Original Article

The Possible Role of Partial Pressure of Carbon dioxide Level Changes in the Outcome of Acute Carbon Monoxide Poisoning

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ABSTRACT

Background: Acute carbon monoxide (CO) poisoning remains a health concern worldwide and is associated with increased morbidity and mortality. Recognizing critical cases is highly valued to provide early efficient management and improve patient outcomes. **Aim:** This study aims to measure the partial pressure of carbon dioxide (PaCO2) level in patients with acute CO poisoning and to assess the role of PaCO2 level changes in the outcome of acute CO poisoning. **Methods**: This prospective study was conducted by collecting demographic, clinical data, blood samples from 35 patients with acute CO poisoning admitted to the Poison Control Center, Ain Shams University. Carboxyhemoglobin (COHb), arterial blood gases and cardiac markers were measured on admission. **Results:** The studied patients with acute CO poisoning were 20 males (57.1%) and 15 females (42.9%), with an average age of 36.3 ± 13.6 years. Patients had lower than normal levels of PaCO2, pH, and HCO3 and higher than normal levels of troponin I and B-Natriuretic Peptide (BNP). A substantial negative weak to moderate correlation was found between the length of the hospital stay and pH, HCO3 and PaCO2 measurements. On the other hand, BNP had a significant positive moderate correlation with length of hospital stay and a negative correlation with PaCO2. Survivors, displayed significantly higher mean levels of PaCO2, pH and HCO3 than cases who died. **Conclusion:** The current study suggests that changes in PaCO2 levels play an important role in the outcome of patients with acute CO poisoning, potentially acting as a marker of severity and indicating an increased risk of cardiotoxicity. Lower levels of PaCO2 might be associated with a more severe clinical presentation and poorer prognosis. Clinicians could use PaCO2 as a useful clinical indicator to identify patients at a higher risk of adverse outcomes.

Keywords: Acute carbon monoxide poisoning, PaCO2, cardiotoxicity, mortality.

I. INTRODUCTION:

Acute carbon monoxide (CO) poisoning is a common medical emergency and one of the leading causes of death due to exposure to high levels of CO gas. CO is a colorless, odorless and tasteless gas, which makes it difficult to detect. In survivors, morbidity persists following initial stabilization in nearly 40 percent of patients (Rose et al., 2017; Kinoshita et al., 2020). CO binds to hemoglobin in red blood cells with a much greater affinity than oxygen, leading to the formation of carboxyhemoglobin (COHB). This reduces the oxygen-carrying capacity of the blood, leading to tissue hypoxia and potentially fatal outcomes (Kudo et al., 2014).

In the heart, the resulting tissue hypoxia causes acute myocardial injury which is commonly observed in CO-poisoned patients and is associated with an increased rate of long-term mortality (Can et al., 2019). This acute myocardial injury is manifested clinically in the form of myocardial infarction, arrhythmia or heart failure. Cardiac toxicity is thought to be the cause of mortality in most cases of acute CO poisoning (Geng et al., 2020).

The partial pressure of arterial carbon dioxide (PaCO2) is the measure of concentration of carbon dioxide in arterial blood. It is an essential component of acid-base balance and plays a significant role in maintaining optimal pH levels in the body. In acute CO poisoning, PaCO2 can be altered by stimulation of the peripheral chemoreceptors due to hypoxia-induced COHB formation, by stimulation of nociceptors due to pulmonary edema, by central respiratory center-induced neurologic damage, or by a compensatory response to metabolic changes (Ozyurt et al., 2017; Moon et al., 2020).

This study aims to measure the PaCO2 level in patients with acute carbon monoxide poisoning and to assess the role of PaCO2 level changes in the outcome of acute carbon monoxide poisoning.

II. PATIENTS AND METHODS:

Study Design: A prospective cohort study.

Study population: Patients admitted to the Poison Control Center – Ain Shams University Hospitals (PCC- ASUH) and diagnosed with acute carbon monoxide poisoning from October 2021 till March 2022 and fitting the inclusion criteria.

- Inclusion Criteria: Adult Patients of both sex aged 18 years or older, with a confirmed diagnosis of acute carbon monoxide poisoning. Diagnosis of acute CO poisoning was established according to the history of exposure, clinical characteristics of acute CO

poisoning and elevated blood carboxyhemoglobin (COHB) levels of more than 5%.

- Exclusion Criteria: Patients with a history of cardiac disease, chronic obstructive pulmonary disease, asthma or any other pre-existing cardiac or respiratory condition or chronic disease that may affect PaCO2 levels.

Sample Size: By using Power Analysis and Sample Size Software (PASS 15) (Version 15.0.10) for sample size calculation, setting the confidence level at 90%, the margin of error + 0.15 and after reviewing previous study results (Moon et al., 2020) showing that the incidence rate of hypocapnia at presentation after acute CO poisoning was (67.5%). Based on that and considering 10% dropout rate due to missing data, a sample size of at least 35 patients with acute CO poisoning was sufficient to achieve study objective.

