




Original Article

Prehospital characteristics, incidence trends, and outcome of emergency self-inflicted injury patients with gas substances: a population-based descriptive study in Osaka, Japan

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Aim: Little is known about the detailed characteristics of patients using gas substances for self-inflicted injury in prehospital settings. The aim of this study was to investigate the characteristics, incidence trends, and outcomes of patients who used gas substances for self-inflicted injury in Osaka City, Japan, using ambulance records.

Methods: This was a retrospective observational study that used data from 2009 to 2015. We extracted details from ambulance records of self-inflicted injury patients who used gas substances. The annual incidence of self-inflicted injury by gas substance and age group and Poisson regression models were applied for calculating the annual incidence trend by type of gas substance. The main outcome was confirmed death at the scene, and we also calculated the crude odds ratios and 95% confidence intervals for each gas substance.

Results: During the study period, there were 324 self-inflicted injury patients who used gas substances. The most commonly used gases were carbon monoxide (CO) (54.9%), followed by hydrogen sulfide (12.7%), helium (6.5%). The incidence of CO and hydrogen sulfide have subsequently decreased (P for trend = 0.023 and <0.001 , respectively); however, the incidence of helium did not change during the study period (P for trend = 0.586). The mortality rate was highest in patients who used helium (66.7% [14/21]) and the crude odds ratio of helium was 3.857 (95% confidence interval, 1.267–11.745; $P = 0.017$) compared with hydrogen sulfide.

Conclusion: This study revealed that the incidence of self-inflicted injury with helium did not change and its proportion of death at the scene was high in Osaka City.

Key words: Emergency, epidemiology, gas substance, incidence, self-inflicted injury

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INTRODUCTION

SUICIDE PREVENTION IS an important public health issue worldwide. In Japan, approximately 20,000 people commit suicide every year, that is, approximately 20 victims per 100,000 residents, and Japan's incidence was third highest among the 36 OECD countries.¹ Hanging by the neck has been the most commonly adopted method of suicide,

followed by jumping from a height and gassing oneself.² People in Japan began committing suicide with hydrogen sulfide generated from detergent and acid so frequently that it temporarily became a social problem around 2010.³ Therefore, it is important to reveal the time trend, characteristics, and outcomes of self-inflicted injury patients using gas substances. A previous study revealed the characteristics and time trends of suicide patients with domestic gas or CO.⁴ However, little is known about the actual detailed situations of self-inflicted injury with gas substances, such as hydrogen sulfide or helium, in prehospital settings, and analyzing the population-based ambulance records would be, therefore, helpful for the prevention and management of self-inflicted injuries using gas substances. Indeed, it is unclear whether there are differences in characteristics in terms of age groups and mortality at the scene between the types of gas substances. In Japan, emergency medical service (EMS) such as an ambulance use is public service and the records have collected exhaustingly. The aim of this study was to describe the detailed characteristics of emergency patients with self-inflicted injuries involving gas substances by analyzing the population-based ambulance records in Osaka City, Japan.

METHODS

Study design and dataset

THIS WAS A retrospective observational study of patients transported by the Osaka Municipal Fire Department in Japan during the 7 years from 1 January 2009 to 31 December 2015. Osaka City, the largest metropolitan community in western Japan, covers an area of 222 km² and had a population of approximately 2.6 million in 2015. The municipal EMS system is basically the same as that in other areas of Osaka Prefecture, as previously described.⁵ The EMS system is operated by the Osaka Municipal Fire Department and is activated by phoning 119. In 2013, there were 25 fire stations with 60 ambulances and one dispatch center in Osaka City and the number of dispatches in Osaka City is approximately 200,000 per year. Emergency medical service life support is available 24 h a day. Usually, each ambulance has a crew of three emergency providers.⁶ The ambulance records were from an anonymized dataset and this study was approved by the Ethics Committee of Osaka University Graduate School of Medicine (Suita, Japan).

