Acute and Critical Care

Acute and Critical Care 2024 November 39(4):526-534
https://doi.org/10.4266/acc.2024.00199

| pISSN 2586-6052 | eISSN 2586-6060

Long-term mortality of adult patients with carbon monoxide poisoning presenting to the emergency department in Korea: a population-based cohort study

Sang Hwan Lee[1,*], Soo Rack Ryu[2,*], Kyung Hun Yoo[1], Juncheol Lee[1], Yongil Cho[1], Tae Ho Lim[1], Hyunggoo Kang[1], Jaehoon Oh[1], Byuk Sung Ko[1]

[1]*Department of Emergency Medicine, Hanyang University College of Medicine, Seoul, Korea*
[2]*Biostatistical Consulting and Research Laboratory, Medical Research Collaborating Center, Hanyang University, Seoul, Korea*

Background: Carbon monoxide (CO) poisoning can lead to significant morbidity and mortality. However, relatively few studies have investigated its long-term mortality impact. This nationwide population-based cohort study examined the association between CO poisoning and long-term mortality.
Methods: This retrospective study utilized data from the National Health Insurance Service database in South Korea. We compared the patients with CO poisoning to those without CO poisoning. Inverse probability treatment weights were applied to both groups to control for potential confounding factors. Subsequently, mortality was assessed using the incidence rate and Cox proportional hazard ratios.
Results: This study included 23,387 patients with CO poisoning and 359,851 without it. Over a median follow-up period of 7.6 years after CO poisoning diagnosis, the mortality risk was 2.6 times higher in patients with CO poisoning compared to that in the control group. In a long-term follow-up of patients surviving beyond 30 days, mortality remained 2.18 times higher. Additionally, a higher mortality risk was observed in the relatively younger age group (18–39 years) and the group with fewer underlying diseases, as indicated by a Charlson Comorbidity Index score of 0.
Conclusions: CO poisoning is associated with an elevated long-term mortality rate particularly in a relatively young and healthy population.

Key Words: carbon monoxide; carbon monoxide poisoning; mortality

Original Article

Received: February 26, 2024
Revised: August 2, 2024
Accepted: August 9, 2024

Corresponding author
Byuk Sung Ko
Department of Emergency Medicine, Hanyang University College of Medicine, 222-1 Wangsimni-ro, Seongdong-gu, Seoul 04763, Korea
Tel: +82-2-2290-8999
Fax: +82-2-2290-9280
Email: postwinston@gmail.com

*These authors contributed equally to this article as co-first authors.

INTRODUCTION

Despite an estimated global cumulative incidence of 137 carbon monoxide (CO) poisoning cases and 4.6 deaths per million, there has been no significant decrease in the incidence of CO poisoning [1]. In contrast, a few Northeast Asian countries are experiencing an alarming upward trend. Taiwan has witnessed a surge in CO poisoning cases, with the incidence of suicide by charcoal burning increasing nearly 25-fold [2,3]. Similarly, China experienced a rising trend in CO poisoning from 1990 to 2019 [4]. The late 2000s saw a spike in CO suicides following the high-profile death of a famous actor due to CO poisoning. Additionally, South Korea has seen a rise in CO poisoning due to its growing population and the reckless use of camping supplies such as fuel and heating appliances [3,5,6].

CO poisoning, caused by the incomplete combustion of hydrocarbons, is a significant health concern due to its high toxicity [7-13]. CO's affinity for hemoglobin is over 200 times greater than that of oxygen, leading to the formation of carboxyhemoglobin and subsequent cellular hypoxia [14]. Moreover, CO triggers inflammation, disrupts mitochondrial respiration, and generates free radicals, contributing to cardiac and neurological injuries [7]. While research has explored the complications of CO poisoning, such as epilepsy, venous thromboembolism, and myocardial infarction, long-term mortality data from large-scale populations remains scarce. This nationwide population-based cohort study addresses this gap by examining the association between CO poisoning and long-term mortality.

KEY MESSAGES

- Our study investigated the long-term mortality of carbon monoxide poisoning patients using National Health Insurance Service data.
- Carbon monoxide poisoning is associated with an elevated long-term mortality rate, particularly in a relatively young and healthy population.
- Although the short-term 30-day mortality rate was also high, survivors beyond 30 days had an even higher mortality rate.
- We provide valuable insights for developing effective policies aimed at prevention and post-poisoning management.

MATERIALS AND METHODS

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Hanyang University Hospital (protocol codes 2023-10-025 and October 19, 2023). Given the retrospective nature of this study, the need for written informed consent was waived.

Study Design and Setting

This population-based study used data from the National Health Insurance Service (NHIS) database in South Korea. South Korea operates a government led single payer health insurance system. The NHIS, a mandatory universal public health insurance system, covers approximately 97% of the Korean population and provides medical aid to 3% of those with the lowest income. The NHIS serves approximately 50 million people.

