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Unintentional Carbon Monoxide Poisoning National Estimates using Hospitalization and Emergency Department Data

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Abstract

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By Dorothy Stearns

Objectives: Unintentional non-fire-related (UNFR) carbon monoxide (CO) poisoning is a preventable cause of death and is a leading cause of poisoning in the United States. Our purpose was to produce the most recent national estimates of accidental CO poisoning and characterize the burden of cases.

Methods: UNFR CO poisoning cases were assessed using hospitalization and emergency department (ED) data using the Healthcare Costs and Utilization Project's National Inpatient Sample and Nationwide Emergency Department databases. We used hospitalization data from 2003 to 2013 and ED data from 2007 to 2013. Test for trend using linear regression of UNFR CO poisonings over the study period and age-adjusted rates using direct standardization were calculated.

Results: From 2003 to 2013, approximately 14,365 confirmed cases (4 cases/million annually) of UNFR CO poisoning were admitted to hospitals and the trend of poisonings remained consistent each year (R^2 = .0218). From 2007 to 2013, approximately 100,859 cases (47 visits/million annually) visited the ED, which was significant (R^2 = .8606). The majority of hospital cases were among those that are older (aged 50 and older), white, male, or living in the South (a novel finding) or Midwest. Seasonal trends exist depending on geographic region and winter months had the majority of cases. For ED visits, the majority of cases lived in the Northeast or Midwest and were 26 to 49 years of age. Overall, there was no change in trend over the study periods for hospitalizations.

Conclusion: Accidental CO poisoning is preventable and these cases represent the national public health burden. National estimates show that ED visits showed a downward trend, but trend in hospitalizations over the study period did not change significantly. This emphasizes the need for prevention efforts, such as education in the ED setting, increased use of CO alarms, and proper maintenance of gas-powered household appliances.

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Dorothy Stearns

1. INTRODUCTION:

Carbon monoxide (CO) is an odorless, colorless gas that is created by the incomplete combustion of carbon-based fuel products. CO is difficult to detect without special equipment, like a CO alarm or monitor. When inhaled, CO binds to hemoglobin in red blood cells, reducing their ability to carry oxygen throughout the body. CO combines preferentially with hemoglobin heme groups to produce COHb, which displaces oxygen and reduces systemic arterial oxygen [1], leading to CO poisoning. CO poisoning is dose-dependent; symptoms worsen as the percentage of CO in the blood rises. Diagnosing CO poisoning may be difficult due to the time lapse between presenting symptoms and emergency department arrival, as well as its non-specific clinical effects [1]. Sometimes loss of consciousness, chest pain, cardiovascular disease, delayed neurologic sequelae, coma, and death can result in more severe cases. Treatment can include hyperbaric oxygen therapy, supplemental oxygen treatment, and ventilator support using endotracheal tubes.

Unintentional non-fire-related carbon monoxide (UNFR CO) poisonings are responsible for an estimated 450 deaths each year, more than any other non-medical toxicant [2], and are the leading cause of morbidity in post-disaster situations. In 2007, there were approximately 21,000 emergency department (ED) visits related to CO poisoning [3]. In this study, we describe population trends for UNFR CO hospitalizations and ED visits using the Healthcare Costs and Utilization Project (HCUP) databases to update national estimates of the burden of CO poisoning. We also assess UNFR hospitalizations and ED visits over time to determine possible longitudinal trends.

2. METHODOLOGY:

HCUP is a family of databases sponsored by the Agency for Healthcare Quality and Research (AHRQ). Annual assessments of healthcare trends, diagnoses, and other statistics in the HCUP databases are nationally representative. This analysis uses the Nationwide Emergency Department Sample (NEDS) and the National Inpatient Sample (NIS).

The NEDS is the largest all-payer emergency department (ED) U.S. database that approximates national estimates of encounter-level ED visits in HCUP participating hospitals. NEDS has sampled HCUP state partners from the HCUP State Emergency Department Databases (SEDD) annually since 2006. The NEDS is a stratified probability sample of U.S. EDs that approximates a 20% sample of hospital-based EDs; therefore, determining national estimates requires weighting. This study analyzes yearly ED samples from 2007 to 2013.

