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A New Promising Treatment Strategy for Carbon Monoxide Poisoning: High Flow Nasal Cannula Oxygen Therapy

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEFG 1 **Onder Tomruk**
CDEF 1 **Kıvanç Karaman**
ADEF 2 **Bulent Erdur**
AE 1 **Hamit Hakan Armagan**
CF 1 **Nesrin Gökben Beceren**
BE 1 **Alten Oskay**
CDEF 3 **Haci Ahmet Bircan**

1 Department of Emergency Medicine, Medical Faculty, Suleyman Demirel University, Isparta, Turkey
2 Department of Emergency Medicine, Medical Faculty, Pamukkale University, Denizli, Turkey
3 Department of Chest Diseases, Medical Faculty, Suleyman Demirel University, Isparta, Turkey

Corresponding Author: Bulent Erdur, e-mail: bulenterdur@hotmail.com
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Background: High-flow nasal cannula (HFNC) is an alternative to conventional normobaric oxygen therapy (NBO) for hypoxemic patients. Since nothing is known about its effect on carbon monoxide (CO) poisoning, we hypothesized that HFNC might be a useful device in the treatment of CO poisoning victims.

Material/Methods: We retrospectively reviewed the medical records of patients who were admitted consecutively to the emergency department with CO intoxication. Patients were divided into 2 groups: patients treated with HFNC and patients treated with conventional face mask (CFM). Demographic data, pretreatment, and control (after 1 hour) arterial blood gas analyses values of the patients were evaluated.

Results: Sixty-eight patients (mean age 35.8±18.7 years) were included in this study. NBO was given via HFNC to 38 patients (55.9%), and via CFM to 30 patients (44.1%). The demographic characteristics and pretreatment values of carboxy-hemoglobin (COHb) were similar in the 2 groups. The mean COHb value of the HFNC group at the first hour was found significantly lower than the CFM group: 9.5±4.7 and 12.0±5.1, respectively (*P*=0.041). Improvement of COHb level was significantly higher in the HFNC group compared to the CFM group: 12.5±4.5 versus 6.7±3.7, respectively (*P*=0.001).

Conclusions: HFNC was superior than CFM in alleviating COHb levels in the victims of CO poisoning. We believe that using HFNC will increase patient comfort by shortening the duration of treatment in emergency department settings, especially in patients who have mild clinical findings of CO poisoning.

MeSH Keywords: **Anoxia • Carbon Monoxide Poisoning • Emergency Service, Hospital**

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Background

Carbon monoxide (CO) is a colorless and odorless gas produced by the inefficient burning of fuels and organic materials. Nearly 50 000 victims visit the emergency departments (EDs) in United States of America per year due to CO poisoning [1]. Although many of these cases are nonfatal exposures with various degrees of toxicity, an estimated 1000 to 2000 patients a year die from severe CO toxicity [1]. CO has greater affinity for hemoglobin than oxygen (approximately 230–270 times greater), so the oxygen level in the tissues is reduced. The basic treatment strategy for CO poisoning is to reduce the level of CO in the blood with administration of 100% normobaric oxygen (NBO) or hyperbaric oxygen. The elimination half-life of CO is associated with the amount of dissolved oxygen in a patient's bloodstream because oxygen and CO competitively bind hemoglobin [2]. There is no consensus in the published guidelines on how to triage patients with CO poisoning in ED settings. Since most symptoms in CO poising may improve with only NBO, EDs provide suitable services for most patients [3]. As a general approach, patients with minor symptoms should receive NBO in EDs until their carboxy-hemoglobin (COHb) levels decrease to less than 10% and their symptoms have resolved, usually treatment lasts for about 6 hours [4].

For hypoxemic patients, oxygen therapy can be delivered via low-flow, intermediate-flow, or high-flow devices. Limitation of fractional inspired oxygen (FiO_2), insufficient warming, and humidification of inspired gas are disadvantages of low/intermediate flow devices. High-flow nasal cannula (HFNC) has been introduced as an alternative oxygen delivery tool for patients with hypoxemia and is comprise of a flow-meter and an oxygen–air blender connected to a humidifier. HFNC is considered to have a number of advantages over conventional oxygen delivery systems, which results in better physiological effects. It increases washing out carbon dioxide (CO_2) in anatomical dead space, improves oxygenation by creating positive upper airway pressure, and decreases metabolic cost of breathing by reducing CO_2 generation as well as better secretion clearance and superior comfort [5].

