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ORIGINAL PAPER

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Epidemiological Study of Carbon Monoxide Deaths in North Jordan 2009–2018

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ABSTRACT

Background: Carbon monoxide (CO) poisoning rate has stayed the same around the globe over the last quarter of a decade. However, the number of people who die compared to the number of people who get poisoned, and the mortality rate has declined dramatically. **Objective:** The aim of this study was to evaluate the severity of the CO poisoning problem in Jordan and compare it to other countries and to search for any related factors that could affect the death rate. **Methods:** A retrospective study was conducted in the Forensic Medicine Teaching Centre, Irbid, Jordan for a 10-years period (2009–2018). 5,725 autopsy reports were assessed, and only 71 CO-related death cases were selected and analyzed based on the following risk factors: age, gender, year and month of death, nationality, address, the settings that the cases occurred in, carboxyhemoglobin saturation (COHb%) and the presence of alcohol and drugs in blood. **Results:** The rate of deaths due to CO poisoning showed a general decline over the reviewed years. Most victims were males (70.4%). And although the death rate showed an increase with age, the age group between 20-year-old and 39-year-old accounted for 38% of all cases. Most cases happened in the winter months, December, January, and February. 87.1% of the cases occurred at home settings. The average COHb% was 68%±13% and ranged from 12%-83%. **Conclusion:** Although the incidence is decreasing with time, CO is still a threat that must be dealt with. As all cases in our study were accidental cases and good preventive measures, such as good CO detectors and good air flow in the places that hold devices that could generate CO, and proper education to the public, especially in the colder regions of the country, could prove useful in decreasing the incidence of CO deaths further.

Keywords: Carbon monoxide, CO, Poisoning, Accidental, Death, Jordan.

1. BACKGROUND

Carbon monoxide (CO) is a gas composed of a single carbon atom with a single oxygen atom. It has no color, taste, or odor. It is mostly generated during incomplete burning of carbon containing fuels; it occurs from many sources like fires, engines, and defective heating systems. CO binds with high affinity to many ferrous heme-containing proteins. Hemoglobin (Hb) has an extreme affinity for CO approximately 250-fold greater than for oxygen creating what is called carboxyhemoglobin (COHb). CO levels of only 10 ppm can cause noticeable COHb levels of nearly 2% (1, 2). WHO suggests that exposure over a long period to CO levels more than 6 ppm could be toxic (3). COHb level is considered abnormal when it reaches 2% or more in nonsmokers and 10% or more in smokers (3, 4).

CO poisoning signs and symptoms are highly dependable on the concentration of COHb, where levels below the 10% barrier usually do not cause any symptoms. While over this mark symptoms start to increase in number and severity, from headache, nausea, dizziness to elevated respiratory rate and pulse, loss of consciousness, paralysis, and confusion when levels reach over 30%. Life viability has many factors that determine the percentage of COHb needed to be life-threatening, and these values are extremely important to the diagnosis of CO poisoning (5).

Only few signs can be thought of as signs of CO poisoning, most notably a cherry-red discoloration of the skin, blood, organs, and muscles.

Figure 1. Number of cases in each age group when adjusting for the population age group ratios

Figure 2. Number of cases in males and females

Figure 3. number of cases in each month

Figure 2. Number of cases in each month

Pulmonary edema and organs congestion are very common in these cases (6). Necrosis in the globus pallidus is the most frequent brain involvement in CO poisoning. It usually occurs immediately. It is thought to be related to either the ischemic effects of CO poisoning in the watershed areas or because of the CO binding to the high iron concentrations in the tissue in the globus pallidus (7). Moreover, although it is rare but there have been few cases of acute myocardial infarction in some CO poisoning cases, however, it should be noted that this happened mostly with the presence of preexisting cardiac conditions (8).

We conducted our study in Northern Jordan cities (Irbid, Ajloun, Jarash, and Mafrq) due to the high number of CO-related deaths in these cities. There are no updated records that can help us understand the pattern and the attributing factors surrounding the increase or decrease in the number of CO-related deaths in Jordan.

2. OBJECTIVE

The study aim is to evaluate the severity of the CO poisoning problem in Jordan and compare it to other countries and to search for any related factors that could affect the death rate.

3. MATERIALS AND METHODS

Study Design:

For the retrospective analysis proposed, a study was conducted in the Forensic Medicine Teaching Centre, Irbid, Jordan for a 10-years period (2009–2018). This center serves Northern Jordan including Irbid, Jarash, Ajloun, and Al-Mafrq, covering a population of almost 3 million people.

Figure 4. Number of cases per 100000 persons in each city

Study Sample:

Out of 5,725 autopsy reports were assessed, and only CO-related deaths were selected.

