Lactate Level Is More Significant Than Carboxihemoglobin Level in Determining Prognosis of Carbon Monoxide Intoxication of Childhood

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Objectives: To evaluate the demographics, risk factors, correlation between carbon monoxide (CO) level and clinical findings, and laboratory findings determining the prognosis and ischemic myocardial injury due to CO intoxication in patients admitted to pediatric emergency department.

Materials and Methods: Six hundred seventy-four patients were admitted with CO intoxication between May 2007 and October 2009, 288 patients who required hospitalization were enrolled into the study prospectively.

Results: Incidentally, 144 (50%) of the patients were evenly distributed as girls and boys. Their age ranged between 7 months and 17 years; mean age was 8.6 years. The mean CO level was 26.8. The high levels were detected regarding lactate in 199 (90.1%) patients, creatine kinase (CK)-MB in 130 (45.1%) patients, CK in 80 (27.8%) patients, cardiac Troponin I in 35 (17.2%) patients, and lactate dehydrogenase in 34 (15.7%) patients. There was a significant positive correlation when symptoms like syncope, loss of consciousness, and convulsion were compared with carboxyhemoglobin, lactate, CK, CK-MB, and lactate dehydrogenase levels ($P < 0.05$), whereas there was no correlation when compared with cardiac Troponin I ($P > 0.05$). To determine the accuracy of predicting severe CO intoxication, sensitivity of 52.6% and specificity of 85.7% were found in receiver operating characteristic analysis when the lactate level was 3.85 mmol/L, whereas sensitivity of 70.5% and specificity of 59.6% were found when the carboxyhemoglobin level was 27.1%. One hundred forty-six (%50.8) of the patients had normal electrocardiographic findings, whereas 135 (46.8%) had sinus tachycardia, 6 (2%) had right branch block, and 1 (0.34%) had atrioventricular block. In 34 patients who had high CK-MB and Troponin I levels, only sinus tachycardia was detected in electrocardiography, and there were no ST changes. Hyperbaric oxygen was necessary in 2 patients admitted with coma.

Conclusions: In children admitted because of CO intoxication, the blood lactate levels may give more accurate information in terms of loss of consciousness and convulsion, lactate level could be taken as a measure of severe poisoning and may help to decide for hyperbaric oxygen treatment.

Key Words: carbon monoxide intoxication, carboxyhemoglobin, lactate

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Carbon monoxide (CO) intoxication is an important and preventable cause of intoxications resulting in death and one of the most common cause of intoxications caused by accidents. It results in more than 40,000 cases and 15,200 visits per year to emergency departments (EDs) in the United States and is a serious public health problem in developing countries due to the widespread use of coal stoves and unsafe heating systems.[1–6] Symptoms are nonspecific, such as fatigue, headache, nausea, vomiting occurs in mild intoxication; it may lead to confusion, loss of consciousness and death in severe exposure.[1] The affinity of CO to hemoglobin is 200 times more than oxygen, thus even it is inhaled low levels, shifts the oxyhemoglobin dissociation curve to the left, increases quickly the carboxyhemoglobin (COHb) content and leads hypoxia reducing oxygen delivery.[2] Lactate is the product of anerobic glycolysis which is an important marker of tissue hypoxia and elevated lactate levels have been increasingly used in the management of critical patients as well as CO poisoning.[7–9] In addition, in an adult study, authors concluded that an initial lactate level could be taken into consideration as a predictive parameter of severity, together with the clinical criteria and levels of COHb.[6] One of the most affected tissue CO intoxication-induced oxidative stress is cardiac tissue, and clinical studies in children are not sufficient in this regard. The purpose of this study is to evaluate the demographics, risk factors, clinical correlation in terms of COHb and lactate levels, and to investigate CO intoxication-induced ischemic myocardial injury with laboratory findings determining the prognosis in patients admitted to a pediatric ED.

