EVALUATION OF THE CHANGES IN SPCO INDEX IN PATIENTS WITH INHALATION INJURY

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ABSTRACT

Objective: *Evaluate the variation of SpCO index with clinical symptoms, medical support pre-hospital, and mortality rate of inhalation injury patients.*

Subjects and methods: *Prospective descriptive study with longitudinal follow-up in inhalation injury patients at the Intensive Care Unit - Le Huu Trac National Burns Hospital from March 2022 to May 2023. 50 patients with inhalation injuries were hospitalized within the first 72 hours. Patients were treated according to the treatment regimen for inhalation injury and CO poisoning. Subclinical and clinical symptoms were recorded and compared. The data was processed using STATA 16.0 software.*

Results: *The average SpCO index upon admission in the study patients was 15.7%. 24 patients admitted to the hospital before 5 hours had an average SpCO index was 8.3 ± 7.6%. 88% of patients were hospitalized within 12 hours of the accident. Medical support pre-hospital: Oxygen supply 63.3%, endotracheal intubation 35% and mechanical ventilation 25%. Respiratory assessment indicators including SpO_2 and average PaO_2 were high and had no statistical difference. Patients with a severe grade of inhalation injury have a high SpCO index upon admission. The mortality rate was high (> 70%) and the SpCO index at admission has no relationship with mortality rate.*

Conclusion: *Patients with CO poisoning were hospitalized early, the SpCO index decreased over time and did not correlate with treatment outcome. Patients with more severe inhalation injuries had a higher SpCO index upon admission. Symptoms are non-specific mortality rate was high, causing confusion and making it difficult to diagnose and predict inhalation injury patients.*

Keywords: *Carbon monoxide poisoning, inhalation injury*

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1. INTRODUCTION

Inhalation injury patients often suffer burns in closed rooms with the main agents being flame burns and accompanying combustion products that can be inhaled during the burn process. In addition to the cause of death due to severe burns, the cause of carbon monoxide poisoning is a factor that aggravates respiratory disorders. During combustion, most materials produce toxic gases, the common being CO and CO_2. CO poisoning is the leading cause of death in fires and accounts for about half of all burn deaths [1].

Toxicity to humans is often overlooked because CO is odorless and tasteless, and its clinical symptoms and signs are nonspecific. CO poisoning would be definitively diagnosed when that index in the blood reaches 10% and above [2].

To measure the CO index in the blood, specialized equipment such as a non-invasive pulse SpCO meter or a separate blood gas kit is not common in Vietnam, definitive diagnosis is still difficult. This greatly affects the treatment attitude, prognosis of medical staff with CO poisoning in general and inhalation injury patients in particular.

2. SUBJECTS AND METHODS

2.1. Subjects

Criteria for Selecting Study Patients

- 50 inhalation injury patients, treated at the Intensive Care Unit - Le Huu Trac National Burns Hospital from March 2022 to May 2023.

- Patients were diagnosed with inhalation injury burns based on bronchoscopy results. Classify the grade of inhalation injury according to Endorf (2007).

- Patients had measured SpCO index with a handheld Masimo Radical -7 meter.

Exclusion criteria: The patient is hospitalized after 72 hours.

2.2. Methods

- Prospective study describing longitudinal follow-up, comparing before and after according to clinical criteria.

- Diagnosis of CO poisoning is still based on measuring COHb concentration, Masimo's Rad-7 meter determines COHb [4].

- Diagnosis of CO poisoning is confirmed when the measured SpCO index is 10% or higher. Monitor SpCO index every 2 hours and clinical symptoms.

- Group 1 is hospitalized patients with a measured SpCO index of 10% or more.

- Group 2 is hospitalized patients with a measured SpCO index below 10%.

2.3. Data processing

- Study data are processed according to medical statistical methods by STATA 16.0 software.

- Data were expressed as either mean and standard deviation ($\bar{X} \pm SD$) or numbers and percentages, the X^2 test was performed for comparing groups.

- P value < 0.05 is considered statistically significant.

3. RESULTS

Table 3.1. Characteristics of study patients

Characteristics	$\bar{X}$ ± SD (n = 50)	Min-Max
Age	37.1 ± 11.9	16 - 65
Total burn surface area (%)	63.5 ± 23.3	1 - 95
Deep burn area (%)	37.3 ± 22.6	0 - 89
Male/Female	42/8 (84%)	

Comments: The study patients had average burn areas of severe burns. The total burn area (TBA) is over 60%, the deep burn area is nearly 40%. The patients are mainly male (84%).