Data Collection Tools:

A data extraction sheet was used to record the required data which included:

- Patient demographics, medical history and presenting symptoms, demographic data (age, sex, occupation), intoxication data (source of CO, duration of exposure, and delay time before medical treatment) and clinical data (gastrointestinal symptoms such as nausea, vomiting, and abdominal pain; cardiovascular symptoms such as palpitations and chest pain).
- Clinical examination which included vital data (pulse, temperature, blood pressure and respiratory rate) and examination of body systems.
- **Laboratory investigations on admission included**:
  - Laboratory investigations using arterial blood samples:

Arterial blood samples were collected from each subject under complete aseptic precautions in a plastic disposable syringe and the levels of PaO2, PaCO2, pH, SaO2, and HCO3 were measured as well as carboxyhemoglobin (COHB) level by a blood gas analyzer (Cobas 221) that was supported by a CO-oximetry panel developed by Roche Company

  - Laboratory investigations using venous blood samples:

Venous blood samples were collected under complete aseptic precautions with a plastic disposable syringe. Samples were spun then they were divided into two tubes. One was used for Troponin I

level determination, while the other was stored at –80°C to be used for B-Natriuretic Peptide (BNP) level determination. Plasma levels of Troponin I were analyzed using an automatic auto-analyzer in the biochemistry laboratory, it was estimated by microplate immuno-enzymometric assay using Te DRG® cTnI ELISA provided by Monobind. BNP level was measured using an enzyme immunoassay kit (Human pro-brain natriuretic peptide ELISA Kit) Bioassay Technology Laboratory, Catalogue Number E3041Hu following the manufacturer's instructions.

- Treatment protocols and clinical outcomes were recorded, including the need for mechanical ventilation, length of hospital stay, and mortality.

Data management and Statistical analysis:

Data were tabulated and statistically analyzed using SPSS, version 20 (SPSS Inc., Chicago, IL). Quantitative variables were described as mean and standard deviation. Qualitative variables were expressed as frequencies (n) and percentages (%). Fisher exact test was used to assess the relation between qualitative variables. An Independent t-test was used to compare quantitative variables between survived and dead patients. Pearson correlation coefficient was used to correlate between quantitative variables. P-value ≤ 0.05 was considered statistically significant.

Ethics Considerations: Approval was obtained from the Research Ethics Committee at the Faculty of Medicine, Ain Shams University **R116/2023** as well as approval from the Poison Control Center ASUH Director. Informed consent was collected from patients and privacy of data throughout the study was maintained.

III. RESULTS:

In this prospective study, 35 patients with carbon monoxide poisoning 20 males (57.1%), 15 females (42.9%), with average age of (36.3 years ± 13.6) were included. Most of them were manual workers (40%) and housewives (29%).

Table 1: Distribution of the clinical picture and outcome of cases with acute CO poisoning at Poison Control Center - Ain Shams University Hospitals from October 2021 till March 2022

Parameters		**Number**	**Percentage %**
Delay (hours) *Mean ± SD (Min – Max)*		4.3 ± 1.7 (1-6)	
Disturbed Consciousness Level (DCL)	**Present on admission**	20	57.1%
	Absent on admission	2	5.7%
	Occurred before admission	13	37.1%
Glasgow Coma Scale (GCS) Mean ± SD	10.5 ± 3.9		
Vomiting	**Present**	32	91.4%
	Absent	3	8.6%
Difficult breathing	**Present**	5	14.3%
	Absent	30	85.7%
Blood pressure	**Normal**	20	57.1%
	Hypotension	14	40.0%
	Hypertension	1	2.9%
Pulse	**Normal**	6	17.1%
	Tachycardia	28	80.0%
	Bradycardia	1	2.9%
Temperature	**Normal**	35	100.0%
Respiratory rate	**Normal**	30	85.7%
	Tachypnea	5	14.3%
Shock	**Present**	8	22.9%
	Absent	27	77.1%
Chest pain	**Present**	0	0.0%
	Absent	35	100.0%
Electrocardiography (ECG)	**Normal**	7	20.0%
	Sinus tachycardia	28	80.0%
Site of admission	**Intensive Care Unit (ICU)**	20	57.1%
	Inpatient	15	42.9%
Need for mechanical ventilation	**Present**	20	57.1%
	Absent	15	42.9%
Duration of hospital stay (days)	**Mean ± SD (range)**	3.8 ± 3.9 (1-15)	
Outcome	**Survival**	28	80.0%
	Death	7	20.0%

Number of studied patients= 35, SD: Standard Deviation

Table (1) shows that over fifty percent of the patients had a history of disturbed consciousness level; most of them had vomiting but did not have difficulty breathing; 40% of the patients had hypotension and 80% of them had tachycardia; 22% of them experienced shock. Mechanical ventilation was required by about half of them and sinus tachycardia affected 80% of them. Patients with acute CO poisoning had an 80% survival rate. According to **Table (2),** admission to an ICU, having shock, and requiring mechanical ventilation were all significantly associated

with mortality from acute CO poisoning. Patients with acute CO poisoning had lower than normal levels of PaCO2, pH and HCO3 and higher than normal levels of both troponin I and BNP as shown in **(Table 3).**