Study setting and population

In this study, we extracted emergency patients with self-inflicted injuries from gas substances, such as CO and helium, from EMS ambulance records. Excluding accidental cases

and self-inflicted injury using drugs, knife, neck hanging, fall from a height, other methods, and unknown means, this study focused on gas substances and divided them into the following five groups: CO, hydrogen sulfide, helium, other, unknown. The others category included city gas, stove gas, lighter gas, paint thinner, air duster, gas canister, herbicide, insecticide, chlorofluorocarbon, air-conditioner, and carbon dioxide. Unknown cases were those without detailed records about the sources of gas substances.

Data collection and quality control

Data were uniformly collected using specific data collection forms and included age, sex, reason for ambulance call, location of accident, time of the day, day of the week, and used tool.⁶ Detailed accident situation and patient information were recorded in the text form. These data were completed by EMS personnel and then transferred to the information center in the Osaka Municipal Fire Department. If the data sheet was incomplete, it was returned to the relevant EMS personnel for them to correct.

Data analysis

First, we described the characteristics of patients by type of gas substance and the annual incidence of self-inflicted injury patients per 100,000 habitants by gas substance and age group (divided by 20-year age stratum). In addition, Poisson regression models were applied for calculating the annual incidence trend by type of gas substance. The main outcome was confirmed death at the scene, and we also calculated the crude odds ratio and 95% confidence intervals for each gas substance. All statistical analyses were undertaken using SPSS statistical package version 23.0 J (IBM, Armonk, NY, USA). All tests were two-tailed, and *P*-values <0.05 were considered statistically significant.

RESULTS

Characteristics

FIGURE 1 shows an overview of patients in this study. Among the 1,493,106 ambulance dispatches in Osaka City during the study period, 11,258 emergency patients with self-inflicted injuries were enrolled. Excluded patients were 4,702 patients who overdosed on a drug, 1,498 patients who injured themselves with a knife, 641 patients who hanged themselves, 182 patients who fell from a height, 1,436 patients who injured themselves with other methods, and 2,475 patients who used unknown means. A total of 324 patients used gas substances, and 137 (42.3%) patients died at the scene.

Table 1 shows the characteristics of all cases by type of gas substance. The most commonly used gases were CO (54.9%), followed by hydrogen sulfide (12.7%), helium (6.5%), and city gas (2.9%). Among the patients using CO, 33.7% were injured by themselves in a car; among those using helium, 66.7% were injured by themselves in a residential indoor location. The patient characteristics regarding other gas substances are shown in Table S1.

Figure 2 shows the incidence of self-inflicted injury patients per 100,000 habitants by gas substance and age group. Carbon monoxide was the most common in any age group. The annual incidence of self-inflicted injury with CO was high in the group aged 20–49 years old (peak 1.66 in the group aged 40–49 years old), and the incidence of helium was 0.42 among patients aged 20–29 years old. In terms of the source of CO, 139 patients (78%) used a clay charcoal stove with artificial coal, 20 patients (11%) used unknown methods, and 19 patients (11%) used exhaust by automobile. In the 41 cases that used hydrogen sulfide, there were nine cases with a notice on the wall saying the occurrence of hydrogen sulfide in their rooms, and seven cases died at the scene. In the 21 cases with helium, there were 16 cases with plastic bags on their faces, and 10 cases dead at the scene. There were no cases that used helium in the group aged over 60 years old.

Incidence and outcome

Figure 3 shows the incidence of all self-inflicted injury per 100,000 habitants. In Osaka, the incidence of self-inflicted injury per 100,000 habitants decreased since 2010, and it was 25.2 in 2015 (P for trend <0.001). Figure 4 shows the secular changes in self-inflicted injury by type of gas substance. The incidence of self-inflicted injury with gas substances decreased in total. The incidence of hydrogen sulfide has subsequently decreased (P for trend <0.001) and the incidence of CO has subsequently decreased (P for trend = 0.023); however, the incidence of helium did not change during the study period (P for trend = 0.586).

Table 2 shows the proportion of confirmed deaths at the scene by type of gas substance. The mortality rate was highest in patients who used helium (66.7% [14/21]). Compared with hydrogen sulfide, the crude odds ratio of helium was 3.857 (95% confidence interval, 1.267–11.745; P = 0.017).

