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Trends in Suicide by Carbon Monoxide Inhalation in King County, Washington: 1996–2009

ABSTRACT: Carbon monoxide (CO) inhalation is one of the leading methods of suicide in the United States. A sharp increase in suicide by inhaling the CO produced from burning charcoal has been reported in parts of Asia; however, the incidence of this method has not been determined in a U.S. population. Thus, we determined trends of CO suicide in the ethnically diverse population of King County, Washington, U.S.A. During the period 1996–2009, we identified 158 cases of suicide by CO poisoning, with 125 because of automotive exhaust, 26 because of charcoal burning, and seven from other CO sources. While historical U.S. data indicate >99% of CO suicides in the United States occurring by automobile exhaust inhalation, in the most recent years analyzed, *c.* 40% of CO-related suicides in King County, Washington, were because of charcoal burning, indicating a possible shift in suicide trends that warrants further scrutiny in additional populations.

KEYWORDS: forensic science, suicide, carbon monoxide, charcoal, briquette, automobile, exhaust

Carbon monoxide (CO) inhalation results in hypoxia because of the *c.* 250-fold greater affinity of CO for hemoglobin relative to oxygen, with high concentrations of CO leading to unconsciousness and death within minutes (reviewed in [1]). Because of the lethality of CO and the perception of a relatively painless means of death, intentional inhalation of CO is a commonly utilized method of suicide (2). In the past, fatal levels of CO were readily accessible by simply turning on a home oven because of the widespread use of coal gas for the domestic gas supply. Following the widespread detoxification of home gas in the 1960s, domestic gas no longer contained significant levels of CO, and the incidence of this suicide method plummeted (3). In the United Kingdom, it was shown that the overall suicide rate dropped at this time as well, suggesting that restricting access to lethal means can reduce the total number of suicides (4).

In the following years, as automobile ownership increased, inhalation of car exhaust grew as a suicide mechanism, becoming responsible for nearly all CO suicides in the United States (5). However, introduction of the catalytic converter in the 1970s reduced the CO concentration of automobile exhaust by *c.* 95%. While inhalation of automobile exhaust was formerly fatal within minutes, modern exhaust can potentially be tolerated for extended periods, as suggested by a published report of an individual who ran a car engine for 10 h with a tube attached directly from the tailpipe to the passenger compartment of the vehicle without developing a critically elevated carboxyhemoglobin level (6). In conjunction with the decreased lethality of inhalation of automobile

exhaust, the discomfort of the method has increased, with increased time of exposure to unburned gasoline vapor and other unpleasant fumes, as well as an increased risk of discovery. Accordingly, the suicide rate by automobile exhaust inhalation has dropped (5). This trend has the potential to decrease the overall suicide rate, but also may result in a compensatory increase in alternate methods of suicide.

Other sources of CO that have been reported in suicide include gasoline-powered tools, which generally lack catalytic converters and therefore produce highly toxic exhaust; direct chemical production of CO from the reaction of formic acid with sulfuric acid (7); and burning charcoal, which smolders and therefore undergoes incomplete combustion with high CO production. Suicide by the latter method, previously very rare, increased sharply in Hong Kong after a single case in November of 1998 in which a 35-year-old woman burned charcoal briquettes in a sealed bedroom. The event was widely reported in the regional media, with explicit description of the details of her suicidal method and commentary on its rapid, painless, and nonviolent nature. Over the following 9 weeks, 22 additional suicides occurred in Hong Kong by the same method (8). By 2002, charcoal-burning suicide had become the second most common method of suicide in Hong Kong, responsible for *c.* 25% of total suicide deaths (9). Moreover, the increase in suicide by charcoal burning resulted in an overall increase in the suicide rate, with no compensatory decrease in suicide by other methods. Thus, the knowledge of this specific suicide method apparently resulted in additional deaths in individuals who presumably would not have carried out suicide otherwise, suggesting suicide clustering because of direct media reporting as well as social learning from other individuals in the local population (10,11). Suicide by charcoal-burning method has subsequently increased elsewhere in Asia and is responsible for up to one-fourth

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of total suicides in Taiwan (12), with a rising incidence also reported in Japan (13). The alarming increase in charcoal-burning suicide has resulted in multiple control methods being both proposed and enacted in Asia, including printing suicide help line phone numbers on charcoal bags, restricting the sale of charcoal in convenience stores, enforcing media guidelines regarding the reporting of suicides, and selective installation of CO monitors (12); however, it remains to be seen whether these control measures have been effective.

