

CARBON MONOXIDE RELATED DEATHS IN ALQURAYYATE, SAUDI ARABIA FROM 2004 TO 2018

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ABSTRACT

Objectives: The current work aimed to study carbon monoxide (CO) related deaths in Alqurayyate during the period from 2004-2018. **Methods:** All medico-legally examined cases with carboxyhemoglobin [COHb] levels $\geq 10\%$, within the study years, were investigated. The demographic data, autopsy findings and toxicological laboratory results for the cases of interest were collected. **Results:** Among 461 autopsied cases, 52 cases [11.3%] show carboxy-hemoglobin (COHb) levels $\geq 10\%$. Higher COHb levels were significantly more common among males, young and elderly and Saudi people [0.012, 0.009, and 0.3 respectively]. was the cause of death in 19 cases [4.1%] while CO poisoning was suggested as a contributing factor in another 33 [7.2%] deaths. The mode of deaths was mainly accidental [78.8%]. Houses were the most common place of death [63.5%] and most CO related deaths happened in the winter months [73.1%]. The most common suggested source for exposure to CO among carbon monoxide poisoning (COP) deaths were car exhaust [36.8%], followed by charcoal heaters [31.6%]. Regarding autopsy findings, the external appearance revealed cherry red hypostasis in only 26.9% of CO related cases. The most common findings were pulmonary edema, cerebral edema, and congested lungs [96.2, 82.7, and 80.8 % respectively]. **Conclusion:** COP remains a common cause of death, inspite of the safety precautions. More public awareness programs about COP are recommended. Also,

COHb levels should be routinely estimated in the autopsied cases, especially with suggestive history and death scene.

Keywords: Carbon monoxide poisoning; autopsy; carboxy hemoglobin; myocardial ischemia; poisoning, analytical toxicology.

INTRODUCTION

Carbon monoxide (CO) is a colorless, odorless and tasteless gas, which was estimated to be 100 ppb in earth's atmosphere and it is considered to be the second a major atmosphere pollutant after carbon dioxide. The incomplete combustion of hydrocarbons is the main source of CO (Kreuzer et al., 2009). It is produced by fuel-burning appliances and devices such as water heaters, Furnaces or boilers, gas stoves, ovens, and motor vehicles. Carbon monoxide can be produced in the human body with the normal body catabolism (Raub et al., 2000). The normal level of carboxy-haemoglobin (COHb) can be about 0.5% with normal variations among individual. Its level can be elevated up to 15% in among heavy smokers. Levels of 5% were found in patients with hemolytic anemia and pregnant ladies (Lippi et al., 2012).

Exposure to CO is fatal and can lead to death due to conversion of hemoglobin to COHb with significant tissue hypoxia as the affinity of hemoglobin to CO is 220-240 times its affinity to oxygen. This leads to less oxygen carrying capacity of hemoglobin and lower release of oxygen to the tissues with marked tissue hypoxia (Varon et al., 1999). The brain and heart are the main organs affected by CO poisoning (COP). The symptoms of carbon monoxide poisoning are non-specific and varied, and include headache, fatigue, visual disorders, cardiac palpitation, chest pain, coma and syncope with more

morbidities and mortalities in people suffering other cardiac disorders (Hampson and Weaver, 2007). Poisoning by CO is mostly underdiagnosed because of the varied nonspecific manifestations. However, it is estimated that at least 40000 COP cases are attending to the American Emergency departments annually (Ghosh et al., 2015). While it was reported that 5312 cases of CO poisoning were diagnosed in British hospitals within 10 years from 2000-2010 (Cobb and Etzel, 1991).

Carbon monoxide poisoning is a major cause of death worldwide. Several safety precautions were considered to decrease CO deaths with much more decrease in CO mortality rates (Sircar et al., 2015). However, CO was reported to be the second most common nonmedicinal poisoning mortalities in the United states from 1999-2012 (Statista, 2017) The Centers of Disease Control and Prevention (CDC) estimated that CO was a contributing cause of death in 16,447 cases during the period 1999–2004, with 2,631 deaths were unrelated to fires (CDC, 2007) While 715 deaths were reported in England due to unintentional CO poisoning in the period from 1995-2016 (Aldossary et al., 2015) Global data regarding Saudi Arabia CO deaths are not clear. The forensic chemistry laboratory in Dammam (Eastern province) had reported CO poisoning in 68 autopsied cases during the period from 2004-2013 among 894 autopsied cases (de Juniatic et al., 2012). Carbon monoxide deaths are mostly accidental; however, other suicidal and homicidal were also reported (Lippi et al., 2012). Some cases showed higher mortalities due to

