

18-EH-01

Committee: Environmental Health**Title: Standardized Surveillance for Carbon Monoxide Poisoning** Check this box if this position statement is an update to an existing standardized surveillance case definition.**I. Statement of the Problem**

Carbon monoxide (CO) is a colorless, odorless, nonirritating gas that is produced through the incomplete combustion of carbon-containing substances. Sources of CO include: boilers: furnaces, cars and trucks, generators and other gasoline or diesel-powered engines, gas and propane heaters, woodstoves, gas stoves, fireplaces, tobacco smoke, forklifts, and fires. The most common location of exposures causing CO poisoning are in homes and less commonly in workplaces. CO poisoning occurs from breathing in elevated air levels of carbon monoxide. Unusual sources include exposure to methylene chloride, which is metabolized to CO and hemolysis, with increased metabolism of hemoglobin. Symptoms are generally non-specific and commonly include headache, dizziness, weakness, vomiting, chest pain and confusion. Large exposures can result in loss of consciousness, arrhythmias, seizures, or death. Unintentional, non-fire related CO poisoning is responsible for approximately 450 deaths and 21,000 emergency department (ED) visits each year.^{1,2,3} CO poisoning is a leading cause of unintentional poisoning deaths in the United States.² Outbreaks of CO poisoning associated with equipment used during natural disasters have been well documented.⁴⁻⁸

II. Background and Justification

CSTE adopted the *Surveillance Case Definition for Acute Carbon Monoxide Poisoning* in 1998 (position statement EH-1), *Updates to 1998 Case Definition for Acute Carbon Monoxide Poisoning Surveillance* in 2007 (position statement EH-03), and an updated Position Statement titled *Public Health Reporting and National Notification for Carbon Monoxide Poisoning* in 2013 (13-EH-01). Revisions are being recommended here to 13-EH-01 at the request of a number of parties, to simplify the definitions and to reflect best practices in CO poisoning surveillance at the state and national levels.

This position statement describes two tiers for surveillance of CO poisoning: (1) case reporting/case ascertainment based on public health legal authorities, and (2) analysis of administrative data without access to personal identifiers. Its overarching difference from 13-EH-01 is that it describes two rather than four tiers of surveillance activities.

The first tier – case reporting based on public health legal authorities – describes traditional public health surveillance practice based on case identification and follow-up investigation. Reporting includes reports from providers or laboratories. It also includes identification of potential cases from administrative data (e.g. identified based on discharge diagnosis codes in hospital discharge) or from syndromic surveillance using data from emergency departments, poison control centers, or urgent care centers where individual records are used to conduct additional case investigation in order to have data to complete case classification.^{11,12} The first tier replaces the fourth tier in 13-EH-01: “case finding using multiple data sources with individual case investigation”.

The second tier is a set of recommendations for surveillance using administrative data, without personal identifiers. These activities can be conducted by any agency that has access to de-identified morbidity and mortality data, including agencies such as CDC and the American Association of Poison Control Centers.⁹ It utilizes electronic data and does not generally include additional case investigation as follow-up to individual records in administrative data.¹⁰ It includes conducting syndromic surveillance using data from emergency departments, poison control centers, or urgent care centers. It replaces the first three tiers described in 13-EH-01: “Poison Control Center (PCC) data alone, case finding using multiple data sources including PCC, and case finding using multiple data sources with matching a record linkage”.

This Position Statement addresses public health reporting and case classification of carbon monoxide poisoning. It does not describe specific surveillance methods for analysis of the data that should be considered because they

are associated with types and levels of public health actions for follow-up. The reader is advised to consider analysis based on intentionality of the poisoning and whether the CO poisoning was related to a fire.

Note: CSTE recommends states also consider using the methodology for counting and summarizing administrative data for carbon monoxide poisoning that states participating in the CDC’s Environmental Public Health Tracking (“Tracking”) program (<https://ephrtracking.cdc.gov/showHome>) use. The Tracking procedures for data analysis for hospital discharge, emergency department, and mortality data are available by contacting the Tracking program. They include subdividing the data into: unintentional fire related, unintentional non-fire related, and unknown mechanism or intent. They exclude ICD codes indicating that the CO poisoning was intentional. These codes can be included where surveillance includes surveillance of intentional poisonings.

III. Statement of the desired action(s) to be taken

CSTE recommends the following actions:

1. Utilize standard sources (e.g. reporting*) for case ascertainment for carbon monoxide (CO) poisoning.

Note: Surveillance for CO poisoning should use the following recommended sources of data to the extent of coverage presented in Table III.

Table III. Recommended sources of data and extent of coverage for ascertainment of cases of CO Poisoning

Source of data for case ascertainment	Coverage	
	Tier 1: Population-wide	Tier 2: Population-wide
Clinician reporting	X	
Laboratory reporting	X	
Reporting by other entities (e.g., hospitals, poison centers, hyperbaric facilities, medical examiners)	X	
Death certificates	X	
Hospital discharge, emergency department, or urgent care	X	X
Extracts from electronic medical records	X	X
Telephone survey		
School-based survey		
Other: Poisoning Control Center (PCC) data without identifiers reported to the American Association of Poison Control Centers for the National Poison Data System (NPDS) or made available to states; state workers compensation data		X

2018 Template

*Reporting: process of a healthcare provider or other entity submitting a report (case information) of a condition under public health surveillance TO local or state public health. Note: notification is addressed in a Nationally Notifiable Conditions Recommendation Statement and is the process of a local or state public health authority submitting a report (case information) of a condition on the *Nationally Notifiable Conditions List* TO CDC.