We used the National Inpatient Sample (NIS) to assess the number of UNFR CO poisonings that resulted in hospitalizations from 2003 to 2013. Similar to NEDS, the National Inpatient Sample collects data in those same participating hospitals. Multi-year trend analyses using NIS data from 1993 to 2011 require discharge trend weights to make the estimates comparable each year. These weights adjust for changes in healthcare trends each year.

Both of these databases use the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes and E-codes to classify

patients diagnosed with CO poisoning. CO poisoning cases are defined using criteria established in the Council for State and Territorial Epidemiologists (CSTE) position statement [4]. UNFR CO poisoning cases are classified either confirmed or probable with the exclusion of the fire-related and/or intentional E-codes listed below:

- Confirmed cases: 986, E868.3, E868.8, E868.9, and E982.1
- Probable cases: E868.2, E982.0
- Excluded codes: E890 - E899, E950 - E979, and E990 - E999

We used SAS 9.3 software to conduct the statistical analysis on the burden of UNFR CO poisonings and for general trend analysis using the NIS and NEDS databases. For NIS, weighted data from 2003 to 2013 were used for trend analysis of hospitalizations. For NEDS, weighted data from 2007 to 2013 were used for trend analysis of ED visits. Age-adjusted rates were calculated annually, using direct standardization and the U.S. Census Bureau population estimates for 2010 as the denominator [5]. We stratified cases and calculated 95 percent confidence intervals for UNFR CO poisoning cases by sex, age, race/ethnicity, U.S. region of the hospital defined by HCUP, payer method, admission season, and mortality. Race is not recorded in the NEDS database, therefore, we did not analyze ED visits by race. Admission seasons were defined based upon standard season classifications (i.e. December, January, and February are winter). We tested for trends using a linear regression of the age-adjusted annual rates.

3. RESULTS:

3.1 Hospitalizations:

Approximately 14,365 confirmed cases of UNFR CO poisoning were admitted to hospitals from 2003 to 2013 (4 cases/million annually). Annual trend analysis revealed a slight upward trend of UNFR CO poisoning cases in 2006 (5.7 cases/million) and 2007 (5.5 cases/million). However, the annual rate of cases remained consistent in the study period and was not significant (R^2= 0.0218) (Figure 1).

Table 1 describes the demographic characteristics of UNFR CO poisoning hospitalizations. Adults aged 50 and older had the largest number of hospitalizations, approximately 55.9 % of the total cases. 56.1 % of CO poisoning cases hospitalized were male. Whites (65.7 %) accounted for the majority of cases. Also, the majority of patients used Medicare (34.4 %) and private insurance (28.5 %) for payment. Out of the 14,365 cases of CO poisoning, mortality was approximately 2.0 %, with 223 confirmed deaths. Approximately 67.8 % of deaths were among males, more than twice the percentage of deaths among women (32.1 %).

The South and the Midwest regions had the largest number of hospital encounters, with 31.8 % and 29.0 % respectively. Cases occurred primarily in the winter (40.0 %) and fall (25.3 %), with January having the largest percentage of cases (14.7%). From April to September, the South had the largest percentage of cases. From November to March, the Midwest and the Northeast had the majority of cases (Figure 2).

3.2 Emergency Department:

From 2007 to 2013, 100,859 CO poisoning cases (47 visits/million annually) presented to the ED, with a statistically significant ($R^2 = 0.8606$) downward trend of ED visits by year (Figure 3). The majority of ED visits were 26 to 49 years old (37.8 %) and 0 to 18 years old (27.4 %) (Table 2). The percentages of male (48.7 %) and female (51.3 %) ED visits were approximately even. Payment method was largely private insurance (38.4 %), followed by Medicaid (21.0 %). Mortality of ED visits accounted for 190 of the total 100,859 ED visits. When stratified by sex, men accounted for approximately 78% (148) of the deaths either in the ED or hospitalized. In Figure 4, the Northeast (34 %) and the Midwest (31.2 %) accounted for the majority of ED visits. The majority of cases occurred in the winter (41.4%) and fall (24.1 %) seasons.

4. DISCUSSION

From 2003 to 2013, hospitals admitted approximately 14,365 confirmed cases of UNFR CO poisoning. From 2007 to 2013, EDs admitted approximately 100,859 CO poisoning cases. There was not change in trend in hospitalizations ($R^2 = 0.0218$), but there was a significant downward trend in ED visits ($R^2 = 0.8606$). This decrease in ED visits may be attributable to utilizing other urgent care facilities instead. Another possibility may be that cases are being hospitalized at the same rate even though less patients are visiting the ED.

