



Suicide Deaths by Gas Inhalation in Toronto, Canada – An Observational Study of Emerging Methods of Suicide From 1998 to 2020

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Abstract: *Background:* Inert gases are an emerging means of suicide in Toronto, Canada. Trends in suicide by these methods change over time, yet long-term patterns remain uncharacterized in cities like Toronto. *Aims:* To update trends in suicide using inhalational gas and explore the profiles of individuals using different methods in Toronto. *Methods:* Suicide deaths were identified from coroner's records and classified by suicide methods. Time trends were explored, and bivariate analyses were performed to characterize differences in profiles between groups. *Results:* There were 229 suicide deaths by inert gas between 1998 and 2020. For 2016–2020, suicide by nitrogen increased by 100%, whereas there was a decrease in suicide by helium (–38%) and charcoal burning (–57%) compared to 2011–2015. Males comprised a higher proportion of inhalational gas deaths compared to other methods. Individuals who died by compressed gas and charcoal burning were more likely to have left suicide notes compared to people who died by other methods. *Limitations:* The number of suicide deaths by gas inhalation may be underestimated due to potential misclassification. *Conclusions:* Suicide prevention strategies including restricting access to suicidal means, providing helpline information on the products, and responsible media reporting should each be advocated for.

Keywords: suicide prevention, mental health, suicide methods, asphyxia, population health

Suicide is a serious public health concern. In Canada, approximately 4,500 people die by suicide per year, and it is the second leading cause of death among youth and young adults (Statistics Canada, 2023). The World Health Organization (WHO)'s LIVE LIFE implementation guide states that limiting access to the means of suicide is one of the key effective interventions for suicide prevention (World Health Organization, 2021). Inert gases represent a major means of suicide by asphyxia in many places worldwide including suicide by compressed gas (e.g., helium, nitrogen, argon), charcoal burning, or motor

vehicle exhaust exposure (leading to carbon monoxide toxicity). Suicide by inert gases predominately occurred in Asia, and an emerging trend has been identified in Canada in recent years (Gunnell et al., 2015; Sinyor et al., 2019; Yeung et al., 2023).

Charcoal burning has been a common suicide method in East Asia (i.e., Hong Kong, Japan, Taiwan, South Korea) since 1998 (Yeung et al., 2023). A recent systematic review shows that the peak rates of suicide by charcoal burning appear to have passed in Hong Kong, Taiwan, and Japan. Meanwhile, rates continue to rise in

South Korea. Although this method is not prevalent in regions outside Asia, our group's first study of this method in Toronto in 2019 found that charcoal-burning suicides increased by 533% between 1998–2003 and 2010–2015, mainly accounted for by suicides using this method in the Asian population of Toronto (Sinyor et al., 2019). There are some distinct profiles of individuals who die by suicide by charcoal burning. For example, studies in Hong Kong, Mainland China, Taiwan, Japan, South Korea as well as Canada have suggested that males are more likely to use charcoal burning (Chan et al., 2005; Chang et al., 2016; Y.-R. Choi et al., 2014; Kamizato et al., 2009; Sinyor et al., 2019). The most common age groups of individuals who used charcoal burning in Hong Kong has changed from 25–44 years to 45–65 years from 1997 to 2018 (Men et al., 2022). In Hong Kong, individuals who died by charcoal burning were more likely to live alone, be employed, less likely to be married or widowed, more likely to leave suicide notes, and to experience stressors such as family, relationships, and financial difficulties (Men et al., 2022).

In terms of inert gases, there are also distinct profiles and differences in gases used worldwide. In Hong Kong, coroner data from 2005 to 2013 found that, whereas 97.5% of suicides by gases occur via charcoal burning, only 1.2% were by helium inhalation (Chang et al., 2016). A few studies in Hong Kong, Netherlands, and England and Wales showed that individuals who used helium were younger than people who died by charcoal burning (Chang et al., 2016; Gunnell et al., 2015; van den Hondel et al., 2021). The study in Hong Kong also found that individuals who died by helium inhalation were more likely to have financial difficulties and less likely to have received psychiatric treatment (Chang et al., 2016). In some parts of Australia and Sweden, increases in cases of suicide by inert gas have also been observed; however, rates of suicides by all methods were observed to remain constant or decreased, suggesting a potential substitution effect (Austin et al., 2011).