Study variables:

The cases were evaluated according to age (0-19, 20-39, 40-59 and 60+ year old), gender (males or females), year (from 2009–2018), month of death, nationality, address (Irbid, Jarash, Ajloun, Al-Mafrq or not recorded), the settings that the cases occurred in (Home, Work place, others or not recorded), carboxyhemoglobin saturation (COHb%) and the presence of alcohol and drugs in blood (positive, negative or not ordered).

Study procedure:

We obtained ethical approval from IRB at faculty of medicine, Jordan University of science and technology, Irbid, Jordan. The data were collected from autopsy reports of all CO-related deaths in Northern Jordan from January 1, 2009 to December 31, 2018. All the data from all the cases (whether complete or not) were included in the analysis using SPSS version 25 and Microsoft Excel 2016. Descriptive statistics were used to describe study variables using frequencies, percentages, means, and standard deviations.

4. RESULTS

We analyzed 5,725 autopsy reports performed in the period from 2009 to 2018 in the Forensic Medicine Teaching Centre Irbid, Jordan. We selected only the CO-related death cases in Northern Jordan, which includes Irbid, Mafrq, Ajloun and Jarash, of those cases only 1.24% (n=71) were due to CO poisoning, all of which were accidental.

We divided the population into 4 age groups, 0-19, 20-39, 40-59 and 60+. In our study, we found 15 (21% of all cases), 27 (38%), 19 (27%) and 10 (14%) cases in each age group, respectively, however when adjusting to the population age groups ratios, we noticed an increase in the number of

cases with age (Figure 1). 70.4% of all cases were males and only 29.6% were females (figure 2).

From total number 78.9% of cases happened in December, January, and February, and only 1 case from all the reviewed cases happened in months June, July, and August (Figure 3). Number of cases was highest in Irbid ($n=53$) then Mafraq ($n=8$), Ajlun ($n=6$) and lastly in Jarash ($n=3$), however when comparing those results with the population of each city, we found that Irbid had the highest number of cases per 100000 persons then Jarash, Ajlun and lastly Mafraq (Figure 4). 31.8% of all cases were non-Jordanians of which 61.9% were Syrians and 38.1% were from Egypt, China, Al Yemen, and Bangladesh.

Data about the settings that the cases occurred in were not available for most cases. Only 31 cases recorded the setting of the accident. 27 cases (87.1%) occurred at home settings and only 4 cases (12.9%) in the work settings. CO deaths in just 51 cases were confirmed by carboxyhemoglobin saturation (COHb%) in postmortem blood. The average COHb% was $68\% \pm 13\%$ and ranged from 12-83%.

Alcohol and Drugs toxicological analysis was ordered for only 45 cases of those only 2 cases had significant alcohol levels in their blood and only 3 cases had drugs in their blood.

5. DISCUSSION

We found that the rate of death due to CO poisoning ranged from 0.03% to 0.24% from all recorded deaths in Northern Jordan amongst all reviewed years, with the highest number of cases ($n=12$) in 2011. However, the trend showed a general decline in CO deaths; as in 2009 CO deaths accounted for 0.1% of all recorded deaths in 2009, and for 0.05% of all deaths in 2018, although, according to the Jordanian department of statistics, the population almost doubled (10).

CO Poisonings rate has stayed the same around the globe over the last quarter of a decade. However, the number of people who die compared to the number of people who get poisoned has declined dramatically by almost 40% and the mortality rate has decreased too by 36% (9). Almost similar results were found in the US in 2016 and in the UK in 2014 where they found that the number and rate of deaths from CO poisoning greatly dropped (11, 12). Comparing with the only two studies ever done in Jordan on the CO poisoning in 1999 and 2004, our study showed lower incidence of CO deaths on autopsies (1.24%) compared with 1.8% over the reviewed years in both studies (13, 14). This decrease can be attributed to the increased awareness in society, improvements in the CO detection systems and the safety mechanisms used in heating systems.

In Jordan, males account for around 52% of the population and females for 48%. And even when adjusting to the population ratio, our study showed that males CO deaths were more common, accounting for more than two thirds of the cases reviewed. In the study done by Mattiuzzi & Lippi in 2020 on the data on the Global Health Data Exchange registry, they found that the number of CO poisoning cases in males and females was not different, but the death rates in males was almost twice that in the females (9). A higher mortality from CO poisoning in males was found in multiple

other studies in the US, the UK, China and in WHO European Member States (11, 12, 15, 16). Zavorsky explained these results that "women had a shorter CO elimination halftime compared to men, even after adjusting for ventilation rate. This implies that CO toxicity is predictably lower in women and, accordingly, the risk of death is higher in the male sex. Which was explained by the difference in alveolar ventilation and total hemoglobin mass between genders" (17).