Table 2: Fisher exact test and Independent t test for the clinical characteristics at hospital admission in relation to the outcome of the studied patients with acute CO poisoning at Poison Control Center - Ain Shams University Hospitals from October 2021 till March 2022

Parameters		Outcome				P
		Survival		Death		
		Number	Row %	Number	Row %	
Delay (hours)		4.1 ± 1.7 (1-6)		5 ± 1.5 (2-6)		0.206
Disturbed Consciousness Level (DCL)	**Present on admission**	13	65.0%	7	35.0%	0.059
	Absent on admission	2	100.0%	0	0.0%	
	Occurred before admission	13	100.0%	0	0.0%	
Glasgow Coma Scale (GCS)		11.5 ± 3.5 (5-15)		6.6 ± 2.7 (3-10)		0.003*
Vomiting	**Present**	25	78.1%	7	21.9%	1.000
	Absent	3	100.0%	0	0.0%	
Difficult breathing	**Present**	3	60.0%	2	40.0%	0.256
	Absent	25	83.3%	5	16.7%	
Blood pressure	**Normal**	18	90.0%	2	10.0%	0.150
	Hypotension	9	64.3%	5	35.7%	
	Hypertension	1	100.0%	0	0.0%	
Pulse	**Normal**	5	83.3%	1	16.7%	1.000
	Tachycardia	22	78.6%	6	21.4%	
	Bradycardia	1	100.0%	0	0.0%	
Temperature	**Normal**	28	80.0%	7	20.0%	--
Respiratory rate	**Normal**	25	83.3%	5	16.7%	0.256
	Tachypnea	3	60.0%	2	40.0%	
Shock	**Present**	4	50.0%	4	50.0%	0.033*
	Absent	24	88.9%	3	11.1%	
Chest pain	**Absent**	28	80.0%	7	20.0%	---
Electrocardiography (ECG)	**Normal**	6	85.7%	1	14.3%	1.000
	Sinus tachycardia	22	78.6%	6	21.4%	
Site of admission	**Intensive Care Unit (ICU)**	13	65.0%	7	35.0%	0.012*
	Inpatient	15	100.0%	0	0.0%	
Need for mechanical ventilation	**Present**	13	65.0%	7	35.0%	0.012*
	Absent	15	100.0%	0	0.0%	
Duration of hospital stay (days)		2.2 ± 1.5 (1-7)		10.3 ± 3.7 (4-15)		0.000*

Number of studied patients= 35, Fisher exact test was used, P value ≤ 0.05 is considered statistically significant; (*) = Significant

Table 3: Laboratory investigations including cardiac markers in the 35 studied patients with acute CO poisoning at Poison Control Center - Ain Shams University Hospitals from October 2021 till March 2022

Laboratory test	Mean ± SD
COHB (%)	23.5 ± 8 (2.9-38)
PH	7.3 ± 0.1 (7.1-7.4)
HCO3 (mEq/L)	20.5 ± 4.7 (11-28)
PaO2 (mmHg)	92.4 ± 6.7 (60-98)
PaCO2 (mmHg)	38 ± 7.1 (20-51)
Troponin I (µg/L)	2.2 ± 1 (0.7-5.5)
BNP (pg/mL)	852.9 ± 603.8 (110-2250)

Number of studied patients= 35, COHB: Carboxyhemoglobin; HCO3: Bicarbonate; PaO2 Arterial oxygen pressure; PaCO2: Partial pressure of carbon dioxide in arterial blood; BNP: Brain Natriuretic Peptide; SD: Standard Deviation

Table 4: Pearson correlation coefficient for correlation between cardiac markers and duration of hospital stay with other factors affecting them among the studied patients with acute CO poisoning at Poison Control Center - Ain Shams University Hospitals from October 2021 till March 2022

Laboratory tests & hospital stay		Troponin I (µg/L)	BNP (pg/mL)	Duration of hospital stay (days)
COHB (%)	**R**	0.016	-0.006	-0.190
	P	0.928	0.971	0.273
PH	**R**	-0.145	-0.105	-0.629**
	P	0.407	0.549	0.000
HCO3 (mEq/L)	**R**	-0.108	-0.253	-0.594**
	P	0.536	0.142	0.000
PaO2 (mmHg)	**R**	0.147	0.168	-0.207
	P	0.400	0.335	0.232
PaCO2 (mmHg)	**R**	-0.081	-0.509**	-0.343*
	P	0.644	0.002	0.044
Troponin I (µg/L)	**R**	1	0.048	0.047
	P		0.782	0.787
BNP (pg/mL)	**R**	0.048	1	0.402*
	P	0.782		0.017
Duration of hospital stay (days)	**R**	0.047	0.402*	1
	P	0.787	0.017	