In the last decade, the use of HFNC has been increasing in all critical care units. Chronic obstructive lung disease (COPD), sleep apnea, cardiogenic pulmonary edema, acute severe respiratory infection, and other respiratory conditions are the main diseases where HFNC has been applied [6–9].

We could not find a previous study that had investigated the usefulness of HFNC in victims of CO poisoning. For this study, we hypothesized that oxygen treatment with HFNC might rapidly decrease COHb levels in patients with CO poisoning and it might be superior to conventional oxygen delivery via conventional face mask (CFM) in patients with CO poisoning.

Material and Method

This study was conducted in the ED of our university hospital with an average admission of 60 000 patients per year. We retrospectively reviewed the medical records of patients who presented to the ED with CO poisoning. HFNC device (Airvo 2, Fisher & Paykel HealthCare, Auckland, New Zealand) has been available in our department since November 2016. As of this date, all patients with suspicion of CO poisoning received oxygen therapy via HFNC (36°C and 40 L/min flow-rate). For comparison, the patients who received oxygen by CFM with suspicion of CO poisoning were screened retrospectively from November 2016 to April 2015. Demographic characteristics, pretreatment, and control (the first hour oxygen treatment) arterial blood gas analyses (ABG) (Siemens PAPIDPoint® 500 System, Erlangen, Germany) values of the CFM and HFNC groups were recorded. Patients were excluded from the study if: 1) patient was referred directly for hyperbaric oxygen therapy, 2) patient had low COHb level despite having a history of CO exposure, 3) patient had received oxygen therapy prior to admission to the ED, 4) patient had no ABG analysis at beginning and/or at the first hour of oxygen treatment.

Statistical analyses were done with Statistical Package for Social Sciences (SPSS) for Windows (version 20.0; Chicago, IL, USA). Normally distribution of quantitative data was checked using the Kolmogorov-Smirnov test. Descriptive data was expressed as mean ± standard deviation. As for the independent groups, statistical comparisons were done with Student *t*-test and Mann-Whitney U test for normally and for non-normally distributed variables, respectively. Chi-square test was applied for categorical variables. A *P* value <0.05 is considered statistically significant. The study was approved by Suleyman Demirel University Clinical Research Ethics Board of Medical Faculty (19 December 2018/209).

Results

Archive files of all patients with CO poisoning who were admitted to our ED between the dates of April 2015 and April 2018 were surveyed. There were 38 and 55 admittance to ED between April 2015–October 2016 and November 2016–April 2018, respectively.

Twenty-five patients were excluded from the study due to predefined exclusion criteria and finally 68 patients were evaluated (Figure 1). NBO was given via HFNC to 38 patients (55.9%) and via CFM to 30 patients (44.1%).

The demographic characteristics, COHb levels, and PO_2 levels of the 2 groups are shown in Table 1. Age and gender distribution of the groups were similar. Although it was not significant,

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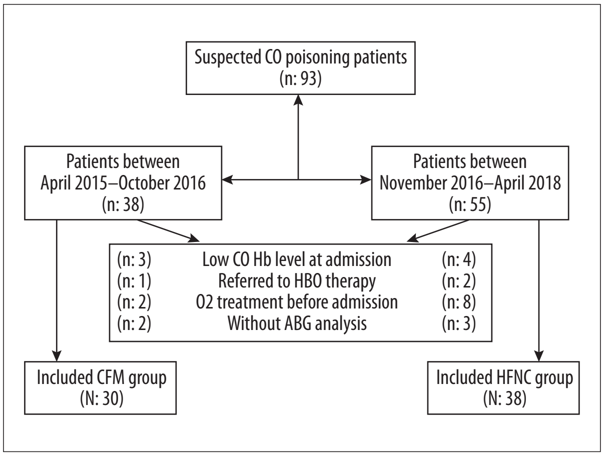

Figure 1. Flow chart of the enrollment of patients.
CO – carbonmonoxide; COHb – carboxy-hemoglobin; HBO – hyperbaric oxygen; ABG – arterial blood gas analysis; CFM – conventional face mask; HFNC – high-flow nasal cannula.

pretreatment COHb values in the HFNC group were higher than in the CFM group. But, control COHb values (at the first hour) were lower in the HFNC group than in the CFM group (P=0.041) (Table 1).

