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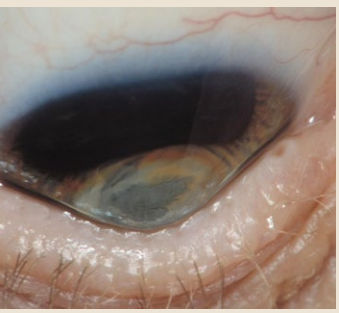


Carbon Monoxide Poisoning, Active and Reserve Component Service Members and Non-Service Member Beneficiaries of the Military Health System, U.S. Armed Forces, July 2009–June 2019

Valerie F. Williams, MA, MS; Alyssa Fedgo, MPH; Shauna Stahlman, PhD, MPH

Morbidity and mortality from carbon monoxide (CO) poisoning are important public health problems, but their full impact is difficult to estimate. The current analysis used the 2018 Council of State and Territorial Epidemiologist criteria and International Classification of Diseases (ICD) code-based data to classify CO poisoning cases by intent, source of exposure, and degree of certainty that poisoning was CO related. During July 2009–June 2019, there were 1,288 CO poisoning cases classified as confirmed/probable among active component service members, 366 among reserve component members, and 4,754 among non-service member beneficiaries. Service members working in repair/engineering occupations accounted for the greatest proportion of confirmed CO poisoning cases among active component members and the second greatest proportion among reserve component members. Compared to suspected cases, confirmed/probable cases were more often associated with intentional self-harm and undetermined causes of injury, whereas suspected cases were more often coded as unintentional. Confirmed/probable active component and non-service member beneficiary cases were more likely than their respective suspected case counterparts to receive care in inpatient settings. The need for improvements in ICD coding to reduce the percentage of CO poisoning cases coded with unknown injury intent and/or unknown CO poisoning source is discussed.

WHAT ARE THE NEW FINDINGS?

During July 2009–June 2019, there were 1,288 confirmed/probable cases of CO poisoning among active component service members and 366 among reserve component service members. Twenty-four active component service member deaths were ascertained within 1 week of CO poisoning-related hospitalizations. Work in repair/engineering was the most frequent specific occupation associated with confirmed CO poisoning cases among active and reserve component service members.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Military personnel encounter unique and potentially lethal sources of significant CO exposure. Primary medical care providers (including unit medics and emergency medical technicians) should be knowledgeable of and sensitive to the diverse and nonspecific early clinical manifestations of CO intoxication. Service members, unit leaders, and supervisors at all levels should be aware of the dangers of CO poisoning and should employ appropriate preventive measures.

Carbon monoxide (CO) is a toxic, colorless, odorless, tasteless, and nonirritating gas that results from the incomplete combustion of carbon-based fuels such as wood, charcoal, gasoline, heating oil, kerosene, methane, propane, and butane.[1] Exposure to excessive amounts of this gas is entirely preventable; nonetheless, CO poisoning is one of the most common causes of unintentional poisoning deaths in the U.S., accounting for hundreds of deaths and thousands of emergency department visits annually.[2–5]

Clinical CO toxicity is due to a combination of tissue hypoxia-ischemia resulting from carboxyhemoglobin (COHb) formation and direct CO-mediated damage at the cellular level.[1] CO binds to hemoglobin with approximately 240 times the affinity of oxygen, and the resulting COHb critically impairs oxygen transport and utilization.[6] The amount of COHb formed depends on the concentration of CO in the inspired air, the duration of exposure to the CO, and the alveolar ventilation (the amount of inspired air available for gas exchange each minute).[7] CO also interferes with peripheral oxygen utilization at the mitochondrial level by binding to intracellular proteins including myoglobin, cytochromes, and nicotinamide adenine dinucleotide phosphate reductase (NADPH).[8–10] In addition, CO can trigger an inflammatory cascade that results in lipid peroxidation affecting myelin proteins, apoptosis in neurons, and delayed neurologic sequelae.[9,11] Other mechanisms of CO toxicity include increased nitrous oxide production and oxidative free radical damage within the vasculature as well as increased amino acid levels (particularly glutamate).[9]

Because the clinical effects of mild to moderate CO poisoning are diverse and largely nonspecific (e.g., dizziness, headache, malaise, fatigue, disorientation, nausea, and vomiting), a high index of suspicion is crucial for an appropriate and timely diagnosis.[1,9,10] Extremely high CO exposure can produce more pronounced and severe symptoms such as altered mental status, confusion, syncope, seizures, acute stroke-like syndromes, and coma.[12,13] Muscular activity that increases oxygen demand exacerbates the symptoms of CO exposure; however, individuals at rest may experience no other symptoms before losing consciousness.[9] Cardiovascular and metabolic manifestations of CO poisoning may include hypotension, dysrhythmia, ischemia, infarction, and severe lactic acidosis.[8,9] Moreover, myocardial injury after moderate to severe CO poisoning is associated with increased long-term mortality.[14] Results of a prospective study of over 200 CO poisoning cases demonstrated a mortality rate of 24%

within 7.6 years of follow-up among those cases with acute myocardial injury.[14] Among cases with evidence of myocardial injury, the observed mortality rate was triple the death rate expected for a comparable, unpoisoned cohort.[14] Finally, CO poisoning may result in persistent or delayed neurologic effects, including reduced memory, cognitive impairment, confusion, seizures, and attention disorders.[1,15,16]

In the U.S., CO poisoning generally results from inhalation of fumes produced by fires, motor vehicles (e.g., automobiles, trucks, tractors, forklifts, motorboats), malfunctioning and/or inadequately ventilated heating or cooking devices (e.g., furnaces, fireplaces, stoves, barbecues, water heaters), and gasoline-powered tools (e.g., pumps, compressors, power generators).[17,18] CO from these sources can accumulate and reach dangerous levels in enclosed or partially enclosed spaces.[19] The Centers for Disease Control and Prevention (CDC) found that the most frequently recorded locations for CO exposures reported to poison control centers between 2000 and 2009 were "residence" and "workplace" (77.6% and 12.0%, respectively).[3]

By their natures, many military activities, materials, and settings pose CO hazards.[20–22] In 2009, the Department of Defense (DoD) removed CO poisoning from the list of reportable medical events.[23] However, healthcare providers within the Military Health System (MHS) are still encouraged to report any patient diagnosed with CO poisoning to their local preventive medicine service or public health detachments.[22] Because case definitions for CO poisoning vary by state, clinicians are encouraged to report any suspected cases.[22]

MSMR surveillance reports on episodes of CO poisoning among members of the U.S. Armed Forces date back to 2001.[24–28] The current analysis updates and expands on these earlier reports by including non-service member beneficiaries of the MHS, using International Classification of Diseases, 9th and 10th Revision (ICD-9 and ICD-10, respectively) codes to classify cases by degree of certainty that poisoning was CO related, intent, and source of exposure. Counts and locations of CO poisoning cases classified as confirmed are also reported for the period from July 2009 through June 2019.

METHODS

The surveillance period was 1 July 2009 to 30 June 2019. The surveillance population included all individuals who served in the active or reserve component of the Army, Navy, Air Force, or Marine Corps at any time during the surveillance period. The nonmilitary surveillance population consisted of other beneficiaries of the MHS including retired service members, family members, other dependents of service members and retirees, and other authorized government employees and their family members. Diagnoses indicative of CO poisoning were ascertained from electronic records of all medical encounters of individuals who received care in fixed (i.e., not deployed or at sea) medical facilities of the MHS or in civilian facilities in the purchased care system documented in the Defense Medical Surveillance System (DMSS). Healthcare encounters of deployed service members are maintained in the Theater Medical Data Store (TMDS), which is incorporated into the DMSS. For service members, cases were classified as active or reserve component using component at the time of the case-defining diagnosis.

For the current analysis, an incident case of CO poisoning was defined by inpatient, outpatient, or TMDS medical encounters with a qualifying ICD-9 or ICD-10 diagnosis code in any diagnostic position. Qualifying diagnosis codes were drawn from the 2018 Council of State and Territorial Epidemiologists (CSTE) criteria for defining a case of CO poisoning from administrative records and are presented in **Table 1**.[29] For the purpose of identifying incident CO poisoning cases, TMDS records were treated as outpatient encounters.

Drawing on the 2018 CSTE criteria, cases were classified by degree of certainty that poisoning was CO related **(Table 1)**.[29] A case of CO poisoning was considered "confirmed" if the medical encounter was coded with ICD-9 code 986 (toxic effect of CO), ICD-10 code T58.* (toxic effect of CO), or an ICD-9 external cause of injury code (E code) explicitly indicating CO exposure (E868.3, E868.8, E868.9, E952.1, E982.1). A "probable" case of CO poisoning was defined as any inpatient or outpatient encounter with an ICD-9 E code explicitly indicating motor vehicle exhaust exposure (E868.2, E952.0, E982.0) and no ICD-9 code 986. "Suspected" cases were defined as any inpatient or outpatient encounter with an ICD-9 diagnosis or E code inclusive of CO poisoning from exposure to utility gas, conflagration, vehicular, or other sources **(Table 1)** and no ICD-9 code 986. The ICD-9 code set used in the analysis to classify cases as suspected was modified to exclude the following E codes: E962.9 (assault by poisoning, unspecified), E972 (injury due to legal intervention by gas), and E978 (legal execution). The ICD-10 codes used to classify cases as suspected are not included in the 2018 CSTE list **(Table 1)**. Classification by degree of certainty was based on the first-occurring diagnostic position containing a qualifying diagnosis code, with prioritization of codes classified as confirmed over those classified as probable over those classified as suspected within the given encounter.

Cases were then categorized separately by intent as "undetermined," "assault," "unintentional," or "intentional self-harm" based on ICD-9 E codes or specific ICD-10 codes pertaining to the nature of the CO poisoning exposure **(Table 2)**.[29] Categorization of intent was based on the first-occurring case-qualifying diagnosis code that was not ICD-9 code 986, 987.0, 987.1, or 987.9. If any of these 4 codes occurred alone, the case was categorized as undetermined intent **(Table 2)**. It is important to note that because of the coding logic, the diagnosis code used for the classification of degree of certainty (confirmed/probable/suspected) could have been different from the diagnosis code used in the categorization of intent type.

To exclude follow-up encounters for single CO intoxication episodes, only 1 episode per individual per year was included in the analysis. Also, for ICD-10 codes T58.*, T59.89*, T59.81*, T59.9*, only initial encounters as indicated by a seventh digit of "A" were included in the analysis **(Table 1)**. Because CO poisonings are more frequent in the fall and winter, a surveillance year was defined as 1 July through 30 June for analysis purposes. Only 1 poisoning episode per individual per July–June period (cold year) was included in the analysis. If multiple encounters occurred in the same cold year, a 2-step prioritization was used: cases classified as confirmed were prioritized over those classified as probable, which were prioritized over those classified as suspected; inpatient encounters were prioritized over TMDS encounters, which were prioritized over outpatient encounters.

TABLE 1. ICD-9 and ICD-10 diagnostic codes and ICD-9 E codes used to identify cases of CO poisoning and to classify them as confirmed, probable, or suspected[a]

ICD-9		ICD-10	
Confirmed			
986	Toxic effect of CO	T58.***A	Toxic effect of CO
E codes explicitly indicating CO exposure was present:			
E868.3	Accidental poisoning by CO from incomplete combustion of other domestic fuels	T58.2**A	Toxic effect of CO from incomplete combustion of other domestic fuels
E868.8	Accidental poisoning by CO from other sources	T58.8**A	Toxic effect of CO from other source
E952.1	Self-inflicted poisoning by other CO source		
E982.1	Undetermined cause of poisoning by other CO source		
E868.9	Accidental poisoning by CO from an unspecified source	T58.9**A	Toxic effect of CO from unspecified source
		T58.1**A	Toxic effect of CO from utility gas[b]
Probable			
E codes explicitly indicating motor vehicle exhaust exposure was present:			
E952.0	Self-inflicted poisoning by motor vehicle exhaust gas not elsewhere classifiable		
E868.2	Accidental poisoning by motor vehicle exhaust gas not elsewhere classifiable		
E982.0	Undetermined cause of poisoning by motor vehicle exhaust gas not elsewhere classifiable		
Suspected			
E codes inclusive of CO poisoning from exposures to utility gas, conflagrations, vehicles, or other sources:			
E818.*	Other noncollision motor vehicle traffic accident; includes “accidental poisoning from exhaust gas generated by motor vehicle while in motion”		
E825.*	Other motor vehicle nontraffic accident; includes “accidental poisoning from CO generated by motor vehicle while in motion not on the public highway”		
E838.*	Other and unspecified water transport accident; includes “accidental poisoning by gases or fumes on ship”		
E844.*	Other specified air transport accidents; includes “accidental poisoning by CO from aircraft while in transit without accident to aircraft”		
E867	Accidental poisoning by gas distributed by pipeline, or CO from combustion of such gas		
E868.0	Accidental poisoning by LPG 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		
E869.9	Accidental poisoning by other gases or vapors, unspecified		
E890.2	Other smoke and fumes from conflagration in a private dwelling; includes “CO from conflagration in private building”	X00.1XXA	Exposure to smoke in uncontrolled fire in building or structure, initial encounter
E891.2	Other smoke and fumes from conflagration in other building; includes “CO from conflagration in building or structure”	X00.1XXA	Exposure to smoke in uncontrolled fire in building or structure, initial encounter
E951.0	Suicide and self-inflicted poisoning by gases in domestic use, pipeline		
E951.1	Suicide and self-inflicted poisoning by gases in domestic use, liquid petroleum gas distributed in mobile containers		
E951.8	Suicide and self-inflicted poisoning by gases in domestic use, other utility gas		
E952.9	Suicide and self-inflicted poisoning by other gases or vapors, unspecified	X76.XXXA	Intentional self-harm by smoke, fire and flames, initial encounter
E958.1	Suicide and self-inflicted injury by burns, fire		
E962.2	Assault by poisoning from other gases and vapors	X97.XXXA	Assault by smoke, fire and flames, initial encounter
E968.0	Assault by fire	Y38.3X2A	Terrorism involving fires, conflagration and hot substances, civilian injured, initial encounter
E979.3	Terrorism involving fires, including asphyxia		
E981.0	Poisoning by liquefied petroleum gas distributed by pipeline, undetermined whether accidently or purposely inflicted		
E981.1	Poisoning by liquefied petroleum gas distributed in mobile containers, undetermined whether accidently or purposely inflicted		
E981.8	Poisoning other utility gas, undetermined whether accidentally or purposely inflicted	Y26.XXXA	Exposure to smoke, fire and flames, undetermined intent, initial encounter
E988.1	Injury by burns or fire, undetermined whether accidentally or purposely inflicted	T59.89*A	Toxic effect of other specified gases, fumes and vapors (includes accidental [1A], intentional [2A], assault [3A], undetermined [4A] specifiers)
987.0	Toxic effect of liquid petroleum gases		
987.1	Toxic effect of other hydrocarbon gas	T59.81*A	Toxic effect of smoke (includes accidental [1A], intentional [2A], assault [3A], undetermined [4A] specifiers)
987.9	Toxic effect of unspecified gas, fume, or vapor	T59.9**A	Toxic effect of unspecified gases, fumes vapors (includes accidental [1XA], intentional [2XA], assault [3XA], and undetermined [4XA] specifiers)

[a]The list of codes classified as "suspected" is a modified version of the 2018 CSTE list.[29] The following E codes were not included in the current analysis: E962.9 (assault by poisoning, unspecified), E972 (injury due to legal intervention by gas), and E978 (legal execution). The ICD-10 codes classified as "suspected" here are not included in the 2018 CSTE list.
[b]ICD-10 code T58.1* does not map to any of the ICD-9 E codes classified as confirmed or probable.
ICD, International Classification of Diseases; E code, external cause of injury code; CO, carbon monoxide; LPG, liquefied petroleum gas; CSTE, Council of State and Territorial Epidemiologists.