Table 3.2. Characteristics of respiratory index upon admission

Characteristics	Group 1	Group 2	p
	$\bar{X}$ ± SD (n = 20)	$\bar{X}$ ± SD (n = 30)	
pH	7.3 ± 0.11	7.29 ± 0.12	0.33
pO_2	168.1 ± 129.1	147.1 ± 77.4	0.24
Lactate	4.8 ± 3.1	3.9 ± 1.7	0.08
SpO_2	96.3 ± 2.9	97.2 ± 3.2	0.82
SpCO	15.7 ± 4.7	1.2 ± 1.8	

Comments: Inhalation burn patients with CO poisoning had a high average pO_2 index of 168.1mmHg. The pH, pO_2, SpO_2 indices had no difference between the two groups. The lactate index in the CO poisoning group was high but not statistically significant compared to the non-CO poisoning group with p = 0.08.

Table 3.3. Characteristics of pre-hospital treatment and result

Pre-hospital treatment	Group 1 n = 20 (%)	Group 2 n = 30 (%)	p
Oxygen supply	10 (50%)	19 (63.3%)	0.349
Endotracheal intubation	7 (35%)	14 (28%)	0.413
Mechanical ventilation	5 (25%)	12 (24%)	0.273
Results of the treatment			
Survival	5 (25%)	6 (20%)	0.676
Death	15 (75%)	24 (80%)	

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Comments: CO poisoning patients received respiratory support pre-hospital equivalent to non-CO poisoning patients ($p > 0.05$). Mortality was high and had no difference between the two groups ($p > 0.05$).

Table 3.4. SpCO index measured by the time of admission

SpCO index by the time of admission	n (%)	$\bar{X}$ ± SD (%)	Min-max
0 - 5h	24 (48%)	8.3 ± 7.6	0 - 24
6 - 12h	20 (40%)	6.9 ± 8.7	0 - 27
13 - 24h	3 (6%)	1.3 ± 2.3	0 - 4
> 24h	3 (6%)	2 ± 2.6	0 - 5

Comments: There were 24 patients admitted before 6 hours with an average SpCO index of 8.3%, the highest measured was 24%. Patients with the highest index recorded were 27% hospitalized after 8 hours

Table 3.5. The risk factors for death

Risk factors	p	Hazard-ratio	95% Confidence Interval
Age (age)	0.008	1.035	1.009 - 1.061
Admission time (hour)	0.481	0.984	0.94 - 1.028
Total surface area (%)	< 0.001	1.034	1.016 - 1.053
Deep burn area (%)	< 0.001	1.032	1.016 - 1.047
SpCO index admission (%)	0.736	0.993	0.961 - 1.133

Comments: The risk factors for death by age and burn area are statistically significant ($p < 0.05$). SpCO index at admission has no relationship with mortality rate.

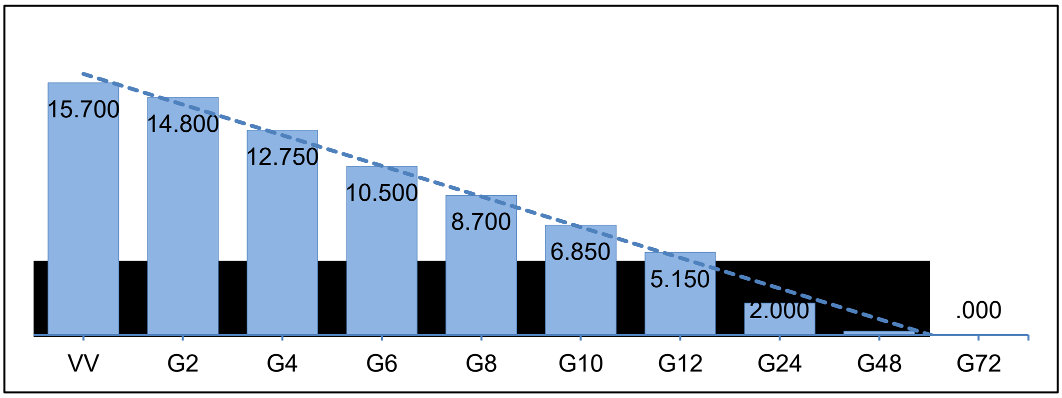

Figure 3.1. Evolution over time

Comments: The SpCO index gradually decreases over time of hospitalization. After 6 hours, the SpCO index decreased to less than 10% and no patient was detected with CO after 72 hours.

Table 3.6. SpCO index according to a grade of inhalation injury

Classification according to Endorf	n	%	SpCO index (%)	
			$\bar{X} \pm SD$	p
Grade 1	15	30	3.3 ± 5.6	$p^{1-2} = 0.06$
Grade 2	27	54	6.9 ± 8.2	$p^{2-3} = 0.03$
Grade 3	7	14	13.3 ± 6.3	$p^{1-3} < 0.001$
Grade 4	1	2	19	

Comments: Patients with a more severe grade of inhalation injury have an average higher SpCO index. One patient with a 4th-grade inhalation injury had a SpCO index of 19%.