DISCUSSION

WE REVEALED THE prehospital characteristics, incidence trends, and outcomes of self-inflicted injury with gas substances using population-based ambulance records in Osaka City, Japan. Carbon monoxide was used

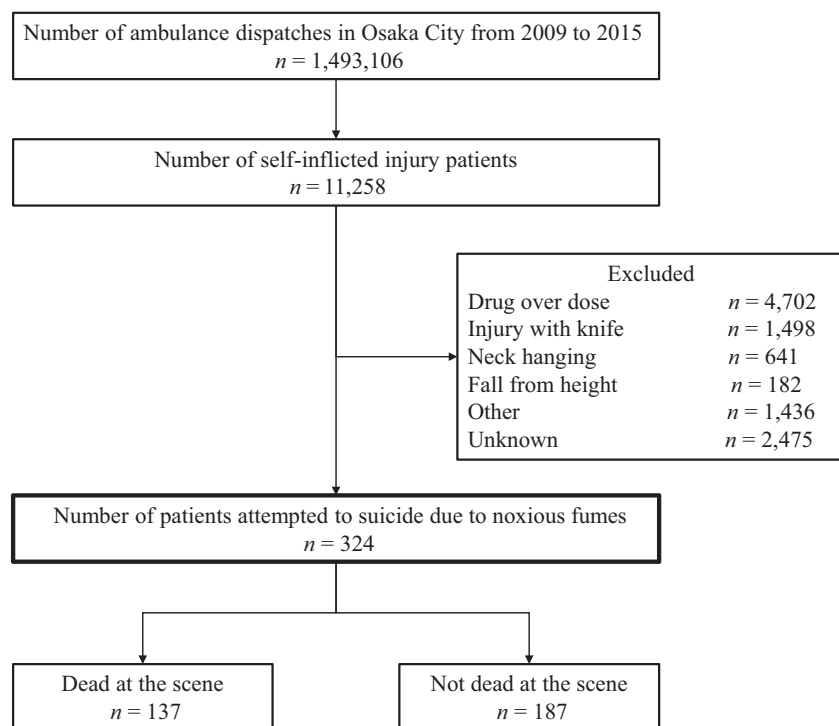


Fig. 1. Proportion of deaths at the scene among patients who injured themselves using gas substances in Osaka City, Japan, 2009–2015.

Table 1. Characteristics of 324 Japanese patients who self-harmed using gas substances, grouped by type of gas substances

	Total <i>n</i> = 324	Type of noxious fumes					<i>P</i> -value	
		Carbon monoxide <i>n</i> = 178	Hydrogen sulfide <i>n</i> = 41	Helium <i>n</i> = 21	Others <i>n</i> = 49	Unknown <i>n</i> = 35		
Sex								
Male	207 (63.9)	123 (69.1)	27 (65.9)	13 (61.9)	27 (48.6)	17 (55.1)	0.157	
Female	97 (29.9)	48 (27.0)	12 (29.3)	6 (28.6)	17 (40.0)	14 (34.7)		
Unknown	20 (6.2)	7 (3.9)	2 (4.9)	2 (9.5)	5 (11.4)	4 (10.2)		
Age group (years)								
10–19	8 (2.5)	2 (1.1)	3 (7.3)	1 (4.8)	2 (4.1)	0 (0.0)	0.150	
20–29	72 (22.2)	28 (15.7)	10 (24.4)	10 (47.6)	18 (36.7)	6 (17.1)		
30–39	73 (22.5)	43 (24.2)	5 (12.2)	4 (19.0)	13 (26.5)	8 (22.9)		
40–49	67 (20.7)	47 (26.4)	7 (17.1)	3 (14.3)	6 (12.2)	4 (11.4)		
50–59	33 (10.2)	23 (12.9)	4 (9.8)	1 (4.8)	2 (4.1)	3 (8.6)		
60–69	24 (7.4)	13 (7.3)	2 (4.9)	0 (0.0)	1 (2.0)	8 (22.9)		
70–79	6 (1.9)	5 (2.8)	0 (0.0)	0 (0.0)	1 (2.0)	0 (0.0)		
≥80	4 (1.2)	3 (1.7)	1 (2.4)	0 (0.0)	0 (0.0)	0 (0.0)		
Unknown	37 (11.4)	14 (7.9)	9 (22.0)	2 (9.5)	6 (12.2)	6 (17.1)		
Location of accident								
Residential indoors	122 (37.7)	52 (29.2)	11 (26.8)	14 (66.7)	30 (61.2)	15 (42.9)	0.001	
Car	72 (22.2)	60 (33.7)	4 (9.8)	0 (0.0)	0 (0.0)	8 (22.9)		
Bathroom	62 (19.1)	45 (25.3)	11 (26.8)	0 (0.0)	1 (2.0)	5 (14.3)		
Toilet	25 (7.7)	10 (5.6)	7 (17.1)	1 (4.8)	6 (12.2)	1 (2.9)		
Hotel	12 (3.7)	1 (0.6)	2 (4.9)	4 (19.0)	3 (6.1)	2 (5.7)		
Other	28 (8.6)	8 (4.5)	5 (12.2)	2 (9.5)	9 (18.4)	4 (11.4)		
Unknown	3 (0.9)	2 (1.1)	1 (2.4)	0 (0.0)	0 (0.0)	0 (0.0)		
Time of day when the patient was discovered								
0.00–5.59 AM	39 (12.0)	22 (12.4)	3 (7.3)	2 (9.5)	3 (6.1)	9 (25.7)		0.618
6.00–11.59 AM	76 (23.5)	40 (22.5)	12 (29.3)	3 (14.3)	10 (20.4)	11 (31.4)		
12.00–5.59 PM	107 (33.0)	63 (35.4)	13 (31.7)	9 (42.9)	18 (36.7)	4 (11.4)		
6.00–11.59 PM	102 (31.5)	53 (29.8)	13 (31.7)	7 (33.3)	18 (36.7)	11 (31.4)		

