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Original Article

Outcome and prognostic factors of patients treated in the intensive care unit for carbon monoxide poisoning

Wei-Chih Liao [a,b,c,1], Wen-Chien Cheng [a,b,1], Biing-Ru Wu [a,b], Wei-Chun Chen [a,b,d], Chih-Yu Chen [a,b], Chia-Hung Chen [a,d,*], Chih-Yen Tu [a,b,c,**], Te-Chun Hsia [a,b,d]

[a] *Division of Pulmonary and Critical Care Medicine, Department of Internal Medicine, China Medical University Hospital, China Medical University, Taichung, Taiwan*
[b] *Hyperbaric Oxygen Therapy Center, China Medical University Hospital, Taichung, Taiwan*
[c] *School of Medicine, College of Medicine, China Medical University, Taichung, Taiwan*
[d] *Department of Respiratory Therapy, China Medical University, Taichung, Taiwan*

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KEYWORDS
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Background: Carbon monoxide (CO), a colorless and odorless gas, is one of the common causes of poisoning-related deaths worldwide. CO poisoning can result in hypoxic brain damage and death, but intensive care can improve the likely outcome for critically ill patients. However, there is a paucity of clinical data regarding the prognostic factors and association between organ dysfunction and clinical outcome of patients treated for CO poisoning in the intensive care unit (ICU).
Methods: We performed a retrospective study of patients admitted to a university affiliated hospital ICU between July 2001 and December 2010 following CO poisoning. Outcomes were survival to ICU discharge and to hospital discharge.
Results: Seven hundred and eighty-seven patients were admitted to the university hospital following CO poisoning, of which 140 (17.8%) were admitted to the hospital ICU. The overall mortality rate of the patients admitted to the ICU was 14.3% (20/140). Univariate analysis indicated that non-surviving patients with CO poisoning were more likely to have initial blood carboxyhemoglobin (COHb) level $>$ 30%, shock, acute respiratory failure, Acute Physiology and Chronic Health Evaluation II (APACHE II) score $\geq$ 25, Glasgow coma scale (GCS) score of 3, acute renal failure, dysfunction or failure of more than 3 organs, low blood pH, low HCO3- level, high potassium level, and high glucose level. They were also more likely to have not

* Corresponding author. Department of Internal Medicine, China Medical University Hospital, No. 2, Yude Road, Taichung, Taiwan. Fax: +886 4 22038883.
** Corresponding author. Department of Internal Medicine, China Medical University Hospital, No. 2, Yude Road, Taichung, Taiwan. Fax: +886 4 22038883.
E-mail addresses: hsnu758@gmail.com (C.-H. Chen), chesttu@gmail.com (C.-Y. Tu).
[1] Both authors contributed equally to this article.

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received hyperbaric oxygen (HBO) intervention. Multivariate logistical regression analysis indicated that the mortality rate of patients treated in the ICU for CO poisoning was higher if their initial APACHE II score was ≥25, GCS was 3, and more than 3 organs were dysfunctional. Moreover, HBO intervention in ICU significantly decreased patients' risk of mortality due to CO poisoning.

Conclusion: In conclusion, we observed that APACHE II score >25, GCS 3, and dysfunction of more than 3 organ systems on admission to emergency department was associated with a significant mortality risk in patients treated in the ICU for CO poisoning. Moreover, HBO therapy could reduce the risk of mortality in patients with CO poisoning in ICU.

Introduction

Carbon monoxide (CO) poisoning is the most common type of fatal air poisoning, and severe intoxication may cause seizure, coma, and fatality.[1] CO poisoning can be accidental or intentional (suicide attempt).[2,3] Acute CO intoxication is an important clinical entity of great significance to public health and remains a leading cause of morbidity and mortality.[4] Carbon monoxide toxicity results from a combination of tissue hypoxia and direct carbon monoxide-mediated damage at the cellular level. There are studies focusing on CO poisoning-related cognitive sequelae[5,6] and the effectiveness of hyperbaric oxygen (HBO) therapy for patients with CO poisoning.[5,7,8] HBO therapy is the treatment of patients with 100% oxygen at a pressure higher than atmospheric pressure. Numerous pathophysiological mechanisms have been proposed for CO-related brain injuries, including hypoxia,[9] vascular endothelium damage,[10] inflammation,[11] and apoptosis or programmed cell death.[12,13] Validated and established severity of poisoning or outcomes affect management and disposition decisions. However, there is a paucity of data regarding predictability of outcome in patients admitted in intensive care unit (ICU) to treat CO poisoning.

