ORIGINAL ARTICLE

An Outbreak of Carbon Monoxide Poisoning in Yamagata Prefecture Following the Great East Japan Earthquake

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Background: In the aftermath of the Great East Japan Earthquake, most of the areas in Yamagata prefecture experienced a serious power failure lasting for approximately 24 hours. A number of households were subsequently poisoned with carbon monoxide (CO) due to various causes. In this study, we conducted a survey of CO poisoning during the disaster.
Methods: A questionnaire regarding CO poisoning associated with the disaster was sent to 37 emergency hospitals in Yamagata prefecture.
Results: A total of 51 patients were treated for unintentional CO poisoning in 7 hospitals (hyperbaric oxygen chambers were present in 3 of the hospitals). The patients (18 men, 33 women) ranged in age from 0 to 90 years. The source of CO exposure was charcoal briquettes (23 cases; 45%), gasoline-powered electric generators (18 cases; 35%), electric generators together with oil stoves (8 cases; 16%), oil stoves (1 cases; 2%), and automobile exhaust (1 cases; 2%). Blood carboxyhemoglobin levels ranged from 0.5% to 41.6% in 49 cases. Of these, 41 patients were treated by normobaric oxygen therapy, while one was intubated for artificial respiration. Additionally, 5 patients (10%) were treated by hyperbaric oxygen therapy, and 3 patients (6%) experienced delayed neuropsychiatric sequelae.
Conclusion: CO sources included gasoline-powered electric generators and charcoal briquettes during the disaster. Storm-related CO poisoning is well recognized as a disaster-associated accident in the United States, but not in Japan. We emphasize that public education is needed to make people aware of the dangers of CO poisoning after a disaster. In addition, a pulse CO-oximeter should be set up in hospitals.

Keywords: Carbon monoxide; the Great East Japan Earthquake; Electric generator; Charcoal briquette; Poisoning

INTRODUCTION

On March 11th 2011, a 9.0 magnitude earthquake (The Great East Japan Earthquake) struck northeastern Japan (1). In the aftermath of the earthquake, electric power service was disrupted in East Japan. Yamagata prefecture has a population of 1,000,000 and abuts the western borders of Miyagi and Fukushima prefectures, which face the Pacific Ocean on their eastern sides (Figure 1). Both Miyagi and Fukushima prefectures suffered severely in the disaster, while Yamagata prefecture experienced one of the largest power failures lasting for approximately 24 hours (2). In addition, the temperature was below 0°C, and snowfall occurred throughout the night. Therefore, some people used alternate fuel sources to provide power and warmth. Consequently, a number of citizens were poisoned with CO after the earthquake, and were transferred to Yamagata University Hospital (2).

In this study, we conducted a survey of CO poisoning after the Great East Japan Earthquake in Yamagata prefecture.

METHODS

We sent a questionnaire regarding CO poisoning associated with the disaster to 37 emergency hospitals in Yamagata prefecture. The questionnaire included items on patient information, such as the date of admission, sex, age, blood carboxyhemoglobin (CO-Hb) level, the cause of CO exposure, treatment, and sequelae. The diagnosis was made using a combination of the information available, including the situation, symptoms, and CO-Hb levels. Clinical manifestations on admission were obtained from medical records of hospital and fire station.

Data from the questionnaire and medical records including age, CO-Hb levels and clinical manifestation were summarized and calculated. Data are shown with frequency and percentage. Age and CO-Hb levels are shown with mean and standard deviation (SD).

RESULTS

All hospitals sent back completed questionnaires. Seven hospitals, including 3 with hyperbaric oxygen chambers, received patients with CO poisoning. The hospitals in areas with no power outage during the disaster had no patient with CO poisoning.