TABLE 2. Classification of qualifying ICD-9/ICD-10 codes and ICD-9 E codes by intent[a]

ICD-9/ICD-10 code	ICD-9/ICD-10 code description (poisoning source)	Injury category
E868.2	Accidental poisoning by motor vehicle exhaust gas not elsewhere classifiable	Unintentional
E868.3	Accidental poisoning by CO from incomplete combustion of other domestic fuels	Unintentional
E868.8	Accidental poisoning by CO from other sources	Unintentional
E952.1	Self-inflicted poisoning by other CO source	Intentional self-harm
E982.1	Undetermined cause of poisoning by other CO source	Undetermined
E868.9	Accidental poisoning by CO from unspecified source	Unintentional
E952.0	Self-inflicted poisoning by motor vehicle exhaust gas	Intentional self-harm
E982.0	Undetermined cause of poisoning by motor vehicle exhaust gas	Undetermined
E818.x	Other noncollision motor vehicle traffic accident, including accidental poisoning from exhaust gas	Unintentional
E825.x	Other motor vehicle nontraffic accident of other and unspecified nature, including accidental poisoning from CO	Unintentional
E838.x	Other and unspecified water transport accident, including accidental poisoning by bases or fumes on ship	Unintentional
E844.x	Other specified air transport accidents, including poisoning by CO while in transit	Unintentional
E867	Accidental poisoning by gas distributed by pipeline, or CO from combustion of such gas	Unintentional
E868.0	Accidental poisoning by LPG in mobile containers, or CO from combustion of such gas	Unintentional
E868.1	Accidental poisoning by other/unspecified utility gas, or CO from combustion of such gas	Unintentional
E869.9	Accidental poisoning by other gases or vapors, unspecified	Unintentional
E890.2	Other smoke and fumes from conflagration in a private dwelling, including CO	Unintentional
E891.2	Other smoke and fumes from conflagration in other building, including CO	Unintentional
E962.2	Assault by poisoning from other gases and vapors	Assault
E968.0	Assault by fire	Assault
E951.0	Suicide and self-inflicted poisoning by gases in domestic use, pipeline	Intentional self-harm
E951.1	Suicide and self-inflicted poisoning by gases in domestic use, LPG (mobile)	Intentional self-harm
E951.8	Suicide and self-inflicted poisoning by gases in domestic use, other utility gas	Intentional self-harm
E952.9	Suicide and self-inflicted poisoning by other gases or vapors, unspecified	Intentional self-harm
E958.1	Suicide and self-inflicted injury by burns, fire	Intentional self-harm
E979.3	Terrorism involving fires, including asphyxia	Undetermined
E981.0	Poisoning by gases in domestic use, undetermined intent, pipeline	Undetermined
E981.1	Poisoning by gases in domestic use, undetermined intent, LPG (mobile)	Undetermined
E981.8	Poisoning by gases in domestic use, undetermined intent, other utility gas	Undetermined
E988.1	Undetermined cause of injury by fire, burns	Undetermined
986	Toxic effect of CO	Undetermined
987.0, 987.1, 987.9	Toxic effect liquid petroleum gases; other hydrocarbon gas; unspecified gas, fume, or vapor	Undetermined
T58.01XA	Toxic effect of CO from motor vehicle exhaust, accidental (unintentional)	Unintentional
T58.02XA	Toxic effect of CO from motor vehicle exhaust, intentional self-harm	Intentional self-harm
T58.03XA	Toxic effect of CO from motor vehicle exhaust, assault	Assault
T58.04XA	Toxic effect of CO from motor vehicle exhaust, undetermined	Undetermined
T58.11XA	Toxic effect of CO from utility gas, accidental (unintentional)	Unintentional
T58.12XA	Toxic effect of CO from utility gas, intentional self-harm	Intentional self-harm
T58.13XA	Toxic effect of CO from utility gas, assault	Assault
T58.14XA	Toxic effect of CO from utility gas, undetermined	Undetermined
T58.2X1A	Toxic effect of CO from incomplete combustion of other domestic fuels, accidental (unintentional)	Unintentional
T58.2X2A	Toxic effect of CO from incomplete combustion of other domestic fuels, intentional self-harm	Intentional self-harm
T58.2X3A	Toxic effect of CO from incomplete combustion of other domestic fuels, assault	Assault
T58.2X4A	Toxic effect of CO from incomplete combustion of other domestic fuels, undetermined	Undetermined
T58.8X1A	Toxic effect of CO from other source, accidental (unintentional)	Unintentional
T58.8X2A	Toxic effect of CO from other source, intentional self-harm	Intentional self-harm
T58.8X3A	Toxic effect of CO from other source, assault	Assault
T58.8X4A	Toxic effect of CO from other source, undetermined	Undetermined
T58.91XA	Toxic effect of CO from unspecified source, accidental (unintentional)	Unintentional
T58.92XA	Toxic effect of CO from unspecified source, intentional self-harm	Intentional self-harm
T58.93XA	Toxic effect of CO from unspecified source, assault	Assault
T58.94XA	Toxic effect of CO from unspecified source, undetermined	Undetermined
X00.1XXA	Exposure to smoke in uncontrolled fire in building or structure, initial encounter	Undetermined
X76.XXXA	Intentional self-harm by smoke, fire and flames, initial encounter	Intentional self-harm
X97.XXXA	Assault by smoke, fire and flames, initial encounter	Assault
Y38.3X2A	Terrorism involving fires, conflagration and hot substances, civilian injured, initial encounter	Undetermined
Y26.XXXA	Exposure to smoke, fire and flames, undetermined intent, initial encounter	Undetermined
T59.891A	Toxic effect of other specified gases, fumes and vapors, unintentional	Unintentional
T59.892A	Toxic effect of other specified gases, fumes and vapors, intentional	Intentional self-harm
T59.893A	Toxic effect of other specified gases, fumes and vapors, assault	Assault
T59.894A	Toxic effect of other specified gases, fumes and vapors, undetermined	Undetermined
T59.811A	Toxic effect of smoke, accidental	Unintentional
T59.812A	Toxic effect of smoke, intentional	Intentional self-harm
T59.813A	Toxic effect of smoke, assault	Assault
T59.814A	Toxic effect of smoke, undetermined	Undetermined
T59.91XA	Toxic effect of unspecified gases, fumes, and vapors, accidental	Unintentional
T59.92XA	Toxic effect of unspecified gases, fumes, and vapors, intentional	Intentional self-harm
T59.93XA	Toxic effect of unspecified gases, fumes, and vapors, assault	Assault
T59.94XA	Toxic effect of unspecified gases, fumes, and vapors, undetermined	Undetermined

[a]Code classifications drawn from CSTE 2018 criteria for CO poisoning case ascertainment from administrative records.[29]
Note: ICD-9 codes 986, 987.0, 987.1, and 987.9 were categorized as undetermined as long as there were no other intent codes in that encounter. If ICD-9 codes 986, 987.0, 987.1, or 987.9 were accompanied by a qualifying E code, the E code was used in classification of intent.
ICD, International Classification of Diseases; E code, external cause of injury code; CO, carbon monoxide; LPG, liquified petroleum gas; CSTE, Council of State and Territorial Epidemiologists.

The disposition of active and reserve component CO poisoning cases was examined and coded as returned to duty with no limitations, returned to duty with limitations, not returned to duty, or death. If there was no indication of disposition in the record of the medical encounter (14.3% of active component cases and 45.0% of reserve component cases), then the service member was assumed to be returned to duty with no limitations. In addition, for active and reserve component inpatient cases, casualty data for active duty and activated reserve component members were checked for any deaths within +/- 7 days of any CO poisoning-related hospitalizations. Finally, the diagnostic position of the case-defining diagnosis (first through second, third though fourth, fifth +) was also examined for active and reserve component CO poisoning cases.

RESULTS

Active component

During the 10-year surveillance period, there were 24,223 incident diagnoses that met the 2018 CSTE criteria for confirmed, probable, or suspected CO poisoning among active component service members **(Table 3)**. The vast majority (n=22,935; 94.7%) of these diagnoses were classified as suspected, 5.2% (n=1,269) were classified as confirmed, and 0.08% (n=19) were classified as probable. More than four-fifths (85.1%; n=20,611) of the total incident diagnoses were recorded during outpatient encounters, 7.0% (n=1,685) during inpatient encounters, and 8.0% (n=1,927) during TMDS encounters. A total of 24 active component service member deaths were ascertained from casualty data within +/- 7 days of CO poisoning-related hospitalizations.

Among the 1,288 confirmed/probable cases of CO poisoning, 613 (47.6%) were classified as having unintentional intent, 538 (41.8%) as having undetermined intent, 136 (10.6%) as having self-harm intent, and 1 (0.1%) as due to assault **(Table 3)**. More than four-fifths (81.4%) of incident CO poisoning diagnoses classified as confirmed/probable were recorded in an outpatient setting. In terms of disposition, the vast majority of confirmed/probable cases were categorized as having returned to duty with no limitations (88.5%), 9.2% were not returned to duty, and 1.9% were categorized as having returned to duty with limitations. Among the 22,935 suspected cases, roughly seven-eighths (87.4%) were associated with unintentional causes of injury and 11.7% were associated with undetermined intent **(Table 3)**. Less than 1% of suspected cases were associated with intentional self-harm (0.6%; n=141) or assault (0.3%; n=64) intent. The majority (85.3%) of suspected CO poisoning diagnoses among active component members were recorded in outpatient settings.

The source of CO poisoning was "other or unspecified" for 913 (71.9%) of the confirmed active component cases based on associated ICD-9 or ICD-10 codes **(data not shown)**. Motor vehicle exhaust was the second most common source of confirmed cases (n=216; 17.0%) and accounted for all of the probable cases (n=19) **(data not shown)**. Less frequent sources of CO among confirmed cases included utility gas (n=73; 5.8%), domestic fuel (n=54; 4.3%), smoke/fumes from fire (n=12; 0.9%), and liquefied petroleum gas (n=1; 0.1%). For suspected cases, motor vehicle exhaust was the most common source of CO poisoning, accounting for more than four-fifths (82.2%; n=18,849) of the cases. The next most frequent source was "other and unspecified" (n=3,071; 13.4%) followed by smoke/fumes from fire (n=938; 4.1%); domestic fuel, utility gas, and liquefied petroleum gas each accounted for 0.1% of suspected cases **(data not shown)**.

TABLE 3. Active component cases with confirmed/probable versus suspected CO poisoning, July 2009–June 2019

Characteristic	Confirmed/ probable[a]		Suspected		Total	
	No.	%	No.	%	No.	%
Total	1,288	5.3	22,935	94.7	24,223	100.0
Injury category[b]						
Unintentional	613	47.6	20,036	87.4	20,649	85.2
Assault	1	0.1	64	0.3	65	0.3
Intentional self-harm	136	10.6	141	0.6	277	1.1
Undetermined	538	41.8	2,694	11.7	3,232	13.3
Encounter setting						
Inpatient	137	10.6	1,548	6.7	1,685	7.0
Outpatient	1,048	81.4	19,563	85.3	20,611	85.1
TMDS	103	8.0	1,824	8.0	1,927	8.0
Disposition						
Returned to duty no limitations	1,140	88.5	18,225	79.5	19,365	79.9
Returned to duty with limitations	24	1.9	2,647	11.5	2,671	11.0
Not returned to duty	119	9.2	2,044	8.9	2,163	8.9
Death	5	0.4	19	0.1	24	0.1
Position of case-defining ICD-9/ICD-10 code						
First–second diagnostic position	1,179	91.5	14,321	62.4	15,500	64.0
Third–fourth diagnostic position	96	7.5	8,292	36.2	8,388	34.6
Fifth diagnostic position or higher	13	1.0	322	1.4	335	1.4

[a]19 incident CO poisoning cases were classified as probable.
[b]The most descriptive case-defining ICD-9 or ICD-10 code was used to categorize the case as unintentional, intentional self-harm, or undetermined.
CO, carbon monoxide; No., number; TMDS, Theater Medical Data Store; ICD, International Classification of Diseases.

Approximately three-fifths (60.2%; n=776) of the case-defining diagnoses of confirmed/probable cases were recorded as ICD-9 codes **(data not shown)**. Of these confirmed/probable ICD-9 cases, 460 (59.3%) were coded with ICD-9 diagnosis code 986 and no qualifying E codes, 234 (30.3%) were coded with 986 and a qualifying E code, and 82 (10.6%) were coded with a confirmed/probable E code alone (i.e., no 986 code) **(data not shown)**.

During July 2009–June 2019, the majority of active component service members classified as confirmed CO poisoning cases were male (80.5%), 29 years old or younger (68.2%), and non-Hispanic white (60.8%) **(Table 4)**. Army members accounted for the greatest proportion of confirmed CO poisoning cases (41.4%), and Marine Corps members the lowest (8.4%). Enlisted service members made up almost seven-eighths (86.9%) of the confirmed CO poisoning cases. Service members in repair/engineering occupations accounted for the greatest proportion of confirmed CO poisoning cases (30.2%), and those working in motor transport accounted for the lowest proportion (3.2%).

Annual counts of confirmed/probable CO poisoning cases among active component service members fluctuated between 107 (July 2009–June 2010 and July 2017–June 2018) and 170 (July 2016–June 2017) **(Figures 1a, 1b)**. Examination of cases by year and month showed that the greatest monthly count of confirmed/probable CO poisoning cases occurred in January 2017 (n=61). Cumulative monthly counts of confirmed/probable cases increased from late summer through early fall, were highest in late fall and early winter, and were lowest in late spring and early summer **(Figure 2)**. Cumulative monthly counts of suspected cases followed a broadly similar trend.

Active component confirmed CO poisoning cases were widely distributed among units and installations in the U.S. and overseas. During the 10-year surveillance period, confirmed CO poisoning cases were diagnosed at more than 190 military installations and geographic locations worldwide. Fourteen U.S. military installations accounted for more than one-third (35.0%) of total confirmed cases **(Table 5)**. The 2 installations with the most confirmed cases during the surveillance period included Fort Carson, CO (n=60; 4.7%), and Naval Medical Center (NMC) San Diego, CA (n=52; 4.1%). Less than 5% (4.1%; n=52) of all confirmed cases affected service members assigned outside of the U.S., and 13.8% of cases (n=175) were diagnosed in unknown locations. The known locations with the largest clusters of confirmed CO poisoning cases within the same calendar weeks included Seymour Johnson Air Force Base (AFB), NC (n=20; December 2015); Joint Base Langley-Eustis, VA (n=18; January 2014); NMC San Diego, CA (n=15; November 2017); Keesler AFB, MS (n=14; January 2013); Landstuhl Regional Medical Center, Germany (n=12; September 2016), and Fort Wainwright, AK (n=11; September 2014) **(data not shown)**.

Reserve component

From July 2009 through June 2019, there were 4,046 incident diagnoses that met the 2018 CSTE criteria for confirmed, probable, or suspected CO poisoning among reserve component service members **(Table 6)**. The vast majority (n=3,680; 91.0%) of these diagnoses were classified as suspected, 9.0% (n=361) were classified as confirmed, and 0.1% (n=5) were classified as probable. Roughly five-sixths (83.8%; n=3,389) of the total incident cases were documented in outpatient settings, and 4.6% (n=186) were treated in inpatient settings; 11.6% of cases were derived from TMDS encounters (n=471). No deaths were ascertained from reserve component casualty data within +/- 7 days of CO poisoning-related hospitalizations.

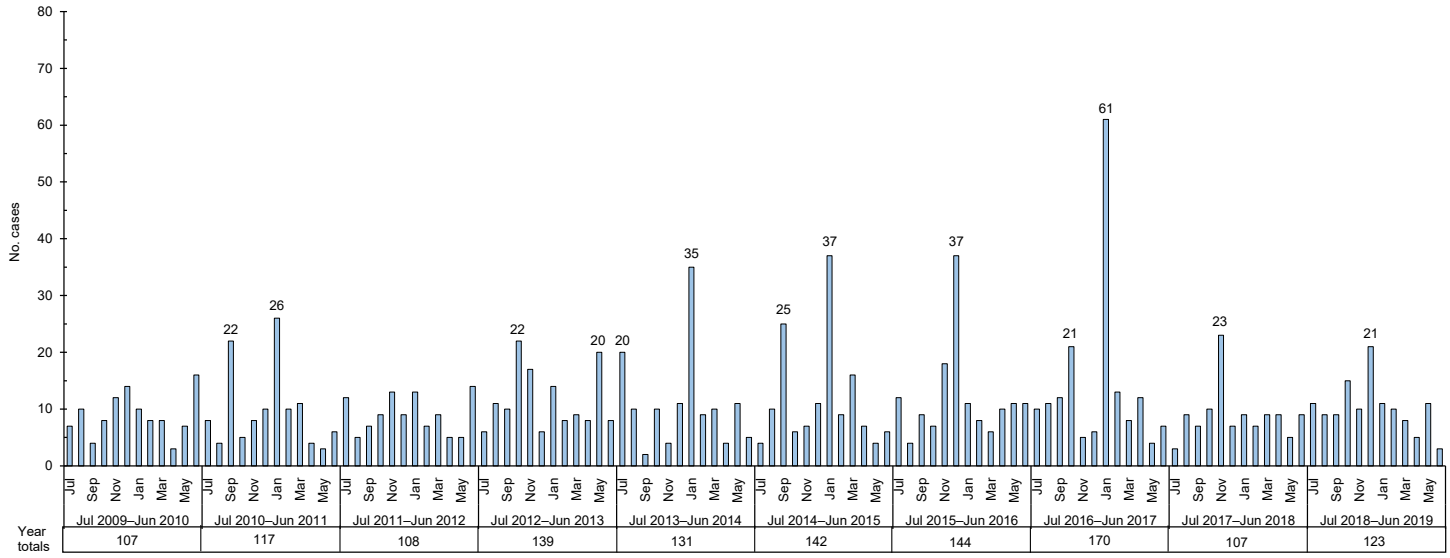
Of the 366 confirmed/probable cases of CO poisoning among reserve component members, 180 (49.2%) were classified as having unintentional injury intent, 160 (43.7%) were classified as having undetermined intent, and 26 (7.1%) were classified as having intentional self-harm intent; there were no cases classified as having assault intent **(Table 6)**. The vast majority (91.0%) of incident CO poisoning diagnoses classified as confirmed/probable were recorded in outpatient settings. In terms of disposition, 96.4% of confirmed/probable cases were categorized as having returned to duty with no limitations. Among the 3,680 suspected cases, more than three-quarters (78.8%) were associated with unintentional causes of injury and 20.7% were associated

TABLE 4. Incident cases of confirmed CO poisoning and percentages, by demographic and military characteristics, active component, U.S. Armed Forces, July 2009–June 2019

	No.	%
Total	1,269	100.0
Sex		
Male	1,021	80.5
Female	248	19.5
Age group (years)		
<20	64	5.0
20–24	461	36.3
25–29	341	26.9
30–34	210	16.5
35–39	101	8.0
40–49	84	6.6
50+	8	0.6
Race/ethnicity		
Non-Hispanic white	771	60.8
Non-Hispanic black	234	18.4
Hispanic	153	12.1
Asian/Pacific Islander	36	2.8
Other/unknown	75	5.9
Service		
Army	525	41.4
Navy	267	21.0
Air Force	371	29.2
Marine Corps	106	8.4
Rank		
Junior enlisted (E1–E4)	642	50.6
Senior enlisted (E5–E9)	461	36.3
Junior officer (O1–O3; W1–W3)	111	8.7
Senior officer (O4–O10; W4–W5)	55	4.3
Military occupation		
Combat-specific[a]	158	12.5
Motor transport	40	3.2
Pilot/air crew	79	6.2
Repair/engineering	383	30.2
Communications/ intelligence	254	20.0
Healthcare	111	8.7
Other/unknown	244	19.2

[a]Infantry/artillery/combat engineering/armor.
CO, carbon monoxide; No., number.