While charcoal-burning suicide is clearly widespread in parts of Asia, with a small number of cases also reported in Europe (14–16), to our knowledge, the incidence of this method has not been investigated in a U.S. population. Thus, in the present study, we have determined longitudinal trends in suicide by CO poisoning in the predominantly urban population of King County, Washington, over a 13-year period. King County has one of the largest Asian populations in the United States, including regular immigration from Hong Kong and Taiwan and therefore may represent an opportunity to identify whether emerging suicide trends seen in Asia are influencing CO-based suicide methods in the United States.

Methods

King County encompasses an area of 2100 square miles in Northwest Washington State, with a population of 1.9 million in 2008. The population is 75% white, 6% black, and 14% Asian/Pacific Islander. King County includes the city of Seattle, which consists of 602,000 residents and represents the 9th largest Asian population among United States cities (17).

The King County Medical Examiner's Office investigates all sudden, unexpected, and unnatural deaths that occur within the county. Records were searched from 1996 through September 2009 to identify every case where CO inhalation was listed on the death certificate as either a primary or a contributing cause of death, and where the manner of death was suicide. We excluded cases where CO production occurred from intentionally setting a building on fire. Information regarding historical modes of suicide from 1996 to 2008 was taken from the 2008 annual report of the King County Medical Examiner's Office.

We used logistic regression to determine whether the probability of suicide by CO inhalation from charcoal burning, as opposed to other sources, was increasing over the time period studied. In this analysis, the date of suicide was used as an independent variable and the method of CO inhalation (charcoal burning vs. not charcoal burning) was the dependent variable. We also performed a multivariate logistic regression to control for gender, age, marital status, and race.

Results

From 1996 through 2009, we identified 158 suicides where CO inhalation was a cause of death. The overall incidence of suicide and the incidence of suicide by CO inhalation were both essentially constant over the studied interval (Fig. 1). CO poisoning represented 6% of suicide deaths over the period 1996–2008 and was the fifth most frequent mode of suicide, exceeded in frequency by firearms (45%), hanging (18%), drugs/poisoning (15%), and jumping (7%).

Among the 158 cases of CO poisoning, 125 (80%) were because of inhalation of automotive exhaust, 26 (16%) were because of burning charcoal in an enclosed space, and 7 (4%) were from running a gasoline-powered tool (generator, lawn mower, or lawn edger) in an enclosed space (Table 1). The racial identity and age group of decedents were similar among all types of CO suicides

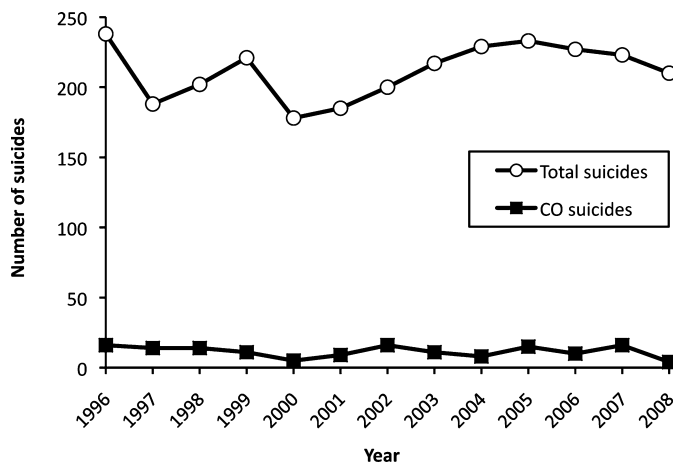


FIG. 1—Overall and carbon monoxide-specific suicide rate in King County, WA, 1996–2008.

TABLE 1—Classification of carbon monoxide (CO) inhalation suicides in King County, WA, 1996–2009.

