Carbon Monoxide Poisoning
Among Recreational Boaters

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Objective.—To describe the case characteristics of a series of patients poisoned with carbon monoxide (CO) while boating for recreation.

Design.—Cases of patients referred for treatment of CO poisoning with hyperbaric oxygen were reviewed. Those cases that occurred during recreational boating were selected for analysis.

Setting.—A private, urban, tertiary care center studied from July 1984 to June 1994.

Patients.—Thirty-nine patients ranging in age from 6 months to 69 years who were poisoned in 27 separate incidents.

Main Outcome Measures.—Characteristics of the poisoning incidents were assessed at initial patient presentation, immediately following treatment, and with follow-up telephone interviews.

Results.—Of 512 patients treated for acute unintentional CO poisoning, 39 cases (8%) occurred in 27 incidents related to recreational boating activities. Individuals typically lost consciousness as a result of the poisoning. Most cases occurred aboard a boat that was older than 10 years, had an enclosed cabin, and was longer than 22 feet, was powered by a gasoline engine, and was without a CO detector on board.

Conclusions.—Carbon monoxide poisoning is a serious hazard associated with recreational boating. The installation of CO detectors aboard boat types typically associated with this syndrome should be strongly encouraged.

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RECREATIONAL boating is common in the United States, with more than 75 million persons engaging in this activity annually. Injuries commonly occur while boating for recreational purposes, but previously published reports have typi- currently been limited to musculoskeletal trauma. During the past decade, we have treated numerous patients for carbon monoxide (CO) poisoning sustained while boating for recreational purposes.

Carbon monoxide intoxication is common in the United States, with an estimated 80,000 persons seeking medical attention or missing at least 1 day of normal activity because of the syndrome each year. Based on death certificate reports compiled by the National Center for Health Statistics, approximately 3000 individuals die annually from unintentional or suicidal CO poisoning, making it the most common cause of death from poisoning. Many cases of CO poisoning result from activities not recognized to be hazardous by the victim.

Few reports of CO poisoning among boaters have been previously published. We review our experience with CO poisoning among recreational boaters, describe the risk factors and characteristics of this syndrome, and suggest possible prevention measures.

Methods

Records of patients treated for CO poisoning in the Hyperbaric Department of Virginia Mason Medical Center, Seattle, Wash, from July 1984 through June 1994 were reviewed. A case of CO poisoning was defined as an individual with a history of CO exposure exhibiting symptoms characteristic of CO intoxication (eg, headache, nausea, dizziness, or loss of consciousness) and an elevated blood carboxyhemoglobin (COHb) level. An elevated COHb level was defined as greater than 2% for nonsmokers and greater than 5% for smokers. Individuals with COHb levels less than these limits were still considered to be poisoned if supplemental oxygen had been administered prior to obtaining the blood sample. All poisonings that occurred during recreational boating activities were selected for this report. Individuals poisoned during commercial boating activities were excluded. Information was collected from emergency department and hyperbaric department records. Telephone interviews with patients and/or their parents were subsequently per-

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formed to obtain missing data and to determine long-term outcome. Frequen-
cies reported for specific data variables represent calculations based on obtai-
ned information.

Carboxyhemoglobin levels reported are the values measured during initial emergency department evaluation at our institution or another facility. Prior to obtaining blood samples for COHB de-
termination, all patients had been re-
moved from the source of CO exposure and some received supplemental oxy-
gen from transfer.

Patients were treated with hyperbaric oxygen therapy at multiple hyperbaric cham-
bers. Treatment consisted of hyperbaric oxygen administration at 2.8 to 3.0 atm absolute pressure for 46 to 92 minutes, followed in some cases by administra-
tion of additional oxygen at 1.9 atm abso-
olute pressure. Duration of treatment was based on the severity of clinical pre-

tentation.

Results

During the decade evaluated, 512 pa-

ents were treated on an emergency basis for accidental acute and severe CO poisoning. Of these, 39 patients (8%) were poisoned with CO while boating for recreation in 27 separate incidents. Complete information was not obtain-
able in every case because of inability to contact two patients for follow-up and lack of recall of all details by others. In 27 incidents, CO level was confirmed in air samples in two cases and in blood samples in four cases. In one of these cases, CO level was confirmed in both air and blood samples.

To the best of our knowledge, this is the first report documenting the incidence of CO poisoning in boaters. The findings suggest that CO poisoning is a significant problem in recreational boating. Further research is needed to determine the extent of the problem and to develop effective preventive strategies.

