was gradually increased by 2 cmH_2O steps during the first hour of ventilation to observe adequate patient respiratory effort. The FiO_2 rate was also increased gradually up to 50% by 5% steps to obtain at least 92% SpO_2. Our aim was to provide 6–8 mL/kg tidal volume during the NIMV procedure. During NIMV, ABG was checked every 30 min, and FiO_2 was reset according to ABG results. The NIMV settings were recorded after the initial period and NIMV was kept continuous for 2 h with these settings.

Parameters were recorded at 20 min before the NIMV (T0) and at initiation of NIMV (T1), 30 min of NIMV (T2), 60 min of NIMV (T3), 90 min of NIMV (T4), 120 min of NIMV (T5), 30 min after NIMV (T6), 24 h after NIMV (T7), 48 h after NIMV (T8). Values during ICU discharge were also recorded (T9). The ABG was recorded at times T2, T3, T4, T5, T6, T7, T8, and T9 in all patients. The RR, hemodynamic values (SAP, DAP, MAP, and HR), and PaO_2/FiO_2 values were recorded. Compliance of patients to the mask and helmet was evaluated by using the patient tolerance scale (PTS) at the first and second hours of NIMV, using a blackboard. PTS was evaluated as follows.

1. Bad: Patients try to remove mask.
2. Moderate: Mask ventilation is successful with suggestions.
3. Good: Mask is somewhat disturbing to patients, but they want to use it.
4. Excellent: Complete tolerance.

Face laceration and erythema in Group F and axillary erythema and laceration in Group H were accepted as mask-related complications. Duration of ICU, duration of NIMV, IMV requirements, and mortality rate were recorded. Study-related axillary and face pressure wounds and erythema were recorded at the end of the study.

2.1. Statistical analysis
It was found that each group's sample size should be at least 19 in order to determine a 40% difference between the groups' success rates at 0.05 type I error rate and 80% power. Statistical analysis was performed using SPSS for Windows 15.0 (SPSS Inc., Chicago, IL, USA). For continuous variables, the normality of the distribution was checked. Descriptive statistics were given as mean ± standard deviation if the distribution of variables was normal. Median (25th–75th percentile) was used for the variables that were not normally distributed. Differences between the 2 groups were compared with independent sample t-test and Mann–Whitney U test for normally and nonnormally distributed variables, respectively. To evaluate the parametric data in the groups, two-way analysis of variances for repeated measures was used. The Friedman test was performed to evaluate the nonparametric data in the groups. When differences existed, pairwise comparisons were done by Bonferroni test. Categorical variables were compared by chi-square test. P-values of less than 0.05 were accepted as significant.

3. Results
Forty-eight patients (Group F, n = 23; Group H, n = 25) completed this study. Two patients were excluded from the study due to resistant respiratory acidosis during NIMV procedure in Group F. The mean age was significantly higher in Group H (P < 0.05). There was no difference between groups in terms of demographic values (P > 0.05) (Table 1). The MAP, DAP, SAP, and HR values were comparable between the groups (P > 0.05).

There was no significant difference between the groups in terms of initial respiratory, ABG, and NIMV parameters (P > 0.05) (Table 2).

Table 1. Demographic characteristics of the patients.

	Group F (n = 23)	Group H (n = 25)	P-value
	(mean ± SD)	(mean ± SD)	
Age (years)	64.3 ± 10.1	69.5 ± 7.41	0.044*
APACHE II	16.87 ± 4.78	16.48 ± 3.89	0.758
Sex (F/M)	8/15	6/19	0.610
BMI	28.06 ± 6.58	25.02 ± 4.48	0.060
Comorbidity (%)	14 / 23 (61)	16/25 (24)	1.000

*$P < 0.05$: Compared between the groups. Values presented as mean ± standard deviation (SD) or patient number and percentage. F: Female, M: male, H: helmet, F: full face mask, BMI: body mass index, APACHE II: Acute Physiology Assessment and Chronic Health Evaluation II.

