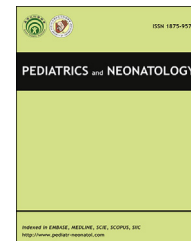


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ORIGINAL ARTICLE

Risk Factors and Outcome Analysis in Children with Carbon Monoxide Poisoning

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Key Words

carbon monoxide poisoning;
neurological sequelae;
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risk factors

Background: Carbon monoxide (CO) poisoning is one of the common causes of poisoning in patients and can result in significant morbidity and mortality. However, few studies have focused on the pediatric group.

Methods: We retrospectively reviewed children (age < 18 years) with CO poisoning from non-fire accidents at a tertiary medical center in Taiwan from 2002 to 2010. We analyzed the patients' characteristics, management, and outcome; compared the data of patients who received hyperbaric oxygen (HBO) to those who received normobaric oxygen (NBO) therapy; and identified the risk factors for patients who developed delayed neurological sequelae (DNS) or permanent neurological sequelae (PNS).

Results: A total of 81 children were enrolled. The annual case number increased from five cases in 2002 to 20 in 2010, particularly during the cold months (December to February). The most common source of exposure was an indoor heating system (54.3%). The most common presenting symptoms were vomiting (32.1%) and consciousness changes (30.9%). HBO treatment tended to be administered to patients with a higher initial COHb (%) ($p < 0.001$), an initial Glasgow coma scale change ($p < 0.001$), and admission to the hospital ($p = 0.002$). After multivariate analysis, treatment in the intensive care unit because of prolonged loss of

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consciousness ($p = 0.002$) was the only independent risk factor for patients with DNS; only rescue by a ventilator ($p < 0.001$) was an independent risk factor for patients with PNS. In comparison to the HBO therapy, HBO treatment did not show benefit or harm to patients according to the incidence of inducing DNS or PNS after multivariate analysis.

Conclusion: For those with treatment in the intensive care unit because of prolonged loss of consciousness and rescue by a ventilator, special attention should be given and follow-up should be performed to determine whether DNS or PNS occurs, particularly epilepsy and cognitive deficits.

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1. Introduction

Carbon monoxide (CO), an odorless gas formed during an incomplete combustion of organic material, is one of the most common poisons found in patients at the emergency department (ED).¹ In the United States, about 50,000 ED visits annually are attributed to CO poisoning, resulting in about 1000–2000 deaths annually.² In England, 4000 ED visits and 40 deaths are noted annually.³ In Taiwan, from 1997 to 2003, a significant increase from 1.6–3.5/10⁶ person-years was found in the rate of unintentional deaths from CO poisoning induced by inappropriately ventilated gas heating appliances, fires, and automobile exhaust fumes⁴; these causes were similar in Florida, and most (50–70%) of them occurred within the home.⁵

CO, which has 210 times the affinity for hemoglobin than that of oxygen, impairs oxygen delivery and peripheral utilization. CO can cause cellular hypoxia, subsequent oxidative stress and inflammation, and possibly neurological, cerebrovascular, or cardiovascular disorders, including encephalopathy, ischemia, and peripheral nerve injury.^{6–11} The outcome of poisoning is correlated with the initial carboxyhemoglobin (COHb) level, exposure duration, and underlying diseases of the exposed adult patients.^{1,12}

After acute CO poisoning, two neurological syndromes may occur: permanent neurological sequelae (PNS) and delayed neurological sequelae (DNS).⁶ The symptoms and signs range from subtle headache, mood disorders, personality changes, and memory loss to focal neurological injuries and severely disabling manifestations of hypoxic brain injury. PNS is characterized by central nervous system (CNS) symptoms or signs persisting for more than 3 months after CO poisoning. DNS is characterized by the development of new CO poisoning-associated symptoms or signs that may occur dramatically and abruptly after a period of days to weeks. About 40% of adults with CO exposure develop DNS. In the pediatric population, the incidence of DNS is lower (3–17%).¹³ A lack of pupil reflex and a loss of consciousness have been found to be independent predictors of neurological sequelae in patients with CO poisoning.¹⁴ However, the risk factors for pediatric patients developing DNS or PNS remain unknown.

Whether hyperbaric oxygen (HBO) treatment prevents the occurrence of DNS remains controversial.^{6,15} Some authorities recommend specific indications for HBO therapy (e.g., severe CO poisoning, prolonged exposure, pregnancy

or COHb levels $\geq 25\%$); however, there is no absolute indication for HBO therapy for patients with CO poisoning. The mortality rate for HBO-treated CO-poisoned patients is 2.6%; factors most strongly associated with mortality are severe metabolic acidosis and the need for endotracheal intubation.¹⁶ Whether HBO treatment benefits pediatric children remains to be determined.

Currently, few studies have focused on pediatric patients with CO poisoning. We performed a cohort study to analyze pediatric patients with CO exposure over 9 years at a medical center and analyzed the risk factors correlated with DNS or PNS.

2. Methods

2.1. Ethics

The present retrospective observational study was approved (Institutional Review Board number: 101-4247B) by the Medical Ethics Committee of Chang Gung Memorial Hospital, a 3700-bed tertiary referral center with 24-hour HBO service, and complied with the guidelines of the Declaration of Helsinki.

2.2. Study design, setting, study population, and inclusion criteria

From January 2002 to December 2010, we reviewed pediatric patients (age < 18 years) with a diagnosis of CO poisoning who received treatment at Chang Gung Memorial Hospital, a 3700-bed tertiary medical center. Most patients with CO intoxication were referred from other hospitals. We excluded those from fire accidents to avoid confounding factors.

2.3. Data collection and definition of variables

We recorded the patients' age and sex, causes of CO poisoning, initial presentations, first arterial blood gas and initial COHb levels, imaging studies, management, intensive care unit (ICU) stays, development of DNS, and outcome by chart review and telephone interview. All patients were followed for at least 6 months. For those developing PNS, they were followed for more than 1 year. We defined "consciousness change" as any changes in the

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