Does Simple Face Mask or Diffuser Mask Matter in the First Hour Treatment of Carbon Monoxide Intoxication? A Prospective Randomized Clinical Study

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Cite this article as: Hocagil AC, Hocagil H, Tatli M. Does Simple Face Mask or Diffuser Mask Matter in the First Hour Treatment of Carbon Monoxide Intoxication? A Prospective Randomized Clinical Study. Eurasian J Emerg Med. 2018; 17 (4): 165-70.

Abstract

Aim: In patients who do not have any indication for hyperbaric oxygen (O_2) treatment, the main treatment to eliminate carbon monoxide (CO) is by giving O_2 using a face mask. In the absence of a non-rebreathing face mask, a diffuser mask (DMG) or simple face mask (SMG) is an option that can be used for treatment. There are insufficient data about the acute efficacy of these masks. To study the ability of DMG and SMG in lowering carboxyhemoglobin (COHb) levels after the first hour of O_2 treatment in patients with CO intoxication.

Materials and Methods: This was a prospective randomized clinical study conducted in patients aged ≥16 years old who were diagnosed with CO intoxication. They were randomly given 15 L/min O_2 (from hospital central O_2 supplies) treatment with DMG (n=29) or SMG (n=52). Partial pressure of O_2 (PaO_2), carbon dioxide, and COHb levels and saturation of O_2 were measured before and after 1 h of treatment.

Results: A total of 81 (42 female and 39 male) patients with a mean age of 39.1±14.7 years were included in the study. There were no differences with regard to age, gender, body mass index, comorbidity, source of CO, initial symptoms, and initial COHb levels before treatment. After the first hour of treatment, DMG had lower mean COHb (mg/dL) levels (9.6±5.0 vs. 12.8±6.2, p=0.0203) and higher mean PaO_2 levels (224.4±56.5 vs. 183.4±63.7, p=0.0046) than SMG.

Conclusion: Diffuser mask (DMG) appears to be better than simple face mask (SMG) in the first hour of treatment of CO intoxication.

Keywords: Carbon monoxide intoxication, diffuser mask, simple face mask, emergency department

Introduction

Carbon monoxide (CO) intoxication is the most common cause of death among all intoxications (1-3). It affects many organs through tissue hypoxia and causes damage at the cellular level. The central nervous system and the heart are the most important organs affected (4). CO can cause permanent neurological sequel (5), changes in heart rate, arrhythmia, myocardial damage, necrosis, cardiogenic shock, and sudden cardiac death.

It is important to start treatment early in cases of CO intoxication, as exposure time is one of the key factors that determine the severity of toxicity (6). Treatment consists of hemodynamic stabilization and elimination of CO. The elimination largely includes administering 100% oxygen (O_2) with non-rebreathing face mask or providing hyperbaric O_2 therapy (HBOT) (7-9). In the absence of a non-rebreathing face mask, diffuser mask (DMG) and simple face mask (SMG) are two types of masks commonly used. To the best of our

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This study was presented in Intercontinental Emergency Medicine Congress as a poster on May 2014, Antalya, Turkey.
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Received: 29.06.2017 • **Accepted:** 13.09.2017

DOI: 10.5152/eajem.2018.46320

knowledge, there is no study that compares the effectiveness of DMG with an SMG on CO intoxication treatment.

The aim of the present study was to evaluate the effectiveness of DMG and SMG on decreasing the levels of carboxyhemoglobin (COHb) after the first hour of CO intoxication treatment.

Materials and Methods

Study design

This was a prospective randomized clinical study conducted between December 1, 2012 and April 30, 2013. Patients were recruited from the emergency department (ED) of Dr. Lutfi Kırdar Kartal Training and Research Hospital, which has an average daily admittance of 800-1000 patients. Ethics committee approval was received for this study from the Ethics Committee of Dr. Lutfi Kirdar Kartal Training and Research Hospital (Approval Date: 30.04.2012, No:8951337/1009/141). Written informed consent was obtained from all patients who participated in this study.

Study population

Patients who were >16 years old, diagnosed with CO intoxication (COHb >10 mg/dL), having no indication of hyperbaric (n=48), or having indications of hyperbaric but needed to be monitored in the emergency room until transferred to another facility with available HBOT after at least 1 h of O_2 treatment with one of the masks used (n=33) were included in the study. Patients having no need for intensive care, receiving proper treatment protocol, and having full medical records were also included.

Patients who were <16 years old, refused to participate, and who needed intubation were excluded from the study. Patients with diseases that cause hemoglobin dissociation curve shift to the left or diseases that cause increased endogenous CO production, such as chronic obstructive pulmonary disease (COPD), asthma, sickle cell anemia, polycythemia vera, and smoking, were also excluded.

