

An Analysis of Patients With Carbon Monoxide Poisoning Transported by a Physician-Staffed Helicopter

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Abstract

OBJECTIVE: We retrospectively investigated a series of patients with carbon monoxide (CO) poisoning transported by a physician-staffed helicopter (DH) to seek evidence supporting the daily management of patients with CO poisoning. **STUDY DESIGN:** Subjects were divided into two groups: the carboxyhemoglobin saturation (SpCO) (+) group, which included patients who had a pulse CO-oximeter attached during transportation; and the SpCO (-) group, which included all other patients. We compared the level of SpCO before and after transportation when the level was noted. **RESULTS:** The subjects were predominantly middle-aged and male. Seventeen subjects (53.1%) received a diagnosis of CO poisoning based on the situation in which the subjects were found, without the carboxyhemoglobin level being measured. No subjects show deterioration of their condition after transportation, and none ultimately died. The frequency of male gender, normobaric oxygen treatment and return to the base hospital in the SpCO (+) group was significantly greater than in the SpCO (-) group. The SpCO levels after transportation were significantly lower than they had been before transportation. **CONCLUSION:** This is the first study to show the results of the analysis of patients with CO poisoning transported by the DH. All patients with CO poisoning were safely transported.

Keywords: Carbon monoxide poisoning; Doctor helicopter; Oximeter.

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1. Introduction

Open-type burning heating apparatuses achieve combustion using oxygen in the air and produce exhaust gases, including carbon monoxide (CO), through the incomplete combustion of substances containing carbon. CO diffuses rapidly through the alveolar membrane and binds with an affinity that is 230–300 times that of oxygen, preferably to the iron ion in heme. The clinical symptoms of acute CO poisoning range from headache and dizziness to loss of orientation, symptoms of cardiac angina, loss of consciousness, and death, depending on the concentration and duration of exposure. [Eichhorn, et al. \[1\]](#), [Rose, et al. \[2\]](#), [Wu and Juurlink \[3\]](#) Administration of 100% oxygen (normobaric oxygen [NBO]) as early as possible is recommended for all patients with CO poisoning, although the higher the partial pressure of oxygen provided, the shorter the elimination period, so hyperbaric oxygen (HBO) therapy is recommended for patients with CO poisoning whenever possible. [Weaver \[4\]](#) However, medical facilities capable of providing HBO are limited, especially for severely ill patients who need intensive care. Accordingly, some patients with CO poisoning receive just NBO therapy [\[5\]](#).

Izu peninsula is a popular recreational scuba area located near Tokyo. For patients with decompression illness (DCI), a physician-staffed helicopter (called a doctor helicopter [DH], in Japan) is dispatched in order to transport patients to a hospital for recompression (HBO) treatment; a helicopter is necessary for such cases because there are no suitable hospitals on the Izu peninsula. Our hospital is the base of the DH in eastern Shizuoka prefecture, where the Izu peninsula is located, and we routinely evacuate patients with DCI at the scene and transport them to medical facilities able to provide HBO. [Yanagawa, et al. \[6\]](#), [Oode, et al. \[7\]](#) Because our hospital has only a monoplace chamber for HBO treatment and severely ill patients with DCI cannot undergo sufficient HBO therapy such as United State Treatment Navy because the monoplace chamber is not suitable the (<https://www.eubs.org/documents/DHM%20Sep2012%20Suppl%20Treatment%20tables.pdf>) Patients transported by a ground ambulance take about 1.5 to 4 h to reach medical facilities with a multiplace HBO chamber.

The DH in eastern Shizuoka treats patients suffering from a variety of endo- and exogenous diseases, including CO poisoning. [Omori, et al. \[8\]](#) Severely ill patients with CO poisoning are also transported in order to receive HBO therapy, similar to patients with DCI. [Holt and Weaver \[9\]](#) However, there has been only one case report describing a patient who was transported by air for HBO; the patient had been initially diagnosed with arterial gas embolism. Accordingly, we retrospectively investigated the patients with CO poisoning who had been transported by the DH in search of evidence supporting the daily management of patients with CO poisoning.