The case-based changes in COHb levels for each group are shown in Figure 2. The improvement in delta carboxy-hemoglobin (Δ COHb) level was more prominent in the HFNC group compared to the CFM group (P=0.001). Delta arterial oxygen tension (Δ PaO_2) level was also higher in the HFNC group compared to the CFM group, but without statistically significance (Table 2).

Discussion

In our study, 2 different routes of NBO treatments on blood COHb levels were compared in the ED. The similarity of clinical and laboratory values at the time of admission in both patient groups allowed us to compare the efficacy of these 2 different treatment modalities.

Comparable pretreatment COHb levels between the groups, significantly lower COHb level at the first hour, and significantly higher decrease in COHb levels in the HFNC group suggested that NBO treatment with HFNC was more effective than NBO treatment with CFM in the victims of CO poisoning. Considering this results, length of stay in the ED for NBO treatment might be shortened by using HFNC, especially in patients who have mild clinical symptoms and do not require hyperbaric oxygen therapy for CO poisoning. Our study results highlight the potential of HFNC to rapidly decrease COHb levels as an alternative to CFM, and thus warrants further, large scale and prospective controlled trials. Furthermore, it is not always easy, and it can take a long time, to achieve hyperbaric oxygen treatment. NBO therapy with HFNC might be conceivable as an alternative method, even for hyperbaric oxygen treatment in patients with CO poisoning. Although more clinical studies are needed on this topic, HFNC therapy can eliminate the need for hyperbaric oxygen therapy in certain patient groups.

The COHb is influenced by FiO_2 and falls more quickly as FiO_2 increases [3,4]. Supplementation with up to 100% oxygen via a tight-fitting mask at normal atmospheric pressure decreases the half-life of COHb from 320 minutes to 60 minutes [3,4]. However, these systems can provide maximum oxygen flow rates up to 15 L/min. Furthermore, insufficient heating and humidification of the inspired gas, and the obtrusiveness of the masks are disadvantages of these systems compared to nasal cannula. The successful results with HFNC in our study might be due to its ability to provide higher flow rate and oxygen fraction.

HFNC has been used as an alternative to standard oxygen delivery systems for over 20 years and it may deliver a flow rate up to 60 L/min in adults [5]. The device is generally better

Table 1. Demographic and ABG values of study groups.

	All	HFNC	CFM	P value
Number (%)	68 (100)	38 (55.9)	30 (44.1)	–
Age (years), (mean ±SD)	35.8±18.7	32.4±17.3	40.1±19.8	0.091
Gender, Male/Female	30/38	13/25	17/13	0.064
COHb, pretreatment (mean ±SD)	20.6±8.0	22.0±7.8	18.7±8.0	0.095
PaO_2, pretreatment (mean ±SD)	115.3±35.7	119.3±37.2	110.2±33.7	0.271
COHb, 1-hour control (mean ±SD)	10.6±5.0	9.5±4.7	12.0±5.1	**0.041**
PaO_2, 1-hour control (mean ±SD)	189.7±66.0	199.2±73.8	177.6±53.3	0.439

PaO_2 – arterial oxygen tension; COHb – carboxy-hemoglobin; HFNC – high-flow nasal cannula; CFM – conventional face mask; SD – standard deviation.