FIGURE 1a. Incident confirmed/probable CO poisoning cases, by month, active component, U.S. Armed Forces, July 2009–June 2019



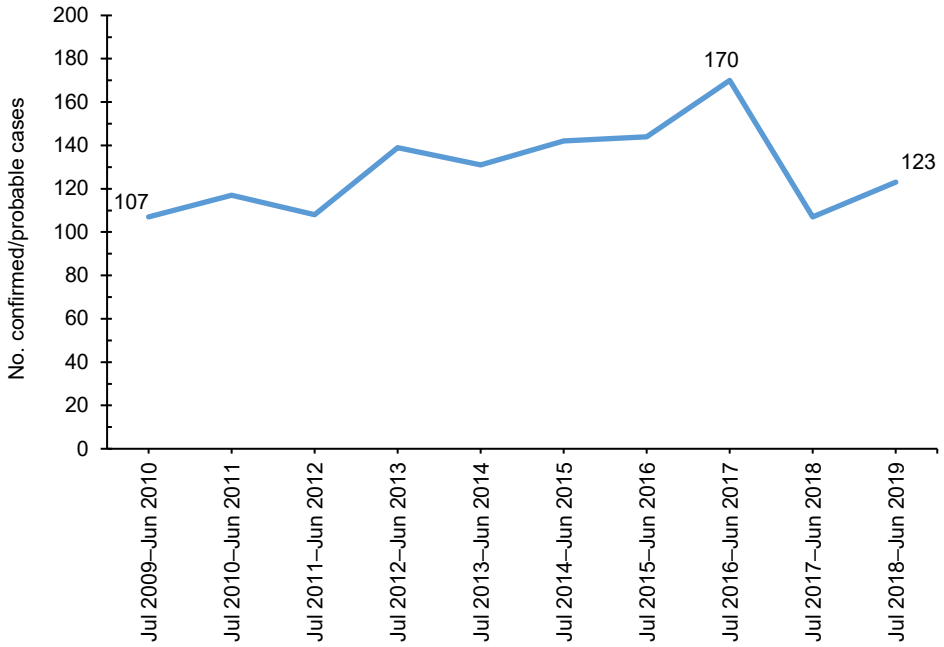
CO, carbon monoxide; No., number.

with undetermined intent **(Table 6)**. Less than 1% of suspected cases were associated with intentional self-harm (0.4%; n=15) or assault (0.2%; n=7) intent. The majority (83.0%) of suspected CO poisoning diagnoses among reserve component members were recorded in outpatient settings.

Among reserve component members, the source of CO poisoning was "other or unspecified" for 296 (82.0%) of confirmed cases **(data not shown)**. Motor vehicle exhaust was the second most common source of CO among confirmed cases (n=42; 11.6%) and accounted for all of the probable cases (n=5) **(data not shown)**. Less frequent sources of CO among confirmed cases included utility gas (n=16; 4.4%), domestic fuel (n=5; 1.4%), and liquefied petroleum gas (n=2; 0.5%). For suspected cases, motor vehicle exhaust was the most common source of CO poisoning, accounting for more than two-thirds (68.9%; n=2,534) of the cases. The next most frequent source of CO exposure for suspected cases was "other and unspecified" sources (n=881; 23.9%) followed by smoke/fumes from fire (n=235; 6.4%); liquefied petroleum gas and utility gas each accounted for approximately 0.4% of suspected cases. Domestic fuel accounted for 0.1% of suspected cases **(data not shown)**.

More than half (56.6%; n=207) of the case-defining diagnoses of confirmed/probable cases were recorded as ICD-9 codes **(data not shown)**. Of these confirmed/probable ICD-9 cases, 140 (38.3%) were coded with ICD-9 diagnosis code 986 and no qualifying E codes, 55 (15.0%) were coded with 986 and a qualifying E code, and 12 (3.3%) were coded with a confirmed/probable E code alone (i.e., no 986 code) **(data not shown)**.

FIGURE 1b. Incident confirmed/probable CO poisoning cases, by year, active component, U.S. Armed Forces, July 2009–June 2019



CO, carbon monoxide; No., number.

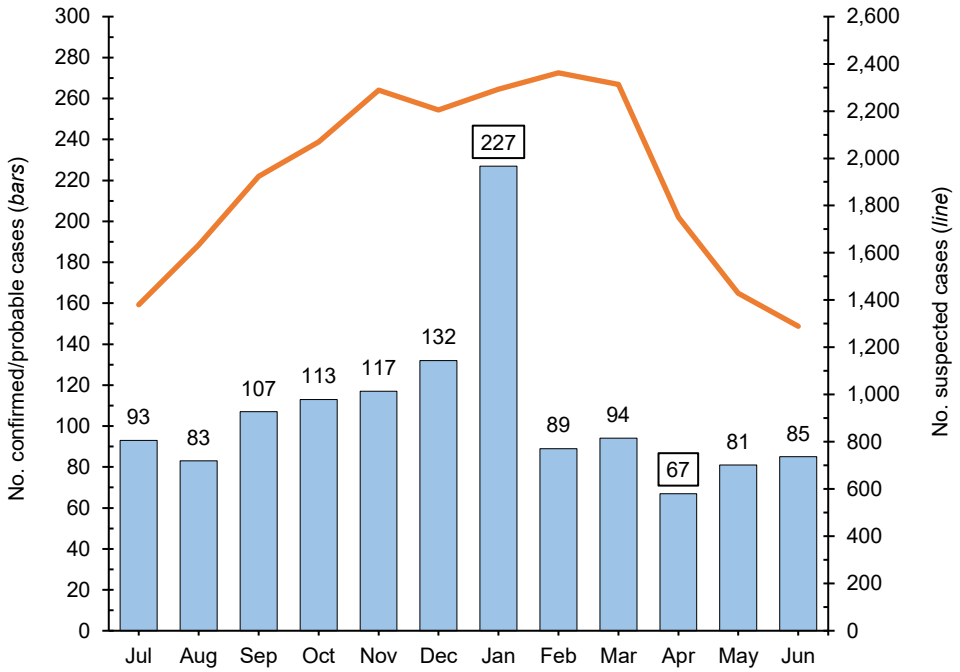
Similar to the active component, the majority of reserve component service members classified as confirmed CO poisoning cases were male (73.4%), non-Hispanic white (68.1%), in the Army (74.0%), and enlisted (89.2%) **(Table 7)**. Almost one-half (47.6%) of confirmed reserve component cases were 29 years old or younger. Service members in other/unknown and repair/engineering occupations accounted for the greatest proportions of confirmed

TABLE 5. Confirmed CO poisoning cases, by location of diagnosis/report (with at least 20 cases during the period), active component, U.S. Armed Forces, July 2009–June 2019

Location of diagnosis	No.	%
Fort Carson, CO	60	4.7
NMC San Diego, CA	52	4.1
NMC Portsmouth, VA	38	3.0
Fort Hood, TX	37	2.9
Fort Bragg, NC	33	2.6
Fort Bliss, TX	30	2.4
MCB Camp Pendleton, CA	30	2.4
Elmendorf, AK	28	2.2
JB Langley-Eustis, VA	26	2.0
Camp Lejeune, NC	24	1.9
Fort Wainright, AK	23	1.8
Fort Riley, KS	21	1.7
Walter Reed, NMMC, MD[a]	21	1.7
Seymour Johnson AFB, NC	21	1.7
Outside U.S.	52	4.1
Unknown locations	175	13.8
All other locations	598	47.1
Total	1,269	100.0

[a]Walter Reed NMMC is a consolidation of National Naval Medical Center (Bethesda, MD) and Walter Reed Army Medical Center (Washington, DC). This number represents the sum of the 2 sites before the consolidation (November 2011) and the number reported at the consolidated location.
CO, carbon monoxide; No., number; NMC, Naval Medical Center; MCB, Marine Corps Base; JB, Joint Base; NMMC, National Military Medical Center; AFB, Air Force Base.

FIGURE 2. Cumulative numbers of incident confirmed/probable and suspected CO poisoning cases, by month of diagnosis, active component, U.S. Armed Forces, July 2009–June 2019



CO, carbon monoxide; No., number.

TABLE 6. Reserve component cases with confirmed/probable versus suspected CO poisoning, July 2009–June 2019

Characteristic	Confirmed/ probable[a]		Suspected		Total	
	No.	%	No.	%	No.	%
Total	366	9.0	3,680	91.0	4,046	100.0
Injury category[b]						
Unintentional	180	49.2	2,898	78.8	3,078	76.1
Assault	0	0.0	7	0.2	7	0.2
Intentional self-harm	26	7.1	15	0.4	41	1.0
Undetermined	160	43.7	760	20.7	920	22.7
Encounter setting						
Inpatient	20	5.5	166	4.5	186	4.6
Outpatient	333	91.0	3,056	83.0	3,389	83.8
TMDS	13	3.6	458	12.4	471	11.6
Disposition						
Returned to duty no limitations	353	96.4	3,221	79.6	3,574	88.3
Returned to duty with limitations	3	0.8	258	6.4	261	6.5
Not returned to duty	10	2.7	201	5.0	211	5.2
Death	0	0.0	0	0.0	0	0.0
Position of case-defining ICD-9/ICD-10 code						
First–second diagnostic position	339	92.6	2,370	64.4	2,709	67.0
Third–fourth diagnostic position	24	6.6	1,267	34.4	1,291	31.9
Fifth diagnostic position or higher	3	0.8	43	1.2	46	1.1

[a]5 incident CO poisoning cases were classified as probable.
[b]The most descriptive case-defining ICD-9 or ICD-10 code was used to categorize the case as unintentional, intentional self-harm, or undetermined.
CO, carbon monoxide; No., number; TMDS, Theater Medical Data Store; ICD, International Classification of Diseases.

CO poisoning cases (27.7% and 26.3%, respectively), and those working as pilots/air crew the lowest (2.2%).

Annual counts of confirmed/probable CO poisoning cases among reserve component service members fluctuated between 28 (July 2016–June 2017) and 58 (July 2018–June 2019) **(Figures 3a, 3b)**. The greatest monthly counts of confirmed/probable CO poisoning cases occurred in May 2013 (n=15) and April 2019 (n=15). During the surveillance period, cumulative monthly counts of confirmed/probable cases among reserve component members were highest in May (n=43) and January (n=41) and lowest in December (n=20) and September (n=22) **(Figure 4)**. Cumulative monthly counts of

TABLE 7. Incident confirmed cases of CO poisoning and percentages, by demographic and military characteristics, reserve component, U.S. Armed Forces, July 2009–June 2019

	No.	%
Total	361	100.0
Sex		
Male	265	73.4
Female	96	26.6
Age group (years)		
<20	14	3.9
20–24	73	20.2
25–29	85	23.5
30–34	66	18.3
35–39	40	11.1
40–49	67	18.6
50+	16	4.4
Race/ethnicity		
Non-Hispanic white	246	68.1
Non-Hispanic black	57	15.8
Hispanic	32	8.9
Asian/Pacific Islander	12	3.3
Other/unknown	14	3.9
Service		
Army	267	74.0
Navy	20	5.5
Air Force	64	17.7
Marine Corps	10	2.8
Rank		
Junior enlisted (E1–E4)	140	38.8
Senior enlisted (E5–E9)	182	50.4
Junior officer (O1–O3; W1–W3)	23	6.4
Senior officer (O4–O10; W4–W5)	16	4.4
Military occupation		
Combat-specific[a]	40	11.1
Motor transport	17	4.7
Pilot/air crew	8	2.2
Repair/engineering	95	26.3
Communications/intelligence	81	22.4
Healthcare	20	5.5
Other/unknown	100	27.7

[a]Infantry/artillery/combat engineering/armor.
CO, carbon monoxide; No., number.

suspected cases were lowest in the early and late summer months and highest in the late fall and early winter months.

From July 2009 through June 2019, confirmed CO poisoning cases were diagnosed among reserve component members at more than 90 military installations and geographic locations worldwide. Less than 1% (0.6%; n=2) of all confirmed cases affected service members assigned outside of the U.S., and 7.5% (n=27) of cases were diagnosed in unknown locations. Five installations accounted for one-eighth (12.5%) of the total confirmed CO poisoning cases among reserve component members **(Table 8)**. These locations included Fort Belvoir, VA (n=16; 4.4%); Marine Corps Base (MCB) Camp Pendleton, CA (n=12; 3.3%); Wright-Patterson AFB, OH (n=7; 1.9%); Fort Bragg, NC (n=5; 1.4%); and NMC Portsmouth, VA (n=5; 1.4%). The largest cluster of confirmed CO poisoning cases reported within the same calendar week occurred at MCB Camp Pendleton, CA (n=9), in May 2012 **(data not shown)**.

Non-service member beneficiaries

During the 10-year surveillance period, there were 28,394 incident diagnoses that met the 2018 CSTE criteria for confirmed, probable, or suspected CO poisoning among non-service member beneficiaries of the MHS **(Table 9)**. More than four-fifths (n=23,640; 83.3%) of these diagnoses were classified as suspected, 16.6% (n=4,714) were classified as confirmed, and 0.1% (n=40) were classified as probable. The vast majority (93.1%; n=26,442) of the total incident diagnoses were recorded during outpatient encounters, with 6.9% (n=1,952) recorded during inpatient encounters.

Among the 4,754 confirmed/probable cases of CO poisoning among non-service member beneficiaries, 2,461 (51.8%) were classified as having undetermined intent, 2,070 (43.5%) were classified as having unintentional injury intent, 215 (4.5%) were classified as having intentional self-harm intent, and 8 (0.2%) were classified as having assault intent **(Table 9)**. The vast majority (90.0%) of incident CO poisoning diagnoses classified as confirmed/probable were recorded in outpatient settings. Among the 23,640 suspected cases, over three-quarters (75.9%) were associated with unintentional causes of injury and 22.5% were associated with undetermined intent **(Table 9)**. Approximately 0.5% (n=124) of suspected cases were associated with assault intent, with 1.0% (n=241) associated with intentional self-harm intent. The vast majority (93.7%) of suspected CO poisoning diagnoses among non-service member beneficiaries were recorded in outpatient settings.

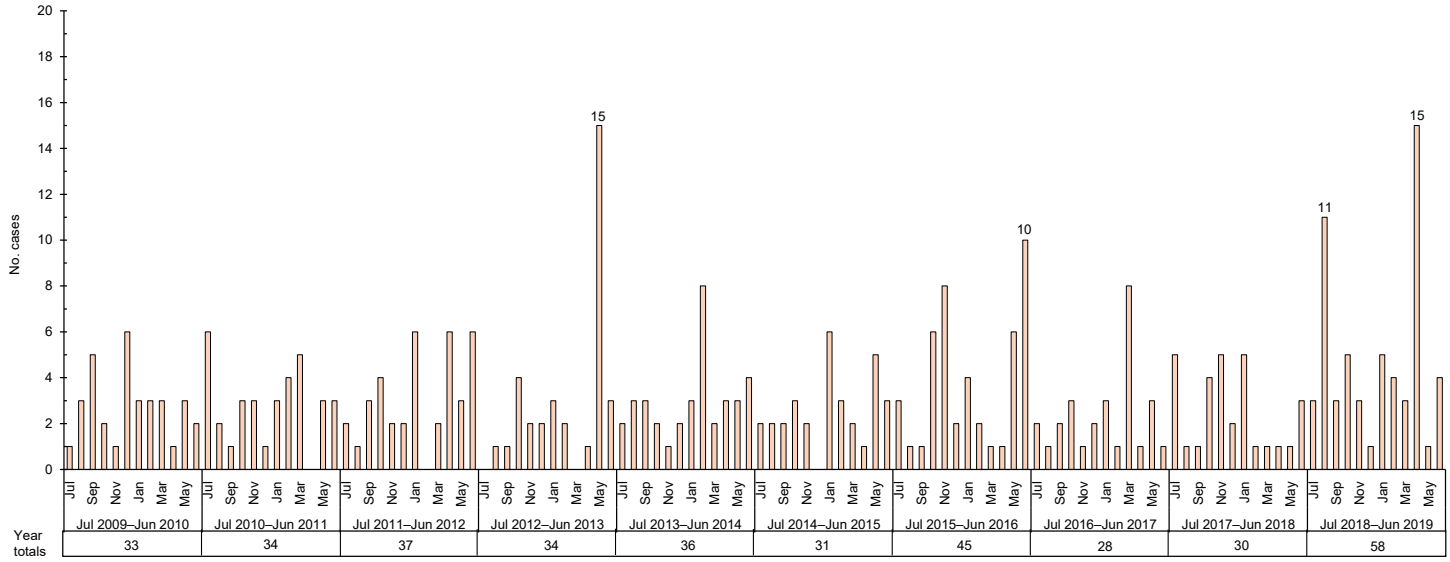
The most common source of CO poisoning among non-service member beneficiaries was "other or unspecified" for 3,859 (11.9%) of confirmed cases based on associated ICD-9 or ICD-10 codes **(data not shown)**. Motor vehicle exhaust was the second most common source of confirmed cases (n=404; 8.6%) and accounted for all of the probable cases (n=40) **(data not shown)**. Less frequent sources of CO among confirmed cases included utility gas (n=309; 6.6%), domestic fuel (n=109; 2.3%), smoke/fumes from fire (n=20; 0.4%), and liquefied petroleum gas (n=13; 0.3%). For suspected cases, motor vehicle exhaust was the most common source of CO poisoning, accounting for more than three-fifths (63.3%; n=14,972) of the cases. The next most frequent source of suspected cases was "other and unspecified" sources (n=6,136; 26.0%) followed by smoke/fumes from fire (n=2,317; 9.8%); utility gas, liquefied petroleum gas, and domestic fuel each accounted for less than 1.0% of suspected cases **(data not shown)**.