METHODS

A total of 674 children were admitted with CO intoxication between May 2007 and October 2009, 288 consecutive children known to be healthy with no previous cardiologic, neurological or metabolic disease, and who required hospitalization (having manifest symptoms of CO intoxication or detected COHb level > 25) were enrolled into the study prospectively, and informed consent was obtained from the parents/care givers of the patients. The pediatric emergency care unit is a referral center in capital city which has 20 emergency observation beds where nearly 300 to 500 patients per day are followed up. The patients with missing/incomplete data, patients with previous cardiologic, neurological or metabolic diseases, and patients not coming for control visits were excluded from the study. The age ranged from 7 days to 17 years. After approval from the local ethics committee, the reason how patient was intoxicated, the distribution of cases, the type and duration of hospital admissions, and the complaints of the patients, that is, chest pain, palpitations, and syncope and demographic features, such as age, sex, height, weight, and thorough physical and neurological examination findings, were recorded for the purpose of study by the attending pediatrician. Symptomatic data, such as dizziness, nausea, and seizures, are obtained from the parents/care givers of young infants and supported by the observation of attending pediatrician during hospitalization. All patients included in the study were subjected to full history taking, physical examination, and routine laboratory investigations, such as arterial blood gases, complete blood count, creatine kinase (CK), CK-MB, lactate dehydrogenase (LDH), and cardiac Troponin I (cTnI) tests. All children were monitored for vital functions, such as heart and respiratory rate, blood pressure, pulse oximetry, and 12-lead electrocardiography (ECG). Vital signs and laboratory test results were determined according to ages in the reference lists,[10] and attending pediatrician was responsible for ECG interpretations. Corrected QT (QT_C) was calculated with Bazett's formula (QT Interval / $\sqrt{}$ (RR interval), and corrected QT of 440 milliseconds or

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TABLE 1. The Distribution of Patients' Complaints According to the COHb Level

Complaints	15–29.9% (n = 235), n (%)	%30–39.9% (n = 43), n (%)	40–60% (n = 10), n (%)
Nausea	171 (72.8)	25 (58.1)	3 (30.0)
Vomiting	137 (58.3)	20 (46.5)	3 (30.0)
Dizziness	132 (56.2)	26 (60.5)	—
Headache	111 (47.2)	23 (53.5)	—
Somnolence	99 (42.1)	29 (67.4)	1 (10.0)
Weakness	101 (43.0)	19 (44.2)	1 (10.0)
Fainting	78 (33.2)	24 (55.8)	9 (90.0)
Abdominal pain	27 (11.5)	12 (27.9)	1 (10.0)
Loss of consciousness	8 (3.4)	9 (20.9)	10 (100)
Convulsion	6 (2.6)	6 (14.0)	4 (40.0)

less was defined as normal. Myocardial injury was diagnosed with ECG readings and increased cTnI levels.

The patients were divided into 2 groups as mild and severe CO intoxication according to neurological examination based on their clinic status and compared in both groups. Syncope, alteration/loss of consciousness and convulsions, coma, and focal neurological deficit were considered as important signs of severe poisoning. One hundred forty of the patients were classified as mild and 148 of the patients as severe poisoning according to the criteria mentioned above. The neurological condition was determined according to Glasgow Coma Scale.[11] Patients were treated mostly with normobaric oxygen (NBO). However, 2 unconscious patients who had Glasgow coma score of 4 were applied 2 sessions of 2.8 absolute atmospheric pressure hyperbaric oxygen (HBO) treatment for 90 minutes in ETC's monoplace pressure chamber. The control arterial blood gases of the patients were taken after treatment in an average of 12 to 72 hours, and the patients were discharged when COHb level decreased below 2% or when the clinic recovered completely. All patients were called for the control after 4 weeks for physical and neuropsychiatric examinations.

Statistical Analysis

Descriptive statistics were summarized as counts and percentages for categorical variables and as medians, minimums, and maximums for continuous variables. Normal distribution of continuous variables was investigated by Shapiro-Wilk test. Significance of the difference between the groups was analyzed by Student *t* test. The median value of the difference between the groups was investigated with Mann-Whitney *U* test, and for significance between more than 2 independent groups, the Kruskal-Wallis test was used. Spearman correlation coefficient was used to analyze positive correlations between nonparametric variables. A receiver operating characteristic (ROC) curve analysis was carried out to determine the sensitivity and specificity of elevated lactate levels in patients with severe CO poisoning. All the data were analyzed using statistical software (Statistical Package For Social Sciences) for Windows 17 (SPSS Inc, Chicago, IL). A level of *P* less than 0.05 was considered statistically significant.

RESULTS

In the study, eligible 288 patients who were admitted to the hospital consecutively from inside 674 patients with a diagnosis of CO intoxication were included. One hundred forty-four patients (50%) were boys and girls incidentally. Patients were between the ages of 7 days and 17 years, the mean age was 8.6 ± 4.3 years. The mean height and weight were 130.6 ± 26.5 cm and 32 ± 15.9 kg, respectively. There was no significant difference between the patients' sex, height, and weight in terms of symptoms, signs, and laboratory values of CO intoxication ($P > 0.05$).