Table 2. Initial noninvasive mechanical ventilation and respiratory parameters.

	Group F (n = 23) (mean ± SD)	Group H (n = 25) (mean ± SD)	P-value
RR (min)	27.1 ± 5.6	24.4 ± 6.3	0.130
SaO_2 (%)	85.73 ± 9.6	86.70 ± 8.6	0.630
PaO_2 (mmHg)	62.5 ± 11.6	60.4 ± 14.1	0.610
$PaCO_2$ (mmHg)	69.7 ± 10.0	65.4 ± 12.0	0.450
pH	7.28 ± 0.04	7.30 ± 0.03	0.107
FiO_2 (%)	38.9 ± 2.9	39.4 ± 3.0	0.570
PS (cmH_2O)	18.7 ± 3.35	18.3 ± 2.42	0.585
Ppeak (cmH_2O)	18.9 ± 3.7	20.1 ± 2.23	0.181
PEEP (cmH_2O)	4.43 ± 0.84	4.16 ± 0.55	0.185

Mean ± standard deviation (mean ± SD). SaO_2: Peripheral oxygen saturation, PO_2: partial oxygen pressure, RR: respiratory rate, PCO_2: partial carbon dioxide pressure, FiO_2: fraction of inspired O_2, PS: pressure support, Ppeak: peak pressure, PEEP: positive end expiratory pressure, F: full face mask, H: helmet.

There was no significant difference between the groups in terms of SpO_2 values during all study periods ($P > 0.05$). SpO_2 values were significantly higher at 30, 60, and 120 min in Group F and Group H compared to the initial values ($P < 0.05$).

There was no significant difference between the groups in terms of RR throughout the whole study period ($P > 0.05$). The diminishing of RR was statistically significant at 60 and 90 min in Group F and 90 and 120 min in Group H compared to initial values ($P < 0.05$).

The PTS at the first hour and second hour of NIMV, and the NIMV success rate, were not found to be statistically different between the groups ($P > 0.05$). The PS, Ppeak, PEEP, and PaO_2/FiO_2 values were not found to be significantly different between the groups ($P > 0.05$). The FiO_2 values were not statistically different between the groups ($P > 0.05$). In Group F, the FiO_2 values were not significantly different when compared to the initial FiO_2 value ($P > 0.05$); it was significantly lower at 60 min in Group H ($P < 0.05$).

There was no difference between groups in terms of $PaCO_2$ level among the whole study period ($P > 0.05$). Decrease in $PaCO_2$ was statistically significant at 60 min in Group F ($P < 0.05$). There was no statistically significant difference in Group H compared to initial $PaCO_2$ values ($P > 0.05$) (Figure 1).

The PaO_2 values were not significantly different when comparing the groups ($P > 0.05$). The PaO_2 levels were increased significantly at 30 and 60 min compared to initial PaO_2 level in both groups ($P < 0.05$) (Figure 2).
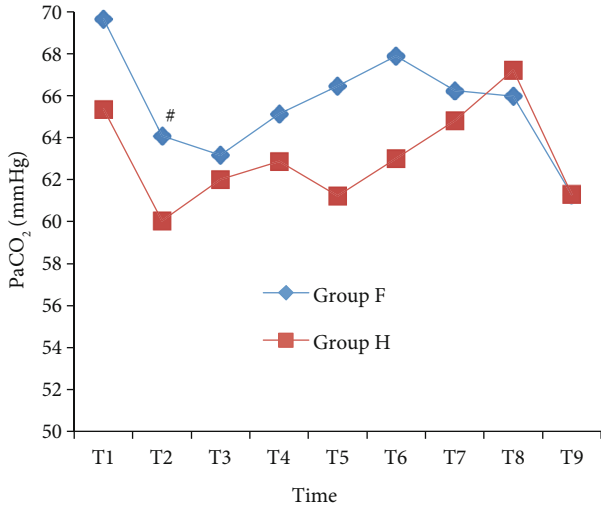