2. Utilize standardized criteria for case identification and classification (Sections VI and VII and Technical Supplement) for CO poisoning.
3. Please see accompanying NNC Recommendation Statement for additional Desired Actions to be Taken (page 11).

IV. Goals of Surveillance

The goals for CO poisoning surveillance include.¹³

- Immediate response, to block the occurrence of further cases
- Planning for prevention programs
 - Estimation of the magnitude of the problem and tracking trends over time
 - Identification of high-risk areas and population sub-groups
- Assessment of the effectiveness of prevention programs
- Investigation of novel exposure pathways and previously unknown determinants/poisoning scenarios.

V. Methods for Surveillance: Surveillance for CO poisoning should use the recommended sources of data and the extent of coverage listed in Table III.

Data sources (See appendix 1 for details):

Hospitals/emergency departments: Population based. Includes multiple diagnosis codes (ICD10-CM). May include individual identifiers so that case follow-up can take place.

PCC: Population based. Coded information identifies CO poisoning but not exposure source. Access to “notes” fields for information about exposure source, smoking status requires legal authority. Can be very timely.

Death certificates: Population-based. Includes multiple cause of death codes. Limited access to personal identifiers. Typically not timely.

Laboratory reports of carboxyhemoglobin: Case investigation may be required to determine smoking status and whether CO exposure occurred in order to interpret results. Timely.

Provider/medical examiner reports: Compliance with reporting requirements variable across states.

VI. Criteria for case ascertainment

A. Narrative: A description of suggested criteria for case ascertainment of carbon monoxide poisoning

Tier 1

Reporting refers to the process of healthcare providers or institutions (e.g., clinicians, clinical laboratories, hospitals, poison control centers) submitting basic information to governmental public health agencies about cases of carbon monoxide poisoning that meet certain reporting requirements or criteria. Cases of carbon monoxide poisoning may also be ascertained by the secondary analysis of administrative data or through syndromic surveillance algorithms where individual information is available for follow-up case investigation.

Clinical Presentation Criteria:

- A person with signs or symptoms consistent with carbon monoxide poisoning, which may include an elevated pulse CO-oximetry measurement^{14,15} and non-specific symptoms such as nausea, vomiting, confusion, shortness of breath, chest pain, and loss of consciousness.¹⁶

Laboratory Criteria:

- A person with a carboxyhemoglobin (COHb) level of $\geq 2.5\%$ as measured in a blood sample.

Tier 2

Case ascertainment based on secondary analysis of administrative data without access to personal identifiers

Criteria for case ascertainment using administrative data:Healthcare records, including hospital discharge and emergency department records

- A person whose healthcare record includes mention of carbon monoxide poisoning (see Appendix 2 and Appendix 6)

Poison Control Center Records

- A person whose poison control center record indicates an exposure to carbon monoxide (see Appendix 3)

Workers compensation records

- A person whose workers compensation record contains a finding, problem, diagnosis, or other indication of exposure to carbon monoxide or carbon monoxide poisoning (see Appendix 4)

Death Certificates

- A person whose death certificate lists carbon monoxide poisoning, toxic effect of carbon monoxide, or carbon monoxide exposure as a cause of death or a significant condition contributing to death (see Appendix 5)

VII. Case Definition for Case Classification**A. Narrative: Description of criteria to determine how a case of carbon monoxide poisoning should be classified.****Tier 1****Criteria for case classification using clinical, laboratory, epidemiologic, and exposure data:****Clinical Criteria***Presumptive clinical evidence:*

- Loss of consciousness **OR**
- Death

Supportive clinical evidence:

- A person with signs or symptoms consistent with carbon monoxide poisoning, which may include elevated pulse CO-oximetry measurement and/or non-specific symptoms such as nausea, vomiting, confusion, shortness of breath, and chest pain

Laboratory Criteria*Confirmatory laboratory evidence:*

- A person who does not smoke, or a child (age < 14 years) whose smoking status is unknown, and has a carboxyhemoglobin (COHb) level of $\geq 5.0\%$ as measured in a blood sample ¹⁶⁻¹⁸ **OR**
- A person who smokes, or a person (age ≥ 14 years) whose smoking status is unknown, with a carboxyhemoglobin (COHb) level of $> 12.0\%$ as measured in a blood sample ^{17,18}

Presumptive laboratory evidence:

- A person who smokes, or whose smoking status is unknown (age ≥ 14 years), and has a carboxyhemoglobin (COHb) level of $\geq 9.0\%$ and $\leq 12.0\%$ as measured in a blood sample

Supportive laboratory evidence:

- A person who does not smoke, or a child (age < 14 years) whose smoking status is unknown, and has a carboxyhemoglobin (COHb) level of $\geq 2.5\%$ and < 5.0% as measured in a blood sample ¹⁹
OR
- A person who smokes, or whose smoking status is unknown (age ≥ 14 years), and has a carboxyhemoglobin (COHb) level of $\geq 7.0\%$ and < 9.0% as measured in a blood sample ¹⁸

Exposure Criteria**Confirmatory exposure evidence:*

- A person who had an exposure to an elevated level of CO based on a dedicated or multi-gas meter/instrument (e.g., fire department notation) for a known duration that is consistent with CO poisoning.

