Carbon monoxide exposures in long-term care facilities and hospitals: Developing a monitoring framework

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Outline

- Project overview & objectives
- Indoor air guidelines and detectors
- Gaps in research and practice
- Discussion questions
Project Overview

• In 2010, BCCDC was contacted by Saskatoon Health Region to provide guidance on how to monitor CO in LTC facilities after the St. Mary’s incident

• BCCDC provided guidance on detector technology, placement, and available indoor air guidelines
Project Objectives

(1) To develop a health-protective CO monitoring framework for LTC facilities and hospitals which includes establishing specific values that trigger a) maintenance, b) increased ventilation, and c) evacuation.

(2) To suggest practical means to support the implementation of the framework.
Approach

• **Year 1**: Review health effects related to acute, sub-acute, and chronic CO exposures in healthy and vulnerable populations

• **Year 2**: Conduct toxicokinetic modeling to predict COHb levels based on various CO exposures in vulnerable populations

• **Year 3**: To bring together experts to discuss development of a monitoring framework
Carbon monoxide exposures indoors

• Product of incomplete combustion
• Many indoor and outdoor sources
• Most indoor CO is generated indoors
  √ Back-drafting furnaces
  √ Wood and gas stoves
  √ Underground parking garages
  √ Smoking
Health effects

• CO reduces the oxygen carrying capacity of blood, leading to tissue hypoxia
• Early symptoms: headache, fatigue, nausea, vomiting, and dizziness
• Continued exposure: coma, convulsions, and cardio-respiratory arrest
• Some populations may be particularly vulnerable
  – Those with cardiovascular disease have been considered to be most vulnerable
Other physiologic vulnerabilities

• Not adequately investigated:
  – Persons with respiratory disease who may have higher CO uptake due to air trapping
  – Anaemic persons who have higher endogenous CO production and lower haemoglobin
  – Elderly who may have reduced capacity to respond to lower blood O₂ levels
What the research shows
<table>
<thead>
<tr>
<th>Health outcome</th>
<th># of studies</th>
<th>Lowest % COHb for measured response</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise performance</td>
<td>4</td>
<td>3.95 ± 0.491^1</td>
<td>Decrease in mean exercise time until exhaustion [from 697.7 s to 662.7 s (p&lt;0.001)]</td>
</tr>
<tr>
<td>Cardiovascular effects</td>
<td>4</td>
<td>2.4^2</td>
<td>P-wave changes [in 3/15 participants]</td>
</tr>
<tr>
<td>Respiratory effects</td>
<td>6</td>
<td>3.95 ± 1.873^3</td>
<td>Decrease in inspiratory capacity (p&lt;0.05) and total lung capacity (p&lt;0.02)</td>
</tr>
<tr>
<td>Nervous system &amp; behaviour</td>
<td>6</td>
<td>5.1 ± 0.574^4</td>
<td>Impaired visual manual tracking</td>
</tr>
<tr>
<td>Other physiological effects</td>
<td>2</td>
<td>8.5 ± 0.9%5^5</td>
<td>Increase in retinal artery diameter [(by +3.5 ±3.8% (P&lt; 0.01) ]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Increase in retinal vein diameter [by +4.3± 3.0% (P&lt; 0.01) ]</td>
</tr>
</tbody>
</table>
# Cardiovascular disease

<table>
<thead>
<tr>
<th>Health outcome</th>
<th># of studies</th>
<th>Lowest % COHb for measured response</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise-induced angina</td>
<td>9</td>
<td>2.0 ± 0.05&lt;sup&gt;6&lt;/sup&gt;</td>
<td>Decrease in time to onset of angina [4.2 % decrease]</td>
</tr>
<tr>
<td>Exercise-induced arrhythmias</td>
<td>4</td>
<td>5.91 ± 0.07&lt;sup&gt;7&lt;/sup&gt;</td>
<td>Frequency of single premature ventricular contractions per hr during exercise was significantly higher (p=0.03)</td>
</tr>
<tr>
<td>Other CV effects</td>
<td>6</td>
<td>2.38 ± 0.05&lt;sup&gt;8&lt;/sup&gt;</td>
<td>Significant decreases in time to development of ischemic ST-segment changes (p = 0.01)</td>
</tr>
<tr>
<td>Nervous system and behaviour</td>
<td>1</td>
<td>3.90&lt;sup&gt;9&lt;/sup&gt;</td>
<td>No observable response [No significant decrease in visualization test performance]</td>
</tr>
</tbody>
</table>
## Other Vulnerable Groups