Our country is a developing country using domestic stoves and unsafe heating systems (ie, water heaters, furnaces, fireplaces, kitchen ranges) as means of heating and coal/natural gas is used as fuel. One hundred seventy-three of the patients (60.1%) were admitted in the winter months unintentionally, and the monthly distribution of cases was consistent with the need for heating. Two hundred fifteen cases (74.7%) were intoxicated because of coal stoves with malfunctioning chimneys, 37 (12.8%) with natural gas leakage used to warm up, and 36 (12.5%) of them with water heater gas leakage. The mean duration of reaching to a hospital

TABLE 2. Relationship Between Symptoms and COHb/Lactate

Variables	% COHb	Lactate, mmol/l
Dizziness		
No(n = 130)	25.3 (16.7–60.8)	3.6 (0.7–23.1)
Yes (n = 158)	25 (16–37.1)	3.1 (0–9.9)
P	>0.05	0.008
Somnolence		
No (n = 159)	24.7 (16–60.8)	3 (0–23.1)
Yes(n = 129)	25.9 (17.2–47.1)	3.6 (0.7–11.7)
P	<0.05	<0.05
Syncope		
No (n = 177)	24.5 (16–43.2)	3 (0–23.1)
Yes (n = 111)	26.7 (17.2–60.8)	3.9 (1.2–14)
P	<0.001	<0.001
Loss of consciousness		
No (n = 261)	24.9 (16–38)	3.2 (0–9.9)
Yes (27)	35.6 (19.9–60.8)	6.2 (2.5–23.1)
P	<0.001	<0.001
Convulsion		
No (n = 272)	25 (16–60.8)	3.2 (0–14)
Yes (n = 16)	31.8 (20.7–53.8)	6.1 (2.5–23.1)
P	<0.001	<0.001
Nausea		
No (n = 89)	26.7 (16–60.8)	3.2 (0–23.1)
Yes (n = 199)	25 (16.7–46.9)	3.3 (1.1–14.0)
P	<0.05	>0.05
Vomiting		
No (n = 128)	25.1 (16–60.8)	3.3 (0–23.1)
Yes (n = 160)	25.2 (16.7–46.9)	3.3 (1.4–14)
P	>0.05	>0.05
Headache		
No (n = 154)	25.2 (16–60.8)	3.5 (0.7–23.1)
Yes (n = 134)	25.1 (17–37.1)	3.2 (0-9.9)
P	>0.05	>0.05
Abdominal pain		
No (n = 248)	25 (16–60.8)	3.2 (0–23.1)
Yes (n = 40)	25.9 (17.8–41)	4.3 (2–10.4)
P	>0.05	0.002
Weakness		
No (n = 167)	25.4 (16.7–60.8)	3.5 (0–23.1)
Yes (n = 121)	24.5 (16–46.9)	3 (0.7–14)
P	>0.05	>0.05

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was found to be 37.4 (min, 15; max, 120) minutes. Although 246 patients (85.4%) were coming to the hospital on their own efforts, 42 (14.6%) patients were brought by ambulance.

The most common symptoms were listed as nausea (n = 199), 69.1%; vomiting (n = 160), 55.6%; dizziness (n = 158), 54.9%; headache; somnolence; and weakness. Other less common complaints were found to be crying, restlessness/agitation, tinnitus/buzzing, shortness of breath, burning/pain in the throat, arthralgia, fever, palpitations, chest pain, and sweating. The distribution of patients' hospital admission complaints according to the COHb level are summarized in Table 1.

It has been determined that syncope, unconsciousness, and convulsions, which were initial complaints, increased while COHb and lactate levels were increasing (positive correlation); syncope, consciousness, and convulsions increased while pH and base deficit were decreasing (negative correlation) ($P < 0.001$). Relationship between symptoms and COHb/lactate levels are summarized in Table 2.

The initial complaints of the patients were also compared with markers of myocardial ischemia. Although there was a significant positive correlation between loss of consciousness and convulsions and CK, CK-MB, and LDH levels ($P < 0.05$), no correlation was found between cTnI ($P > 0.05$). Relationship between symptoms and cardiologic markers are summarized in Table 3.

The most common findings with CO intoxication on physical examination was found to be tachycardia (n = 154, 54.2%). The significance of clinical findings with COHb and lactate levels is presented in Table 4.

