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Original Contribution

Domicile-related carbon monoxide poisoning in cold months and its relation with climatic factors

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Abstract

Background: Many studies have identified strong correlations between winter months and acute, unintentional carbon monoxide (CO) poisoning. In this study, we aimed to investigate the incidence pattern of acute domicile-related CO poisoning in Beijing and its relation with climatic factors.

Methods: Data on CO poisoning were collected from the emergency medical service system during August 1, 2005, to July 31, 2007, in Beijing. Variations of the monthly and seasonal distribution of CO poisoning occurrences were examined with χ^2 testing. Climatic data including temperature, barometric pressure, humidity, wind speed, and visibility were obtained from the Beijing Meteorological Bureau. Correlations between the occurrence of CO poisoning and mean of each meteorological parameter spanning 3 days were analyzed with partial correlation test, with related parameters controlled.

Results: Significant differences were found among the cases occurring each month of the year ($P <$ .001). The monthly caseload reached the peak and the nadir in January and in September, respectively. During the cold period, 3331 patients were recorded, accounting for 88.4% of the total cases of the 2-year study period. Among the 5 climatic parameters, only temperature had a significant inverse correlation with the occurrence of CO poisoning ($P <$ .001, r = –0.467).

Conclusions: The incidences of CO poisoning were highest during winter, particularly during the time period when charcoal or coal use for indoor heating would be most prevalent in Beijing.

1. Introduction

Carbon monoxide (CO) is but one gaseous molecule in a larger composite of particulates and gaseous species termed *products of incomplete combustion* resulting from incomplete fuel combustion [1]. Including CO, a range of volatile carbonyl compounds such as formaldehyde, benzene, and 1,3-butadiene has also been measured from the incomplete combustion of biomass and coal [2]. Long-term exposure to

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smoke from combusted hydrocarbon-containing fuel sources may lead to chronic respiratory illness, lung function reduction, lung cancer, and impaired immunity [3]. Symptoms of acute exposure to CO may include headache, nausea, vomiting, and dizziness in mild exposure and cardiopulmonary collapse and death in severe cases [4]. Understanding the epidemiology of CO poisoning is of importance in developing preventive strategies to combat this common problem affecting industrial and developing nations.

Carbon monoxide poisoning poses an important public health problem in China and elsewhere. In the study of Liu et al [5] conducted in Shenyang, a major city in north China, CO poisoning ranked second in all kinds of poisoning cases in the adult. Hitherto, there have no large-scale epidemiologic investigation on CO poisoning in Beijing. The city of Beijing, which is situated at latitude 39° north and longitude 116° east, has a warm, temperate, subhumid continental monsoon climate, with an annual average temperature of 10°C to 12°C. In January, the mean temperature varies from –7°C to –4°C; and in July, from 28°C to 26°C. Several studies have identified strong correlations between winter months and inclement weather conditions (eg, ice storms) and acute unintentional CO poisoning [6-8]. In this study, we aimed to investigate the seasonal pattern of acute CO poisoning in Beijing and its relation with climatic factors.

2. Methods

2.1. Study population

To investigate the incidence pattern of domicile-related CO poisoning in Beijing and its relation with climatic factors, the medical records from the emergency medical service (EMS) system during August 1, 2005, to July 31, 2007, in Beijing were collected and reviewed, with industrial-, fire-, and work-related cases excluded. The diagnosis, the time of occurrence of CO poisoning of each case, and the age and sex of the patients were extracted for the purpose of the present study.

2.2. Climatic data

To study the influences of climatic factors on the presentation of domicile-related CO poisoning, climatic data were obtained from the reports of the Beijing Meteorological Bureau during the study period. Climatic parameters including temperature, barometric pressure, humidity, wind speed, and visibility were recorded every 3 hours.

2.3. Data and statistical analysis

Each case and incident had the day, month, and hour of occurrence assigned for statistical analysis. Variations in monthly and seasonal distribution of CO poisoning occurrences were examined over a 2-year period. All distribution patterns were examined with χ^2 testing.

Based on historical weather patterns, the period from November 1 to March 31 was defined as the "cold period." To understand the age distribution of CO poisoning, cases in cold periods were grouped by each decade in age up to 79 years and by those older than 79 years. Based on the population ratio data from the Beijing Statistical Yearbook 2006 [9], adjusted frequency, corresponding to the relative frequency, was calculated by the following equation: adjusted frequency = cases of the age group/population ratio of the age group (%)/100.