Data categorization was based on the International Statistical Classification of Diseases, 10th Revision (ICD-10) codes. The NHIS database includes patient information, including sex, age, income, date of death, and medical history, encompassing medication prescriptions and procedures. Researchers cannot identify personal information due to the anonymized nature of data transmission.

Patients with CO poisoning between January 2005 and December 2021 were included and identified using the ICD-10 code T58 for CO poisoning. To establish a control group, we evaluated the initial control pool. This pool comprised individuals who were approximately 1:8 matched to the CO poisoning group based on age and sex and were provided by the NHIS for research purposes. To refine the definition of acute intoxication, patients with CO poisoning were defined as those diagnosed with CO poisoning in the emergency department (ED) during the study period. The ED diagnosis was based on the emergency medical care fees billed upon utilizing emergency services in South Korea.

Study Population

To ensure follow-up beyond 5 years, patients diagnosed with CO poisoning in 2004 (during the wash-out period) and from 2017 to 2021 were excluded. Patients without emergency medical management fees, those under 18 years of age, and those with missing covariates were excluded from the study.

Study Covariables

We divided the study population into four income quartiles to assess socioeconomic status. Overall comorbidity burden was determined using the Charlson Comorbidity Index (CCI), which evaluates the following comorbidities: hypertension, diabetes mellitus, dyslipidemia, chronic pulmonary disease, ischemic heart disease, myocardial infarction, congestive heart failure, stroke, dementia, solid cancer, hematologic malignancy, and chronic kidney disease/end stage renal disease.

Additionally, we identified psychotic, bipolar, substance related, depressive, unspecified mood, and anxiety disorders. Disease severity was categorized as mild, moderate, or severe, corresponding to discharge, general ward admission, and intensive care unit admission, respectively.

Study Outcomes

The primary objective of this study was to compare the long-term mortality risk between patients with CO poisoning and controls. The study population was followed up until either their date of death or December 31, 2021. We assessed short-term mortality within the initial 30 days following a CO poisoning diagnosis and long-term mortality in patients surviving beyond 30 days. Additionally, we aimed to identify risk factors associated with long-term mortality in patients with CO poisoning.

Statistical Analysis

Categorical variables are presented as numbers and percentages. To compare categorical variables between the two groups, Fisher's exact test was employed. The Shapiro-Wilk test was utilized to assess the normality of continuous variables. Normally distributed continuous variables are represented as mean and standard deviation. In contrast, non-normally distributed variables are represented by the median and interquartile range (IQR). Either the Student t-test or the Wilcoxon rank-sum test was performed, depending on the normality test results.

The propensity score was estimated using logistic regression, incorporating all covariates. The inverse probability of treatment weighting (IPTW) method was applied using the estimated propensity scores. The primary analysis results are presented for both the patient and control groups after applying IPTW. The standardized mean difference (SMD) was employed to evaluate the balance between the patient and control groups before and after IPTW for each covariate. An SMD value of less than 0.1 was considered negligible regarding the differences between the two groups.

The Cox proportional hazards model was used to calculate the hazard ratio (HR), 95% CI, and P-value. To analyze the risk of mortality based on general characteristics, the number of deaths and person-years of observation were calculated, and the incidence rate was estimated per 1,000 person-years. The Kaplan-Meier method was employed to describe survival curves and probabilities for both groups. Statistical analyses were conducted using the SAS Enterprise Guide, version 7.1 (SAS Institute Inc.). The significance level was set at $P<0.05$; any P-value below 0.05 was considered statistically significant.

RESULTS

Baseline Characteristics of the Study Population

Between 2005 and 2021, 59,282 patients with CO poisoning were identified, while the initial control group comprised 469,456 individuals. Following the application of exclusion criteria to both groups, 35,895 and 106,705 individuals were excluded, respectively, resulting in 23,387 patients with CO poisoning and 359,851 controls (Figure 1). Table 1 summarizes the baseline characteristics of the study population. In both

