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Review Article

Carbon monoxide poisoning: assessment, treatment, and outcomes

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ABSTRACT

Many complications can occur secondary to carbon monoxide (CO), including serious complications to the cardiovascular system and neurological complications that might even end up with death. It has been estimated that around 30-40% of patients suffering from CO poisoning usually die before presenting at the emergency department. Accordingly, management of these patients is a critical approach to enhance the outcomes and prognosis of the affected patients. In the present literature review, we have discussed the current evidence regarding the assessment, treatment, and outcomes of patients with CO poisoning. Our results indicate that attending clinicians should adequately assess the suspected patients with their clinical manifestations, laboratory parameters, and history of exposure to CO. Besides, imaging techniques can also be indicated in some cases with a suspected brain injury. After the diagnosis has been successfully established, management of symptoms and administration of the validated therapeutic modalities should be rapidly performed to enhance the outcomes and intervene against the development of further complications. However, it should be noted that even after achieving adequate management, long-term complications might develop with the survivors and can even lead to death. Accordingly, further research is needed to help formulate successful interventions that can enhance the prognosis of the condition.

Keywords: CO, Poisoning, Toxicology, Management, Complications, Assessment, Diagnosis

INTRODUCTION

Incomplete combustion of carbonaceous materials leads to the significant release of enormous amounts of CO into the surrounding environment. CO is tasteless, colorless, and odorless and the affected patients usually become unconscious before they recognize that they were exposed to CO poisoning. Estimates indicate that among the different cases of poisoning, CO poisoning might account for up to 50% of the total fatalities from these events.

Many effects have been reported following the process of CO poisoning. However, evidence indicates that such events are hugely variable based on the affected patients.[1-3] Many research has been identified in the literature to discuss these effects and how to manage them.

Among the reported effect, many complications can occur, including serious complications to the cardiovascular system and neurological complications that might even end up with death.[4] It has been estimated that around 30-40% of patients suffering from CO poisoning usually die before presenting at the emergency department.[5,6] Accordingly, management of these patients is a critical approach to enhance the outcomes and prognosis of the affected patients. In the present literature review, we aim to discuss the different approaches that have been proposed for the assessment, and treatment of patients with CO poisoning and discuss the anticipated outcomes for these patients.

LITERATURE REVIEW

This literature review is based on an extensive literature search in Medline, Cochrane, and EMBASE databases which was performed on 16th September 2021 using the medical subject headings (MeSH) or a combination of all possible related terms, according to the database. To avoid missing poetential studies, a further manual search for papers was done through Google Scholar while the reference lists of the initially included papers. Papers discussing patients with CO poisoning were screened for useful information. No limitations were posed on the date, language, age of participants, orthe the publication type.

DISCUSSION

Assessment and evaluation of patients

Obtaining a full clinical history and adequate examination of the patients presenting with CO poisoning-like symptoms is the first in achieving adequate early management. Evidence indicates that the diagnosis of CO poisoning should be conducted according to the evaluation of a clinical tried that includes 1) having a history of recent exposure to CO, 2) developing symptoms that mimick CO poisoning, and 3) elevated COHb levels in the blood of the affected patient.[7] It should also be noted that a differential diagnosis should be conducted with other conditions that can cause chronic poisoning of lower-level CO nature.[8,9] Assessment of the ambient levels of CO can also aid to the diagnostic value in cases when there is no apparent presentation and clinical manifestations. The reported symptoms that most patients with CO poisoning present with include dizziness, headache, nausea, vomiting, fatigue, chest pain, altered mental state, loss of consciousness, and shortness of breath (Figure 1).[7]

CO-Hb (%)	clinical symptom
< 1	normal range (due to endogenous production)
< 10	smoker's blood (no symptom)
10–20	headache, fatigue, ear ringing
20–30	headache, weakness, nausea, vomitting
30–40	severe headache, dizziness, nausea, vomitting
40–50	syncope, confusion, increased respiration and heart rate
50k60	coma, convulsions, depressed respiration
60–70	coma, convulsions, cardiopulmonary depression, often fatal
70 <	respiratory failure, death

Figure 1: Symptoms of CO poisoning in relation to the levels of CO-Hb.[10]