Past studies have shown that older, non-Hispanic white men who live in the Midwest have the highest risk of UNFR CO poisoning [6]. In this study, the majority of CO poisoning hospitalizations were among older, non-Hispanic white men as well. Possible reasons for hospitalization include presence of comorbid conditions, such as

heart or chronic pulmonary disease, which increases the risk of severe symptoms in older populations [7]. In contrast, the largest number of ED visits were among those 26 years to 49 years of age. In addition, the majority of visits occur in winter months.

EDs admitted similar percentages of males and females, while the number of hospitalizations differed between the sexes. Males may have greater potential for CO exposure, due to engaging in high-risk behaviors like improper placement of carbon-fuel based products during power outages [8]. Because of physiological differences, females were more likely to present symptoms earlier, thus receiving medical treatment for less severe poisonings [3, 9]. The exception to this difference in number of hospitalizations would be pregnant women, who have an increased risk of severe symptoms [7].

In contrast with most literature, the South region had the largest percentage of CO poisoning hospitalizations from April to September. In the South region, this increase may be due to hurricanes and other natural disasters, resulting in CO exposures from generators, dehumidifiers, and pressure washers used during cleanup in the weeks and months post-disaster [10]. The Northeast and the Midwest had the largest percentage of hospitalizations from November to March, which is consistent with other studies [11]. The highest frequency of cases occurred in winter months, possibly attributable to vehicle warm-up, improper maintenance of home heating systems, and loss of power during winter storms [9, 12, 13]. Many CO exposures are often the result of risk-taking behavior that occurs when a disaster situation arises and power sources are limited.

Deaths from CO poisoning were a rare occurrence in both the ED and hospital during the study period. There were 223 hospital deaths and 190 ED deaths. The majority of CO poisoning deaths occur in residences before arrival to a hospital [9]. If a patient is

able to make it to a hospital, they have a low probability of dying. Often persons with severe symptoms of CO poisoning, including death, are proximate to the original source of CO. However, others with less severe symptoms, but exposed, may also need medical attention, especially pregnant women [14]. Although HCUP does not provide the source of exposure, we know from case reports and surveillance that exposure sources such as generators, charcoal grills and briquettes, kerosene heaters, and stoves are the main household sources of UNFR CO poisoning [8].

These results may be underestimated since CO poisoning has non-specific symptoms and misdiagnosis can occur. For example, differential diagnoses can include food poisoning, depression, flu-like illness, etc. HCUP's sampling and weighting process to create nationally representative estimates does not include all states all years, therefore we may have made inaccurate generalizations about the population [3]. These generalizations may have affected the results, because we assumed that weighted samples were approximate depictions of the total population. In addition, we used confirmed and probable cases only. Although we have high confidence that these cases are CO poisoning, using these definitions may underestimate the total number of cases. In addition, definitions using ICD-9-CM codes are susceptible to variation by coders. One healthcare professional may interpret and diagnose a particular case differently from another [8].

In this study, we have estimated a nationally representative number of cases of CO poisoning, based on HCUP's large sample size of hospital and ED discharge data. HCUP is the largest all-payer database (including the uninsured) and undergoes quality

checks for accuracy and standardization. Therefore, these estimates are a close approximation to the true burden of CO poisoning in the United States.

The National Carbon Monoxide Poisoning Surveillance Framework uses mortality records, CO alarm prevalence surveys, laboratories, hyperbaric chambers, and exposure data from the National Poison Data System (NPDS) to assess the full burden of CO poisoning cases [15]. In addition, ED and hospitalization data from studies like this are also used. This framework is comprehensive and its resources are used to monitor and report CO exposures. This data is used by local agencies to produce intervention efforts to prevent CO poisoning.

CO poisoning is preventable. Since most CO poisoning cases occur inside the home, CO alarms are recommended for residential use [16, 17] and should be placed on every floor [12] and in hallways near sleeping areas [17]. Their low cost makes them a feasible intervention for preventing CO poisoning. Although CO detectors can reduce exposures, routine maintenance and proper installation of alarms is necessary for them to be effective. Because they are electronic, their batteries need to be replaced every 6 months [9].

