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Prognostic factors of carbon monoxide poisoning in Taiwan: a retrospective observational study

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ABSTRACT

Objectives To identify the risk factors related to the prognosis of carbon monoxide (CO)-poisoned patients in the hospital.

Design Retrospective observational study.

Setting Tri-Service General Hospital, Taiwan.

Methods We conducted a review of the medical records of 669 CO-poisoned patients, who were admitted to the Department of Emergency, Tri-Service General Hospital, Taiwan, from 2009 to 2014. Demographic, clinical and laboratory data were collected for analysis. In the study, the end points for poor outcome were patients who either still had sequelae, were bedridden or died after treatment. The independent t-test, χ^2 test and binary logistic regression were used to identify the association between the prognostic factors and the outcomes.

Results The logistic regression analysis confirmed that the Glasgow Coma Scale (GCS) score (p=0.008) and blood urea nitrogen (BUN) (p=0.002) were related to poor outcomes. Furthermore, the receiver operating characteristic (ROC) curve showed that the cut-off point of intubation days was 1.5 days (area under the ROC curve [AUC]=0.793) for all patients and 2.5 days (AUC=0.817) for patients with intubation when predicting poor outcomes.

Conclusion We identified the factors that most strongly predict the prognosis of CO poisoning, including the GCS score, serum BUN and intubation days. Moreover, the number of hyperbaric oxygen treatments seems to have impact of the outcome.

Strengths and limitations of this study

- ► Most biochemical factors were considered in the study.
- ► Most of the carbon monoxide (CO)-poisoned patients received the hyperbaric oxygen therapy in the hospital.
- ► The rate of recovery was similar to other studies.
- ► Some data missing of the patients transferred from other hospitals.
- ► Give the specific indications for clinical research work and clinical practice with CO-poisoned patients.

INTRODUCTION

Carbon monoxide (CO) poisoning is a global health issue. In a study by Mott *et al*, 116 703 people died from non-fire CO poisoning in the USA from 1968 to 1998, with around 10 deaths per day.[1] In an UK-based study, 2463 CO poisoning admissions were noted from 2001 to 2010, most of which were preventable.[2] The incidents of CO poisoning usually have a higher rate in winter, because people tend to use heaters and close the windows when the weather is cold.[2–5] The causes of CO poisoning include defective heaters, fires, cooking appliances, the exhaust of vehicles, smoke, waterpipe smoking and so on.[6–8] Besides accidental CO poisoning, the number of deliberate CO intoxications increased due to the increased suicide rate by facing higher stress in their lives now than the past.[9] The suicide rate has increased in Taiwan from around 15 to 35 per 100 000 for males and from 8 to 16 per 100 000 for females from 1992 to 2006. Most of them used charcoal as the source of CO.[10 11]

CO poisoning causes cellular hypoxia by reducing oxygen delivery to tissues and decreasing the dissociation of oxygen from haemoglobin (Hb) to the cells. Energy depletion is the direct cause of CO-induced cell damage, as oxidative phosphorylation is suppressed when cytochrome a3 in the inner membrane of mitochondria is inhibited by CO.[12 13] The most vulnerable organs are the heart and the brain because of their high oxygen demand. The symptoms of acute CO poisoning are headache, fatigue, nausea, vomiting, convulsion and death.[14 15] Although there are some discussions on the use of hyperbaric oxygen (HBO) therapy in treating CO poisoning,[16 17] it has been shown to enhance CO elimination and reverse cytochrome a3 inhibition, resulting in a lower severity of neurological sequelae after CO poisoning.[18] The neuropsychological sequelae include neurological deficits,

cognitive impairments and affective disorders,[19 20] which may cause a drastic impact on the quality of life.