To better understand the outcome of patients in ICU admitted due to CO poisoning, we retrospectively analyzed prognostic factors in a cohort of patients admitted to our ICU due to CO poisoning over the past 9.5 years, particularly with respect to the outcome predictors in these patients.

Patients and methods

Enrolled patients

Over a period of 9.5 years (from July 2001 to December 2010), all patients who had received a diagnosis of CO poisoning and were admitted to the 44-bed medical ICU of China Medical University Hospital (CMUH), a regional referral center providing HBO therapy for CO poisoning, were potentially eligible for inclusion in this investigation. A diagnosis of CO poisoning was made if there was evidence of a CO poisoning source, symptoms consistent with CO poisoning, and/or an elevation in the level of blood carboxyhemoglobin (COHb). Criteria used for recommending HBO therapy to a patient with CO poisoning typically included elevation of COHb level to more than 25% with transient or prolonged unconsciousness, abnormal neurologic findings on physical examination, or cardiovascular damage. The protocol of HBO therapy was initial treatment with 3.0 atmospheres absolute (ATA) with 100% oxygen for 90 minutes[14] For the next three days, the treatment was provided with 2.5 ATA with 100% oxygen in a multiplace hyperbaric chamber. The contraindications of HBO therapy for patients with CO poisoning included unstable hemodynamic status, uncooperative even under sedation, and refusal of patient or family to HBO therapy. HBO therapy also has some risks like worsening the neuropsychological sequelae. National Health Insurance of Taiwan covered the fees of providing HBO therapy for patients with CO poisoning. Patients were excluded from the study if their age was less than 18 years old or their chart was incomplete.

Data collection

The protocol was approved by the institutional review board of the China Medical University Hospital and it waived the requirement for obtaining informed consent from patients. The following data were analyzed for each patient: age, gender, Acute Physiology and Chronic Health Evaluation (APACHE) II scores, arterial blood gas, complete blood count, COHb level, Glasgow Coma Scale (GCS), HBO therapy, and patient clinical outcomes. Outcomes were described as full recovery or in-hospital mortality.

Definitions

To evaluate specific organ function, relevant medical data was recorded for each patient upon admission to the ICU for the following categories: respiratory failure and the consequent need for mechanical ventilation; shock/hypotension (systolic blood pressure ≤ 90 mm Hg or mean arterial pressure ≤ 65 mm Hg for 1 h), despite fluid bolus; acute renal failure—low urine output, (e.g., <0.5 mL/kg/hour), increased creatinine (Cr) ≥50% increase from baseline or need for acute dialysis; metabolic acidosis—low pH and bicarbonate levels (e.g., pH < 7.30 and plasma bicarbonate < 24 mmol/l); central nervous system

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failure—altered consciousness and GCS score (recorded prior to sedation) ≤ 8; multiple organ dysfunction syndrome (MODS)—occurrence of three or more simultaneous organ system dysfunction.

Statistical analysis

The data was compiled and analyzed by using commercial statistical software (SPSS for Windows, version 15.0, Chicago, IL, USA). Differences in continuous variables were compared using a two-tailed Student's *t* test or Mann—Whitney U between two independent groups and one-way analysis of variance (ANOVA) or Kruskal—Willis test between three independent groups; all continuous variables are reported as mean $\pm$ standard deviation. Categorical variables are reported as patient number and percentages. Differences in categorical variables were examined using Chi-square test or Fisher's exact test. The cut-off values of all clinical predictors of overall survival were performed by determining the receiver operating characteristic curve (ROC) and the values were defined by Youden Index (the maximum value of sensitivity + specificity-1). The results of the cut-off values were shown in tables supplement. Therefore, univariate and multivariate logistic regression were used to identify the independent prognostic factors for overall survival. A forward stepwise multivariate logistic regression model was applied when variables were found to be significantly associated ($p < 0.05$) with survival in the univariate analysis. All tests of significance were two sided; $p \leq 0.05$ was considered statistically significant. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated.