Patients who met the enrollment criteria were randomized to cohorts according to randomization numbers assigned by the computer and randomized (2:1 within each group) to receive O_2 with DMG or SMG (we had limited numbers of DMG in ED compared with SMG).

Data collection and processing

Patients were divided into two groups: one group treated with SMG and the other group treated with DMG. Five minutes after diagnosis, both groups received 15 L O_2 therapy/min from hospital central O_2 supplies.

Data on existing symptoms, height and weight of the patients, causes of CO exposure, smoking habits, and comorbidities were collected. Patients' brachial arterial blood gases, COHb, partial pressure of O_2 (PaO_2), saturation of O_2 (SaO_2), COHb values on admission, and PaO_2 and SaO_2 values 1 h after treatment were recorded for each patient. Before receiving treatment, electrocardiography (ECG) was obtained, and respiratory rate was noted for each patient. ECG was repeated 1 h after treatment, and speed was evaluated in terms of rhythm and ECG disparities.

All blood gas determinations were made by the Radiometer ABL 700 (441R0226N010) (Radiometer Medical, Bronshoj, Denmark). The ABL 700 series blood gas analyzer that incorporates co-oximetry, electrolyte, and metabolite measurements uses heparinized whole blood as the preferred sample (10). A 195 µL blood sample was required by the ABL 700. This analyzer is designed for laboratory use only and is not portable. The ABL 700 was routinely calibrated every 4 h according to the manufacturer's recommendations (11).

Features of the masks used

Diffuser mask (OxyMask; Southmedic Inc., Ontario, Canada) is an open-system mask that can deliver 24%-90% fractional inspired O_2 concentration when O_2 flow is between 1 and 15 L/min. The mask consists of two parts: a diffuser system that forms a vortex with O_2 molecules and a pin. An umbrella-shaped pin is located in the triangle-shaped diffuser cup. This form of pin channels provides a vortex of the gas stream. High velocity accelerates this vortex. This vortex, which formed through angled diffuser cup portion, is routed directly to the mouth and nose (12) (Figure 1).

Simple face mask (HS-3031; Hsiner, Taichung Hsien, Taiwan), placed on the patient's nose and mouth, is made of transparent plastic reservoirs. It is fixed to the patient's head with an elastic strip. O_2 reaches the mask with a small connection tube. There are holes on both sides of the mask, and these holes deplete the exhaled air. These holes also allow mixing of room air into the reservoir (Figure 2).

Statistical analysis

The patient characteristics between the two groups were compared using the chi-square test or Fisher's exact test for categorical variables and the Student's t-test for continuous variables. Differences between the two groups in terms of before and after treatment values of COHb, PaO_2, and SaO_2 were compared using the Wilcoxon-Mann-Whitney test, as the parametric test assumptions did not meet. Statistical analyses were performed using the Statistical Package for Social Sciences 12.0 software (SPSS Inc.; Chicago, IL, USA). A two-sided $p<0.05$ was considered statistically significant.

Results

Between the dates of our study, 151 patients were diagnosed with CO intoxication in the ED. Among those, 20 patients were excluded due to missing information on their medical records or standard treatment disruptions. The other 23 patients were excluded from the study, as they received HBOT (n=18) within the first hour of treatment and had admission to the intensive care unit (n=5) in the first hour they were admitted to the ED. Twenty-seven patients were also excluded from the study, as 2 of them had asthma, 4 had COPD, and 21 were smokers (Figure 3).

A total of 81 patients were enrolled in the study. There were 42 female and 39 male patients. The mean age of the patients was 39.11±14.7 years. DMG was used for 35.8% of the patients. Among all patients, the two most common complaints were headache (50.6%) and dizziness (14.8%), respectively. Other complaints were fatigue, confusion, syncope, nausea, vomiting, and shortness of breath. The least common complaint was chest pain (1.3%) (Table 1). There were no significant differences in patient's age, sex, and body mass index

