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Experience of carbon monoxide poisoning and the outcome predicting score: A multicenter retrospective study

Ying Jen Chi [a], Hsiu-Yung Pan [a,b], Fu-Jen Cheng [a], Ye-In Chang [c], Po-Chun Chuang [a,*]

[a] Department of Emergency Medicine, Kaohsiung Chang Gung Memorial Hospital, Chang Gung University College of Medicine, Kaohsiung, Taiwan
[b] Chang Gung University College of Medicine, Guishan District, Taoyuan City, Taiwan
[c] Department of Computer Science and Engineering, National Sun Yat-sen University, Kaohsiung, Taiwan

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ABSTRACT

Background: Carbon monoxide poisoning (COP), resulting from accidental and intentional exposure, is a leading cause of fatal poisoning worldwide. Except for early death, neurological sequelae are common and impose a large burden on patients, caregivers, and the society.
Materials and methods: This retrospective study included patients who visited the emergency departments (EDs) of the medical institutes of Chang Gung Memorial Hospital after COP with a carboxyhemoglobin level > 10% between January 2009 and October 2018. Patients who experienced out-of-hospital cardiac arrest (OHCA) were excluded. Poor outcome was defined as mortality or a Glasgow coma scale (GCS) <13 at discharge. Stepwise regression analysis was performed, and a receiver operating characteristic (ROC) curve was applied to analyze our newly created scoring system for prognosis prediction.
Results: This study enrolled 1171 patients. Fire scene (F) (aOR, 20.635; 95% CI, 8.345–51.023), intentional CO exposure (I) (aOR, 2.634; 95% CI, 1.335–5.196), respiratory failure (R) (aOR, 9.944; 95% CI, 5.533–17.873), every point of reduced GCS (E) (aOR, 1.253; 95% CI, 1.186–1.323), and diabetes mellitus (D) (aOR, 2.749; 95% CI, 1.201–6.292) were identified as predictors of poor outcomes. The FIRED score was created.
Conclusion: The FIRED score could predict the outcomes of non-OHCA patients with a carboxyhemoglobin level > 10% after COP using five factors that can be obtained by history taking and basic examination. An FIRED score ≥ 10 was associated with a poor outcome (sensitivity, 89.6%; specificity, 82.4%; AUC0.930).

1. Introduction

Carbon monoxide (CO) is an odorless, colorless gas that can cause poisoning by accident or intentional exposure. CO is generally produced by the incomplete combustion of carbon compounds. Common sources of CO include fires, poorly functioning heating systems, inappropriately vented fuel-burning devices, and motor vehicles operating in poorly ventilated areas [1]. CO poisoning (COP) accounts for more than half of the fatal poisoning worldwide [2]. In the United States, the number of CO intoxication cases is estimated to be 50,000 each year, and COP accounts for 1000–2000 accidental deaths. The incidence of intentional COP in Taiwan increased from 0.22/100,000 in 1999 to 5.4/100,000 in 2009 [1,3,4]. CO toxicity primarily arises from its high affinity for hemoglobin, which competes for oxygen binding and causes tissue hypoxia [5]. However, other cellular toxicity mechanisms, such as free radical generation [6], mitochondrial inhibition [7], and platelet and inflammatory effects, are thought to be associated with CO-mediated cardiac and neurological injury [1,8,9].

The diagnosis of CO intoxication is made by the triad of (1) symptoms consistent with CO intoxication, (2) history of recent CO exposure, and (3) elevated carboxyhemoglobin (COHb) levels [10]. The clinical manifestations of CO intoxication include headache, dizziness, nausea, chest pain, loss of consciousness, dyspnea, shock, and early death [5]. In addition to acute symptoms, delayed neuropsychiatric syndrome (DNS) can develop 3–240 days after exposure, with an occurrence rate of approximately 10–30% in victims of poisoning [5,11,12]. Symptoms

Abbreviation: aOR, adjusted odds ratio; AUC, area under the curve; BUN, blood urea nitrogen; CDR, clinical dementia rating; CGMH, Chang Gung Memorial Hospital; CI, confidence interval; CO, carbon monoxide; COHb, carboxyhemoglobin; COP, carbon monoxide poisoning; DM, diabetes mellitus; DNS, delayed neuropsychiatric syndrome; ED, emergency department; GCS, Glasgow coma scale; HBOT, hyperbaric oxygen therapy; MMSE, Mini-mental State Examination; NPV, negative predictive value; OHCA, out-of-hospital cardiac arrest; OPD, outpatient department; PPV, positive predictive value; PSS, poison severity score; ROC, receiver operating characteristic; SOFA, sequential organ failure assessment.