Suicide by gas inhalation is known to occur more frequently following popular media portrayals of such suicides or by online sources. Most studies of suicide by helium have shown that decedents use the Internet as a source of information with detailed instructional videos widely available, or in the context of an increase in “prosuicide” websites (Austin et al., 2011; Gunnell et al., 2015; Nowak et al., 2019). Other than online sources, print novels such as *Final Exit: The Practicalities of a Self-Deliverance and Assisted Suicide*, which described suicide methods involving inert gas (Gilson et al., 2003), have also been found to have contributed to increases in inhalational gas suicide rates (Howard et al., 2011; Marzuk et al., 1993). Finally, an example of media influence

occurred in Hong Kong where media comprehensively covered the highly unusual event, for that location, of a young man who died by helium inhalation, showing the helium canisters and describing how and where they can be purchased locally (Chang et al., 2016). Following this extensive media reporting, another suicide with the same method occurred within 10 days (Chang et al., 2016).

Our previous paper identified a substantial rise over time in deaths by compressed gas and charcoal burning in Toronto in 2010–2015, as well as a numerical reduction in deaths by motor vehicle exhaust (Sinyor et al., 2019). The previous paper also found that these deaths were more common among males without a previously identifiable history of mental disorders, were frequently associated with suicide notes, and that compressed gases were often purchased from local stores (Sinyor et al., 2019). Finally, our previous results showed some indication that deaths by compressed gases were more common among Caucasians, while death by charcoal burning was more common among Asians (Sinyor et al., 2019). Although the previous study was the largest in Canada to focus on suicide by inhalational gas, there is now newer data until 2020 to facilitate an updated examination. The literature described above indicates that trends in suicide by these methods can vary substantially over time and that there is a need to routinely update the state of knowledge. Therefore, the current study aims to assess how these emerging methods have evolved over the subsequent five years.

Methods

Data Source

We examined 5,288 suicide deaths in Toronto spanning the years 1998–2020 using data from the Office of the Chief Coroner of Ontario (OCC). Data were provided by OCC staff including individuals whose death had been ruled a suicide by the OCC. To be included in our study, the decedent had to reside and die by suicide within the city of Toronto. Trained research assistants extracted information such as demographics (age, sex, marital status, and living situation), precipitating stressors (i.e., bereavement, interpersonal, and relationship breakup), suicide characteristics (i.e., suicide note present), mental health history, physical health history, toxicology information, and mode of death. Relevant stressors and psychiatric and medical history were obtained from the OCC's investigation and may have arisen from sources including the deceased's medical records

and interviews with relatives, friends, and/or acquaintances. Note that physician-assisted deaths (often termed medical assistance in dying in Canada) were not included or coded in this study. All coders who contributed to this study achieved high interrater reliability of $\kappa \geq 0.8$ before coding independently. All coders remained in close discussions when there was ambiguous or unanticipated data; the senior investigators ultimately made final decisions in cases where coders remained uncertain.

Sample

For the purposes of this study, the entire sample was split into four groups for comparison based on the primary method of death: (1) individuals who died by compressed gas (helium or nitrogen), (2) individuals who died by charcoal burning, (3) individuals who died by motor vehicle exhaust, and (4) individuals who died by all other methods not involving gas inhalation (other). Toxicology reports were also used to support the identification of the primary method of death when multiple methods contributed. For inert gas suicides, toxicology reports were completed for approximately 92% of cases. For compressed gases, we collect more detailed information such as the source of the tanks, the number of tanks present, and whether the individual had recent, known, major stressors. Examples of major stressors included longstanding conditions such as cancer, new-onset clinical conditions such as a serious infection, as well as personal crises such as housing loss. Ethnicity of the deceased was also collected for deaths by gas inhalation in cases where it was explicitly mentioned in coroner charts, usually in the police report.

Statistical Analysis

Time trends of suicide deaths by compressed gas, charcoal burning, motor vehicle exhaust, and all other methods were described from 1998 to 2020. Descriptive statistics, including means with *SD*, were provided, and four by two chi-square tests (or Fisher's exact test if more than 20% of the expected count was less than five) were used to determine the association between the four groups and binary demographic and suicide-related characteristics. Binary variables were sex, relationship status, living circumstance, stressors, presence of suicide note, presence of the book *Final Exit*, past suicide attempts and identified history of mental illnesses (i.e., depression, bipolar, substance misuse disorder, and anxiety/panic attack), and presence of a medical condition. One ANOVA test examined the relationship between

the continuous age variable and the four groups; the mean and range were provided. Additional pairwise comparisons were performed to examine the differences in the demographic and clinical characteristics of individuals in the four categories. An additional analysis was conducted only for suicide decedents from compressed gas, and descriptive analysis was provided. All statistics were performed using IBM SPSS Statistics 29 (SPSS Inc, Chicago IL). Thresholds for significance remained at 2-tailed at 0.05.

