Carbon Monoxide Exposure in Norwegian Rescue Helicopters

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Abstract

Objective: Exposure to exhaust fumes from combustion engines can lead to carbon monoxide (CO) poisoning. Sea King Rescue helicopter crews are frequently subjected to engine exhaust. This study investigates the extent of CO exposure and potential for intoxication for flight crews during standard operational training procedures.

Methods: Over a 2-week period, rescue helicopter flight crews were monitored for exposure to exhaust fumes and clinical symptoms of CO intoxication by means of a written survey and measurements of carboxyhemoglobin saturation (SpCO) with a handheld pulse CO oximeter (RAD-57; Masimo, Irvine, CA). Normal ranges for SpCO were defined as ≤ 4%.

Results: Sixty-nine completed surveys and 138 SpCO measurements of 37 crewmembers were included in the study. Sixty-four percent (n = 44) experienced subjective exposure to engine exhaust during training. Clinical symptoms were reported in 8.6% (n = 6) and included exhaustion (n = 4), headache (n = 1), and nausea (n = 1). Twenty-nine percent (n = 20) showed postflight SpCO levels outside the normal range (≥ 4%). The maximum postflight SpCO level among all measurements was 7%.

Conclusion: Exposure to engine fumes is common, even more so during open cargo door operations. However, clinical symptoms are infrequent and mild. Toxic SpCO levels were not reached in this study, but approximately one third of postflight SpCO levels were outside the normal range.

Introduction

Carbon monoxide (CO) is a nonirritating gas without color, taste, or odor produced by incomplete combustion.[1] Exogenous sources include house fires, cigarette smoke, engine exhaust, heaters, grills, and camp stoves. Intoxications usually occur in confined spaces, but CO poisoning has also been described in nonconfined spaces like the back of pickup trucks, on ice skating rings, and during recreational boating.[2] Poulton[3] identified CO exposure for medical staff working beneath the running rotors of a helicopter as a potential problem causing mild illness. MacDonald et al[4] described occupational exposures of jet fuel combustion products in different engine ignition scenarios for medical transport personnel operating fixed wing aircraft. They found a low risk of exposure, and the US and Canadian health safety limits were not exceeded. However, substantial variations in exposure were found between "minimized" and "exposed" scenarios. Our study intended to examine the extent of CO exposure and potential for intoxication in Sea King rescue helicopters during standard training missions.

The common mode of CO intoxication is absorption through the lungs and depends on minute ventilation, blood volume, metabolic activity, and length of exposure.[2,5,6] The following symptoms of CO exposure and intoxication are nonspecific and share similarities with viral illness: headache, nausea, vomiting, myalgia, dizziness, weakness, shortness of breath, chest pain, confusion, and coma.[5] Headache is the most common symptom.[7] Carboxyhemoglobin (COHb) levels equal or above 4% for nonsmokers and equal or above 10% in smokers are considered to be beyond the normal range.[8]

Sea King rescue helicopter crews are frequently exposed to engine exhaust fumes. This holds true especially for engine ignition, operational procedures that involve an open cargo door like hoist maneuvers, confined area landings, and loading/unloading of the patient with rotors running ("hot extract"). The purpose of this study was to examine the extent of CO exposure and the potential for intoxication for flight crews during standard training procedures.

Methods

Over a 2-week period, 37 Sea King helicopter crewmembers were monitored for exposure to engine exhaust fumes, clinical signs of CO intoxication, and levels of carboxyhemoglobin saturation (SpCO) after standard operational training flights. The participation of crewmembers in the study was voluntary and required written consent. The study was approved by the Regional Ethics Committee (2013/2339-3) and the Social Science Data Service.

Crewmember data were gathered by means of a written survey that every member filled out after each flight. The collected

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Figure 1. System operator and engineer during hoist operation.