When the correlation between physical examination findings in COHb and lactate levels was investigated, a positive correlation

TABLE 3. The Relationship Between Symptoms and Cardiologic Markers

Variables	CK	CK-MB	LDH	Troponin-I
Dizziness				
No (n = 130)	126 (36–2697)	28 (12–143)	247.5 (92–568)	0.022 (0.005–7.4)
Yes (n = 158)	117 (37–537)	24.4 (11–134)	214 (124–411)	0.015 (0.005–0.39)
P	>0.05	0.009	<0.001	<0.05
Somnolence				
No (n = 159)	122 (36–2697)	26 (13–143)	226 (92–568)	0.015 (0.005–3.85)
Yes (n = 129)	122 (37–704)	26 (11–126)	223 (117–404)	0.019 (0.005–7.40)
P	>0.05	>0.05	>0.05	>0.05
Syncope				
No (n = 177)	117 (36–2697)	26 (11–143)	220 (92–506)	0.015 (0.005–3.85)
Yes (n = 111)	126 (37–704)	27.9 (12–126)	227 (125–568)	0.021 (0.005–7.40)
P	>0.05	<0.05	>0.05	>0.05
Loss of consciousness				
No (n = 261)	117 (36–704)	26 (11–134)	221 (92–484)	0.016 (0.005–7.40)
Yes (27)	149 (42–2697)	39 (17–143)	259 (155-568)	0.025 (0.005–3.85)
P	<0.05	<0.001	0.006	>0.05
Convulsion				
No (n = 272)	117 (36–704)	26 (11–134)	223 (92–484)	0.017 (0.005–7.40)
Yes (n = 16)	210 (68–2697)	43 (16–143)	283 (195–568)	0.025 (0.005–3.85)
P	<0.001	<0.05	0.005	>0.05
Nausea				
No (n = 89)	136 (44–2697)	26 (12–143)	225 (128–568)	0.018 (0.005–3.85)
Yes (n = 199)	112 (36–537)	26 (11–126)	223 (92–484)	0.017 (0.005–7.4)
P	0.008	>0.05	>0.05	>0.05
Vomiting				
No (n = 128)	129 (44–2697)	25.5 (12–143)	225 (124–568)	0.019 (0.005–3.85)
Yes (n = 160)	115 (36–537)	26.5 (11–126)	223 (92–484)	0.016 (0.005–7.4)
P	>0.05	>0.05	>0.05	>0.05
Headache				
No (n = 154)	127.5 (36–2697)	27 (11–143)	241 (117–568)	0.018 (0.005–7.4)
Yes (n = 134)	114 (37–537)	25 (13–134)	212.5 (92–417)	0.015 (0.005–0.39)
P	>0.05	>0.05	<0.001	>0.05
Abdominal pain				
No (n = 248)	119 (36–2697)	26 (11–143)	221 (117–568)	0.016 (0.005–7.4)
Yes (n = 40)	127 (48–449)	31.6 (15–82)	246 (92-411)	0.019 (0.005–0.10)
P	>0.05	<0.05	<0.05	>0.05
Weakness				
No (n = 167)	126 (36–2697)	27.3 (13–143)	231 (92–568)	0.018 (0.005–7.4)
Yes (n = 121)	116 (37–537)	24 (11–126)	214.5 (128–417)	0.016 (0.005–0.39)
P	>0.05	<0.05	0.003	>0.05

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TABLE 4. The Significance of Clinical Findings With COHb and Lactate Levels

Variables	% COHb	Lactate (mmol/L)
Alteration in consciousness		
No (n = 260)	25 (16–38)	3.1 (0–8.7)
Yes (n = 28)	31.9 (20.8–60.8)	6.4 (3.1–23.1)
P	<0.001	<0.001
Tachycardia		
No (n = 132)	24.2 (16.7–43)	2.5 (1.1–5.9)
Yes (n = 156)	26.1 (16–60.8)	3.9 (0–23.1)
P	<0.001	<0.001
Hypotension		
No (n = 260)	25 (16–47.1)	3.2 (0–10.4)
Yes (n = 28)	27.8 (20.9–60.8)	4.4 (2–23.1)
P	0.003	<0.001

between alteration in consciousness, tachycardia, hypotension, and COHb and lactate levels was observed ($P < 0.001$). Although significant relationship between changes in consciousness and cTnI levels could not be demonstrated ($P > 0.05$), a significant positive correlation was found with CK-MB level ($P < 0.001$). A significant positive correlation was observed between tachycardia with both CK-MB and cTnI levels ($P < 0.05$). In 29.5 %, 59.8%, and 22.2% of patients with tachycardia, the levels of CK, CK-MB, and cTnI were over the normal range, respectively. Similarly, a significant correlation was seen between hypotension with CK-MB and cTnI levels ($P < 0.05$ and $P < 0.001$). The results of laboratory tests are given in Table 5. The correlation coefficients between laboratory parameters and COHb and lactate levels and significance levels are given in Table 6. The correlation coefficients between laboratory parameters and troponin I and CK-MB levels and significance levels are given in Table 7.

