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Evaluation of Electronic Health Records to Monitor Illness From Harmful Algal Bloom Exposure in the United States

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Abstract

Harmful algal blooms (HABs) are the rapid growth of algae that can produce toxic or harmful effects in people and animals. Potential health effects include respiratory illness, gastrointestinal illness, skin and eye irritation, and sometimes more severe toxic effects such as liver damage. Defining HAB exposure and related illness is challenging for many reasons, including characterizing the exposure. Large electronic health record databases present an opportunity to study health encounters specifically related to HAB exposure through querying medical diagnostic codes. We queried the MarketScan Research Databases between January 2009 and April 2019 for use of the International Classification of Diseases (ICD) codes for HAB exposure. We found a total of 558 records that used either the ICD-9 or ICD-10 code for HAB exposure. Respiratory illness was most commonly reported along with the HAB exposure code. Use of HAB exposure codes showed seasonal fluctuations during 2012–2019. We found that although the HAB-related ICD-9 and ICD-10 codes were used infrequently, they were most often recorded during bloom seasons in warmer months. This analysis is the first that utilizes a large-scale national database of de-identified health records to understand the use of medical diagnostic codes related to algae exposure.

Introduction

Harmful algal blooms (HABs) are the rapid growth of algae that can produce toxic or harmful effects in people and animals (National Oceanic and Atmospheric Administration, 2020). Short-term health effects have been associated with HAB exposure through skin contact, ingestion, or inhalation of algal toxins. Health effects include respiratory illness, gastrointestinal illness, skin and eye irritation, and sometimes more severe toxic effects such as liver failure or paralysis (Centers for Disease Control and Prevention, 2020; Fleming et al., 2011; National Institute of Environmental Health Sciences, 2021). HABs are increasing in frequency and duration within the U.S., presenting an increased risk for

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adverse health outcomes associated with exposure (Davis & Gobler, 2016). Information about the prevalence and long-term health effects of HAB exposure is more limited.

Defining HAB exposure and related illness is difficult due to challenges with characterizing and reporting HAB contact (Backer et al., 2015; Bradley et al., 2013; Serrano et al., 2015; Torbick et al., 2018). Electronic health records (EHRs) present an opportunity to study health encounters specifically related to HAB exposure through use of medical diagnostic codes. Figure 1 presents the International Classification of Diseases (ICD) codes available to classify HAB exposures (ICD-9 and ICD-10) and toxic effects of HABs (ICD-10 only) during a medical encounter (hereafter referred to as HAB exposure codes). Important to note for this analysis, we excluded HAB exposure related to seafood poisonings and concentrated on environmental exposures to HABs.

Only one study has examined the utility of HAB exposure diagnostic codes; however, the analysis was limited to the state of New York and to the use of ICD-9 codes (medical facilities have been using ICD-10 codes since 2015) (Figgatt et al., 2016). It is unclear how these diagnostic codes are used across the U.S. and how the updated ICD-10 codes might result in different or improved HAB-related illness classification.

If medical diagnostic codes for HAB exposure are used effectively, EHRs could provide a platform for enhanced surveillance of HAB exposures and related illnesses, including potential assessment of long-term health effects. Additionally, assessing corresponding procedure or laboratory codes used during the medical encounter might provide insight into health effects that have not been extensively studied. The purpose of this study was to evaluate the use of ICD-9 and ICD-10 medical diagnostic codes for HAB exposure across the U.S. using a large, de-identified EHR database.

Methods

Description of Data Set and Study Population

We used the IBM MarketScan Research Databases (IBM Watson Health), which contain de-identified healthcare claims data for individuals with commercial insurance and some Medicaid beneficiaries. The Commercial Claims and Encounters Database (hereafter referred to as Commercial database) contains data from currently employed persons and their dependents, former covered employees insured using the extended COBRA plans, and early retirees who are not eligible for Medicare (IBM Watson Health, 2017). The Medicaid Database includes data from several state-based Medicaid programs for individuals covered under the fee-for-service and managed care plans (IBM Watson Health, 2017).

A convenience sample of claims records across the U.S. was used to populate both databases. Records include physician office visits, hospital stays (inpatient and outpatient), pharmacy orders (outpatient pharmacy orders), and other healthcare services such as mental health care. Available variables in the Commercial database include age, sex, proximate events that occur on the same day as the event of interest, region of occurrence, cost of medical visit, and hospitalization status including length of stay. Available variables in the

Medicaid database include age, sex, race, proximate events that occur on the same day as the event of interest, cost of visit, and hospitalization status.