2. Methods

The protocol of this retrospective study was approved by the review board of Shizuoka Hospital, Juntendo University, and all examinations were conducted in accordance with the standards of good clinical practice and the Declaration of Helsinki.

Shizuoka Hospital of Juntendo University is a hospital with 577 beds and is a medical emergency center in eastern Shizuoka Prefecture, which is located near Tokyo. This hospital serves a population of approximately 1,230,000. The DH staff generally consists of one pilot, one mechanic, one doctor and one nurse. The indications for air evacuation in Japan are decided upon the receipt of a 119 (emergency) call based on key words, such as hemiplegia, chest pain, unconsciousness or severe traffic accident when the emergency medical technician receives the dispatch request or based on the judgment of the emergency medical technicians placed in contact with the patient(s).

We retrospectively investigated the medical chart of the patients who were transported by the DH from March 2004, when the DH in eastern Shizuoka started service, to January 2019 and received a diagnosis of CO poisoning. These patients were included as subjects in the present study. The exclusion criterion was cancellation of DH dispatch. We collected data on each subject's sex, age, mechanism of CO poisoning, route by which CO poisoning was diagnosed, dispatch details (dispatched to the scene or interhospital transportation), vital signs (Glasgow Coma Scale [GCS], systolic blood pressure, heart rate) when staff of the DH checked the subject, pulse CO-oximeter attached or not (RAD-57; Masimo, Tokyo, Japan) to measure the carboxyhemoglobin saturation (SpCO) [10], SpCO level, treatment provided by DH staff (drip infusion, oxygen therapy, tracheal intubation), condition deterioration during transportation (present or absent), purpose of transportation (for HBO treatment or NBO), return to the base hospital or not, and final outcome (survived or died).

Subjects were divided into two groups: the SpCO (+) group, which included patients who had a pulse CO-oximeter attached during transportation; and the SpCO (-) group, which included all other patients. DHs have been equipped with a pulse CO-oximeter since 2013. The variables mentioned above were compared between the two groups.

We compared the level of SpCO before and after transportation when the level was noted because patients who were transported by the DH were in a relatively hypobaric hypoxic condition compared to at ground level.

Statistical analyses were performed using a non-paired Student's *t*-test, paired Student's *t*-test and a chi-square test, as appropriate. A P value less than 0.05 was considered to indicate a statistically significant difference. All of the data are presented as the mean \pm standard deviation.

3. Results

During the investigation period, the DH was dispatched 41 times. In nine cases, the dispatch was cancelled after the patient was evaluated by emergency medical technicians due to cardiac arrest with an inability to obtain spontaneous circulation or signs of rigor mortis. After excluding these 9 dispatches, the remaining 32, which involved 32 patients, were defined as the subjects.

The background characteristics of the subjects are shown in Table 1. The subjects were predominantly middle-aged and male. The number of accidental CO poisoning incidents was 18, and the number of suicides was 14. Seventeen subjects (17/32=53.1%) received a diagnosis of CO poisoning based on the situation in which the subjects were found, without the carboxyhemoglobin level being measured. All subjects underwent drip infusion and NBO with at least 10 L of oxygen with a reservoir mask during transportation. No subjects show deterioration of their condition after transportation, and there were no deaths. Six of 32 subjects underwent NBO therapy after arriving at the receiving hospitals in the end. Five of the six patients were transported to our hospital for NBO, and the remaining one was transported to the burn center without receiving HBO. All subjects who underwent NBO in our hospital obtained a survival outcome without any sequelae.

Table 2 shows the results of the comparisons between the SpCO (+) and SpCO (-) groups. The frequency of male gender, NBO treatment and return to the base hospital in the SpCO (+) group was significantly greater than in the SpCO (-) group.