Comment

Recreational boating is increasingly popular in the United States. In 1982, the US Coast Guard estimated that 5.05 million boats were in use in the community, and usage increased to 5.40 million in 1985.1 These figures are not in conflict, however, because the data sources are not always consistent. The US Coast Guard estimates that 3.80 million boats were in use in 1988.2

The prevalence of CO poisoning among recreational boaters is unknown, but it is likely that additional cases of both similar and lesser severity occurred in the Seattle area during the same period. These cases may not have been referred to our facility for treatment because of the lack of need for hyperbaric oxygen therapy, patient death, or failure to recognize the syndrome.1,2

Typical symptoms experienced by pa-


tients in this study (headache, nausea, weakness, and dizziness) may be attrib-
uted to boaters' skin sensitivity, viral ill-


dness, or other causes. In fact, some of the patients poisoned with CO initially believed their symptoms to be the result of these more benign etiologies. It is likely that similar outcomes occur throughout the United States and that our experience is not simply a reflection of

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of excess recreational boating activity in our region. Washington ranks 10th nationally with regard to number of boats licensed statewide, containing only 2% of boats registered in the United States.

The typical poisoning incident in this study occurred during the afternoon of a cool winter day on a boat in salt water. The characteristic boat involved was older than 35 years and longer than 22 feet and had an enclosed cabin. Additionally, the boat was propelled by a gasoline-powered inboard or outboard engine and did not have a CO detector on board. The boat was either cruising or moored at the time of the poisoning incident. The individuals poisoned were usually located in the cabin at the time of the exposure and usually inhaled CO from engine exhaust. Patients treated at our facility typically had histories consistent with the poisoning, although others were frequently present who were less severely poisoned.

We speculate that these factors contributed to the risk for CO exposure in a combination of ways. Carbon monoxide is a byproduct of incomplete combustion, soot is present in large quantities in gasoline engine exhaust. All involved boats were relatively long and had an enclosed cabin, which potentially allows for accumulation of fumes containing CO. This is likely a significant risk factor for CO poisoning since the majority of recreational boats in the United States are shorter in length and presumably do not have cabins. The incineration typically occurred in cold weather, possibly increasing the amount of time individuals spent within the cabin. A CO detector was rarely present to warn of the hazard. Because individuals frequently attributed early symptoms to alternate causes such as seasickness, they may have prolonged their exposure by remaining within the toxic environment.

Accumulation of exhaust fumes in the rear of moving vehicles such as station wagons and pickup trucks has been previously described. As a vehicle moves through air, a relative vacuum is generated behind it by the Venturi effect. This negative pressure may draw fumes into the rear of the vehicle. In the current study, boats were frequently cruising. When there is space, the rear cabin door was usually open and the bow hatch closed. We speculate that exhaust was drawn into the cabin by the same mechanism as that described in motor vehicles. The "wind" produced by boat motion may actually contribute to, rather than prevent, CO accumulation in the cabin.

Some boats were moored at the time of the poisoning incident. The mechanism of CO exposure in these cases was variable, including accumulation of fumes from leaking exhaust systems. Blowing by wind of properly vented exhaust into the cabin, and local CO production by means other than incomplete combustion (such as gas stoves, etc.). The mechanism here is obviously different than that involved in moving boats and involves simple accumulation of CO within the boat.

It is apparent that these individuals were more or less concerned about the risk of CO intoxication aboard their boats. This is evidenced in part by the fact that only one of 27 boats (involved had a CO detector on board. In the single case where a detector was present, it was not the type that emits an audible warning to alert persons nearby. Furthermore, most treated individuals stated that they had no concern about the risk for CO exposure at the time of their accident.

These findings have several implications for prevention of future CO poisonings among recreational boaters. First, boat exhaust systems should be regularly maintained and inspected to minimize the incidence of leaks. Second, strong consideration should be given to installation of CO detectors within the cabins of boats similar to those described. If it is possible for individuals to be at risk within the cabin, that are out of sight from the detector, an electronic sensor that emits an audible alarm may be preferred over a colorimetric CO detector that provides only a visual cue. Finally, public educational programs may be helpful. Among recreational boats involved in accidents in 1983, only 20% of the operators were reported to have received any formal instruction in boat safety. Programs directed at improving awareness of the mechanisms of CO exposure on boats and early symptoms of CO intoxication could help minimize unintentional CO poisoning.

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