Türk Pediatri Arşivi
Turkish Archives of Pediatrics

Original Article

Evaluation of neurological and cardiological findings in carbonmonoxide poisoning in children

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Abstract

Aim: The aim of our study was to investigate the relation of blood carboxyhemoglobin level with presentation finding and clinical properties and to demonstrate neurological and cardiological findings which are indicators of tissue hypoxia in patients followed up because of carbonmonoxide (CO) poisoning.

Material and Methods: Three hundred and twenty-five patients who were followed up because of carbonmonoxide poisoning between 2011 and 2013 in our pediatric emergency department were evaluated prospectively. Ethics committee approval was obtained for the study on 10.19.2011 (number: 0437). The carbonmonoxide levels, source of intoxication, neurological and cardiological findings and treatment methods were recorded. Blood gases and cardiac enzymes were studied and electrocardiography (ECG) was performed. The data were analysed using SPSS for windows 16.0 package program.

Results: One hundred and sixty-eight (51.7%) of the patients were female and the median age was 9 years (11 days-17 years). Two hundred and twenty-eight (70.2%) of the patients were poisoned while using heater and 78.1% presented during winter months. The median carbonmonoxide level of the patients was found to be 24.8%. Cardiac enzymes were found to be increased in 10.5% of the patients, first degree A-V block was found in 0.6% and negative T wave was found in 0.3%. Glasgow coma score was found to be below 14 in 4.6% of the patients. A significant correlation was found between the carboxyhemoglobin levels and neurological findings, cardiological findings and lactate ($p<0.05$). Normobaric oxygen treatment was given to 76.3% of the patients and hyperbaric oxygen treatment was given to 23.7%.

Conclusions: We think that neurological disorders and cardiac findings may be closely related, since systemic involvement may be easier in carbonmonoxide poisoning in children, Glasgow coma score should be assessed in the follow-up of the patients and cardiac enzymes and serum lactate levels should be monitored closely from the time of presentation. (Türk Ped Arş 2014; 49: 314-22)

Key words: Child, hyperbaric oxygen, carbonmonoxide poisoning, cardiological finding, neurological finding

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Received: 19.04.2014 **Accepted:** 11.08.2014

DOI:10.5152/tpa.2014.201010

Introduction

Carbonmonoxide (CO) poisoning is the most common cause of mortality related with poisoning in the whole world and in our country. It continues to be a significant cause of mortality and morbidity (1-3). Carbonmonoxide is a colorless, odorless, tasteless and unirritable gas. It forms as a result of incomplete burning of substances and fuels containing carbon. Exposure to factory and exhaust gases, breathing of fire smoke, poor ventilation in places where firewood and coal are burned and use of geyser are the main causes of carbonmonoxide poisoning (4, 5).

Carbonmonoxide shows toxic effect by leading to tissue hypoxia. It is more toxic for the heart and brain which are sensitive to hypoxia. Carbonmonoxide leads to shifting of the oxyhemoglobin dissociation curve to the left by competing with oxygen and binding to hemoglobin (Hb). Thus, oxygen use in the tissues decreases and oxydative stress occurs. Oxydative stress directly causes to tissue damage and leads to occurence of signs (4). Children show manifestations early in carbonmonoxide poisoning, since they have less blood volume, faster basal metabolism and higher oxygen requirement in tissues and are more sensitive to the toxic effects of CO (6).

The aim of our study was to investigate the relation of blood carboxyhemoglobin (COHb) level with the findings and clinical properties at presentation and to elucidate the neurological and cardiological findings which are indicators of tissue hypoxia.

Material and Methods

The patients who were diagnosed with CO poisoning in the Ministry of Health Ankara Education and Research Hospital Pediatric Emergency Department between 2001 and 2013 were evaluated prospectively. The sources of poisoning, residental types and forms of presentation to the hospital were interrogated. The age, gender, physical examination findings and coma scores according to the Glasgow coma scale (GCS) were recorded. Blood pressure and pulse measurements were done in terms of cardiac findings and electrocardiography was performed. Echocardiography (ECHO) was performed in patients who had increased cardiac enzymes and pathological findings on ECG.