most frequently and helium was characteristic of adolescents and young adults. Although the incidence of CO and hydrogen sulfide has been decreasing over the years, the incidence of helium did not change. Compared with hydrogen sulfide, the proportion of deaths at the scene involving helium was high. We assessed the large-scale population-based ambulance records and these findings would be helpful for measures to reduce the number of self-inflicted injuries using gas substances.

Carbon monoxide was the most frequently used gas substance in this study, followed by hydrogen sulfide and helium. Carbon monoxide was most the frequently used suicide method using gas substances around the world. However, as the source of CO, the proportion of charcoal burning was high in many East Asian countries, including Japan,^{7–9} but the proportion of motor vehicle exhaust was high in the USA.¹⁰ In addition, although the second most

commonly used gas substance was hydrogen sulfide in this study, the second was helium in the USA.¹⁰ These difference in suicide method might be due to lifestyle differences, in that the general public uses charcoal for their daily lives in East Asia, and variation between countries in exposure to suicide-related information other than CO through the mass media and the Internet. In particular, if the information on self-inflicted injuries with any gas substances increased on the Internet, the frequency and method of self-inflicted injuries with gas substances would change in the future.

In addition, the incidence of self-inflicted injury due to CO was high in adults aged 20–49 years old, and the incidence of hydrogen sulfide was high in young adults aged 20–29 years old. Information as to how to injure themselves using gas substances can be easily accessed using the Internet at any time for everyone, especially younger adults. For example, suicides due to helium in the Netherlands during

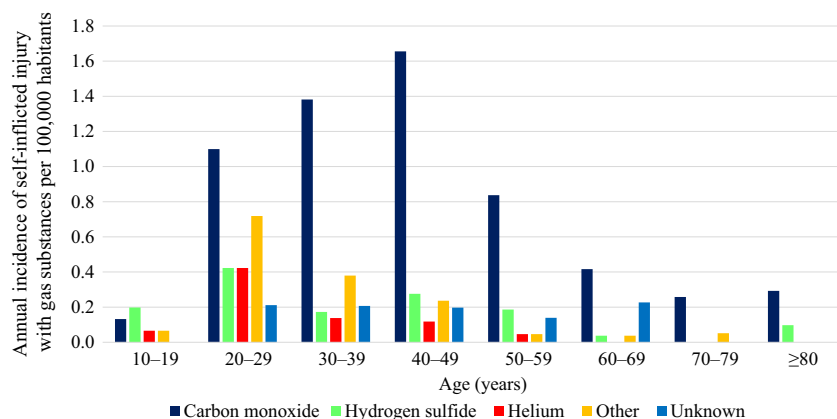


Fig. 2. Incidence of self-inflicted injury patients per 100,000 habitants by gas substance and age group in Osaka City, Japan, 2009–2015.