* Correspondng author at: Department of Emergency Medicine, Kaohsiung Chang Gung Memorial Hospital, No. 123, Dapi Rd., Niaosong Dist., Kaohsiung 833, Taiwan.
E-mail address: zhungboqun@gmail.com (P.-C. Chuang).

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of DNS include cognitive impairment, akinetic mutism, incontinence, gait ataxia, and extrapyramidal syndromes such as chorea, dystonia, and Parkinsonism [11,13]. An objective evaluation of DNS symptoms is lacking. Some have employed the Mini-mental State Examination (MMSE) to evaluate cognitive function [14,15]. The mechanism of DNS is still unclear; however, it is thought to be associated with brain injury caused by hypoxia, oxidation, antioxidant depletion, and lipid peroxidation [16-18]. The therapy for CO intoxication is 100% normobaric or hyperbaric oxygen [1]. Approximately 100% normobaric oxygen can reduce the half-life of CO from 320 min to 74 min in room air [19]. Comparatively, hyperbaric oxygen therapy (HBOT) can reduce the half-life of COHb to 20 min [20]. Moreover, HBOT is thought to have cellular effects such as anti-inflammation, decreased neutrophil adhesion, reduced reperfusion injury, and alternating oxidative balance [15,21,22]. Although theoretically beneficial, the efficacy of HBOT remains conflicting in the real world [22].

Risk factors related to early death after CO intoxication, such as the need for intubation during HBOT, severe metabolic acidosis, the initial loss of consciousness, fire as a source of CO, and high COHb levels, have been reported [23]. DNS development was reported to be associated with a Glasgow coma scale (GCS) score of <9 and a longer duration elapsed between CO exposure and HBOT [22]. To better understand the prognosis of CO intoxication in modern society and to evaluate the clinical efficacy of HBOT in DNS prevention, we conducted a retrospective multicenter study to identify factors associated with poor outcomes and impaired cognitive function and develop an outcome prediction scoring system to detect those at risk early.

2. Method

This retrospective study was approved by the Foundation Institutional Review Board (approval number: 202100900B0).

2.1. Study setting

We searched the electronic medical records of the Chang Gung Memorial Hospital (CGMH) system for the key laboratory examination of 'COHb.' Four medical institutions (the Keelung, Linkou, Chiayi, and Kaohsiung branches) located in northern and southern Taiwan were included in this study. A total of 1171 patients were enrolled in this study after their medical records were carefully reviewed by the first author.

2.2. Patients

All patients who visited the emergency department (ED) between January 2009 and October 2018 following CO exposure with COHb levels of >10% were enrolled in the study.

2.3. Measurements

The time from CO exposure to the ED visit was also measured. We used the time documented in the medical records if it was described clearly. We defined "for hours" and "just now" as 6 h; "yesterday" and "last night" as 12 h if the patient was brought to the ED before noon, as 24 h after then, "for 1 day" as 24 h, "for days" as 72 h if the time was not described in the medical records. The time from the ED visit to HBOT was defined as the period from ED visit to the time when the patients were sent for HBOT in the nursing records. The HBOT protocol for CO intoxication in the branch of the Chang Gang Memorial System was as follows: 1) treatment at 2.5 atm for 90 min with a 25/5 min air break, 2) frequency of treatment: once daily, 3) the total number of sessions ≥3, and 4) oxygen supply: face mask (an intubated patient was unable to receive the treatment). The mechanisms of CO intoxication were classified as fuel burning, fire scenes, defective heaters, and others (including diving and unknown reasons). Impending death discharge was regarded as mortality [24-26]. Poor outcomes were defined as a GCS score of <13 during discharge or mortality (including in-hospital mortality and impending death discharge). A subgroup analysis was performed on patients who underwent cognitive tests in the outpatient department (OPD). DNS was diagnosed using an MMSE score of <24 after COP. The following demographic data were extracted from the CGMH electronic medical records: age, sex, mechanism of intoxication, vital signs, underlying disease, laboratory examinations, MMSE scores, clinical dementia rating (CDR), and duration of hospital stay.