CO poisoning coronary heart diseases, anemia, pregnant women and their fetus and infants, and the elderly (Mehta et al., 2001)

In autopsied cases died due to CO poisoning certain neuroanatomical injuries can be found as white matter damage, atrophied globus pallidus, hippocampus, thalamus and cerebral cortex (Zhu et al., 2006). Myocardial ischemic changes and elevated cardiac biomarkers also can be found as increased creatinine kinase MB and troponin (Battah et al., 2009). As autopsy and chemical analysis are the most trustable tools to evaluate the cause of death, the current study aimed to analyze the cases which gave positive results for CO in Alqurayyate during the period from 2004 to 2018. All demographic data, the circumstances and the laboratory data were considered.

MATERIALS AND METHODS

Ethical issues: The study was conducted and the data were accessed after a formal permission form the central administration of Forensic medicine in Riyadh

Study designs; According to laws in Saudi Arabian, all suspected unnatural deaths are notified to the police for further investigations about the cause of death and any possibility of homicide. The current study is a retrospective study for autopsied cases in Qurayyat (a city located in Al Jawf Province, in northern Saudi Arabia) during the years' period from January 2004 till December 2014, then prospective study was conducted for cases of interest from January 2014 till December 2018. All cases with COHb $\geq 10\%$ were evaluated considering all data from police reports, scenes of death, autopsy reports, and toxicological reports. Demographic data including sex, age, and nationality

were collected. Manner of death, place of death, suggested source of carbon monoxide and the season at which the studied cases were recorded for further analysis. For all cases the medico legal autopsy included systematic analysis for the different body organs with samples obtained [blood, urine liver, kidney, stomach, stomach content, lung, brain bladder, intestine] for toxicological evaluation. Tissue sections were obtained for histopathologic examination.

Analytic method; Toxicological samples were analyzed for COHb, ethanol, illicit drugs [Amphetamine, barbiturates, benzodiazepine, cannabis, cocaine, and opiates] and pesticide. Carboxyl hemoglobin level was analyzed on Ultraviolet system following Lucini et al. (2009). Whole blood preserved on EDTA was used. To measure COHb, one to three drops of case sample were added to a 1 cm cuvette containing 2 -3 ml of 0.5 % ammonia solution. Reference sample [blank] was prepared by adding 2 -3 ml of 0.5 % ammonia solution to a 1 cm cuvette without blood. At least one positive and one negative control samples were analyzed with each group of case samples. The absorbance of the solution is scanned at wave length 650 nm to 500 nm on Ultraviolet system. The absorbance ratio at A541nm /A555 nm is calculated and the percent COHb is determined for the negative, positive control samples and the case samples from the slope of the known calibration curve. Calibration curve was obtained by saturating negative blood with known concentrations of COHb.

Statistical analysis; The data were processed and analyzed by GraphPad Prism V (GraphPad Software Inc., San Diego, CA). Chi square was used for analysis of the categorical data. Data were represented as a percentage of the totals. Significance was considered with $p\text{-value} < 0.05$.

RESULTS

During the study years, 461 cases were autopsied [378 (81.9%) males and 83 (18.1%) females]. Among them, 54 cases (11.7%) show COHb levels >10%. The distribution of cases over the study years is shown in **Table (1)**.

Higher COHb levels were significantly more common among males and elderly in relation to the other autopsied cases (**Table 2**). CO was reported as a cause of death among 19 cases while CO was suggested as a contributing factor in the other 33 deaths (**Table 3**). Houses were the most common place of death and most deaths attributed to CO happened in the winter

months. The mode of deaths was reported to be accidental in most of cases (**Table 4**).

According to the reports, the most common suggested source for exposure to Co was smoking (35.2%) followed by fires (27.8%) (**Table 4**), while the source of exposure was not identified among 3 cases. Charcoal heating represented 60% of COP deaths among Saudi people.

Regarding autopsy findings, the external appearance revealed cherry red colour red hypostasis in only 14 autopsied cases. The most common findings were pulmonary edema, cerebral edema, and congested lungs (96.2, 82.7, and 80.8 % respectively).