To investigate possible correlations between the occurrence of domicile-related CO poisoning and climatic parameters, the records of temperature, barometric pressure, wind speed, humidity, and visibility during the cold period were extracted. Because climatic factors influence each other, Pearson correlation tests were performed to evaluate the relations between climatic factors. Partial correlation tests were performed between the case number and each mean of meteorological parameter spanning 3 days, with related parameters controlled. Two-tailed tests were used to measure significance during hypothesis testing. $P < .05$ was considered to be statistically significant. All analyses were carried out using the software Statistical Package for Social Sciences 11.5 (SPSS Inc, Chicago, IL).

3. Results

3.1. Monthly and seasonal distribution of domicile-related CO poisoning

A total of 3768 domicile-related CO poisoning cases (3163 incidents) were extracted from the medical records of the EMS system in Beijing. Significant differences were found among the cases occurring each month of the year

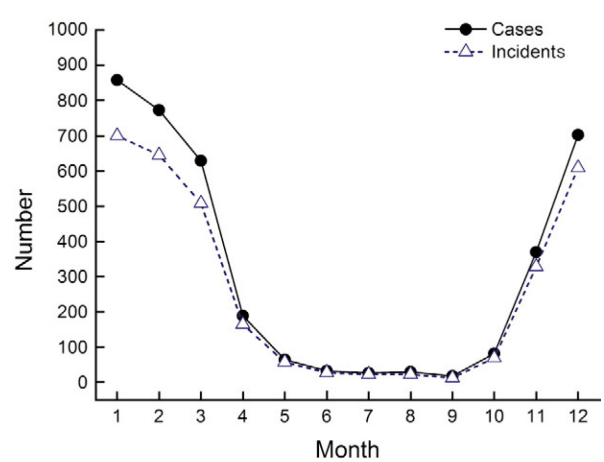

Fig. 1 Monthly variation in the incidence of CO poisoning.

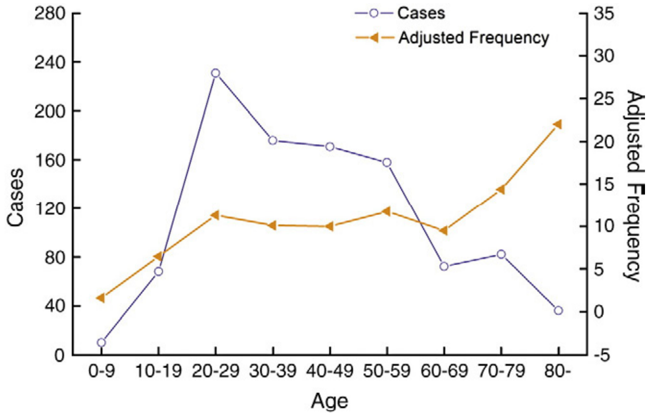

Fig. 2 Age distribution and adjusted frequency of CO poisoning cases during cold periods.

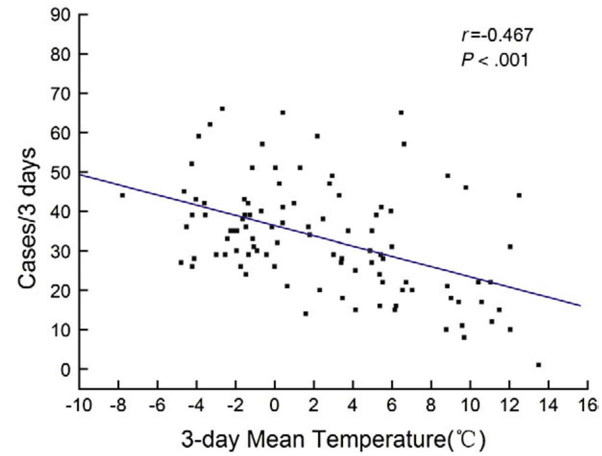

Fig. 3 Inverse correlation between the mean temperature and cases of CO poisoning in 3-day groups.

($\chi^2 = 672$, $P < .001$). The monthly caseload reached the peak and the nadir in January and in September, respectively. The highest number of cases occurred during the winter and spring months; and the fewest, in summer. A similar monthly and seasonal variation of incidents was observed (Fig. 1).

3.2. Demographic distribution of domicile-related CO poisoning in cold period

Of all CO poisoning cases, 88.4% occurred during the cold period spanning November 1 to March 31 of the 2-year study. During this time, a total of 3331 patients were diagnosed with CO poisoning. Among these, 2623 (79%) were male and 708 (21%) were female, with the ages ranging from 1 to 90 years. Grouped by decade, the age distribution of cases of CO poisoning were analyzed. The highest case number occurred in the third decade (20-29 years old). When data were normalized to the population ratio of each decade, there was a relatively stable frequency in age groups through the third to seventh decades. The incidence increased to 1.27-fold in the eighth decade and 1.95-fold in the ninth decade in comparison to that in the third decade (Fig. 2).