2.4. Data analysis

Continuous variables, such as age, vital signs, laboratory examination results, GCS scores, and length of hospital stay, are presented as medians and first quartile to third quartile (Q1–Q3). Categorical data are presented as numbers and percentages. The Mann–Whitney *U* test was used to analyze continuous variables. The chi-square test and Fisher's exact test were used to analyze categorical data. Stepwise regression was used to analyze the associations between variables and poor outcomes and was presented as adjusted odds ratios (aORs) and 95% confidence intervals (CIs). A receiver operating characteristic (ROC) curve was used to analyze and find an optimal cut-off value for our newly created prognosis prediction scoring system and was presented as a percentage of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and area under the curve (AUC). The results were considered statistically significant for a two-tailed test if the *P-value* was <0.05. All statistical analyses were performed using SPSS for Windows, version 22.0 (released 2013, IBM Corp., Armonk, NY, USA).

3. Results

Between 2009 and 2018, 1219 adults experienced CO intoxication. Among them, 81 (6.6%) died (Fig. 1), and 48 patients in this group presented with cardiac arrest upon ED visit (defined as out-of-hospital cardiac arrest [OHCA]). The incidence of OHCA was higher in patients with intentional CO intoxication (37 [6%] vs. 11 [1.8%] in the intentional and non-intentional CO intoxication groups, respectively; $P < 0.001$). After excluding patients who experienced OHCA, the demographic and clinical characteristics of the patients included in the study are listed in Table 1, which were categorized by the outcome. Among these patients, 182 (15.5%) patients were defined as having poor outcomes. A total of 148 patients had a GCS score of <13, 18 had impending death on discharge, and 16 had in-hospital mortality. Older age, male sex, rescue from a fire scene, higher heart and respiratory rates, lower peripheral oxygen saturation, lower mean arterial pressure, lower GCS score on arrival, and a history of hypertension, diabetes mellitus (DM), and cerebrovascular accident were associated with poor outcomes. Higher white blood cell count, hemoglobin, creatine, and troponin I levels and lower pH and bicarbonate levels were observed in patients with poor outcomes. In addition, a higher rate of admission, prolonged hospital stay, higher rate of respiratory failure, lower rate of receiving HBOT, and higher CDR during OPD follow-up were observed in the poor outcome group. A trend towards lower MMSE scores was observed in patients with poor outcomes, although statistical significance was not achieved.

To identify the variables that could be used to predict poor outcomes, stepwise regression analysis was performed, and the results are shown in Fig. 2 as aORs with 95% CIs. DM (aOR, 2.749; 95% CI, 1.201–6.292), reduced GCS score (aOR, 1.253; 95% CI, 1.186–1.323), intentional CO exposure (aOR, 2.634; 95% CI, 1.335–5.196), rescue from a fire scene (aOR, 20.635; 95% CI, 8.345–51.023), and respiratory failure (aOR, 9.944; 95% CI, 5.533–17.873) were identified as predictors of poor outcomes. With these five variables, a scoring system was developed by adding 13 points for patients from a fire scene, 4 points for intentional COP, 10 points for respiratory failure, 1 point for each reduced GCS value, and 4 points for patients with a history of DM. We used the

