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Original Contributions

CARBOXYHEMOGLOBIN MEASUREMENT BY HOSPITALS: IMPLICATIONS FOR THE DIAGNOSIS OF CARBON MONOXIDE POISONING

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□ **Abstract—Most case definitions for carbon monoxide (CO) poisoning include demonstration of an elevated blood carboxyhemoglobin (COHb) concentration. Further, it is generally believed that treatment of CO poisoning is more effective when performed as soon as possible after the exposure. This suggests that a hospital's inability to measure blood COHb could lead to delayed or missed diagnosis or treatment. This study evaluated the ability of hospitals in the Pacific Northwest to measure COHb levels. The clinical laboratory of every acute care hospital in Washington, Idaho, Montana, and Alaska was surveyed regarding the ability to measure COHb levels, the method utilized and the time required. If they could not measure COHb, they were asked whether samples are sent elsewhere, the location of the referral laboratory, and time required. Results were then compared to the list of hospitals referring CO-poisoned patients to a regional center for hyperbaric oxygen therapy from 2003–2004. In the four states, only 44% of acute care hospitals have the capability to measure COHb. The remaining 56% send blood samples to other laboratories. The average time to get a result is 10 ± 10 min in hospitals with co-oximetry and 904 ± 1360 min in those without, a difference of 15 h ($p < 0.0001$). When samples are sent out, the average distance is 121 miles, often bypassing a hospital with CO-oximetry capability. Over 90% of CO-poisoned patients referred for hyperbaric treatment came from hospitals able to measure COHb. Fewer than one-half of acute care hospitals in a four-state region have the capability to measure COHb levels. This has the potential to significantly impact diagnosis or treatment of patients with acute CO poisoning.** © 2006 Elsevier Inc.

□ **Keywords—carbon monoxide poisoning; carboxyhemoglobin; clinical laboratory; hyperbaric oxygen; CO-oximetry**

INTRODUCTION

Carbon monoxide (CO) poisoning is common in the United States, accounting for an estimated 40,000 Emergency Department visits for diagnosed cases annually (1). Because the signs and symptoms of CO poisoning are nonspecific, it is likely that many more cases are unsuspected, attributed to other etiologies, and therefore go undiagnosed.

When CO poisoning is suspected, measurement of blood carboxyhemoglobin (COHb) is typically performed. An elevated COHb level (greater than 2% for nonsmokers and greater than 9% for smokers) documents exposure to exogenous CO and supports the diagnosis (2). COHb is measured in hospital laboratories by multi-wavelength CO-oximetry. Not all hospitals have CO-oximeters due to the expense of the equipment. In that case, blood samples are typically sent to an outside laboratory for COHb measurement. Alternate methods that are sometimes used to demonstrate CO exposure include a qualitative colorimetric screening test performed on blood or measurement of exhaled carbon monoxide (3).

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Lack of ability to measure COHb in a hospital has the potential to result in failure to diagnose cases of CO poisoning or contribute to delay in diagnosis in the case where a blood sample is sent elsewhere. To assess the capability to measure COHb in a region of the United States with a high incidence of CO poisoning (4), we surveyed all acute care hospitals in the states of Alaska, Idaho, Montana, and Washington. Results were then compared with the list of hospitals referring patients with acute CO poisoning to a major regional center for hyperbaric oxygen (HBO_2) therapy.

METHODS

The clinical laboratories of all acute care hospitals in the states of Alaska (n = 20), Idaho (n = 37), Montana (n = 50) and Washington (n = 97) were surveyed by telephone in January 2005. The laboratory supervisor was asked the following questions:

Can your laboratory measure carboxyhemoglobin levels?

If yes:

1. What type of blood sample do you use (arterial, venous, either)?
2. What method do you use?
3. From the time blood is drawn in your Emergency Department, how long does it take to get the result?

If no:

1. What do you do if the test is ordered?
2. If blood is sent out for carboxyhemoglobin measurement, where is it sent and how long does it take to get the result?

Secondly, medical records of patients referred to Virginia Mason Medical Center in Seattle for hyperbaric oxygen treatment of acute CO poisoning from January 2003 through December 2004 were reviewed. Names of referring hospitals were extracted and compared to the list compiled above with regard to COHb measurement capability.

Descriptive statistics were used to analyze results. The Institutional Review Board of Virginia Mason Medical Center approved the study.

RESULTS

Of the 204 acute care hospitals in the four-state region, 90 (44%) have the capability to measure carboxyhemoglobin, all with laboratory CO-oximetry. The frequency ranges from a low of 32% in both Idaho and Montana to a high of 54% in Washington. The rest of the hospitals send blood samples to outside laboratories for COHb measurement. None use the qualitative colorimetric blood assay for detection of COHb. The population of the town in which a hospital is located correlates significantly with COHb measurement capability. The average town population is 105,000 ± 167,000 (mean ± SD; range 2,000 to 563,000) for those with CO-oximetry and 30,000 ± 90,000 for those without CO-oximetry ($p < 0.0001$).

Among the 104 hospitals in Washington, Idaho, and Montana that send blood for outside measurement, distances that samples are sent range from 1 to 1188 miles (121 ± 182 miles). Average referral distances for the three states are 67, 119, and 196 miles, respectively.