The majority of patients with CO poisoning are around 25–45 years of age in Taiwan representing the most productive group in the society.[10 21] If the factors related to the prognosis were known, then more effective treatments could have been offered. Some predictive factors have been proposed, including hydrogen ion, serum lactate, myocardial injury, Glasgow Coma Scale (GCS) score, leucocytosis and troponin I (TnI).[6 18 19 22–25] However, the clinical indications are still controversial for predicting the outcomes in patients with CO poisoning.[26] In the present study, we tried to find factors for predicting the prognosis of CO poisoning and providing indications for further clinical research work.

METHODS

Study design

A retrospective observational study was conducted at the Hyperbaric Oxygen Therapy Centre, Tri-Service General Hospital, Taipei, Taiwan. Data were collected on all CO-poisoned patients admitted to the hospital and were coded with CO poisoning (International Classification of Diseases, Ninth Revision, Clinical Modification Diagnosis Code 986-Toxic Effect of Carbon Monoxide) from September 2009 to August 2014. There were 669 patients in the study and data were also retrieved from the medical records (paper and digital records) and online database of the hospital, including demographic data, clinical data and laboratory data. Patient data that were missing clinical information or laboratory information or did not have defined outcome information were excluded from the study.

Data collection

For patients included in the study, the following variables were collected and analysed: CO source; height; weight; body mass index (BMI); sex; suicide attempt; habits of smoking and drinking; chronic diseases of the patients, including psychosis, diabetes and hypertension; the initial GCS score on arriving at the emergency department (ED); times of HBO treatment for patients since they arrived at the ED; the number of days for which the patients were intubated, stayed in the intensive care unit (ICU) and were hospitalised; whether they used benzodiazepines (BZD) and also the clinical symptoms of poisoning, including metabolic acidosis, rhabdomyolysis and myocardial injury.

The initial laboratory data after they arrived at the ED in the Tri-Service General Hospital were recorded in the study, including the COHb level, arterial blood gas data, white blood cell (WBC) and platelet count, Hb level, creatine kinase (CK), creatine kinase-myocardial band (CKMB), TnI, serum levels of glucose, blood urea nitrogen (BUN), serum creatinine (Cre), aspartate aminotransferase (AST), alanine aminotransferase (ALT) and base excess (BE).

Patient and public involvement

Patients were involved in this study.

Definition

The clinical criteria were defined as follows: when a patient's BE was lower than −2 mmol/L, then the patient was assumed to be in metabolic acidosis; rhabdomyolysis was assumed in those who had CK >5000 units/L; patients who have CKMB >25 units/L and those with TnI of >1.5 ng/mL were described to have myocardial injury.

Patients were separated into two groups (poor outcome and non-poor outcome). Patients in the poor-outcome group were those who either still had sequelae, were bedridden or died after treatment.

Statistical analysis

For the two groups in the study (ie, poor outcome and non-poor outcome), factors that may relate to the outcomes were analysed using the t-test for continuous variables (eg, age, height and concentration of CK) and χ^2 test for categorical variables (eg, sex, psychosis and myocardial injury). A multivariate logistic regression model with adjusting variables was applied to find the factors that are related to the outcome. A p value <0.05 was considered to be statistically significant, and all p values were two-sided. The IBM SPSS Statistics 24 statistical software (IBM, Armonk, New Y, USA) was used for data management and modelling.

RESULT

Characteristics of the study group

In the study, there were three different categories of CO poisoning: deliberate (336 patients), accidental fire-related (31 patients) and accidental non-fire-related (ANFR, 273 patients). The sources of CO poisoning in the ANFR case (29 patients had no data) were categorised into different types. The primary sources of CO poisoning in Taiwan were charcoal burning (43, 15.7%) and gas boilers or water heaters (216, 79.1%). These two sources accounted for 95% of the all CO poisoning cases, whereas car exhaust (1, 0.4%) and other factors (13, 4.8%) accounted for <10% of the data.

