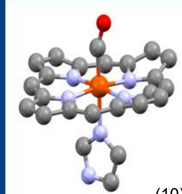
Management of Acute Carbon Monoxide Poisoning with Positive Airway Pressure as a Viable Alternative to Conventional Oxygen Therapy and Hyperbaric Therapy in Rural Emergency Departments



(10)

Quincey Frick - Respiratory Therapy Student

School of Health and Public Safety - Southern Alberta Institute of Technology

Introduction

When carbon monoxide (CO) binds with hemoglobin in the blood it forms carboxyhemoglobin (COHb). COHb in those not exposed to extrinsic CO is 1-3% (non-smokers) and 5-10% (smokers) (1). The consequences of elevated COHb levels range from headache when COHb reaches 20%, to syncope at 40%, to fatal when COHb reaches 80% (2).

The objective of this research is to convey that continuous positive airway pressure (CPAP) therapy should be the primary intervention used for CO poisoning, especially in rural centers where hyperbaric chambers are not readily available. The findings from these studies argue that **CPAP therapy is a viable alternative intervention over conventional oxygen therapy and hyperbaric therapy for the management of adult patients with CO poisoning in rural emergency departments**. The purpose of this research is to provide evidence that the implementation of **CPAP for treatment of CO poisoning is an emerging and promising advancement in healthcare that respiratory therapists should be conscious of and advocate for continued research in.**

Effects of Carbon Monoxide Poisoning

CO binds to hemoglobin with 210x greater affinity than oxygen (3), this increases the affinity of oxygen to bind and remain bound to hemoglobin and causes a left shift in the oxyhemoglobin-dissociation curve (4). The effect of this shift is decreased oxygen delivery to the tissues and histotoxic hypoxia (4).

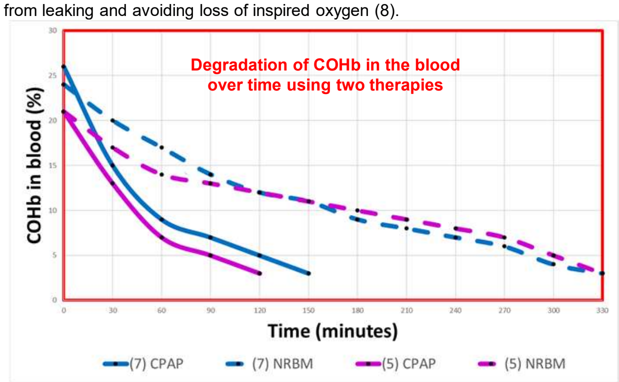
CO poisoning presents as metabolic acidosis, ground-glass appearance on chest x-ray, and COHb levels >25% with a PaO2 <60 mmHg (1). Prolonged CO exposure can lead to further respiratory complications including pneumonia, pulmonary edema, and acute respiratory distress syndrome (1). Multiple systems in the body are affected by COHb, especially highly perfused organs such as the heart and brain. Long term consequences include chronic cognitive sensory and motor deficits termed neurological sequelae which cause uncontrollable emotional alterations and seizures (5).

Carbon Monoxide Poisoning in Canada

- CO poisoning was responsible for 3,027 hospital admissions between 2002 and 2016 (6).
- 4,990 accidental CO poisoning deaths occurred between 2000 and 2013 (6).
- No decline in hospitalizations in the past 18 years despite the widespread implementation of CO detectors (6).

Comparing CPAP therapy to Standard Oxygen therapy

A non-rebreather mask (NRBM) reduces the half-life of COHb from 5 hours to 2 hours (1). The loose-fitting seal of the mask on a NRBM delivers 70-90% oxygen when flow is 15LPM. In comparison, CPAP uses a tight mask capable of providing a higher inspired fraction of oxygen (FiO_2) compared to a NRBM (5), increasing FiO_2 to 100% (7). This is credited to the nature of the CPAP mask that must fit tightly for pressures to be achieved, preventing air from leaking and avoiding loss of inspired oxygen (8).



- In a case-study conducted by *Idil et al*. (7), 2 patients exposed to CO in their home while asleep had COHb measuring 24% and 26%. The concentration of COHb dropped to 3% within 5 hours for the patient with the NRBM and within 2 hours for the patient with CPAP
- In a study with similar structure by *Roth et al*. (5), COHb levels fell from 21% to 3% in 120 minutes using CPAP, and nearly 3 times longer, 330 minutes for the patient treated using a NRBM.
- A larger experimental study was conducted by *Delvau et al*. (8) using swine exposed to CO as the test population. The results revealed that COHb half-life was reached in 58 minutes for the swine receiving CPAP therapy and 85 minutes for the swine with NRBM (8).

How CPAP aids in CO clearance from the blood

Airways are stented open throughout the breath from constant positive airway pressure and alveolar collapse at end-exhalation is minimized, optimizing lung diffusion and gas exchange area. The effect of this is that oxygenation becomes more efficient at any given FiO_2 and the tissues can be more rapidly supplied with oxygen (8), allowing oxygenated hemoglobin to more effectively compete with COHb at the binding site (8).

- CPAP is indicated for refractory hypoxemia, "when PaO2 cannot be maintained at greater than 50 to 60 mmHg with FiO2 0.50 or greater" (9 p1031), a common sign in CO poisoning.
- CPAP effectively decreases the sensation of dyspnea, which is one of the most prevalently reported symptoms (1).
- CPAP improves functional residual capacity (FRC), which is reduced from elevated hydrostatic pressure and fluid accumulation in the interstitial space (3) causing cardiogenic pulmonary edema.

