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Carbon Monoxide Exposure in Nepalese Workers at Mount Everest Base Camp

Meghan Sawyer[1], **Kris Brickman, MD**[1]

[1] University of Toledo College of Medicine and Life Sciences

Email: meghan.deutsch@rockets.utoledo.edu

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Abstract

Carbon monoxide (CO) is an often encountered but undetected toxin that can produce devastating adverse health effects. Sources of CO are commonplace, such as stoves or generators. While clinical effects of short-term exposure are well studied, effects of long-term, low-level exposure remain under characterized. We hypothesized that long-term, low-level exposure to CO may be prevalent at Everest Base Camp (EBC). Cooking stoves in poorly ventilated tents may provide a source for this long-term CO exposure at Mount Everest Base Camp (EBC). Our study intended to monitor carbon monoxide levels in this setting via non-invasive SpCO testing, and survey associated symptoms to determine what significance of carbon monoxide exposure, if any, was present.

Keywords: Carbon monoxide, environmental exposure, long-term CO exposure, Mount Everest

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1. Introduction

Carbon monoxide (CO) is a common source of poisoning in countries around the globe. Produced by combustion of carbon containing compounds, carbon monoxide is an odorless gas which displaces oxygen in the blood leading to oxygen deprivation (1). Since CO is difficult to detect, there is a high chance of long-term unknown exposure which can result in carbon monoxide poisoning, causing a variety of symptoms ranging from headache to coma, and death (2). Sources of CO may be commonplace, including vehicles, generators, cigarettes, and stoves (2). With few treatment options, CO poisoning can result in permanent deficits. Multiple mechanisms contribute to this toxicity leading to cardiovascular and neurologic dysfunction, including ischemia and inflammation. For example, excess CO activates platelets, leading to an inflammatory cascade driven by reactive oxygen species and neutrophil activation/degranulation that can cause permanent neurologic deficits and cardiac injuries including arrhythmia and myocardial infarction/ventricular dysfunction (1). Cardiovascular involvement may lead to cardiomyopathies, myocardial infarction, and arrhythmias (3). Therefore, it is important to identify potential sources of carbon monoxide and take measures to avoid toxic exposure.

While the clinical effects of short-term CO exposure are well characterized, the long-term effects of repeated low-level CO exposure are less clear. A review of the literature by Townsend and Maynard suggests that chronic exposure to CO may be linked to long-term cardiovascular and neurologic effects which may be irreversible, however, these relationships remain understudied, and the correlation remains unclear (4). A more recent 2009 study involving barbecue workers correlated CO exposure with c-reactive protein, an important inflammatory marker. Their results showed positive correlation between the two, in addition to a positive correlation between CO exposure and carotid intima-media thickness and therefore suggested that long-term low-level exposure may be related to increased inflammation and risk of atherosclerotic cardiovascular events (5). What is clear is that it is important to identify potential sources of CO and take measures to avoid toxic exposure.

Mount Everest Base Camp (EBC) in Nepal becomes a small city from March through May each year due to the Everest climbing season. Hundreds of Nepali staff live and work in tents found at base camp; the staff cook and provide meals to over 1500 staff and climbers during the season. The Everest population is separated into climbing teams, with approximately 10 to 50 workers and climbers within each team. Workers may spend upwards of eight hours per day working with stoves operated by fuel generators and propane. Furthermore, these working conditions are negatively affected by the frigid temperatures, and poorly ventilated conditions. The unique working conditions of EBC create the possibility for workers to have long-term exposure to low levels of CO. Previous studies have shown that using a stove in a camping tent for as little as two hours can lead to significant levels of CO in the blood (6). Similarly, other studies and case reports have demonstrated the presence and potential dangers of CO from stoves in unventilated homes in Nepal (7-9). We therefore hypothesize that workers experience CO exposure resulting from use of stoves and generators in poorly ventilated tents.

In this study, we monitored CO levels and surveyed associated symptoms, to determine if low levels of CO exposure are present. If determined that toxic exposure is significant, a simple and low-cost ventilation system could be introduced to eliminate or minimize this exposure.

2. Methods

Methods

This study (# 300961-UT) was approved by the University of Toledo IRB. The dining work crew consisted of eight Nepalis, including two servers, five kitchen and cleaning staff, and one assistant that floated to both areas. The longest period of time that staff were confined in one of these tents was for meal preparation, three times a day for approximately one to two hours, for a total duration of five weeks each year at EBC starting in April through the end of May. Other than for initial food preparation, the kitchen workers were noted to be transiting in and out of these tents on a frequent basis throughout the dining hours. The cooking tent and the dining tent were two separate 20’ x 40’ canvas tents with an open flap on each end functioning as an access point in and out of the tent. Commonly, the flap would be kept open in both the dining and cooking tents to allow easy transfer of workers, climbers and food. Due to the typically frigid weather conditions, all cooking, eating, and cleaning activities for the group were within these tents throughout climbing season. Rarely were the kitchen or dining tents completely closed (for instance, in the event of extreme weather).