Results

All four by two χ^2 tests and the independent *t*-test for characteristics of suicide are presented in Table 1. Of 5,288 suicides occurred in Toronto between 1998 and 2020, suicide deaths by inert gases ($N = 229$) accounted for 4.3%. Of these, 105 (45.9%) individuals died by compressed gas, including helium and nitrogen, 43 (18.8%) died by charcoal burning, and 81 (35.4%) died by motor vehicle exhaust. Individuals who died by compressed gases were the youngest ($M = 43$ years, range = 15–81 years) followed by those who died by charcoal burning ($M = 46$ years, range = 16–86 years), all other suicides ($M = 47$ years, range = 11–97 years), and motor vehicle exhaust ($M = 52$ years, range = 15–89 years; $t = 3.86$, $df = 3$, $p < .01$). Notably, all three gas inhalation methods had higher M:F ratios compared to other suicides (compressed gas 5.2:1 vs. charcoal burning 5.1:1 vs. motor vehicle exhaust 4.4:1 vs. others 2.3:1, $p < .05$). Compressed gas decedents and, to a slightly lesser extent, charcoal burning decedents were also more likely to leave a suicide note (compressed gas 72.4% vs. charcoal burning 60.5% vs. other 28.7%, $p < .01$). Compressed gas decedents were less likely to have a history of substance misuse disorder (compressed gas 4.8% vs. others 19.4%; $p < .01$). Decedents by charcoal burning and decedents by motor vehicle exhaust were more likely to have relationship breakups (charcoal burning 20.9% vs. motor vehicle exhaust 17.3 vs. others 7.8%, $p < .01$), have employment/financial stressors (charcoal burning 30.2% vs. motor vehicle exhaust 33.3% vs. others 17.5%; $p < .05$) compared to individuals died by other methods. Decedents by motor vehicle exhaust were more likely to have depression (motor vehicle exhaust 66.7% vs. others 50.8%, $p < .01$) compared to people who died by other methods.

Time trends in suicide deaths by inert gases are presented in Figure 1. For 2016–2020, there was a decrease in suicide by helium (–38.2%) and charcoal burning (–57.1%) compared to 2011–2015, while suicide by nitrogen increased by 100%. Over the epoch of the study,

Table 1. Comparison of characteristics of suicide by compressed gas, charcoal-burning, motor vehicle exhaust suicides, and all other suicides in Toronto, 1998–2020

Characteristic	A	B	C	D	χ^2 or <i>F</i> <i>df</i> <i>p</i>	A	A	A	B	B	C
	Compressed gas suicides ^c (n = 105) n (%)	Charcoal-burning suicides (n = 43) n (%)	Motor vehicle exhaust suicides (n = 81) n (%)	All other suicides ^a (n = 5,059)		vs. B	vs. C	vs. D	vs. C	vs. D	vs. D
<i>M</i> _{age} (years, range) ^e	43 (15–81)	46 (16–86)	52 (15–89)	47 (11–97) ^e	3.86 3 **	NS	**	*	NS	NS	*
Age category											
10–24	17 (18.3)	3 (7.0)	6 (7.4)	537 (10.6)							
25–44	41 (39.0)	17 (39.5)	20 (24.7)	1803 (35.6)							
45–65	38 (36.2)	20 (46.5)	35 (43.2)	1896 (37.5)							
>65	9 (8.6)	3 (7.0)	20 (24.7)	822 (16.3)							
Male sex	88 (83.8)	36 (83.7)	66 (81.5)	3516 ^d (69.5)	18.99 6**	NS	NS	**	NS	*	*
Married	19 (18.1)	13 (30.2)	28 (34.6)	1,266 (25.0)	7.22 3 NS	NS	*	NS	NS	NS	NS
Living alone	51 (48.6)	19 (44.2)	36 (44.4)	2,215 (43.7)	.969 3 NS	NS	NS	NS	NS	NS	NS
Stressors											
Employment/financial stress	23 (21.9)	13 (30.2)	27 (33.3)	887 (17.5)	19.12 3 **	NS	NS	NS	NS	*	**
Relationship breakup	7 (6.7)	9 (20.9)	14 (17.3)	395 (7.8)	19.67 3 **	*	*	NS	NS	**	**
Final exit	12 (11.4)	† ^b	† ^b	30 (0.6)	151.99 3 **	*	**	**	NA	NS	NS
Presence of suicide note	76 (72.4)	26 (60.5)	26 (32.1)	1,454 (28.7)	112.96 3 **	NS	**	**	**	**	NS
Past suicide attempt(s)	17 (16.2)	14 (32.6)	19 (23.5)	1,320 (26.5)	6.81 3 NS	*	NS	*	NS	NS	NS
Mental illness											
Depression	48 (45.7)	21 (48.8)	54 (66.7)	2,572 (50.8)	9.26 3 *	NS	**	NS	NS	NS	**
*Bipolar	5 (4.8)	† ^b	5 (6.2)	327 (6.5)	.53 3 NS	NS	NS	NS	NS	NS	NS
History of substance misuse disorder	5 (4.8)	† ^b	12 (14.8)	983 (19.4)	18.0 3 **	NS	*	**	NS	NS	NS
Anxiety/PA	7 (6.7)	† ^b	† ^b	316 (6.2)	2.04 3 NS	NS	NS	NS	NS	NS	NS
Presence of any medical condition	31 (29.5)	8 (18.6)	25 (30.9)	1712 (33.8)	5.52 3 NS	NS	NS	NS	NS	*	NS