At the end of the study; the elevations of lactate, CK-MB, CK, cTnI, and LDH were detected in 199 (90.1%), 130 (45.1%), 80 (27.8%), 35 (17.2%), 34 (15.7%) patients, respectively.

Twelve-lead ECG monitoring of all patients hospitalized with a diagnosis of CO intoxication were taken. Normal ECG, sinus tachycardia, right bundle branch block, and complete atrioventricular block were detected in 146 (50.8%), 135 (46.8%), 6 (2%), and 1 (0.34%), respectively. QT intervals were calculated; the measurements was average of 41 (min, 38; max, 43) seconds, and pathology was not detected. The CK-MB and troponin I levels of patients that block was identified in ECG and were found to be in normal ranges. In 34 patients with high CK-MB and troponin I levels, there was no finding in ECG except for sinus tachycardia, and ST changes were not detected.

TABLE 5. The Results of Laboratory Tests

Parameters	n	Median (Range)
COHb level	288	26.2 (16–60.8)
Lactate, mmol/L	219	3.8 (0–23.1)
pH	288	7.34 (6.8–7.45)
Base excess, mmol/L	288	−3.6 (−28 to 2.4)
Hemoglobin, g/dL	244	13.1 (8.9–19.2)
WBC, mm^3	244	12.2 (4.3–40.2)
LDH, U/L	217	236.1 (92–568)
CK, U/L	241	150 (36–2697)
CK-MB, U/L	230	29.8 (11–143)
Troponin I, ng/mL	203	0.08 (0.005–7.4)

TABLE 6. The Correlation Coefficients and Significance Levels Between Laboratory Parameters and COHb and Lactate Levels

	% COHb		Lactate, mmol/L	
Variables	r	*P*	r	*P*
pH	−0.289	<0.001	−0.427	<0.001
Base excess	−0.284	<0.001	−0.691	<0.001
LDH	0.165	<0.05	0.215	<0.05
CK	0.144	<0.05	0.044	>0.05
CK-MB	0.224	0.001	0.273	<0.001
Troponin I	0.122	>0.05	0.179	<0.05
WBC	0.198	<0.05	0.366	<0.001

Two hundred eighty-six patients were hospitalized for an average of 24 hours, and NBO therapy was administered. Patients' blood gases were checked after 12 hours. The patients whose COHb level decreased under 2% with good general condition and who did not have any symptoms were discharged. The follow-up duration of the patient with neurological findings and mental status changes in the first admission has been extended. The blood lactate levels of the patients with high initial CK, CK-MB, LDH, and cTnI values were also high. In these patients, ECG monitoring was performed, and cardiac enzymes were repeated at the sixth and 12th hours of the admission. The enzyme and lactate levels of patients taken at the sixth and 12th hours were found to be improved compared to initial values.

We constructed an ROC curve to determine the accuracy of predicting severe CO intoxication, and the area under the curve for plasma lactate concentration was 0.721 (95% confidence interval, 0.654–0.788; $P < 0.001$; Fig. 1). When the lactate level was 3.85 mmol/L, sensitivity of 52.6% and specificity of 85.7% were found. Also, we found that a lactate level of 1 mmol/L had a positive predictive value of 80% and negative predictive value of 62.5% (Fig. 1).

Also, we constructed an ROC curve to determine the accuracy of predicting severe CO intoxication, and the area under the curve for plasma COHb concentration was 0.677 (95% confidence interval, 0.616–0.738; $P < 0.001$; Fig. 2). When the COHb level was 27.1%, sensitivity of 70.5% and specificity of 59.6% were found. We found that a COHb level of 1% had a positive predictive value of 50% and negative predictive value of 70.9% (Fig. 2).

Regarding our results, a lactate value greater than 3.85 mmol/L could be taken as a measure to predict severe CO intoxication.