Results

Patient clinical characteristics

From July 2001 to December 2010, 834 patients with CO poisoning visited our emergency department (ED). Of these, 43 patients were excluded as they did not meet the age requirement (they were younger than 18 years old) and 4 patients were excluded due to incomplete chart. The remaining 787 patients were initially included in the study. Of these patients, 140 patients were admitted to ICU and 632 patients were admitted to ordinary ward. Moreover, 15 patients died because of out-of-hospital cardiac arrest without successful resuscitation in ED. Of the 140 ICU patients, 20 succumbed to the poisoning (14.29%).

The clinical features of the patients in ordinary ward and in ICU are summarized in Table 1. One hundred and forty patients (18%) were admitted to the ICU. COHb, pH, partial pressure of carbon dioxide in arterial blood ($PaCO_2$), bicarbonate (HCO_3) of arterial blood gas, serum glucose, serum creatinine (Cr), blood urea nitrogen (BUN), serum troponin I level, serum lactate and CO exposure time, GCS scores and APACHE II scores were identified as significant risks related to CO poisoning patients who required ICU care. The patients who needed ICU care also had a higher

Table 1 Clinical characteristics of patients with CO positioning, stratified by out of hospital cardiac arrest versus ordinary ward and ICU.

	All patients N = 787	Subgroup			p value
		OHCA N = 15	Ward N = 632	ICU N = 140	
Age (years)	36.5 ± 12.5	36.4 ± 12.2	36.2 ± 12.5	37.6 ± 12.4	0.235
Male/Female	386/401	8/7	305/327	73/67	0.456
Body weight (Kg)	62.0 ± 12.1	63.1 ± 17.9	61.8 ± 11.7	62.9 ± 13.3	0.450
Length of hospital (days)	5.3 ± 11.7	0	3.5 ± 6.8	13.9 ± 21.8	<0.001
Mortality	35, 4.4%	15, 100%	0, 0%	20, 14.3%	<0.001
Exposure CO time (hrs)	3.7 ± 5.5	16.2 ± 4.2	2.8 ± 2.8	5.7 ± 8.9	0.015
CO intoxication due to suicide	586, 74.5%	15, 100%	454, 71.8%	117, 83.6%	0.04
COHb (%)	20.4 ± 17.7	72.2 ± 16.9	17.6 ± 14.2	27.7 ± 21.6	<0.001
pH	7.38 ± 0.14	6.63 ± 0.23	7.40 ± 0.06	7.32 ± 0.17	<0.001
PCO_2	35.0 ± 13.8	108.9 ± 48.2	34.2 ± 6.5	31.7 ± 11.8	0.001
HCO_3	20.5 ± 4.8	10.2 ± 2.9	21.5 ± 3.9	16.5 ± 5.3	<0.001
GCS scores	11.4 ± 4.3	3.0 ± 0.0	12.7 ± 3.3	6.5 ± 4.1	<0.001
CPK	2264.6 ± 10007.0	595.3 ± 421.6	1151.0 ± 4794.3	7047.7 ± 20137.8	0.001
WBC	12288.9 ± 6740.9	13361.3 ± 6356.5	11323.0 ± 6365.8	16528.7 ± 6783.1	<0.001
Hb	14.4 ± 2.2	16.7 ± 3.0	14.3 ± 2.1	14.8 ± 2.6	0.033
Platelet	258625 ± 106448	181250 ± 82378	255822 ± 78523	275544 ± 184798	0.038
Glucose	135.6 ± 63.5	148.1 ± 90.0	125.6 ± 47.3	179.0 ± 97.8	<0.001
BUN	14.1 ± 11.2	14.2 ± 5.3	13.0 ± 9.2	19.0 ± 16.8	<0.001
Creatinine	1.0 ± 0.7	2.02 ± 1.09	0.91 ± 0.49	1.50 ± 0.94	<0.001
Sodium	139.4 ± 4.7	142.0 ± 12.4	139.2 ± 4.7	140.0 ± 3.9	0.114
Potassium	3.8 ± 1.8	14.5 ± 11.9	3.6 ± 0.5	3.8 ± 0.9	0.679
Troponin I	0.8 ± 2.8	0.8 ± 0.7	0.3 ± 1.0	2.5 ± 5.5	<0.001
Lactate	45.1 ± 44.4	122.2 ± 24.0	32.4 ± 24.6	69.5 ± 61.6	<0.001