Table 1: Distribution of CO related deaths from 2004-2018 in Alquryyat

Year	Total autopsies	COHb>10%	CO deaths	CO contribute in death
2004	24 (100%)	7(29.2)	3(12.5)	4(8.5)
2005	20 (100%)	1(5)	0	1(5)
2006	21 (100%)	1(4.8)	0	1(4.8)
2007	23 (100%)	1(4.3)	0	1(4.3)
2008	17 (100%)	1(5.9)	0	1(5.9)
2009	20 (100%)	1(5)	1 (5)	0
2010	28 (100%)	1(3.6)	1(3.5)	0
2011	15 (100%)	1(6.7)	1 (6.7)	0
2012	25 (100%)	3(12)	2(8)	1(4)
2013	20 (100%)	1(5)	0	1
2014	48 (100%)	2(4.2)	2(4.2)	0
2015	40 (100%)	4(10)	2 (5)	2(5)
2016	55 (100%)	6(10.9)	3 (5.5)	3(5.4)
2017	50 (100%)	10(20)	4 (8)	6(12)
2018	55 (100%)	14(25.5)	2 (3.6)	12(21.9)
Totals	461 (100%)	52 (11.3%)	19 (4.1%)	33 (7.2)

Table 2: Effect of age, gender and nationalities on percent of CO related deaths among the autopsied cases. *P*-values were estimated by Chi Square test. * means *p*-value<0.05, while *** means *p*-value<0.001.

Variables		Total (%)	COHb < 10	COHb ≥ 10	<i>P</i> -values
Gender	Females	83 (100)	80 (96.4)	3 (3.6)	0.012*
	Males	378(100)	329(87.1)	49 (12.9%)	
Ages (years)	≤30	144 (100)	130 (90.3)	14 (9.7)	0.0009***
	31-50	309 (100)	290 (93.9)	19 (6.1)	
	>50	108 (100)	83 (81.4)	19(18.6)	
Nationalities	Saudi	285 (100)	260(91.2)	25 (8.8)	0.03*
	Non-Saudi	176 (100)	149 (84.7)	27 (15.3)	

Tables 3: Causes of death among autopsied cases with COHb ≥ 10

Cause of death		Number(%)	COHb (%) Mean(M) ±Standard deviation (SD) Range
CO poisoning deaths		19(36.5)	M (43.3) ± SD (12) Range(40-65)
CO contributes	Head injury	1(1.9)	30
	Burn and Carbonization	10(19.2)	M (36.4) ±SD (22.5) Range(15-64)
	Co poisoning with cardiac comorbidities	21(40.4)	M (19) ±SD (8.2) Range(10-35)
	Hyperthermia vehicle entrapment	1(1.9)	25
Totals		52(100)	M (30) ±SD (19.4) Range(10-65)

Table 4: Place, seasons, and mode of deaths and suggested sources of CO exposure among the autopsied cases with COHb ≥ 10

Parameter	COP		CO contributed		Total	
	Number	%	Number	%	Number	%
A. Place of death						
Home	15	78.9	18	54.5	33	63.5
Car	2	10.5	9	27.3	11	21.2
Workplace	2	10.5	3	9.1	5	9.6
B. Seasons						
Autumn	1	5.3	3	9.1	4	7.7
Winter	15	78.9	23	69.7	38	73.1
Spring	3	15.8	1	3.0	4	7.7
Summer	1	5.3	5	15.2	6	11.5
C. Mode of death						
Accidental	18	94.7	23	69.7	41	78.8
Homicide	1	5.3	1	3.0	2	3.8
Suicide			9	27.3	9	17.3
D. Suspected CO source						
Car exhaust	7	36.8	3	9.1	10	19.2
Charcoal heaters	6	31.6	1	3.0	7	13.5
Fire	6	31.6	9	27.3	15	28.8
Smoking	0	0.0	17	51.5	17	32.7
Unknown	0	0.0	3	9.1	3	5.8
Totals	19	100.0	33	100.00	52	100.00

DISCUSSION

The current study was conducted to evaluate COHb levels in autopsied cases in Alqurayyate from 2004 to 2018. During the study years, 461 cases were autopsied. Among them, 54 cases [11.7%] showed COHb levels $>10\%$. Carboxyhemoglobin levels were significantly higher among males and cases below 30 and above 50 years. COP was reported as a cause of death among 19 [4.1%] cases while CO was suggested as a contributing factor in the other 33 deaths. The mode of deaths was reported to be accidental in most of cases. Houses were the most common place of death and most deaths attributed to CO happened in the winter

months. The most common suggested source for exposure to Co was smoking [35.2%] followed by fires [27.8%]. Regarding autopsy findings, the external appearance revealed cherry red color red hypostasis in only 14 autopsied cases. The most common findings were pulmonary edema, cerebral edema, and congested lungs [96.2, 82.7, and 80.8 % respectively].