Possible exposure evidence:

- A person who was in a location where a CO detector's alarm sounded **OR**
- A person who had onset of CO-related symptoms associated physically and temporally with a CO-emitting source (e.g., gasoline-powered generator, power washer, malfunctioning furnace, and fire)

* Note: Exposure evidence that is provided by the patient is sufficient for meeting exposure evidence criteria.

Epidemiologic Linkage

- A person who was present and exposed in the same CO exposure event as that of a confirmed CO poisoning case

Tier 1**Case Classifications using clinical, laboratory, epidemiologic, and exposure data***Confirmed:*

- A person with confirmatory laboratory evidence* **OR**
- A person with presumptive or supportive clinical evidence AND with confirmatory exposure evidence

Probable:

- A person with presumptive laboratory evidence[†] **OR**
- A person with presumptive clinical evidence AND possible exposure evidence, **OR**
- A person with presumptive or supportive clinical evidence AND epidemiologic linkage

Suspect:

- A person with supportive laboratory evidence **OR**
- A person with supportive clinical criteria AND possible exposure evidence

* Other plausible clinical explanations should be considered, including chronic obstructive lung disease and hemolysis.

† Other plausible clinical explanations should be considered, including chronic obstructive lung disease and hemolysis.

Tier 2**Case Classification using administrative data***Confirmed:*Healthcare records, including hospital discharge and emergency department records

- A person whose healthcare record contains an explicit diagnosis of carbon monoxide poisoning (see Appendix 2)

Death Certificates

- A person whose death certificate explicitly lists carbon monoxide poisoning, toxic effect of carbon monoxide, or carbon monoxide exposure as a cause of death or a significant condition contributing to death (see Appendix 5).

*Probable:*Healthcare records, including hospital discharge and emergency department records

- A person whose healthcare record contains a diagnosis of carbon monoxide poisoning by motor vehicle exhaust (see Appendix 2)

Poison Control Center Records

- A person whose poison control center record indicates an exposure to carbon monoxide **AND** a moderate medical outcome, major medical outcome, or death (see Appendix 3)

Workers compensation records

- A person whose workers compensation paid claim contains a finding, problem, diagnosis, or other indication of exposure to carbon monoxide or carbon monoxide poisoning (see Appendix 4).

*Suspect:*Poison Control Center Records

- A person whose poison control center record indicates an exposure to carbon monoxide **AND** a minor medical outcome (see Appendix 3)

Workers compensation records

- A person whose workers compensation submitted claim contains a finding, problem, diagnosis, or other indication of exposure to carbon monoxide or carbon monoxide poisoning (see Appendix 4).

Healthcare records, including hospital discharge and emergency department records

- A person whose healthcare record contains a diagnosis that is inclusive of carbon monoxide poisoning by sources other than motor vehicle exhaust (see Appendix 2).
- A person whose emergency department record mentions exposure to carbon monoxide in the chief complaint.

Death Certificates

- A person whose death certificate lists a cause of death that is inclusive of carbon monoxide poisoning, toxic effect of carbon monoxide, or carbon monoxide exposure as a cause of death or a significant condition contributing to death (see Appendix 5).

B. Criteria to distinguish a new case of this disease or condition from reports or notifications which should not be enumerated as a new case for surveillance

A case should be categorized as a new (incident) case when there is either:

- New exposure to CO from different exposure source

- Repeated exposure as defined by having the same exposure source as previous occurrence where the criteria used to designate a case has been resolved prior to repeat exposure

A case is categorized as a prevalent case when there are multiple reports for the same person for the same episode, such as when there are multiple COHb lab test results or when a patient receives multiple hyperbaric treatments following a single poisoning event.

VIII. Period of Surveillance

On-going

IX. Data sharing/release and print criteria

CSTE recommends that states use procedures for analyzing administrative data developed by the CDC Tracking program and to report the data to CDC utilizing security protocols developed by CDC.

CSTE recommends that states report non-confidential CO surveillance data to CDC for annual publication in MMWR annual non-infectious surveillance summaries.

CSTE recommends the following case statuses be included in the CDC Print Criteria as appropriate to data source and whether Tier 1 or Tier 2 of surveillance:

- Confirmed
- Probable
- Suspect
- Unknown

CSTE supports the CDC in directly accessing and analyzing PCC data reported by PCCs to the AAPCC which is available as the National Poison Data System (NPDS). NPDS contains adequate data elements for surveillance of carbon monoxide poisoning.³

X. Revision History

Position Statement ID	Section of Document	Revision Description
13-EH-01	Background and justification	Describes overall revisions, including going from 4 tiers of surveillance to 2
13-EH-01	Statement of desired actions to be taken	Revises Table III to indicate source data for case ascertainment by Tier 1 and Tier 2
13-EH-01	Goals of Surveillance	Keeps bulleted goals; adds paragraph on goals for Tier 1 surveillance; adds statement about syndromic surveillance; deletes most of commentary to fit with word restrictions.
13-EH-01	Methods for surveillance	Greatly shortened to include description of data sources; more detailed summary of characteristics of data sources moved to appendix; added statement about syndromic surveillance. Paragraphs about the four tiers and recommendations for various surveillance strategies deleted.