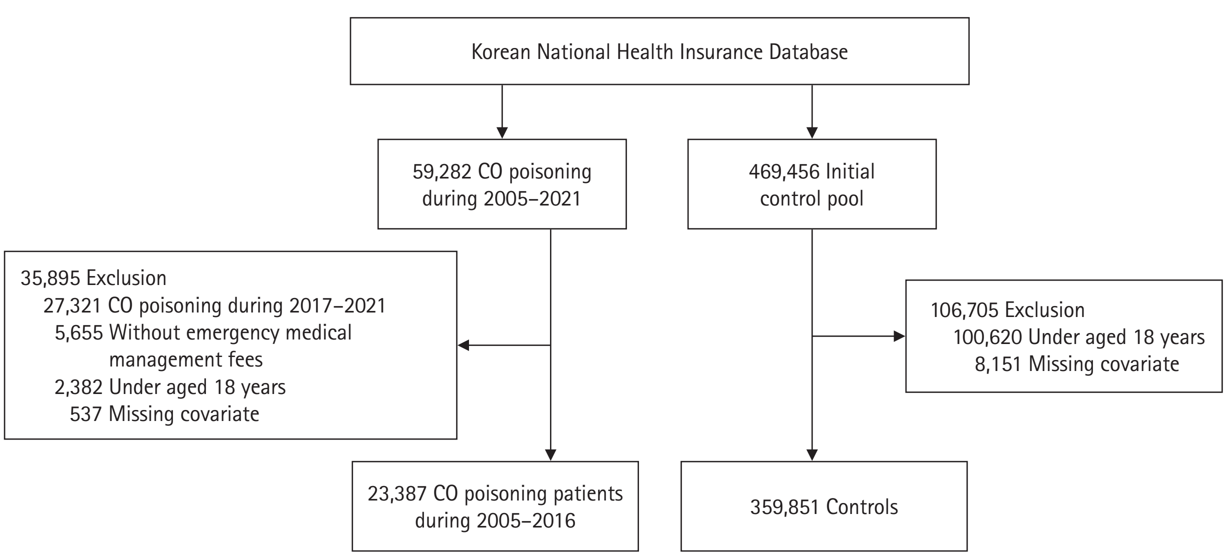

Figure 1. Flowchart of the study population. CO: carbon monoxide.

Table 1. Demographic characteristics of study population and after IPTW adjustment

Variable		Before IPTW					After IPTW				
		CO poisoning (n=23,387)		Control (n=359,851)		SMD	CO Poisoning (n=191,841)		Control (n=191,397)		SMD
Age (yr)	18–39	9,340	39.9	144,451	40.1	−0.004	73,932	38.5	76,753	40.1	−0.032
	40–64	10,009	42.8	154,210	42.9	−0.001	81,837	42.7	82,030	42.9	−0.004
	≥65	4,038	17.3	61,190	17.0	0.007	36,072	18.8	32,613	17.0	0.046
Sex	Male	13,034	55.7	191,196	53.1	0.052	100,744	52.5	102,009	53.3	−0.016
	Female	10,353	44.3	168,655	46.9	−0.052	91,097	47.5	89,388	46.7	0.016
Income	Q1 (Highest)	4,199	18.0	91,614	25.5	−0.183	48,310	25.2	47,849	25.0	0.004
	Q2	5,314	22.7	90,511	25.2	−0.057	48,183	25.1	47,855	25.0	0.003
	Q3	5,990	25.6	89,859	25.0	0.015	47,506	24.8	47,861	25.0	−0.006
	Q4 (Lowest)	7,884	33.7	87,867	24.4	0.206	47,842	24.9	47,833	25.0	−0.001
CCI	0	13,455	57.5	232,007	64.5	−0.143	120,914	63.0	122,561	64.0	−0.021
	1	5,483	23.4	74,997	20.8	0.063	40,495	21.1	40,191	21.0	0.003
	2	2,197	9.4	28,756	8.0	0.050	16,043	8.4	15,464	8.1	0.010
	≥3	2,252	9.6	24,091	6.7	0.108	14,389	7.5	13,182	6.9	0.024
Psychiatric disorder (yes)		5,576	23.8	43,576	12.1	0.309	24,854	13.0	24,526	12.8	0.004
	Psychotic d/o	431	1.8	2,585	0.7	0.100	1,605	0.8	1,514	0.8	0.006
	Bipolar d/o	538	2.3	1,683	0.5	0.157	1,121	0.6	1,117	0.6	0.000
	Substance related d/o	697	3.0	1,165	0.3	0.210	956	0.5	943	0.5	0.001
	Depressive d/o	2,841	12.2	14,756	4.1	0.298	8,757	4.6	8,796	4.6	−0.002
	Unspecified mood d/o	134	0.6	944	0.3	0.048	530	0.3	541	0.3	0.000
	Anxiety d/o	4,079	17.4	33,639	9.4	0.239	18,866	9.8	18,838	9.8	0.000
Severity	Mild	18,908	80.9	321,213	89.3	−0.238	170,030	88.6	169,848	88.7	−0.003
	Moderate	4,182	17.9	36,938	10.3	0.221	20,758	10.8	20,550	10.7	0.003
	Severe	297	1.3	1,700	0.5	0.086	1,054	0.6	999	0.5	0.004

Severity was categorized as mild, moderate, and severe, corresponding to discharge, general ward admission, and intensive care unit admission, respectively. IPTW: inverse probability of treatment weighting; CO: carbon monoxide; SMD: standardized mean difference; Q, quartile; CCI: Charlson Comorbidity Index; d/o: disorder.

groups, most individuals were aged 40–64 years, accounting for 42.8% and 42.9%, respectively. Males constituted 55.7% and 53.1% of patients in the CO poisoning and control groups, respectively. Regarding income, the lowest quartile was more prevalent in the CO poisoning group (33.7%), while the highest quartile was relatively low (18%). The CO poisoning group had a lower proportion of individuals with a CCI score of 0 and a higher proportion with scores of 1, 2, and 3 or more than that in the control group. The prevalence of underlying psychiatric disorders was higher in the CO poisoning group (23.8%) than in the control group (12.1%). Additionally, the CO poisoning group had a higher proportion of individuals in the moderate to severe categories.