Carboxyhemoglobin was expected to be related to 11.7% of autopsied cases during the studied years. CO poisoning was reported as the direct cause of death in 19 cases [4.1% of the autopsied cases]. It is lower than what was reported in Dammam, the capital of Saudi eastern principality, as CO was

reported as the direct cause of death among 7.6% of the autopsied cases during the years from 2004-2013 (**de Juniac et al., 2012**). However, their study did not consider cases in which CO was suggested as a contributing factor. Data about CO deaths in the other Saudi principalities are deficient. However, in a nearby country, Jordan, COP was reported as a cause of death among 1.8% of the autopsied cases during the years from 2000-2004 which is lower than our estimated ratio for COP deaths (**Hosseininejad et al., 2018**). It is clear that COP deaths rates are different among the different cities and in the same city over years.

which may be usually misdiagnosed with repeated exposure to the hazardous CO source or location (**Peters et al., 2004**).

The current data reported accidental exposure as the most common mode of CO related deaths and houses were the main places of deaths and winter months are the most common time for COP. This is in accordance with other studies (**Girman et al, 1998; Omaye , 2002; de Juniac et al., 2012; Karapirli et al., 2013; Sircar et al., 2015; Hosseininejad et al., 2018**). As CO is not commonly used to commit suicide or an assault. In addition, accidental fires and exposure to gas appliances and car exhaust with incomplete combustion are a common source for CO. Houses are the commonest place as they are the most common closed place for exposure to gas appliances as gas heaters and gas stoves. While COP is common in winter months due to higher use of gas heaters and charcoal heaters especially in localities with severe cold as in our research city.

Among cases where COP was considered as a cause of death fires were the commonest sources for CO [27.8%]. While the kerosene heaters were suspected to be the first suggested

Carbon monoxide poisoning is more common among males and elderly people, which is on line with the other studies (**Girman et al, 1998; Omaye , 2002; de Juniac et al., 2012; Karapirli et al., 2013; Sircar et al., 2015; Hosseininejad et al., 2018**). Males are expected to have more outdoor activities with more exposure to CO sources than females. While elderly population are subjected to have other comorbidities as cardiovascular disorders which may explain higher rates of CO related deaths as CO was shown to exacerbate cardiopulmonary diseases even in low levels of exposure

source of CO among CO deaths in Jordan [43%] (**Hosseininejad et al., 2018**). Other sources were suggested in other studies as gas stoves and water gas heaters (**Girman et al, 1998; Karapirli et al., 2013; Sircar et al., 2015**). This means that the main source of CO is different among different communities regarding to their pattern of life and traditional use for the different expected sources of CO. For example, charcoal heaters are commonly used among Saudi people in Alqurayyate, as a community tradition, for heating and it the commonest cause of COP deaths among them in the studied years.

Carbon monoxide was suggested as a contributing factor of death in 33 autopsied cases. Carbon monoxide [CO] was suggested to play a role in cardiac deaths (**Tonne et al., 2006; Samoli et al., 2007**). In an experimental healthy rats' model, it was shown that CO can alter calcium handling with the cardiomyocytes with increased sympathetic activity and arrhythmias (**Reboul et al., 2017**). In addition, in the same rats' ischemic heart model study, CO was shown to reduce the cardiac contractility at the cardiomyocyte level with associated mitochondrial dysfunction and oxidative damage to

the cardiomyocytes in the rat's model of ischemic heart (Miziara et al., 2015).

Regarding autopsy findings, the external appearance revealed cherry red colour red hypostasis in about one quarter of autopsied cases, while retinal hemorrhage was found in about 9% only. The most common findings were pulmonary edema, dark red hypostasis, cerebral edema, congested lungs, and brain hemorrhagic spots were the main findings (94.4, 94.4, 79.6, 77.8, and 38.8 respectively). These findings are in accordance with Mehta et al. (2001) who reported deep red discoloration of skin and serous membranes, pulmonary edema, cerebral edema, and brain pinpoint hemorrhages in 80%, 100% and 40% of the autopsied COP deaths. Cherry red was a fixed finding in other publications about COP deaths autopsy specially among Caucasians (Kumazawa et al., 2000; Jorge Dinis-Oliveira et al., 2010) However, we found its absence is not exclusion for COP and the laboratory investigations for carboxy hemoglobin should be done routinely especially with suggestive history of scene of death as it is also expected that carboxy hemoglobin levels will decline markedly with resuscitation attempts (Ernst et al., 1998).