<table>
<thead>
<tr>
<th>Health Status</th>
<th>Outcome</th>
<th># of studies</th>
<th>Lowest % COHb for measured response</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory disease (COPD)</td>
<td>Exercise performance</td>
<td>2</td>
<td>$4.08^{10}$</td>
<td>Decrease in mean exercise time until dyspnea in patients with COPD [from 218.5 to 146.6 seconds ($p&lt;0.001$)]</td>
</tr>
<tr>
<td>Anaemia</td>
<td>Exercise performance</td>
<td>1</td>
<td>$3.38 \pm 0.83^{11}$</td>
<td>Reduction in exercise duration [18% reduction]</td>
</tr>
<tr>
<td>Elderly</td>
<td>Neuro-physical function</td>
<td>1</td>
<td>$5.0^{12}$</td>
<td>No observable response [No effects on reaction time and late positive component of visual evoked potential]</td>
</tr>
</tbody>
</table>
Indoor air guidelines and CO detectors
<table>
<thead>
<tr>
<th>Organization</th>
<th>Population</th>
<th>Avg. period</th>
<th>Guideline/Limit (ppm)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Canada&lt;sup&gt;13&lt;/sup&gt;</td>
<td>General public</td>
<td>1 hour</td>
<td>25</td>
<td>Values are derived from studies of individuals with coronary disease. Values are considered to be protective of the entire population.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hour</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>World Health Organization (WHO)&lt;sup&gt;14&lt;/sup&gt;</td>
<td>General public</td>
<td>15 min</td>
<td>86</td>
<td>Assuming light exercise and that exposure to these levels occurs only once/day.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 hour</td>
<td>30</td>
<td>Assuming light to moderate exercise.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 hour</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hour</td>
<td>6</td>
<td>Assuming exposures occur when people are awake and alert but not exercising.</td>
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CO detectors

• Readily available, but their use is not mandatory expect:
  – in provinces that require installation through provincial building codes or,
  – in municipalities that have enacted by-laws requiring their installation

• Saskatchewan is the now the only province that requires CO detectors in health care facilities
Monitoring indoor CO

- Alarms are triggered when specific concentration-duration algorithms are reached

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<th>CO concentration</th>
<th>Time period$^{15}$</th>
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<tr>
<td>400 ppm</td>
<td>4-15 min</td>
</tr>
<tr>
<td>150 ppm</td>
<td>15-50 min</td>
</tr>
<tr>
<td>70 ppm</td>
<td>1-4 hours</td>
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Discrepancy between guidelines and detectors

World Health Organization & Health Canada Guidelines

2 % COHb

Based on lowest observed COHb level associated with a health outcome in a vulnerable population

Canadian Standards Association Approved Detectors

10 % COHb

Based on efforts to reduce non-emergency calls made to first responders
Gaps in Research and Practice

- Exposure and health effects in those with respiratory disease, anaemia, and the elderly
- Health effects of sub-acute and long-term exposures to low levels
- How best to monitor levels
- Levels that should trigger action
Discussion questions

Are commercially available CO detectors protective of short & medium term exposures in vulnerable persons?
• are current triggers sufficiently protective of all populations?
• are current logging capabilities of detectors sufficient for monitoring purposes?

What is the margin of safety for CO exposures in the short and medium term which would compensate for various conditions related to the monitoring framework, including
• sub-optimal monitor placement
• moderate under-responsiveness
• location of CO source
• multiple sources, etc.
Discussion questions (2)

• What alternate ambient concentration/duration algorithm would optimally protect vulnerable groups?

• How could these health protective measures be implemented in practice?
References


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