High-risk populations may not be aware of the benefits of CO alarms, as well as the dangers of gas-powered devices in the home. The 2005 *HealthStyles* Survey asked respondents to evaluate the safety of running a generator in a garage as long as the door is open. Approximately 63.3 % of respondents either agreed that the practice was safe or were unsure. These respondents were mainly from high-risk populations: older (65 years and older), non-Hispanic, white men living in the Midwest. When asked if running generators in the basement were safe, respondents who agreed practice is safe or who

were unsure were mainly non-Hispanic black, middle-aged (35 years to 64 years old) men from the Northeast, another high-risk population. In the 2006 survey, less than half of the participants reported having a CO alarm. This result emphasizes gaps in education about these products, especially in high-risk populations [18].

Disaster-related CO exposure impacts racial and ethnic minorities as well. These populations represent a disproportionate fraction of both fatal and nonfatal disaster-related CO poisonings [8]. Many studies have noted a majority of severe outcomes in immigrant and foreign-born communities [19]. In one study, 45% of households used English as their primary language, and 55% of households included at least one member whose primary language was not English. These estimates show that targeted risk communication and disaster preparation are essential for preventing CO exposures among these vulnerable groups during an emergency.

5. CONCLUSION

This study reveals that trends in ED visits due to UNFR CO poisoning have decreased annually, but trends in hospitalizations have not changed. White males 50 years or older living in the South or Midwest, and high-risk populations are consistently the most vulnerable to CO exposure [3, 6, 9]. This may suggest that our prevention efforts are not reaching target populations. These vulnerable populations are a target audience for communication and intervention to eliminate education gaps and reduce unintentional CO poisoning mortality. Firefighters, state and local health agencies, and local channels could promote CO detectors before disasters occur. Public service announcements before storms, post-hurricane season for southern states, and during winter months could inform

residents about the need for alarms [20]. Alternative forms of communication, such as mail or newspaper, can fill communication gaps for those without access to television or internet. To assess exposure to CO, healthcare professionals can measure COHb in patients who may be exposed and educate them on the dangers of CO poisoning [21].

6. RECOMMENDATIONS

Future research on UNFR CO poisoning must explore why trends in healthcare utilization have remained constant among certain high-risk groups. Although this study provides comprehensive national estimates using healthcare data, additional research is needed to specifically explore exposures related to CO poisoning.

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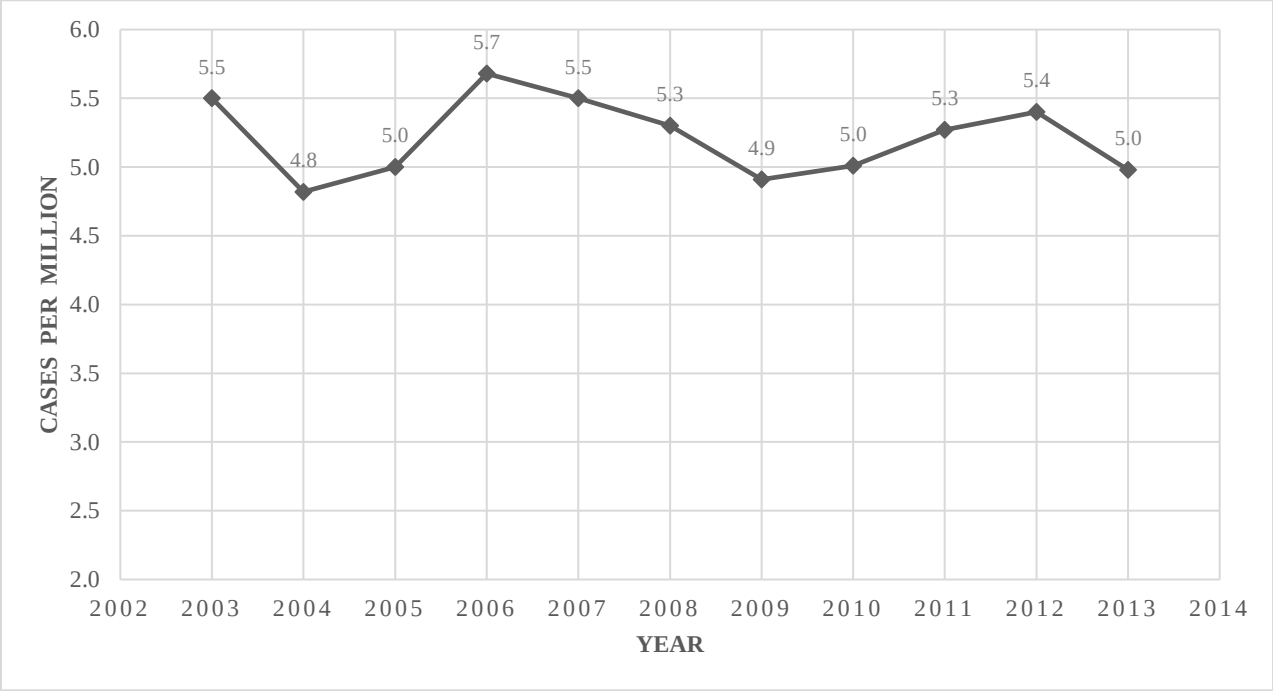
TABLES AND FIGURES