Roughly five-eighths (62.6%; n=2,975) of the case-defining diagnoses of confirmed/probable cases were recorded as ICD-9 codes **(data not shown)**. Of these confirmed/probable ICD-9 cases, 2,167 (45.6%) were coded with ICD-9 diagnosis code 986 and no qualifying E codes, 626 (13.2%) were coded with 986 and a qualifying E code, and 182 (3.8%) were coded with a confirmed/probable E code alone (i.e., no 986 code) **(data not shown)**.

Among non-service member beneficiaries, nearly three-fifths of confirmed CO poisoning cases were among females (59.2%) **(data not shown)**. More than one-quarter (26.9%) of confirmed cases were among those aged 17 or younger, with 30.6% of confirmed cases aged 18–44 years, 22.3% aged 45–65 years, and 20.2% aged 65 years or older **(data not shown)**.

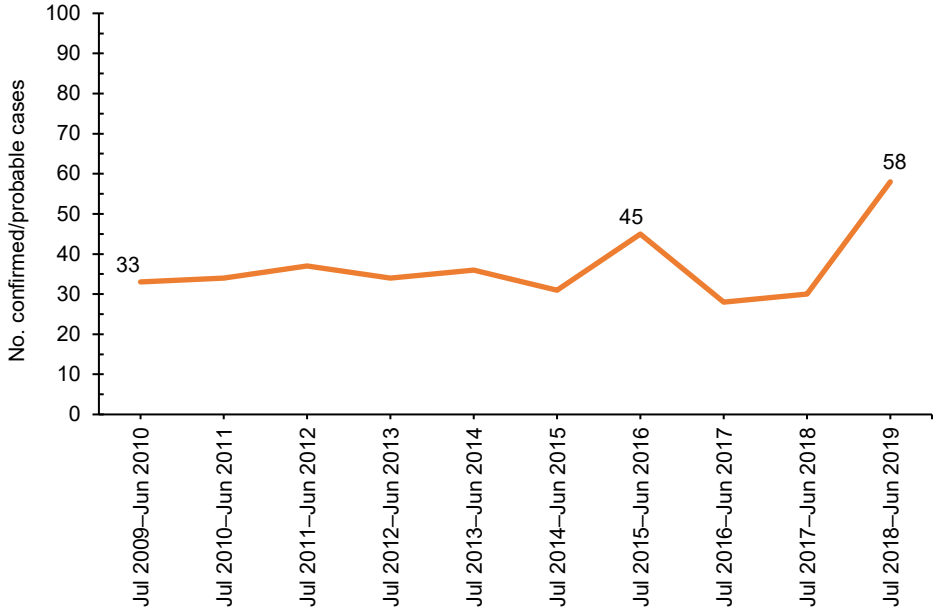
Annual counts of confirmed/probable CO poisoning cases among non-service member beneficiaries fluctuated between

FIGURE 3a. Incident confirmed/probable CO poisoning cases, by month, reserve component, U.S. Armed Forces, July 2009–June 2019



CO, carbon monoxide; No., number.

FIGURE 3b. Incident confirmed/probable CO poisoning cases, by year, reserve component, U.S. Armed Forces, July 2009–June 2019



CO, carbon monoxide; No., number.

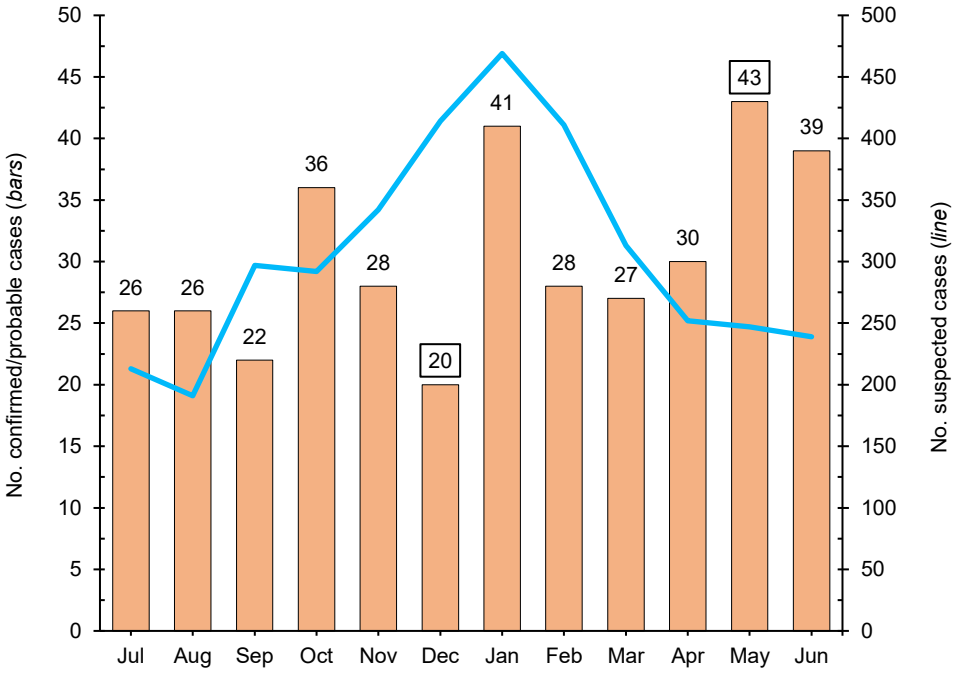
397 (July 2016–June 2017) and 576 (July 2011–June 2012) **(Figures 5a, 5b)**. Examination of cases by year and month showed that the greatest monthly count of confirmed/probable CO poisoning cases occurred in January 2015 (n=85). During the surveillance period, cumulative monthly counts of confirmed/probable cases increased from late summer through early fall, were highest in late fall and early winter, and were lowest in late spring and early summer **(Figure 6)**. Cumulative monthly counts of suspected cases peaked in January and February and were lowest in December and August.

From July 2009 through June 2019, confirmed CO poisoning cases were diagnosed in non-service member beneficiaries at more than 195 military installations and geographic locations worldwide. Nineteen installations accounted for more than one-quarter (26.4%) of the total confirmed CO poisoning cases among this population **(Table 10)**. The 5 locations with the greatest numbers of cases included Fort Carson, CO (n=180; 3.8%); NMC Portsmouth, VA (n=97; 2.1%); Fort Belvoir, VA (n=96; 2.0%); Joint Base San Antonio-Lackland, TX (n=90; 1.9%); and Walter Reed National Military Medical Center, MD/DC (n=82; 1.7%). Less than 1% (0.8%; n=36) of all confirmed cases affected non-service members located outside the U.S., and 6.5% (n=307) of cases were diagnosed in unknown locations. The known installations with the largest clusters of confirmed CO poisoning cases within the same calendar weeks included Navy Branch Health Clinic Earle, NJ (n=15; March 2009); and Fort Campbell, KY (n=15; April 2018) **(data not shown)**.

EDITORIAL COMMENT

Morbidity and mortality from CO poisoning are important public health problems, but their full impact is difficult to estimate. Studies of CO-related morbidity and mortality in the U.S. have generated varying estimates using a variety of databases and have relied on different (often study-specific)

FIGURE 4. Cumulative numbers of incident confirmed/probable and suspected CO poisoning cases, by month of diagnosis, reserve component, U.S. Armed Forces, July 2009–June 2019



CO, carbon monoxide; No., number.

TABLE 8. Confirmed CO poisoning cases, by location of diagnosis/report (with at least 5 cases during the period), reserve component, U.S. Armed Forces, July 2009–June 2019

Location of diagnosis	No.	%
Fort Belvoir, VA	16	4.4
MCB Camp Pendelton, CA	12	3.3
Wright-Patterson AFB, OH	7	1.9
Fort Bragg, NC	5	1.4
NMC Portsmouth, VA	5	1.4
Outside U.S.	2	0.6
"Unknown" locations	27	7.5
All other locations	287	79.5
Total	361	100.0

CO, carbon monoxide; No., number; MCB, Marine Corps Base; AFB, Air Force Base; NMC, Naval Medical Center.

TABLE 9. Non-service member beneficiary cases with confirmed/probable versus suspected CO poisoning, July 2009–June 2019

Characteristic	Confirmed/ probable[a]		Suspected		Total	
	No.	%	No.	%	No.	%
Total	4,754	16.7	23,640	83.3	28,394	100.0
Injury category[b]						
Unintentional	2,070	43.5	17,954	75.9	20,024	70.5
Assault	8	0.2	124	0.5	132	0.5
Intentional self-harm	215	4.5	241	1.0	456	1.6
Undetermined	2,461	51.8	5,321	22.5	7,782	27.4
Encounter setting						
Inpatient	474	10.0	1,478	6.3	1,952	6.9
Outpatient	4,280	90.0	22,162	93.7	26,442	93.1
Position of case-defining ICD-9/ICD-10 code						
First–second diagnostic position	4,188	88.1	14,173	60.0	18,361	64.7
Third–fourth diagnostic position	490	10.3	8,819	37.3	9,309	32.8
Fifth diagnostic position or higher	76	1.6	648	2.7	724	2.5

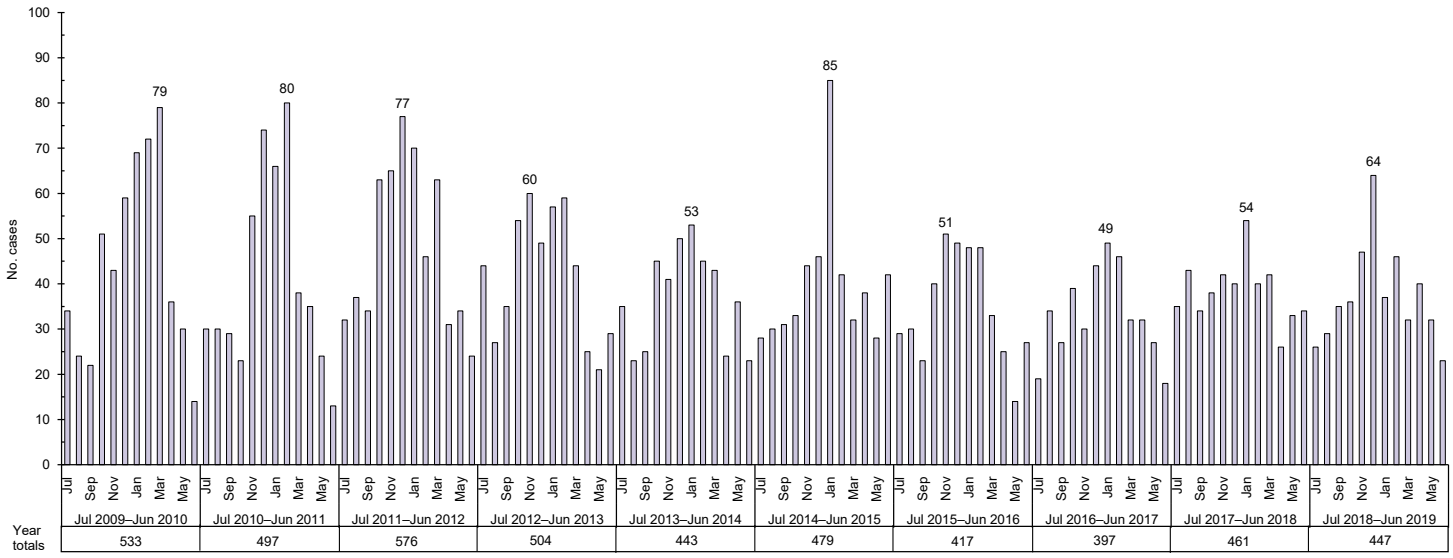
[a]40 incident CO poisoning cases were classified as probable.
[b]The most descriptive case-defining ICD-9 or ICD-10 code was used to categorize the case as unintentional, intentional self-harm, or undetermined.
CO, carbon monoxide; No., number; ICD, International Classification of Diseases.

methods for case ascertainment. The ability to accurately describe CO-related injury and death from administrative data depends on the type of data available and the methods used to identify and classify cases.

Previous *MSMR* reports on CO poisoning employed case definitions that required that the primary (first-listed) diagnosis be directly related to or likely caused by acute CO intoxication (e.g., headache, syncope). The most recent *MSMR* report on CO poisoning (July 1998–June 2008) applied an additional criterion for inclusion—only outpatient encounters associated with lost duty time were included as cases. The rationale for excluding ambulatory visits with dispositions of "released without limitations" was to restrict the analysis to clinically significant cases. During July 1998–June 2008, out of more than 1,000 medical encounters with "toxic effect of carbon monoxide" as a diagnosis (ICD-9 diagnosis code 986), there were 277 clinically significant cases of CO poisoning among active and reserve component service members.

The current analysis used the 2018 CSTE criteria[29] and ICD code-based data to group CO poisoning cases into confirmed, probable, and suspected categories based on degree of certainty that poisoning was CO related. Cases were also classified by intent based on ICD-9 E codes or specific ICD-10 codes pertaining to the nature of the CO poisoning

FIGURE 5a. Incident confirmed/probable CO poisoning cases, by month, non-service member beneficiaries, July 2009–June 2019

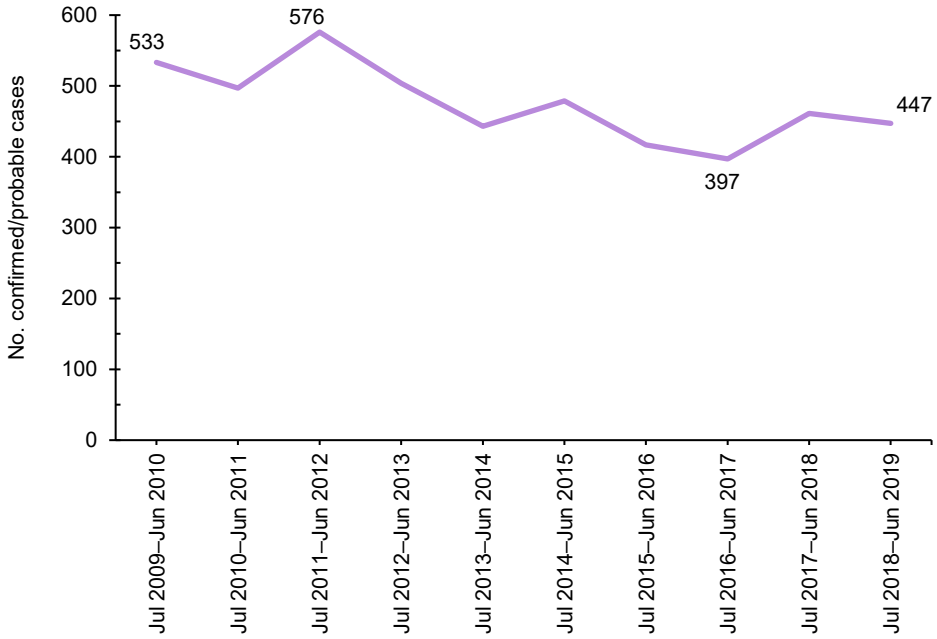


CO, carbon monoxide; No., number.

exposure. To date, very few of the studies that have employed this type of data for CO poisoning case finding included the more current ICD-10 coded data for comparison to ICD-9 code-based estimates.[30–32] Despite the limitations of using administrative ICD code-based data for surveillance purposes, there are several important advantages of this type of data; such data can be used at national and Armed Forces-wide levels with relatively few resources and their analysis may provide useful information on trends and risk factors that can be used in targeting intervention methods and assessing the impact of prevention on the cause-specific burden of CO-related poisonings.

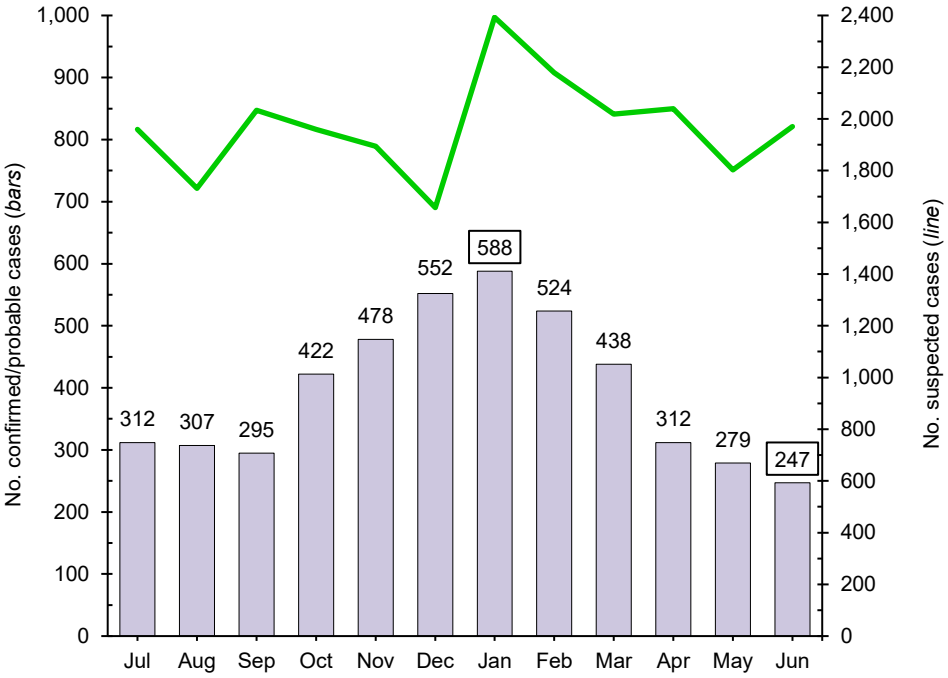
During the 10-year surveillance period of the current study, there were 1,288 CO poisoning cases classified as confirmed/probable among active component service members—an average of about 129 cases per year. There were approximately 37 confirmed/probable CO poisoning cases per year among reserve component members during this period. In both of these populations, pronounced differences were observed between confirmed/probable and suspected CO poisoning cases in terms of injury/intent. Compared to suspected cases, confirmed/probable cases were more often associated with intentional self-harm (10.6% vs 0.6%, active component; 7.1% vs 0.4%, reserve component) and undetermined causes of injury (41.8% vs 11.7%, active component; 43.7% vs 20.7%, reserve component), whereas suspected cases were more often coded as unintentional (87.4% vs 47.6%, active component; 78.8% vs 49.2%, reserve component). The same general pattern of differences between confirmed/probable and suspected cases was observed among non-service member beneficiaries. Furthermore, confirmed/probable active component and non-service member beneficiary cases were more likely than their respective suspected case counterparts to receive care in inpatient settings (10.6% vs 6.7%, active component; 10.0% vs 6.3%, non-service member beneficiaries). A recent study of CO poisoning using the 2018 CSTE case

FIGURE 5b. Incident confirmed/probable CO poisoning cases, by year, non-service member beneficiaries, July 2009–June 2019



CO, carbon monoxide; No., number.