TABLE 7. The Correlation Coefficients and Significance Levels Between Laboratory Parameters and Troponin I and CK-MB Levels

	Troponin I, ng/mL		CK-MB, U/L	
Variables	r	*P*	r	*P*
COHb	0.122	>0.05	0.224	<0.001
Lactate	0.179	<0.05	0.273	<0.001
pH	−0.088	>0.05	−0.213	<0.001
Base Excess	−0.087	>0.05	−0.252	<0.001
CK	−0.009	>0.05	0.236	<0.001
LDH	0.248	<0.001	0.640	<0.001
WBC	0.243	<0.001	0.133	>0.05

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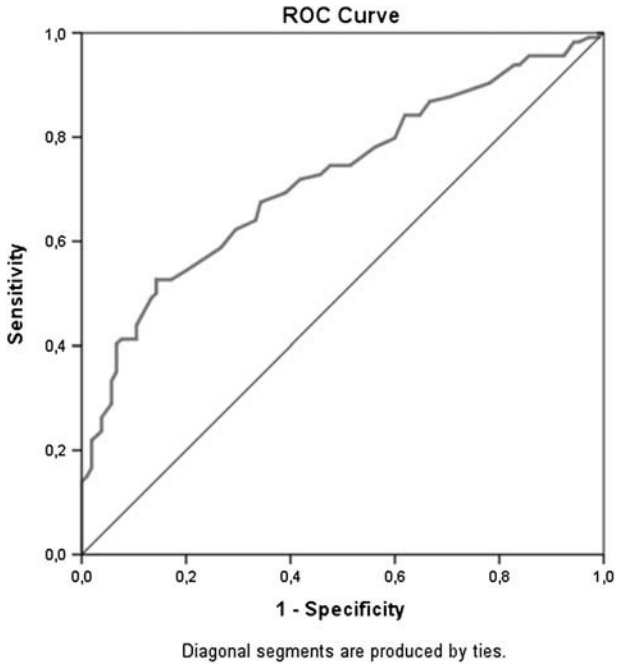

FIGURE 1. The ROC curve analysis for lactate level.

A 6-year-old female unconscious patient, whose COHb level was 53%, and a 17-year-old male patient, whose COHb level was 60.8% (GCS = 4), were treated with HBO. At the end of the second session, patients were conscious, and the treatment was continued with NBO in the follow-up. All patients who were followed up with the diagnosis of CO intoxication and included in the study were called for the control after 4 weeks, and physical/neuropsychiatric examinations were performed. Neurological worsening or death was not observed among the patients at control follow-up.

DISCUSSION

Carbon monoxide intoxication is one of the major causes of morbidity and mortality worldwide. It comes first in the causes of death occurring by accident due to failure to provide proper heating conditions and the lack of controls of chimneys. Carbon monoxide intoxication exhibits with nonspecific signs and symptoms. Although mental changes were the initial findings in a study conducted in this area, the most common presenting complaints in our study were listed as nausea, vomiting, dizziness, and headache.[12]

Age groups were compared with the laboratory findings in the literature, mostly adults and children were compared with each other and such a relationship under the age of 15 years was not shown.[2,3,12,13] In a study conducted in children, authors stated that severity of symptoms increased with age and therefore adolescents are at greater risk.[14] In our study, a significant negative correlation between age groups and increase in white blood cell (WBC) levels, CK and LDH values was determined. It has been shown that, WBC, CK and LDH values were found to be higher with younger ages ($P < 0.05$). A relationship between COHb levels of patients and the clinical correlation was not found, and this was consistent with other studies.[2,12,13,15,16] This situation can be explained by the contact with normal atmospheric oxygen after leaving the environment of intoxication and the elimination of COHb during the time of arrival to the hospital. Especially, receiving 100% oxygen treatment by mask in the ambulance may be the cause of detection of COHb level lower than expected. Consistent with the adult studies, we believe that normal COHb levels cannot be used to rule out CO as an etiology of severe symptoms.[5,6]

The presence of neurological signs is an indication of severe CO intoxication, and the levels of COHb have been found high in these patients in many studies. In our study, similarly, COHb levels were significantly higher in lethargic, unconscious patients than conscious patients. A significant positive correlation was found between changes in consciousness and the level of COHb ($P < 0.05$), and the results were consistent with other studies in this area.[1–3,12] Although there is a positive correlation between changes in consciousness and blood lactate levels and WBCs, a negative significant relationship was observed with blood pH and base deficit ($P < 0.05$). This condition suggested that there was as a long-term exposure to CO, tissue hypoxia, and metabolic acidosis continued for a long time and the presence of cerebral ischemia.