Blood gases, hemogram, biochemical tests and creatinine kinaze (CK), CK-MB, cardiac troponin T (cTnT), lactate and lactate dehydrogenase (LDH) were studied in the peripheral blood obtained at presentation. The tests were repeated 6 and 24 hours later. The normal ranges for the tests were as follows: COHb: 10% and above; lactate: 0-2 mmol/L; pH: 7.35-7.45; CK: 0-145 U/L; CK-MB: 0-24 U/L; LDH: 110-295 U/L; cTnT: 0-13 ng/L. The patients were classified as group 1 (10-30%) (mild poisoning), group 2 (30-40%) (moderate poisoning) and group 3 (40-60%) (severe poisoning) according to COHb levels and divided into three groups according to age groups as infancy (0-2 years), preschool-school (3-10 years) and adolescence (11-17 years) (5).

The patients were evaluated according to presence of neurological and cardiological findings. Complaints including loss of consciousness, seizure, somnolance, loss of vision were considered as neurological findings and hypotension, chest pain, ECG changes, increased cardiac enzymes (CK-MB, cTnT, LDH) were considered as cardiological findings.

100% oxygen treatment was given to the patients by mask with reservoir bag (normobaric oxygen treatment) (NBO). Hyperbaric oxygen (HBO) treatment was given to the patients who had neurological findings including focal neurological signs, loss of consciousness, coma and seizure and whose blood COHb level was >40%. Efficiency of treatment was defined as decrease of COHb value below 5% after 6-8 hours and complete regression of the symptoms.

Informed consent was obtained from the patients for the study and approval was obtained from the Education and Coordination Planning Committee (decision number 0437 dated 10.19.2011).

Statistical analysis

Analysis of the data was performed using Statistical Package for the Social Sciences (SPSS, Inc., New York, USA) Window 16,0 package program. Kolmogorov-Smirnov test was used to investigate if the distribution of the continuous and discontinuous numerical variables was close to normal or not. Descriptive statistics were espressed as mean±SD or median (the lowest-the highest) for continuous and discontinuous numerical variables and as subject number and % for categorical variables. Since the distribution of the numerical variables was poor, the

significance of the difference in terms of median values was investigated using Mann-Whitney U test and Kruskal Wallis test. The categorical variables were evaluated using Pearson's chi-square, Fischer's exact chi-square or likehood ratio test; a p value of <0,05 was considered statistically significant.

Results

Three hundred and fifty-three patients presented because of carbonmonoxide poisoning. 28 patients were excluded, since they had a COHb level of <10% and been followed up for shorter than 6 hours. 325 patients who had a blood COHb level of >10% and who were hospitalized were included in the study. 168 of the patients (51.7%) were female and the median age was 9 years (11 days-17 years) (Table 1). According to the distribution by age groups, the highest rate of presentation was observed in the 3-10 year age group (48%). Two hundred and twenty-eight of the patients (70.2%) were poisoned by stove and 97 (29.8%) were poisoned by geyser. 63.9% of the patients who were poisoned by stove were living in shanty houses; 62.5% of the patients who were poisoned by geyser were living in apartment houses and presentations occured most commonly in autumn-winter months (78.1%). When evaluated by months, 77 of the patients (23.7%) presented in November, 50 (15.4%) presented in December, 71 (21.8%) presented in January and 56 (17.2%) presented in February. While 282 of the patients presented by their own possibilities, 43 patients (13.2%) were brought by ambulance.

Table 1. Demographic data of the patients

Variables	n=325
Age groups	n (%)
0-2 years	31 (9.8)
3-10 years	157 (48)
11-17 years	137 (42.2)
Gender	
Male	157 (48.3)
Female	168 (51.7)
Residental type	
Apartment house	162 (49.8)
Shanty	156 (48)
Single family house	7 (2.2)
CO source	
Stove	228 (70.2)
Geyser	97 (29.8)

CO: carbonmonoxide

The most common presentation complaint was nausea-vomiting (n=90; 27.7%). The patients who had no complaint, but presented with suspicious poisoning, since there was CO poisoning in family members were in the second order (n=74; 22.8%). The other complaints included headache, loss of consciousness, weakness and seizure. In addition, two patients presented with decreased sucking and one patient presented with loss of vision. When the presentation complaints and age groups were compared, it was found that nausea-vomiting was observed most commonly in the 0-2 year age group and headache was observed most commonly in the 11-17 year age group. The results were statistically significant (p=0.008; 0.003) (Table 2).