	All CO Suicides	Vehicle Exhaust	Charcoal	Other*	All Suicides (1996–2008)
	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
Suicides	158	125 (79)	26 (16)	7 (4)	2748
Race					
White	143 (91)	113 (90)	23 (88)	7 (100)	2413 (88)
Black	6 (4)	4 (3)	2 (8)	0 (0)	102 (4)
Asian	7 (4)	6 (5)	1 (4)	0 (0)	180 (7)
Other	2 (1)	2 (2)	0 (0)	0 (0)	53 (2)
Gender					
Male	116 (73)	87 (70)	22 (85)	7 (100)	2138 (78)
Female	42 (27)	38 (30)	4 (15)	0 (0)	610 (22)
Marital Status					
Married	51 (32)	44 (35)	6 (23)	1 (14)	814 (30)
Not married	107 (68)	81 (65)	20 (77)	6 (86)	1934 (70)
Age					
<20	1 (1)	1 (1)	0 (0)	0 (0)	135 (5)
20–39	58 (37)	51 (41)	7 (27)	0 (0)	971 (35)
40–59	74 (47)	53 (42)	16 (62)	5 (71)	1096 (40)
60–79	16 (10)	12 (10)	2 (8)	2 (29)	374 (14)
>79	9 (6)	8 (6)	1 (4)	0 (0)	172 (6)

*Other sources of carbon monoxide were: gasoline-powered generator ($n = 4$), lawn edger ($n = 2$), and lawn mower ($n = 1$).

and closely paralleled the trends seen in suicide overall, indicating that this mode of suicide is not disproportionately utilized by a specific age or ethnic group. As with overall suicide trends in King County, decedents tended to be men, Caucasian, unmarried, and 40–59 years of age.

The trend toward an increase in charcoal-burning suicides that has been noted in Taiwan and Hong Kong was not reflected by a higher incidence in Asian individuals within King County: of 158 CO inhalation suicides, 7 (4%) occurred in Asians, and among charcoal-burning suicides, only 1 (4%) occurred in an Asian individual. Suicide is overall under-represented in Asians, as King County is 13% Asian with 7% of total suicides occurring in this population. It might be expected that a novel suicide method would be disproportionately utilized by younger individuals; however, this also was not the case. The average age was nearly identical between those committing suicide by inhaling vehicle exhaust (45.5 ± 16.4 years old [mean \pm standard deviation]) versus suicide by charcoal burning (46.2 ± 12.6 years old).

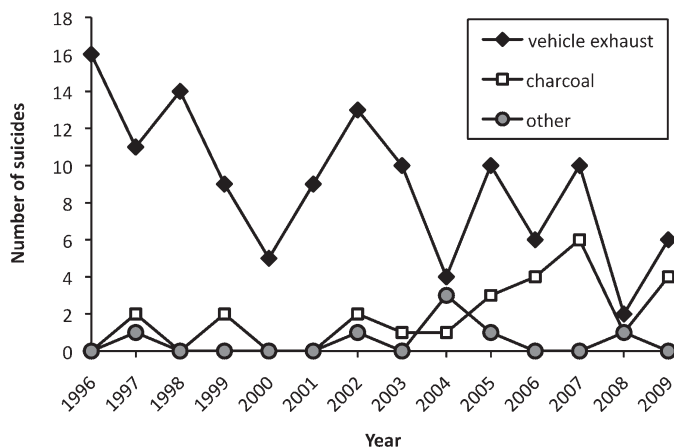


FIG. 2—Classification of carbon monoxide suicides in King County, WA, 1996–2009.

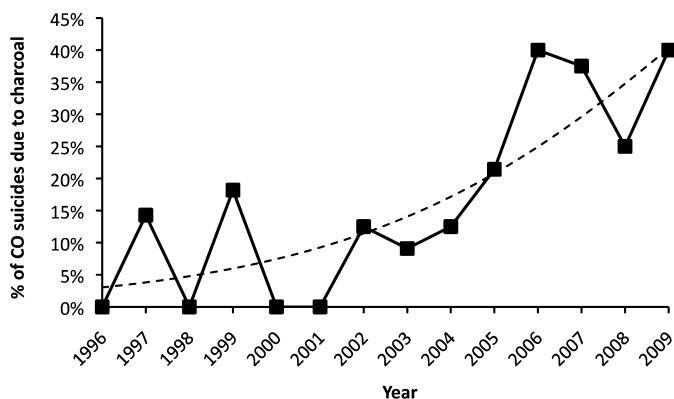


FIG. 3—Percentage of carbon monoxide (CO) suicides because of charcoal burning in King County, WA, 1996–2009. The dashed line represents the logistic regression function, which indicates a statistically significant increase over time in suicide from charcoal burning as opposed to other CO sources ($p < 0.005$).