Variables related to CO poisoning outcomes

The variables related to the CO poisoning outcome of patients are shown in tables 1–3. Eighteen per cent of all patients (116 patients) were in the poor-outcome group. The mean age of all patients was 37.40±16.79 years, with 46.7% (269 patients) males and 53.3% (338 patients) females. The category 'deliberate' accounted for around half of all patients. The percentages of chronic diseases in the patients were about 30% with psychosis, 6% with diabetes mellitus and 10% with hypertension. The key findings were as follows:

- Patients with poor outcomes were older than those who did not have poor outcomes (p<0.001).

Table 1 Demographic characteristics related to the CO poisoning outcome

Variables	Total n (%)/mean±SD	Non-poor outcome (n=518) n (%)/mean±SE	Poor outcome (n=116) n (%)/mean±SE	P value
Age	37.40±16.79	35.77±0.73	43.14±1.56	<0.001
Height	162.11±14.85	161.53±0.78	164.00±0.86	0.035
Weight	59.63±15.60	59.11±0.77	60.06±1.58	0.608
BMI	22.43±3.99	22.26±0.19	22.70±0.42	0.357
Sex				0.319
Men	296 (46.7)	237 (45.8)	59 (50.9)	
Women	338 (53.3)	281 (54.2)	57 (49.1)	
Deliberate*				<0.001
No	309 (49.8)	276 (54.5)	33 (28.9)	
Yes	311 (50.2)	230 (45.5)	81 (71.1)	
Smoking†				0.161
No	283 (58.6)	230 (60.2)	53 (52.5)	
Yes	200 (41.4)	152 (39.8)	48 (47.5)	
Drinking†				0.115
No	349 (72.6)	282 (74.2)	67 (66.3)	
Yes	132 (27.4)	98 (25.8)	34 (33.7)	
Psychosis‡				<0.001
No	428 (69.8)	365 (73.0)	63 (55.8)	
Yes	185 (30.2)	135 (27.0)	50 (44.2)	
Diabetes mellitus‡				0.002
No	566 (93.9)	467 (95.3)	99 (87.6)	
Yes	37 (6.1)	23 (4.7)	14 (12.4)	
Hypertension‡				<0.001
No	539 (89.4)	451 (92.0)	88 (77.9)	
Yes	64 (10.6)	39 (8.0)	25 (22.1)	

*Patients exposed to CO intentionally or by accident.
†Patients' habits.
‡Patients' chronic diseases.
BMI, body mass index; CO, carbon monoxide.

- Suicidal patients had a higher chance of poor outcomes compared with those who were exposed to CO by accident (p<0.001).
- Patients with rhabdomyolysis, myocardial injury and metabolic acidosis may be apt to have poor outcomes.
- Patients who had chronic diseases may tend to have poor outcomes.
- The patients' weight, BMI, gender and habits (smoking and drinking) had no significant correlation with the outcomes.

The clinical characteristics exhibited more significant results (table 2). The mean score of the GCS was around 11. The average number of HBO treatment sessions was about five for all patients. The percentages after exposure to CO were approximately 40% with metabolic acidosis, 8% with rhabdomyolysis and 21% with myocardial injury. In the poor-outcome group, the patients had a lower initial GCS score than those in the non-poor-outcome group (p<0.001). In the study, there were 646 patients who received HBO therapy, excluding those who did not receive HBO therapy or had missing data. The average number of HBO treatment sessions was around nine in the poor-outcome group and 3.5 in the non-poor-outcome group. The intubation days, the days for which the patient stayed in the ICU and the days of hospitalisation were greater in the poor-outcome group than in the non-poor-outcome group (p<0.001). Moreover, 42% of the patients took BZD in the poor-outcome group compared with 22.3% in the non-poor-outcome group (p<0.001). When patients were exposed to CO and then suffered from metabolic acidosis, rhabdomyolysis or myocardial injury, they had a higher chance of a poor outcome (p<0.001).