4. DISCUSSION

4.1. Characteristics of study patients

Inhalation injury patients are at high risk of CO poisoning. According to 2021 global statistics, the global mortality rate from CO poisoning is 0.366 per 100,000; with 28,900 deaths and 1,18 million cases across all ages. Nearly 70% of deaths occur in men, and the 50 - 54 age group has the highest number of deaths [5].

The study patients were a group of adult patients, on average of working age (mean age 37.1 ± 11.9). It can be explained by the fact that burn injuries are mainly due to work and daily life accidents. The TBSA (total body surface area) is very large, on average 63.5 ± 23.3%, but is unevenly distributed. The smallest case had 1%. Similar to the area of deep burns, an average of 37.3 ± 22.6% of the TBSA and there were patients in the study who did not have deep burn lesions.

The average TBSA is similar to the results of author Nguyen Nhu Lam and colleagues (2019) in their study on inhalation injury [6]. Regarding the characteristics of the group of inhalation injury patients with CO poisoning (group 1), there were no differences in age, deep burn area and Apache II score upon admission compared to the group inhalation injury patients without CO poisoning (group 2). There was a difference in the overall burn area: Group 2 had a statistically significantly larger area than Group 1 (p = 0.03). This may indicate that a large burn area is not a factor related to CO poisoning. The study patients were severe burn patients, so they had burn wounds in many locations on the body, but the common characteristic was that 100% had burn wounds on the head, face, and neck area.

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4.2. Subclinical characteristics of study patients

4.2.1. Characteristics of non-invasive assessment

SpO_2 index:

Although it has been proven effective in monitoring respiratory status in emergency situations, in cases of CO poisoning the SpO_2 index is considered inaccurate [7]. The SpO_2 index of group 1 was 96.3 ± 2.9% and that of group 2 was 97.2 ± 3.2%. The SpO_2 index was all high and according to the assessment criteria, the patients did not have respiratory failure. That is the same conclusion as the studies on situations of CO poisoning by Rehberg (2009) and Mlcak (2020) [8], [9]. The reason is that conventional pulse oximetry devices cannot distinguish between COHb and HbO_2.

SpCO index:

The SpCO index was measured using a Radical-7 monitor from Masimo (USA). Research by Piatkowski (2009), and Feiner (2013) has proven that the Radical-7 monitor accurately detects hypoxia in the blood and accurately detects carboxyhemoglobin [10], [11]. Although some studies have not fully confirmed the accuracy of this device, the benefits of a device that can detect CO poisoning early and non-invasively cannot be denied [12].

The SpCO index depends on the time and circumstances of the fire. Inhalation injury patients must have their SpCO index checked upon admission. Our study results on patients with a confirmed diagnosis of inhalation injury show that patients hospitalized early tend to have a high SpCO index. Hospitalized patients had an average index of 15.7%, in the first 5 hours the SpCO index was 8.3 ± 7.6%, then from the 6th to 12th hours it was 6.9 ± 8.7%. When patients were admitted to the hospital after 12 hours, the SpCO index visibly dropped, and most of these patients were not found to have CO poisoning. This may explain the high rate of victims in fires who often die before being hospitalized.

The process of tracking changes in the SpCO index gradually decreases over time. The patients were treated according to the treatment regimen for inhalation injury and CO poisoning. After 6 hours, the SpCO index reached the limit of 10% and continued to decrease in the following hours. No patient had CO detected by the meter after 72 hours. This result corresponds to the pathophysiology of CO poisoning, in conditions of 100% O_2, the half-life of CO is less than 90 minutes. With hyperbaric oxygen at 3 ATA pressure, the half-life of CO is reduced to 23 minutes. The only appropriate treatment for significant CO poisoning is hyperbaric oxygen therapy (HBOT) [13].

However, the study patients were severe burn patients who were not suitable for HBOT treatment using pressure chambers. When admitted to the hospital, all patients had their SpCO index measured, after endotracheal intubation, mechanical ventilation was adjusted to oxygen ventilation with 100% FiO_2 mixing for 6 hours.

The SpCO index upon admission depends not only on time but also on initial emergency treatment. In respiratory emergency measures, the main measures are oxygen supply, endotracheal intubation, and mechanical ventilation. In the group 1, only 50% of patients received oxygen, 63.3% less than the group 2. The rate of endotracheal intubation is 35% and mechanical ventilation is 25% but the number is less than group 2. This is the main cause of the high pre-hospital death rate. Part of the reason is that measures to diagnose and monitor poisoning are limited and not many medical staff are regularly trained in this emergency.

