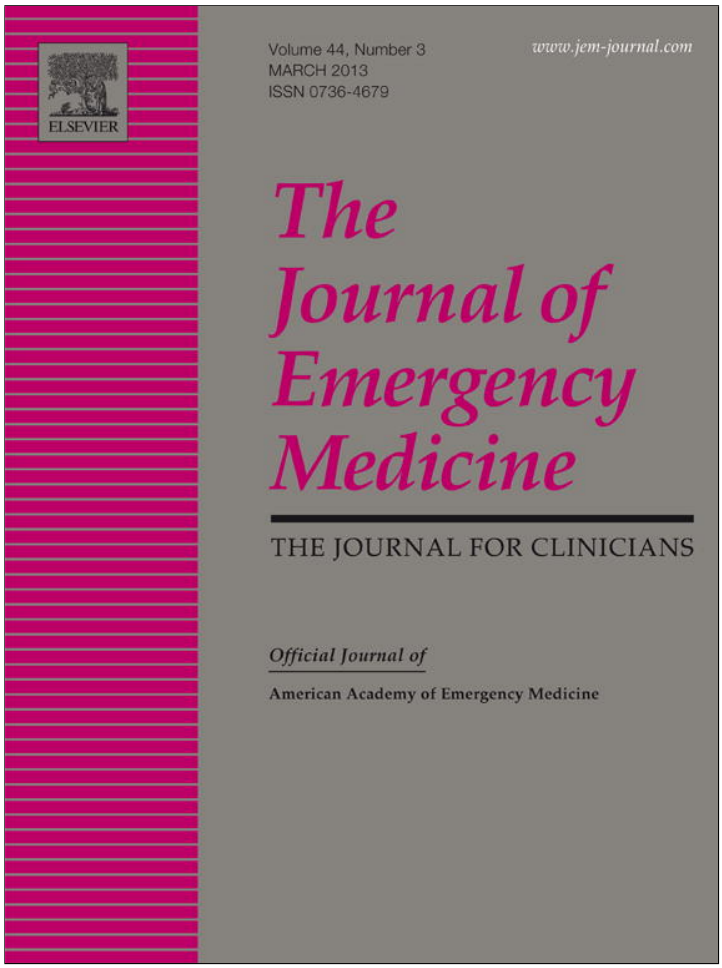

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Selected Topics: Toxicology

TOXIC CO-INGESTIONS IN INTENTIONAL CARBON MONOXIDE POISONING

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☐ **Abstract—Background: Intentional carbon monoxide (CO) poisoning is responsible for two-thirds of the deaths from CO poisoning in this country and an estimated 15,000 Emergency Department visits annually. Objectives: In an attempt to optimize medical management of such patients, this study was conducted to examine the frequency and types of toxic co-ingestions that may accompany CO inhalation. Methods: Records of all patients treated with hyperbaric oxygen for acute, intentional CO poisoning at a regional referral center for hyperbaric medicine in Seattle from 1980 to 2005 were reviewed. For those where co-ingestions were identified, information about type of poison(s) and results of toxicology screens was recorded and analyzed. Results: Over the 25-year period examined, 433 patients were treated for intentional CO poisoning and records were available for 426. Of those, 188 (42%) had ingested one or more poisons in addition to CO. Ethanol was most common, but a wide variety of other drug classes were also identified. Toxicology screening studies of some type were performed in 49 patients. Conclusions: Toxic co-ingestions seem to be relatively common in patients treated for intentional CO poisoning. For this reason, providers should be vigilant and open to clinical signs that can't be explained with CO exposure alone, and ready to treat clinical issues that arise from co-ingestions.** © 2013 Elsevier Inc.

☐ **Keywords—carbon monoxide; poisoning; suicide**

INTRODUCTION

Intentional carbon monoxide (CO) poisoning occurs with significant frequency in the United States. According to a 2007 estimate by the U.S. Centers for Disease Control and Prevention, there are approximately 2733 deaths from all forms of CO poisoning in the country each year (1). Because approximately two-thirds of CO poisoning deaths in the United States are intentional, about 2000 people die each year from intentional (suicidal) CO poisoning (2).

The number with non-fatal intentional poisoning is even greater. CO poisoning of all types accounts for an estimated 50,000 Emergency Department (ED) visits annually in the United States (3). Most patients with CO poisoning who survive to receive maximal hospital emergency care survive, although they may suffer long-term neurological sequelae. In a recently reported series of 1505 patients treated at a single center with hyperbaric oxygen for acute CO poisoning, only 2.6% experienced short-term mortality, as defined by death within 90 days of poisoning (4). In that series, 30% of cases were intentional CO exposures. If that series is representative of the CO-poisoned population seen in EDs in general, one could extrapolate that there are 15,000 ED visits for intentional CO poisoning annually (30% of 50,000).