Note. NA = not applicable. NS = not statistically significant. PA = panic attack. ^aThere were 5,288 cases; for age and male, there were 5,284 cases, but for all other characteristics, there were 5,288 cases. [†]Values <5 were suppressed due to low sample size. ^cIncludes helium (n = 93) and nitrogen (n = 12). ^dSex unknown for 3 cases. ^eAge unknown for 1 case. **p* < .05. ***p* < .01.

the number of motor vehicle exhaust suicides was higher than helium suicides until about 2008, when helium started to surpass the motor vehicle exhaust suicides. Helium inhalation counts spiked between 2009 and 2016. Generally, total inhalation suicide deaths spiked in 2009 and have been in a decreasing trend since. While there were no nitrogen gas suicides for most of the years from 1998 to 2014, Figure 1 observes an increasing trend since 2015.

Additional demographic characteristics and suicide-specific characteristics for compressed gas are presented in Table 2. Among the 105 decedents who died by compressed gas, 31.4% were Caucasian, 20% were Asian, 6%

were Other, and 45% had an ambiguous/undetermined ethnicity. Whereas most cases had an unknown source of compressed gas (79%), party supply stores were the most common in remaining cases (11.4%). One tank was present in 74.3% of the cases.

Discussion

This study provides updated findings from the largest study to date focusing on suicide by gas inhalation in Canada. The more recent data reveal a decline in