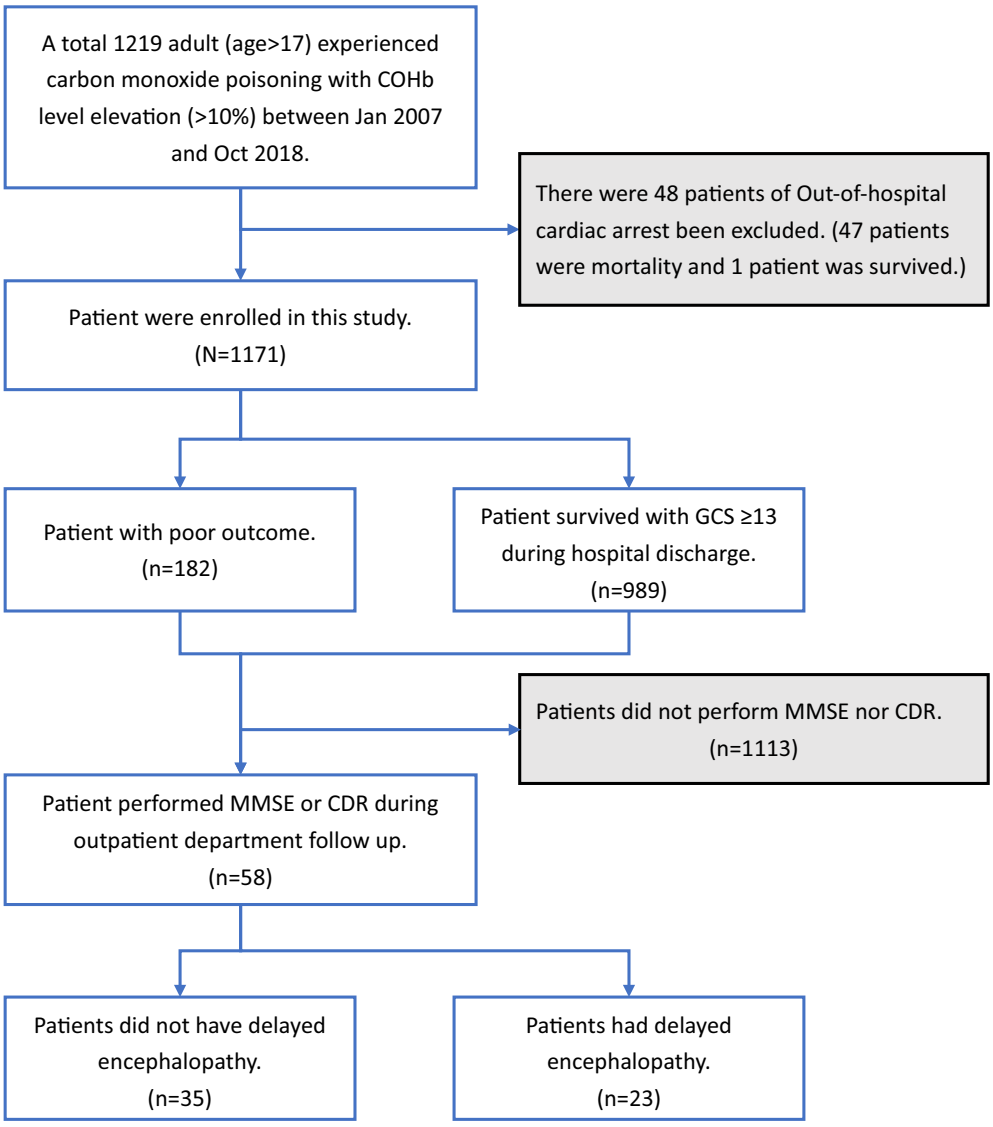

Fig. 1. Flowchart of carbon monoxide patients' enrollment and subgroup analysis. Poor outcome was defined as in-hospital mortality, impending death discharge, or GCS <13 during discharge. Abbreviations: MMSE, mini-mental state examination; CDR, clinical dementia rating.

abbreviation of each variable (F for fire scene, I for intentional COP, R for respiratory failure, E for every point of reduced GCS, and D for DM) to name the model the FIRED score, ranging from 0 to 43 points (Table 2). Fig. 3 shows the ROC curve for the FIRED score. The AUC was 0.930 (95% CI, 0.911–0.949), and the optimal cut-off score was 10. The sensitivity and specificity were 89.6% and 82.4%, respectively, when a FIRED score of ≥10 was defined as having a high risk of poor outcomes (Table 3). PPV and NPV were 48.4% and 97.7%, respectively.

In the subgroup analysis, 58 patients had a record of either MMSE or CDR during the OPD follow-up after an episode of CO intoxication, and 23 had DNS (Table 3). Factors related to delayed encephalopathy include older age and lower GCS scores upon discharge. The mean MMSE and CDR scores for patients with DNS were 16 (10–21) and 1 (0.5–2) vs. 29 (27–30) and 0 (0–0.5) for patients without neurological sequelae. The proportion of patients receiving normobaric oxygen therapy or HBOT within 24 h between the two groups was not statistically different.