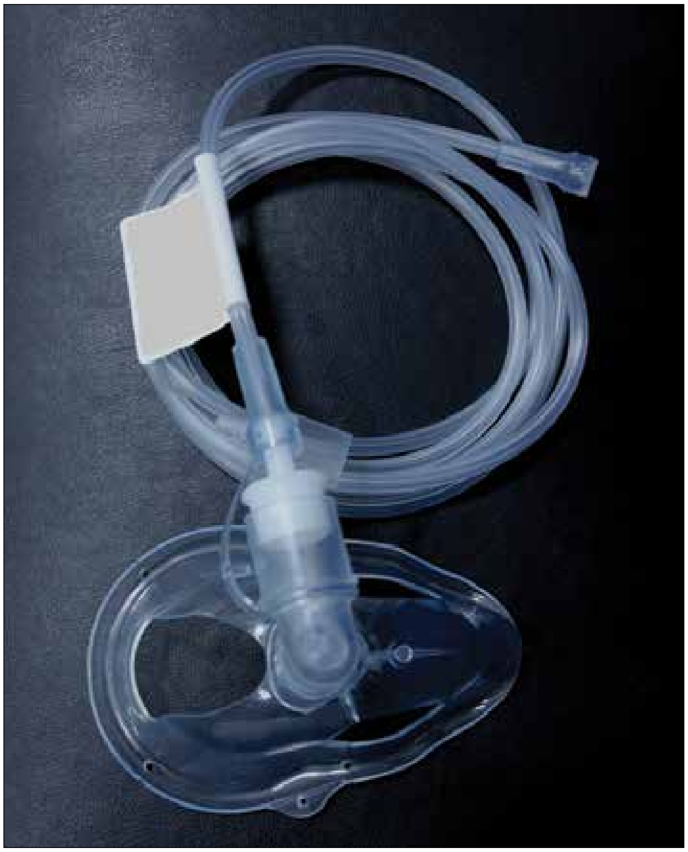

Figure 1. Diffuser mask

(BMI) between patients who were treated with SMG and patients who were treated with DMG (Table 1).

Of the study participants, 75 were exposed to CO due to stove smoke, whereas 6 were exposed to CO due to house fire. There were no statistically significant differences between patients before treatment with SMG and patients treated with DMG in terms of the mean values of the initial COHb, PaO_2, and SaO_2 (Table 1).

The mean value of PaO_2 (183.4±63.7 mm Hg) in patients after treatment with SMG was higher than that (224.4±56.5 mm Hg) in patients treated with DMG (Z=2.83, p=0.0046) (Table 1). The