A total of 51 patients (18 men, 33 women) referred to emergency outpatient units in Yamagata prefecture because of disaster-associated CO poisoning (Table 1). Mean (SD)

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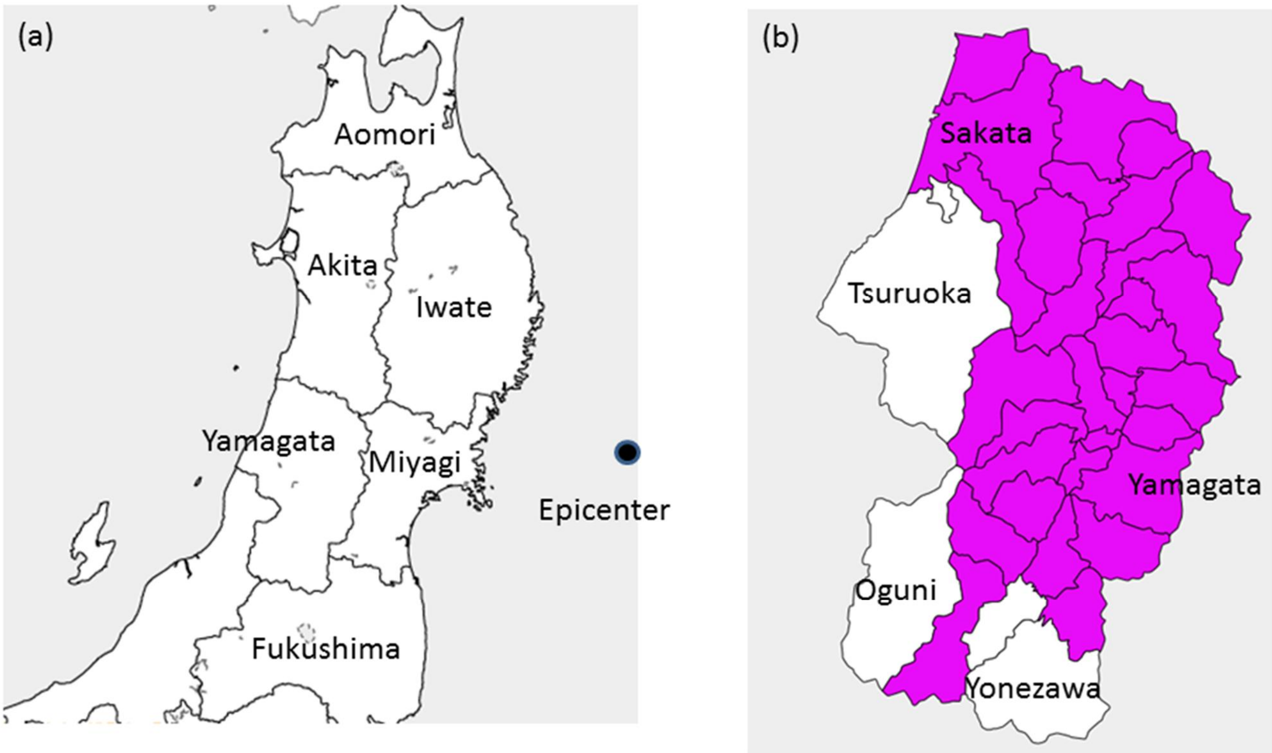

Figure 1. Geographical locations affected by the Great East Japan Earthquake (a). The area of the power outage in Yamagata prefecture (b)

Epicenter is the point where the earthquake originates

age of the patients was 49.8 (26.4) years (range: 0–90 years). The source of CO exposure was charcoal briquettes (23 cases; 45%), gasoline-powered electric generators (18 cases; 35%), electric generators together with oil stoves (8 cases; 16%), oil stoves (1 case; 2%), and automobile exhaust (1 case; 2%) (Figure 2). The first recorded patient admitted to hospital 7 hours after the earthquake (Figure 3). The last case was a man suffered CO poisoning from burning charcoal in his car while waiting in line for a gas station to open, 10 days after the earthquake (March 22).