Characteristics of the Population after Adjustment by IPTW

The IPTW results demonstrated that the SMD of all variables converged to nearly 0.1, indicating a well-balanced comparison between patients with CO poisoning and controls. Table 1 outlines the baseline characteristics of the two groups. No statistically significant differences were observed in any variables between the two groups. For all covariates, the SMD was less than 0.1, confirming the absence of substantial differences between the two groups.

Incidence Rate and Risk of Mortality in the CO Patient Group Versus The Control Group

The cohort of CO patients had a median follow-up duration of 7.6 years (IQR, 6.0–9.9 years), while the control group had a median follow-up duration of 8.0 years (IQR, 6.8–10.7 years). Long-term mortality was significantly higher in the CO poisoning group compared to that in the control group (18.84 vs. 7.13 per 1,000 person-years, P<0.001) (Table 2). The HR for mortality was 2.60 (95% CI, 2.55–2.66) in the CO poisoning

Table 2. Incidence rate and risk of mortality in CO poisoning versus controls

Variable		No. at risk	No. at death	Person years	IR (/1,000 PY)	HR (95% CI)	P-value
Overall	Control	191,397	12,040	1,688,675	7.13	Reference	
	CO poisoning	191,841	28,529	1,514,045	18.84	2.60 (2.55–2.66)	<0.001
30-Day follow-up	Control	191,397	118	4	29,278.37	Reference	
	CO poisoning	191,841	5,134	88	58,673.09	1.61 (1.34–1.93)	<0.001
Survivor ≥30 days	Control	191,279	11,922	1,688,671	7.06	Reference	
	CO poisoning	186,707	23,395	1,513,958	15.45	2.18 (2.14–2.23)	<0.001

CO: carbon monoxide; IR: incident rate; HR: hazard ratio.

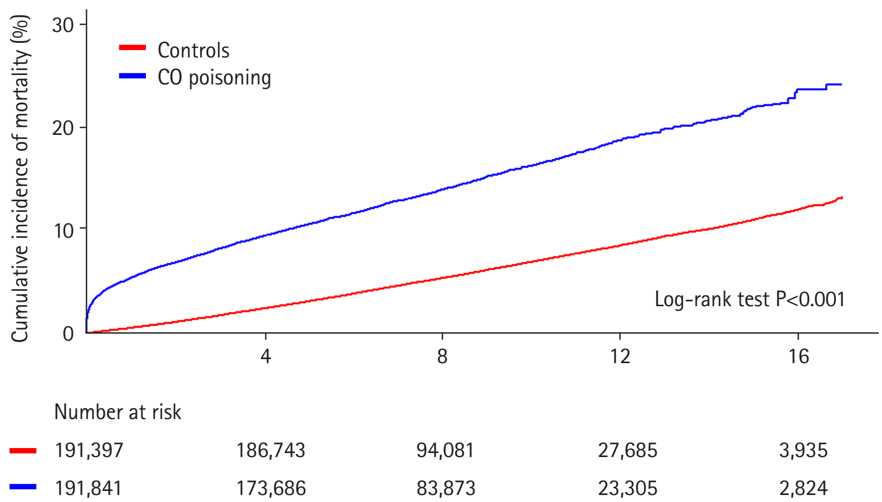

Figure 2. Cumulative incidence of mortality between the two groups during the follow-up period. CO: carbon monoxide.

group compared to that in the controls. Similarly, 30-day follow-up mortality was significantly higher in patients with CO poisoning (HR, 1.61; 95% CI, 1.34–1.93]). Moreover, long-term mortality in individuals surviving for 30 days or more was significantly elevated in this group (HR, 2.18; 95% CI, 2.14–2.23). The cumulative incidence probability of mortality exhibited a significant difference between patients with patients with CO poisoning and controls (log-rank P<0.001) (Figure 2).

When considering all variables, the HR for mortality was significantly higher in the CO poisoning group than that in the control group (Figure 3). In the CO poisoning group, the HR for the age group 18–39 years was particularly high at 11.38 (95% CI, 10.32–12.55), and the HR for individuals with a CCI score of 0 was significantly elevated at 4.04 (95% CI, 3.89–4.19). Additionally, the relatively lower income group (Q3, Q4) showed a higher HR compared to the higher income group (Q1, Q2). The figures for the number of risks, number of deaths, and incident rates are provided in Supplementary Table 1.