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risk of mortality (14.3%, vs 0%, $p < 0.001$) and more length of hospital stay as compared with patients in ordinary ward (3.5 ± 6.8, vs 13.9 ± 21.8, $p < 0.001$).

The demographic characteristic of 140 patients (17.8%) admitted to the ICU due to CO intoxication were as follows: the male/female ratio was 1.09, 92 patients (66%) were $\leq$40 years of age [mean age was 37.6 ± 12.4 years (range, 18–84 years)], 61 patients (44%) had chronic underlying diseases and/or had received chronic drug treatment. The remaining 79 (56%) patients were comparatively healthy before admission, and were hence, admitted to ordinary ward. They suffered from associated comorbidities enumerated here in order of decreasing frequencies: psychological disease (n = 48), diabetes mellitus (n = 6), hyperthyroidism (n = 4), congestive heart failure (n = 2), malignancy (n = 2), and alcoholism (n = 1). Majority of CO poisoning cases were intentional suicide attempts (n = 117, 84%), and 98 patients (70%) were treated by HBO therapy. One hundred and twenty-two patients (91.4%) developed at least one organ system dysfunction at hospital admission. The most common systems involved were central nervous and respiratory (101 occurrences and 98 occurrences, respectively). None of the 18 patients who had suffered one or less organ system involvement died. However, the mortality rate gradually increased from 2% (1/51) for two organ systems dysfunction to 17% (6/36) for three organ systems dysfunction and to 72% (13/18) when more than four organ systems dysfunction were present. The mean APACHE II score was 13.8 ± 8.2 in all patients admitted in ICU. Of these 140 patients with CO poisoning admitted in ICU, the overall hospital mortality rate was 14.3% (20/140). Baseline characteristics of the patients who did not survive (n = 20) and those who survived the poisoning (n = 120) are reported in Table 2. Statistical analyses of data to compare the baseline characteristics such as age, body height, body weight, WBC count, Hemoglobin (Hb) level, platelet count, BUN, sodium level, and troponin I did not show any significant difference. However, patients who succumbed to poisoning had higher COHb, PaCO2, Cr, potassium, glucose, lactate level and APACHE II score and lower blood pH level, HCO_3, and GCS score as compared to those who survived.

Prognostic factors

To identify the prognostic factors for mortality in CO poisoning patients admitted to the ICU, the cut-off values of all clinical predictors were performed by determining the receiver operating characteristic curve (ROC) and the values were defined by Youden Index (the maximum value of sensitivity + specificity-1). Univariate and multivariate analyses were conducted using data from the initial admission of these patients. Table 3 summarizes the variables with significant influence ($p < 0.05$) on mortality, as determined by preliminary univariate analysis. Patients with COHb $\geq$30% ($p = 0.026$), concurrent shock in the ICU ($P < 0.001$), acute respiratory failure ($p = 0.004$), APACHE II scores ≥ 25 ($p < 0.001$), GCS sore = 3 ($p < 0.001$), acute renal failure ($p = 0.024$), blood pH level < 7.35 ($p = 0.001$), more than 3 organ systems dysfunction ($p < 0.001$) and with no HBO therapy ($p < 0.001$), lower

Table 2 Clinical characteristics of patients with CO positioning admitted to the intensive care unit stratified by survival versus non-survival.