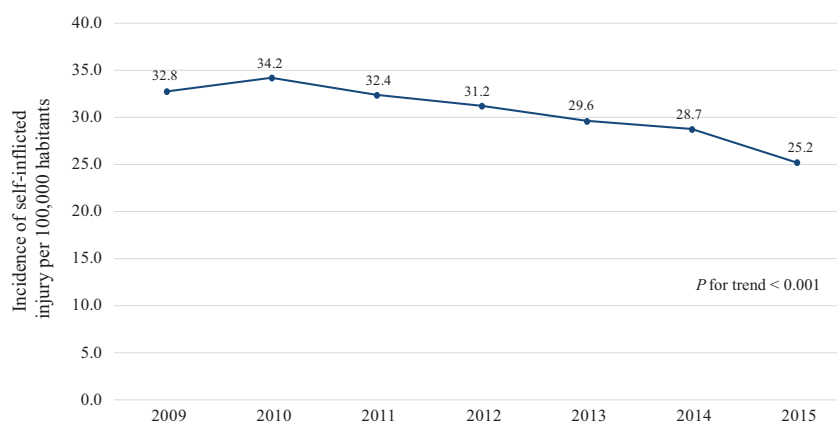


Fig. 3. Secular changes in all self-inflicted injury in Osaka City, Japan, 2009–2015.

2013/2014 occurred after a movie on suicide by helium was released in 2012.¹¹ Therefore, the regulation of information related to gas substances, such as helium, would be helpful for reducing the incidence of emergency patients with self-inflicted injuries, especially in younger victims.

This study underscored that the incidence of self-inflicted injury with gas substances decreased in Osaka City between 2009 and 2015. Indeed, the number of suicide cases has recently decreased in Japan as a whole.¹² In this study, the number of all self-inflicted injury patients also decreased after the peak in 2010. Although this reason was unclear, it might be due to aggressive suicide countermeasures or the revival of business activity in Japan during the study period. As for hydrogen sulfide, the incidence of self-inflicted injury decreased during the study period. A previous study revealed that the methods of suicide attempts were affected by media, such as television and newspapers,¹¹ and media releases regarding suicide attempts due to hydrogen sulfide

were thriving in Japan around 2007.¹³ However, the releases settled thereafter and the detergent used to generate hydrogen sulfide was also prohibited in 2008, which would explain the decreased incidence trend of self-inflicted injury due to hydrogen sulfide. Thus, the methods of self-inflicted injuries are influenced by the discontinuation of the causative substances as well as the mass media.

The use of helium was characteristic among young adults, and helium caused the highest proportion of deaths at the scene in this study. A report on patients with suicide attempts due to helium using an “exit bag” has been published since the 2000s.¹⁴ Generally, when people try to suffocate themselves by covering their head with a plastic bag, they feel respiratory distress due to breathing a high level of carbon dioxide for a long time. Although helium and argon are considered harmless to the human body, people using these gases die without feeling fear or panic.¹⁵ For example, in animal models using gas substances, respiratory arrest