DISCUSSION

Even after adjusting for potential confounders, the mortality risk among patients with CO poisoning remained 2.6 times higher than in controls during a median follow-up duration of 7.6 years after CO poisoning diagnosis. This elevated risk persisted in both the 30-day follow-up (1.61 times higher mortality) and the long-term follow-up for patients surviving beyond 30 days (2.18 times higher mortality). A higher mortality risk was observed in the relatively younger age group (18– 39 years) and the group with fewer underlying diseases, as indicated by a lower CCI.

Our study's nationwide approach enabled us to comprehensively evaluate long-term mortality rates among patients with CO poisoning. While previous studies have analyzed national claims data, their scale was limited, with no study involving tens of thousands of patients [15]. Our comprehensive subgroup analyses identified groups with higher risk factors for

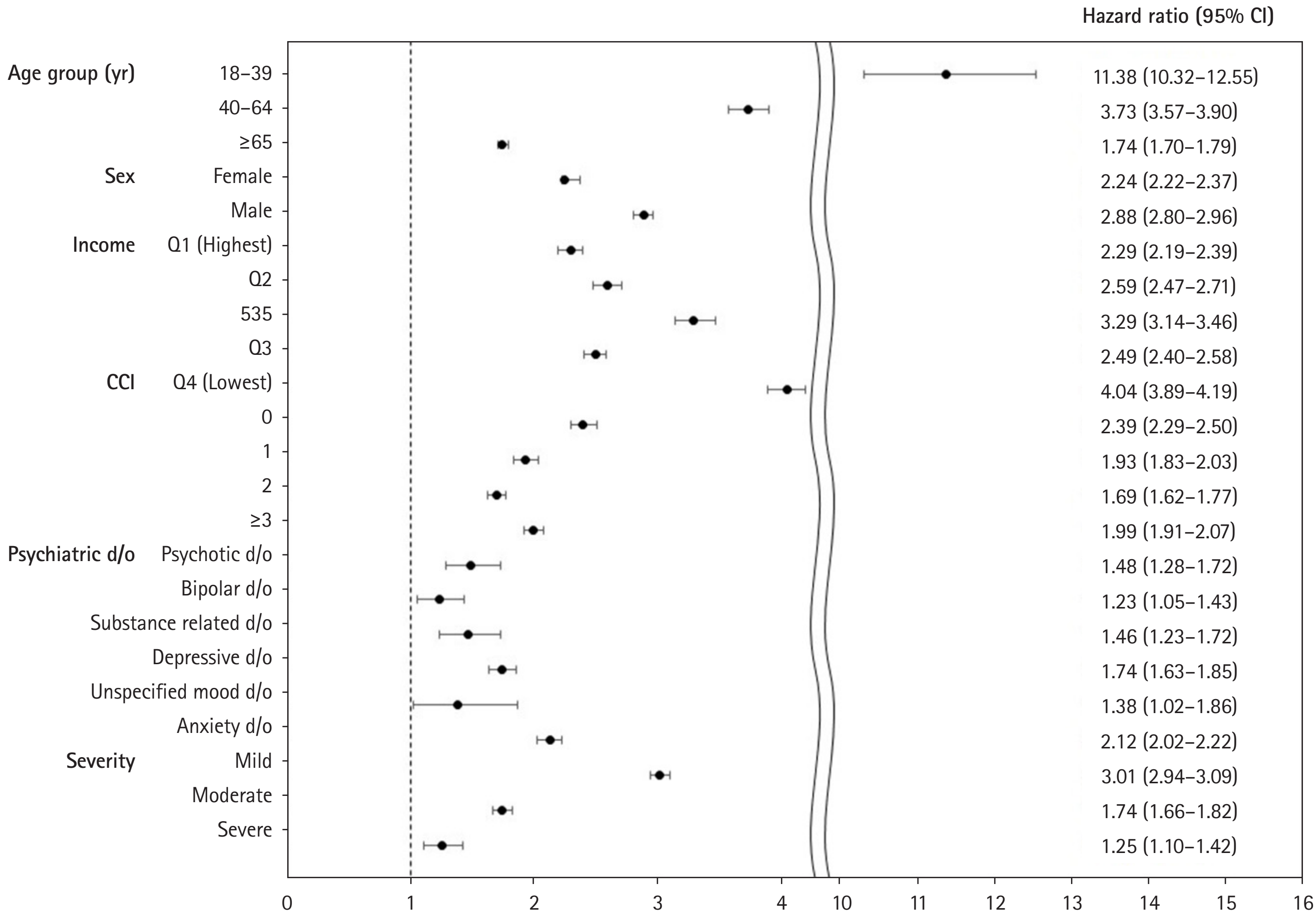

Figure 3. Increased mortality in carbon monoxide poisoning versus matched controls, stratified analysis according to age group, sex, income, Charlson Comorbidity Index (CCI), psychiatric disorder, severity. Severity was categorized as mild, moderate, and severe, corresponding to discharge, general ward admission, and intensive care unit admission, respectively. Q: Quartile; d/o: disorder.

mortality. We adjusted risk estimates by controlling for covariates and employed IPTW to strengthen causal influence. By identifying CO poisoning groups with higher mortality than the control group, we provide valuable insights for developing effective policies aimed at prevention and post-poisoning management.