We divided the population into 4 age groups, 0-19, 20-39, 40-59 and 60+, and we found that the group age 20-39 had the highest number of CO deaths. The age group with the highest number of CO poisoning cases differed widely between literatures. In Mattiuzzi & Lippi's worldwide study, they reported two peaks in the number of cases in ages 0-14 years and 20-39 years (9). While Hampson in the US found that the group age 45-54 years had the highest numbers (12). And Braubach reported that 63.2% of the cases were found in the age group 25-64 years (15). However, just like all other studies reviewed here, our data suggests that the percentage of people who die from CO poisoning increases with age (9, 12, 18). As according to the Jordanian department of statistics, each of the age groups mentioned before accounted for 44.3%, 33.1%, 17.2% and 5.5% of the population, respectively (10). And when adjusting for the population age groups ratios, we found that there was a noticeable increase in the rate of CO deaths with age, especially above the age of 60, which could be explained by the higher chronic diseases' percentages in this group and the longer smoking periods which could lead to lower COHb percentages required to be fatal.

We found that most cases occurred in December, January, and February, which correlates with the winter season in Jordan, and the lowest numbers in June, July, and August with only one case recorded in these months in all the reviewed years. Across all the reviewed studies from the UK, China and Iran, there was a clear incline in the number of cases in the cold winter and a decline in the warm summer. Although there was a variation between these studies, in general the numbers started to soar in the beginning of September, peaking in December, drop in the end of March and reach its lowest numbers in late June and the beginning of July (18, 16, 19).

In our study, Number of cases per 100000 persons was highest in Irbid then Jarash, Ajlun and lastly in Mafraq, which is the warmest area of them all. Regions around the globe differed in the number of cases and the rate of deaths from CO poisoning. Where in the WHO European states the yearly death rate per 100000 people ranged greatly from 0.02 in Azerbaijan to 12.81 in Russia (15). In the US higher death rate was found in the colder states like Alaska, Montana, North Dakota (12). Ghosh found that south England had lower rates of accidental non-fire-related CO poisoning than the north and they thought it might be explained by the lower temperatures and the higher usage percentage of heating appliances usage in the North (18). However, that was not the case for all regions, where even though Sweden faces one of the coldest winters in the planet and despite their huge usage of wood-based warming devices, it has the lowest unintentional CO poisoning rate between all the WHO European states. Which could be explained by the

good precautionary measures and the excellent safe practice education amongst the population (15). This difference could also be attributed to the different sociodemographic index (SDI) between the different areas or that is what Mattiuzzi & Lippi think at least. They found that the number of cases grows parallel with it. And the mortality rate shows similar patterns, where they observed a 2.1-3.6-fold higher in the middle and middle-to-high than in low to-middle SDI countries (9). However, we found that a significant percentage of cases appeared in low socioeconomic communities, with almost one third of all cases were from non-Jordanian origins, mostly Syrians, and that could be explained by them using any source of fuel to warm which could lack the proper safety measures required to prevent such cases.

We also found that the most common place for such accidents happened at home and very few numbers appearing at work. Similar results were found in the collected data from other studies (11, 15, 19).

Unlike other reviewed studies (20), Alcohol and drugs did not pose any risk in our study. As only 2 cases had alcohol and only 3 cases had drugs in their blood. This could be explained by the low drug and alcohol usage in our society because of Islamic practices and Jordanian values and traditions.

6. CONCLUSION

Our study showed that although the incidence is decreasing with time, CO is still a threat that must be dealt with. As all cases in our study were accidental cases and good preventive measures, such as good CO detectors and good air flow in the places that hold devices that could generate CO, and proper education to the public, especially in the colder regions of the country, and establishing a cooperation with the government to enact a stricter approval measures for devices that could produce CO and be a danger to the public, could prove useful in decreasing the incidence of CO deaths further.

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- **Authors Contribution:** A.M.S and R.S. gave substantial contributions to conception and design of the study. All the authors had a part in acquisition of data, or analysis and interpretation of data. All the authors had a part in article preparing for drafting or revising it critically for important intellectual content. All the authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
- **Conflict of Interest:** The authors declare no conflict of interest.