3.3. Relations between climatic parameters and domicile-related CO poisoning in cold period

Relations between climatic parameters are shown in Table 1. Grouped by 3-day intervals, the relations between the occurrence of CO poisoning and the mean values of temperature, barometric pressure, wind speed, humidity, and visibility during the cold period were analyzed, with the related climatic parameters controlled. The results of the partial correlation test indicated that temperature had a statistically significant inverse relation with the occurrence of CO poisoning (Fig. 3). The other 4 climatic parameters had no statistical significance in relation to the occurrence cases of CO poisoning (Table 2).

4. Discussion

In the present study, we did not seek, but we did discover that there was a significant sex difference in the EMS-diagnosed domicile-related CO poisoning cases. One explanation for the sex difference could be related to the numerous off-farm workers in Beijing from rural regions; most of off-farm workers are men. Their domicile conditions are generally poor, and utilization of coal for heating and cooking is prevalent among off-farm workers. Besides, men may be less circumspect and cautious than women. However, to support such a speculation, occupational and demographical data would be needed. The exact reason of the sex difference is worth further investigation.

Table 1 Correlations between meteorological parameters

	WS	Temp.	Humid.	Vis.
Press.	−0.006 (0.640)	−0.833 (<0.001) [a]	−0.211 (<0.001) [a]	0.163 (<0.001) [a]
WS	–	0.067 (<0.001) [a]	−0.477 (<0.001) [a]	0.425 (<0.001) [a]
Temp.	–	–	0.081 (<0.001) [a]	−0.012 (0.349)
Humid.	–	–	–	−0.682 (<0.001) [a]

Data are shown as Pearson correlation coefficient (significance). WS indicates wind speed; Temp., temperature; Humid., humidity; Vis., visibility; Press., barometric pressure.

[a] Correlation $P < .05$.

Table 2 Partial correlation test between the cases of CO poisoning and the means of meteorological parameters in 3-day intervals

	Press.	Vis.	WS	Temp.	Humid.
Cases	−0.180 (0.078)	−0.100 (0.330)	0.059 (0.565)	−0.467 (<0.001) [a]	0.047 (0.647)

Data are shown as partial correlation coefficient (significance). Press. indicates barometric pressure; Vis., visibility; WS, wind speed; Temp., temperature; Humid., humidity.
[a] Correlation $P < .05$.

In the present study, we cannot distinguish intentional cases from all the EMS-diagnosed CO poisoning cases because the data are insufficient. However, it is interesting to note that CO overdose is not a popular way for suicide in China. In one study on CO poisoning in a major city of China, intentional CO poisoning cases accounted for only 0.6% (3/469) of all CO poisoning cases, whereas household heating accounted for the causes in 93.8% (440/469) of all cases [10]. The authors believe that the present data represent the epidemiological characteristics of unintentional domicile-related CO poisoning cases in Beijing.

The association between unintentional domicile-related unintentional CO poisoning and cold weather has long been established in other settings. In a population-based case-control study of risk factors for unintentional mortality from CO poisoning in Taiwan, Shie and Li [11] found that mortality odd ratio peaked in cold periods and that a daily maximum temperature of less than 18.4°C was associated with a 2.15-fold increase in mortality compared with a daily maximum temperature of 27.1°C or greater. Kim [12] also reported a 9-fold increase in the number of cases of CO poisoning in December as in August in Seoul, Korea. In the United States, unintentional CO poisoning has been linked to winter months and outbreaks of ice storms [6-8]. In the *Morbidity and Mortality Weekly Report* published by the US Centers for Disease Control and Prevention, the greatest number of nonfatal, unintentional, non–fire-related CO exposure cases occurred during winter and the average daily number of CO-related deaths was greatest during the months of January and December and lowest during the months of July and August [13,14]. Our data support that this is true for the Beijing metropolitan area, where the incidences of CO toxicity during winter were nearly 3-fold that in spring and 5-fold that in autumn. We also demonstrated in the present study that temperature is the only independent meteorological factor related to the occurrence of CO poisoning in Beijing.

It has been postulated that the rise in unintentional CO poisoning during the cold periods is due to indoor CO release from heating sources. In the United States, where solid fuels (eg, biomass and coal) are seldom used for household cooking and/or heating, unconventional indoor heating devices such as indoor grills or gas generators used during power outages because of inclement weathers have been implicated as the source of CO in unintentional CO poisoning [6,8]. Sinton et al [15] undertook the momentous task of reviewing some 120 published studies measuring the indoor concentration of pollutants in rural and/or urban households of 29 provinces and municipalities of Beijing, Shanghai, Tianjin, and Chongqing. Coal was consistently identified as the heating source responsible for generating indoor CO in Beijing before 1996. In a study investigating the association between childhood asthma and indoor air pollution in Shunyi County of Beijing, the utilization of coal for heating and cooking was still prevalent [16]. However, the direct correlation between CO poisoning and increased charcoal and coal use in Beijing can only be inferred from our study. In present study, 88.4% of CO poisoning occurred during days when charcoal and coal heating would be most prevalent in Beijing. We obtained the sales data of the study period from one of the largest home-use coal supplier in Beijng (Beijng Golden Tide Co, Ltd). The sales data show obvious seasonal variation. A dramatic rise in coal sales in August was in anticipation of its use during the cold months. Coal sales persisted throughout winter and tapered in Spring (Fig. 4).