Two key factors were considered in evaluating the association between CO poisoning and long-term mortality. Firstly, CO poisoning is a severe condition linked to significant morbidity. Studies have shown an increased risk of myocardial infarction and venous thromboembolism during the first month following [9,16]. Additionally, research indicates that CO poisoning can lead to cardiac fibrosis, stroke, and epilepsy [8,17,18]. Apart from direct solid organ damage, studies have reported an increased risk of adrenal insufficiency as an endocrine issue following CO poisoning [19]. There is a possibility of death due to these complications following CO poisoning. The second factor involves intentional exposure to CO poisoning, followed by the recurrence of suicide as the cause of death. According to one study, 35.2% of CO poisoning cases involved intentional exposures [20]. A previous suicide attempt is a strong predictor of future suicide, with approximately 30% of individuals who attempt suicide making repeated attempts, and the all-cause mortality rate was 11.6% three months after a suicide attempt [21,22]. The incidence of suicide varies across countries and is relatively high in South Korea [23].

Despite an HR of 1.61 within the initial 30 days, the HR during the follow-up period for survivors within the initial 30 days was even higher at 2.18. This emphasizes the importance of ongoing management after initial treatment for CO poisoning. Previous studies reported an HR of 8.4 for epilepsy following CO poisoning compared to that in the control group [8].

Additionally, research indicates that more than 6 years after CO poisoning, the CO poisoning group had a 1.84-fold higher risk of ischemic stroke than that in the control group [18]. Furthermore, 1 year after CO poisoning, the incidence of adrenal insufficiency was 2.1 times higher in the CO poisoning group compared to that in the control group [19].

In Figure 3, compared to the controls, HRs of CO poisoning were higher among the relatively healthy group who were young, had a low CCI, and had mild disease severity. We think that it might be because older individuals, those with high CCI, and those with high severity are more likely to die from other causes even without CO poisoning, resulting in a comparatively lower HR (Supplementary Table 1). For example, the incident rate of death per 1,000 person-years among the controls aged 18–39 was 0.62, while it was 7.36 for those with CO poisoning. However, for those aged 65 and over, the incident rate was 35.59 for the controls and 62.59 for those with CO poisoning. In other words, the proportion of patients who would not have died if not for CO poisoning is higher in the relatively healthy group. And we cautiously suggest that suicide, being the leading cause of death among teens and people in their twenties and thirties in Korea, may have influenced mortality rates in an otherwise healthy demographic [24]. Additionally, it was observed that the lower income groups (Q3, Q4) exhibited relatively higher mortality rates compared to the higher income groups (Q1, Q2). We considered two possible reasons to explain this result. Firstly, there may be issues related to medical costs and insurance. In South Korea, there is a public health insurance system that covers approximately 64.5% of total medical expenses [25]. However, previous studies have reported that having private insurance in addition to the NHIS is associated with lower costs, increased inpatient utilization, and lower mortality, particularly among high-income individuals who are more likely to have private insurance [26,27]. We think that differences in healthcare utilization may contribute to the differences in mortality. Secondly, individuals with higher socio-economic status are more likely to make greater use of preventive healthcare services, which enhances the likelihood of better post-treatment management. CO poisoning can lead to numerous complications after the initial poisoning event, such as delayed neuropsychiatric syndrome, myocardial infarction, and venous thromboembolism. Preventive management of these complications could have influenced the observed differences in mortality rates.

There are two ways of being exposed to CO poisoning: intentional and unintentional. Previous research in South Korea indicates that approximately 65% of CO poisoning cases are unintentional, while about 35% are intentional [20]. The most common sources of unintentional exposure are fires and charcoal, and there is a growing incidence of CO exposure during campus activities, especially with the recent population increase [6]. Beyond providing appropriate treatment, preventing safety incidents requires societal attention. This includes considering ventilation needs, adherence to safety regulations, and installing CO detectors. If intentional exposure is suspected, early psychiatric referral may be crucial to preventing suicide reattempts [22]. Referral to psychiatric services within seven days has been associated with a decreased risk of suicide reattempts. Additionally, given the increase in CO poisoning suicides following a well-known actor's suicide, it is necessary to exercise caution when reporting on such celebrity suicides to mitigate the potential "Werther effect," where media reporting on a celebrity's suicide can influence others to take similar actions.

A previous study reported a 5.24-fold standardized mortality ratio for all-cause mortality in patients with CO poisoning compared to that in controls [15]. We attribute the differences between our study and the previous findings to several factors. First, the previous study focused on patients admitted to the intensive care unit, which likely contributed to the higher mortality rate due to the increased disease severity of patients in that cohort. Secondly, including children aged 0–18 years in the previous study may have elevated the risk. Our study excluded pediatric cases, and our findings and those of previous studies suggest a trend of increased HR among younger age groups [15]. Additionally, our study included approximately 53 times more patients with CO poisoning than in previous studies.