13-EH-01	Criteria for case ascertainment	Revised to separate case ascertainment from administrative data (tier 2), which is based only on searching of electronic data sources, and from reporting of individual cases with identifiers (tier 1). All codes were moved to appendices. Lowered reportable laboratory level based on blood carboxyhemoglobin to 2.5%. Added pulse co-oximetry to list of clinical signs and symptoms. Added syndromic surveillance and added reference to new Appendix 6 (to be developed). This section was simplified and modified to meet guidelines of the 2018 Position statement template. Table VI was moved to the Technical Supplement, as per the 2018 Position Statement template.
13-EH-01	Case definitions for case classification	Modified to reflect guidelines of the 2018 Position Statement template and to reflect additional modifications to definitions, particularly as relating to cut points for laboratory data., including raising the definition of an elevated COHb level in smokers/smoking status unknown from >10% to >12%. Added case definition for cases detected by syndromic surveillance. Moved pulse CO oximetry to list of clinical signs/symptoms from laboratory criteria. Refined definition of non-smoker to include person less than age 14 where smoking status is unknown. Modified/simplified exposure criteria.
13-EH-01	Data sharing and print criteria	Revised to delete wording specific to the AAPCC NPDS system and added wording regarding sharing of Tier 1 and Tier 2 data with CDC programs for display and publication. Added paragraph with recommendation from CSTE to CDC for use of NPDS data from AAPCC.

XI. References

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Nationally Notifiable Conditions (NNC) Recommendation Statement

Position Statement Title: Standardized surveillance for Carbon Monoxide poisoning

Disease/Condition: Carbon Monoxide poisoning

- This statement updates a disease/condition already on the *Nationally Notifiable Conditions List*.
 - No change to the CDC notification timeframe is recommended.
 - No new subtypes or additional disease/condition categories are added to the accompanying position statement.

This NNC Recommendation Statement recommends the following:

1. Utilize standardized criteria for case identification and classification (based on Sections VI and VII and Technical Supplement of accompanying position statement) for carbon monoxide poisoning and continue to keep carbon monoxide poisoning on the *Nationally Notifiable Condition List*
 - Immediately notifiable, extremely urgent (within 4 hours)
 - Immediately notifiable, urgent (within 24 hours)
 - Routinely notifiable
 - No longer notifiable
2. CSTE recommends that all States and Territories enact laws (statute or rule/regulation as appropriate) to make this disease or condition reportable in their jurisdiction. Jurisdictions (e.g. States and Territories) conducting surveillance (according to these methods) should submit case notifications* to CDC.
3. Expectations for Message Mapping Guide (MMG) development for a newly notifiable condition: NNDSS is transitioning to HL7-based messages for case notifications; the specifications for these messages are presented in MMGs. When CSTE recommends that a new condition be made nationally notifiable, CDC must obtain OMB PRA approval prior to accepting case notifications for the new condition. Under anticipated timelines, notification using the Generic V2 MMG would support transmission of the basic demographic and epidemiologic information common to all cases and could begin with the new MMWR year following the CSTE annual conference. Input from CDC programs and CSTE would prioritize development of a disease-specific MMG for the new condition among other conditions waiting for MMGs.
4. CDC should publish data on carbon monoxide poisoning as appropriate (see Section IX of corresponding position statement).
5. CSTE recommends that all jurisdictions (e.g. States or Territories) with legal authority to conduct public health surveillance follow the recommended methods as outlined here and in the accompanying standardized surveillance position statement.

*Notification: process of a local or state public health authority submitting a report (case information) of a condition on the *Nationally Notifiable Conditions List* TO CDC.

Technical Supplement

Table VI. Table of criteria to determine whether a case should be reported to public health authorities

Criterion	Report of CO Poisoning
<i>Clinical Evidence (Tier 1)</i>	
A person with signs or symptoms consistent with carbon monoxide poisoning, which may include an elevated pulse CO-oximetry measurement and non-specific symptoms such as nausea, vomiting, confusion, shortness of breath, chest pain, and loss of consciousness	S
<i>Laboratory Evidence (Tier 1)</i>	
Carboxyhemoglobin (COHb) \geq 2.5% as measured in a blood sample	S
<i>Administrative Records Evidence (Tier 2)</i>	
A person whose healthcare record contains a diagnosis of carbon monoxide poisoning (see Appendix 2)	S
A person whose emergency department record includes mention of carbon monoxide in the chief complaint (See Appendix 6)	S
A person whose poison control center record indicates an exposure to carbon monoxide (see Appendix 3)	S
A person whose workers compensation record contains a finding, problem, diagnosis, or other indication of exposure to carbon monoxide or carbon monoxide poisoning (see Appendix 4)	S
A person whose death certificate lists carbon monoxide poisoning, toxic effect of carbon monoxide, or carbon monoxide exposure as a cause of death or a significant condition contributing to death (see Appendix 5)	S

Notes:

S = This criterion alone is SUFFICIENT to report a case.