The median value of COHb level of the patients was 24.8% (the lowest: 10.2- the highest: 60). When the presentation complaints and COHb groups were compared, it was found that group 1 presented most commonly with nausea-vomiting (n=80; 31.5%), group 2 (n=18; 35.3%) and group 3 (n=13; 65%) presented most commonly with loss of consciousness. A statistically significant relation was found between group 1 and nausea-vomiting (p=0.008) and between group 3 and loss of consciousness and seizure (p=0.002; p=0.005) (Table 3). When the neurological and cardiological findings were compared with the COHb groups, significant relation was found in both (p<0.001; p=0.001) (Table 4). The mean GCS score of the patients was 14.8±0.9 and GCS was <15 in 4.6% of the patients. As the carboxyhemoglobin level increased, the GSC value decreased (p<0.001).

The median values of the other laboratory tests were as follows: lactate: 2.1 (0.1-6.5) mmol/L, pH: 7.38 (6.70-7.60); CK: 120 (0.7-473) U/L; CK-MB: 2.7 (0.7-156) U/L; LDH: 240 (103-589) U/L, cTnT: 4.6 (0-2718) ng/mL, myoglobin: 20 (20-1874) g/dL.

Serum lactate level was found to be increased in 192 of the patients (59.1%), CK was found to be increased in 69 (21.2%), LDH and cTnT were found to be increased in 62 (19.1%), CK-MB was found to be increased in 28 (8.6%) and myoglobulin was found to be increased in 11 (3.4%) (Figure 1). Serum lactate level was found to be increased in 59.1% of the patients and in 78.1% of the patients who had neurological findings (p<0.01). In

Table 2. Distribution of presentation complaints according to age groups

Presentation complaints	0-2 years, n (%)	3-10 years, n (%)	11-17 years, n (%)	p value
Nausea-vomiting	12 (38.7)	40 (25.5)	38 (27.7)	0.008
Loss of consciousness	2 (6.5)	26 (16.6)	22 (16.1)	0.342
Headache	0	29 (18.5)	36 (26.3)	0.003
Suspicious poisoning	11 (35.5)	35 (22.3)	28 (20.4)	0.193
Somnolance	3 (9.7)	19 (12.1)	9 (6.6)	0.273
Abdominal pain	0	1 (0.6)	1 (0.7)	
Seizure	1 (3.2)	7 (4.5)	2 (1.5)	0.331
Visual loss	0	0	1 (0.7)	
Decrease in sucking	2 (6.5)	0	0	
Total	31 (100)	157 (100)	137 (100)	

Table 3. Distribution of presentation complaints according to carboxyhemoglobin levels

	Group 1, n (%)	Group 2, n (%)	Group 3, n (%)	p value
Nausea-vomiting	80 (31.5)	9 (17.6)	1 (5)	0.008
Loss of consciousness	19 (7.5)	18 (35.3)	13 (65)	0.002
Headache	55 (21.7)	9 (17.6)	1 (5)	0.181
Suspicious poisoning	63 (24.8)	10 (19.6)	1 (5)	0.107
Somnolance	28 (11)	3 (5.9)	0	0.063
Abdominal pain	2 (0.8)	0	0	0.610
Seizure	5 (2)	2 (3.9)	3 (15)	0.005
Visual loss	0	0	1 (5)	
Decrease in sucking	2 (0.8)	0	0	
Total	254 (100)	51 (100)	20 (100)	

Table 4. Distribution of carboxyhemoglobin groups according to neurological and cardiological findings

	Group 1, n (%)	Group 2, n (%)	Group 3, n (%)	p value
Neurological finging				<0.001
Yes	24 (9.4)	21 (41.2)	19 (95)	
No	230 (90.6)	30 (58.8)	1 (5)	
Cardiological finding				<0.001
Yes	47 (18.5)	17 (33.3)	10 (50)	
No	207 (81.5)	34 (66.7)	10 (50)	

the patients in group 3, serum myoglobulin and lactate levels were found to be statistically significantly higher compared to the other groups (p=0.033; p<0.001). Although serum CK, CK-MB, cTnT and LDH levels were found to be higher in the patients in the same group compared to the other groups, no statistically significant difference was found between the groups (p>0.005). GCS was found to be <14 in 4.6% (n=15) of the patients. Hypotension which necessitated inotropic support developed in 20% of these patients.