In cases when the patient is severely ill or unconscious, it should be noted that having adequate history from this patient would be impossible. However, emergency technical advances might provide adequate evidence of exposure by measuring the environmental levels of CO.[7] In cases of suspected exposure, COHb levels can furtherly indicate the diagnosis. Evidence from previous investigations also indicates that neurological disorders and cognitive functions might be associated with cases of chronic lower-level CO poisoning, although the diagnosis of the condition is not always easy.[8,9,11] Other symptoms that might increase the ability to diagnose the condition also include vertigo, chronic fatigue, polycythemia, paraesthesias, recurrent infections, diarrhea, and abdominal pain.[8,12] Barker et al also previously concluded that using conventional pulse oximetry might not be valid in all cases as it cannot significantly differentiate between oxyHb and COHb.[13] Therefore, it might not be able to detect cases with profound hypoxia and elevated COHb levels. On the other hand, pulse CO oximetry has been validated to measure the multiple types of Hb, in addition to decreasing the delays in patients that administer hyperbaric O_2.[14,15] However, it should be noted that the current evidence is still scarce about whether this modality is more accurate than the laboratory-based measurement of COHb by spectrophotometry. Therefore, it should not be used alone and confirmed by laboratory measurements should always be indicated.[7,15,16] This has been demonstrated in a previous investigation which showed that CO poisoning could not be established by depending on the reading of the pulse CO oximetry for measuring COHb levels.[16]

Taking adequate care of the clinical manifestations of the affected patients can significantly enhance the diagnosis of the condition. Evidence shows that some patients might present with a critical condition that requires immediate admission to the intensive care unit. Increased

long-term mortality might also be present secondary to myocardial injury among patients that suffer from cardiovascular diseases. Estimates show that the prevalence of these conditions in such settings is about one-third among patients with moderate-to-severe CO poisoning.[17,18] Acute and chronic events of myocardial infarction were also reported to be associated with increased levels of COHb.[19] Many mechanisms have been proposed for developing cardiovascular events in patients with CO poisoning and have been adequately described elsewhere.[10] Affective and neurological complications might also be observed in cases of CO poisoning. If adequate management was significantly achieved, survivors might suffer from long-term neurological complications,[7,20] such as cognitive dysfunction, impaired memory, anxiety, depression, motor and vestibular effects.[7,20] Evidence shows that the incidence of these symptoms might be present in 40% of the affected case by 6 weeks following CO poisoning.[20] It has also been furtherly demonstrated that patients may not achieve complete remission from long-term neurological complications.[20-22] Besides, evidence also shows that the severity of the initial presentation with CO poisoning is not necessarily be associated with the long-term outcomes of the neurological complications.[23] Imaging modalities can also be used to assess and evaluate patients with CO poisoning. Computed tomography (CT) of the head, in addition to magnetic resonance imaging (MRI), can be used to detect brain changes and determine the severity of the case. Hippocampal atrophy and white matter hyperintensities are the usual findings on MRI.[24,25] Posterior structures of the brain might also show signs of severe ischemia in cases of severe CO poisoning.[26,27] Therefore, clinicians and emergency physicians should be aware of these procedures to establish an adequate diagnosis and enhance the outcomes by approaching the patient with a proper management plan based on the pathological parameters that were assessed during this initial evaluation.