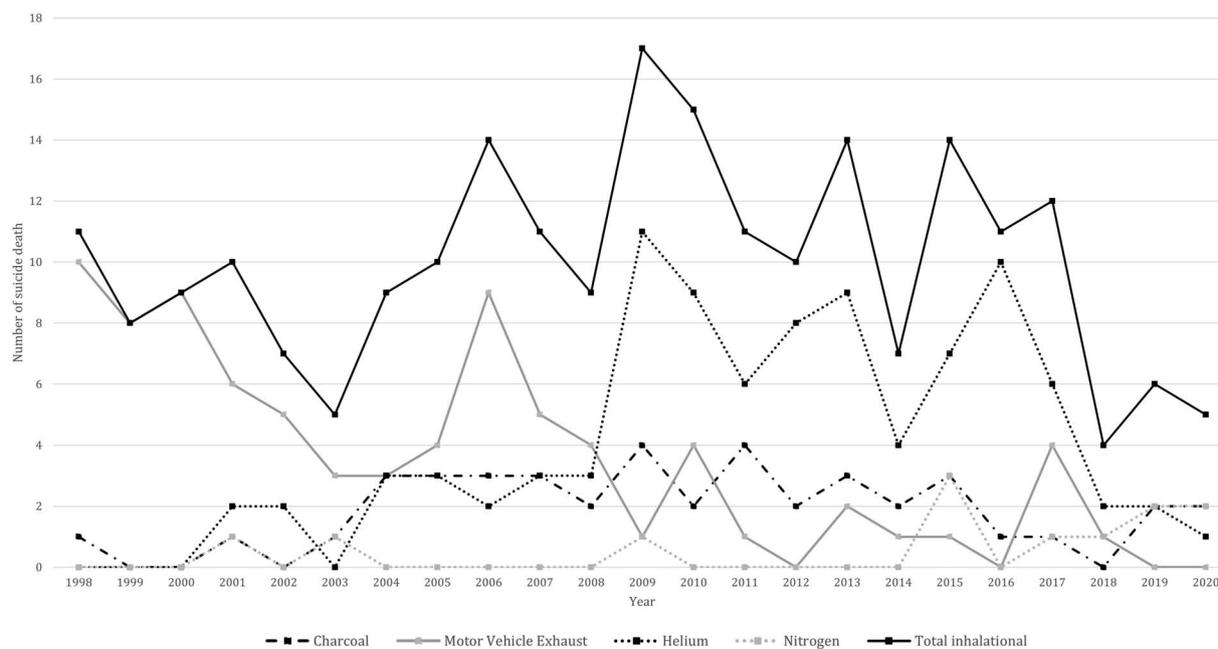


Figure 1. Suicide death by helium, nitrogen, charcoal, motor vehicle exhaust, and by all inhalational means in Toronto (1998–2020).

Table 2. Additional demographic characteristics and suicide-specific characteristics of people who died by compressed gas ($n = 105$) in Toronto (1998–2020)

Characteristic/variable	Compressed gas suicides ($n = 105$) ^a n (%)
Ethnicity	
Caucasian	33 (31.4)
Asian	21 (20.0)
Other	6 (5.7)
Ambiguous/undetermined	45 (42.9)
Major stressors^b	
Yes	52 (49.5)
No	53 (50.5)
Source of compressed gas tanks	
A. Party supply store	12 (11.4)
B. Large department store	6 (5.7)
C. Specialized helium supplier	3 (2.9)
D. Medical supplier	1 (1.0)
E. Unknown	83 (79.0)
Number of tanks present	
1	78 (74.3)
≥2	27 (25.7)

Note. ^aIncludes helium ($n = 93$) and nitrogen ($n = 12$). ^bPreviously detected mental or physical health problem that is of a chronic nature (i.e., distinct from an acute illness or short-term condition).

suicides by helium and charcoal burning, and a rise in suicide by nitrogen in the five years between our studies underscoring the importance of routinely updating the

literature in this area. The study also found that the proportion of males was significantly higher among suicides by gas inhalation compared to other methods. Individuals who died by charcoal burning and motor vehicle exhaust were more likely to have experienced employment and financial-related stressors and relationship breakup prior to death. People who died by compressed gas were more likely to leave suicide note and less likely to have a history of substance misuse disorder compared to people who died by non-gas methods. Additionally, among those who died by compressed gas, the majority obtained their gas tanks from public stores.

The number of suicides by motor vehicle exhaust was fewer than 10 each year in the past two decades. We may speculate that deaths by this method may already have been lower, as has been observed elsewhere, due to the automotive industry's previous transition to the use of catalytic converters making vehicle emissions less toxic (Amos et al., 2001; Skilling et al., 2008). Compared to 2011–2015, there was a notable decrease of 38% and 57% in helium and charcoal burning suicide, respectively, in 2016–2020. This decline may, in part, be related to the effectiveness of media adherence to responsible media guidelines in Canada. Prior research from our group identified improvements in suicide-related media reporting with reductions in harmful contents and increase in protective contents after the implementation of a Canadian national initiative on responsible reporting regarding suicide in November 2015 (Sinyor et al., 2024). Previous research also demonstrated a strong association between

the media's portrayal of novel suicide methods, such as charcoal burning, and the subsequent spread of such methods within the community (Chen et al., 2012; Lee et al., 2014). This suggests that responsible media reporting may play a crucial role in preventing the spread of these suicide methods, highlighting the importance of promoting media reporting guidelines in suicide prevention efforts. On the other hand, the study also observed an increase in nitrogen suicide by 100% in 2016–2020 compared to 2011–2015. An increasing trend in nitrogen suicide was also identified in Australia (Byard, 2018). Although there were only 12 nitrogen suicide cases across the study period, nine of them happened after 2016 and the number of nitrogen suicide in recent years is comparable with other gas-related methods. Therefore, it is essential to maintain adherence to media reporting guidelines as well as to implement other useful strategies such as limiting access to these methods. Ongoing vigilance is crucial to prevent the spread of this method within the community.