Cardiac pathology was not found in 251 of the patients (77.2%). Sinus tachycardia was found in 37 of the patients (11.4%), increased cardiac enzymes were found in 34 (10.5%), 1° AV block was found in 2 (0.6%) and negative T wave was found in one (0.3%). Cardiovascular complaints including palpitation and chest pain were not observed in the patients who were found to have increased cardiac enzymes and no pathological finding was observed on ECG. On ECHO, ejection fraction and ventricular functions were assessed to be

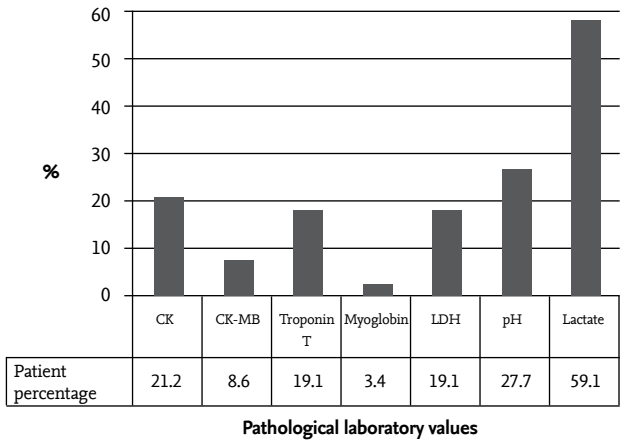

Figure 1. % distribution of pathological laboratory findings
CK: creatinine kinase; LDH: lactate dehydrogenase

normal in these patients. When the median COHb levels in the patients who had increased cardiac enzymes (n=34) were compared with the group who did not have increased cardiac enzymes (n=291), no statistically significant relation was found (p=0.678). A statistically significant but weak relation was found between the carboxyhemoglobin level and CK-MB, troponin and myoglobulin levels (p<0.001, r=0.233; p<0.001, r=0.210; p<0.001, r=0.237). In the patients who were found to have increased enzyme levels, the tests repeated after 6-24 hours revealed decreased enzyme levels.

While there was a significant relation between increased enzymes (cTnT, CK-MB, myoglobulin) and lactate level (p=0.01), no significant relation was found between increased enzymes and COHb and pH levels (p=0.678; p=0.055). No significant relation was found between A-V block and COHb, lactate and pH (p=0.731; p=0.301; p=0.154). While a significant relation was found between T negativity and COHb and pH (p=0.006; p=0.006), no significant relation was found between T negativity and lactate (p=0.129). While a significant relation was found between loss of consciousness and COHb and lactate levels (p<0.001 and p=0.006), no significant relation was found between loss of consciousness and pH (p=0.760). There was no statistically significant relation between somnolance and COHb, lactate and pH levels (p=0.957; p=0.855 and p=0.090). While a significant relation was found between seizure and COHb level (p=0.013), no significant relation was found between seizure and lactate and pH levels (p=0.127 and p=0.449). No significant relation was found between loss of vision and COHb, lactate and pH levels (p=0.532; p=0.167; p=0.155) (Table 5).

While NBO treatment was given to 76.3% of the patients (n=248), HBO treatment was given to 23.7% (n=77). HBO treatment was given to 59 (92.2%) of 64 patients who had neurological findings and 40 (54.1%) of 74 patients who had cardiological findings. Presence of need for HBO treatment was found to be statistically significant in the patients who had neurological and cardiological findings (p<0.001). A 12 year old patient who presented with loss of consciousness and had a COHB level of 55% was lost.

Discussion

Carbonmonoxide poisoning shows difference by region, climate, socioeconomical level, seasons and months. It is observed more commonly in winter months and cold climates (5). In our study, the rate of poisoning in winter months was found to be 78.1%. Presentation was found most commonly in November (23.7%) and January (21.8%). In studies conducted in our country, the rate of presentations because of CO poisoning in winter months has been reported to be 64.6% (5). While some studies have reported stove as the most common source of CO poisoning (3, 4, 8), some other studies have reported geyser more commonly (9, 10). In our study, stove was found to be the source of poisoning with a rate of 70.2% and geyser was found with a rate of 29.8% which was compatible with the literature.

Severe CO poisonings may result in mortality. In a study conducted in our country, 10 154 CO cases were found in one year and 0.3% of these were reported to result in mortality (11). In a study performed by Yarar et al. (5), it was reported that 3 of 107 pediatric patients who were followed up because of CO poisoning were lost. In our study, one of the patients who were being followed up because of CO poisoning was lost.