Table 2 Clinical characteristics related to CO poisoning outcomes

Variables	Total n (%)/mean±SD	Non-poor outcome (n=518) n (%)/mean±SE	Poor outcome (n=116) n (%)/mean±SE	P value
GCS	10.66±5.01	11.5±0.21	7.45±0.44	<0.001
HBO therapy sessions	4.69±5.29	3.50±0.16	9.39±0.77	<0.001
Intubation days*	2.22±8.64	0.50±0.06	10.08±1.78	<0.001
ICU days	1.93±6.75	0.59±0.06	7.99±1.39	<0.001
Hospitalisation days	6.91±16.92	3.31±0.28	22.84±3.17	<0.001
Metabolic acidosis†				<0.001
No	353 (59.4)	307 (63.4)	46 (41.8)	
Yes	241 (40.6)	177 (36.6)	64 (58.2)	
BZD				<0.001
No	459 (74.2)	393 (77.7)	66 (58.4)	
Yes	160 (25.8)	113 (22.3)	47 (41.6)	
Rhabdomyolysis‡				<0.001
No	550 (91.5)	463 (94.9)	87 (77.0)	
Yes	51 (8.5)	25 (5.1)	26 (23.0)	
Myocardial injury§				<0.001
No	457 (78.8)	399 (84.9)	58 (52.7)	
Yes	123 (21.2)	71 (15.1)	52 (47.3)	

*Intubation days: days for which the patient underwent intubation.
†Metabolic acidosis:base excess <−2 mmol/L.
‡Rhabdomyolysis:creatine kinase > 5000 U/L.
§Myocardial injury:creatine kinase-myocardialband >25 U/L or troponin I >1.5 ng/mL.
BZD, benzodiazepines; CO, carbon monoxide; GCS, Glasgow Coma Scale; HBO, hyperbaric oxygen; ICU, intensive care unit.

Table 3 shows the laboratory data. With the exception of Hb, platelets, the level of pH and plasma bicarbonate concentration (HCO_3^-), all other variables exhibited abnormal values from the reference values. The concentration of WBCs, Hb, platelets, CKMB, the level of pH and the arterial oxygen tension (PO_2) showed no significant difference between the poor-outcome group and the non-poor-outcome group. Patients had a higher concentration of CK in the poor-outcome group than in the non-poor-outcome group (p=0.031 in men, p<0.001 in women). The concentrations of TnI, glucose, BUN, creatinine, AST and ALT were higher in the poor-outcome group than in the non-poor-outcome group. However, the pressure of arterial carbon dioxide tension (PCO_2), HCO_3^-, the concentration of COHb and BE were lower in the poor-outcome group than in the non-poor-outcome group.

Table 4 shows the variables that may predict the outcome of CO-poisoned patients after they underwent the HBO treatments. The variables in the model included psychosis, diabetes mellitus, metabolic acidosis, hypertension, GCS score, CK, TnI, glucose, BUN, Cre and AST. Age and sex were used as adjusting variables in the model. The OR of GCS was 0.932 (95% CI 0.872 to 0.997). When the patients had a higher score of GCS, they had a lower chance of having a poor outcome. The OR of BUN was 1.089 (95% CI 1.031 to 1.150). If the patients had a higher concentration of BUN, they had a higher chance of having a poor outcome. The remaining variables in the model showed no statistically significant relationship with the outcomes.

Intubation days and CO poisoning outcomes

For cases of acute respiratory failure, patients' consciousness and haemodynamic variables were evaluated every hour. Ventilator management and weaning were performed by respiratory therapists according to the protocol of this hospital. Extubation criteria included stable haemodynamic variables, able to protect airway and spontaneously breathing for 30 min with reliable respiratory effort and oxygen saturation. Figures 1 and 2 show the receiver operating characteristic (ROC) curve of intubation days, including all patients (figure 1) and patients who were intubated (figure 2). The area under the ROC curve (AUC) was 0.757 for the intubation days of all patients (615 patients) and 0.817 for intubated patients (188 patients). The cut-off point was 1.5 intubation days in all patients and 2.5 intubation days in intubated patients. Therefore, for all patients, if their intubation days were >1.5 days, they may have a higher chance of having a poor outcome after treatment; for