Number of studied patients= 35, COHB: Carboxyhemoglobin; HCO3: Bicarbonate; PaO2 Arterial oxygen pressure; PaCO2: Partial pressure of carbon dioxide in arterial blood; BNP: Brain Natriuretic Peptide
(*) Weak to moderate correlation; (**) Moderate correlation; (-) Negative correlation

A substantial negative weak to moderate correlation was found between the length of the hospital stay and pH, HCO3, and PaCO2 measurements. On the other hand, BNP had a significant positive moderate correlation with length of hospital stay and a negative correlation with PaCO2 as stated in **(Table 4).** Patients who survived, laboratory tests (PH, HCO3, and PaCO2) displayed significantly

higher mean levels than cases who died as indicated in **(Table 5).**

Table 5: Independent t test for Laboratory tests and the outcome of the studied patients with acute CO poisoning at Poison Control Center - Ain Shams University Hospitals from October 2021 till March 2022

Laboratory tests	Outcome				P
	Survival		Death		
	Number	Row %	Number	Row %	
COHB (%)	24.1 ± 8.1 (2.9-38)		21.4 ± 7.7 (7-27)		0.439
PH	7.3 ± 0.1 (7.2-7.4)		7.2 ± 0.1 (7.1-7.4)		0.001*
HCO3 (mEq/L)	22.1 ± 3.8 (14-28)		14.4 ± 2.7 (11-17)		0.000*
PaO2 (mmHg)	92.9 ± 7.4 (60-98)		90.7 ± 1.6 (89-92)		0.458
PaCO2 (mmHg)	39.9 ± 5.6 (20-51)		30.3 ± 7.2 (22-43)		0.001*
Troponin I (µg/L)	2.2 ± 1 (0.7-5.5)		2.3 ± 1 (1.3-3.7)		0.739
BNP (pg/mL)	695.5 ± 505.6 (110-1950)		1482.1 ± 581.4 (375-2250)		0.115

Number of studied patients= 35, COHB: Carboxyhemoglobin; HCO3: Bicarbonate; PaO2 Arterial oxygen pressure; PaCO2: Partial pressure of carbon dioxide in arterial blood; BNP: Brain Natriuretic Peptide, Independent t test was used, P value $\leq$ 0.05 is considered statistically significant; (*) = Significant

IV. DISCUSSION:

Acute carbon monoxide (CO) poisoning remains a health concern worldwide, as it is associated with increased morbidity and mortality. Current research aims at recognizing critical cases for early handling in order to improve patient outcomes (Moon et al., 2020; Zhang et al., 2022). The current study included 35 patients admitted to the Poison Control Center Ain Shams University Hospitals with acute CO poisoning. They were 20 males (57.1%) and 15 females (42.9%), with an average age of 36.3 ± 13.6 years. The majority of these patients were manual workers (40%) and housewives (29%). Demographic data always offer insights into the populations most at risk for acute CO poisoning and can guide public health strategies (Can et al., 2019). Manual workers may be exposed to higher levels of CO due to occupational hazards, particularly if they work in environments with poor ventilation. Housewives, on the other hand, might be at risk due to prolonged exposure to household sources of CO such as poorly ventilated stoves, heaters or fires. Similar findings were recorded by Abdel Aziz et al., (2021) where the average age of their studied CO-poisoned patients was 32 ± 10.1 years and the majority of poisoning was caused by household heaters. Similarly, Yurtseven et al.,(2016) reported that a large percentage of CO poisoning in their study was caused by

household appliances such as stoves, boilers, and heaters.

The classic triad of diagnosing acute CO poisoning is the history of recent exposure, symptoms consistent with acute CO poisoning, and elevated levels of carboxyhemoglobin COHB (Lee et al., 2015). All patients in the current study had a history of recent exposure to CO with varying intervals of exposure and varying duration of time till seeking medical help. More than half of the patients had disturbed consciousness level, a common symptom of acute CO poisoning. Similarly, Rose et al., (2017) reported disturbed consciousness level in over 60% of their patients. The majority of patients in the current study (91.4%) primarily presented with vomiting, 40% presented with hypotension, and a large majority (80%) had tachycardia, where the two latter symptoms are indicators of cardiovascular distress. Similar findings were recorded by El-Nagdy et al., (2020) where most of their CO poisoned patients were tachycardic.

The cardiovascular system is one of the main targets sensitive to the effects of acute CO toxicity. Multiple factors account for the occurrence of cardiotoxicity in cases of CO poisoning such as coronary vasospasm, increase in the permeability of vessel walls, and induction of cellular apoptosis. ECG alterations in cardiotoxicity of CO poisoning indicate myocardial ischemia in many cases (Unlu et al., 2016; Yücel et al, 2016).

Approximately 22% of patients went into shock and mechanical ventilation was required in about half of the patients due to the presence of severe respiratory distress or failure. These findings emphasize the potential severity of acute CO poisoning among the patients of the current study and the recorded survival rate was 80% among those patients.

Acute CO poisoning is known to be the most common cause of poison-related deaths in many countries around the world (Lee et al. 2015). The current study investigated the correlation between presenting patient status and increased mortality aiming to highlight several key factors associated with its occurrence.