Table VII.A. Classification Table: Criteria for defining a case of carbon monoxide poisoning using clinical, laboratory, and exposure evidence (Tier 1)

Criterion	Suspected			Probable			Confirmed					
<i>Demographic</i>												
Age < 14 years old		O	N	O			O		O	N	O	
Age ≥ 14 years old		O		O	N		O	N		N	O	O
Person does not smoke		N										N
Person smokes				N			N			N		
Person with unknown smoking status			N		N			N		N		N
<i>Clinical Evidence</i>												
Loss of consciousness						O	O		O			
Death						O	O		O			
Elevated pulse CO-oximetry measurement	O					O			O			
Nausea	O					O			O			
Vomiting	O					O			O			
Confusion	O					O			O			
Shortness of breath	O					O			O			
Chest pain	O					O			O			
<i>Laboratory Criteria</i>												
COHb ≥ 2.5% and < 5.0% as measured in a blood sample		N	N									
COHb ≥ 5.0% as measured in a blood sample											N	N
COHb ≥ 7.0% and < 9.0% as measured in a blood sample				N	N							
COHb ≥ 9.0% and ≤ 12.0% as measured in a blood sample							N	N				
COHb > 12.0% as measured in a blood sample										N	N	
<i>Environmental Exposure Criteria</i>												
Exposure to an elevated level of CO based on a dedicated or multi-gas meter/instrument (e.g., fire department notation) for a known duration that is consistent with CO poisoning									N			
Person was in a location where there was documentation that a CO detector's alarm sounded	O						O					
Person physically and temporally associated with a CO-emitting source (e.g., gasoline-powered generator, power washer, malfunctioning furnace, and fire) at the time of onset	O						O					
<i>Epidemiologic evidence</i>												
Person who was present and exposed in the same CO exposure event as that of a confirmed CO poisoning case						N						

CO = Carbon monoxide

Notes:

N = All "N" criteria in the same column are NECESSARY to classify a case. A number following an "N" indicates that this criterion is only required for a specific disease/condition subtype (see below). If the absence of a criterion (i.e., criterion NOT present) is required for the case to meet the classification criteria, list the absence of criterion as a necessary component.

O = At least one of these "O" (ONE OR MORE) criteria in **each category** (categories=clinical evidence, laboratory evidence, and epidemiologic evidence) **in the same column**—in conjunction with all "N" criteria in the same column—is required to classify a case. A number following an "O" indicates that this criterion is only required for a specific disease/condition subtype.

Table VII.B. Classification Table: Criteria for defining a case of carbon monoxide poisoning using evidence from administrative records (Tier 2)

Criterion	Suspected				Probable			Confirmed
<i>Administrative Records Evidence</i>								
A person whose healthcare record contains an explicit diagnosis of CO poisoning (see Appendix 2)								S
A person whose healthcare record contains a diagnosis of CO poisoning by motor vehicle exhaust (see Appendix 2)						S		
A person whose healthcare record contains a diagnosis inclusive of CO poisoning by sources other than motor vehicle exhaust (see Appendix 2)			S					
A person whose poison control center record indicates an exposure to CO (see Appendix 3)		N				N		
A person whose poison control center record indicates a moderate or major medical outcome, or death (see Appendix 3)						N		
A person whose poison control center record indicates a minor medical outcome (see Appendix 3)		N						
A person whose workers compensation record contains a <u>paid</u> claim with a finding, problem, diagnosis, or other indication of exposure to CO or CO poisoning (see Appendix 4)					S			
A person whose workers compensation record contains a <u>submitted</u> claim with a finding, problem, diagnosis, or other indication of exposure to CO or CO poisoning (see Appendix 4)	S							
A person whose death certificate lists explicitly CO poisoning, toxic effect of CO, or CO exposure as a cause of death or a significant condition contributing to death (see Appendix 5)								S
A person whose death certificate lists a cause of death that is inclusive of CO poisoning, toxic effect of CO, or CO exposure as a cause of death or a significant condition contributing to death (see Appendix 5)				S				
A person whose emergency department record mentions exposure to CO in the chief complaint			S					

CO = Carbon monoxide

Notes:

S = This criterion alone is SUFFICIENT to classify a case.

N = All "N" criteria in the same column are NECESSARY to classify a case. A number following an "N" indicates that this criterion is only required for a specific disease/condition subtype (see below). If the absence of a criterion (i.e., criterion NOT present) is required for the case to meet the classification criteria, list the absence of criterion as a necessary component.