Figure 1: UNFR CO Poisonings Hospitalizations from 2003 to 2013, United States, NIS Database



This figure shows the UNFR CO poisoning confirmed cases per million from 2003 to 2013. An average of approximately 4 cases (4.2) per million occurred annually. During the time period, the trend remained consistent ($R^2 = 0.0218$).

Table 1: UNFR Confirmed CO Poisoning Hospitalizations from 2003 to 2013, United States, NIS Database

	Demographics	N	Standard Deviation (N)	Percent (%)	Standard Error (%)	95% Confidence Interval (%)	
Sex						(Lower)	(Upper)
	Male	8,031	131	56.14	0.91	54.35	57.93
	Female	6,273	131	43.86	0.91	42.07	45.65
	**Missing = 61*						
	Total	14,304	25	100.00			
Age							
	0 to 18	1,381	77	9.63	0.54	8.58	10.69
	19 to 25	631	54	4.40	0.37	3.67	5.14
	26 to 49	4,313	121	30.08	0.84	28.43	31.74
	50 and older	8,011	132	55.88	0.91	54.09	57.67
	**Missing = 28*						
	Total	14,337	25	100.00			
Race							
	White	7,521	112	65.73	0.98	63.81	67.64
	Black	1,929	89	16.85	0.77	15.34	18.37
	Hispanic	1,238	73	10.82	0.64	9.57	12.07
	Asian or Pacific Islander	83	20	0.73	0.17	0.39	1.07
	Native American	49	16	0.43	0.14	0.16	0.70
	Other	623	53	5.44	0.47	4.53	6.36
	**Missing = 2,921*						
	Total	11,443	22	100.00			
Region of Hospital							
	Northeast	3,496	112	26.65	0.85	24.98	28.32
	Midwest	3,799	116	28.96	0.87	27.24	30.67
	South	4,169	116	31.78	0.89	30.04	33.52
	West	1,654	83	12.61	0.63	11.37	13.85
	**Missing = 1,246*						
	Total	13,118	24	100.00			
Expected Payer Method							
	Medicare	4,926	125	34.37	0.87	32.66	36.09
	Medicaid	2,356	98	16.44	0.68	15.11	17.78
	Private insurance	4,083	119	28.49	0.83	26.86	30.12
	Self-pay	1,673	84	11.67	0.59	10.52	12.83
	No charge	88	21	0.61	0.14	0.33	0.90
	Other	1,205	73	8.41	0.51	7.41	9.40
	**Missing = 34*						
	Total	14,331	25	100.00			

Admission Season							
	Winter	5,436	126	40.03	0.93	38.21	41.84
	Spring	2,752	103	20.26	0.76	18.78	21.75
	Summer	1,953	90	14.38	0.66	13.08	15.69
	Fall	3,439	112	25.32	0.82	23.71	26.94
	**Missing = 785*						
	Total	13,580	24	100.00			
Mortality							
	Discharged alive	14,142	41	98.45	0.23	98.00	98.90
	Died	223	33	1.55	0.23	1.10	2.00
	Total	14,365	25	100.00			

Table 1 summarizes the demographics of UNFR CO poisoning cases admitted to hospitals.