FIGURE 6. Cumulative numbers of incident confirmed/probable and suspected CO poisoning cases by month of diagnosis, non-service member beneficiaries, July 2009–June 2019



CO, carbon monoxide; No., number.

definition among U.S. military veterans who received Veterans Health Administration care during 2010–2017 observed a similar pattern of results.[31] However, during the course of that study, a review of a subset of over 500 confirmed/probable cases with undetermined injury intent revealed that 53% represented unintentional cases; this finding led the authors to propose that the unintentional category of injury may have been underrepresented among the confirmed/probable CO poisoning cases in their study.

In the current study, suspected CO poisoning cases were more likely to be associated with lost duty time compared to their respective confirmed/probable counterparts (20.5% vs 11.5%, active component; 12.5 vs 3.6%, reserve component). It is important to note that there was no indication of disposition in the records of the medical encounters of 14.3% of active component cases and 45.0% of reserve component cases. Moreover, examination by case classification category revealed that a considerably greater proportion of confirmed/probable cases lacked information on disposition compared to suspected cases (41.1% vs 12.8%, active component; 77.0% vs 41.8%, reserve component).

The demographic characteristics of the active and reserve component service members classified as confirmed CO poisoning cases generally reflected the demographic composition of the U.S. Armed Forces overall during a comparable time period.[33,34] It is noteworthy that those working in repair/engineering occupations accounted for the greatest proportion of confirmed CO poisoning cases among active component members and the second greatest proportion among reserve component member cases. This finding warrants further analysis to examine the overall incidence rates of CO intoxication across occupations and highlights the importance of appropriate preventive measures for military personnel who repair or maintain vehicles.[22,35]

This report also documents that confirmed/probable cases among active component service members and non-service member beneficiaries exhibited the expected cold weather seasonal trends commonly associated with CO poisoning. This seasonal pattern generally corresponds to times of increased use of indoor heating. Suspected active component cases demonstrated a broadly similar trend. However, among reserve component members, suspected cases exhibited a trend that more closely followed the expected seasonal pattern of CO poisoning than did the confirmed/probable cases. Further investigation of the ICD-9 E codes and ICD-10 diagnosis codes associated with the relatively higher cumulative counts of confirmed/probable cases in May and June may provide insight into this pattern.

As the results of the current study show, CO poisoning-related injuries/diagnoses in the military often involve a single exposure that affects multiple personnel. For example, 21 soldiers showed CO poisoning symptoms

TABLE 10. Confirmed CO poisoning cases, by location of diagnosis/report (with at least 35 cases during the period), non-service member beneficiaries, U.S. Armed Forces, July 2009–June 2019

Location of diagnosis	No.	%
Fort Carson, CO	180	3.8
NMC Portsmouth, VA	97	2.1
Fort Belvoir, VA	96	2.0
JBSA-Lackland AFB, TX	90	1.9
Walter Reed, NMMC, MD[a]	82	1.7
Fort Bliss, TX	74	1.6
Fort Bragg, NC	68	1.4
Fort Hood, TX	68	1.4
JB Lewis-McChord, WA	60	1.3
NMC San Diego, CA	56	1.2
Fort Campbell, KY	54	1.1
JB Langley-Eustis, VA	47	1.0
Wright-Patterson AFB, OH	44	0.9
MCB Camp Pendleton, CA	39	0.8
West Point, NY	39	0.8
Fort Knox, KY	38	0.8
MCB Camp Lejeune/Cherry Point, NC	38	0.8
JB Elmendorf-Richardson, AK	37	0.8
Travis AFB, CA	36	0.8
Outside U.S.	36	0.8
Unknown locations	307	6.5
All other locations	3,128	66.4
Total	4,714	100.0

[a]Walter Reed NMMC is a consolidation of National Naval Medical Center (Bethesda, MD) and Walter Reed Army Medical Center (Washington, DC). This number represents the sum of the 2 sites before the consolidation (November 2011) and the number reported at the consolidated location.
CO, carbon monoxide; No., number; NMC, Naval Medical Center; JBSA, Joint Base San Antonio; AFB, Air Force Base; NMMC, National Military Medical Center; MCB, Marine Corps Base.

TABLE 11. General recommendations to prevent CO poisoning[a]

Install, operate, and maintain fuel-burning appliances in accordance with manufacturer's instructions and local building codes.
Have heating systems (including chimneys and vents) inspected and serviced by a trained/qualified technician every year.
Check chimneys and vents regularly for blockages, cracks, corrosion, and loose or improper connections.
Never leave the motor running in a vehicle parked in an enclosed or partially enclosed space (e.g., garage), even with doors open.
Never burn charcoal (for cooking, heating, etc.) inside a home, garage, vehicle, or tent.
Never use gas appliances such as ranges, ovens, or dryers for heating living spaces.
Never install or service fuel-burning appliances without proper knowledge, skills, and tools. Always refer to the owner's manual when performing minor adjustments to these appliances.
Never operate unvented fuel-burning appliances in a closed room/tent or in rooms/tents in which people are sleeping.
Never run a generator, pressure washer, or any gasoline-powered engine indoors, even if the doors or windows are open.
Open the fireplace damper before lighting a fire and keep it open until the ashes from the fire are cool. An open damper may help prevent the buildup of poisonous gases, including CO, inside the home.
Always operate portable generators outdoors and away from open doors, windows, or vents that could allow CO indoors.
Install CO detectors/alarms that meet the requirements of the most recent UL, IAS, or CSA standards. Test CO detectors/alarms regularly and replace dead batteries. A CO detector/alarm can provide added protection but is no substitute for proper installation, use, and maintenance of appliances that can produce CO.
If you think that you may be experiencing symptoms of CO poisoning, such as headache, fatigue, shortness of breath, nausea, or dizziness, get fresh air immediately and call for assistance from another location. Seek medical attention immediately and inform medical professionals that CO poisoning is suspected.

[a]Sources: U.S. Consumer Product Safety Commission's Carbon Monoxide Safety Tips[39] and the Center for Disease Control and Prevention's CO Poisoning Prevention Tips.[40]
CO, carbon monoxide; UL, Underwriters Laboratory; IAS, International Approval Services; CSA, Canadian Standards Association.

during a multiday exercise at the Yukon Training Area near Eielson AFB in late September 2014. Among the symptomatic soldiers, 4 were admitted to Bassett Army Community Hospital and 7 were released after examination.[36] Clusters of CO exposures among nonservice member beneficiaries have also been reported. For example, in late August 2019, 2 service members and 3 family members from 3 different residences presented to the Womack Army Medical Center emergency department with symptoms associated with CO exposure.[37] Results of laboratory testing showed that all 5 individuals had been exposed to CO.[37] It was later determined that the residents of more than 80 homes within Fort Bragg housing were found to be at risk for CO exposure.[38] Examination of the heating, ventilation, and air conditioner units in the laundry rooms of these homes revealed that vents were partially blocked and that closing the laundry room doors while doing laundry allowed CO concentrations in those rooms to reach dangerous levels.[38] The most recent general recommendations from the CDC and the U.S. Consumer Product Safety Commission for preventing CO poisoning are presented in **Table 11**.[39,40]

Results of the current study should be interpreted in the context of several important limitations. Several factors may have resulted in the underestimation of the actual numbers of CO poisoning cases among the study populations. First, as incident CO poisoning cases were identified based on the presence of qualifying ICD-9 or ICD-10 codes recorded during a healthcare encounter, the validity of the results depends upon the accuracy of the physician-assigned coding generated by a given encounter. Because the clinical effects of mild to moderate CO poisoning are diverse and largely nonspecific, clinicians may not have considered CO poisoning when patients presented for care. In addition, cases among National Guard and Reserve members that were diagnosed in their civilian communities outside of the MHS were not included in the analysis. Furthermore, the high degree of ICD-9 986 diagnosis codes lacking qualifying ICD-9 E codes precluded the classification of a sizable proportion of cases in terms of intent and CO source and hampered the ability to make prevention recommendations based on the causes of injury. External cause code reporting is not mandatory; however, the "ICD-10-CM Official Guidelines for Coding and Reporting" encourage medical professionals to code external causes "as they provide valuable data for injury research and evaluation of injury prevention strategies."[41] Finally, for 2017, 2018, and 2019, medical data from sites that were using MHS GENESIS, the new electronic health record for the MHS, are not available in the DMSS. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounter data for individuals seeking care at any of these facilities during 2017–2019 were not included in the current analysis.

Other circumstances may tend to result in overestimation of the number of incident cases of CO poisoning. For example, diagnoses of CO poisoning recorded in electronic health records may represent misdiagnoses or tentative (rule-out) diagnoses that are not confirmed. While the current study attempted

to limit the inclusion of follow-up cases from earlier episodes of CO poisoning, the analysis may have included some cases that did not represent incident diagnoses of CO poisoning. Conversely, limiting cases to diagnoses coded as initial encounters may have eliminated cases that represented true second exposures (e.g., repeat suicide attempts or unintentional in-home exposures where the original CO source was not addressed).

Standardization of ICD-coded case-ascertainment criteria for estimating CO-related morbidity and mortality is necessary to describe the public health burden of CO poisoning (including the various mechanisms and intent of injury), to target prevention efforts, and to evaluate the impact of interventions. However, the results of the current study highlight the need for improvements in ICD coding to reduce the percentage of cases coded with unknown injury intent and/or unknown CO poisoning source.

In summary, service members, unit leaders, and supervisors at all levels should be aware of and responsive to the dangers of CO poisoning and CO hazards related to residential, recreational, occupational, and military operational circumstances, equipment, and activities. Moreover, service members, unit leaders, and supervisors at all levels should be familiar with and employ appropriate preventive measures. Finally, primary medical care providers (including unit medics and emergency medical technicians) should be knowledgeable of and sensitive to the early clinical manifestations of CO intoxication.

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Respiratory Pathogen Surveillance Trends and Influenza Vaccine Effectiveness Estimates for the 2018–2019 Season Among Department of Defense Beneficiaries

Geeta D. Kersellius, MPH, MBS; William E. Gruner, MS, MB; Anthony C. Fries, PhD; Laurie S. DeMarcus, MPH; Anthony S. Robbins, MD, MPH, PhD (Lt Col, USAF)

This report primarily focuses on the data collected and analyzed from the worldwide network of sentinel military treatment facilities chosen to participate in the Department of Defense Global Respiratory Pathogen Surveillance (DoDGRS) program. Sites that participated in the 2018–2019 DoDGRS program submitted 24,320 respiratory specimens for diagnostic testing. Clinical results showed a total of 5,968 positive influenza cases. In the beginning of the season, starting in surveillance week 48, influenza A(H1N1)pdm09 was the predominant subtype. The predominant subtype switched to influenza A(H3N2) beginning in week 6 and continued through the end of the season. Influenza B virus detection was less common during the surveillance period (i.e., 1% of total submitted specimens and 5% of total influenza detected). In addition to routine surveillance, the DoDGRS program also conducts vaccine effectiveness (VE) studies twice per year to determine interim and end of season estimates. Overall, the adjusted end of season VE for all dependents regardless of influenza type was 30% (95% CI: 22%–38%).

WHAT ARE THE NEW FINDINGS?

DoDGRS program data showed that influenza A(H1N1)pdm09 was the dominant A subtype from October 2018 through February 2019. Influenza A(H3N2) was the predominant subtype from February through May 2019, extending this season further into the spring than prior seasons. The influenza vaccine reduced the odds of medically attended, laboratory-confirmed influenza of all types examined by 30% among all dependents.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

The tendency for prevalent influenza viruses to be rapidly succeeded by viruses with different antigenic characteristics highlights the need for researchers to continually assess VE to help reduce influenza burden and improve military influenza vaccination policies. Future research on influenza VE in the active duty population to assess the effects of waning immunity and the impact of repeated vaccinations would inform better influenza vaccination policy.

In 1976, the U.S. Air Force initiated a global influenza surveillance network called "Project Gargle."[1] In 1997, a Presidential Decision Directive, National Science and Technology Council 7 (NSTC-7) created the Department of Defense's (DoD's) Global Emerging Infections Surveillance and Response System (GEIS) and formally expanded Project Gargle's mission to become a tri-service program.[1,2] Since then, GEIS has provided central coordination and financial support for Project Gargle, which was renamed the DoD Global Respiratory Pathogen Surveillance (DoDGRS) program in 2017. DoDGRS is managed by the U.S. Air Force School of Aerospace Medicine's (USAFSAM's) epidemiology laboratory and the Defense Health Agency's (DHA's) Air Force Satellite at Wright-Patterson Air Force Base in Dayton, OH.

The DoDGRS program consists of a network of sentinel and partner laboratories worldwide that monitor respiratory pathogen activity among military members and their beneficiaries. The operational goals of the program are to identify outbreaks, determine the incidence of influenza-like illness (ILI), characterize circulating influenza viruses, and evaluate influenza vaccine effectiveness (VE). Results from these efforts are shared with the Food and Drug Administration (FDA), the Centers for Disease Control and Prevention (CDC), and the World Health Organization (WHO) to facilitate the selection of hemispheric vaccine components. The purpose of this report is to provide an overview of the DoDGRS program and to summarize influenza activity during the 2018–2019 influenza season.

METHODS

Data collection

Each year, military treatment facilities are selected using criteria relating to geographical location to participate in the DoDGRS program.[2] These sites submit 6 to 10 respiratory specimens per week from patients meeting the ILI case definition: 1) presentation within 72 hours after illness onset with a fever (i.e., ≥ 100.5°F) and cough or sore throat or 2) physician-diagnosed ILI. Patients' clinical histories, vaccination statuses, and demographic data are recorded by the healthcare provider or self-reported using a questionnaire. Vaccination status is obtained from the Air Force Complete Immunization Tracking Application (AFCITA) or self-reported on the DoDGRS questionnaire. Three laboratories process the specimens: Landstuhl Regional Medical Center (LRMC) for all European Command (EUCOM) sites, Brooke Army Medical Center (BAMC) for the San Antonio region, and USAFSAM for all other locations.

Laboratory testing

The gold standard and preferred method for specimen collection is the nasal wash method because of the amount of sample (i.e., 3 mL) that can be obtained.[1,3] However, the USAFSAM epidemiology laboratory is validated to accept either nasal wash specimens or nasopharyngeal swabs for diagnostic testing and patient management. USAFSAM and LRMC specimens were tested via multiplex reverse transcriptase polymerase chain reaction (RT-PCR) and viral culture (USAFSAM only) to identify the presence of influenza and other respiratory pathogens. For BAMC specimens, the cobas® Liat® influenza A/B assay and/or BioFire® FilmArray® testing were utilized. Viruses from a subset of the laboratory-confirmed influenza cases were sequenced utilizing a whole genome amplification approach on the Illumina MiSeq platform and analyzed using the iterative refinement meta-assembler (IRMA) software.[4–6]

Statistical analysis for VE estimation

A test-negative case-control study design was used to calculate end of season VE for DoD dependents. A subset of the total cases and controls was chosen based on a period of peak influenza activity (> 10% influenza positivity rate) between 16 December 2018 and 27 April 2019 (weeks 51–17). The analysis was restricted to this time frame to minimize bias that might occur with an overrepresentation of controls that are typically seen earlier or later in the influenza season. Individuals were classified as vaccinated if at least 1 immunization occurred at least 14 days before specimen collection. If an individual's vaccination status could not be determined, their record was not included in the analysis.

Cases were defined as individuals whose specimens were laboratory-confirmed influenza positives, and controls were persons with negative influenza test results. The influenza VE point estimates were derived from an odds ratio (OR) that compared the odds of influenza vaccination among the cases versus the controls. Crude and adjusted VE estimates were calculated as [1 - OR] x 100% along with their 95% confidence intervals (CIs) using multivariable logistic regression. The regression models were adjusted for potential confounding factors such as age group, sex, time of specimen collection, and geographical region. VE estimates with an associated 95% CI that excluded zero were considered statistically significant. The VE analyses were stratified by influenza subtype (i.e., influenza A, A(H1N1)pdm09, A(H3N2), B) and demographic population (i.e., all dependents, children, adults, elderly). Since service members are typically highly vaccinated (i.e., > 90%), they were excluded from the analyses. Severe cases were also excluded from the VE analysis because of a smaller sample size for this subgroup. While the elderly population was included in the VE analysis, this subgroup also had a smaller sample size leading to statistically insignificant results, which were not reported. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

Viral surveillance

During the 2018–2019 season, the DoDGRS program received a total of 24,320 specimens from 111 locations. The demographic profile of the persons who provided specimens can be found in **Table 1**. Most of the specimens came from children (i.e., non-service member beneficiaries < 18 years; n=8,387), followed by service members (n=7,797), adults (i.e., spouses of service members and retirees 18–64 years; n=4,885), and the elderly (i.e., non-service member beneficiaries 65+ years; n=2,190), with 1,061 specimens from beneficiaries with an unknown age category. **Table 2** shows the distribution of respiratory pathogens identified during the season. Among the submitted specimens, 5,968 tested positive for influenza (including influenza coinfections). Of these influenza positives, 1,497 were influenza A (not subtyped), 1,529 were influenza A(H1N1)pdm09, and 2,369 were influenza A(H3N2). There was low influenza B activity during this period (n=170); detected lineages included B/Victoria (n=88) and B/Yamagata (n=21).