Table 3 Laboratory data related to CO poisoning outcomes

Variables	Non-poor outcome (n=518) Mean±SE	Poor outcome (n=116) Mean±SE	P value	Reference value
WBC	13.54±0.74	15.06±0.58	0.327	4.0–8.0
Hb				
Men	148.71±1.07	147.49±3.22	0.649	135–176
Women	126.23±1.01	127.70±2.72	0.557	113–152
Platelet*	244.40±2.89	242.44±7.39	0.777	150.0–350.0
CK				
Men	1121.20±212.91	6231.71±2297.13	0.031	57–197
Women	668.36±147.27	2656.16±645.47	<0.001	32–180
CKMB	26.96±2.09	35.09±3.29	0.077	<25
TnI	0.53±0.09	2.90±0.78	0.003	<0.5
Glucose†	128.14±2.44	156.24±6.60	<0.001	70–110
BUN	15.09±0.33	20.07±0.95	<0.001	9–21
Cre	0.89±0.02	1.23±0.07	<0.001	0.2–0.9
AST	39.18±2.84	140.81±26.26	<0.001	6–43
ALT	46.61±14.99	228.25±72.84	0.031	11–33
pH	7.40±0.003	7.40±0.01	0.556	7.40±0.07
PCO_2	37.75±0.37	34.65±0.93	0.002	40±4
PO_2	225.34±7.99	256.37±15.67	0.079	95±7
HCO_3–	22.88±0.18	20.63±0.43	<0.001	24±2
COHb	12.52±0.18	8.22±1.12	0.001	<5
BE	–1.88±0.23	–3.66±0.44	0.001	0±2

*Platelet (10^3/μL).
†Glucose (mg/dL).
ALT, alanine aminotransferase (U/L); AST, aspartate aminotransferase (U/L); BE, base excess (mmol/L); BUN, blood urea nitrogen (mg/dL); CK, creatine kinase (U/L); CKMB, creatine kinase-myocardial band (U/L); CO, carbon monoxide; COHb, COHb concentration (%); Cre, serum creatinine (mg/dL); Hb, haemoglobin (g/dL); HCO_3–, plasma bicarbonate concentration (mmol/L); PCO_2, arterial carbon dioxide tension (mm Hg); pH, potential of hydrogen; PO_2, arterial oxygen tension (mm Hg); TnI, troponin I (mg/dL); WBC, white blood cell (10^3/μL).

intubated patients, if their intubation days were >2.5 days, they may have a higher chance of having a poor outcome.

DISCUSSION

The epidemiology of CO poisoning differs from one country to another because of the weather, geographical and cultural variations. The main sources of CO poisoning in Taiwan are gas boilers or water heaters (accidental) and charcoal burning (intentional). The charcoal burning cases accounted for more than the half of the cases. The results were very different in Western countries. For example, the main sources of CO poisoning were heaters' and vehicles' exhaust in the UK and the USA.[1 4 27 28] Charcoal burning accounted for around 23% of all suicides in Asia, a percentage that is 10 times higher than in Western countries.[10] The mean age of patients in this study was 37.4 years. The age of CO-poisoned patients was around 40 years in Turkey, the USA and Italy.[5 19 26] The reason for the lower age in Taiwan may be the type of suicide prevalent in Taiwan. Recently, charcoal burning has become one of the main methods of suicide and has increased both in urban and in rural areas.[10 11] Most of the suicides are in the group of young adults. An early prognostic factor evaluation is more important for this group of patients, because young adults may impose a heavier burden to their family and to the medical society if they have a worse neurological treatment outcome. Our data revealed that patients exposed to CO intentionally have a significantly worse treatment outcome than those by accident. This further stresses the importance of early diagnosis and management of this group of patients. Clinicians should refer patients who attempted suicide to psychiatrists to minimise the incidence of poor outcome.