Whatever the exact numbers, the significance of intentional CO poisoning is apparent. Efforts directed at emergency management of the condition require accurate, comprehensive information. Toward that end, we sought to describe the toxic co-ingestions taken by those attempting suicide with CO inhalation.

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METHODS

The population reviewed consisted of patients treated with hyperbaric oxygen for acute, intentional CO poisoning at a regional referral center for hyperbaric medicine in Seattle, Washington from 1980 to 2005. Information was extracted from an Institutional Review Board-approved clinical research database and department records. In addition to basic demographic data, information was sought regarding source of CO, mention of any toxic co-ingestion in addition to CO inhalation, drugs or poisons reported to have been ingested, and results of ED toxicology studies, when performed and available.

Although guidelines for hyperbaric treatment of CO-poisoned patients have evolved over the 25 years encompassed by this study, in general, patients were accepted for hyperbaric oxygen therapy if they manifested transient or prolonged unconsciousness, abnormal neurological findings on physical examination, evidence of cardiac ischemia, or carboxyhemoglobin (COHb) level >25–30%.

Because almost all patients were initially managed and then referred for hyperbaric oxygen treatment from outside medical centers, information about co-ingestions and toxicology screening came almost exclusively from copies of outside records originally sent with the transferred patient. The rationale for obtaining or not obtaining toxicology studies in a particular patient was only occasionally apparent from the chart records. In addition, drugs screened or measured in blood or urine tests varied from hospital to hospital.

Basic statistical calculations were used to summarize demographic and exposure data. In addition, results from toxicology screens on patients either admitting or denying co-ingestions were compared with recorded patient-reported information.

RESULTS

Over the 25-year period studied, 433 patients were treated for intentional CO poisoning. Records were not available for 7 (2%). Of the remaining, 316 (74%) were male and 110 (26%) were female. Patients ranged in age from 15 to 92 years, averaging 39 ± 15 years (mean ± SD). With regard to race or ethnicity, 371 (87%) were non-Hispanic white, 9 black, 4 Asian, 3 Hispanic white, and 39 race undetermined from record review. Source of CO was motor vehicle in 403 (94%), charcoal grill in 10, fire in 4, lawnmower in 3, generator in 2, boat 1, CO cylinder 1, forklift 1, rototiller 1, welding equipment 1, and unknown 1. For the total group, initial blood COHb level was 24.2 ± 12.7% (mean ± SD; range 0.1–72.3%), 280 (66%) experienced loss of consciousness, and 112 (26%) were intubated.

Table 1. Agents Reported to Have Been Co-ingested by 182 Patients with Intentional Carbon Monoxide Poisoning*

Reported Co-ingestion	n
Ethanol	119
Benzodiazepines	24
Stimulants	20
Antidepressants	16
Opioids	15
Sedatives	12
THC	8
Salicylates	7
Acetaminophen	4
NSAID	4
Muscle relaxant	3
Antibiotic	1
Anticonvulsant	1
Antiemetic	1
Antipsychotic	1
Beta blocker	1
Drain cleaner	1
General anesthetic	1
Steroid hormone	1
Oral hypoglycemic	1
Unspecified	8

THC = tetrahydrocannabinol; NSAID = non-steroidal anti-inflammatory drug.
* Numbers sum to >100% because multiple co-ingestions were sometimes reported.

Co-ingestion of a drug or poison in addition to CO was mentioned in the medical records of 182 (43%). One additional agent was reported to have been taken by 132 patients, two by 40, three by 8, and four by 2, for an average of 2.2 drugs taken per multi-drug suicide attempt. Most common were ethanol, 119 (65%); benzodiazepines, 24; stimulants, 20; antidepressants, 16; and opioids, 15 (Table 1). Ethanol was the only additional poison ingested in 97 (53%).

Those who reported any co-ingestion were 76% male, average age 39 ± 13 years, 86% non-Hispanic white, and exposed to CO from a motor vehicle in 93% of cases. Initial blood COHb level was 22.4 ± 11.9%, loss of consciousness occurred in 69% and intubation in 29%.

Some form of toxicological testing was performed in 49 patients. Among the 244 patients without mention of co-ingestion in their recorded chart history, 19 (8%) had toxicology testing. Among the 182 with co-ingestion(s) mentioned, 30 (16%) had testing performed. Selection criteria utilized for ordering toxicology tests were not specified. The reason for testing most apparent from chart review was obtaining a blood alcohol level in patients believed to be inebriated.