Children become symptomatic earlier in CO poisoning, since they have less blood volume, faster basal metabolism and higher tissue oxygen requirement and they are more sensitive to the toxic effects of CO (6). Clinically, CO poisoning can present with a wide spectrum of manifestations ranging from mild compliants to fainting, seizure and coma. Since there is no direct pathognomonic finding, the main determinant in the diagnosis is "suspicion". The most common complaints have been found to include nausea-vomiting, headache, somnolance-weakness and loss of consciousness

Table 5. The relation of neurological and cardiological findings with COHb, lactate and pH

Variables Increased cardiac enzymes	COHb (%) Median (min-max)	Lactate mmol/L Median (min-max)	pH median (min-max)
No (n=291)	24.7 (10.4-60)	2.2 (0.1-6.5)	7.37 (6.70-7.50)
Yes (n=34)	24.0 (10.2-44.7)	2.8 (1.1-6)	7.39 (7.26-7.46)
p	0.678	0.010	0.055
A-V block			
No (n=232)	24.6 (10.2-60)	2.2 (0.1-6.5)	7.37 (6.70-7.60)
Yes (n=2)	27.4 (18.9-36)	2.7 (2.4-3)	7.33 (7.32-7.35)
p	0.731	0.301	0.154
T negativity			
No (n=324)	24.5 (10.2-57.9)	2.2 (0.1-6.5)	7.37 (7-7.6)
Yes (n=1)	60 (60-60)	4 (4-4)	6.70 (6.70-6.70)
p	0.006	0.129	0.006
Loss of consciousness			
No (n=275)	23.3 (10.2-60)	2.2 (0.2-6)	7.37 (7.00-7.6)
Yes (n=50)	35.2 (15.0-60)	2.9 (0.1-6.5)	7.35 (6.70-7.46)
p	<0.001	0.006	0.760
Somnolence			
No (n=293)	24.7 (10.2-60)	2.2 (0.1-6.5)	7.37 (6.70-7.60)
Yes (n=32)	23.9 (10.4-40)	2.3 (0.8-6)	7.34 (7.00-7.49)
p	0.957	0.855	0.090
Seizure			
No (n=315)	24.5 (10.2-60)	2.2 (0.1-6.5)	7.37 (6.70-7.50)
Yes (n=10)	32.8 (17.5-48.6)	2.9 (1.6-6)	7.36 (7.12-7.60)
p	0.013	0.127	0.449
Visual loss			
No (n=324)	24.7 (10.2-60)	2.2 (0.1-6.5)	7.37 (6.70-7.60)
Yes (n=1)	30 (30-30)	3.6 (3.6-3.6)	7.30 (7.30-7.30)
p	0.532	0.167	0.155

max: maximum; min: minimum

(3, 4, 11, 12). In our study, the most common complaints included nausea-vomiting, headache and loss of consciousness which was compatible with the literature. In addition, 22.8% of the patients presented with suspicious CO poisoning, since CO poisoning was found in family members. The COHb level was found to be 10-30% in 85.1% of these patients. This suggested that "suspicion" was important in the diagnosis in CO posioning. It has been reported that especially mental status changes and feeding intolerance are observed in infancy and headache and vomiting are observed more commonly in older children in CO poisoning (4, 5, 12, 13). In accordance with the literature, infants presented most commonly with complaints including decrease in sucking and somnolance and the patients in the 11-17 year age group presented most commonly with headache.

Presence of neurological findings is an indication of severe CO poisoning and the level of COHb was found to be increased in patients with neurological findings in many studies (3-5, 12). In our study, the level of COHb was found to be above 30% in the patients who presented with loss of consciousness and seizure. The mean GCS score was found to be 13.8±2.5 in the study performed by Kandiş et al. (9) and 14 in the study performed by Kurt et al. (12). Our results were found to be similar to the other studies conducted. Studies have

reported that patients with hypotension have more severe clinical signs and lower GCS score (6). GCS was found to be <14 in 4.6% of the patients in our study group. Hypotension which necessitated inotropic support was developed in 20% of these patients. This result suggested that patients who have neurological findings or who present with severe CO poisoning should be followed up closely in terms of cardiovascular impact.

It has been reported that visual disorder may occur when carboxyhemoglobin is 30-40% (14). In a study conducted by Genç et al. (15) in adults, visual disorder was reported in 37.7% of the cases of CO poisoning. In our study, a 16-year old patient presented with transient vision loss. It was thought that one should be careful in patients presenting with vision loss.