While the overall incidence of suicide by CO poisoning has remained relatively constant, a trend was seen over the period 1996–2009 toward a decrease in suicide by inhalation of automotive exhaust, with a corresponding increase in suicide by charcoal burning (Fig. 2). The overall trend was toward an increasing proportion of all CO inhalation suicide to occur by charcoal burning; in the most recent year of the study (2009), 40% of all CO suicides were because of this method (Fig. 3). Univariate logistic regression demonstrated a statistically significant increase over time in the probability of suicide from charcoal burning as opposed to other CO sources ($p = 0.00026$). The dashed logistic function in Fig. 3 shows the estimated increase in the probability of suicide from charcoal burning derived from this model. In a multivariate analysis controlling for possible effects of gender, age, marital status, and race on the probability of charcoal-burning suicides, the statistically significant increase over time persisted ($p = 0.0015$). No other covariate was a significant predictor of the method of CO inhalational suicide.

Discussion

Suicide by inhalation of charcoal fumes represents a developing trend in parts of Asia, with *c.* 25% of all suicides in Hong

Kong and Taiwan occurring by this single method. We sought to determine whether a similar trend is developing in the U.S. population of King County, Washington, which is an urban center with a significant Asian population. We determined that suicide by charcoal burning is increasing in King County and is correlated with a decrease in suicide by inhalation of automotive exhaust. While charcoal-burning suicide remains infrequent in King County, representing <1% of total suicides, it is significantly increasing in incidence and was responsible for *c.* 40% of all CO inhalation suicides in the most recent years studied. In our population, charcoal-burning suicides occurred mostly in white men, paralleling overall suicide trends in King County. Despite the charcoal-burning suicide trend that has been reported in Asia, we did not find a large number of suicides by this method in Asian individuals in King County. However, it is conceivable that the sizeable Asian population in King County may have contributed to knowledge of the charcoal-burning suicide method among non-Asians.

The trend toward an increase in charcoal-burning suicide is likely influenced by several factors, including the decreased toxicity of automobile exhaust because of the nearly universal use of catalytic converters. While the exhaust of gasoline-powered tools remains highly toxic, relatively few suicides occurred from inhalation of tool exhaust, possibly because of lack of awareness of the toxicity of this type of exhaust and the relatively limited ownership of gasoline-powered tools in a largely urban population. However, charcoal is readily available and produces fumes that are highly toxic. Requiring only an enclosed space, charcoal briquettes, and a receptacle in which to burn them, suicide by charcoal burning is additionally inexpensive and convenient. This method is also considered relatively painless, with inhalation of sufficiently high concentrations of CO leading to unconsciousness within minutes. Therefore, charcoal burning is likely to appeal strongly to individuals seeking to end their life with a minimum of effort or discomfort, which also represents a population in whom suicide might be most readily prevented. Accordingly, implementation of charcoal-suicide control measures, as has occurred in Asia, may prove necessary in the United States as well.

The high incidence of charcoal burning as a means of CO inhalation suicide in King County is in stark contrast to reported historical trends across the United States: a study by Mott et al. (5) determined that during the period 1968–1998, >99% of CO suicides in the United States occurred by inhalation of vehicle exhaust. Notably, the period analyzed by that study was prior to the sharp increase in charcoal suicide in Hong Kong and largely predates the time period investigated by the present study as well. Our finding that charcoal-burning suicide is increasing may represent a shift that is unique to the population of King County; however, the trend may also reflect a more widespread change in U.S. suicide trends analogous to that which has been seen in Asia. In addition, even though a high incidence of charcoal-burning suicide was first noted in Asian populations, we found that suicide by this method in King County occurred primarily among white males, indicating that the trend is not restricted to a single region or demographic group. Thus, surveillance of additional populations is needed to determine whether charcoal-burning suicide represents a developing epidemic in the United States.

Acknowledgments

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