The types and results of toxicology testing performed are detailed in Table 2. Blood testing was used to measure levels of alcohol, acetaminophen, and salicylates. Urine testing yielded qualitative results for a variety of common drugs of abuse, as indicated in the Table. Twenty-six had

Table 2. Results of Toxicology Testing in the 49 Patients in Whom Testing was Performed

	Blood Toxicology Testing			Urine Toxicology Testing									
Patient	ETOH	Acetaminophen	Salicylate	Amphetamine	Barbiturate	Benzodiazepine	Cocaine	Methadone	Methamphetamine	Opiates	PCP	TCA	THC
1	Neg												
2				Neg	Pos	Neg	Neg			Neg	Pos		Neg
3	Neg		Neg										
4	Neg	Neg		Neg	Neg	Neg				Neg	Neg	Neg	
5	Neg	Neg	Neg										
6	Neg												
7	Neg	Neg											
8	Neg												
9	Neg	Neg	Neg										
10	Neg												
11		Neg	Neg	Neg	Neg	Neg	Neg			Neg	Neg		Neg
12				Neg	Neg	Neg	Neg			Neg	Neg	Neg	Neg
13	Neg												
14	Neg	Neg	Neg										
15				Neg	Neg	Neg	Neg			Neg	Neg		
16		Neg	Neg	Neg	Pos	Neg	Neg			Pos		Neg	Neg
17	322	Neg	Neg				Pos			Pos			
18	Neg	Neg	Neg	Pos	Neg	Neg				Neg	Neg	Neg	
19	Neg												
20	103												
21	200												
22	“Pos”		Neg										
23	“Pos”												
24	103												
25	Neg	Neg	Neg										
26	158			Neg	Neg	Pos*	Neg			Neg	Neg	Neg	Neg
27	118	Neg	Neg										
28	Neg		Neg	Neg	Neg	Pos	Neg		Neg	Neg			Neg
29	192												
30	Neg												
31	208												
32		Neg	Neg	Pos	Neg	Neg	Neg			Neg	Neg		
33				Neg	Neg	Neg	Neg			Neg	Neg	Neg	Pos
34	257		Neg	Neg	Neg	Pos*	Neg			Pos*	Neg	Neg	Neg
35	140		Neg	Neg	Neg	Neg	Neg	Neg		Neg	Neg	Neg	Neg
36	133			Neg	Neg	Neg	Pos	Neg		Neg		Neg	Neg
37				Pos	Neg	Neg	Neg	Neg		Pos		Pos	Pos
38	158			Neg	Neg	Neg	Neg			Neg	Neg	Neg	Neg
39	Neg	Neg	Neg	Neg	Neg	Neg	Neg			Pos	Neg	Neg	Neg
40	157			Neg	Neg	Neg	Neg			Neg	Neg	Neg	Neg
41	123												
42				Neg	Neg	Neg	Neg		Neg	Neg	Neg	Neg	Pos
43	254												
44	Neg			Neg	Neg	Neg	Pos		Neg	Neg	Neg	Neg	Neg
45	Neg	Neg	Neg							Pos			

(*Continued*)

Table 2. Continued

	Blood Toxicology Testing			Urine Toxicology Testing								
Patient	ETOH	Acetaminophen	Salicylate	Amphetamine	Barbiturate	Benzodiazepine	Cocaine	Methadone	Methamphetamine	Opiates	PCP	TCA	THC
46	106	Neg	Neg										
47	169	Neg	Neg	Neg	Neg	Neg	Neg			Neg	Neg		Neg
48				Pos*	Neg	Neg	Neg			Neg	Neg	Neg	Neg
49	78			Neg	Neg	Pos*	Neg	Neg	Neg	Neg	Neg	Neg	Neg

ETOH = ethanol (values expressed in mg/dL); PCP = phencyclidine; TCA = tricyclic antidepressant; THC = tetrahydrocannabinol; Pos = positive qualitative test; Neg = negative qualitative test.

* Medication administered by first responders or taken chronically by patient could explain positive test result.

only blood testing, 6 had only urine screening, and 17 had both. Of 39 blood alcohol levels measured, 20 were positive, with an average value of 166 ± 64 mg/dL (mean ± SD, range 78–322 mg/dL). No acetaminophen or salicylate levels were above the therapeutic range.

After excluding positive results that could be explained by drugs administered by first responders (e.g., morphine, diazepam) and chronic medication taken by the patient as listed on their medication list in the medical record (e.g., narcotic analgesics), urine screening was positive for amphetamines in 3, barbiturates 2, benzodiazepines 1, cocaine 3, opiates 5, phencyclidine 1, tricyclic antidepressants 1, and tetrahydrocannabinol 3.

DISCUSSION

Effective ED management of the poisoning victim requires identification of the clinical effects of likely offending poisons. In the event that the clinical presentation is not consistent with the known poison alone (CO in this case), knowledge of most likely co-ingestions may be helpful for management.