Figure 1 shows influenza activity trends and the corresponding positivity rates. Additionally, the multiplex assay for USAFSAM and LRMC identified 4,404 specimens that were positive for a single noninfluenza respiratory pathogen, 545 noninfluenza coinfections, and 294 influenza coinfections. The noninfluenza pathogens detected were rhinovirus/enterovirus (n=1,750), coronavirus (n=821), respiratory syncytial virus (RSV) (n=613), parainfluenza (n=464), adenovirus (n=320), human metapneumovirus (n=295), *Mycoplasma pneumoniae* (n=63), *Chlamydophila pneumoniae* (n=43), and human bocavirus (n=35) **(Table 2)**.

Genetic sequencing

From 30 September 2018 through 13 August 2019, a total of 2,711 influenza virus RNA gene sequences were either generated at USAFSAM or contributed by partner laboratories at the Armed Forces Research Institute of Medical Sciences (AFRIMS), Naval Medical Research Unit No. 2 (NAMRU-2), or the Naval Health Research Center (NHRC). In total, 1,187 (43.8%) influenza A(H1N1)pdm09, 1,304 (48.1%) influenza A(H3N2), 179 (6.6%) influenza B/Victoria lineage, and 41 (1.5%) influenza B/Yamagata lineage hemagglutinin (HA) sequences were characterized **(data not shown)**.

All 1,187 of the influenza A(H1N1) pdm09 HA sequences were in clade 6B.1A, a subclade that is well inhibited by the 2018–2019 influenza A(H1N1)pdm09 vaccine component, A/Michigan/45/2015-like virus (clade 6B.1) **(data not shown)**.

The 1,304 influenza A(H3N2) HA sequences belonged to clades 3C.3a (69.9%), 3C.2a1b (27.2%), 3C.2a2 (2.2%), 3C.2a3 (0.5%), or 3C.2a (0.2%) with no further subclade designation. An early season predominance of the 3C.2a1b clade was replaced by the 3C.3a clade through the remainder of the season **(Figure 2)**. The 2018–2019 influenza A(H3N2) vaccine component, A/Singapore/INFIMH-16-0019/2016-like virus resided in the 3C.2a1 clade, which has shown a lack of protection against 3C.3a clade viruses.[7]

The 179 influenza B/Victoria HA sequences belonged to clade V1A.1 (24.0%) containing a 2-amino-acid deletion at positions 162–163, V1A-3Del (67.6%) containing a 3-amino-acid deletion at positions

TABLE 1. Demographic data for sources of specimens and results of routine testing, DoD beneficiaries, 2018–2019 influenza season

	Influenza A	Influenza B	Other respiratory pathogen	No pathogen detected	Total
Total	5,681	287	5,368	12,984	24,320
Sex					
Male	1,915	65	2,861	2,746	7,587
Female	1,418	34	2,266	2,239	5,957
Unknown	2,348	188	241	7,999	10,776
Age group (years)					
Active duty	1,638	75	1,959	4,125	7,797
0–5	789	41	1,858	2,181	4,869
6–9	674	26	306	664	1,670
10–17	642	38	285	883	1,848
18–24	115	8	94	472	689
25–44	384	24	268	1,193	1,869
45–64	429	25	246	1,627	2,327
65+	210	13	189	1,778	2,190
Unknown	800	37	163	61	1,061
Command					
NORTHCOM	4,350	232	3,761	11,497	19,840
EUCOM	800	5	1,013	986	2,804
INDOPACOM	422	44	495	430	1,391
CENTCOM	109	6	99	71	285
Data source					
USAFSAM	3,754	134	4,539	4,240	12,667
BAMC	1,501	150	7	7,887	9,545
LRMC	426	3	822	857	2,108

DoD, Department of Defense; NORTHCOM, Northern Command; EUCOM, European Command; INDOPACOM, Indo-Pacific Command; CENTCOM, Central Command; USAFSAM, U.S. Air Force School of Aerospace Medicine; BAMC, Brooke Army Medical Center; LRMC, Landstuhl Regional Medical Center.

TABLE 2. Distribution of respiratory pathogens, DoD beneficiaries, 2018–2019 influenza season

Pathogen type	No. cases	%
Influenza		
A(H1N1)pdm09	1,529	6.3
A(H3N2)	2,369	9.7
A (not subtyped)	1,497	6.2
B	170	0.7
B/Victoria	88	0.4
B/Yamagata	21	0.1
Influenza coinfections[a]	294	1.2
Not influenza		
Adenovirus	320	1.3
Coronavirus	821	3.4
Human bocavirus	35	0.1
Human metapneumovirus	295	1.2
Parainfluenza	464	1.9
RSV	613	2.5
Rhinovirus/enterovirus	1,750	7.2
Chlamydophila pneumoniae	43	0.2
Mycoplasma pneumoniae	63	0.3
Noninfluenza coinfections[b]	545	2.2
Other outcomes		
No pathogen detected	12,984	53.4
Test failed	80	0.3
Test results inconclusive	2	0.0
Test not performed	337	1.4
Total	24,320	100.0

[a]Influenza coinfections include infection with an influenza virus and a noninfluenza respiratory pathogen.
[b]Noninfluenza coinfections include infection with more than 1 noninfluenza respiratory pathogen.
DoD, Department of Defense; No., number; RSV, respiratory syncytial virus.

162–164, or V1A (8.4%). Following the 2017–2018 season, there was an increase in the proportion of the V1A-3Del clade viruses **(Figure 3)**. The 2018–2019 influenza B/Victoria vaccine component (B/Colorado/06/2017-like virus) was a V1A.1 clade, which has shown limited protection against both the V1A and V1A-3Del clade viruses.[7]

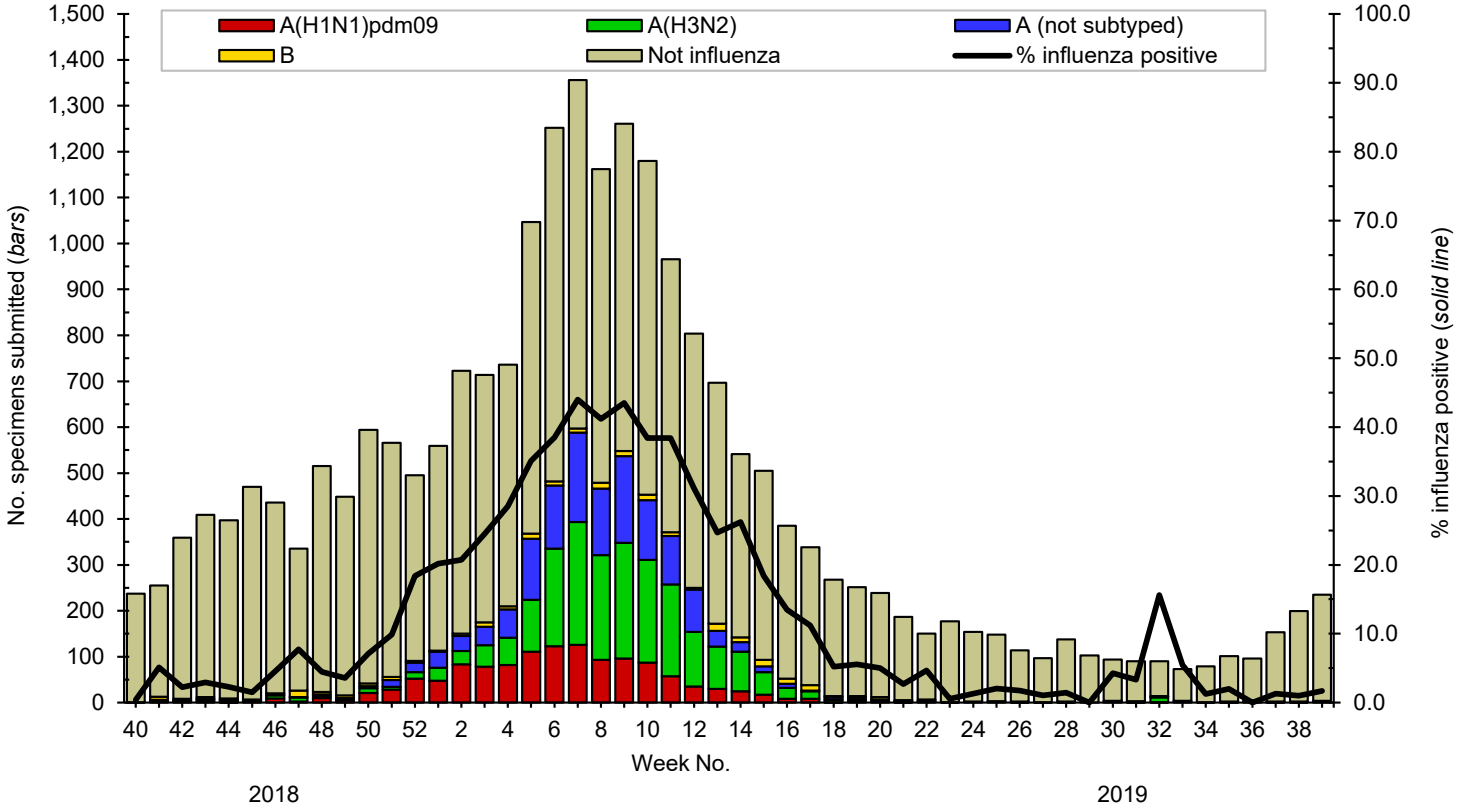
All 41 of the influenza B/Yamagata HA sequences were in clade Y3. This clade has changed little in the last several seasons and is the clade represented in the 2018–2019 influenza B/Yamagata vaccine component, B/Phuket/3073/2013-like virus, which is included in the quadrivalent vaccine only.

VE

During this surveillance period, there were 2,216 cases and 3,702 controls. When comparing the proportions of cases to controls, statistically significant differences were observed for the following demographic characteristics: sex, age, month of illness, vaccination status, and influenza type **(Table 3)**. The cases and controls did not differ significantly by geographical region. The vaccination rate was approximately 58% among the cases and 68% among the controls.

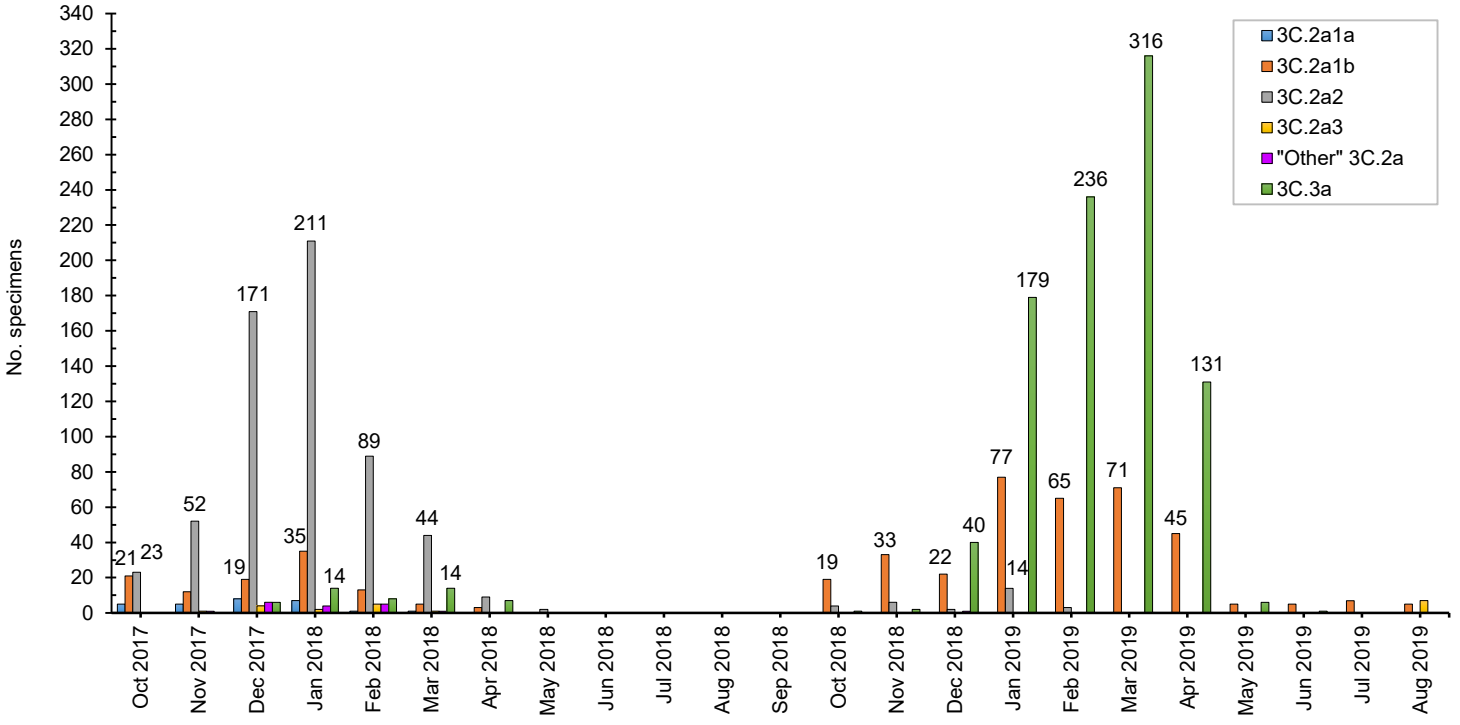
A summary of the VE estimates stratified by subtype is displayed in **Figure 4**. Overall, the adjusted VE for all influenza types and dependents was 30% (95% CI: 22%–38%). The adjusted VE for children

FIGURE 1. Number of specimens submitted and percent of influenza positive by week, DoD beneficiaries, 2018–2019 influenza season



DoD, Department of Defense; No., number.

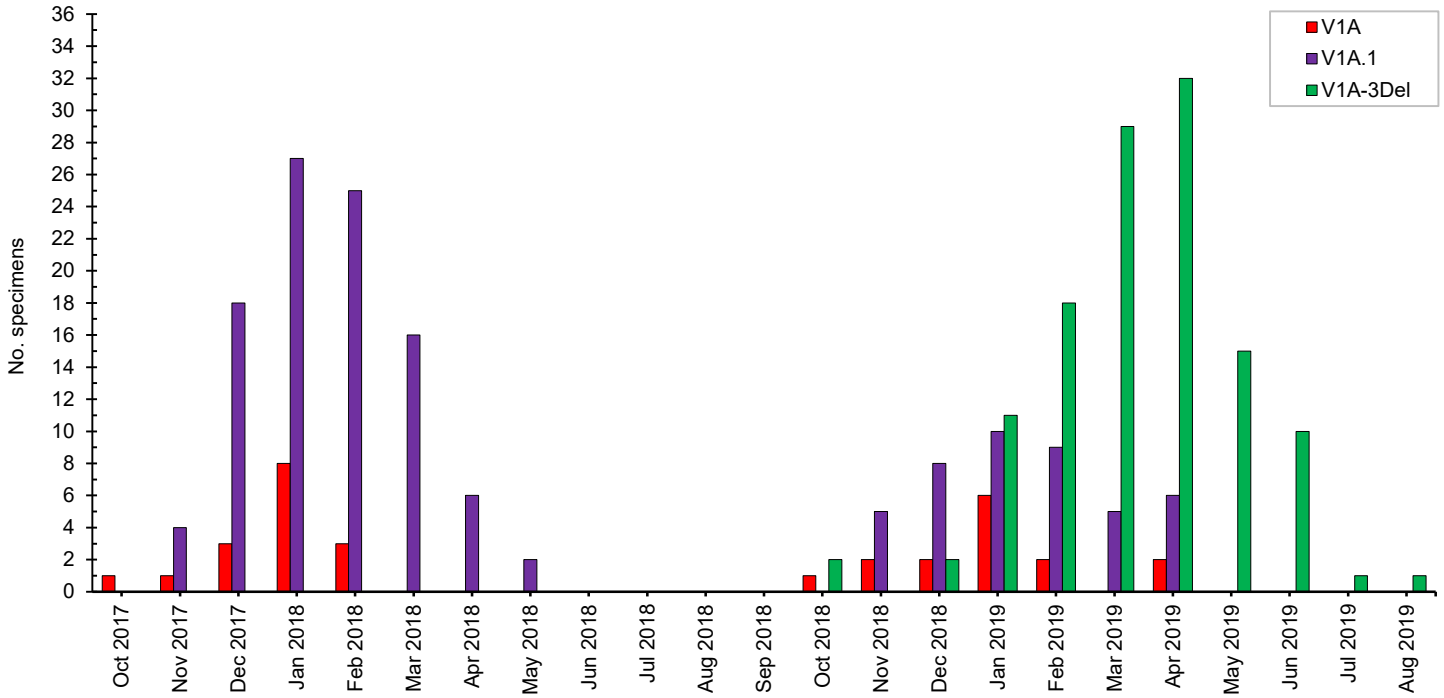
FIGURE 2. Influenza A(H3N2) clade dynamics over 2 seasons, DoD beneficiaries, October 2017–August 2019



Note: The clade category "Other" 3C.2a includes clades 3C.2a and 3C.2a1 with no further subclade designations because of low respective numbers. The 2017–2018 A(H3N2) vaccine strain, A/Hong Kong/4801/2014-like virus was a clade 3C.2a virus. The 2018–2019 A(H3N2) vaccine strain, A/Singapore/INFIMH-16-0019/2016-like virus was a clade 3C.2a1 virus.

DoD, Department of Defense; No., number.

FIGURE 3. Influenza B/Victoria clade dynamics over 2 seasons, DoD beneficiaries, October 2017–August 2019



Note: The 2017–2018 B/Victoria vaccine strain, B/Brisbane/60/2008-like virus was a clade V1A virus. The 2018–2019 B/Victoria vaccine strain, B/Colorado/06/2017-like virus was a clade V1A.1 virus.