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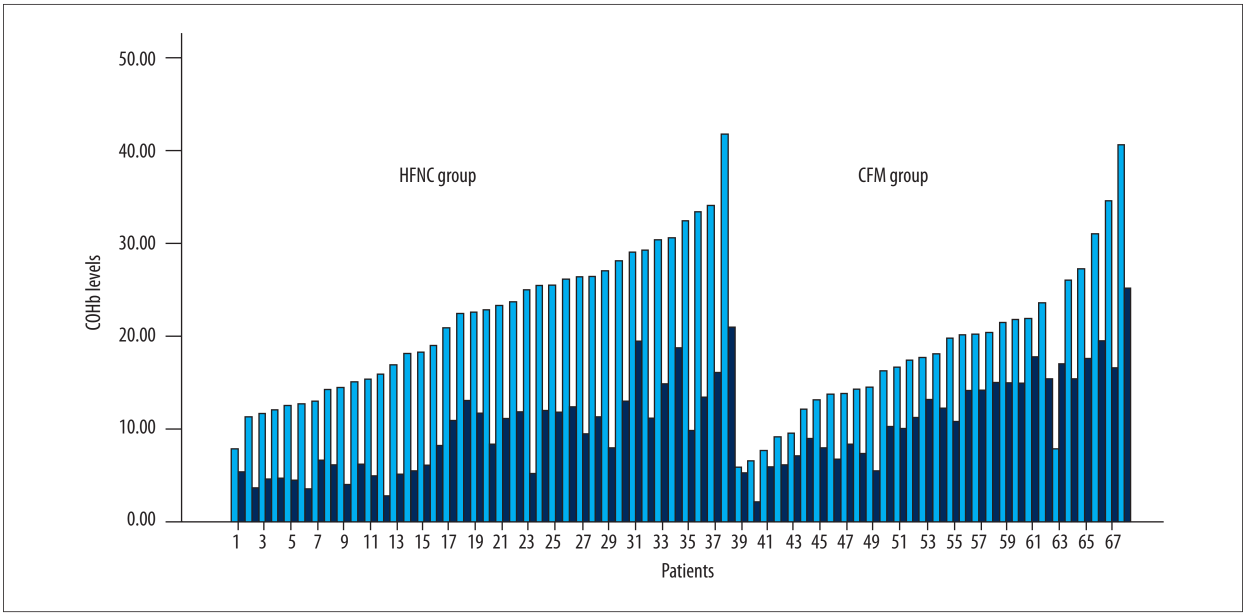

Figure 2. Case-based changes in COHb levels. COHb – carboxy-hemoglobin; HFNC – high-flow nasal cannula; CFM – conventional face mask.

Table 2. Changes in COHb and PaO_2 levels.

Difference	HFNC	Conventional mask	*P* value
Δ COHb	12.5±4.5	6.7±3.7	**0.001**
Δ PaO_2	80.5±67.8	70.5±51.3	0.711

PaO_2 – arterial oxygen tension; COHb – carboxy-hemoglobin; Δ PaO_2 – delta arterial oxygen tension; Δ COHb – delta carboxy-hemoglobin; HFNC – high-flow nasal cannula; CFM – conventional face mask.

tolerated than CFM and allows adjustment of FiO_2 independent from the flow rate [5]. It has been used effectively for hypoxemia correction compared to CFM in small patient groups with acute respiratory failure in the settings of intensive care units and EDs [10–12]. Lenglet et al. reported that HFNC alleviates dyspnea scores and improves respiratory parameters by increasing oxygen saturation and PaO_2 values in patients with acute hypoxic respiratory failure in EDs [10]. In that study, it was also reported that 76% of health caregivers preferred HFNC instead of other oxygen therapy [10].

In the present study, PaO2 values significantly increased with both oxygen delivery methods used in the retrospective study, but the improvement in PaO2 level was more prominent in the HFNC group. We suggest that increasing the availability of this device in EDs could provide management of patients in shorter treatment periods.

The present study had certain limitations. First, this was a retrospective study and included a small number of patients. To the best of our knowledge, there is no study that has indicated that HFNC can be safely used instead of hyperbaric oxygen therapy. That is why the patients who needed immediate hyperbaric oxygen treatment and who were referred to us for direct hospitalization in the intensive care unit were not enrolled in this study. Second, our study had no data about clinical symptoms assessment before and after NBO treatment with different types of oxygen delivery. Future, well-organized studies are required to evaluate the effect of HFNC on acute and chronic outcomes of CO poisoning.

Conclusions

Our study showed that HFNC for NBO treatment was more effective than CFM in reducing COHb levels in patients with CO poisoning. We believe that using HFNC will increase patient comfort by shortening the duration of treatment in the ED settings, especially in patients who have mild clinical findings of CO poisoning.

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