In the case of acute carbon monoxide poisoning, another factor comes into play. CO poisoning is treated with oxygen, either normobaric by non-rebreather reservoir mask in the ED or hyperbaric oxygen in a hyperbaric chamber. When the use of hyperbaric oxygen is considered, a number of independent criteria for referral are generally considered (5). Among others, these include loss of consciousness, neurological impairment, or significant metabolic acidosis. Attributing the presence of any of these to only the CO exposure in a patient with co-ingestion could result in hyperbaric oxygen treatment for a patient who might not otherwise be referred, and also result in failure to diagnose and treat a co-existing poisoning.

Information regarding multi-agent intentional poisonings is quite limited. One report described the 38,000 U.S. ED visits in 2008 for drug-related suicide attempts among young adults (6). The report noted that "many" of the attempts involved ingestion of multiple drugs. When multidrug ingestion did occur, the average number of drugs was 2.2 (including ethanol). Interestingly, when more than one drug was taken in addition to CO inhalation in the present series, the average number was also 2.2.

Published data on drug co-ingestion in intentional CO poisoning are almost non-existent. In a study of 4341 combined accidental and intentional poisonings in Poland, ethanol and carbon monoxide poisoning were combined in 6.2% (7). This was similar in frequency to co-ingestion of ethanol and pharmaceuticals (6.4%) in that population.

Three important messages can be distilled from the current data. First, co-ingestion of a second poison in

Table 3. Examples of Screening Emergency Department Toxicological Screening Studies Inconsistent with Patient Report

Co-ingestion Reported by Patient	Results of Screening Toxicology Study
None	Barbiturate, opioid
None	Ethanol, cocaine, opioid
None	Opioid, barbiturate
None	Benzodiazepine
None	Amphetamine
Antidepressant	Amphetamine
Ethanol	Ethanol, benzodiazepine
Ethanol	Ethanol, benzodiazepine
Methamphetamine	THC, methamphetamine
Methamphetamine	Antidepressant, THC, opioid, methamphetamine
Opioid, ibuprofen	Negative screen
Sedative (Unisom®)	Opioid

THC = tetrahydrocannabinol.

patients with intentional CO poisoning occurs frequently, in almost one-half of patients. Because ethanol is the most common, and other sedative-hypnotics are sometimes taken, this must be taken into account when assessing the effect of carbon monoxide on mental status. Because common indications for hyperbaric oxygen treatment of CO poisoning include alteration of mental status or loss of consciousness, intoxication with ethanol can certainly confuse the clinical picture and make the decision regarding hyperbaric oxygen treatment difficult. Alcohol effects likely result in overtreatment of CO-exposed individuals.

A second important message is that many of the co-ingested agents listed have specific therapies or antidotes other than oxygen. Attempting to identify them may have relevance. Finally, toxicological screening, when performed, often revealed information different from the patient history (Table 3). When the clinical picture does not fit with the history, obtaining toxicology screening may be helpful.

Limitations

The main limitation to this study is the potential for underreporting. For us to have identified a co-ingestion, ED staff would have had to ask the question, patients would have needed to respond accurately, and the result would need to be recorded in the medical record. Alternatively, toxicology screening studies would have needed to be ordered. Because this was a retrospective review and the data were not collected in a prospective systematic fashion, we very likely did not capture many cases of co-ingestion. The present findings likely represent an underestimate of the occurrence of co-ingestion in this population.

In addition, we only studied patients who survived to medical treatment with hyperbaric oxygen. If an individual completed suicide and died in the field, we have no information about other toxins that they may have ingested. In fact, it may be that agents as yet unidentified are more toxic when combined with CO poisoning.

CONCLUSIONS

The data in this study illustrate that co-ingestions frequently accompany intentional CO poisoning. The second agent ingested is usually ethanol. If the suicidal patient's clinical symptoms do not seem consistent with the CO exposure, it may be prudent to consider measuring a blood alcohol level. If it is negative, other poisons should be considered.

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ARTICLE SUMMARY

1. Why is this topic important?

This topic is important because intentional carbon monoxide (CO) poisoning is common in the United States, most non-fatal cases are managed by emergency physicians, and little has previously been written to provide clinical guidance.

2. What does this study attempt to show?

This study attempts to show the other types of toxic agents simultaneously ingested by patients with intentional CO poisoning.

3. What are the key findings?

Of 433 patients with intentional CO poisoning, 42% ingested at least one additional toxic agent; most common was ethanol (65%).

4. How is patient care impacted?

The emergency physician needs to be aware that toxic co-ingestions are common in intentional CO poisoning, especially ethanol. If the clinical status of the patient does not seem consistent with the CO poisoning history, evaluation for ingestion of other poisons should be considered.