The current study has some limitations as some cases may be died due to COP but they were not diagnosed or misdiagnosed due to other cases and not autopsied. Also COHb data may be affected by the resuscitation attempts or time between the exposure and the occurrence of death. Also, COHb levels do not correlate well with the severity of COP which depends mainly on the dissolved CO concentration.³⁰ In addition, the duration between death and sampling for COHb may affect the results.

CONCLUSION

The current data show that COP remains a direct cause and a

contributing cause of death whatever the safety precautions and the advance in mechanical engineering to eliminate its production from the engines and appliances.

RECOMMENDATIONS

- The public awareness regarding COP and its sources still deficient and more awareness programs should be planed and implemented, mainly before and during the cold months.
- COHb levels should be routinely estimated in the autopsied cases, especially with suggestive history.
- Mostly postmortem signs as cherry red colour and retinal hemorrhages are not found in all cases with high COHb levels. This should not mislead the forensic examiner and he should ask for COHb levels in COP suspicious cases

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الملخص العربي

الوفيات المرتبطة بأول أكسيد الكربون في محافظة القريات ، بالمملكة العربية السعودية في الفترة من

٢٠٠٤ إلى ٢٠١٨

مدحت جلال عطية^١ ، إكرامى المرسي^{٢،٣} ، أميرة علي الشامان^٤ ، هناء محمد الزاهد^٥ ، عبد الرحمن البلوي^٤ ، مركز الطب الشرعي ، مديرية الشؤون الصحية بالقريات ، المملكة العربية السعودية ، قسم الطب الشرعي و السموم الإكلينيكية، كلية طب المنصورة ، مصر ، قسم الأمراض ، كلية الطب ، جامعة الحدود الشمالية ، عرعر ، المملكة العربية السعودية ، مركز تبوك لمراقبة السموم ، مديرية الشؤون الصحية بالقريات مديرية الشؤون الصحية بتبوك، المملكة العربية السعودية ، قسم الطب الشرعي والسموم ، كلية الطب ، جامعة القاهرة ، مصر .

نبذة مختصرة :

يهدف العمل الحالي إلى دراسة الوفيات المرتبطة بأول أكسيد الكربون في القريات خلال الفترة من عام ٢٠٠٤ إلى عام ٢٠١٨. فمن بين ٤٦١ حالة تم تشريحها ، أظهرت ٥٢ حالة [١١,٣٪] مستويات الهيموجلوبين الكربوكسي ≤ 10 ٪. وقد كانت مستويات الهيموجلوبين الكربوكسي المرتفعة أكثر شيوعاً بين الذكور والشباب والمسنين والسعوديين (نسبة احتمالية = ٠,٠١٢ ، ٠,٠٠٩ ، ٠,٣ على التوالي). وكان سبب الوفاة في ١٩ حالة [٤,١٪] التسمم بأول أكسيد الكربون في حين أنه تم اقتراح كعامل مساهم في ٣٣ حالة وفاة أخرى [٧,٢٪]. كانت أغلب الوفيات قد تم حدوثها بشكل عرضي [٧٨,٨٪]. وكانت المنازل هي مكان الوفاة لمعظم لحالات محل الدراسة [٦٣,٥٪] وحدثت معظم الوفيات المرتبطة بأول أكسيد الكربون في أشهر الشتاء [٧٣,١٪]. كان المصدر الأكثر شيوعاً للتعرض لأول أكسيد الكربون بين الوفيات هو عدم السيارة [٣٦,٨٪] ، يليه التدفئة بالفحم [٣١,٦٪]. وفيما يتعلق بنتيجة تشريح الجثة ، فقد كشف فحص المظهر الخارجي عن ان لون الكرز الأحمر للرسوب الدموي قد لوحظ في ٢٦,٩ ٪ فقط من الحالات التسمم بأول أكسيد الكربون وبينما كانت النتائج الأكثر شيوعاً هي الوذمة الرئوية ، الوذمة الدماغية ، و احتقان الرئتين [٨٢,٧، ٩٦,٢ ، ٨٠,٨٪ على التوالي]. لذلك ، يظل التسمم بأول أكسيد الكربون سبباً شائعاً للوفاة ، على الرغم من احتياطات السلامة. لذا يوصى بمزيد من برامج التوعية العامة حول التسمم بأول أكسيد الكربون. وأيضاً ، يجب تقدير مستويات الهيموجلوبين الكربوكسي بشكل روتيني في الحالات التي يتم فيها تشريح الجثث ، خاصةً مع وجود شبهة للتعرض لمصدر من مصادره.