Consistent with previous findings, our study showed that more than 80% of individuals who died by compressed gas, charcoal burning, and motor vehicle exhaust were male, which was significantly higher than the proportion observed among all other methods (69.5%; Sinyor et al., 2019). The high prevalence of male suicides by gas inhalation may be attributed to employment and financial-related stressors, which have been identified as significant risk factors for suicide by gas inhalation and are more frequently found among men (M. Choi et al., 2021; Yeung et al., 2023). In the current study, it was also observed that 30% and 33% of individuals who died by charcoal burning and motor vehicle exhaust, respectively, experienced employment or financial stress prior to death. These proportions were significantly higher than the 18% of individuals who experienced such stressors and died by other suicide methods.

The results also indicated that people who died by compressed gas were more likely to leave suicide notes and less likely to have a history of substance misuse disorder compared to those who died by other non-gas methods. This finding was consistent with the results from other studies (van den Hondel et al., 2021). It might suggest that those who died by these methods displayed greater planning and lower impulsivity.

Among 105 suicide cases by compressed gas, there were 22 deaths where the source of compressed gas tanks was identified, and of these, 18 individuals obtained their gas tanks from party supply stores or large department stores. This finding underscores the potential for targeted population-based suicide prevention strategies. Previous studies in other regions have demonstrated the effectiveness

of means restriction in suicide prevention, such as securing access to charcoal in department stores to reduce charcoal-burning suicide (Chen et al., 2015; Yip et al., 2012). Implementing similar strategies in Toronto, such as restricting access to gas tanks in stores or online and providing training for sales personnel to recognize and respond to signs of depression and stress in customers, could be effective in reducing suicide by compressed gas. Additionally, warning signs and helpline information should be printed on the gas tanks. An even more effective strategy may be legislation to require nonindustrial, commercially available compressed helium and nitrogen tanks to include 20% oxygen which would render them ineffective as a means of suicide. Inert gas products diluted with oxygen are commercially available; however, there may be barriers to their widespread use meaning that governmental/legislative intervention may be necessary for this to be feasibly implemented (Australian Competition & Consumer Commission, 2022).

Limitations

There are several limitations in this study. First, the deaths included were suicides by gas inhalation where the manner of death was determined by the coroner. It is possible that the number of such deaths is underestimated, as some cases may be misclassified as accidental, natural, or homicidal deaths. Second, clinical information regarding physical and mental disorders was obtained from the medical records as well as from family members and friends. Additionally, not all points such as the deceased's ethnicity and the source of compressed gas tanks were systematically recorded in coroner's reports and are often missing from coroner's reports. Therefore, findings related to these characteristics should be interpreted recognizing the limitations of the data. In addition, due to the small sample size in inert gas deaths in the two comparison year groups (2011–2015 vs. 2016–2020), we were not able to conduct a reliable analysis to examine whether the changes were significant. Finally, the study sample was drawn from Toronto, the largest city in Canada. Therefore, the study results may not be generalizable to other cities or regions.

Conclusion

This study adds to the previous study by updating the trends and the characteristics of suicide by different types of inhalational gases. The results indicate that the number of suicides by helium and charcoal burning decreased in recent years; however, an increase in suicide by nitrogen

was observed. The demographic and clinical characteristics of individuals who died by different types of compressed gases remained relatively consistent with the earlier study results. Continuous and timely monitoring of suicides by gas inhalation, along with adherence to responsible media reporting and the promotion of means restriction is crucial. Furthermore, both population-based and high-risk approaches to suicide prevention strategies should be implemented to address suicides by gas inhalation and other novel suicide methods.

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The authors have none to report.

Authorship

VYM: Conceptualization; Formal analysis; Methodology; Writing – original draft; Writing – review & editing. PPMC: Formal analysis; Data curation; Project administration; Validation; Writing – original draft; Writing – review & editing. AS: Conceptualization; Writing – review & editing; Supervision. RS: Methodology; Writing – review & editing. RHM: Methodology; Writing – review & editing. JMD: Methodology; Writing – review & editing. PSFY: Methodology; Writing – review & editing. SH: Methodology; Writing – review & editing. MS: Conceptualization; Methodology; Writing – review & editing; Supervision.

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