The poor-outcome group in the study represented around 18% of the total. This treatment outcome was similar to those in the studies by Kao *et al* in Taiwan.[22] In other countries, Weaver *et al* reported a poor treatment outcome of 25.0% in CO-poisoned patients treated with

Table 4 Factors related to CO poisoning outcomes

	Model		
Variable	OR	95% CI	P value
Psychosis	1.467	0.793 to 2.714	0.222
Diabetes mellitus	1.352	0.412 to 4.444	0.619
Metabolic acidosis	1.435	0.761 to 2.703	0.264
Hypertension	1.285	0.491 to 3.362	0.609
GCS	***0.932***	***0.872 to 0.997***	***0.039***
CK	1.000	1.000 to 1.000	0.685
TnI	1.078	0.975 to 1.191	0.141
Glucose	1.000	0.995 to 1.005	0.989
BUN	***1.089***	***1.031 to 1.150***	***0.002***
Cre	0.850	0.402 to 1.797	0.671
AST	1.003	0.999 to 1.007	0.205

Adjusting variables, age and sex.
AST, aspartate aminotransferase; BUN, blood urea nitrogen ; CK, creatine kinase; CO, carbon monoxide; Cre, serum creatinine; GCS, Glasgow Coma Scale ; TnI, troponin I.

HBO and of 46.1% in those with normobaric oxygen treatment alone.[18] Pepe *et al* also found that 34 patients out of 141 (24%) had delayed neuropsychological sequelae (DNS) after they left the hospital by 1 month.[19] The better treatment outcome in Taiwan might be due to the high medical accessibility for CO poisoning in this country. Patients can reach hospitals with treatment facilities within 2 hours and the hospitals could quickly initiate HBO therapy or transfer to other treatment facilities in another 2 hours. Moreover, the treatment outcome in this study may be underestimated because of the high disease severity in our patients. This hospital is equipped with HBO therapy facilities for critically ill patients using ventilator and provides emergency treatments on an all year basis. Sixty per cent of our patients were transferred from other hospital for HBO therapy and 40% among them were using ventilator on arrival. For patients with such high severity, the treatment outcome could have been worse than it was analysed in this study. Certainly, other factors such as short duration of outcome assessment might also contribute to the lower incidence of poor outcome in this study. DNS usually occur around 20 days after poisoning.[18] We evaluated the outcome based on the medical records that were available when the patients left the hospital or when they made return visits to the hospital 1 week later, so some patients may not have had later sequelae detected.

The GCS, an index of severity of neurological awareness, may be also an indicator of some injuries to other organs. An acute CO poisoning may severely suppress central drive of respiration, causing acute respiratory failure. However, a deeply comatous consciousness could be a consequence of overdose of sedatives, which happens frequently in patients attempting to suicide.

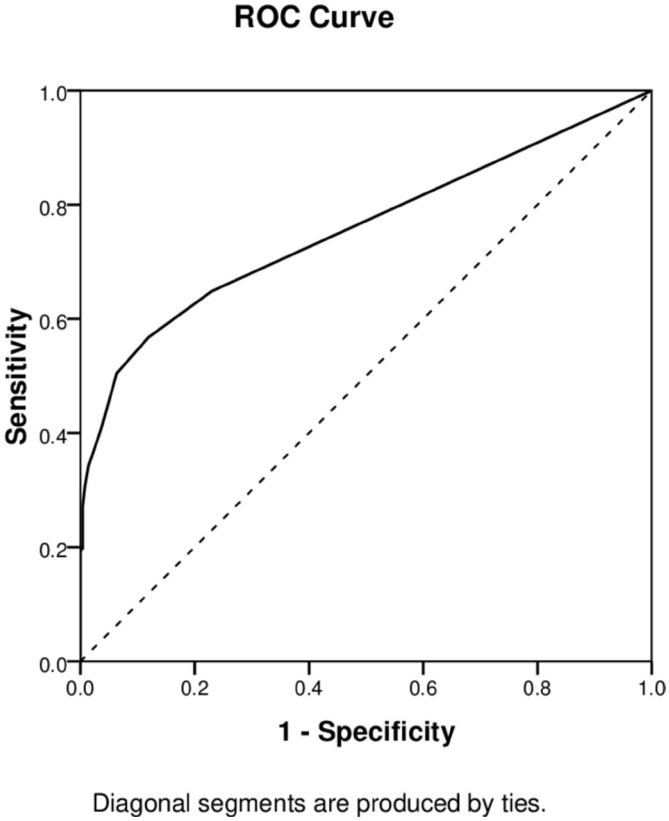

Figure 1 Receiver operating characteristic (ROC) curves for the intubation days of all patients (n=615).