This holds significant implications in public health. In several countries in Northeast Asia including South Korea, there is an increasing prevalence of CO poisoning contrary to global trends. Moreover, over 80% of CO poisoning patients are relatively young individuals, not elderly over 65 years old. CO poisoning elevates the risk of death by approximately 11 times in the younger age group of 18–39 years. Given these results, there is a critical need for heightened awareness. Young patients presenting to the emergency room with CO poisoning require not only hospital-level follow-up but also national-level strategies.

This study had several limitations. Firstly, the national claims database lacks clinical and laboratory data, such as duration of CO exposure, carboxyhemoglobin levels, and exposure intentionality. Secondly, in order to maximize the association between CO poisoning and mortality, we used IPTW and included covariates that may affect mortality. However, due to the limitations of the data, we could not determine the cause of death. Identifying the cause of death could have been more effective in preventing mortality. Further research is needed. Thirdly, only ED based patients were included. Patients with CO poisoning seeking outpatient care were excluded because the study population was defined as those with both an emergency medical care fee and a diagnosis of CO poisoning. However, considering that CO poisoning primarily occurs after suicide attempts or accidents (e.g., fires, gas leaks), we believe that the number of patients with CO poisoning visiting outpatient facilities may be relatively low. Fourth, a high HR was observed in patients with psychotic disorders, with anxiety disorders showing the highest results among them. However, we were unable to determine the specific mechanisms behind this finding.

The long-term mortality risk among patients with CO poisoning was significantly higher than that of matched controls. This difference was particularly evident in younger patients and those without underlying conditions. CO poisoning poses a significant social burden, necessitating increased social awareness, preventive measures, and long-term monitoring of post-poisoning complications. Additionally, survivors of suicide attempts should receive ongoing psychiatric care.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

FUNDING

This research was supported by the Bio & Medical Technology Development Program of the National Research Foundation (NRF) and funded by the Korean government (MSIT) (NRF-2021R1C1C1004929).

ACKNOWLEDGMENTS

None.

ORCID

Sang Hwan Lee https://orcid.org/0000-0001-5782-4551
Soo Rack Ryu https://orcid.org/0000-0002-8828-839X
Kyung Hun Yoo https://orcid.org/0000-0003-2250-5280
Juncheol Lee https://orcid.org/0000-0003-3058-4759
Yongil Cho https://orcid.org/0000-0001-5027-6345
Tae Ho Lim https://orcid.org/0000-0003-1045-413X
Hyunggoo Kang https://orcid.org/0000-0002-9522-2532
Jaehoon Oh https://orcid.org/0000-0001-8055-1467
Byuk Sung Ko https://orcid.org/0000-0002-4212-2255

AUTHOR CONTRIBUTIONS

Conceptualization: BSK, HK, THL. Methodology: BSK, YC, KHY. Software: SHL, BSK, KHY, SRR. Formal analysis: SRR, SHL, BSK, JL. Investigation: SRR, SHL. Data curation: SRR, SHL. Visualization: SHL. Supervision: BSK, JO. Validation: BSK, YC, JO. Writing -original draft: SHL. Writing - review & editing: BSK, THL, HK, JO. All authors read and agreed to the published version of the manuscript.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found via https://doi.org/10.4266/acc.2024.00199.

REFERENCES

1. Mattiuzzi C, Lippi G. Worldwide epidemiology of carbon monoxide poisoning. Hum Exp Toxicol 2020;39:387-92.
2. Huang CC, Ho CH, Chen YC, Lin HJ, Hsu CC, Wang JJ, et al. Demographic and clinical characteristics of carbon monoxide poisoning: nationwide data between 1999 and 2012 in Taiwan. Scand J Trauma Resusc Emerg Med 2017;25:70.
3. Choi YR, Cha ES, Chang SS, Khang YH, Lee WJ. Suicide from carbon monoxide poisoning in South Korea: 2006-2012. J Affect Disord 2014;167:322-5.
4. Cui P, Jin Y, Feng H, Li Z, Ding S, Li Y. Burden of carbon monoxide poisoning in China, 1990-2019: a systematic analysis of data from the global burden of disease study 2019. Front Public Health 2022;10:930784.
5. Bae S, Lee J, Kim K, Park J, Shin D, Kim H, et al. Epidemiologic characteristics of carbon monoxide poisoning: emergency department based injury in-depth surveillance of twenty hospitals. J Korean Soc Clin Toxicol 2016;14:122-128.
6. Kim YJ, Sohn CH, Oh BJ, Lim KS, Kim WY. Carbon monoxide poisoning during camping in Korea. Inhal Toxicol 2016;28:719-23.