In some studies, significant increase in CK, CK-MB, LDH, and cTnI levels, ischemic myocardial injury markers, have been identified in the presence of neurological symptoms.[12,13,15–19] In our study, similarly, a significant positive correlation was found between neurological symptoms and CK, CK-MB, LDH, and cTnI. We believe that examination of cardiac enzymes is useful in patients with neurological symptoms.

Tachycardia has been identified in many studies as the most common physical examination finding in patients admitted with CO intoxication.[3,16,18] Although the mean COHb level in patients with tachycardia was 26.1% (16–60.8), this ratio was 24.2% in those without tachycardia (16.2–43). A statistically significant difference was detected between the presence of sinus tachycardia and COHb level ($P < 0.05$). In a study conducted in adults,[16] there was no significant relationship between sinus tachycardia and COHb level, and our study was different in this respect. This situation can be explained by the different types of case acceptance criteria. In our study, sinus tachycardia was significantly correlated with blood lactate levels, blood pH, base deficit, and increase in WBC level ($P < 0.05$). This result was consistent with other studies.[18] In our study; CK, CK-MB, and cTnI levels were higher than normal limits in 29.5 %, 59.8%, and 22.2% of patients

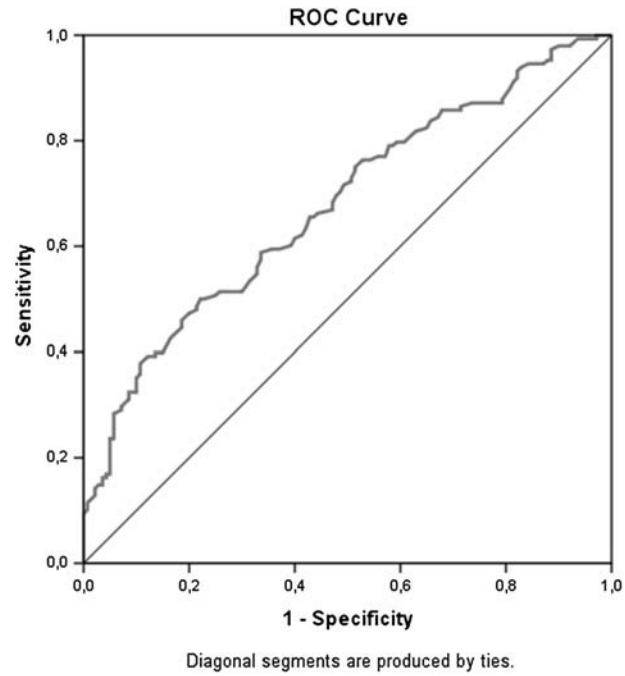

FIGURE 2. The ROC curve analysis for COHb level.

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with tachycardia, respectively. Considering the correlation between cardiac enzymes and tachycardia, a significant relationship was detected with LDH and CK-MB, and the relationship was not observed with CK and cTnI levels ($P > 0.05$).

Hypotension was detected in 9.7% of the cases (n = 28). This symptom was more pronounced in the presence of severe CO intoxication and neurological symptoms. In other studies, the incidence of hypotension was not specified. In our study, considering the correlation between hypotension and laboratory values, a negative significant correlation was detected with COHb, lactate, pH, and base deficit ($P < 0.05$). A positive correlation with cTnI and CK-MB was detected ($P < 0.05$), CK and LDH were not correlated with hypotension ($P > 0.05$). These results suggest that cardiogenic and enzyme monitoring are required in patients with hypotension.

Convulsion was observed in 16 patients (5.7%). This rate was lower compared to other studies[12,17] and seen most frequently in infants (15.9%). The blood COHb lactate, CK, CK-MB, and LDH values of patients with convulsions were significantly higher in accordance with other studies.[12,13,15,18] This was similar with the results of Moon et al[7] who stated that the patients with high plasma lactate levels had a higher incidence of altered mental status on admission to ED. Considering the statistical relationship between convulsion and laboratory findings, a significant positive correlation was found between COHb, lactate, pH, base deficit, CK, CK-MB, and LDH values ($P < 0.05$). Metabolic acidosis and lactate were found to be higher in patients presenting with convulsion. This situation may be associated with tissue hypoxia with longer duration and the severity of intoxication.