In the elderly (>64 years), charcoal briquettes were the cause of CO poisoning in 15 out of 16 cases (93%). Among patients aged 19–64 years of age, in 16 out of 25 cases (64%) the poisoning resulted from gasoline-powered electric generators (Table 1). In patients below 18 years of age, electric generators were responsible for CO poisoning in 9 out of 10 patients (90%). CO poisoning occurred at home (48 cases, 94%), in motor vehicles (2 cases), and in a plastic greenhouse (1 case).

Main clinical manifestations of 51 CO poisoned patients included loss of consciousness (18 cases; 35%), headache (16 cases; 31%) and weakness (13 cases; 25%) (Table 2). All patients except a child showed one or more symptoms of CO poisoning.

Mean blood CO-Hb level in 49 of the patients was 22.0 (8.7) (range: 0.5–41.6) % (Table 3). Of these, 41 patients were treated by normobaric oxygen therapy with a face-mask, while 1 patient was intubated for artificial respiration.

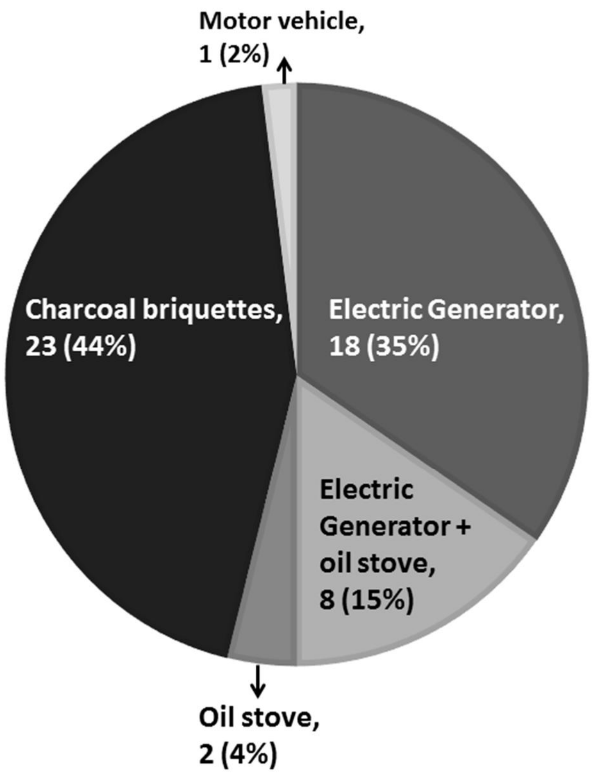

Figure 2. Sources of carbon monoxide poisoning in the disaster

Table 1. Characteristics of the carbon monoxide poisoned patients and sources of carbon monoxide

Age	Total	Male	Female	Source of carbon monoxide				
				Electric Generator	Electric Generator + Oil stove	Oil stove	Charcoal briquette	Motor vehicle
0-3	2	1	1	2	0	0	0	0
4-12	5	1	4	3	2	0	0	0
13-18	3	1	2	1	1	0	1	0
19-40	8	4	4	1	2	0	4	1
41-64	17	9	8	10	3	1	3	0
>64	16	4	12	1	0	0	15	0
Total	51	20	31	18	8	1	23	1
		(39%)	(61%)	(35%)	(16%)	(2%)	(45%)	(2%)

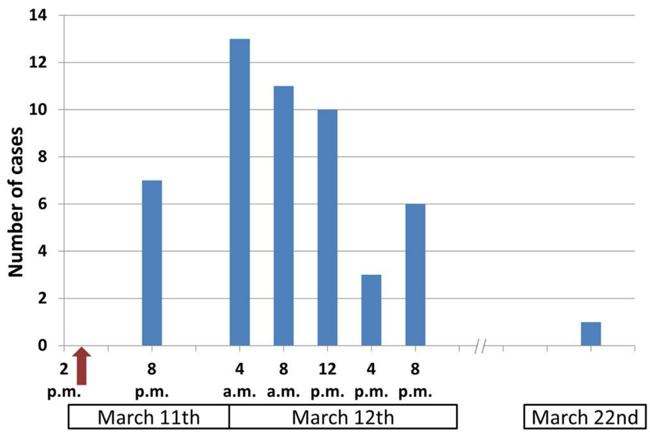

Figure 3. Frequency of disaster-related carbon monoxide poisoned patients after the earthquake admitted to Yamagata university hospitals