Figure 2. Simple face mask

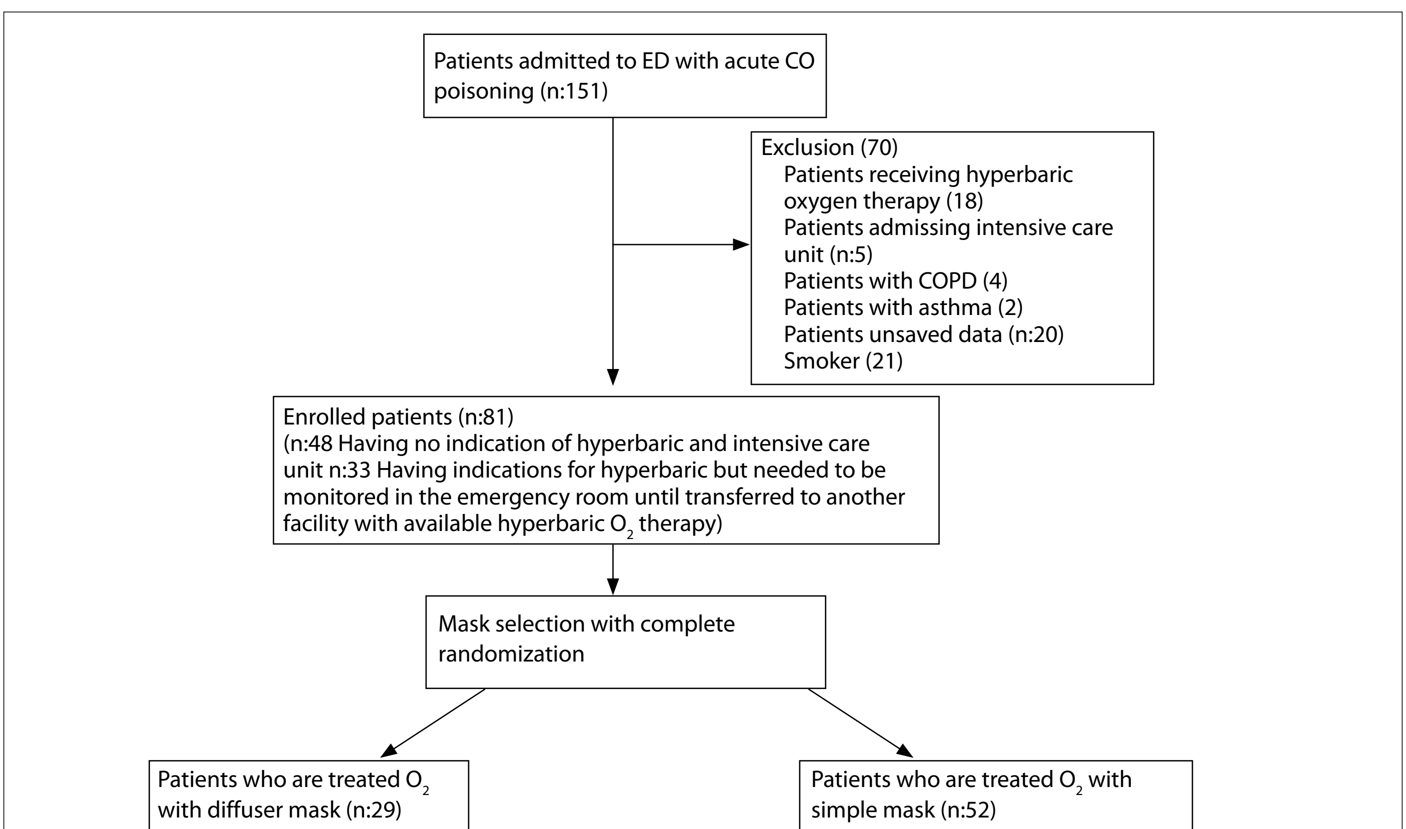

Figure 3. Flowchart of the study

Table 1. Demographic, clinical, and laboratory characteristics of the two groups

	Diffuser mask n (%)	Simple face mask n (%)	p	Total n (%)
n (%)	29 (35.8)	52 (64.2)	-	81 (100.0)
Gender				
Female	18 (62.1)	24 (46.2)	0.1693‡	42 (51.9)
Male	11 (37.9)	28 (53.8)		39 (48.1)
Symptoms				
Headache	16 (19.75)	25 (30.85)	0.690¥	41 (50.6)
Vertigo	7 (8.64)	5 (6.16)		12 (14.8)
Weakness	2 (2.47)	1 (1.23)		3 (3.7)
Confusion	0	4 (4.9)		4 (4.9)
Syncope	3 (3.74)	6 (7.46)		9 (11.2)
Nausea/vomiting	1 (1.2)	6 (7.4)		7 (8.6)
Chest pain	0	1 (1.3)		1 (1.3)
Dyspnea	0	4 (4.9)		4 (4.9)
Source of CO				
Stove fumes	28 (34.39)	47 (58.02)	0.412¥	75 (92.59)
House fire	1 (1.23)	5 (6.18)		6 (7.41)
	Diffuser mask Mean±SD	**Simple face mask Mean±SD**	**p**	**Mean±SD**
Age (year)	36.3±13.7	40.7±15.1	0.1851†	39.1±14.7
Weight (kg)	70.8±15.6	75.4±13.2	0.166†	73.8±14.2
Height (cm)	163.5±7.1	167.8±9.8	0.026†	166.3±9.1
BMI (kg/m^2)	26.6±6.2	26.8±4.1	0.8951†	
ECG rate (beats/minute)	92.3±17.5	87.3±19.3	0.304†	89.4±18.7
Hgb (g/dL)	13.8±2.3	14.5±1.7	0.124†	14.3±1.9
Initial ABG levels				
COHb (mg/dL)	23.2±9.1	23.9±10.5	0.9804*	23.6±10.0
PaO_2 (mm Hg)	87.7±7.5	87.8±8.7	0.8283*	87.8±8.6
SaO_2 (%)	93.6±14.4	96.3±3.7	0.4458*	95.3±9.1
After 1 h of Treat				
COHb (mg/dL)	9.6±5.0	12.8±6.2	0.0203*	11.7±5.9
PaO_2 (mm Hg)	224.4±56.5	183.4±63.7	0.0046*	198.0±64.0
SaO_2 (%)	97.6±6.9	98.6±1.3	0.4327*	98.3±4.2

SD: standard deviation; BMI: body mass index; Hgb: hemoglobin; CO: carbon monoxide; PaO_2: partial pressure of O_2, SaO_2: saturation of O_2, COHb: carboxyhemoglobin; ABG: arterial blood gas; Treat: treatment
‡p-Value was obtained using chi-square test
¥p-Value was obtained using Fisher's exact test
†p was obtained using Student's t-test
*Results were obtained using Wilcoxon-Mann-Whitney test

mean value of COHb (12.8±6.2 mg/dL) in patients treated with SMG was lower than that (9.6±5.0 mg/dL) in patients treated with DMG (Z=−2.32, p=0.0203) (Table 1). The mean values of SaO_2 in patients treated with SMG (98.6±1.3%) and DMG (97.6±6.9%) were comparable (Z=0.79, p=0.4327) (Table 1).