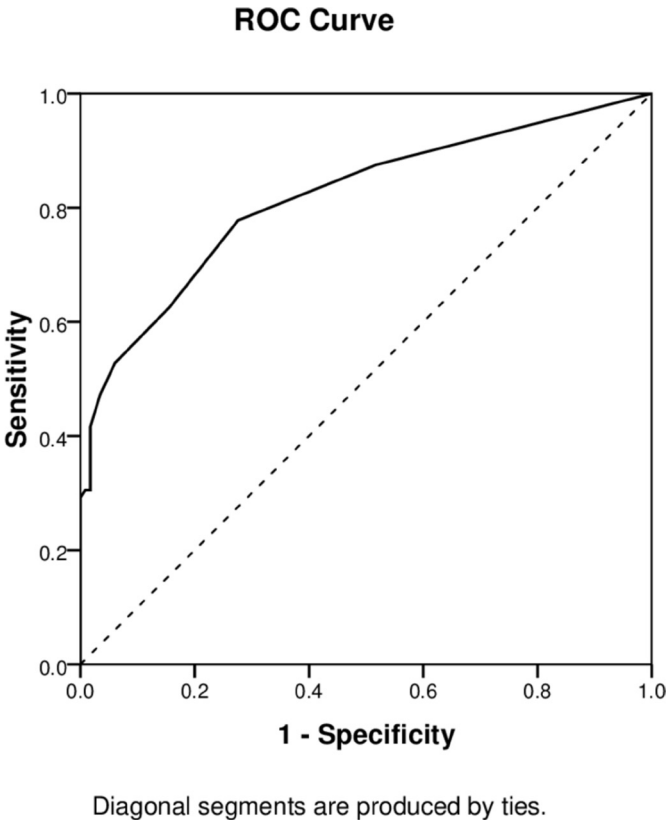

Figure 2 Receiver operating characteristic (ROC) curves for the intubation days of patients with intubation treatment (n=188).

The intubation days of patients, on the other hand, indicate their unconscious time and show the severity of the patients' illnesses.[29] Our previous study also showed that the duration of mechanical ventilation is a predictor of CO poisoning severity.[25] In this study, the intubation days were used as a predictor of the outcome of CO poisoning. The results show that the AUC was around 0.757–0.817 in all patients and in intubated patients. Cha *et al* showed that GCS may be indicative of myocardial injury in CO-poisoned patients.[30] Patients with a myocardial injury are usually more severely affected, so they may be more likely to have poor outcomes.[31 32] In this study, myocardial injury and GCS were closely related to the outcome of CO poisoning. These results are compatible with several other studies,[19 22 23 33 34] suggesting that these two prognostic factors could be used to predict the treatment outcome of CO-poisoned patients. Some studies interpreted their results that people who suffered from a myocardial injury might have been exposed to CO longer than others.[19 30 35 36] However, there has been no report that could clearly identify the exposure duration. Our results showed that elevation of serum BUN in the first blood test is highly associated with poor outcome (table 4). For patients with a normal renal function, serum BUN could be a reliable indicator of body fluid status. Patients with CO poisoning cannot drink any water until the medical intervention, so the concentration of BUN may be related to the time between exposure to CO and presenting at the hospital. Therefore, elevation of BUN might be an indicator to predict the exposure time of CO poisoning and could be a predictor of poor treatment outcome.