	All patients N = 140	Subgroup		p value
		Survive N = 120	Non-survive N = 20	
Age (years)	37.6 ± 12.4	37.7 ± 12.3	37.4 ± 13.1	0.929
Male/Female	73/67	65/55	8/12	0.334
Body weight (Kg)	62.8 ± 13.4	63.2 ± 13.0	60.9 ± 15.4	0.548
Length of hospital (days)	13.9 ± 21.8	14.7 ± 22.7	8.8 ± 14.5	0.258
Exposure CO time (hrs)	5.7 ± 8.9	6.0 ± 9.3	3.8 ± 6.2	0.464
COHb (%)	27.7 ± 21.6	25.9 ± 19.7	38.1 ± 29.1	0.019
pH	7.32 ± 0.17	7.35 ± 0.14	7.12 ± 0.22	<0.001
PCO_2	31.7 ± 11.9	30.6 ± 9.2	37.8 ± 21.3	0.012
HCO_3	20.5 ± 4.8	17.2 ± 5.1	11.7 ± 4.4	<0.001
GCS scores	6.6 ± 4.0	7.1 ± 4.1	3.9 ± 2.2	<0.001
APACHE scores	13.8 ± 8.2	12.0 ± 6.8	23.6 ± 8.6	<0.001
CPK	7047.7 ± 20137.8	6310.3 ± 17161.6	11239.5 ± 32651.7	0.528
WBC	16528.7 ± 6783.1	16375.0.6 ± 6749.0	17443.0 ± 7090.3	0.517
Hb	14.8 ± 2.6	14.9 ± 2.5	14.2 ± 3.0	0.266
Platelet	275543 ± 184798	280442 ± 196334	246400 ± 87167	0.448
Glucose	179.0 ± 97.8	160.3 ± 59.1	295.1 ± 181.7	0.005
BUN	19.0 ± 16.9	18.6 ± 11.8	21.5 ± 34.6	0.720
Creatinine	1.5 ± 0.9	1.42 ± 0.70	1.98 ± 1.77	0.013
Sodium	140.0 ± 3.9	139.6 ± 3.1	142.4 ± 6.8	0.079
Potassium	3.8 ± 0.9	3.7 ± 0.8	4.5 ± 1.3	0.016
Troponin I	2.3 ± 5.4	2.26 ± 5.01	2.80 ± 7.40	0.710
Lactate	69.5 ± 61.6	59.9 ± 44.0	109.2 ± 89.7	0.006

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Table 3 Variable that possible influence the mortality of patients with CO positioning admitted to the intensive care unit: univariate analysis.

Variable	n	Died (n [%])	p value
Sex			
Male	73	8 (11.0)	0.334
Female	67	12 (17.9)	
Suicide attempt			
Yes	117	14 (12.0)	0.101
No	23	6 (26.1)	
HBO therapy			
Yes	98	6 (6.1)	<0.001
No	42	9 (33.3)	
Initial COHb level ≥ 30%			
Yes	61	12 (19.7)	0.026
No	79	7 (8.9)	
Shock			
Yes	32	17 (53.1)	<0.001
No	108	3 (2.8)	
Intubation			
Yes	103	19 (18.4)	0.004
No	37	0 (0)	
APACHE II score			
≥ 25	17	12 (70.6)	<0.001
< 25	123	8 (6.5)	
Glasgow Coma Scale			
> 3	84	3 (3.6)	<0.001
= 3	56	17 (30.4)	
Acute renal failure			
Yes	23	7 (30.4)	0.024
No	117	13 (11.1)	
Blood gas PH level			
≥ 7.35	70	3 (4.3)	0.001
< 7.35	69	17 (24.6)	
Rhabdomyolysis			
Yes	44	5 (11.4)	0.609
No	96	15 (15.6)	
More than 3 organs failure			
Yes	54	19 (35.2)	<0.001
No	86	1 (1.2)	
PCO2			
≥ 35	34	6 (17.6)	0.964
<35	104	18 (17.3)	
$HCO3^-$			
≥ 17	72	2 (2.8)	<0.001
< 17	66	22 (33.3)	
Potassium			
≥4.5	20	12 (60%)	0.001
<4.5	120	12 (10%)	
Glucose			
≥250	20	10 (50%)	0.010
<250	120	14 (11.7%)	
Cr			
≥1.5	48	12 (29.2%)	0.092
<1.5	92	10 (10.9%)	

$HCO3^-$ level ($p < 0.001$), higher potassium level ($p = 0.001$), and higher glucose level ($p = 0.010$) were at statistically significant higher risk of mortality.