*Missing values did not significantly affect the data

Figure 2: UNFR CO Poisoning Hospitalizations by Month and Region from 2003 to 2013, United States, NIS Database

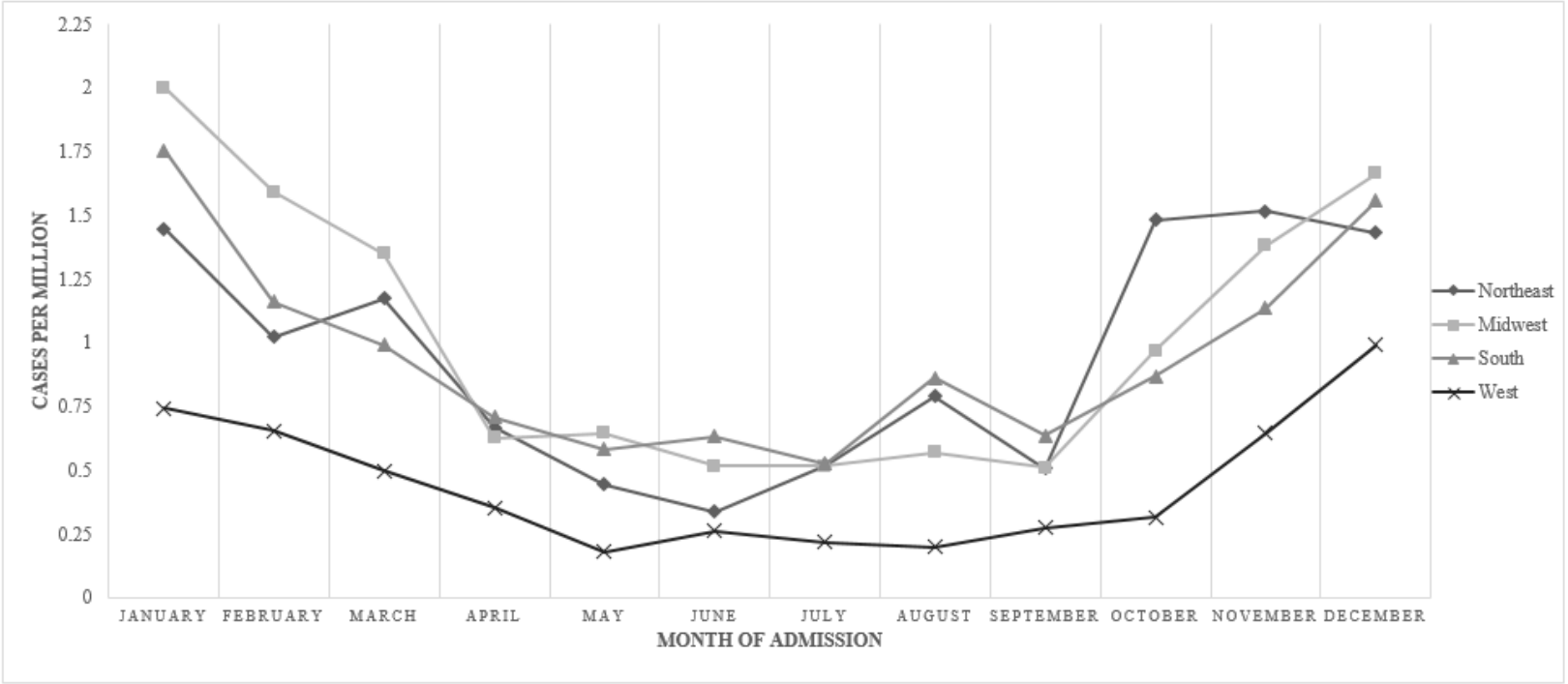


Figure 2 shows that there exists a seasonal peak of UNFR CO poisoning cases in the winter and a seasonal low in the summer. Geographic regions were associated with season of admission. During the summer months, the South had the largest percentage of confirmed cases, possibly attributed to hurricane season. During the winter months, the Midwest and Northeast had the largest percentage of cases. These cases may be related to power outages and snow storms associated with winter months.