The relationship between the level of CO and the type of patients' complaints has been evaluated. There was a significant relationship between the level of CO and the type of complaints (p=0.001). It is also found that nausea, vomiting, and headache were the main complaints in patients who had COHb ≥25 mg/dL, whereas syncope was observed in patients who had COHb ≥34 mg/dL. There was a significant correlation between pre-treatment level of COHb and respiratory rate (r=0.293, p=0.008).

Admission ECG analyses of the patients were as follows: 80% normal sinus rhythm (NSR), 17% tachycardia, and 2.5% T wave inversion. After treatment, tachycardia decreased to 2.5%, and NSR ratio increased to 95%.

Change in CO (ΔCO) level was calculated by subtracting the pre-treatment value of CO from the post-treatment value of CO. There was no significant relationship between BMI and ΔCO among patients treated with DMG (correlation analysis r=−0.12, p=0.522 and percentage change r=−0.27, p=0.158). Similarly, among patients treated with SMG, there was no significant relationship between BMI and ΔCO values (r=−0.16, p=0.265 and percentage change r=−0.14, p=0.335). As a result, we found that BMI did not affect the treatment in our study group.

Discussion

Our study shows that in acute CO intoxication cases, DMG decreases the blood COHb levels and increases the blood PaO_2 levels significantly faster than SMG in the first hour of treatment.

After exposure, CO enters into the bloodstream rapidly. Compared with O_2, CO shows 230-270 times greater affinity to hemoglobin and forms COHb causing the O_2-hemoglobin dissociation curve shift to the left and leading to severe tissue hypoxia (1, 13). As tissue hypoxia is the main mechanism of CO intoxication, to accelerate CO elimination, normobaric 100% O_2 treatment should be started with a mask as soon as possible for patients whose airway is protected and who have adequate ventilation (14, 15). Giving O_2 through a mask is easily accessible and a safe treatment and can be made using different types of masks. DMG that provided concentrated O_2 directly to the mouth and nose and SMG were two treatment options.

Even with low flow rates, DMG helps to achieve the highest O_2 concentration without any risks that may occur in a closed mask system. In DMG, carbon dioxide (CO_2) retention does not occur, as it is an open system (12). In SMG, CO_2 can be inhaled back if O_2 flow is insufficient. Patient cannot be fed during the use of SMG.

After vomiting, there is a high risk of aspiration. SMG may not be fit to each face type, and if it is tight fitted, it can cause irritation (16). To avoid inhalation of CO_2 and additional respiratory failure load, at least 5 L/min flow rate has been proposed (17).

Based on our study results, after the first hour of treatment, DMG can cause a significant decrease in CO levels compared with SMG. It seems to create this effect by increasing the level of PaO_2 much faster than SMG. DMG can deliver the same level of O_2 more effectively than SMG. In a study by Beecroft et al. (12), they found that using DMG increases the level of PaO_2 significantly higher than venture mask even though the O_2 flow was low. In other studies, it has been shown that O_2 is delivered effectively and reliably with DMG (18, 19).

In our study, we did not find any difference between the two groups in terms of SaO_2 levels after the first hour of treatment. Although saturation of hemoglobin with O_2 increases depending on arterial PaO_2 level, this increase is not linear (20).

Study limitations

Our study has several limitations. First, this is a single-center study. Second, our findings cannot be generalized to intubated patients or patients who need HBOT. Third, this is not a blinded study as the type of mask was seen by both the patient and the doctor.

Conclusion

In conclusion, in the first hour of CO intoxication treatment, DMG appears to be more effective than SMG. It is because of the fact that O_2 can be delivered more effectively by a DMG. It will be beneficial to keep DMG in a quick and easily accessible location. In addition, it may be a more appropriate choice to treat patients with DMG when preparing patients for HBOT.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Dr. Lutfi Kırdar Kartal Training and Research Hospital (Approval Date: 30.04.2012; No:8951337/1009/141).

Informed Consent: Written informed consent was obtained from all patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - H.H.; Design - H.H., A.C.H.; Supervision - H.H., A.C.H.; Resources - H.H., M.T.; Materials - H.H., A.C.H., M.T.; Data Collection and/or Processing - H.H., A.C.H., M.T.; Analysis and/or Interpretation - A.C.H., M.T.; Literature Search - H.H., M.T.; Writing Manuscript - H.H., A.C.H.; Critical Review - H.H., A.C.H.

Acknowledgements: The authors would like to thank Mucahit Emet.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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