4. Discussion

After excluding patients who experienced OHCA, the mortality rate was 2.9%, and the poor outcome rate was 15.5%. Compared with previous studies, the mortality rate in our study group was slightly higher than the previously reported 2.6% by Hampson et al. [23], which might reflect the difference in patient composition. The proportion of intentional COP was 49.6% in our study compared with the 30% in Hampson's study. Patients who received HBOT after COP were included in Hampson's study, which also differed from our inclusion criteria.

Poor outcomes were associated with several demographic and clinical characteristics (Table 1), most of which could be interpreted as unstable vital signs, laboratory examinations related to different organ dysfunctions, and underlying diseases such as hypertension, DM, and old age. Many studies have demonstrated a correlation between multiple organ dysfunction after COP and unfavorable outcomes [23,27-29]. HBOT has been shown to be associated with better outcomes. However, intubated patients did not receive HBOT according to the HBOT protocol in our medical facilities. A significantly higher CDR score may also reflect a higher rate of cognitive impairment in patients with poor outcomes.

Stepwise regression analysis revealed five factors that could be predictive of prognosis (Table 2). These factors included rescue from a fire scene, intentional COP, development of respiratory failure, reduced GCS score, and DM. Previous studies have illustrated the association

Table 1
Clinical characteristics of patients with carbon monoxide intoxication ($N = 1171$).

	No poor outcome ($n = 989$)	Poor outcome ($n = 182$)	*P*-value
Age	40 ± 13.7	45 ± 15.8	<0.001
Male sex	502 (50.8%)	122 (67%)	<0.001
Mechanism			
Fuel burning	499 (50.5%)	118 (64.8%)	
Fire scene	21 (2.1%)	56 (30.8%)	<0.001
Defective heaters	262 (26.5%)	3 (1.6%)	
Others	207 (20.9%)	5 (2.7%)	
Vital signs during triage			
Body temperature (°C)	36.5 (36.1–37)	36.4 (35.9–37.3)	0.574
Heart rate (beats/min)	101 (88–114)	109 (89–123)	0.003
Respiratory rate (breaths/min)	20 (18–20)	20 (18–22)	0.004
SpO_2 (%)	97 (95–99)	95 (91–99)	<0.001
MAP (mmHg)	93.3 (83.3–103.7)	90.5 (73.8–107)	0.043
GCS	15 (14–15)	7 (3–11)	<0.001
Hypertension	82 (8.3%)	27 (14.8%)	0.005
Diabetes mellitus	53 (5.4%)	22 (12.1%)	0.001
Liver cirrhosis	64 (6.5%)	11 (6%)	0.829
End-stage renal disease	13 (1.3%)	5 (2.7%)	0.180
Coronary artery disease	25 (2.5%)	7 (3.8%)	0.321
Heart failure	28 (2.8%)	10 (5.5%)	0.062
Cerebrovascular accident	28 (2.8%)	12 (6.6%)	0.010
Malignancy	16 (1.6%)	7 (3.8%)	0.073
Admission	178 (18%)	114 (62.6%)	<0.001
Length of stay (days)	0.6 (0.3–1.8)	4.3 (0.7–10)	<0.001
Laboratory exam			
Carboxyhemoglobin (%)	24.6 (15.6–33.3)	22.8 (15.5–37.7)	0.428
White blood count (1000/L)	10.4 (7.8–13.3)	13.3 (9–17.9)	<0.001
Hemoglobin (g/dL)	14.4 (13–15.7)	14.8 (13.5–16.2)	0.012
Platelets (1000/μL)	245.5 (209–289)	255 (194–298)	0.982
Power of hydrogen, pH	7.416 (7.382–7.449)	7.369 (7.24–7.433)	<0.001
Bicarbonate (mEq/L)	22.6 (19.8–24.6)	20.2 (15.5–23.3)	<0.001
BUN (mg/dL)	13 (9–16.8)	13 (9.9–17.4)	0.469
Creatinine (mg/dL)	0.8 (0.7–1)	1.1 (0.9–1.4)	<0.001
Lactate (mg/dL)	21.2 (10.6–36.7)	32.5 (12.9–54.3)	0.402
Troponin I (ng/mL)	0.02 (0.01–0.04)	0.047 (0.02–0.25)	<0.001
HBO therapy	435 (44%)	43 (23.6%)	<0.001
Respiratory failure	27 (2.7%)	106 (58.2%)	<0.001
MMSE score during OPD follow-up	27 (21−30)	21.5 (12–28)	0.086
CDR during OPD follow-up	0 (0–0.5)	0.5 (0.5–2)	0.018