In a study,[14] although a correlation between COHb levels and CK, CK-MB, and cTnI was not demonstrated, the moderately significant positive correlation was found between COHb and lactate, and a low degree of significant relationship was found with CK, CK-MB, and LDH ($r = 0.144$, $P < 0.05$; $r = 0.224$, $P = 0.001$; $r = 0.165$, $P < 0.05$). In a recent adult study,[6] lactate levels were found to be strongly correlated with COHb values ($r = 0.738$, $P < 0.001$) but pediatric age group lacks this knowledge. Similar to several studies, the relationship between COHb level and cTnI was not detected in our study ($P > 0.05$) (4.9–12).

Although lactate levels have been progressively used in the decision-making process of critical patients, few studies have used this value in CO intoxication and only in adults.[7,8] Lactate levels were measured in 1 study, but the numbers of patients with increased levels and the clinical correlation were not studied.[12] In our study, lactate was high in 199 (90.1%) patients. Detection of positive correlation between lactate levels and clinical findings showed that the blood lactate levels may give more accurate information in terms of the duration and degree of hypoxia ($P < 0.05$). A significant relationship was detected between lactate and pH, base deficit, CK-MB, LDH, and cTnI. Although a relationship between COHb levels and lactate was not detected and a significant positive correlation was detected between lactate and cTnI ($P < 0.05$), these situations also suggest that lactate level may be used as an indicator of the ischemic myocardial injury. It was concluded that blood lactate level was more significant compared to COHb level in the determination of the severity of the intoxication, duration of treatment, and monitoring of patients.

Although there are correlations between CK-MB and COHb, CK and cTnI observed in a study conducted,[14] in our study, CK-MB was detected to be correlated in more patients (130 patients [45.1%]) when compared to CK. In 35 (17.2%) patients, cTnI has been found higher which was different from other studies.[12] One of the patients with high troponin I was a 6-year-old male patient with nausea only, and his COHb level was 20.4%. The others were patients with loss of consciousness and convulsions were admitted due to clinically moderate and severe intoxication.

The relationship between troponin I and COHb was not detected ($r = 0.122$, $P > 0.05$), and this was consistent with many studies.[12,13,15,17] There was no finding other than sinus tachycardia in the ECG of 35 patients with high troponin I values. It has been found that cTnI decreased in the control biochemical tests taken after 12 hours of admission. The levels of cTnI reach the maximum at 10th hour in significant myocardial injury and remained high for 5 to 10 days. In this study, the patients' initial troponin I levels and the levels obtained at the 6th to 12th hours were compared, finding the control values lower indicated that myocardial injury was minimal. In one study,[16] single photon emission computed tomography study was performed by using Tc 99 MIB to investigate myocardial injury in patients with high cTnI level, and defect was not detected. This situation suggests that the myocardial injury which occurred because of CO intoxication was in a smaller area which might not be detected by scintigraphy. In a study including adult patients, authors have found that CO-induced cardiomyopathy occurred in 3% of acute CO poisoning patients and stated that myocardial stunning due to a catecholamine surge plays an important role in the development of CO-induced cardiomyopathy.[20] The authors are aware of the limitations of the study related to its single-centered design and the scarcity/restrictions of available opportunities in a developing country environment. It would be more valuable if we had evaluated each patient with echocardiographic assessment and determined each stage with a pediatric cardiology specialist for cardiologic evaluation. However, unfortunately, we cannot consult a pediatric cardiologist for 24 hours per day, so perhaps we might be insufficient to demonstrate every acute or long-term myocardial injury. In addition, there were only 2 HBO therapy patients in whom this was indicated, thus outcomes of patients receiving normobaric and HBO could not be compared statistically.

We believe that a patient subjected to CO and found unconscious at home might be transported by ambulance taking high concentration of oxygen with oronasal mask and therefore measured COHb levels might result lower than expected when he/she reaches the hospital. However, this does not exclude hypoxia at tissue level. We think that we do not give enough importance to lactate levels when assessing patients with CO intoxication. Perhaps, we might underdiagnose these patients because detected COHb level was low, preventing patient to receive appropriate therapy. Also, we believe that the finding of an elevated lactate might influence HBO treatment decisions as previously established in an adult study, and an elevated lactate level can help to predict the need for HBO treatment and to identify patients with severe CO poisoning.[6]

CONCLUSIONS

To our knowledge, this is the first study carried out in children admitted because of CO intoxication. The blood lactate levels may give more accurate information in terms of the duration and degree of hypoxia. In addition, lactate level is found to be more significant than COHb level in CO intoxication regarding loss of consciousness and convulsion so that lactate level could be taken as a measure of severe poisoning and may help to decide for HBO treatment. Further clinical investigations with larger samples in pediatric age group are required to validate these findings.

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