Table 4 Variable that significantly influence the mortality of patients with CO positioning admitted to the intensive care unit: multivariate analysis.

Variable	Death: OR (95% CI)	p value
Shock		
Yes	0.85 (0.14–5.20)	0.862
No	1	
APACHE II score		
≥ 25	11.39 (1.29–100.39)	0.028
< 25	1	
Glasgow coma scale		
= 3	40.8 (8.02–207.66)	<0.001
>3	1	
HBO therapy		
Yes	0.13 (0.022–0.733)	0.021
No	1	
Initial COHb level ≥ 30%		
Yes	1.12 (0.18–6.99)	0.906
No	1	
Acute renal failure		
Yes	1.02 (0.23–4.56)	0.978
No	1	
Intubation		
Yes	0.46 (0.73–2.84)	0.399
No	1	
Blood gas PH level		
≥ 7.35	1.14 (0.18–7.38)	0.888
< 7.35	1	
Organ failure		
≥ 3	19.38 (1.08–346.30)	0.044
< 3	1	
$HCO3^-$		
< 17	1.95 (−0.804.74)	0.140
≥ 17	1	
Potassium		
≥4.5	1.25 (0.26–6.33)	0.78
<4.5	1	
Glucose		
≥250	2.30 (0.52–10.31)	0.275
<250	1	

Multivariate logistic regression analysis was performed with all the significant variables identified in univariate analysis. The data indicated that those CO poisoning patients with initial APACHE II score ≥25 [relative risk (RR) 11.39; 95% CI 1.29–100.39], GCS of 3 [relative risk (RR) 40.8; 95% CI 8.02–207.66], and more than 3 organ systems dysfunctions [relative risk (RR) 19.38; 95% CI 1.08–346.30] significantly increased the likelihood of mortality, whereas receiving HBO therapy on admission significantly decreased the likelihood of mortality [relative risk (RR) 0.13, 95% CI 0.022–0.733] (Table 4).

Discussion

In this study, the characteristics and outcomes of patients with CO poisoning admitted to ICU were evaluated. The most common cause of ICU admission was central nervous

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system failure. There were significant differences in the baseline characteristics of patients who survived and those who succumbed to the poisoning. Compared with survivors, non-survivors had higher COHb and $PaCO_2$ level, higher APACHE II score, lower GCS score, arterial pH and HCO_3, accompanied by more than 3 organ systems dysfunctions and no HBO intervention on admission. In conjunction with clinical judgment and taking into consideration the patient's preferences and values, the knowledge of these outcome predictors may be useful in helping physicians to identify patients who might benefit from the intensive care and to improve discussions and counseling on patients' prognosis, especially for patients with initial APACHE II scores $\geq$25, GCS 3, and dysfunction of more than 3 organ systems at ICU admission.

Recent study has stated that severe metabolic acidosis and need for endotracheal intubation were strongly associated with mortality.[15] Another early study also reported that severe metabolic acidosis at presentation was a better predictor of future treatment requirements.[16] A previous study has also shown that neurological abnormalities at admission are important predictors of prognosis in severe CO poisoning.[17] From our results, it was clear that metabolic acidosis and GCS of 3 significantly increased the risk of mortality for patient with CO poisoning in ICU. Moreover, APACHE II score was also an important predictor of mortality for these ICU patients. APACHE II score has been used to evaluate the severity score and mortality estimation of patients admitted to ICU with variable diseases.,[18,19] but to the best of our knowledge, there was no paper presented that evaluated the role of APACHE II score in the outcome of ICU patients with CO poisoning. In our results, APACHE II score over 25 was an independent predictor of mortality in ICU patients with CO poisoning. This result reflects that severe CO poisoning is a disease with multisystem involvement leading to multiple organ damage, and systemic evaluation of the disease severity is better than just depending on a single parameter for the initial evaluation of estimating the need for ICU admission at ED.