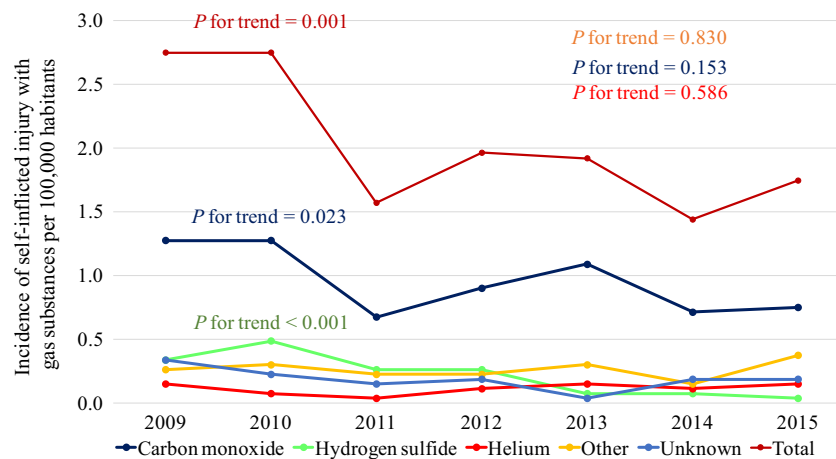


Fig. 4. Secular changes in self-inflicted injury by type of gas substance in Osaka City, Japan, 2009–2015.

occurred within 30–40 s, followed by cardiac arrest 2–3 min after exposure in a chamber in which the oxygen was depleted completely.¹⁶ If patients inhale gases containing helium or argon and a relatively small fraction of oxygen, they become unconscious from hypoxia before feeling respiratory distress from the rapid accumulation of exhaled carbon dioxide. Consequently, fatal hypoxia in the central nervous system of patients using these gases would lead to death^{15,17} that would be attributable to the rapid consumption of the relatively small amount of available oxygen rather than to the helium itself. However, there was evidence of gas embolism in suicide patients with helium using post-mortem computed tomography,¹⁸ and further research is needed to reveal the mechanism of helium suffocation. People can easily buy helium cylinders on the Internet because helium is used to inflate balloons for commercial use. Importantly, the present study showed that the incidence of self-inflicted injuries did not change during the study period. Therefore, regulation of helium sales would contribute to

reducing the incidence of emergency patients with self-inflicted injury due to helium.

Limitations

First, this study did not address the toxicity of noxious fumes because the information obtained was from on-the-scene reports and/or interviews with patients and bystanders. Second, although we analyzed the ambulance records in this study, our records did not include data about the purpose or motivation of self-inflicted injuries, such as suicidal intention, history of suicide attempts or self-harm, and medication. Therefore, it was unclear whether these emergency patients injured themselves with gas substances for suicide attempts or not. Third, as we assessed the ambulance records not including the coroner cases, we excluded the coroner cases in this study. Finally, this study was a retrospective chart review using ambulance records and we could not assess forensic and psychiatric examinations of the

Table 2. Proportion of self-injury cases in Osaka City, Japan (2009–2015) confirmed dead at the scene, grouped by type of gas substance

Type of gas substance	Proportion of cases, % (n/N)	Crude OR (95% CI)	P-value
Carbon monoxide	49.4 (88/178)	1.887 (0.928–3.833)	0.080
Hydrogen sulfide	34.1 (14/41)	Reference	
Helium	66.7 (14/21)	3.857 (1.267–11.745)	0.017
Other	2.0 (1/49)	0.040 (0.005–0.323)	0.002
Unknown	57.1 (20/35)	2.571 (1.015–6.517)	0.047

CI, confidence interval; OR, odds ratio.

survivors. We did not collect data regarding patient outcomes in a hospital or during transportation. In the future, use of the ORION database, which includes ambulance records and in-hospital treatments and outcomes in Osaka,¹⁹ will allow us to analyze detailed information on emergency patients with suicide attempts or self-inflicted injuries.

CONCLUSIONS

FROM LARGE -scale population-based ambulance records, this study revealed that the incidence of self-inflicted injuries due to CO and hydrogen sulfide decreased in Osaka City, Japan, from 2009 to 2015, but the incidence of self-inflicted injury with helium did not change and its proportion of deaths at the scene was high during the study period. Our fundamental descriptive study showing the characteristics of self-inflicted injuries due to gas substances provides helpful clues for reducing and preventing emergency patients with self-inflicted harm in prehospital settings.

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DISCLOSURE

Approval of the research protocol: The protocol was approved by the Ethics Committee of Osaka University as the corresponding institution.

Informed consent: The requirement for informed consent of patients was waived.

Registry and the registration no. of the study/trial: This study was not registered.

Animal studies: N/A.

Conflict of interest: None declared.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Patient characteristics about other gas substances.