Admission to an Intensive Care Unit (ICU) was associated with increased mortality. While this may at first seem unlikely as ICU admission is often accompanied by a higher level of care. However, in the current study, it typically indicated that the patient is in a severe or critical condition. Additionally, a low Glasgow Coma Scale (GCS), indicating poor neurological function, was also associated with increased mortality among

patients in the current study. This is in line with previous research indicating that a lower GCS score at presentation is a negative prognostic indicator in patients with acute CO poisoning (Huang et al., 2022; Lee et al., 2022).

Similarly, patients in the current study presenting with shock had higher mortality. Ku et al., (2015) concluded in their study that shock was highly correlated with morbidity and mortality in patients with acute CO poisoning. In addition, the need for mechanical ventilation was significantly associated with mortality. This is likely reflective of the severity of acute CO poisoning, as patients who require mechanical ventilation typically have significant respiratory distress. The need for mechanical ventilation may also be a marker of other complications of acute CO poisoning with poor outcomes (Jang et al., 2021).

Laboratory testing revealed a more detailed picture of the effects of acute CO poisoning. Low pH levels were observed in patients of the current study (7.3 ± 0.1) and bicarbonate (HCO3) levels were also low (20.5 ± 4.7) indicating the presence of metabolic acidosis, a common physiological response to acute CO poisoning. This metabolic disturbance is known to be caused by increased lactic acid production as cells shift to anaerobic metabolism in response to the hypoxia-induced by acute CO poisoning (Dogan et al., 2015).

Lower than normal levels of the partial pressure of carbon dioxide in arterial blood PaCO2 (38 ± 7.1) were reported among patients of the present study, which might suggest that these patients are hyperventilating in response to the CO poisoning, causing lower PaCO2 levels. Similar findings were observed by Moon et al., (2020) where hypocapnia was observed in 67.5% of their studied patients on admission.

The level of the partial pressure of carbon dioxide in arterial blood PaCO2 is a critical physiological parameter where abnormal PaCO2 levels reflect inadequate ventilation, altered blood flow, or metabolic issues (Messina & Patrick, 2023).

Cardiac affection was investigated in the current study through laboratory testing for the levels of troponin I and B-type natriuretic peptide (BNP). Troponin is a protein released into the bloodstream in cases of cardiac muscle damage. Brain natriuretic peptide (BNP) is a cardiac hormone with systemic vasodilator effects that is produced in response to myocardial hypoxia as well as other pathological conditions affecting the heart (Kainuma et al., 2015; Yücel et al.,

2016). In the current study, the levels of both markers were high in the studied patients. This indicates that acute CO poisoning could lead to cardiac injury and stress, likely due to the hypoxic conditions created by the poisoning. Similar findings were recorded by Ozyurt et al, (2017) where troponin I levels were high in their patients and correlated with cardiac affection proved by other investigations. In addition, Abdel Aziz et al., (2021) recorded higher than normal levels of both markers in their patients who had cardiac affection that was confirmed by ECG changes.

Myocardial injury is a well-known major complication of acute CO poisoning. It can be mediated by the induced hypoxia, direct alteration to myocardial cellular respiration, or damage to coronary arteries. This results in certain electrical and functional alterations of the heart (Ozyurt et al., 2017).

Correlating the laboratory results with morbidity reflected by the length of hospital stay, low PaCO2, pH, and bicarbonate (HCO3), were correlated with lengthy hospital stay. These findings suggest that patients presenting with a more severe initial clinical condition and more significant physiological disturbances tend to require a more extended hospital stay. This aligns with previous research showing that severe CO poisoning, can be associated with worse outcomes and a prolonged course of hospitalization (Huang et al., 2022). Similar results were reported by Lee et al. in (2015) who recorded short-term mortality of 30–50% in CO-poisoned patients with initial pH not exceeding 7.20.

The current study found that BNP, a marker of cardiac stress and heart failure, had a significant positive moderate correlation with the length of hospital stay. This is consistent with other studies which found that acute CO poisoning could lead to cardiac injury and stress, potentially contributing to a more severe clinical course and longer hospitalization (Kinoshita et al., 2020).

Interestingly, BNP showed a negative correlation with PaCO2. This finding helps to emphasize the role of hypocapnia in CO-induced cardiotoxicity. This association suggests that patients with lower PaCO2 levels have a higher degree of cardiotoxicity as a result of acute CO poisoning. Hashemzaei et al., (2018) reported in their study that hypocapnia is associated with a reduction of blood flow in CO2-responsive vascular beds as the coronary and cerebral circulations and this supports the finding of the current study. In addition, Moon et al., (2020) proved in their study that the recorded hypocapnia played a role in the occurrence of

cardiotoxicity observed in their studied patients.

Surprisingly, despite COHB level being one of the triad of diagnosing CO poisoning, the increase in its level was not correlated with increased hospital stay suggesting that the rise in its level is not a reliable marker of the severity of CO poisoning. Lee et al. (2015) stated a similar conclusion where they reported that the utility of COHB measurement as a predictor of the clinical status in acute CO poisoning was not apparent in their study.