Figure 1. Partial carbon dioxide ($PaCO_2$) level in groups.
#: $P < 0.05$ in Group F. Values presented as mean ± standard deviation or patient numbers. H: Helmet, F: full face mask.
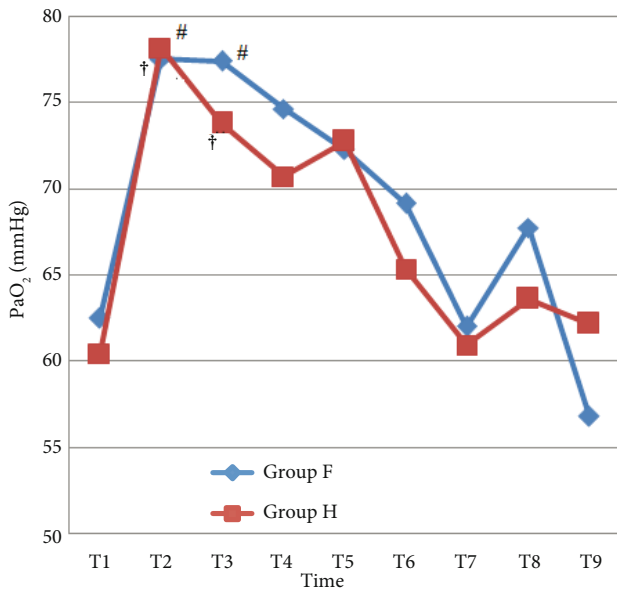

Figure 2. Partial arterial oxygen (PaO_2) values.
#: $P < 0.05$ in Group F, †: $P < 0.05$ in Group H. Values presented as mean ± standard deviation. H: Helmet, F: full face mask.

The pH values were not significantly different between the groups ($P > 0.05$). The pH values were also found significantly higher in Group F at 24 and 48 h, and at discharge from the ICU, compared to the initial value ($P < 0.05$). In Group H, pH values were found to be significantly higher at 48 h and at discharge from the ICU compared to the initial value ($P < 0.05$) (Figure 3).

When the groups were compared in terms of duration of ICU and NIMV, no significant difference was found ($P > 0.05$) (Table 3). One patient in Group F had cardiac arrest on the third day of ICU stay. Cardiopulmonary resuscitation was performed, and the patient died on the fourth day of the ICU stay. IMV was performed on the third day of ICU stay in one patient in Group H due to respiratory failure. Cardiac arrest happened on day 27 and the patient died. Severe respiratory acidosis happened in another patient in Group H. IMV was performed on this patient. When the groups were compared in terms of complications, no significant difference was found ($P > 0.05$). The mortality rates were similar between the groups ($P > 0.05$) (Table 3).

4. Discussion

The NIMV success rate was quite high in this study and NIMV reduced the complications significantly both in the full face mask group and in the helmet group during the study period. The overall outcome was also similar in the helmet and full face mask groups. The decrease in $PaCO_2$ was slower in the helmet group, but it was within a clinically reasonable margin.

Avoiding intubation should significantly reduce the risk of ventilator-associated lung injury in COPD patients. NIMV is a functional approach to reduce the IMV requirement in patients with COPD exacerbation (11). The
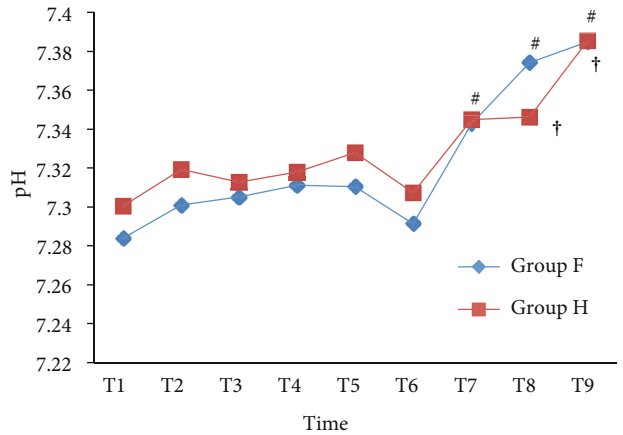

Figure 3. pH values.
*: $P < 0.05$: Comparison between groups, #: $P < 0.05$ in Group F, †: $P < 0.05$ in Group H. Values presented as mean ± standard deviation. H: Helmet, F: full face mask.