Figure 3: UNFR CO Poisoning Emergency Department Visits from 2007 to 2013, United States, NEDS Database

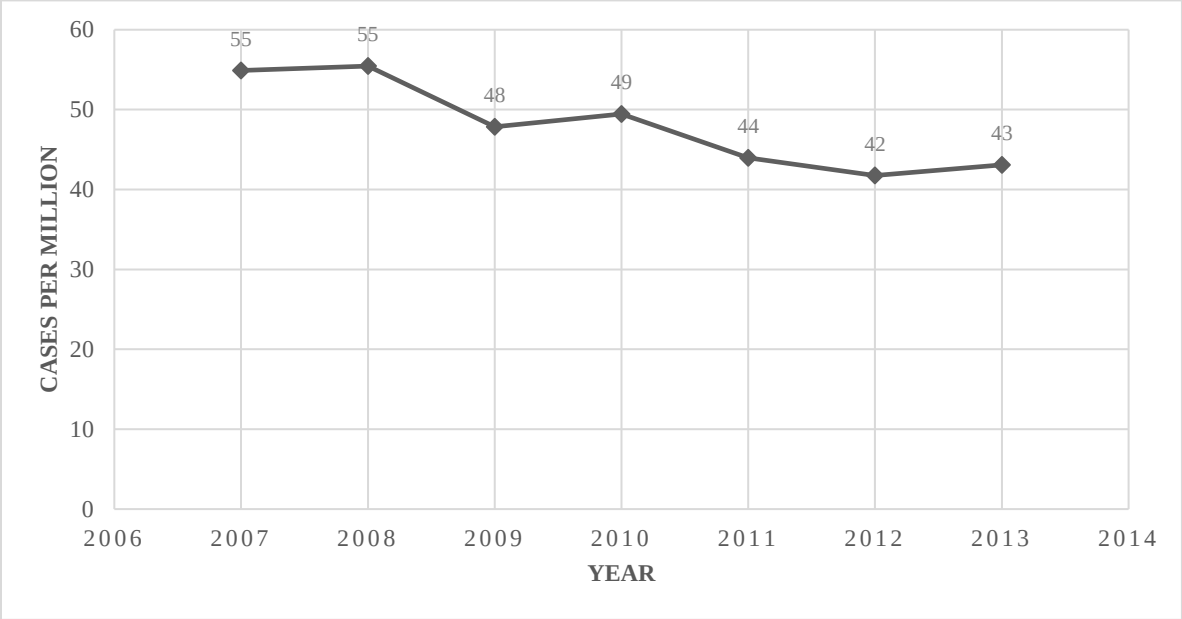


Figure 3 summarizes the general trend of confirmed cases from 2007 to 2013. Approximately 47 visits/million annually occurred during this time period (100,859 cases) with a downward trend ($R^2 = .8606$)

Table 2: UNFR CO Poisoning Emergency Department Visits from 2007 to 2013, United States, NEDS Database

	Demographics	N	Standard Deviation (N)	Percent	Standard Error (%)	95% Confidence Interval (%)	
Sex							
	Male	49,607	379	48.72	0.35	48.02	49.41
	Female	52,218	374	51.28	0.35	50.59	51.98
	**Missing=22*						
	Total	101,825	215	100.00			
Age							
	0 to 18	27,929	323	27.42	0.31	26.81	28.04
	19 to 25	12,240	242	12.02	0.24	11.56	12.48
	26 to 49	38,509	360	37.81	0.34	37.14	38.48
	50 and older	23,169	306	22.75	0.30	22.17	23.33
	Total	101,847	215	100.00			
Region of Hospital							
	Northeast	34,579	336	33.95	0.33	33.30	34.60
	Midwest	31,732	343	31.16	0.33	30.51	31.80
	South	22,996	289	22.58	0.29	22.02	23.14
	West	12,539	275	12.31	0.26	11.80	12.82
	Total	101,847	215	100.00			
Expected Payer Method							
	Medicare	11,301	228	11.21	0.23	10.77	11.65
	Medicaid	21,140	292	20.96	0.29	20.40	21.53
	Private insurance	38,742	356	38.42	0.35	37.74	39.10
	Self-pay	15,938	271	15.81	0.26	15.29	16.32
	No charge	493	49	0.49	0.05	0.39	0.58
	Other	13,222	246	13.11	0.24	12.64	13.59
	**Missing=1,011*						
	Total	100,836	213	100.00			
Admission Season							
	Winter	38,673	366	41.39	0.37	40.67	42.11
	Spring	18,426	281	19.72	0.30	19.14	20.30
	Summer	13,837	240	14.81	0.26	14.30	15.31
	Fall	22,496	291	24.08	0.31	23.47	24.69
	**Missing=8,415*						
	Total	93,432	209	100.00			
Mortality							
	Did not die	100,669	214	99.81	0.04	99.73	99.89
	Died in the ED	101	24	0.10	0.02	0.05	0.15
	Died in the hospital	89	35	0.09	0.03	0.02	0.16
	**Missing=988*						
	Total	100,859	214	**100.00**			

Table 2 summarizes the demographics of the UNFR CO poisoning cases that visited an ED from 2007 to 2013.