Can et al., (2019) documented that survivor of acute CO poisoning have near double long-term mortality when compared with the normal population. In the current study, patients who survived had higher mean levels of pH, bicarbonate (HCO3) compared to those who died. The higher mean pH values and bicarbonate levels in survivors suggest that they had less acidosis compared to those who died. Bicarbonate acts as a buffer, neutralizing excess acids in the blood, and lower levels often suggest that the body is struggling to maintain a pH balance (Lee et al., 2015).

The current study also recorded that low partial pressure of carbon dioxide (PaCO2) was significantly correlated with increased mortality. Low levels of PaCO2 are typically a result of hyperventilation which is seen in acute CO poisoning as the body attempts to compensate for hypoxia (Cho et al., 2021). Hypocapnia can cause cerebral vasoconstriction, reducing brain blood flow. This can exacerbate the effects of hypoxia on the brain and might contribute to a more severe clinical presentation and stress response, which can have negative effects on the heart and the overall outcome of patients (Hoffman et al., 2021).

Despite the correlation between low levels of pH, HCO3, PaCO2, high levels of BNP, and morbidity in patients of the current study presented by prolonged hospital stay; yet when correlating the same laboratory investigations to mortality, only low levels of pH, HCO3, PaCO2 were correlated to increased rate of mortality. This could be explained by the suggested improvement of CO-induced cardiotoxicity during the treatment of these patients.

The correlation between low PaCO2 levels and increased length of hospital stay and death provides evidence for the potential clinical significance of PaCO2 changes in patients with acute CO poisoning. Patients with lower PaCO2 levels might have a more severe clinical presentation, perhaps due to more significant hypoxia and cardiotoxicity,

which could require a more extended hospital stay and could increase the risk of death.

The results of the current study could aid clinicians in their initial assessment and ongoing management of patients with acute CO poisoning. The correlations observed may help in identifying patients at risk for longer hospitalization and potentially worse outcomes. Early identification of these patients might allow for earlier intervention and improved management strategies, potentially reducing hospital stay and improving patient outcomes.

V. CONCLUSION and RECOMMENDATION

The current study suggests that changes in PaCO2 levels play an important role in the outcome of patients with acute CO poisoning, potentially acting as a marker of severity and indicating an increased risk of cardiotoxicity. The study results reported that lower than normal levels of partial pressure of carbon dioxide (PaCO2) might be associated with a more severe clinical presentation and poorer prognosis. Clinicians could use PaCO2 as a useful clinical indicator to identify patients at a higher risk of adverse outcomes. This could help guide more aggressive treatment strategies and closer monitoring in these patients. Future studies could investigate whether interventions aimed at managing PaCO2 levels could improve outcomes in patients with acute CO poisoning.

VI. Limitations:

The current study has some limitations. The sample size was relatively small, so, further research with larger cohorts is required to validate our findings. Additionally, the study did not examine the long-term outcomes of patients with acute CO poisoning, which could provide further insights into the relationship between the level of PaCO2 and long-term outcomes in these patients.

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VIII. Conflict of interest:

The authors declare that there is no conflict of interest.

IX. Acknowledgment:

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X. References

– Abdel Aziz MH, El Dine FMMB, Hussein HASM, Abdelazeem AM, Sanad IM. (2021). Prediction of troponin I and N-terminal pro-brain natriuretic peptide

levels in acute carbon monoxide poisoning using advanced electrocardiogram analysis, Alexandria, Egypt. Environ Sci Pollut Res Int. 28(35):48754-48766. doi: 10.1007/s11356-021-14171-3.

- Can G, Sayili U, Sayman ÖA, Kuyumcu ÖF, Yilmaz D, Esen E, Yurtseven E, Erginöz E (2019). Mapping of carbon monoxide related death risk in Turkey: a ten-year analysis based on news agency records, BMC Public Health 19:9-16. https://doi.org/10.1186/s12889-018-6342-4
- Cho DH, Ko SM, Son JW, Park EJ, Cha YS. (2021). Myocardial Injury and Fibrosis from Acute Carbon Monoxide Poisoning: A Prospective Observational Study, JACC: Cardiovascular Imaging. 14(9): 1758-1770. https://doi.org/10.1016/j.jcmg.2021.02.020.
- Dogan, N.; Savrun, A.; Levent, S.; Günaydin, G.P.; Çelik, G.K.; Akküçük, H.; Cevik, Y. (2015). Can initial lactate levels predict the severity of unintentional carbon monoxide poisoning? Hum. Exp. Toxicol. 34, 324–329.
- El-Nagdy S, Elfakharany Y, Etewa R. (2020). Role of Glycogen Phosphorylase in Prediction of Cardiotoxicity Associated with Acute Carbon Monoxide Poisoning. Zagazig Journal of Forensic Medicine, 18(2), 59-74. doi: 10.21608/zjfm.2020.21239.1045
- Geng S, Hao X, Xu H, Yao J, He D, Xin H, Gong X, Zhang R. (2020). Cardiac injury after acute carbon monoxide poisoning and its clinical treatment scheme. Exp Ther Med. 20(2):1098-1104. doi: 10.3892/etm.2020.8801.
- Hashemzaei M, Mohammadpour AH, Imenshahidi M, Rezaee R. (2018). Does granulocyte colony stimulating factor have protective effects against carbon monoxideinduced apoptosis? Biologia 73: 1153–1157, https://doi.org/10.2478/s11756-018-0121-7.
- Hoffman SB, Lakhani A, Viscardi RM. (2021). The association between carbon dioxide, cerebral blood flow, and autoregulation in the premature infant. *J Perinatol* 41, 324–329. https://doi.org/10.1038/s41372-020-00835-4
- Huang F, Yang L, Tan Z, Yang B, Liu P, Li Z, Shi W, Peng K, Yuan J, He Q, Yang L, Li X, Li C, Chen D, Peng Z. (2022). Prognostic factors of hyperbaric oxygen therapy for patients with delayed