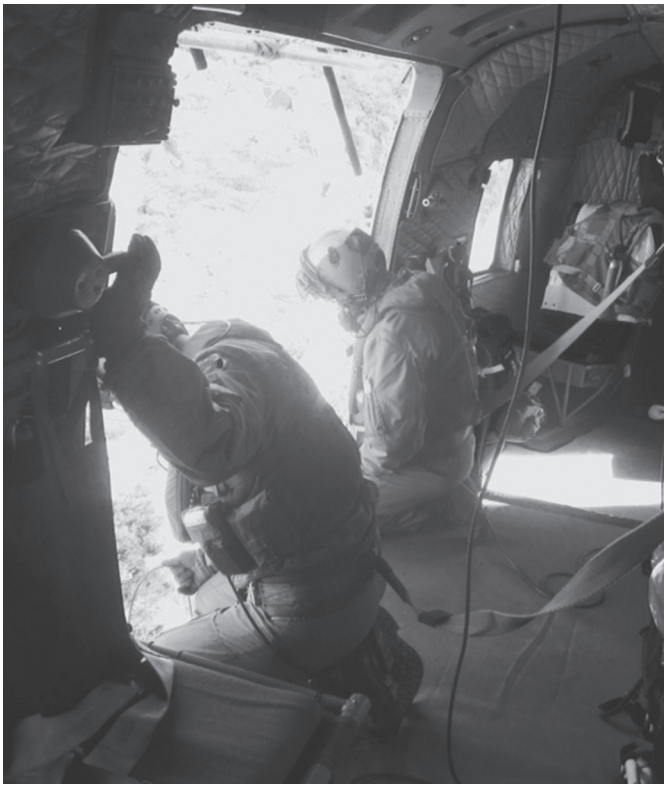

Figure 2. Sea King crew member during confined area landing.

data included crewmember specialty (flight physician, rescuer, engineer, system operator, or pilot), smoker/nonsmoker status, performed operational procedures, duration of training, perception of exhaust fume exposure, signs and symptoms of CO intoxication, and SpCO measurements pre- and postflight. If jet fuel vapor was smelled or the warm exhaust stream was felt by the crewmember in the helicopter cabin, exhaust exposure was marked as positive.

Performed operational procedures were dichotomized into procedures with an open cargo door (hoist maneuvers and confined area landings, Figs. 1 and 2) and training flights in which the cargo door remained closed. A collection of common symptoms of CO intoxication (headache, exhaustion, nausea/vomiting, dizziness, shortness of breath, diarrhea, visual changes, irritability, tachycardia, arrhythmia, and difficulty concentrating) was given on the survey. Experienced symptoms not included in the survey list could be added. All symptoms were graded according to severity from 1 (mild) to 5 (severe). SpCO was measured noninvasively by a handheld fingertip pulse oximeter before and after each flight (RAD-57; Masimo, Irvine, CA) (Fig. 3). The SpCO measurement accuracy given by the manufacturer is ± 3% for a range between 1% and 40%. Normal ranges for COHb were defined as ≤ 4% for nonsmokers.

The Westland Sea King helicopter is a search and rescue helicopter with twin Rolls Royce Gnome H-1400-1 engines, a maximum takeoff weight of 9.7 tons, and a fuel consumption of about 500 L/h. It is operated by many countries worldwide, including the United Kingdom, Germany, Norway, India, Pakistan, Brazil, Australia, and Belgium (F.J. Major, personal communication 2014). The crew in Norway consists of 2 pilots, an engineer, a system operator, a rescuer, and a flight physician. The engine's right exhaust aperture is located above and toward the front of the helicopter's cargo door, which causes the exhaust fumes to stream across the cargo door area (Fig. 4).

Statistical data analysis was performed by means of a spreadsheet program (Excel 2007; Microsoft Corp, Redmond, WA) or a statistical software package (SPSS 15.0; SPSS Inc, Chicago, IL). Descriptive data of continuous variables are reported as medians and interquartile ranges. The chi-square test was used to study categoric variables. $P \leq .05$ was defined as statistically significant.

Results

Seventy-seven surveys were returned for analysis. One survey was excluded because of positive smoking status and 7 because of incomplete documentation. Sixty-nine completed surveys, and 138 SpCO measurements of crewmembers were included in the study. Completed surveys were equally distributed between crew specialities (flight physician [n = 15]), rescuer [n = 11], engineer [n = 11], system operator [n = 14], and pilots [n = 18]). The median training mission duration was 80 minutes (36-180 minutes). Almost two thirds of all training operations (n = 44) involved an open cargo door component (Table 1).

Exhaust exposure was significantly more frequent in open than closed cargo door operations ($P = .03$). Clinical symptoms were reported in 8.6% (n = 6); occurred almost entirely (83%, n = 5) during open cargo door operations; and included exhaustion (n = 4), headache (n = 1), and nausea (n = 1). All symptoms were graded lower than 4 on a scale from 1 (mild) to 5 (severe). Only 2 crewmembers who experienced symptoms displayed postflight SpCO measurements of ≥ 4% (4%