Disadvantages of Hyperbaric Oxygen Therapy (HBOT) for CO poisoning

There are only 3 licensed HBOT facilities in Alberta, 2 are in hospital; Foothills Medical Centre and Misericordia Hospital, cities with populations >800,000. This is problematic in that it delays initiation of therapy, prolongs recovery time, and increases likelihood of long-term consequences. Cost to operate each chamber is ~ $190,000/year without physician billing and purchased in 1995 for $111,000 (9**).** HBOT itself presents adverse effects: claustrophobia, inner ear and sinus damage, decreased cardiac output, fire risk, and can aggravate existing conditions including diabetes and epilepsy (9).

Conclusion

Initial research has been promising in favour of using CPAP with 100% oxygen to reduce the half-life of carboxyhemoglobin at a much faster rate than conventional NRBM. HBOT has traditionally been utilized but is not feasible in rural communities as therapy will not be received within a desirable time and transporting unstable patients to larger centres with HBOT poses additional risks. The implication of CPAP for CO poisoning is immense because it reverses the causative mechanism, treats the signs, and relieves the symptoms. The accessibility, affordability, and reliability of CPAP makes it a preferred method of treatment for those who experience CO toxicity in rural settings.

Limitations and Future Research

The topic is considerably new and there are challenges developing case studies with reliable population size to gain statistically significant data from. Future research with larger sample sizes would be beneficial for the data to be accurately applied as protocol for a greater population. It would be of value to study the use of bi-level positive airway pressure (BiPAP) to optimize ventilation and further aid in relieving the high work or breathing associated with CO toxicity.

References

1. Sönmez FT, Güneş H, Saritaş A, Kandiş H. Carbon Monoxide Poisoning: Clinical Manifestations, Consequences, Monitoring, Diagnosis and Treatment of Toxicity. Konuralp Medical Journal / Konuralp Tip Dergisi [Internet]. 2015 Sep [cited 2019 Jul 9];7(3):192–8. Available from: https://search-ebscohostcom.libresources1.sait.ab.ca/login.aspx?direct=true&db=a9h&AN=115922418&site=eds-live&scope=site

2. Hullin T, Aboab J, Desseaux K, Chevret S, Annane D. Correlation between clinical severity and different non-invasive measurements of carbon monoxide concentration: A population study. Plos One [Internet]. 2017 Mar 28 [cited 2019 Sep 29];12(3):e0174672. Available from: https://search-ebscohost-com.libresources1.sait.ab.ca/login.aspx?direct=true&db=mdc&AN=28350859&site=eds-live&scope=site

3. Kacmerek RM, Dimas D, Craig WM. The essentials of respiratory care. 4th ed. St. Louis, MO: Mosby; 2005. 745-749p.

4. Henretig FM, Calello DP, Burns MM, O'Donnell KA, Osterhoudt KC. Predictable, Preventable, and Deadly: Epidemic Carbon Monoxide Poisoning After Storms. American Journal Of Public Health [Internet]. 2018 Oct [cited 2019 Sep 29];108(10):1320–1. Available from: https://search-ebscohost-com.libresources1.sait.ab.ca/login.aspx?direct=true&db=mdc&AN=30207780&site=eds-live&scope=site

5. Roth D, Mayer J, Schreiber W, Herkner H, Laggner AN. Acute carbon monoxide poisoning treatment by non-invasive CPAP-ventilation, and by reservoir face mask: Two simultaneous cases. The American Journal of Emergency Medicine [Internet]. 2018 Sep [cited 2019 Jul 9];36(9):1718.e5-1718.e6. Available from: https://search-ebscohost-com.libresources1.sait.ab.ca/login.aspx?direct=true&db=mdc&AN=29866417&site=eds-live&scope=site

6. Cohen I, Garis L, Pike I, Rajabali F. Carbon Monoxide Poisoning Hospitalizations and Deaths in Canada. Vancouver, BC; 2017 Oct [cited 2020 Feb 7]. Available from: https://cjr.ufv.ca/wp-content/uploads/2017/10/Carbon-Monoxide-2017-Final-.pdf

7. Idil H, Unek O. Non-Invasive CPAP Ventilation in Acute Carbon Monoxide Poisoning. Prehospital and Disaster Medicine [Internet]. 2019 Jun 26 [cited 2019 Jul 11]; 1–2. Available from: https://search-ebscohost-com.libresources2.sait.ab.ca/login.aspx?direct=true&db=mdc&AN=31239002&site=eds-live&scope=site

8. Delvau N, Penaloza A, Liistro G, Thys F, Delattre IK, Hantson P, et al. Effect of Pressure Support Ventilation on Carboxyhemoglobin Toxicokinetic after Acute Carbon Monoxide Intoxication: a Swine Model. Journal of Medical Toxicology [Internet]. 2018 Jun [cited 2019 Jul 10];14(2):128–33. Available from: https://search-ebscohost-com.libresources2.sait.ab.ca/login.aspx?direct=true&db=a9h&AN=129717609&site=eds-live&scope=site

9. Kacmarek RM, Stoller JK, Heuer AJ, Chatburn RL, Kallet RH. Egans fundamentals of respiratory care. 11th ed. St Louis, MO: Elsevier; 2017. 1031p.

10. Rifleman. Carboxyhemoglobin from 1AJ9.png [Internet]. Wikimedia Commons. [cited 2020Feb 28]. Available from: https://commons.wikimedia.org/w/index.php?curid=19272474