encephalopathy after acute carbon monoxide poisoning. Heliyon. 8(12):e12351. doi: 10.1016/j.heliyon.2022.e12351.

– Jang JH, Jang HJ, Kim HK, Park JH, Kim HJ, Jo KM, Heo W, Kim SH, No TH, Lee JH. (2021). Acute respiratory distress syndrome caused by carbon monoxide poisoning and inhalation injury recovered after extracorporeal membrane oxygenation along with direct hemoperfusion with polymyxin B-immobilized fiber column: a case report. J Med Case Rep. 15(1):456. doi: 10.1186/s13256-021-03023-w.

– Kainuma S, Taniguchi K, Toda K, Shudo Y, Takeda K, Funatsu T, Miyagawa S, Kondoh H, Nishi H, Yoshikawa Y, Fukushima S, Hamada S, Kubo K, Daimon T, Sawa Y. (2015). B-type natriuretic peptide response and reverse left ventricular remodeling after surgical correction of functional mitral regurgitation in patients with advanced cardiomyopathy. Journal of Cardiology 66(4): 279-285. https://doi.org/10.1016/j.jjcc.2015.02.015.

– Kinoshita H, Türkan H, Vucinic S, Naqvi S, Bedair R, Rezaee R, Tsatsakis A. (2020). Carbon monoxide poisoning. Toxicol Rep. 7:169-173. doi: 10.1016/j.toxrep.2020.01.005.

– Ku CH, Hung HM, Leong WC, Chen HH, Lin JL, Huang WH, Yang HY, Weng CH, Lin CM, Lee SH, Wang IK, Liang CC, Chang CT, Lin WR, Yen TH (2015). Outcome of Patients with Carbon Monoxide Poisoning at a Far-East Poison Center. PLoS ONE 10(3): e0118995. https://doi.org/10.1371/journal.pone.0118995

– Kudo K, Otsuka K, Yagi J, Sanjo K, Koizumi N, Koeda A, Umetsu MY, Yoshioka Y, Mizugai A, Mita T. (2014). Predictors for delayed encephalopathy following acute carbon monoxide poisoning. BMC Emerg. Med. 14: 3-12.

– Lee FY, Chen WK, Lin CL, Kao CH (2015). Carbon Monoxide Poisoning and Subsequent Cardiovascular Disease Risk. A Nationwide Population-based Cohort Study. Medicine. 94 (10): 1-8.

– Lee H, Oh J, Kang H, Ahn C, Namgung M, Kim CW, Kim W, Kim, YS, Shin H, Lim TH. (2022). Association between Early Phase Serum Lactate Levels and Occurrence of Delayed Neuropsychiatric Sequelae in Adult Patients with Acute Carbon Monoxide Poisoning: A Systematic Review and Meta- Analysis.