Table 3. Patient outcome.

	Group F (n = 23) Median (min–max)	Group H (n = 25) Median (min–max)	P-value
Length of ICU stay (days)	6 (4–7)	6 (4–10)	0.84
Duration of NIMV(h)	24 (10–40)	17 (6–31)	0.38
ICU mortality (%)	1/23 (4.3)	1/25 (4)	1.00
Rate of IMV requirement (%)	1/23 (4.3)	2/25(8)	1.00
Rate of complication	14/23 (61)	9/25 (36)	0.15

Values presented as median (25th–75th percentile) or patients number and percentage. H: Helmet, F: full face mask. ICU: intensive care unit, NIMV: noninvasive mechanical ventilation, IMV: invasive mechanical ventilation.

performance of NIMV may provide several advantages, such as relief of dyspnea, improvement of vital signs and gas exchange, and diminishing of endotracheal intubation rate (4,12,13). According to these studies, NIMV should be the first treatment option in COPD cases accompanied by acute exacerbations. The efficacy of NIMV in an unstable patient is still controversial. Meduri et al. (5) performed NIMV in 3 patients who had high $PaCO_2$ levels; the success rate was high particularly in patients who had pH of 7.25 or higher. High levels of respiratory failure may increase the IMV requirement. In the present study, we had to perform IMV in 2 cases in the full face mask group due to resistant respiratory acidosis within the first 2 h of the study period. Lower initial pH level of these cases (<7.25) could explain the failure of NIMV in these patients.

Tolerance of a full face mask is one of the most important factors for NIMV success. It is quite important to prevent the need for IMV. Spontaneous ventilation of the patient and the trigger of the air flow by the ventilator are related to the patient's tolerance. Air leakage and an accurate ventilator setting are other significant factors affecting the patient's tolerance (14–16). A comprehensive explanation of the procedure was provided to the patients, and close observation was performed throughout our study. Therefore, we did not observe any significant patient intolerance in either group. Duration of NIMV is another important factor for the patient's tolerance of the NIMV. The NIMV success rate may be reduced in long-term NIMV procedures. According to studies the patient tolerance was reduced by 30% in patients who had a full face mask for NIMV, and patient tolerance was better with a helmet, particularly in long-term NIMV procedures (8,17,18). The helmet has a different design, and the primary aim of the helmet is to improve the patient's tolerance (19). Patients who cannot tolerate the full face mask, who have long-term NIMV requirement, or who have facial deformities are good candidates for a helmet (17). The helmet also

permits the patient to talk, read, and drink better than the facial mask does, improving acceptance and collaboration between the patient and healthcare professionals (19). In the present study we did not find any significant difference according to PTS, but our clinical observations showed that the tolerance for the helmet was better than for the full face mask. NIMV-related complications such as discomfort, skin erythema, claustrophobia, air leaks, eye irritation, and nasal bridge ulceration might be faced during the NIMV procedure, and this may require discontinuation of NIMV. Despite the new advances in face masks, they are still uncomfortable. This is more problematic, particularly in dyspneic patients. Facial ulcers may occur in the first hour of NIMV (6,9). We did not observe claustrophobia in any patients. Facial laceration and hyperemia were observed on the noses of 13 patients in the full face mask group, and axillary laceration and hyperemia were seen in 10 patients in the helmet group. All lacerations and hyperemia healed without any treatment. Diminishing of RR is one of the most important parameters for recovery from acute respiratory failure. Antanoglia et al. (20) found that RR diminished in the full face mask and helmet groups after NIMV. In the present study, our findings are similar to that study, and diminishing of RR was similar in all study periods in both groups. Our study has shown that ABG parameters improved noticeably after the NIMV procedure, but the diminishing of $PaCO_2$ level was slower in the helmet group. The large breathing area in the helmet may cause CO_2 rebreathing, and it prevents the fast diminishing of $PaCO_2$ (21). The volume of the helmet is approximately 6–8 L. It is negligible when pressure support is administered at a sufficient level. If the level of pressure support is kept around 10 cmH_2O, the CO_2 rebreathing level is always lower than 1.5%, similar to the face mask level (20,21). Baglioni et al. (22) performed NIMV with a helmet in 25 patients who had acute respiratory failure due to COPD exacerbations. Sixteen patients responded