REFERENCES

1. Rose JJ, Wang L, Xu Q, et al. Carbon Monoxide Poisoning: Pathogenesis, Management, and Future Directions of Therapy [published correction appears in *Am J Respir Crit Care Med*. 2017 Aug 1; 196(3): 398-399]. *Am J Respir Crit Care Med*. 2017; 195(5): 596-606. doi:10.1164/rccm.201606-1275CI
2. Hall J, Hall M, Guyton A. *Guyton And Hall Textbook Of Medical Physiology*. 14th ed. Philadelphia: Elsevier; 2020: 527.
3. World Health Organization. Regional Office for Europe. (2010). WHO guidelines for indoor air quality: selected pollutants. World Health Organization. Regional Office for Europe. <https://apps.who.int/iris/handle/10665/260127>.
4. Hampson NB, Piantadosi CA, Thom SR, Weaver LK. Practice recommendations in the diagnosis, management, and prevention of carbon monoxide poisoning. *Am J Respir Crit Care Med*. 2012; 186(11): 1095-1101. doi:10.1164/rccm.201207-1284CI
5. Kinoshita H, Türkan H, Vucinic S et al. Carbon monoxide poisoning. *Toxicol Rep*. 2020; 7: 169-173. doi:10.1016/j.toxrep.2020.01.005
6. Saukko P, Knight B. *Knight's Forensic Pathology Fourth Edition*. 4th ed. Boca Raton: Chapman and Hall/CRC; 2015:353.
7. Lo CP, Chen SY, Lee KW, et al. Brain injury after acute carbon monoxide poisoning: early and late complications. *AJR Am J Roentgenol*. 2007; 189(4): W205-W211. doi:10.2214/AJR.07.2425
8. Jang WI, Park JH. Transient left ventricular systolic dysfunction associated with carbon monoxide toxicity. *J Cardiovasc Ultrasound*. 2010; 18(1): 12-15. doi:10.4250/jcu.2010.18.1.12
9. Mattiuzzi C, Lippi G. Worldwide epidemiology of carbon monoxide poisoning. *Human & Experimental Toxicology*. 2020; 39(4): 387-392. doi:10.1177/0960327119891214
10. Population – Jordanian Department of Statistics. dosweb.dos.gov.jo. <http://dosweb.dos.gov.jo/population/>. Published 2020. Accessed December 22, 2020.
11. Fisher DS, Leonardi G, Flanagan RJ. Fatal unintentional non-fire-related carbon monoxide poisoning: England and Wales, 1979-2012. *Clin Toxicol (Phila)*. 2014; 52(3): 166-170. doi:1.3109/15563650.2014.887092
12. Hampson NB. U.S. Mortality Due to Carbon Monoxide Poisoning, 1999-2014. *Accidental and Intentional Deaths*. *Ann Am Thorac Soc*. 2016; 13(10): 1768-1774. doi:10.1513/AnnalsATS.201604-318OC
13. Ragheb SYA-A, Battah AH. Carbon Monoxide Fatalities in Medicolegal Autopsies. *Medicine, Science and the Law*. 1999; 39(3): 243-246. doi:10.1177/002580249903900309
14. Battah AH, Al-Farras MI, Abdallat IM, Hadidi MS. Trends of carbon monoxide fatalities in Jordan. *Saudi Med J*. 2009; 30(6): 853-854.
15. Braubach M, Algoet A, Beaton M, Lauriou S, Héroux ME, Krzyzanowski M. Mortality associated with exposure to carbon monoxide in WHO European Member States. *Indoor Air*. 2013; 23(2): 115-125. doi:10.1111/ina.12007
16. Li F, Chan HC, Liu S, et al. Carbon monoxide poisoning as a cause of death in Wuhan, China: A retrospective six-year epidemiological study (2009-2014). *Forensic Sci Int*. 2015; 253: 112-118. doi:10.1016/j.forsciint.2015.06.007
17. Zavorsky GS, Tesler J, Rucker J, Fedorko L, Duffin J, Fisher JA. Rates of carbon monoxide elimination in males and females. *Physiol Rep*. 2014; 2(12): e12237. Published 2014 Dec 11. doi:10.14814/phy2.12237
18. Ghosh RE, Close R, McCann LJ, et al. Analysis of hospital admissions due to accidental non-fire-related carbon monoxide poisoning in England, between 2001 and 2010. *J Public Health (Oxf)*. 2016; 38(1): 76-83. doi:10.1093/pubmed/fdv026
19. Hosseinienejad SM, Aminiahidashti H, Goli Khatir I, Ghasempouri SK, Jabbari A, Khandashpour M. Carbon monoxide poisoning in Iran during 1999-2016: A systematic review and meta-analysis. *J Forensic Leg Med*. 2018; 53: 87-96. doi:10.1016/j.jflm.2017.11.008
20. Yoon SS, Macdonald SC, Parrish RG. Deaths from unintentional carbon monoxide poisoning and potential for prevention with carbon monoxide detectors. *JAMA*. 1998 Mar 4; 279(9): 685-687. doi: 10.1001/jama.279.9.685.