J. Pers. Med. 12, 651. https://doi.org/10.3390/jpm12040651

- Messina Z & Patrick H. (2023). Partial Pressure of Carbon Dioxide. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. Available from: https://www.ncbi.nlm.nih.gov/books/NBK551648/
- Moon J, Chun B, Cho Y. (2020). Derangement of PaCO2 requires physician attention in acute carbon monoxide poisoning. Human & Experimental Toxicology. 39(5):642-652. doi:10.1177/0960327119898720.
- Ozyurt A, Karpuz D, Yucel A, Tosun MD, Kibar AE, Hallioglu O. (2017). Effects of Acute Carbon Monoxide Poisoning on ECG and Echocardiographic Parameters in Children. Cardiovasc Toxicol 17:326–334. DOI 10.1007/s12012-016-9389-4.
- Rose JJ, Wang L, Xu Q, McTiernan CF, Shiva S, Tejero J, Gladwin MT. (2017). Carbon Monoxide Poisoning: Pathogenesis, Management, and Future Directions of Therapy. Am J Respir Crit Care Med. 195(5):596-606. doi: 10.1164/rccm.201606-1275CI.
- Unlu M, Ozturk C, Demirkol S, Balta S, Malek A, Celik T, Iyisoy A. (2016). Thrombolytic therapy in a patient with inferolateral myocardial infarction after carbon monoxide poisoning. Hum Exp Toxicol. 35:101–105.
- Yücel M, Avsarogullari L, Durukan P, Akdur O, Ozkan S, Sozuer E, Muhtaroglu S, Ikizceli I, Yürümez Y. (2016) BNP shows myocardial injury earlier than Troponin-I in experimental carbon monoxide poisoning. Eur Rev Med Pharmacol Sci. 20(6):1149-54.
- Yurtseven S, Arslan A, Eryigit U, Gunaydin M, Tatli O, Ozsahin F, Karaca Y, Aksut N, Aygun A, Gunduz A. (2016). Analysis of patients presenting to the emergency department with carbon monoxide intoxication. Turk J Emerg Med.;15(4):159-62.
- Zhang L, Wu D, Xu M, Bian Y, Wang Y, Gao G, Sun Q. (2022). Acute carbon monoxide poisoning in Shandong, China: an observational study. Chinese Medical Journal. 135(13): 1539-1544.

الدور المحتمل لتغيرات مستوى الضغط الجزئي لثاني أكسيد الكربون في الدم على نتيجة التسمم الحاد بأول أكسيد الكربون

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الملخص العربي

الخلفية: لا يزال التسمم الحاد بأول أكسيد الكربون مصدر قلق صحي في جميع أنحاء العالم، لأنه يرتبط بزيادة معدلات المرض والوفيات. وبناءً على ذلك، فإن التعرف على الحالات الحرجة أمر ذو قيمة عالية من أجل توفير علاج مبكر وفعال وتحسين نتائج المرضى.

الهدف: تهدف هذه الدراسة إلى قياس مستوى الضغط الجزئي لثاني أكسيد الكربون في المرضى الذين يعانون من التسمم الحاد بأول أكسيد الكربون ولتقييم دور تغييرات مستوى الضغط الجزئي لثاني أكسيد الكربون في نتيجة التسمم الحاد بأول أكسيد الكربون.

الطريقة: أجريت هذه الدراسة المستقبلية من خلال جمع البيانات الديموغرافية والسريرية وعينات الدم من ٣٥ مريضاً مصابين بالتسمم الحاد بأول أكسيد الكربون والذين تم إدخالهم إلى مركز علاج التسمم بمستشفيات جامعة عين شمس. تم قياس الكربوكسي هيموغلوبين وغازات الدم الشرياني ودلالات تأثر عضلة القلب لكل مريض عند الدخول.

النتائج: كان مرضى التسمم الحاد بأول أكسيد الكربون والذين خضعوا للدراسة هم ٢٠ ذكراً (٥٧،١٪) و١٥ إنثى (٤٢،٩٪) بمتوسط عمر ٣٦،٣ ± ١٣،٦ سنة. كان لدى المرضى مستويات أقل من الطبيعية من الضغط الجزئي لثاني أكسيد الكربون ودرجة حموضة الدم والبيكربونات ومستويات أعلى من الطبيعية لكل من التروبونين I والببتيدات الناتريوريتية الدماغية.

كما أظهرت النتائج وجود ارتباط سلبي ضعيف إلى متوسط بين طول فترة الإقامة في المستشفى وقياسات درجة حموضة الدم والبيكربونات والضغط الجزئي لثاني أكسيد الكربون. من ناحية أخرى، كان للببتيدات الناتريوريتية الدماغية علاقة ارتباط موجبة معتدلة مع طول فترة الإقامة في المستشفى وارتباط سلبي مع الضغط الجزئي لثاني أكسيد الكربون. أظهر المرضى الذين نجوا مستويات متوسط أعلى بكثير في نتائج الاختبارات المعملية (الضغط الجزئي لثاني أكسيد الكربون، درجة حموضة الدم، البيكربونات) عن الحالات التي انتهت بالوفاة.

الاستنتاج: تشير الدراسة الحالية إلى أن التغيرات في مستويات الضغط الجزئي لثاني أكسيد الكربون تلعب دورًا هامًا في نتائج المرضى الذين يعانون من التسمم الحاد بأول أكسيد الكربون، ومن المحتمل أن تكون بمثابة علامة على شدة التسمم وزيادة خطر السمية القلبية. كما أفادت نتائج الدراسة أن المستويات الأقل من الطبيعي للضغط الجزئي لثاني أكسيد الكربون قد ترتبط بزيادة شدة التسمم وسوء المآل.

التوصيات: يمكن للأطباء استخدام الضغط الجزئي لثاني أكسيد الكربون كمؤشر سريري مفيد لتحديد المرضى المعرضين لخطر أكبر في حالات التسمم الحاد بأول أكسيد الكربون.

الكلمات المفتاحية: التسمم الحاد بأول أكسيد الكربون، الضغط الجزئي لثاني أكسيد الكربون، السمية القلبية، معدل الوفيات.