Appendix 1: Data Sources for Surveillance

Each data source used for CO poisoning case ascertainment has different characteristics: it may have good sensitivity/completeness (few false negatives); it may have good positive predictive value (few false positives); it may have good timeliness; it may include many unique cases (not found in other data sources); and/or it may have high information value (including facts about the route of exposure or other contributing factors which are less reliable in other sources). No single data source possesses all of these characteristics.¹

Poison Control Centers: Every jurisdiction in the US is covered by a Poison Control Center (PCC) staffed by health care practitioner specialists who assess, triage, manage and monitor calls regarding known exposure to toxic substances or illnesses where a toxic substance is suspected of being the cause, and dispense medical advice under the authority and control of a Medical Director.² The electronic medical record used to document the call and the consultative process has standardized definitions that are used by all PCCs. The patient record includes personal identifiers; coded information for demographics, substance identification, reason for exposure, exposure site (e.g. home, workplace), clinical effects, therapies used, labs, and medical outcomes; and a full case narrative often called case notes. In states where laws/rules require reporting by clinicians, poison control centers (PCCs) may or may not be considered clinicians and therefore requirements for PCCs to report vary from jurisdiction to jurisdiction. Poison Control Center data have high information value, are available in near-real time and contain many unique cases 3-6. Cases where health effects from CO exposure exist and CO exposure is well documented (such as by air monitoring equipment), but the affected individual does not seek medical care, may not be found in other data sources. Calls to PCC can have very good timeliness; rapid dispatch of a municipal fire department vehicle in New York City as a consequence of a call to the PCC is an illustrative example. Every 3-5 minutes, PCCs automatically upload a standardized subset of electronic case data collected to the American Association of Poison Control Centers' (AAPCC) National Poison Data System (NPDS). Anomaly alert analysis, once programed, is conducted autonomously by NPDS every hour. Toxicosurveillance staff (AAPCC and CDC) confirm clusters found via alert notification with the originating PCC. Following confirmation of relevant cluster recognition, alerts can be issued to appropriate agencies. Surveillance staff in the CDC National Center for Environmental Health have full access to NPDS data and can unilaterally utilize the data during instances of a recognized public health threat.^{3,4} Staff in state and territorial health agencies can be similarly enabled for NPDS and/or local PCC data access for their region via dialogue and requests made to their regional PCC. Personal identifiers and the "case notes" section of the PCC case report are not available in NPDS as the case is de-identified prior to upload. This information can be made available to state health department partners per dialogue with and requests to the local PCC. The "case notes" section is the case narrative that may include source of the CO, COHb measurements and/or exposure documentation (e.g. CO alarm went off, CO air levels detected by the fire department). The sensitivity of PCC reporting is moderate: many of the most severe cases may be missed, such as out-of-hospital deaths that may not be reported to the PCC, as well as those who are treated in an ED where no contact the PCC is made. Another limitation of PCC data is that state and ZIP code of the caller is often used as a surrogate measure for the patient's exposure site, which may not accurately represent the patient's actual residence.

Hospitals: Acute care hospitals in almost all states compile electronic data on all in-patient discharges, including patient, clinical, and billing information, and make a combined state-wide in-patient data set available to public health agencies, generally without personal identifiers. The discharge diagnoses were coded using ICD 9-CM until October 2015, when the change to ICD 10-CM was mandated by the Federal Centers for Medicare and Medicaid Services. It should be noted that T58 (Toxic effects of carbon monoxide from all sources) is not a billable code in ICD10-CM; the "child" codes of T58 that are billable codes are more specific (e.g. T58.01XA= initial encounter, toxic effect of CO from motor vehicle exhaust, accidental). Case-based reporting from hospitals has good PPV. Sensitivity for detecting diagnosed cases and timeliness of reports is dependent on compliance with reporting requirements, including the level of detail on exposure and clinical effects provided in the discharge summary that is made available to the public health agency. Information value for details of exposure is variable. Other limitations include: under-diagnosis, due to the non-specific profile of CO poisoning symptoms; federal hospitals may not report; and, resident hospitalizations in out-of-state hospitals may not be included, due to the lack of non-resident data exchange between states.

Emergency Departments: Population-based ED encounter data similar to the dataset for hospital discharges are collected and made available to public health agencies in a limited number of states. Many states obtain near real-time data from Emergency Departments for syndromic surveillance. Algorithms for signal detection vary from state to state, but in general rely on identification of key words in the chief complaints section of the Emergency Department electronic record; some systems also include discharge diagnosis codes.^{6,7} Some jurisdictions have access to personal identifiers directly or through medical records numbers in their syndromic surveillance data, so additional case investigation can be done.

Vital records/death certificates: All states code and compile death information, including demographics and cause(s) of death. Deaths where carbon monoxide was a cause of death are identified by the ICD-10 code T58 (“Toxic effect of carbon monoxide”) that has been assigned by the coding nosologist as a contributing cause of death. Note: ICD-10 T58 is not permitted by national coding rules to be assigned as the underlying cause of death. ICD-10 codes can identify whether the death was fire or non-fire related and whether the cause was intentional or unintentional. Most state public health agencies have access to personal identifiers for public health surveillance.

Medical examiners/coroners: Case-based reporting from Medical Examiners and Coroners (ME/C) has good sensitivity for the most severe cases (out-of-hospital deaths may be uniquely found here), and good PPV. Details from death investigations can provide excellent information value about exposure pathways and other contributing factors. ME/C data often has low timeliness.