Red arrow indicates the time that the earthquake occurred (2:46 p.m. Japanese Standard Time, March 11th 2011)

Table 2. Clinical findings of carbon monoxide poisoned patients

Findings	No. (%)
Clinical manifestations	
Loss of Consciousness	18 (35)
Headache	16 (31)
Weakness	13 (25)
Nausea and Vomiting	9 (18)
Dizziness	5 (10)
Ataxia	4 (8)
Dyspnea	2 (4)
Palpitation	1 (2)
Complications	
Neurologic sequelae	3 (6)
Death	0 (0)

Table 3. Blood carboxyhemoglobin level and treatments administered to CO poisoned patients

Blood carboxyhemoglobin (%)	No. of cases	Treatment		
		Artificial ventilation	HBO	NBO
40-50	1	0	0	1
30-40	7	0	2	5
20-30	20	0	3	17
10-20	19	1	0	18
0-10	2	0	0	1
Total	49	1	5	42

HBO; Hyperbaric oxygenation
NBO; Normobaric oxygenation

In addition, 5 patients (10%) were treated by hyperbaric oxygen therapy.

Three of the patients (6%) experienced delayed neuropsychiatric syndrome, such as mild dementia in 2 cases and severe cognitive impairment in one case, and the others had no sequela. No fatality due to CO poisoning occurred in Yamagata prefecture during the disaster.

Following the restoration of electric power, no other case of CO poisoning occurred in these areas.

DISCUSSION

Japan has experienced a number of large earthquakes and tsunamis so far. In the Great East Japan Earthquake, over 19,000 people were killed or missing, mostly due to the resultant tsunami (3). In the Great Hanshin-Awaji Earthquake in 1995, over 6,300 people were killed, and over 43,000 were wounded because of houses collapsing (4). In both natural disasters, the occurrence of CO poisoning did not appear to be recognized as a safety concern. In the United States, however, storm-related CO poisoning is a well-known consequence of power outages following winter storms and hurricanes, with gasoline-powered electric generators and charcoal briquettes often representing the main sources of CO (5). For instance, in January 1993, both charcoal briquettes (47% of incidents) and gasoline-powered electric generators (33%) represented the primary sources of CO poisoning after a severe ice storm in Washington (6).

In the United States, unintentional, non-fire-related CO poisoning estimated approximately 15,000 emergency department visits and nearly 500 deaths annually (7,8). Between 1991 and 2009, 362 incidents and 1888 cases of disaster-related CO poisoning were reported in the United States and the main source of CO was generator (46.6% of incidents) and charcoal grill (23.6%) (9). In Yamagata prefecture, after the recent earthquake, the main sources of CO exposure were similarly gasoline-powered electric generators (51%) and charcoal briquettes (45%). In Aomori prefecture, a total of 77 patients were affected with CO poisoning during the first 3 days of the disaster, with charcoal briquettes (65%) and gasoline-powered electric generators (25%) as the primary sources of CO exposure (unpubl. data).

In the United States, CO poisoning occurs most commonly through indoor use of charcoal briquettes during ice and snow storms (10). In Japan and other Asian countries, charcoal briquettes have been used for heating and cooking since ancient times. In the CO poisoning outbreak in Washington in 1993, charcoal grills were the primary cause of CO poisoning in Asian-American communities (6,11). In November 1997, with the aim of preventing CO poisoning, the United States Consumer Product Commission started the government-mandated warning label that is printed on charcoal packages (5). This strategy is believed to result in the subsequent progressive lowering of CO poisoning deaths (5). In January 2009, an ice storm struck Kentucky, which caused widespread power outages (12).