For this study, the workers' oxygen saturations, CO levels, and heart rates were assessed throughout the time they were inside the cooking and dining tents. Utilizing an interpreter, participants provided consent to these evaluations with a portable carbon monoxide detector (Masimo Rad-57 Pulse CO-Oximeter). Prior to CO monitoring collection, they were queried on any symptoms or subjective findings including nausea, vomiting, shortness of breath, chest pain, headache, neurologic symptoms or light headedness. This query was followed by non-invasive monitor data collection of CO level utilizing the non-dominant hand ring finger. In addition, the device collected oxygen saturation levels and heart rate, along with CO level.

Monitoring included selected breakfast, lunch, and dinner preparation times. In addition to the individual CO data collection, CO air quality levels were also assessed throughout the different mealtimes within the cooking and dining tents. It should be noted that masks were utilized by most staff but inconsistent in implementation throughout the study.

3. Results

A total of 88 data collection points were attained over five weeks at EBC among people working as kitchen staff for the 2021 Everest climbing season. This data revealed low and clinically insignificant levels of CO across all collected samples among the subject group tested. The only identified medical problems among workers were one cook who had a history of hypertension but currently required no medication. No workers prior to data assessment/CO measurement were exhibiting any symptoms suggestive of CO toxicity or illness.

Fifty-seven of the 88 (65%) data points registered 0 or 1% CO level reflecting negligible CO exposure in these measurements. Of the 88 data points collected, only 3 were greater than 10% (11%, 11%, 13%). Each of these 3 measurements over 10% involved 2 workers who served as primary cooks who had been enclosed in the cooking tent for over an hour in meal preparation. Despite the elevated level, each worker with the elevated CO level was asymptomatic at the testing interval.

Study Limitations

It should be noted that this study was conducted in 2021, when COVID-19 was still prevalent throughout the world. Although measures at EBC were taken by many teams to create an isolated environment to limit external exposure, COVID-19 remained a threat and was an escalating problem throughout the climbing season at base camp. Over the course of the climbing season, hundreds of climbers and staff tested positive for COVID-19 and required quarantine and/or evacuation from EBC. Needless to say, the constant overwhelming presence of COVID-19 significantly changed the EBC environment, including all the various climbing teams that typically socialize, interact and participate in EBC and climbing activities throughout April and May.

Our initial study design was to identify and compare the cooking/dining environment of different climbing teams to evaluate the potential for increased CO exposure. Unfortunately, the overwhelming threat of COVID-19 precluded any ability to collaborate and interact with other climbing teams since an isolated perimeter between each team was necessary. Therefore, this data only represents a single climbing camp of approximately 45 individuals who comprise the team. The testing was focused solely around the kitchen and dining staff who clearly had the most exposure to potential carbon monoxide toxicity. It should also be noted, in random measurements that were obtained of climbers in the dining tent, at no point was there any registration of CO levels above 2% in climbers or individuals who were not part of the kitchen staff.

Other limitations may have also affected data points. It has been previously established that many types of masks can reduce CO levels from pollutants (10). Due to the COVID-19 pandemic, masks were worn, although inconsistently, by Nepali workers at EBC. It has been established in the literature that several kinds of masks including n95s, surgical masks, fabric masks, and carbon masks are capable of limiting levels of CO intake from air pollution (10). It is therefore possible that this may have impacted collected CO levels, therefore impacting data points and the results of the study. Repeat studies outside of the COVID-19 era would be appropriate to further determine the impact of these limitations on study data.

4. Discussion and Conclusion

In this study, no clinically significant levels of CO exposure were detected. Levels less than 12% SpCO, if asymptomatic, do not warrant further medical investigation (11). Furthermore, levels under 15% are often clinically silent, with the patient showing little to no symptoms (11).

All subjects surveyed were asymptomatic, and the highest recorded SpCO level was 13% after no more than 2 hours of continuous exposure to gas stoves in food preparation. Over 85% of the data points were less than 5%. This is likely the result of kitchen workers frequently entering and exiting the tents minimizing any prolonged exposure to carbon monoxide within the combined kitchen tent area. Therefore, based on the cooking and tent configuration of this specific company at Everest Base Camp, this study did not identify any prolonged carbon monoxide exposure or toxicity from intermittent but sustained exposure to CO gas inhalation in this unusual environment at Everest Base Camp during the climbing season.

Further Studies

Acute exposure to CO is well characterized and studied. However, data regarding long-term exposure to low-level carbon monoxide, commonly found in the Nepali population, remains almost non-existent. Data regarding long-term CO exposure at high altitudes is also not available. While our study found no acute CO toxicity present, further research should explore potential chronic effects of low-level CO exposure over prolonged periods of time.

Particularly considering the population at EBC and throughout Nepal, as well as other areas in newly developed and developing countries that have poor ventilation and utilize gas for heating and cooking, there is significant potential for CO exposures. To date, there is little research available on chronic or intermittent exposure to low levels of CO over extended periods of time, i.e. years. Particularly in Nepal where much of the population lives at an extremely high elevation, CO exposure could have a particularly hazardous effect long term. This could be from continued exposure in an enclosed environment due to the harsh weather, living conditions, and current heating and cooking that remains predominantly gas generated.

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