The levels of SpCO are compared between pre- and post-transportation in Figure 1. There were five subjects who had data on their SpCO level before and after transportation. The SpCO levels after transportation were significantly lower than they had been before transportation.

4. Discussion

This is the first study to show the results of the analysis of patients with CO poisoning transported by the DH. All patients with CO poisoning were safely transported. Most patients were transported for HBO therapy. However, following the introduction of SpCO monitoring, some patients were transported to the base hospital for NBO.

Regarding the indications of HBO for patients with CO poisoning, randomized prospective studies and meta-analyses of randomized controlled trials have shown that HBO-treated CO poisoning patients have a lower incidence of neuropsychological sequelae, including headache, memory impairment, difficulty concentrating, disturbed sleep, and delayed neurological sequelae than those treated with NBO. Weaver, *et al.* [11], Lin, *et al.* [12] A guideline for the treatment of CO poisoning is currently in development (AWMF registration number 040-012) and aims to standardize relevant healthcare in Germany. Given this situation, HBO therapy should be the method of choice in adult patients with neurological deficits, cardiac ischemia, loss of consciousness, metabolic acidosis, and carboxyhemoglobin values >25%. Eichhorn, *et al.* [1], Wolf, *et al.* [13], Mathieu, *et al.* [14] However, regardless of

these inclusion criteria, any decision to treat is always an individual decision. Every patient with clinical symptoms of CO intoxication should be treated with high oxygen partial pressure until the COHb concentration has dropped to 3% or clinical symptoms have resolved completely. Eichhorn, *et al.* [1], Wolf, *et al.* [13], Mathieu, *et al.* [14] The level of carboxyhemoglobin values in all patients who received NBO therapy in our hospital was <25%, as confirmed by a pulse CO-oximeter in the prehospital setting, and no patients had any severe symptoms. Accordingly, SpCO monitoring may be useful for selecting the treatment and appropriate medical facility for conveyance in the management of patients with CO poisoning by the DH.

The present study is associated with some limitations, including its retrospective nature and the small patient population. In this study, about half of the patients were diagnosed without having their carboxyhemoglobin level measured, so that this clinical diagnosis of CO poisoning may be fault. Furthermore, this study did not perform a comparison with patients who were transported by ground ambulance. The indications of HBO for patients with CO poisoning have been described. Eichhorn, *et al.* [1], Wolf, *et al.* [13], Mathieu, *et al.* [14] However, who should be transported by air or ground services remains a clinical question. Thus, future prospective studies involving a greater number of patients with a comparison with transportation by ground ambulance or only NBO therapy are needed.

5. Conclusion

This is the first study to show the results of the analysis of patients with CO poisoning transported by the DH. All patients with CO poisoning were safely transported. SpCO monitoring may be useful for selecting treatment and the destination during DH activity.

Acknowledgements

This manuscript received financial support from the Ministry of Education, Culture, Sports, Science and Technology (MEXT)-Supported Program for the Strategic Research Foundation at Private Universities, 2015-2019 concerning [The constitution of total researching system for comprehensive disaster, medical management, corresponding to wide-scale disaster].