For this analysis, we selected the two most recent data sets within MarketScan for Commercial and Medicaid claims. The most recent Commercial data set was available for approximately 90 million people between January 1, 2012, and April 30, 2019. The most recent Medicaid data set was available for approximately 23 million people between January 1, 2009, and December 31, 2018. This study was exempt from Centers for Disease Control and Prevention Institutional Review Board approval because secondary data were used and did not constitute human subject research.

Cohort Creation—Data were accessed for this project through the online MarketScan Treatment Pathways portal. In the portal, a cohort of records was created in both the Commercial and Medicaid databases using the ICD-9 and ICD-10 HAB exposure codes for categories and subcategories (Figure 1).

The created cohorts then consisted of any patient who had an ICD code of interest along with an “index date” for when the code was assigned. The index date corresponds to the first time that ICD code was used for that person and was used to add that record into the cohort. The two cohorts were then analyzed separately to compare results from the two databases.

Analysis—Data were analyzed using the MarketScan Treatment Pathways portal, Excel, and Stata statistical software version 15. Basic demographic information was summarized by frequency of occurrence and percentage of the overall records within the cohort. The total number of records in the two databases (Commercial and Medicaid) was charted by year and quarter to visualize changes in occurrence over time and season. For the Commercial database only, the number of events occurring by U.S. Census Bureau region was displayed and visualized using ArcMap version 10.5.1. Additional health events and procedures were evaluated and described that occurred on the index date that the HAB exposure code was used.

Results

A total of 558 records contained one of the HAB exposure codes, including 380 records in the Commercial database and 178 records in the Medicaid database. Within the two databases, 366 records were coded using the ICD-9 classifications while 192 were coded using the ICD-10 classifications. ICD-9 coding transferred to ICD-10 in October 2015 and ICD-10 was the only available coding system starting in 2016.

Table 1 shows the demographic makeup of the records within the two cohorts. The majority of records were for individuals between the ages of 18–44 (33%) and 45–64 (44%) in the Commercial cohort and under the age of 18 in the Medicaid cohort (62%). Although the cost of a medical visit was somewhat low (median was $122 for the Commercial cohort and $61 for the Medicaid cohort), some visits cost several thousands of dollars for a hospital stay lasting for >1 week. Within both cohorts, 144 people had a hospital inpatient or emergency department visit on the same day in which the HAB exposure code was used. Due to the nature of the database, it is unclear if the hospital stays were directly associated with the HAB exposure code.

Figure 2 shows the number of records with an HAB exposure code in both cohorts by quarter and year, starting in 2012 when both data sets were available. Overall, 2014 and 2018 were the years with the most use of HAB exposure codes. As expected, more HAB exposure code records occurred during the spring and summer months (April–September), which comprise quarters 2 and 3 in Figure 2. The earlier years using ICD-9 codes lacked pronounced peaks during quarters 2 and 3 during 2012 and 2013, whereas the ICD-10 codes had more defined seasonal peaks for the years with complete quarterly reports. In 2018, a large peak was present in quarters 3 and 4 corresponding with a large-scale red tide event in August–November 2018. HAB exposure code use was more prominent in the South Atlantic region, followed by the East North Central and Middle Atlantic regions (Figure 3).

Table 2 displays the top 5 diagnostic codes that were used for people on the same day that an HAB exposure code was used. Respiratory events such as cough and shortness of breath were most often used (16.3%). Codes documenting an allergy were used for 38 people (6.8%). The top 100 diagnostic codes used at the same time as an HAB diagnosis code were grouped into common disorders associated with HAB exposure. These groupings included respiratory events (e.g., asthma, shortness of breath); neurological events (e.g., headache, dizziness); gastrointestinal events (e.g., diarrhea, vomiting); and skin and eye irritation events (e.g., conjunctivitis, rash). When combining cohorts, approximately 207 individuals (37.1%) had respiratory events recorded on the same day an HAB code was used for them. Fewer records listed neurological events such as headaches and dizziness ($n = 66$, 11.8%); eye or skin irritation ($n = 61$, 10.9%); or gastrointestinal events ($n = 32$, 5.7%).