Although HBO therapy has been recommended for serious poisonings with high COHb levels and loss of consciousness,[20–22] there is still no widespread agreement regarding the criteria for selection of patients for HBO therapy in the settings of CO poisoning.[23] In our study, 98 patients with CO poisoning in ICU received HBO intervention, and 42 patients with CO poisoning in ICU received no HBO intervention. The severity between both groups was not different (APACHE II score: 13.90 $\pm$ 7.8 verse 13.48 $\pm$ 9.1, P = 0.821). Unvariate and multivariate analyses under similar severity indicated that HBO intervention was an independent protective factor to reduce the mortality of patients with CO poisoning in ICU, and the relative risk of CO poisoning with HBO intervention in ICU was 0.13 times the risk of CO poisoning without HBO intervention. Comparing with previous studies, our result indicated that HBO intervention would be helpful to reduce mortality of CO poisoning, especially in severe cases admitted to ICU.

Organ dysfunction is a continuum process, with incremental degrees of derangements from normal organ function to severe organ failure, and is a predictor of mortality in ICU patients with CO poisoning. Some investigators have shown that organ dysfunction is a predictor of mortality in acute brain injury patients in ICU.[24,25] We investigated whether the number of organ dysfunction will alter the outcome in ICU patients with CO poisoning. At admission, 91.4% (122/140) patients had at least one organ system dysfunction. Patients succumbed to poisoning with 2 organ systems dysfunction and the hospital survival rates declined steadily as the number of organs involved increased. Our results lend support to the hypothesis that patients with multiple organ dysfunction syndrome (MODS) at admission are significantly associated with increased hospital mortality.

During the 9.5-year study period, 117 patients who attempted suicide by CO poisoning and 23 unintentional cases of CO poisoning were admitted to ICU. Of these intentional CO poisoning patients, age-specific occurrence rate was highest in persons aged 30–39 years (n = 42). The death rate among these intentional CO poisoning patients was 12.0%. On the other hand, the age-specific occurrence rate in the 23 unintentional CO poisoning patients was highest in persons aged 40–49 years (n = 7). Moreover, the death rate among these unintentional CO poisoning patients was 26.1%. According to a previous study,[26] the rate of unintentional death from CO poisoning is decreasing in the United States because of infrastructure changes and improvement in heating and cooking appliances. However, in our study, the outcome of intentional CO poisoning patients was better than unintentional CO poisoning patients. It may be possible because of difference in exposure to carbon monoxide. In the intentional CO poisoning patients, the burning of charcoal in an enclosed space takes a longer time for the carbon monoxide build up to the toxic levels. However, most of our unintentional CO poisoning cases were (87%, 20/23) caused by a house fire which exposed these patients to high, toxic CO levels in a shorter time. Therefore, the mean COHb levels at admission among our unintentional CO poisoning patients was 28.8%, which was higher than intentional COP patients (27.4%).

The average ICU mortality from July 2001 to December 2010 in our hospital was around 22.1%, which is higher than the mortality rate in CO poisoning patients admitted to the ICU (14.3%). The other ICU patients might have different clinical characteristics and associated comorbidities as compared with CO poisoning patients. The data showed that CO poisoning patients requiring ICU admission have better prognosis as compared to other critical ill patients admitted to the ICU.

The present study had several limitations. First, all the patients were recruited from a single hospital; the prevalence of etiologies may differ among patients in other geographic locations. Second, this was a retrospective study involving a relatively small number of the patients admitted to ICU due to CO poisoning. The patients studied may not be representative of the clinical features of the CO poisoning population elsewhere. A large prospective, randomized trial is needed to confirm our results with respect to CO poisoning patients admitted to ICU.

Conclusion

Although the mortality rate in critical ill patients with CO poisoning is low, we posit that initial APACHE II scores >25,

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GCS 3, and dysfunction of more than 3 organ systems are significant prognostic factors in CO poisoning patients admitted to the ICU. Moreover, HBO intervention was protective and could reduce mortality in patients with CO poisoning admitted to the ICU.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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Appendix A. Supplementary data

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