At that time, the most common sources of CO poisoning included Kerosene heaters (45% of incidents) and generators (31%), and charcoal was associated with CO poisoning in only 5% of the cases. Our study revealed that mostly elderly people (aged >64 years) suffered from CO poisoning due to charcoal briquettes. Japan should also introduce similar warning labels on the charcoal bag to provide public education on this issue, especially for elderly

Interestingly, one patient suffered CO poisoning after burning charcoal briquettes in his car to obtain warmth. In northeastern Japan, a severe gasoline shortage occurred because the tsunami destroyed the oil stations in the bay area of the Pacific Ocean. People waited in cars for several hours to obtain gasoline during the middle of the night. A similar situation was also noted in Shirakawa city, Fukushima prefecture (unpubl. data).

Gasoline-powered electric generators are also a major source of storm-related CO poisoning (13). The indoor use of generators can lead to CO poisoning in many storms, but even the outdoor use of generators can result in CO poisoning when placed less than 7 feet from home. Our study showed that most of the patients aged 19-64 years were exposed to CO through the use of generators. We also found that CO poisoning due to generators occurred for the most part in the agricultural region in Yamagata prefecture. Yamagata prefecture is famous for rice and various kinds of fruits; and the farmers use generators in plastic greenhouses. In this disaster, they suffered from CO poisoning while trying to obtain electric power. For preventing CO poisoning, illustrations accompanied with instructions should be attached as warnings on the surface of the generator (14). Moreover, providing public education on the risks of CO poisoning is necessary, especially for those living in agricultural areas in Japan. Public announcements on the radio and television and raising awareness by regional poison centers could play an important role in preventing CO poisoning during disasters.

Headache, nausea, breathlessness, collapse, dizziness and loss of consciousness are major symptoms of CO Poisoning (7,15). In the three years surveillance study of CO poisoning, headache and loss of consciousness were found to be the most common symptoms in the United States (16). Similarly, headache (35.3%), nausea (25.4%), vomiting (21%), dyspnea (10.3%), and reduced level of consciousness (4.8%) were reported as the major manifestations in the west area of Iran (17). In 1997, dizziness, headache and nausea occurred as the major symptoms of CO poisoning after a severe flood in North Dakota (18). In 2008, fatigue (80%), headache (79%), dizziness (84%), nausea (76%) and vomiting (71%) were the main reported symptoms of CO poisoning after a massive ice storm in Southern China (19). Our study showed that similar symptoms such as loss of consciousness (35%), headache (31%) and weakness (25%) were the most frequent in CO poisoned patients after the Great East Japan Earthquake. However, it is noted CO poisoning is often underdiagnosed or misdiagnosed as another illness (9). Therefore, people should be aware of major symptoms described above as CO poisoning (15). Recently, serum plasma levels of CO can be measured with a pulse CO-oximeter placed on the patient's finger (15). However, for the majority of incidents, the diagnosis of CO poisoning was confirmed by blood gas analysis in the hospital. Therefore, we believe that a pulse CO-oximeter is a useful tool for the screening and detection of CO poisoning in disasters. Hospitals and Disaster Medical Assistance Teams (DMAT) should be equipped with pulse

CO-oximeters in preparation for further disasters.

LIMITATIONS

The results presented in this article are only related to Yamagata prefecture and not to other areas affected in the Great East Japan Earthquake. Moreover, in this study, data were not directly collected by the researchers and were collected retrospectively with questionnaire. Hence, bias in data collection could be another limitation.

CONCLUSION

In Japan, large earthquakes are predicted to occur around the Pacific Coast area in the near future. CO poisoning epidemics after disasters are common but preventable. We emphasize that public education is needed to make people aware of the dangers of CO poisoning after a disaster. In addition, a pulse CO-oximeter should be set up in hospitals and for DMAT.

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