Treatment

Among the different studies in the literature, the most commonly used modalities to treat CO poisoning include 100% hyperbaric and normobaric O_2 (HBO_2 and NBO_2).[28,29] These modalities rapidly increase the O_2 partial pressure in the blood. Therefore, it leads to the rapid removal of CO from the blood and significant dissociation of CO from Hb, leading to reduced levels of COHb.[7,30,31] The elimination half-life of CO has been reported to be reduced following the administration of NBO_2 to 74 minutes in room air from 320 minutes.[7,30,32] On the other hand, the reduced half-life of CO was also reported to be 20 minutes with HBO_2. However, studies indicate that the estimated period might be much higher in the clinical settings, and is usually up to 40 minutes.[33-35] Furthermore, the administration of these modalities has been associated with reversed effects that have been induced by CO poisoning including mitochondrial dysfunction and inflammation.[36-38] The administration of NBO_2 is usually done upon arrival at the emergency department. On the other hand, the administration of HBO_2 is usually delayed following diagnosis and arrival at the hospital. Many investigations have compared the efficacy of HBO_2 and NBO_2 in the management of patients with CO poisoning. In a previous meta-analysis by Buckley et al the authors analyzed the results of seven randomized controlled trials.[39] The findings showed that patients that received HBO_2 did not have a significant overall benefit in the neurological manifestations. However, it has been indicated that the included trials were significantly heterogeneous. The only trial that has been published with adequate reporting criteria and a minimal degree of bias was the trial by Weaver et al which indicates a significant improvement in the neurological dysfunctions in a 1-year follow-up investigation.[40] Treating patient with HBO_2 is not mandatory for patients with CO poisoning despite being recommended by the American college of emergency physicians.[41] The administration of HBO_2 in cases of CO poisoning has also been previously suggested by experts in the field.[7] Accordingly, it has been demonstrated that the modality should be indicated for patients presenting with severe CO poisoning. Although the modality has been validated for its efficacy by many investigations, estimates show that a big proportion of the survivors would still suffer from related neurological complications, indicating the urgent need to conduct future investigations to validate other more valid therapeutic modalities.[7] It is worth mentioning that CO poisoning might be associated with ingestion of other substances, and therefore, treating these conditions should also be considered.[7,31,40,42] Moreover, recent research has focused on developing adequate interventional approaches that can also enhance the management of the potentially affected patients by reducing the incidence and/or severity of the condition. However, such approaches are not within the scope of the current review and were described elsewhere.

Outcomes

Previous studies in the literature have indicated that a CO-Hb concentration that exceeds 50-60% is a fatal indicator of CO poisoning.[43,44] Many factors can affect the CO-Hb concentration levels in the blood of the affected patients. Moreover, clinicians should consider the application of medical interventions as cardiopulmonary resuscitation, and O_2 administration to adequately evaluate and assess the management plan for the affected patients. Estimates from previous investigations indicate that younger patients tend to have higher concentrations of CO-Hb at the time of death than the elderly population.[45,46] Besides, evidence also indicates that older patients tend to die from CO poisoning at lower levels of concentration of CO-Hb. This level has been reported to be around 25%, and it has been reported that no other etiologies were found to cause death in such situations.[47] This might be attributable to the fact that younger patients tend to tolerate hypoxia

more significantly than the elderly ones, in addition to having less frequent complications and associated morbidities.

Survivors, after applying an adequate treatment approach usually have long-term complications.[48] For instance, studies indicate that the risk of long-term mortality doubles in these patients compared to the general population.[48] The risk with intentional exposure to CO poisoning is also remarkable than the accidental one. Some of the reported prominent causes of death include accidents, alcoholism, and intentional self-harm, which indicates the persistence of long-term psychiatric and neurological complications.[49] The quality of life of the affected patients might also be affected. Pages et al indicated that months following CO poisoning affected patients had more depression, reduced cognitive abilities, and increased incidence of posttraumatic stress disorders.[50] Accordingly, it has been demonstrated that follow-up evaluation should be conducted for these patients for at least 1-2 months from poisoning to assess the presence of any neurological conditions, anxiety, and depression.[7] If any disorder was evaluated, the attending physician should suggest the patient should be evaluated for neurocognition. Further care should also be offered to the affected patient to care for and adequately intervene against the development of any other medical condition, including myocardial infarction, as we previously mentioned.[19] Finally, further long follow-up investigations should be conducted to assess the outcomes and adequately study the long-term outcomes and the effect of post-treatment care on patients with CO poisoning for a better understanding of the condition and the prognosis. In general, it has been demonstrated that the prognosis of patients with CO poisoning significantly varies based on many factors, including the laboratory parameters, the presence of other comorbidities, and the severity of the condition. However, a poor prognosis has been demonstrated to occur with patients that were initially observed to have abnormal CT and MRI diagnostic findings. Furthermore, a guarded prognosis was reported with patients that suffer from persistent neurological complications as previously discussed.

CONCLUSION

Our results indicate that attending clinicians should adequately assess the suspected patients with their clinical manifestations, laboratory parameters, and history of exposure to CO. Besides, imaging techniques can also be indicated in some cases with a suspected brain injury. After the diagnosis has been successfully established, management of symptoms and administration of the validated therapeutic modalities should be rapidly performed to enhance the outcomes and intervene against the development of further complications. However, it should be noted that even after achieving adequate management, long-term complications might develop with the survivors and can even lead to death. Accordingly, further research is needed to help formulate successful interventions that can enhance the prognosis of the condition.

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