to treatment, but NIMV failed in 3 patients due to high $PaCO_2$ level. On the other hand, we excluded 2 patients in the full face mask group due to resistant respiratory acidosis in the first 2 h. Arterial pH appears to be the paramount marker reflecting both the severity of acute respiratory failure (ARF) and the effect of NIMV in the acute setting. In accordance with these findings, in patients with severe ARF (pH < 7.25), the rate of NIMV failure was inversely related to the severity of respiratory acidosis. This indicates that severe acidosis resulting from acute exacerbation is a relevant predictor for treatment failure of NIMV (23). In the present study, as well as initial pH levels above 7.25, the mean pH level was significantly lower in the full face mask group. Initial $PaCO_2$ levels were also

higher in the full face mask group, but not significantly so. These results can explain the failure of NIMV in 2 patients in the full face mask group. In conclusion, both the helmet and the full face mask are efficient for improving the patient's clinical outcome in COPD cases accompanied by acute exacerbation. However, as reducing of $PaCO_2$ in the helmet group was slower than in the full face mask group, it should be negligible in appropriate NIMV settings. A low pH level might have increased the NIMV failure rate in COPD cases accompanied by acute exacerbation.

Acknowledgment

References

1. Celli BR, MacNee W. ATS/ERS Task Force. Standards for the diagnosis and care of patients with COPD: a summary of the ATS/ERS position paper. Eur Respir J 2004; 23: 932–946.

2. Siafakas NM, Vermeire P, Pride NB, Paoletti P, Gibson J, Howard P, Yernault JC, Decramer M, Higenbottam T, Postma DS et al. ERS consensus statement. Optimal assessment and management of chronic obstructive pulmonary disease (COPD). Eur Respir J 1995; 8: 1398–1420.

3. Luyt CE, Chastre J, Fagon JY. Value of the clinical pulmonary infection score for the identification and management of ventilator-associated pneumonia. Intensive Care Med 2004; 30: 844–852.

4. Antonelli M, Pennisi MA, Pelosi P, Gregoretti C, Squadrone V, Rocco M, Cecchini L, Chiumello D, Severgnini P, Proietti R et al. Noninvasive positive pressure ventilation using a helmet in patients with acute exacerbation of chronic obstructive pulmonary disease: a feasibility study. Anesthesiology 2004; 100: 16–24.

5. Meduri GU, Conoscenti CC, Menashe P, Nair S. Non-invasive face mask ventilation in patients with acute respiratory failure. Chest 1989; 95: 865–870.

6. Antonelli M, Conti G. Noninvasive ventilation in intensive care unit patients. Curr Opin Crit Care 2000; 6: 11–16.

7. Akpınar S, Rollas K, Akpınar EE, Alagöz A, Uçar N, Şipit YT. Effect of presence of pneumonia on noninvasive ventilation success in chronic obstructive pulmonary disease cases with acute hypercapnic respiratory failure. Turk J Med Sci 2013; 43: 373–378.