Disturbance of tissue perfusion and following cellular hypoxia in carbonmonoxide poisoning affect the cardiovascular system in the second order. Satran et al. (16) reported cardiac damage with a high rate of 37% in adults with CO poisoning and increased cardiac enzymes were related with the CO level. Therefore, they recommended that patients should be monitored with ECG and cardiac enzymes and ECHO should be performed in the ones with pathological findings on ECG and increased cardiac enzymes. In a similar study performed by Kalay et al. (17), it was reported that mild-moderate cardiac dysfunction which would recover in 24 hours might develop and CO level and CO exposure time were significant factors in cardiac damage. Information about cardiovascular effects is limited in children with carbonmonoxide poisoning. In the study of Teksam et al. (6), Troponin T was found to be increased in 15% of the patients and CK-MB was found to be increased in 10.2%. In the same study, decreased ejection fraction and left ventricular dysfunction was found on ECHO without anomaly on ECG in 33% of the patients who were found to have increased cardiac enzymes (6). In our study, ECHO was found to be normal which was not compatible with the literature. In the study of Teksam et al. (6), no relation was found between the COHb level and CO posioning findings and it was stated that it was frequently difficult to determine cardiac damage related with CO poisoning in pediatric patients. In our study, a weak relation was found between the COHb level and cardiac enzyme levels. However, it was thought that new studies are needed, since there is a limited number of studies conducted with children in relation with this issue.

The sensitivity of troponin T in indicating myocardial ischemia reaches 90%. Studies have reported that increased enzyme level is a significant variable in indicating myocardial damage and development of myocardial damage is an indicator of poor prognosis (5, 18). cTnT was found to be increased in 17.2% of the patients who presented with CO poisoning in one study and in 20% in another study (19, 20). In our study, the levels of cTnT were found to be decreased in the follow-up of the patients. This suggested that myocardial damage developed with the lowest rate secondary to hypoxia.

Since sinus tachycardia is a balancing response which develops against systemic hypoxia, it is not an indicator of cardiotoxicity and it should not be used as a screening method for indicating myocardial damage. In the study of Gandini et al. (21), it was reported that sinus tachycardia was a common finding in pediatric CO poisoning, was not a specific finding in indicating cardiac damage and "gallop" ryhtym was more determinative for cardiac dysfunction. Sinus tachycardia was found in 11.4% of the patients in our study and tachycardia regressed as the clinical status improved.

In carbonmonoxide poisoning, lactate level increases as a result of tissue hypoxia. Studies have found that mental status changes are found more commonly, COHb level was higher in patients with increased lactate levels and it has been concluded that lactate level is a useful variable for prognosis after CO poisoning (4, 21-23). In our study, serum lactate level was found to be significantly increased in 59.1% of the patients and in 78.1% of the patients with neurological findings.

As a result of rhabdomyolysis, myoglobulin also increases in addition to LDH. The affinity of carbonmonoxide to myoglobulin is 40-fold higher compared to oxygen. When carbonmonoxide binds to myoglobin, it further increases disturbed perfusion and contributes to hypoxic damage. In our study, myoglobulin level was found to be increased as COHb level increased and this increase was found to be statistically significant. This suggested that myoglobulin increased with the increased severity of hypoxia and it could be used as laboratory data in the follow-up of patients. No other literature could be found related with this issue. Our study was different in this context.

Treatment mainly consists of removal of the patient from the setting and oxygenation. Although the effi-

ciency of hyperbaric oxygen treatment in children is controversial, there are publications which report that it is useful (5, 20, 24). In our study, neurological and cardiological findings regressed in the follow-up of the patients in whom HBO treatment was administered.

Conclusively, we think that neurological anomalies and cardiac findings may be closely related, since systemic impact of CO poisoning is easier in children, cardiac enzymes and serum lactate levels should be closely monitored from presentation in the follow-up of the patients and evaluation of the prognosis and it should be kept in mind that low GCS values and hypotension may be an indicator of cardiac affection without ECG changes.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Ankara Training and Research Hospital Training and Coordination Planning Board (19.10.2011).

Informed Consent: Written informed consent was obtained from the parents of the patients.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - Z.Y.; Design - Z.Y.; Supervision - Y.B.D.; Funding - Y.B.D., Z.Y.; Materials - Y.B.D.; Data Collection and/or Processing - H.B.; Analysis and/or Interpretation - H.B., Z.Y.; Literature Review - H.B., Z.Y.; Writer - H.B., Z.Y.; Critical Review - Y.B.D., Z.Y.; Other - H.B., Z.Y., Y.B.D.

Conflict of Interest: No conflict of interest was declared by the authors.

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

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