A new pulse oximeter is available with the capability to measure blood carbon monoxide (CO) levels, in addition to the conventional variables of heart rate and arterial hemoglobin oxygen saturation.1 EMS personnel and other first responders will likely begin using the device soon. It is important that they understand the meaning of the CO measurement provided and have a plan for patient triage and management based upon the reading obtained.

CO is a toxic gas produced as a byproduct from burning. Almost all burning produces CO to some degree; the amount varies depending on the material and the efficiency of the combustion. Examples of common sources of CO include malfunctioning furnaces, gasoline-powered engines and fires. Although one can typically see and smell exhaust and smoke, the CO that they contain is colorless, odorless and tasteless. Most people are unaware that they are being exposed to CO until they develop symptoms.

CO's toxic mechanisms

Carbon monoxide has a variety of toxic mechanisms of action.2,3 One mechanism that has been known for more than a century is its effect on hemoglobin. When inhaled, CO binds to hemoglobin in red blood cells passing through the lungs, forming carboxyhemoglobin (COHb). Because CO binds to hemoglobin much more tightly than oxygen and occupies the sites normally used to bind and carry oxygen from the lungs to the tissues, one mechanism of CO toxicity is decreased oxygen content of arterial blood and a resultant reduction in peripheral oxygen delivery.

Poisoning from CO is common in the United States, accounting for an estimated 40,000 emergency department (ED) visits and 3,800 deaths annually.2,5 Symptoms of CO poisoning range from headache, nausea, vomiting and dizziness to loss of consciousness and even death. Because the milder symptoms of CO poisoning are so non-specific, patients may be misdiagnosed with such conditions as viral illness, food poisoning or motion sickness depending on the circumstances of the exposure. It is felt that the 40,000 cases of CO poisoning diagnosed each year in U.S. emergency departments (EDs) underestimate the actual incidence, and that many more cases are either not seen in an ED or are not diagnosed when seen.

Preliminary studies of the poisoning of the heart and brain are particularly susceptible to injury from CO. The primary treatment for CO poisoning is oxygen, either normobaric or hyperbaric. Depending upon the severity of the poisoning, a large prospective randomized trial showed that treatment with hyperbaric oxygen (HBO) is more effective than normobaric oxygen in preventing long-term neurological sequelae in CO-poisoned patients, so it is now generally accepted by experts in the field that at least some patients with CO poisoning should be treated with HBO, if readily available.4,8

Because CO binds so avidly to hemoglobin, COHb remains in the circulation for hours and is a marker that can be measured to document recent CO exposure. Normal COHb levels are different for smokers and nonsmokers because smokers regularly inhale CO with cigarette smoke. As can be seen in Table 1 (right), the average COHb level in nonsmokers is less than 1%, while the average level in smokers is about 4%.6,8 There is obviously a range of values among individuals in each category, with some having higher levels and some lower than the average. To look at it another way, 99% of nonsmokers have a COHb level ≤ 2.5% and 98% of smokers have a level ≤ 10.0% (Table 1). Of the 2% of smokers whose levels exceed 10%, COHb has been reported as high as 15–30% immediately after smoking.9-12 If an individual's COHb measurement is higher than 3% in a non-smoker or 12% in a smoker, it is quite likely that they were exposed to another source of CO.

New noninvasive CO measurement

Until recently, determining an individual's COHb level required drawing a blood sample and measuring it in a laboratory with a CO-oximeter or estimating it by measuring exhaled CO.10 Laboratory CO-oximeters are capable of measuring COHb.11 The new Reid-57 pulse CO-oximeter, developed by Masimo Corp., utilizes two wavelengths of light and is able to provide a noninvasive measurement of COHb (SpCO) in seconds, in addition to SpO2 and heart rate. The device's accuracy has been demonstrated up to 40% SpCO, with a range of ±3% around the measurement.12 It has been previously demonstrated that the COHb level correlates poorly with the clinical condition of the CO-poisoned patient. As such, most experts have traditionally recommended using the COHb level to confirm the diagnosis in a patient with symptoms suspected to be due to CO exposure, using the actual level to guide management only when elevated to the range of 25% or greater.5

Because a clinician has traditionally ordered blood measurement of COHb only when the condition was suspected, it is likely that there has been a tendency to measure COHb only in the more symptomatic patient or in those whose exposure history was known. Because EMS providers and paramedics commonly use a pulse oximeter to measure SpO2 at the scene, one can predict that many instances of elevated SpCO will be discovered among patients with a classic history or recognized exposure to CO.

Managing an elevated SpCO level

When first responders encounter elevated SpCO levels, they will need guidance and/or a protocol for triage and management. We have suggested such an algorithm in Figure 1 (below).

Because smoking history may be unreliable or unavailable, we do not recommend attempting to determine whether an individual is a smoker or nonsmoker in the field and have not included smoking status in decision making.

For SpCO levels up to 3%, no further evaluation is necessary because they are likely normal (Table 1). If the patient has other indications for treatment or transport, those should obviously be taken into consideration.
Sometimes, the call for a carbon monoxide (CO) incident is obvious—a report of a CO alarm activation with residents feeling ill or an attempted suicide with an ambulance running in a garage. Other times, the call is less obvious—a person feeling sick or even someone arriving home to find a family member unconscious. At the obvious incidents, not many clues are necessary to confirm that CO poisoning is the cause of the situation.

At the not-so-obvious incidents, responders may not realize the problems exist at all and simply treat the patient’s symptoms. They may have no idea that while they are treating the patient, they are being exposed in the same conditions that cause the patient’s illness. In these situations, responders need to maintain a high level of awareness and work diligently to determine cause of the illness or unconsciousness. They must keep in mind that CO poisoning may be the potential cause for the victim’s condition. Based on previous incidents that were eventually traced to CO poisoning, some ambulance units now carry a portable CO monitor in their first-in-bag, permitting the crew to continuously monitor their environment for this potential hazard.

How to respond

As with any response, firefighters must begin to size-up the incident upon dispatch to the call. Activated CO detectors are not necessarily emergencies—unless carbon monoxide is still in the building and/or victims are experiencing symptoms of exposure. Carbon monoxide doesn’t normally trap victims inside a building, unless they’ve fallen unconscious. In that case, emergency response is appropriate, and proper personal protective equipment (PPE) is needed to access and remove the victims from the hazard. Exposed victims who are outside of the hazard zone would generally warrant an emergency response from EMS, although not necessarily from the fire department, unless fire units are providing first response medical care.

Firefighters also may need to respond at emergency speed if CO is building up rapidly in the building at high levels, CO can be explosive. The lower explosive limit of CO is relatively high at 12.5%, but the explosive range is wide, up to an upper explosive limit of 75%. Once CO is identified as a hazard in the building, it is important to apply positive-pressure ventilation. Opening windows will normally be the trick by allowing the building’s interior to air out while minimizing collateral damage.

What to look for

CO is generated from equipment that burns fuel, such as natural gas, propane, gasoline, oil, wood, kerassone or charcoal. Sources include heaters, water heaters, ranges, grills and clothes dryers. Other potential sources of exposure include propane-fueled hot tubs, kilns, fireplaces and various other household appliances. CO can quickly build up from the use of gasoline-powered equipment, such as blowers, cut-off saws, lawn equipment and similar apparatus utilized in poorly ventilated areas. Propane-fueled construction heaters and lift trucks can also cause problems.

CO building is much less likely in well-ventilated areas. However, a sealed-up home, below-grade area, garage or similar location presents conditions where CO levels could be high. This may be particularly