7. Rose JJ, Wang L, Xu Q, McTiernan CF, Shiva S, Tejero J, et al. Carbon monoxide poisoning: pathogenesis, management, and future directions of therapy. Am J Respir Crit Care Med 2017;195:596-606.
8. Meng YH, Hsieh MS, Chi YC, How CK, Chen PC, Chang CM. Effect of carbon monoxide poisoning on epilepsy development: a nationwide population-based cohort study. Ann Emerg Med 2023;82:14551.
9. Cho Y, Kang H, Oh J, Lim TH, Ryu J, Ko BS. Risk of venous thromboembolism after carbon monoxide poisoning: a nationwide population-based study. Ann Emerg Med 2020;75:587-96.
10. Ostrowski RP, Zhang JH. Risk factors for short-term mortality from carbon monoxide poisoning treated with hyperbaric oxygen. Crit Care Med 2008;36:2684-5.
11. Rhee B, Kim HH, Choi S, Min YG. Incidence patterns of nervous system diseases after carbon monoxide poisoning: a retrospective longitudinal study in South Korea from 2012 to 2018. Clin Exp Emerg Med 2021;8:111-9.
12. Lee Y, Kim SH, Cha YS. Serum phosphate is not an early predictor of neurocognitive outcomes in acute carbon monoxide poisoning patients. Clin Exp Emerg Med 2023;10:74-83.
13. Moon JS, Kim SH, Cha YS. Prognostic value of the myeloperoxidase index for early prediction of neurologic outcome in acute carbon monoxide poisoning. Clin Exp Emerg Med 2022;9:230-7.
14. Weaver LK. Clinical practice. Carbon monoxide poisoning. N Engl J Med 2009;360:1217-25.
15. Huang CC, Chung MH, Weng SF, Chien CC, Lin SJ, Lin HJ, et al. Long-term prognosis of patients with carbon monoxide poisoning: a nationwide cohort study. PLoS One 2014;9:e105503.
16. Huang CC, Ho CH, Chen YC, Lin HJ, Hsu CC, Wang JJ, et al. Risk of myocardial infarction after carbon monoxide poisoning: a nationwide population-based cohort study. Cardiovasc Toxicol 2019;19:147-55.
17. Cho DH, Ko SM, Son JW, Park EJ, Cha YS. Myocardial injury and fibrosis from acute carbon monoxide poisoning: a prospective observational study. JACC Cardiovasc Imaging 2021;14:1758-70.
18. Kwak K, Kim M, Choi WJ, Ju YS, Park JT. Association between carbon monoxide intoxication and incidence of ischemic stroke: a retrospective nested case-control study in South Korea. J Stroke Cerebrovasc Dis 2021;30:105496.
19. Huang CC, Ho CH, Chen YC, Hsu CC, Lin HJ, Wang JJ, et al. Association between carbon monoxide poisoning and adrenal insufficiency: a nationwide cohort study. Sci Rep 2022;12:16219.
20. Lee S, Lee J, Kim KH, Park J, Shin DW, Kim H, et al. Trends of carbon monoxide poisoning patients in emergency department: NEDIS (National Emergency Department Information System). J Korean Soc Emerg Med 2021;32:27-35.
21. Carter GL, Clover KA, Bryant JL, Whyte IM. Can the Edinburgh risk of repetition scale predict repetition of deliberate self-poisoning in an Australian clinical setting? Suicide Life Threat Behav 2002;32:230-9.
22. Kim H, Kim Y, Shin MH, Park YJ, Park HE, Fava M, et al. Early psychiatric referral after attempted suicide helps prevent suicide reattempts: a longitudinal national cohort study in South Korea. Front Psychiatry 2022;13:607892.
23. Ministry of Health and Welfare; Korea Foundation for Suicide Prevention. 2021 White paper on suicide prevention. Korea Foundation for Suicide Prevention; 2021.
24. Statistics Korea. Cause of death statistics [Internet]. Statistics Korea; 2023 [cited 2024 Aug 1]. Available from: https://kostat.go.kr/board.es?mid=a10301010000&bid=218&act=view&list_no=427216&tag=&nPage=1&ref_bid=203,204,205,206,207,210,211,11109,11113,11814,213,215,214,11860,11695,216,218,219,220,10820,11815,11895,11816,208,245,222,223,225,226,227,228,229,230,11321,232,233,234,12029,10920,11469,11470,11817,236,237,11471,238,240,241,11865,243,244,11893,11898,12031,11825,246
25. Jung HW, Kwon YD, Noh JW. How public and private health insurance coverage mitigates catastrophic health expenditures in Republic of Korea. BMC Health Serv Res 2022;22:1042.
26. Kwon KN, Chung W. Effects of private health insurance on medical expenditure and health service utilization in South Korea: a quantile regression analysis. BMC Health Serv Res 2023;23:1219.
27. Baek EM, Oh JI, Kwon EJ. The effect of additional private health insurance on mortality in the context of universal public health insurance. Int J Environ Res Public Health 2021;18:8363.