Data are presented as numbers (percentages), means ± standard deviations, or median (Q1–Q3).
Poor outcome was defined as GCS of <13 or mortality.
Abbreviations: SpO2, peripheral oxygen saturation; MAP, mean arterial pressure; GCS, Glasgow coma scale; BUN, blood urea nitrogen; HBO, hyperbaric oxygen; MMSE, Mini-Mental State Examination; OPD, outpatient department; CDR, clinical dementia rating.

between early mortality and fire as a source of COP, intubation during HBOT, and loss of consciousness [23]. Studies have also revealed a higher rate of metabolic acidosis in patients rescued from fire scenes which was possibly due to concomitant burn injury and cyanide intoxication [23,30]. Recent research found that >1.5 days of ventilator support after COP was predictive of poor outcomes [31]. The mortality rate of intentional CO intoxication was higher than that of accidental COP in the United States between 1999 and 2014 [32]. The co-consumption of other substances, such as ethanol, was common in this group and might be the cause of serious intoxication and delayed treatment [33]. A recent study reported that for patients poisoned by CO, a GCS score of <9 was related to a higher rate of DNS, whereas a GCS score of 3 was associated with a higher mortality rate in the intensive care unit [22,29]. Associations between poor outcomes and chronic diseases, such as DM, hypertension, and psychiatric diseases, were mentioned in a previous study; however, the role of DM was emphasized less [31]. In our study, DM was found to be a predictor of poor outcomes. DM is associated with cognitive dysfunction, resulting in structural change [34]. Studies on traumatic brain injury and stroke have also shown a positive relationship between hyperglycemia and poor outcomes [35]. Hyperglycemia and microvascular complications caused by DM might make the brain more vulnerable to hypoxic stress in COP and further lead to an unfavorable prognosis.

No specific laboratory test was found to predict prognosis after the stepwise regression analysis. A previous study found that the blood urea nitrogen (BUN) level was a prognostic factor, which was explained by the dehydration status of the patient [31]. The study population was from a 24-h HBOT referral center that was capable of intubating patients, and the referral cases accounted for 60% of all the patients. Most of our study cases were primary ED visits, which could have resulted in less time from poisoning to ED visits and accounted for the different results. Moreover, we do not routinely check the BUN levels in patients with COP, resulting in lesser analyzable data.

In this study, we created a scoring system named the FIRED score to predict prognosis using demographic characteristics and clinical data only, which could be obtained from history taking and physical examinations. A FIRED score of ≥10 showed good sensitivity and specificity in predicting poor outcomes (sensitivity, 89.6%; specificity, 82.4%; AUC, 0.930). Wang et al. applied the poison severity score (PSS) and sequential organ failure assessment (SOFA) scores to the prognosis of COP. PSS, the initial SOFA score, and the second SOFA score were all good predictors of poor outcomes with a good AUC (0.977, 0.945, and 0.978, respectively). In this study, a poor outcome was defined as a cerebral performance category scale score of 1–2, and mortality was excluded. In comparison, poor outcomes were defined as death or a GCS score < 13 at discharge in our study. Using the FIRED score, pHysicians can predict the prognosis upon ED arrival and initiate aggressive therapies before any laboratory results are available. We believe that this poses as an advantage in clinical treatment and disposition, especially when resources are limited. The PSS and SOFA scores required either a review of the system for symptoms or comprehensive laboratory data related to different organ performances. The PSS and SOFA scores will be suitable for prognosis evaluation on admission and follow-up during hospitalization. To the best of our knowledge, this is the first prognostic prediction score for CO intoxication. Further studies are required to validate the accuracy and usefulness of the FIRED score in clinical settings.