The time required to obtain a COHb result is strongly associated with the hospital's measurement capability, averaging 10 ± 10 min in those with CO-oximetry and 904 ± 1360 min in those without ($p < 0.0001$).

The type of blood sample requested for COHb measurement by laboratories with CO-oximetry is quite variable. Arterial specimens are requested by 23%, venous by 23%, and either arterial or venous by 54%.

In calendar years 2003 and 2004, a total of 85 patients from the four-state region were treated with hyperbaric oxygen at Virginia Mason Medical Center in Seattle for acute CO poisoning. Of these, 81 (95%) were referred from hospitals with the capability to measure COHb and 4 (5%) from hospitals without the capability. With regard to the latter 4 patients, blood for COHb measurement was sent to another laboratory in 2 instances and exhaled breath CO measurement was used to document exposure in 2 others. When blood was sent out, the time to receive the results was approximately 1 h.

DISCUSSION

This study demonstrates that less than one-half of the hospitals in the four-state region surveyed have the capability to measure carboxyhemoglobin. This has great potential significance in light of the fact that CO poisoning is common in the region, with a combined death rate more than twice that of the other 46 states (4). The fact that treatment with hyperbaric oxygen has been proven to dramatically reduce the incidence of long-term cognitive sequelae from CO poisoning further underscores the potential importance of the finding (5).

As noted, lack of availability of COHb measurement capability has the potential to result in either

missed or delayed diagnosis. The Centers for Disease Control and Prevention recently published case definitions for various types of chemical poisoning, including carbon monoxide (6). While these were designed to facilitate uniform reporting of illness resulting from chemical exposure among public health agencies, the importance of demonstrating an elevated blood COHb level to advance a case from "probable" (based on clinical grounds) to "confirmed" is emphasized. In that definition, a COHb concentration greater than 5% in nonsmokers and greater than 10% in smokers, as determined by hospital or commercial laboratory tests, is considered confirmatory.

It would seem that lack of COHb measurement capability does indeed play a role in clinical practice. Over the 2 years before conduct of the present survey, fewer than 10% of CO-poisoned patients referred to the major hyperbaric treatment center in the region came from hospitals without CO-oximetry. Although this could occur because those hospitals do not see patients with CO poisoning or refer preferentially to one of the smaller regional hyperbaric facilities, both seem unlikely. Because so few (four) patients were referred from hospitals without CO-oximetry, it is difficult to draw strong conclusions about the management of patients with suspected CO poisoning in such institutions. For the four who were referred, lack of CO-oximetry did not seem to delay treatment. More likely, lack of COHb measurement capability seems to be contributing to failure to diagnose CO poisoning.

When faced with a suspected case of CO poisoning and lack of CO-oximetry, one option for measuring COHb includes drawing blood and sending the sample with the patient to the hyperbaric treatment facility, if such management would be appropriate if the case is proven. COHb is stable for days in anticoagulated, capped blood specimens (7). Despite this, none of 85 patients reviewed was managed in this fashion, suggesting lack of awareness of this option.

It should be emphasized that an elevated COHb level is primarily used to support the diagnosis of CO poisoning and not necessarily direct management. The Undersea and Hyperbaric Medical Society recommends hyperbaric oxygen therapy for CO-poisoned individuals with the greatest mortality and morbidity risks (8). These include patients with transient or prolonged unconsciousness, neurological signs, cardiovascular dysfunction, or severe metabolic acidosis, irrespective of the degree of elevation of their COHb levels. It is noted, however, that a majority of hyperbaric physicians do use HBO_2 to treat patients with less severe symptoms when COHb levels are elevated to the range of 25% to 30% (9).

Conventional pulse oximetry does not reliably detect COHb, even at levels up to 50% (10). Interestingly, the development of a new pulse CO-oximeter capable of measuring heart rate, arterial hemoglobin oxygen saturation, and also COHb was recently announced (11). In the present study, hospitals without laboratory CO-oximetry were located in smaller towns and are presumably smaller institutions with fewer resources. Presuming that the price of the new pulse CO-oximeter is less than conventional CO-oximeters, this may provide a convenient solution for many hospitals.

When blood samples are sent to other laboratories for COHb measurement, the potential for delay in diagnosis is significant. In this study, the time required to obtain a COHb result averaged 15 h longer when samples were sent elsewhere, although the turnaround time was often much longer. Although the precise window of opportunity for treatment of CO-poisoned patients is unclear, it is generally agreed that therapy should occur as soon as possible (12). Interestingly, hospitals surveyed in this study do not always send samples to the nearest laboratory capable of measuring COHb. In the extreme example, one hospital in Montana sends samples to a national reference laboratory 1188 miles away although another hospital only 55 miles away has CO-oximetry.

Interestingly, hospitals with CO-oximetry do not always use it correctly. Despite the fact that arterial and venous COHb levels have a high correlation at low, medium and high concentrations (13), only about one-half of laboratories surveyed will measure COHb on either type of sample. Because of this, many unnecessary samples are undoubtedly being obtained.

In summary, lack of availability of laboratory CO-oximetry to measure COHb in hospitals in the Pacific Northwest United States likely contributes to missed and delayed diagnosis of CO-poisoned patients, as well as excess morbidity resulting from lack of appropriate treatment. A newly available handheld pulse CO-oximeter may reduce this problem significantly.

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