In this study, almost all of the patients received HBO treatment. Patients were exposed to 100% oxygen at 3 atmospheres absolute for the first chamber session and then to 100% oxygen at 2.5 atmospheres absolute for the second and third chamber sessions. All chamber sessions consisted of three 25 min oxygen-breathing periods with two 5 min air breaks. Due to the fact that most of our patients were referred from other hospitals, their conditions were more severe and they were more in need of HBO treatment than in other local hospitals. In a recent study, Rose *et al* found that HBO treatment may reduce acute and 1-year mortality.[26] They revealed that older age, being a male, respiratory distress and elevated TnI may relate to 1-year mortality, which could be considered as a poor outcome. Compared with the study by Rose *et al*, our results showed that all the above-mentioned factors, except gender, affect the outcome of CO-poisoned patients. It is interesting to note that in our study the poor outcome is associated with a more HBO therapy sections (table 2). In the regression analysis, the patients who received more HBO therapy sessions may have a higher opportunity to be poor outcome. This raise two concerns about the HBO therapy in CO-poisoned patients. First, could HBO therapy by itself cause poor outcome of CO poisoning? Patients in this study were initially treated with HBO therapy for three sessions. After the patient arrived our ED, the first hyperbaric chamber session was provided as soon as possible; and the third section was ideally to be performed <24 hours after the first chamber section. If it was possible, the interval between each section was around 6–12 hours.[25] If the patients' conditions improved, the HBO therapy would stop; otherwise, they would receive more HBO therapy sections. Therefore, we would not interpret these data as that HBO therapy causes poor outcome of CO poisoning, but that patients need more sessions of HBO therapy had a higher disease severity. Second, is a multiple sections of HBO therapy necessary? The HBO therapy protocol adapted in this hospital was following the Undersea Hyperbaric Medical Society treatment indications of acute tissue injuries, such as crush injury, arterial insufficiency or thermal burn injury. In a nationwide population-based cohort study using Taiwan National Health Insurance Research Database (TNHIRD), Huang *et al* reported that CO-poisoned patients who received HBO therapy had a lower mortality rate[37] but a higher risk for neurological sequelae.[38] It is interesting to note that the patient number in the without HBO therapy group was about 3 times of that in the HBO therapy group. In Taiwan, CO poisoning is a health insurance payable indication for HBO therapy and patients are supposed to receive HBO therapy in the hospital or be transferred to other treatment facilities, unless their disease severity did not fulfil treatment criteria. Therefore, the only explanation for lower risk of the without HBO therapy group is their lower severity of poisoning. Unfortunately, data from TNHIRD provide little information about disease severity of CO poisoning. In a small case series, Lo *et al* reported that 8–40 sections of HBO therapy significantly reduced the neurological and image abnormalities in CO-poisoned patients.[39] Therefore, it remains unclear whether HBO therapy or multisection treatment will produce a better outcome than a conservative management.

Due to the fact that this study was retrospective in nature, there are some limitations. One is the incomplete data (eg, the total time of exposure to CO, the initial COHb of patients, the time from exposure to presenting at the hospital and the duration of loss of consciousness), which may affect the outcomes of CO poisoning. Another limitation is that >60% of the patients in this study were transferred from another hospital. This may result in a lack of the initial data, which were recorded in the previous hospital and ambulance.

CONCLUSION

In summary, in the present study, we tried to find the factors related to the poor prognosis of CO poisoning. The factors best at predicting outcomes were a high GCS score, high BUN and more intubation days. Even HBO therapy is paid by insurance in Taiwan, the benefit of repetitive HBO therapy on the treatment outcome remains to be elucidated. Our results in this retrospective study could give the indications for clinical research work in the future.

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Contributors K-TP, C-HS and K-LH are responsible for the conception and design of the study. K-TP and C-HS collected data. K-TP, F-GL, Y-CC and K-LH analysed and interpreted data. K-TP and K-LH drafted the manuscript. K-TP, C-HS, BC, GL and K-LH discussed and approved the final version of the manuscript.

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