A subgroup analysis was conducted on 58 patients with an MMSE or CDR documented after the COP episode, and 23 patients were found to have a GCS score of <24 and were diagnosed with DNS. However, DNS includes a broad spectrum of neurological deficits, cognitive impairments, and affective disorders that are not limited to cognitive symptoms. Hence, the actual number of patients with DNS may have been underestimated in this study. Patients with DNS were older and had lower GCS scores at discharge. Previous studies have suggested that HBOT prevents DNS [15,21,22,36]. However, no beneficial effect was observed in this subgroup of patients who received normobaric oxygen therapy or HBOT within 24 h of CO exposure. This finding might be related to the small number of patients in our study and the HBOT protocol. Selection bias may exist because patients without clinically significant sequelae may not visit the OPD after discharge. Additionally, neuropsychiatric examinations may not be performed by OPD physicians. A prospective randomized study is needed to elucidate the effects of HBOT on cognitive dysfunction prevention following COP.

5. Limitations

This was a retrospective study in which some data or information might not have been well documented in the medical records, which might have interfered with our results. Patients who presented with OHCA or those younger than 17 years of age were not included in our study. In addition, patients with suspected CO exposure and a COHb level of <10% were not included. Thus, these scores could not be applied to these groups. Moreover, only a small proportion of patients had their MMSE completed at the OPD after discharge, which might have resulted in selection bias and reduced statistical power. We used the MMSE to define DNS, which might exclude patients with relatively preserved

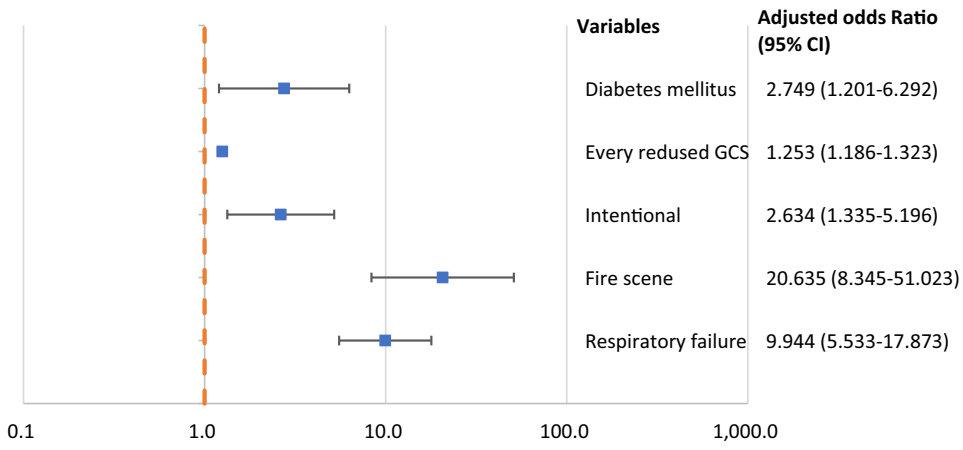

Fig. 2. Adjusted odds ratio and 95% confidence interval of poor outcome in CO intoxication patient. The model was adjusted for the following confounders by forward stepwise method: age, gender, hypertension, diabetes mellitus, liver cirrhosis, end-stage renal disease, coronary artery disease, heart failure, cerebrovascular accident, malignancy, Triage vital signs (including body temperature, heart rate, respiratory rate, mean arterial pressure, every reduced Glasgow coma scale), carboxyhemoglobin, intentional CO poisoning, fire scene, hyperbaric oxygen therapy, and respiratory failure.

Table 2
The carbon monoxide poisoning risk score.

Clinical feature	Points
Diabetes mellitus	+4
Every point of reduced GCS	+1
Intentional carbon monoxide poisoning	+4
Patient was from a fire scene	+13
Patient experienced respiratory failure	+10

Abbreviation: GCS, Glasgow coma scale.