DoD, Department of Defense; No., number.

(aged 2–17 years) against all influenza types was 27% (95% CI: 15%–38%). The adjusted VE against all influenza types for adults (aged ≥ 18 years) was 36% (95% CI: 23%–46%). The dependents VE was 29% (95% CI: 20%–37%) for influenza A(not subtyped), 54% (95% CI: 45%–62%) for influenza A(H1N1)pdm09, 25% (95% CI: 13%–36%) for influenza A(H3N2), and 51% (95% CI: 19%–71%) for influenza B. The highest VEs among children were for influenza A(H1N1)pdm09 (VE = 62%; 95% CI: 51%–70%) and for influenza B (VE = 56%; 95% CI: 17%–76%). The highest VEs among adults were for influenza A(H3N2) (VE = 41%; 95% CI: 23%–55%) and for influenza A(H1N1)pdm09 (VE = 39%; 95% CI: 19%–54%).

EDITORIAL COMMENT

Although the 2018–2019 influenza season was relatively moderate, it was still one of the longest seasons in nearly 10 years, lasting approximately 21 weeks.[7] Data collected from the active surveillance effort conducted by the DoDGRS program showed 2 overlapping waves of influenza A activity throughout this season. In particular, influenza A(H1N1)pdm09 was the dominant subtype from October 2018 through February 2019, with the period of greatest activity occurring in week 4. The second wave was due to the emergence of influenza A(H3N2) as the predominant subtype from February through May 2019, extending this season further into the spring than prior seasons and peaking during weeks 7–11.

Based on the genetic characterization of the influenza A(H3N2) virus, multiple clades (i.e., 3C.3a, 3C.2a1b, 3C.2a2, 3C.2a3, 3C.2a) were cocirculating this season. This finding was consistent with the WHO's determination of an increasing prevalence of different influenza A(H3N2) virus groups in some countries in the Northern Hemisphere, which led to a lower than typical VE for the influenza A(H3N2) strain.[8] As a result, experts from the WHO influenza advisory group recommended postponing the selection of the influenza A(H3N2) vaccine component for the 2019–2020 influenza vaccine.[8] This decision allotted time to monitor the degree of antigenic drift for the circulating influenza A(H3N2) strains and update the candidate viruses that would be included in the 2019–2020 season's vaccine to yield a more optimal VE.[8]

Because of the retrospective nature of the VE analysis, there are some limitations that are inherent in the design of this observational study. Although a typical feature of influenza includes fever, some influenza cases are afebrile. This required criterion in the ILI case definition might decrease the amount of cases that can be captured and therefore reduce the precision of the influenza estimates. To address this concern, a sensitivity analysis was done for the ILI case definition, and no significant differences were found **(data not shown)**.

Since the questionnaires contain

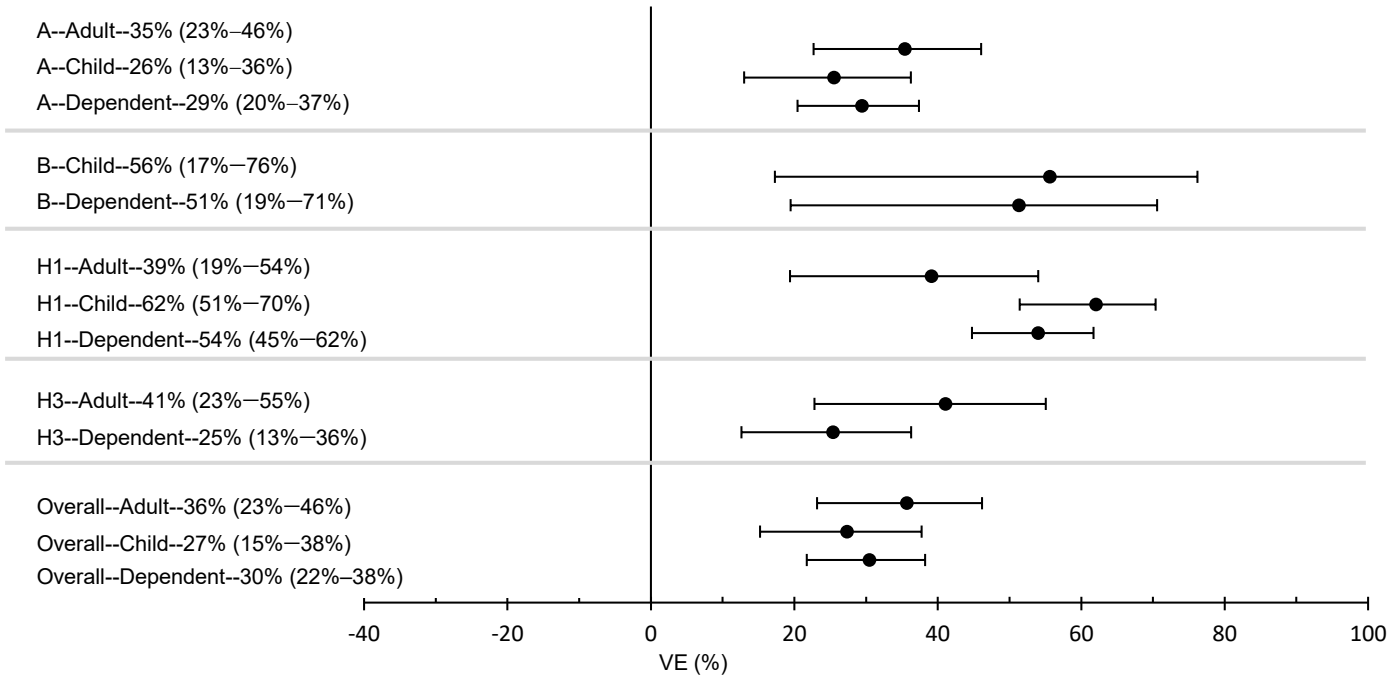
TABLE 3. Demographic characteristics of the laboratory-confirmed influenza positive cases and test-negative controls used in VE analysis, 2018–2019 influenza season

Demographic	Cases (n=2,216)		Controls (n=3,702)		p-value
	No.	%	No.	%	
Total	2,216	--	3,702	--	--
Sex					
Male	1,035	46.7	1,561	42.2	<.001
Female	1,181	53.3	2,141	57.8	
Age group (years)					
2–8	873	39.4	1,075	29.0	<.0001
9–17	548	24.7	562	15.2	
18–49	427	19.3	914	24.7	
50–64	237	10.7	546	14.7	
65+	131	5.9	605	16.3	
Month of illness					
December	72	3.3	422	11.4	<.0001
January	425	19.2	949	25.6	
February	980	44.2	1,076	29.1	
March	599	27.0	870	23.5	
April	140	6.3	385	10.4	
Geographic region					
Eastern U.S.	661	29.8	1,091	29.5	.186
Western U.S.	1,153	52.0	2,001	54.1	
Other	402	18.1	610	16.5	
Vaccination status					
Vaccinated	1,292	58.3	2,511	67.8	<.0001
Unvaccinated	924	41.7	1,191	32.2	
Influenza status					
A(H1N1)pdm09	585	26.4	0	0.0	<.0001
A(H3N2)	976	44.0	0	0.0	
A (not subtyped)	589	26.6	0	0.0	
B	66	3.0	0	0.0	
Not influenza	0	0.0	3,702	100.0	

VE, vaccine effectiveness; No., number.

self-reported data, results of the analysis may be incomplete or inaccurate, overestimating or underestimating the associations of interest. This potential recall bias was addressed by eliminating unknown vaccination status from the analysis and preventing nondifferential misclassification of the exposure. Additionally, electronic vaccination records with more accurate information were used to minimize this bias. Because case-control studies are also prone to selection bias, the cases and controls were selected from the same sentinel site data repository using similar inclusion criteria. Potential confounders were adjusted for in the regression models (i.e., covariates such as age, sex, geographical region, time of specimen collection) to increase the external validity of the study's findings. Influenza outcomes were defined by a sensitive diagnostic test (i.e., RT-PCR) ensuring a precise confirmation of influenza positives, reducing outcome misclassification and any possible negative impact on the VE estimate.[1] It is important to note, however, that influenza VE estimates may be affected by repeat vaccinations, timing of vaccine uptake, or a patient's immune response. Selection of the start and end dates of the period

FIGURE 4. End of season (2018–2019) adjusted VE estimates, by influenza subtype, DoD beneficiaries, 2018–2019 influenza season



VE, vaccine effectiveness; DoD, Department of Defense; CI, confidence interval; A, influenza A; B, influenza B; H1, influenza A(H1N1)pdm09; H3, influenza A(H3N2).

of peak influenza activity may also have affected the VE estimates.

Results of the end of season VE analysis showed that the influenza vaccine reduced the odds of medically attended, laboratory-confirmed influenza by 30% among all dependents, offering moderate protection this season. Nonetheless, the ability of the influenza virus to rapidly change highlights the necessity for public health preparedness in the wake of emerging and reemerging infectious respiratory diseases. Thus, researchers still need to be at the forefront of VE assessments to continually reduce influenza burden and improve military influenza vaccination policies. Additionally, avenues for future research should concentrate on accurately estimating VE in the active duty population as well as evaluating the effects of waning immunity and the impact of repeated vaccinations. More research in these areas would provide important insights and contribute to better influenza vaccination policy decisions.

Author affiliations: Defense Health Agency/ Armed Forces Health Surveillance Branch Air Force Satellite–U.S. Air Force School of Aerospace Medicine, Wright-Patterson Air Force Base, OH (Ms. Kersellius, Ms. DeMarcus, Lt Col Robbins); STS Systems Integration, LLC, San Antonio, TX (Ms. Kersellius, Ms. DeMarcus, Mr. Gruner, Dr. Fries); U.S. Air Force School of Aerospace Medicine epidemiology laboratory, Wright-Patterson Air Force Base, OH (Mr. Gruner, Dr. Fries).

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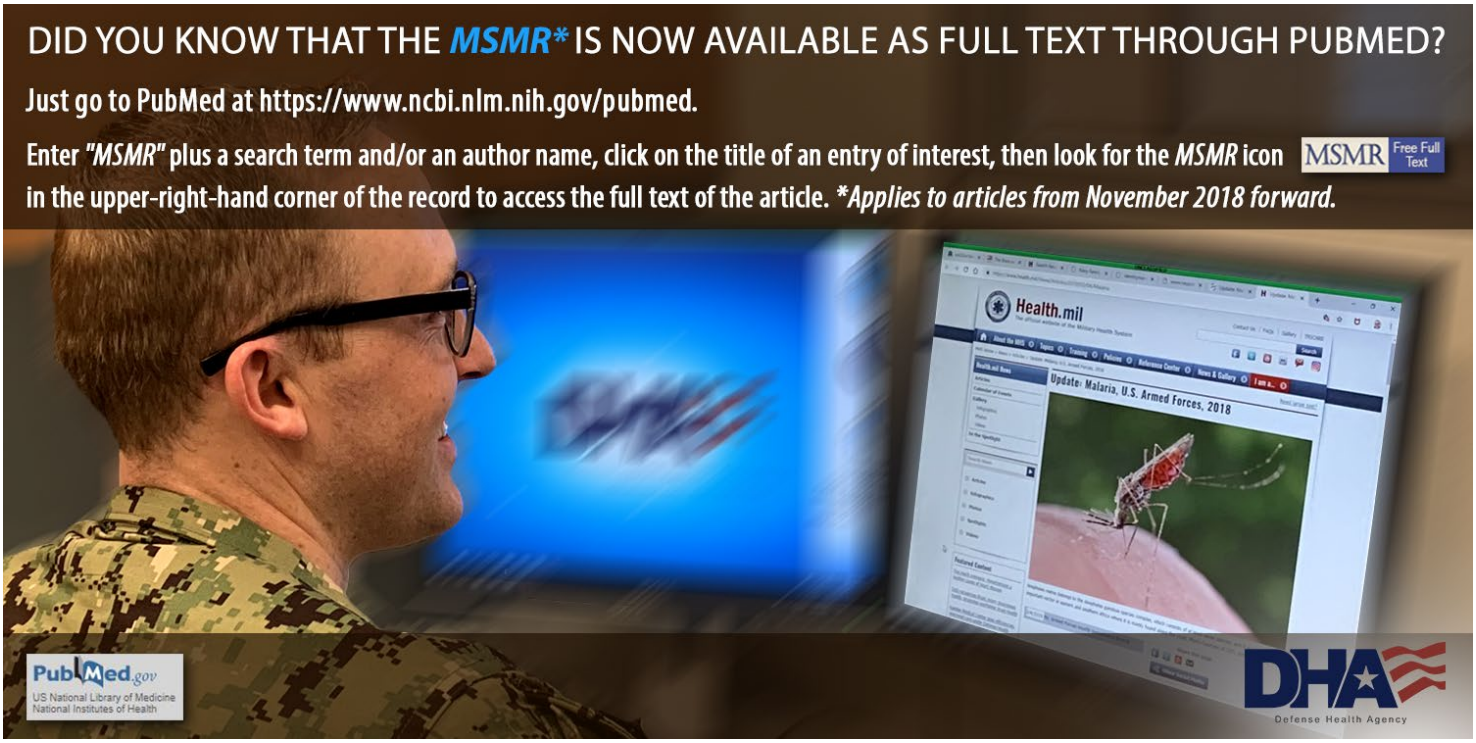


Brief Report

Incidence and Prevalence of Idiopathic Corneal Ectasias, Active Component, 2001–2018

Mark E. Reynolds, MD, MPH (COL, USA); Andrew S. Morgenstern, OD; Rita K. Mallia, OD, MPA; Saixia Ying, PhD; Shauna Stahlman, PhD, MPH

Corneal ectasias are a category of eye diseases characterized by progressive steepening and thinning of the collagen-based corneal stroma.[1] Individually, these conditions are part of their own unique primary disease process or can occur as result of refractive surgery. Conditions characterized as corneal ectasias include keratoconus, pellucid marginal degeneration (PMD), keratoglobus, and post-refractive surgical ectasia. These disorders can be differentiated based on the pattern and location of corneal thinning, age of onset, and surgical history. Keratoconus, the most common corneal ectasia, usually presents around puberty, progresses until approximately 40 years of age, and is characterized by inferior thinning and protrusion of the cornea at its thinnest point.[2] PMD is a rare disorder more common among males. It typically presents between 20–40 years of age and is characterized by inferior corneal thinning.[3] Keratoglobus is most often congenital, although it may be acquired secondary to systemic conditions and consists of generalized thinning of the entire cornea and globular protrusion.[4] Post-refractive corneal ectasia is corneal thinning with a clinical appearance similar to keratoconus; however, it is secondary to prior laser-assisted in situ keratomileusis (LASIK), photorefractive keratectomy (PRK), or small incision lenticule extraction (SMILE).

Corneal ectasias cause progressive and often unpredictable decreases in best-corrected vision. Early in the course of the disease, this effect on vision may be adequately corrected with eyeglasses. As the disease progresses, medical contact lenses (to address the abnormal curvature of the cornea) are often required or corneal cross-linking can be used to slow or halt the progression of keratoconus. When these methods are no longer effective, surgical procedures such as intracorneal ring segment implantation or full or partial thickness corneal transplantation are required to maintain visual function.[5]

The current report summarizes the frequencies, rates, and temporal trends of idiopathic corneal ectasias among active component service members during 2001–2018.

METHODS

The surveillance period was 1 January 2001 to 31 December 2018. The surveillance population included all individuals who served in the active component of the U.S. Army, Navy, Air Force, or Marine Corps at any time during the surveillance period. Diagnoses of corneal ectasias were ascertained from records maintained in the Defense Medical Surveillance System (DMSS) that document outpatient encounters of active component service members. Such records reflect care in fixed military treatment facilities of the Military Health System (MHS) and in civilian sources of health care underwritten by the Department of Defense.

Case-defining diagnoses of corneal ectasias are shown in **Table 1**. For surveillance purposes, an incident case was defined by at least 1 outpatient medical encounter with a qualifying diagnosis in any diagnostic position. The incidence date was the date of the first qualifying outpatient encounter, and an individual was counted as an incident case only once per lifetime. For the incidence rate calculations, person-time at risk included all active component military service time before the date of incident diagnosis, termination of military service, or the end of the surveillance period, whichever came first. Because some corneal ectasias may have resulted from refractive surgical procedures, incident cases of corneal ectasias with any prior outpatient encounter that included a Current Procedural Terminology (CPT) code for refractive surgery (CPT: S0800 or S0810) in any CPT position were excluded from the analysis and person-time was censored at the time of the first-occurring refractive surgery procedure. Incidence rates were calculated as incident idiopathic corneal ectasia diagnoses per 100,000 person-years (p-yrs). Prevalent cases (i.e., service members with case-defining diagnoses occurring before the start of the surveillance period) also were excluded from the analysis of incidence.

Lifetime prevalence of each type of disorder was calculated for each year in the 18-year surveillance period. An individual was identified as a prevalent case during a given year of the surveillance period if they were in active component service at any time during the given year and were diagnosed as an incident case on or before that year (including those who were diagnosed as an incident case before the start of the surveillance period). The denominator for the annual prevalence calculations consisted of the total number of service members in active component service during each year. Annual prevalence estimates were calculated as the number of prevalent cases per 100,000 active component service members.