4.2.2. Characteristics of invasive assessment methods

In measures to assess and monitor respiratory emergencies, arterial blood gas testing is very important. However, studies on arterial blood gases in CO poisoning show very notable problems.

According to Jor (2008), it was found that arterial PaO_2 monitoring was very abnormal in cases of CO poisoning. This is because partial pressure only describes the tendency of gas molecules to escape from the solvent in which they are contained. If the solubility of oxygen (O_2) in the blood is changed by the binding of CO to hemoglobin, the O_2 content will change but the partial pressure will remain the same (as long as the gas mixture with which the blood is in equilibrium remains constant). The cause of death in CO poisoning is reduced O_2 content in the blood because the binding sites of oxygen on hemoglobin are blocked by CO, leading to insufficient oxygen supply to the tissues. This will produce lactic acidosis as a consequence of anaerobic respiration, which may be the only abnormality in the blood gas analysis if carboxyhemoglobin is not measured directly. It can be seen in our study that blood lactate in group 1 was high at 4.8mmol/l, but there was no difference in group 2 with p = 0.08. PaO_2 concentration may decrease slightly at the scene of poisoning, but immediately after the patient is transferred, PaO_2 tends to increase again and increase higher than normal [14].

Moon et al. (2020) study of adult patients with CO poisoning on 340 patients also showed a similar situation [15]. The results of arterial blood gas PaO_2 upon admission in patients in Moon's study were 192mmHg (161 - 225), similar to our study results of 168.1mmHg. This can easily cause misassessment of CO poisoning in medical facilities that do not have tests or diagnostic tools for CO poisoning. Therefore, it is recommended that all burn patients with risk factors be maintained on high-concentration oxygen or artificial ventilation despite testing methods or functional exploration. got good results.

4.3. Clinical characteristics and results of study patients

**** Hospital admission time***

The study patients were adults (18 - 65 years old) and were hospitalized within 72 hours of burn injury. In the treatment of CO poisoning, emergency measures are very important but must also be applied during the half-life of CO to be most effective. The half-life of CO is 4 to 5 hours, but adequate oxygen alone can reduce the half-life to 1 hour [16].

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Therefore, patients in group 2 had a later hospitalization time than patients in group 1 because one of the reasons was that they used more emergency respiratory measures (Table 3.3). The study patients were all inhalation injury and severe burn patients so they were transported to the Burn Hospital sooner, after 1 hour at the earliest and 33 hours at the latest.

**** Classification of inhalation injury***

Our study applied Endorf's (2007) method, which is also widely used today, to diagnose the degree of inhalation harm by using bronchoscopy pictures [17]. Numerous studies have been mentioned about inhalation injury and CO poisoning, but none have included data on the relationship between the severity of inhalation injury and CO poisoning levels. CO poisoning patients mainly had grade 2 (55%) and grade 3 (30%), with 1 patient with the most severe inhalation injury being grade 4. This patient was admitted to the hospital 2 hours after a fire accident and measured CO index of 19% at the time of admission. The majority of patients with grade 1 inhalation injury had an average recorded CO index comparatively lower, 3.3 ± 5.6%. Focusing mainly on patients with grade 2 inhalation injury with an average CO index of 6.9 ± 8.2%. Grade 3 of inhalation injury had CO poisoning and the average CO index was high, 13.3 ± 6.3%. SpCO index increases corresponding to the severity of inhalation injury, between mild (grade 1 - 2) and severe (grade 3) ($p < 0.05$). Thereby showing the relationship between respiratory burns and CO poisoning as well as the grade of inhalation injury and CO index right in the diagnosis upon admission to the hospital.

**** The mortality and risk factors***

The study patients were inhalation injury patients who were evaluated as severe burn patients. According to previous studies in Vietnam, the average rate of inhalation injury is over 70% [6]. Factors that could increase the mortality rate considered in the study including CO concentration and time of hospitalization were not statistically significant because the patients were all diagnosed and treated according to the CO poisoning protocol. The patient's age factor is statistically significant with $p < 0.05$ and the risk ratio HR was 1.035; 95% confidence interval [1.009 - 1.061]. The burn area is also a risk factor for death for patients with inhalation injury and is used in formulas to calculate mortality rates.

5. CONCLUSION

The average SpCO index of inhalation injury patients upon admission is 15.7% and the poisoning rate was 40%. Patients with inhalation injuries who were hospitalized early had respiratory indicators that were not different between patients with CO poisoning and non-CO poisoning. The SpCO index is proportional to the severity of the grade of inhalation injury. After admission, patients received effective treatment for CO removal and the SpCO index did not correlate with mortality.

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