Laboratory reports: Carboxyhemoglobin (CoHb) is a stable complex of carbon monoxide and hemoglobin that forms in red blood cells upon contact with carbon monoxide. The COHb test is useful indicator of CO exposure, although cigarette smoking will also elevate COHb. Because the half-life of COHb in blood is very short – four to six hours, the reliability of the test result is dependent on how close in time blood was drawn after exposure. Laboratory reporting of carboxyhemoglobin (COHb) test results has high information value for clinical aspects, but low information value for details of exposure. Because COHb differs in smokers compared to non-smokers, it also has a low PPV due to high COHb values in heavy smokers.⁸ Pulse co-oximetry provides a non-invasive option to obtain CO blood saturation (S_{pCO}) quickly but the reliability of results obtained from pulse co-oximetry is imperfect; negative results should be confirmed with COHb.⁹

Workers compensation: Records of Individuals with work-related illnesses and injuries and who file and have settled claims for lost work time and/or medical compensation are maintained by state workers compensation agencies. The level of detail and access to data are highly variable across states; and few states use health-based coding systems for the type of injury/illness. Nevertheless, in states where the workers compensation agency grants the public health agency access to the data, it is possible to identify CO cases and match records with other health-based data sources.

Retrospective review of death certificates and administrative records, such as workers compensation records, obviously has low timeliness, but may have high sensitivity. Information about work-related exposure pathways, for example, may be best found in this manner. Limitations include non-specific underlying cause of death codes in ICD-10.¹⁰

When case ascertainment utilizing multiple data sources is operating, case counting without de-duplication results in a need to present case data separately for each data source in tables and charts in published surveillance reports. When case ascertainment utilizing multiple data sources is combined with matching, for linkage and de-duplication, the surveillance data system is able to calculate more accurate counts and rates of morbidity and mortality. Published surveillance reports can include Venn diagrams to depict case-finding overlap.⁹ In the absence of personal identifiers, matching can be done using fields.¹¹

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Appendix 2: ICD-CM Code list - Toxic Effects of Carbon Monoxide

ICD-9-CM Diagnosis Code and Injury Cause E-Codes Explicitly Involving or Inclusive of Carbon Monoxide (CO) Poisoning	
Explicit	
N986	Toxic effect of carbon monoxide
E868.3	Accidental poisoning by carbon monoxide from incomplete combustion of other domestic fuels
E868.8	Accidental poisoning by carbon monoxide from other sources
E868.9	Accidental poisoning by carbon monoxide from an unspecified source
E952.1	Self-inflicted poisoning by other carbon monoxide source
E982.1	Undetermined cause of poisoning by other carbon monoxide source
Inclusive - motor vehicle exhaust	
E868.2	Accidental poisoning by motor vehicle exhaust gas not elsewhere classifiable
E952.0	Self-inflicted poisoning by motor vehicle exhaust gas
E982.0	Undetermined cause of poisoning by motor vehicle exhaust gas
E818.x	Other noncollision motor vehicle traffic accident, including accidental poisoning from exhaust gas
E825.x	Other motor vehicle nontraffic accident of other and unspecified nature, including accidental poisoning from CO
Inclusive excluding motor vehicle exhaust	
E844.x	Other specified air transport accidents, including poisoning by CO while in transit
E867	Accidental poisoning by gas distributed by pipeline, or CO from combustion of such gas
E868.0	Accidental poisoning by liquefied petroleum gas in mobile containers, or CO from combustion of such gas
E868.1	Accidental poisoning by other/unspecified utility gas, or CO from combustion of such gas
E890.2	Other smoke and fumes from conflagration in a private dwelling, including CO
E891.2	Other smoke and fumes from conflagration in other building, including CO
E838.x	Other and unspecified water transport accident, including accidental poisoning by bases or fumes on ship
E951.0	Self-inflicted poisoning by gases in domestic use, pipeline
E951.1	Self-inflicted poisoning by gases in domestic use, LPG (mobile)
E951.8	Self-inflicted poisoning by gases in domestic use, other utility gas

E958.1	Self-inflicted injury by burns, fire
E962.2	Homicidal assault by poisoning from other gases and vapors
E962.9	Homicidal assault by poisoning, unspecified
E968.0	Homicidal assault by fire
E981.0	Poisoning by gases in domestic use, undetermined intent, pipeline
E981.1	Poisoning by gases in domestic use, undetermined intent, LPG (mobile)
E981.8	Poisoning by gases in domestic use, undetermined intent, other utility gas
E988.1	Undetermined cause of injury by fire, burns
N987	Toxic effect of other gases, fumes or vapors
E869.9	Accidental poisoning by other gases or vapors, unspecified
E952.9	Self-inflicted poisoning by other gases or vapors, unspecified
E979.3	Terrorism involving fires, including asphyxia
E972, E978	Legal intervention or execution including asphyxiation by gas