RESULTS

During 2001–2018, a total of 10,562 active component service members received incident diagnoses of idiopathic corneal ectasias, for a crude overall incidence rate of 45.3 per 100,000 p-yrs. Rates among male and female service members were relatively similar. Overall rates were highest among service members 30–34 years

TABLE 1. ICD-9 and ICD-10 diagnostic codes used to identify cases of corneal ectasias

ICD-9	Description
371.60	Keratoconus, unspecified
371.61	Keratoconus, stable condition
371.62	Keratoconus, acute hydrops
371.71	Corneal ectasia
ICD-10	
H18.601	Keratoconus, unspecified, right eye
H18.602	Keratoconus, unspecified, left eye
H18.603	Keratoconus, unspecified, bilateral
H18.609	Keratoconus, unspecified, unspecified eye
H18.611	Keratoconus, stable, right eye
H18.612	Keratoconus, stable, left eye
H18.613	Keratoconus, stable, bilateral
H18.619	Keratoconus, stable, unspecified eye
H18.621	Keratoconus, unstable, right eye
H18.622	Keratoconus, unstable, left eye
H18.623	Keratoconus, unstable, bilateral
H18.629	Keratoconus, unstable, unspecified eye
H18.711	Corneal ectasia, right eye
H18.712	Corneal ectasia, left eye
H18.713	Corneal ectasia, bilateral
H18.719	Corneal ectasia, unspecified eye

ICD, International Classification of Diseases.

of age (54.2 per 100,000 p-yrs) and lowest among those less than 20 years old (30.3 per 100,000 p-yrs). Incidence rates were higher among officers compared to enlisted service members. Rates of idiopathic corneal ectasias were highest among Army personnel (52.6 per 100,000 p-yrs) and lowest among Marines Corps members (27.6 per 100,000 p-yrs). Across military occupations, overall incidence rates of idiopathic corneal ectasia diagnoses were highest among healthcare workers (58.5 per 100,000 p-yrs) and lowest among pilots/air crew (27.9 per 100,000 p-yrs) **(Table 2)**.

During the surveillance period, crude annual rates of incident diagnoses of idiopathic corneal ectasias rose and then fell during the period 2001 through 2010, but rates from 2011 through 2018 were consistently higher than the preceding decade and peaked at 65.1 cases per 100,000 p-yrs in 2016 **(Figure 1)**. Rates among Army and Air Force members peaked in 2016, while rates among Navy members peaked in 2017 and rates among Marine Corps members peaked in 2012 **(Figure 2)**. During 2001–2018, the greatest increase in rates was seen in the Army (122.5%) followed by the Navy (86.0%), the Air Force (66.5%), and the Marine Corps (22.3%). Annual lifetime prevalence rates of idiopathic corneal ectasias increased steadily throughout the surveillance period, from 123.7 per 100,000 service members in 2001 to 315.6 per 100,000 service members in 2018 **(Figure 3)**.

EDITORIAL COMMENT

This report demonstrated a crude overall incidence rate of idiopathic corneal ectasia diagnoses of 45.3 per 100,000 p-yrs among active component service members during 2001–2018. Early studies in Olmstead County, MN, estimated the incidence of keratoconus at 1 in 2,000 in that population, with a corresponding prevalence rate of 54.5 per 100,000 persons (per year).[6] However, these data were collected before widespread use of computerized corneal topography and tomography devices, which provide more accurate and repeatable measurements of the cornea and its structure, including progression analysis of the disease. As recently as 2017, in conjunction with the advent of these newer and more sensitive computerized diagnostic methods, the annual incidence and prevalence of keratoconus in a civilian population were shown to be 5- to 10-fold higher than previously reported.[7] While these estimated rates of keratoconus among civilian populations provide some reference, there are no currently available reports allowing for direct comparisons for the wider group of corneal ectasias. The results of the current analysis provide a baseline for future surveillance of corneal ectasias and evaluation of interventions among military populations. Of note, the relatively lower rates observed for Marine Corps personnel may be due to the younger age range of this group. Additional studies are warranted to explore the factors other than age that are associated with rate differences.

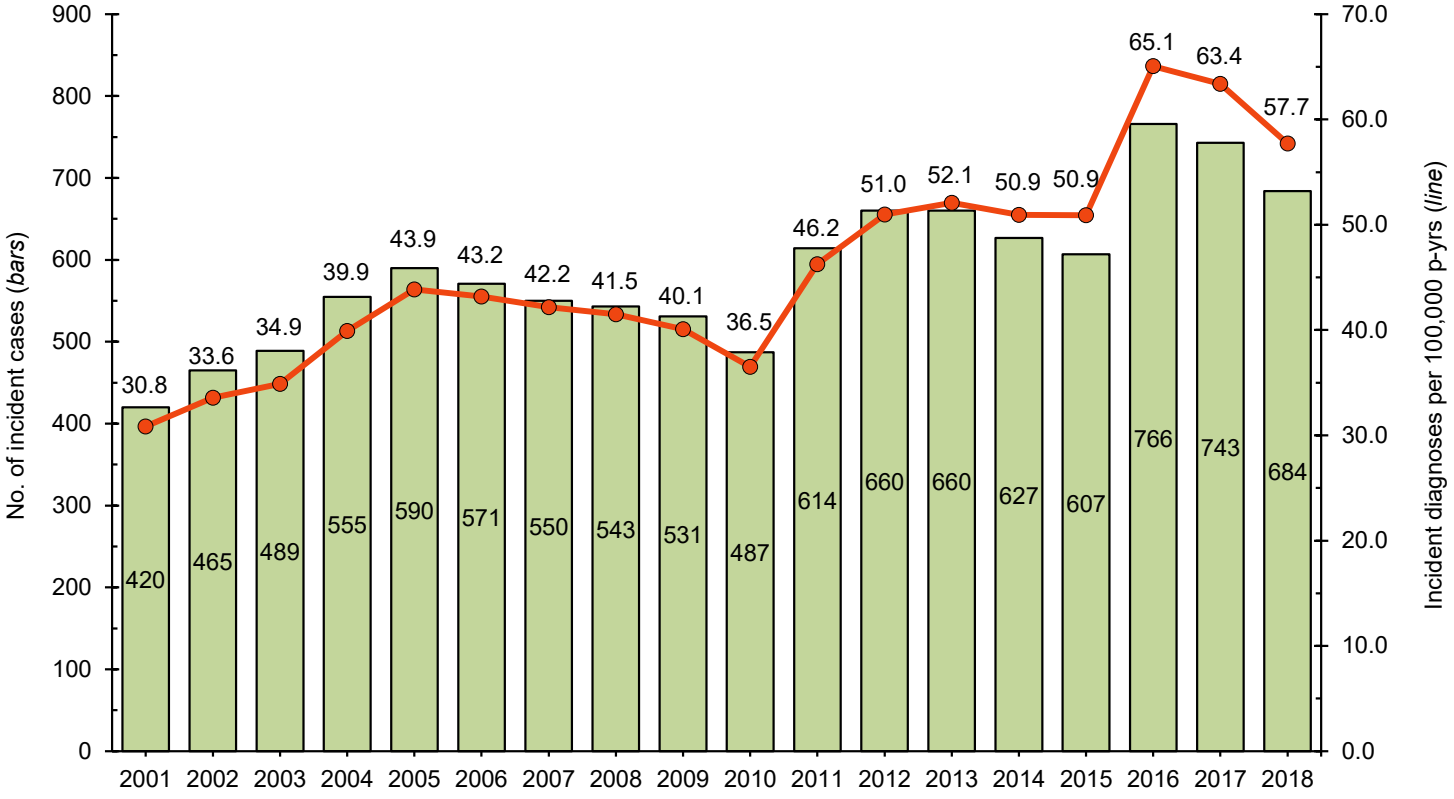
This report is subject to several limitations. There is established coding guidance for conditions such as corneal ectasias, which may lead to incomplete capture of cases. Because the current analysis used administrative data, questions requiring detailed review of clinical records for optimal mapping of signs and symptoms could not be addressed. The Armed Forces Health Longitudinal Technology Application (AHLTA)

TABLE 2. Numbers and rates of incident diagnoses of idiopathic corneal ectasias, by demographics and military characteristics, active component, U.S. Armed Forces, 2001–2018

Incident cases	No.	Rate[a]
Total	10,562	45.3
Sex		
Males	9,132	46.0
Females	1,430	41.4
Age group (years)		
<20	1,000	30.3
20–24	2,518	39.6
25–29	2,726	52.1
30–34	1,845	54.2
35–39	1,386	51.3
40+	1,087	46.5
Service		
Army	4,504	52.6
Navy	2,335	40.2
Air Force	2,835	49.4
Marine Corps	888	27.6
Rank		
Junior enlisted (E1–E4)	4,194	39.6
Senior enlisted (E5–E9)	4,385	48.8
Junior officer (O1–O3; W1–W3)	1,294	55.5
Senior officer (O4–O9; W4–W5)	689	48.6
Military occupation		
Combat-specific[b]	1,173	36.2
Motor transport	349	48.2
Pilot/air crew	250	27.9
Repair/engineering	2,826	41.0
Communications/intelligence	2,630	50.8
Healthcare	1,125	58.5
Other	2,209	49.5

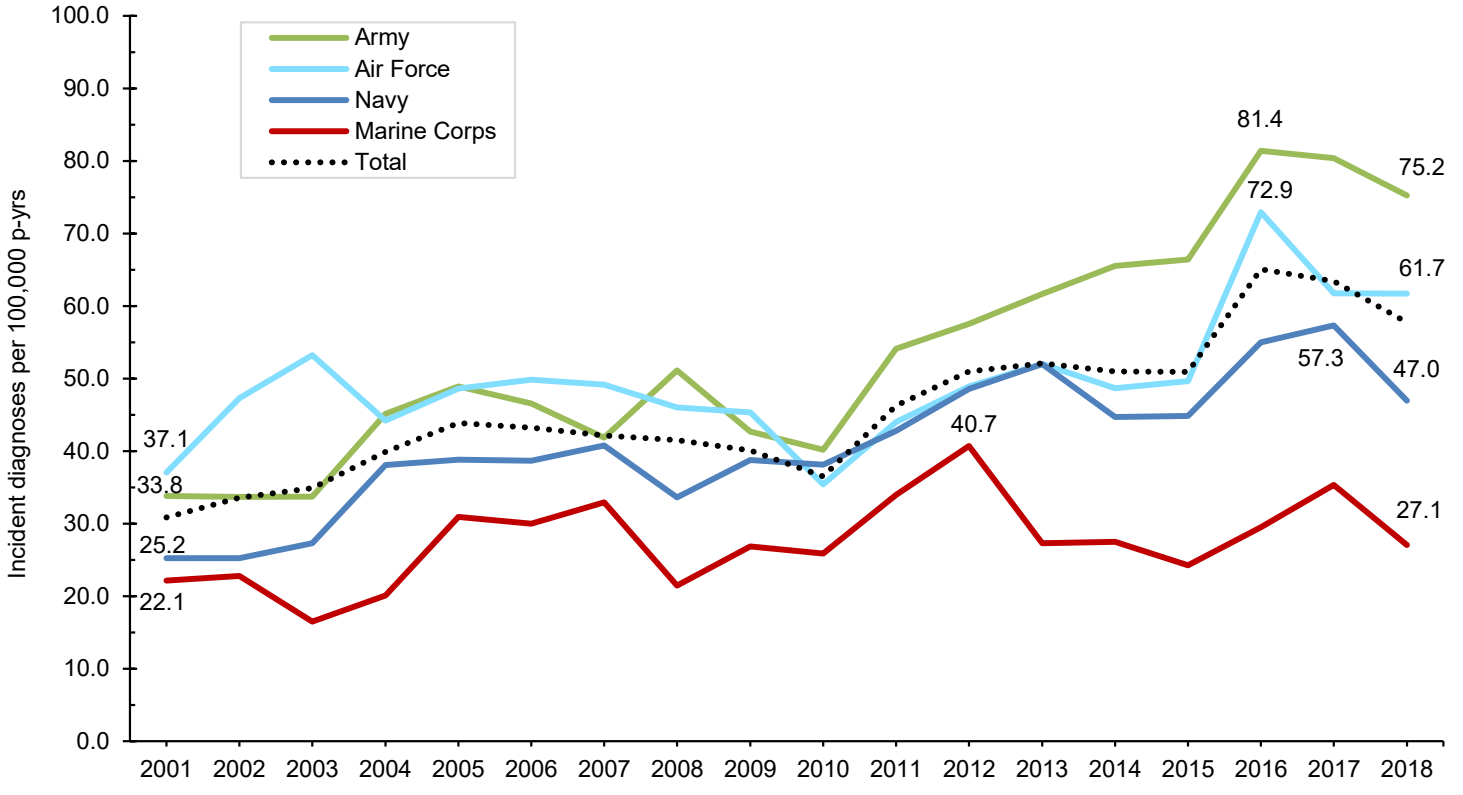
[a]Incidence rate per 100,000 person-years.
[b]Infantry/artillery/combat engineering/armor.
No., number.

FIGURE 1. Numbers of incident cases and incidence rates of idopathic corneal ectasias diagnoses, active component, Armed Forces, 2001–2018



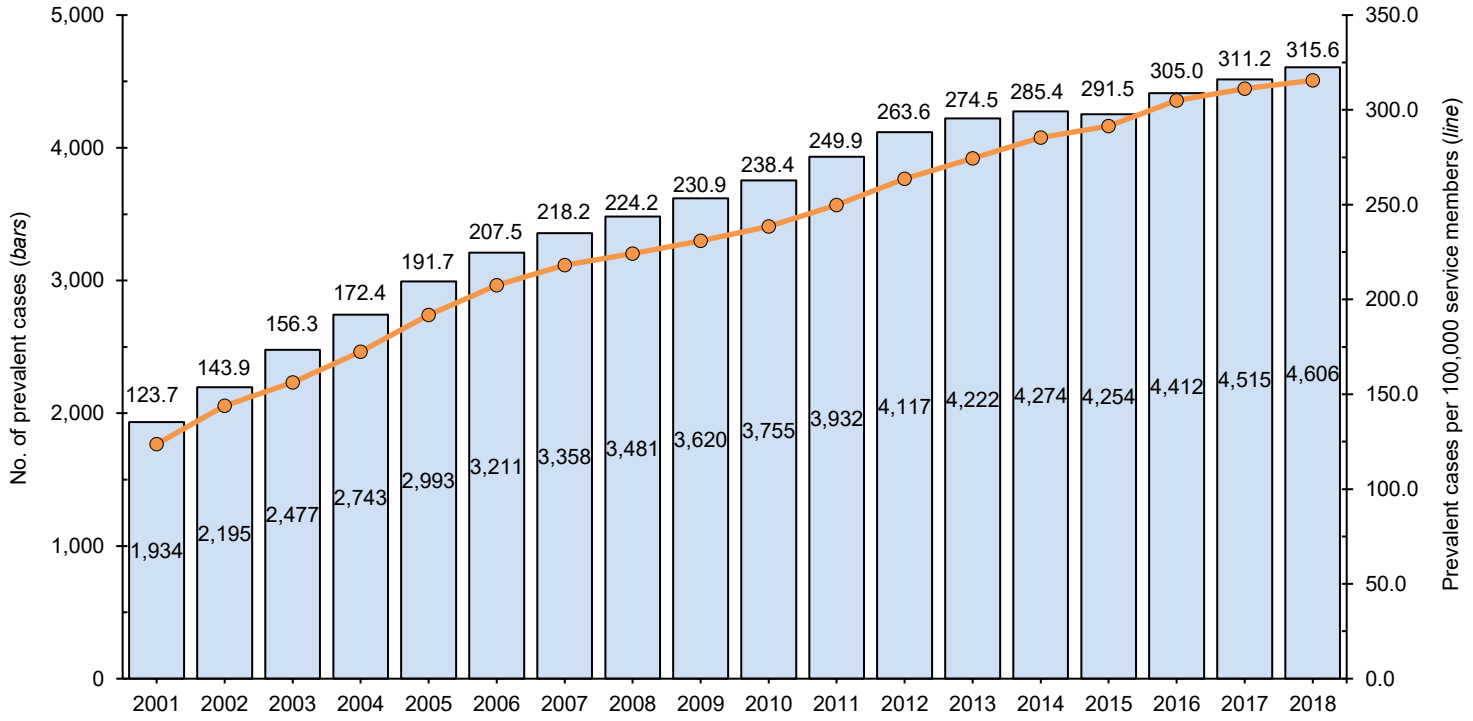
No., number; p-yrs, person-years.

FIGURE 2. Annual incidence rates of idiopathic corneal ectasias diagnoses, by service, active component, Armed Forces, 2001–2018



P-yrs, person-years.

FIGURE 3. Numbers of prevalent cases and annual lifetime prevalence rates of idiopathic corneal ectasias diagnoses, active component, U.S. Armed Forces, 2001–2018.



No., number.

was introduced across the MHS in 2006, and this electronic health record may have influenced coding accuracy throughout the surveillance period. Finally, the new electronic health record for the MHS, MHS GENESIS, was implemented at several military treatment facilities during 2017. Medical data from sites that are using MHS GENESIS are not available in the DMSS. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounters for individuals seeking care at any of these facilities during 2017–2018 were not included in this analysis.

This report demonstrated increasing rates of idiopathic corneal ectasias among active component service members over the course of the surveillance period. The increasing incidence rates reported here may be due to multiple factors, including increased recognition and improved diagnostic capabilities. The steadily increasing annual prevalence rates of idiopathic corneal ectasias are reflective of the chronic nature of these conditions once diagnosed. Corneal degenerations and keratoconus are disqualifying conditions for appointment, enlistment, or induction into the U.S. military.[8] When vision is only correctable by contact lenses because of disease progression, service members must be evaluated for fitness for duty.[9] Corneal ectasias carry high potential for impact on the readiness and retention of trained and experienced service members. Healthcare providers, both eye care professionals and providers responsible for tracking readiness indicators, must be aware of the signs/symptoms of and treatment options for service members suspected of having or diagnosed with these conditions.

Author affiliations: Department of Defense/Veterans Affairs Vision Center of Excellence, Defense Health Agency Research and Development Directorate (COL Reynolds, Dr. Morgenstern, and Dr. Mallia); Defense Health Agency, Armed Forces Health Surveillance Branch (Dr. Stahlman)

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Editorial Oversight
CDR Shawn S. Clausen, MD, MPH (USN)
Mark V. Rubertone, MD, MPH

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