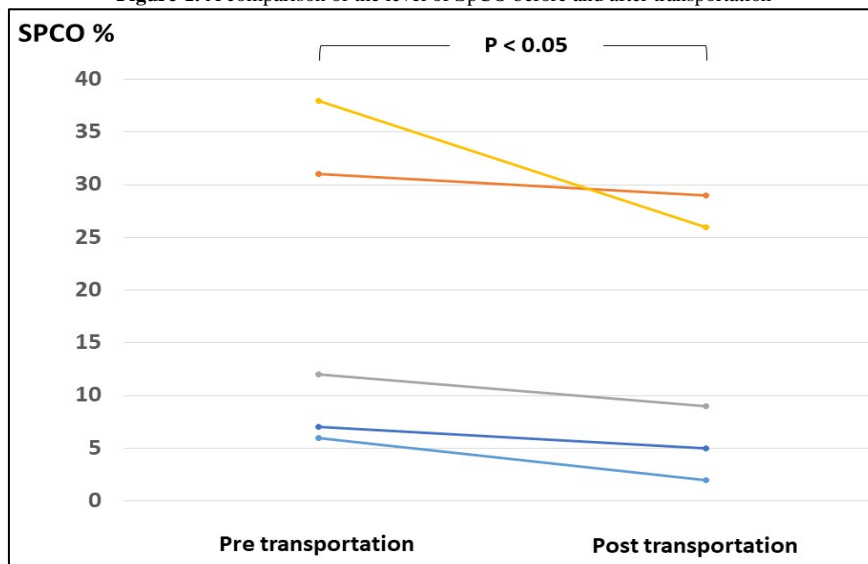
Conflicts of interest

The authors declare no conflicts of interest in association with this study.

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Figure-1. A comparison of the level of SpCO before and after transportation



The SpCO levels after transportation were significantly lower than they had been before transportation
 SpCO: carboxyhemoglobin saturation

Table-1. Background characteristics (n = 32)

Age (years)		21-92 (47.3 ± 17.3)
Sex	Male/Female	25/7
Symptom	Unconsciousness	25
	Nausea	7
Mechanism		
Accident	Heating appliance in closed space	6
	Fire	5
	Factory labor	3
	Tunnel labor	2
	Garage labor	2
	SuicideBriquette combustion in a house	9
	Exhaust gas into a car	5
	Diagnosis of carbon monoxide poisoning	
	Situation	17 (53.1%)
	Value of SpCO	8 (25 %)
	Value of blood gas analysis	7 (21.9 %)
Glasgow Coma Scale		5-15 (14 (9, 15))
Systolic blood pressure (mmHg)		129.2 ± 27.0
Heart rate (beats per minute)		94.0 ± 20.3
Oxygen therapy (Oxygen flow)		32/32 (100%) (10-15 L/minute)
Lactate ringer drip infusion		32/32 (100%)
Tracheal intubation		11/32 (34.4%)
SpCO monitor adaptation		8/32 (25%)
Deterioration during transportation		0
From request to arrival at a hospital (minutes)		22.9 ± 59.3
Purpose of DH dispatch		
	Evacuation from the scene	21 (65.6%)
	Interhospital transportation	11 (34.4%)
Purpose of transportation		
	For NBO	6 (18.8%)
	For hyperbaric oxygen therapy	26 (81.2%)
Outcome (survival rate)		100%

SpCO: carboxyhemoglobin saturation, NBO: normobaric oxygen therapy

Table-2. Comparisons between the SpCO (+) and SpCO (-) groups

	SpCO (+)	SpCO (-)	p value
	(n=8)	(n = 24)	
Age (years)	46.0 ± 16.2	51.2 ± 20.7	n.s.
Sex (male/female)	17/7	7/0	p < 0.05
SpCO			
Level of SpCO	5-38, 15.3 ± 12.3	N/A	
Glasgow Coma Scale	13.5 (10, 15)	14 (8.25, 15)	n.s.
Heart rate (beats per minute)	94.8 ± 17.8	93.7 ± 21.5	n.s.
Tracheal intubation (yes/no)	5/3	6/18	p=0.05
Symptom			
Unconsciousness/nausea	6/2	19/5	n.s.
Request to arrival (minutes)	53.6 ± 3.3	60.7 ± 25.5	n.s.
Evacuation			
Scene/interhospital	7/1	14/10	p=0.1
Transportation for HBO (yes/no)	4/4	22/2	p=0.01
Return to base hospital (yes/no)	5/3	1/23	p<0.05

SpCO: carboxyhemoglobin saturation, n.s.: not significant, HBO: hyperbaric oxygen