8. Scandroglio M, Piccolo U, Mazzone E, Agrati P, Aspesi M, Gamberoni C, Severgnini P, Di Stella R, Chiumello D, Minoja G et al. Use and nursing of the helmet in delivering non invasive ventilation. Minerva Anestesiol 2002; 68: 475–480.

9. Antonelli M, Pennisi MA, Conti G. New advances in the use of noninvasive ventilation for acute hypoxaemic respiratory failure. Eur Respir J 2003; 22: 65–71.

10. GOLD. NHLBI/WHO Global Initiative for Chronic Obstructive Lung Disease (GOLD) Workshop report. Global Strategy for the Diagnosis, Management and Prevention of Chronic Obstructive Pulmonary Disease. Washington, DC, USA: GOLD; 2009.

11. Çelikel TH, Sungur M, Ceyhan B, Karakurt, S. Comparison of noninvasive positive pressure ventilation with standard medical therapy in hypercapnic acute respiratory failure. Chest 1998; 114: 1636–1642.

12. Meduri GU, Turner RE, Abou-Shala N, Wunderink R, Tolley E. Noninvasive positive pressure ventilation via face mask. First-line intervention in patients with acute hypercapnic and hypoxemic respiratory failure. Chest 1996; 109: 179–193.

13. Acıcan T, Gülbay BE. Kronik obstrüktif akciğer hastalığı (KOAH) atak ve tedavisi. Türkiye Klinikleri, Cerrahi Tıp Bilimleri Dergisi 2006; 2: 40–44 (in Turkish).

14. Ambrosino N. Noninvasive mechanical ventilation in acute respiratory failure. Eur Respir J 1996; 9: 795–807.

15. Meyer TJ, Hill NS. Noninvasive positive pressure ventilation to treat respiratory failure. Ann Intern Med 1994; 120: 760–770.

16. Wysocki M., Antonelli M. Noninvasive mechanical ventilation in acute hypoxaemic respiratory failure. Eur Respir J 2001; 18: 209–220.

17. Antonelli M, Conti G, Pelosi P, Gregoretti C, Pennisi MA, Costa R, Severgnini P, Chiaranda M, Proietti R. New treatment of acute hypoxemic respiratory failure: noninvasive pressure support ventilation delivered by helmet - a pilot controlled trial. Crit Care Med 2002; 30: 602–608.

18. Principi T, Pantanetti S, Catani F, Elisei D, Gabbanelli V, Pelaia P, Leoni P. Noninvasive continuous positive airway pressure delivered by helmet in hematological malignancy patients with hypoxemic acute respiratory failure. Intensive Care Med 2004; 30: 147–150.

19. Antonelli M, Penissi P, Conti G. New advances in the use of noninvasive ventilation for acute hypoxaemic respiratory failure. Eur Respir J Suppl 2003; 42: 65s–71s.

20. Antonaglia V, Lucangelo U, Zin WA, Peratoner A, De Simoni L, Capitanio G, Pascotto S, Gullo A. Intrapulmonary percussive ventilation improves the outcome of patients with acute exacerbation of chronic obstructive pulmonary disease using a helmet. Crit Care Med 2006; 34: 2940–2995.

21. Tunç M, Öztürk G, Pehlivanoğlu P, Kokulu S, Şipit T, Şavkılıoğlu E. Noninvasive positive pressure ventilation by the helmet in respiratory failure due to acute exacerbation of chronic obstructive pulmonary disease. J Turk Anaesth Int Care 2011; 39: 326–333.

22. Baglioni S, Eslami A, Scoscia E, Penza O, Dottorini M. Noninvasive mechanical ventilation by helmet in the treatment of acute respiratory failure in patients with ineffectiveness or intolerance to the facial mask ventilation. Chest 2009; 136: abstract 2S-a.

23. Plant PK, Owen JL, Elliott MW. Non-invasive ventilation in acute exacerbations of chronic obstructive pulmonary disease: long term survival and predictors of in-hospital outcome. Thorax 2001; 56: 708–712.