Despite the rapidly increasing pace of urbanization, an estimated 60% of the population in China is still rural [3]. Energy consumption in the forms of biomass and coal in rural Chinese households in 2003 was estimated to be 80% and 10%, respectively [3]. In a study conducted by Zhang et al [17], household coal and biomass cook stoves in China were found to divert more than 10% and up to 38% of their fuel carbon into products of incomplete combustion,

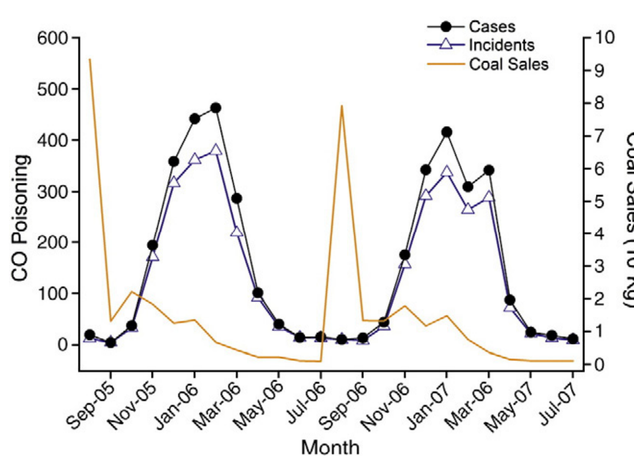

Fig. 4 Cases of EMS-diagnosed domicile-related CO poisoning and home-use coal sales data of Beijng Golden Tide Co, Ltd. The manufacturer notes that people are accustomed to buying heating coal 1 to 2 months before anticipated use.

including CO. The negative impact of indoor air pollution in China has not gone unnoticed. The Chinese government instituted the National Improved Stove Program (NISP) in the early 1980s as a measure to improve stove function, thereby reducing indoor air pollution in rural communities of China. Headed by the Chinese Ministry of Agriculture, rural households were provided more efficient biomass stoves for cooking and heating, which later expanded to include improve coal stoves [18]. Despite the government's ambitious efforts, in an independent, multidisciplinary review of the NISP, Edwards et al [19] concluded that the improvement of the indoor air quality in rural households was still far from the established national standards. Such programs targeting urbanized cities such as the municipality of Beijing have never been instituted. Public health policies addressing CO poisoning in Beijing will be dependent on the source of contribution of CO. One such method is a nationalized approach, such as the NISP, targeting the municipality of Beijing.

There are 2 major limitations of our study. The first is that the diagnosis of CO poisoning was made clinically, in the prehospital setting by EMS physicians, and was not confirmed with further studies. The second is the failure to identify the source of CO poisoning. Although it is generally believed that coal is the main source of CO release in domestic heating system in Beijing, we did not identify this in the present study. To better establish the correlation between increased CO poisoning and increased charcoal/coal use during winter, data pertaining to indoor charcoal/coal use by affected patients should be obtained.

Another weakness is that some other climatic factors such as precipitation and daylight time were not included in the above analysis. As a matter of fact, precipitation is scarce in winter in Beijing, and its influence is minor and quite transient. According to the data of Beijing Statistical Yearbook, precipitation occurs mainly in the warmer spring and summer months. During the study period, only 8.0% precipitation (57.8 mm) occurred during the cold period (November-March) [9,20,21]. The daylight time of Beijing is related to its latitude. In the Spearman correlation test, daylight time shows no significant correlation with the cases of EMS-diagnosed domicile-related CO poisoning (r = –0.100, P = .084). Thus, the increased cases of CO poisoning in cold months cannot be attributed to changes in precipitation or daylight time in winter.

In conclusion, CO poisoning still poses a major public health problem in Beijing. The incidence of CO poisoning was highest in cold months, when charcoal/coal use for indoor heating is most prevalent. During such periods, temperature is the only climatic parameter that demonstrated a statistically significant inverse relation with CO poisoning occurrences. Further studies will need to be conducted to establish the source(s) of CO poisoning to devise public health policies to reduce the number of CO poisoning in Beijing and the myriad cities worldwide using coal or biomass for heating.

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