ICD-10-CM Diagnosis Code and Injury Cause Codes Explicitly Involving Carbon Monoxide (CO) Poisoning	
Code	Descriptor
T58	Toxic effect of carbon monoxide
T58.0	Toxic effect of carbon monoxide from motor vehicle exhaust
T58.01	Toxic effect of carbon monoxide from motor vehicle exhaust, accidental (unintentional)
T58.01XA	Toxic effect of carbon monoxide from motor vehicle exhaust, accidental (unintentional), initial encounter
T58.02	Toxic effect of carbon monoxide from motor vehicle exhaust, intentional self-harm
T58.02XA	Toxic effect of carbon monoxide from motor vehicle exhaust, intentional self-harm, initial encounter
T58.03	Toxic effect of carbon monoxide from motor vehicle exhaust, assault
T58.03XA	Toxic effect of carbon monoxide from motor vehicle exhaust, assault, initial encounter
T58.03XS	Toxic effect of carbon monoxide from motor vehicle exhaust, assault, sequela
T58.04	Toxic effect of carbon monoxide from motor vehicle exhaust, undetermined
T58.04XA	Toxic effect of carbon monoxide from motor vehicle exhaust, undetermined, initial encounter
T58.1	Toxic effect of carbon monoxide from utility gas
T58.11	Toxic effect of carbon monoxide from utility gas, accidental (unintentional)
T58.11XA	Toxic effect of carbon monoxide from utility gas, accidental (unintentional), initial encounter
T58.12	Toxic effect of carbon monoxide from utility gas, intentional self-harm

T58.12XA	Toxic effect of carbon monoxide from utility gas, intentional self-harm, initial encounter
T58.13	Toxic effect of carbon monoxide from utility gas, assault
T58.13XA	Toxic effect of carbon monoxide from utility gas, assault, initial encounter
T58.14	Toxic effect of carbon monoxide from utility gas, undetermined
T58.14XA	Toxic effect of carbon monoxide from utility gas, undetermined, initial encounter
T58.2	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels
T58.2X	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels
T58.2X1	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels, accidental (unintentional)
T58.2X1A	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels, accidental (unintentional), initial encounter
T58.2X2	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels, intentional self-harm
T58.2X2A	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels, intentional self-harm, initial encounter
T58.2X3	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels, assault
T58.2X3A	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels, assault, initial encounter
T58.2X4	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels, undetermined
T58.2X4A	Toxic effect of carbon monoxide from incomplete combustion of other domestic fuels, undetermined, initial encounter
T58.8	Toxic effect of carbon monoxide from other source
T58.8X	Toxic effect of carbon monoxide from other source
T58.8X1	Toxic effect of carbon monoxide from other source, accidental (unintentional)
T58.8X1A	Toxic effect of carbon monoxide from other source, accidental (unintentional), initial encounter
T58.8X2	Toxic effect of carbon monoxide from other source, intentional self-harm
T58.8X2A	Toxic effect of carbon monoxide from other source, intentional self-harm, initial encounter
T58.8X3	Toxic effect of carbon monoxide from other source, assault
T58.8X3A	Toxic effect of carbon monoxide from other source, assault, initial encounter
T58.8X4	Toxic effect of carbon monoxide from other source, undetermined
T58.8X4A	Toxic effect of carbon monoxide from other source, undetermined, initial encounter
T58.9	Toxic effect of carbon monoxide from unspecified source
T58.91	Toxic effect of carbon monoxide from unspecified source, accidental (unintentional)
T58.91XA	Toxic effect of carbon monoxide from unspecified source, accidental (unintentional), initial encounter
T58.92	Toxic effect of carbon monoxide from unspecified source, intentional self-harm
T58.92XS	Toxic effect of carbon monoxide from unspecified source, intentional self-harm, sequela
T58.93	Toxic effect of carbon monoxide from unspecified source, assault
T58.93XA	Toxic effect of carbon monoxide from unspecified source, assault, initial encounter
T58.94	Toxic effect of carbon monoxide from unspecified source, undetermined
T58.94XA	Toxic effect of carbon monoxide from unspecified source, undetermined, initial encounter

Appendix 3. Information typically contained in a poison control center report indicating an exposure to carbon monoxide.

Call type = exposure

Substance = carbon monoxide

Medical outcome = minor, moderate, major, death

Call notes = any mention of carbon monoxide or CO exposure or house fire

Appendix 4. Codes used by workers compensation programs to indicate exposure to carbon monoxide or carbon monoxide poisoning

State-specific codes to be added when available

Appendix 5. International Classification of Disease, Revision 10, (ICD 10) codes typically used to code carbon monoxide poisoning, toxic effect of carbon monoxide, or carbon monoxide exposure (explicit for or inclusive of CO) when they appear on a death certificate.

Explicit:

T58 Toxic effect of carbon monoxide

Incl.:

From all sources

Inclusive:

X47 Accidental poisoning by and exposure to other gases and vapours

Incl.:

carbon monoxide

helium (nonmedicinal) NEC

lacrimogenic gas [tear gas]

motor (vehicle) exhaust gas

nitrogen oxides

sulfur dioxide

utility gas

Excl.:

metal fumes and vapours (X49)

X67 Intentional self-poisoning by and exposure to other gases and vapours

Incl.:

carbon monoxide

helium (nonmedicinal) NEC

lacrimogenic gas [tear gas]

motor (vehicle) exhaust gas

nitrogen oxides

sulfur dioxide

utility gas

Excl.:

metal fumes and vapours (X69)

Y17 Poisoning by and exposure to other gases and vapours, undetermined intent

Incl.:

carbon monoxide

helium (nonmedicinal) NEC

lacrimogenic gas [tear gas]

motor (vehicle) exhaust gas

nitrogen oxides

sulfur dioxide

utility gas

Excl.:

metal fumes and vapours (Y19)

Appendix 6: SyS Guidelines TBD