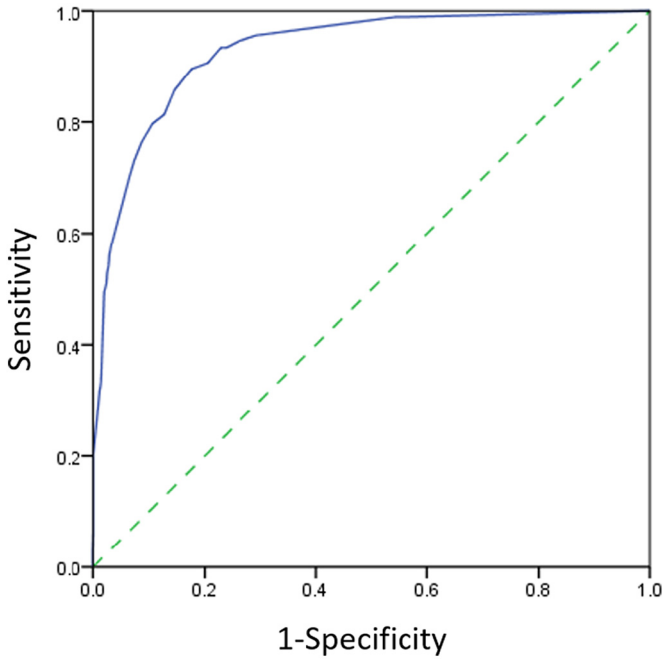

Fig. 3. The receiver operating characteristic (ROC) curve of the carbon monoxide poisoning risk score. The area under curve is 0.930 (95% Confidence Interval, 0.911 to 0.949).

cognitive functions but with sequelae of neurological deficits or affective disorders. In addition, we could not determine whether cognitive dysfunction developed after COP if patients did not visit our medical facilities before this episode.

Table 3
Subgroup analysis of patient with MMSE or CDR exam ($N = 58$).

	No delay encephalopathy ($n = 35$)	Delay encephalopathy ($n = 23$)	P-value
Age	43 (31–52)	49 (45–58)	0.015
Male sex	22 (62.9%)	13 (56.5%)	0.629
Intentional	29 (82.9%)	18 (78.3%)	0.738
Mechanism			
Fuel burning	28 (80.0%)	18 (78.3%)	0.982
Fire scene	1 (2.9%)	1 (4.3%)	
Defective heaters	4 (11.4%)	3 (13.0%)	
Others	2 (5.7%)	1 (4.3%)	
Laboratory exam			
Carboxyhemoglobin (%)	21.7 (13.2–39.4)	31.9 (23.6–40.9)	0.119
Power of hydrogen, pH	7.4 (7.4–7.5)	7.4 (7.3–7.5)	0.639
Bicarbonate (mEq/l)	21.1 (15.9–24)	19.7 (14.6–22.1)	0.569
Lactate (milligrams/deciliter)	41.4 (8.3–52.5)	16.1 (10.9–38.5)	0.705
HBO indicated	26 (74.3%)	21 (91.3%)	0.172
HBO therapy	20 (57.1%)	12 (52.2%)	0.710
HBO therapy within 24 h	11 (31.4%)	7 (30.4%)	0.936
Respiratory failure	6 (17.1%)	9 (39.1%)	0.061
GCS during discharge	15 (15–15)	14 (8–15)	0.013
MMSE score	29 (27–30)	16 (10–21)	<0.001
CDR	0 (0–0.5)	1 (0.5–2)	<0.001

Data are presented as number (percentage) or median (Q1-Q3).
Abbreviations: MAP, mean arterial pressure; SpO2, peripheral oxygen saturation; GCS, Glasgow coma scale; HBO, hyperbaric oxygen; CDR, clinical dementia rating. Poor outcome was defined as GCS < 13 or mortality.

6. Conclusion

The FIRED score could be used to estimate the outcome of non-OHCA patients who experienced CO exposure with concomitant COHb levels of >10%. These factors included rescue from a fire scene (F), intentional COP (I), respiratory failure (R), every point of reduced GCS (E), and medical history of DM (D). A FIRED score of ≥10 implies a high risk of mortality or a GCS score < 13 at discharge (sensitivity, 89.6%; specificity, 82.4%; AUC, 0.930).

Geolocation information

The four medical institutions enrolled in this study are located at the Keelung, Linkou, Chiayi, and Kaohsiung branches, which are located from northern to southern Taiwan.

Prior presentations

None.

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Author contributions

PCC designed the study. FJC supervised the process of data collection, and the data was collected by PCC and YJC. PCC performed the data analysis and takes responsibility for the integrity of the data and the accuracy of the data analysis. YIC supervised the process of data analysis. YJC and HYP drafted the article, and all authors contributed to its revision. YJC takes responsibility for the paper.

Credit authorship contribution statement

Ying Jen Chi: Writing – review & editing, Writing – original draft, Validation, Data curation. **Hsiu-Yung Pan:** Supervision, Writing – original draft, Writing – review & editing. **Fu-Jen Cheng:** Supervision. **Ye-In Chang:** Supervision. **Po-Chun Chuang:** Validation, Supervision, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

None.

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