*Missing values did not significantly affect the data

Figure 4: UNFR CO Poisoning ED Visits Month by Region from 2007 to 2013

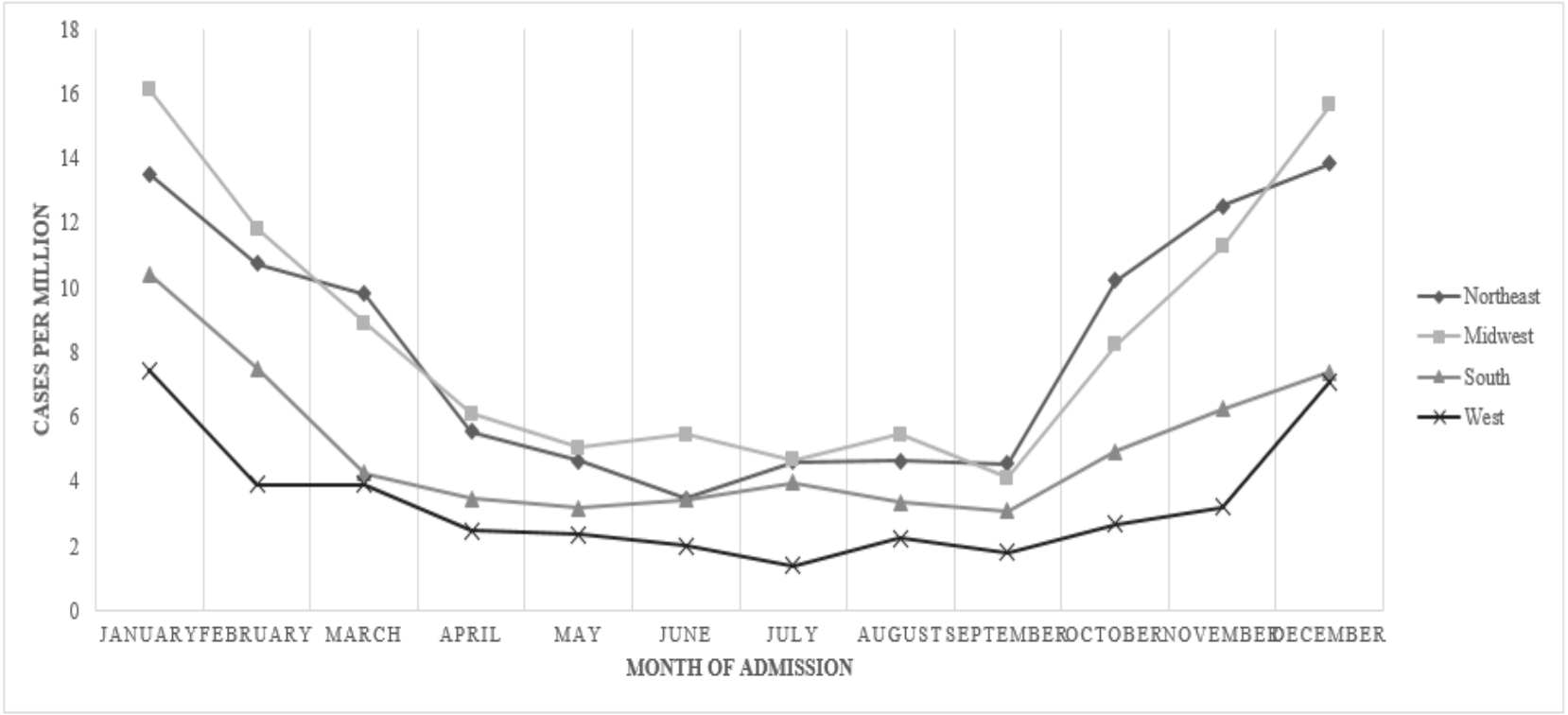


Figure 4 shows the seasonal trend of cases by geographic region from 2007 to 2013. As stated, seasonal lows are associated with summer months while seasonal highs are associated with winter months. The Northeast and Midwest accounted for the largest number of cases, in contrast to the South having the majority of hospitalizations.