Several procedures were listed for the same days as the HAB exposure code visit. Many of the procedures documented were for overall medical evaluations. Several blood draw tests were ordered as part of these medical work-ups as well. For 29 individuals (5.2%) in the cohort, an inhalation treatment was ordered to assist with acute airway obstruction or difficulty breathing.

Discussion

MarketScan data provided an initial platform to investigate the use of HAB exposure diagnostic codes across the U.S. While this database is limited mostly to individuals insured with commercial or employer-based plans, the database provided >90 million Commercial claims records and >20 million Medicaid claim records to review. The main finding from this analysis is that ICD codes for HAB exposure are used infrequently. The data set, however, provided an opportunity to examine whether the ICD-10 codes were used more often or in a more specific way to document HAB exposure than the ICD-9 codes.

Although a relatively small number of records were available in this data set, Figure 2 shows that the use of HAB exposure codes corresponds mostly to the time of year that HAB events occurred, namely during the warmer months when conditions are conducive to algal growth. Interestingly, we observed a difference in age categories when comparing records in the Commercial database and the Medicaid database. A majority of the records in the Medicaid database with HAB exposure codes were for children and teenagers under the age of 18 (62%) compared with more records between the ages of 18–64 in the Commercial database. It is unclear why we saw this difference between the two databases. As of 2019, approximately 71 million people in the U.S. were covered under Medicaid, a large percentage of whom are children (50%) (Mikulic, 2020). Although the Commercial database contains some dependents within it, it is possible that not as many children are covered within this database compared with the Medicaid database, although we could not validate this assumption in our analysis.

Summarizing the other diagnostic codes that were used at the same time as an HAB exposure code helped to identify common health complaints related to these exposures. As expected, the most common ICD codes reported at the same time as an HAB exposure code were those for respiratory events and were most likely associated with the presence of *Karenia brevis* red tides in the Gulf of Mexico (Backer et al., 2005; Fleming et al., 2011; Kirkpatrick et al., 2006). A large peak in HAB exposure code use occurred during a particularly intense red tide event in the Gulf of Mexico in August–November 2018. Examination of the data by region corroborated this assumption, as the South Atlantic region contained approximately 30% of the total records. These results correspond to a study of emergency department admissions in 2002 in Florida that found a significant increase in the rate of admissions for respiratory disease during a red tide event compared with a time when there was no red tide (Kirkpatrick et al., 2006).

Interestingly, the next highest count of respiratory events (coded on the same visit as an individual's HAB exposure code) was in the East North Central region that comprises many Great Lakes states. Other blooms, such as cyanobacterial harmful algal blooms (cyanoHABs), could be the source of respiratory irritants in this region (Backer et al., 2015, 2010; Stewart et al., 2006). Studies on recreational water users have shown that toxins from cyanoHABs are detectable in the air and measurable in personal air samplers, and that these toxins could be directly responsible for respiratory irritation (Backer et al., 2008, 2010). Respiratory irritation, however, is also associated with gases and vapors (e.g., hydrogen sulfide, methane) released as blooms die off, and these chemicals could be responsible for the reported respiratory effects from cyanoHABs. Studies are underway to better understand the health effects from aerosolized cyanoHABs.

Few gastrointestinal (GI) events were recorded during the time an HAB exposure code was used. Past reports of GI events and outbreaks, however, have been associated with HAB exposure (Backer et al., 2008; McCarty et al., 2016). In a prospective study of acute health effects, Lévesque et al. (2014) found that only GI symptoms were associated with recreational exposure to cyanoHABs. The study also found that higher cell counts of cyanobacteria were associated with an increase in the relative risk for GI symptoms. In 2014, a large microcystin HAB bloom occurred on Lake Erie, contaminating municipal drinking water and causing a do-not-drink advisory for over 400,000 people. A community assessment during this event found that the contamination was associated with a variety of health symptoms primarily related to GI distress such as nausea, vomiting, abdominal pain, and diarrhea (McCarty et al., 2016). Although the MarketScan data reported few GI events in the East North Central and Middle Atlantic regions that include Lake Erie and surrounding states, during 2014, most of the HAB-exposure codes (41%) were recorded within these regions.

These results likely represent only a subset of people who have symptoms or illnesses caused by HAB exposure because the data are a subsample from EHRs across the U.S. In addition, it is possible that only those with more severe symptoms are likely to visit a medical provider for treatment. During the 2014 microcystin water contamination in Ohio, most people who reported health symptoms during the do-not-drink water advisory (89%) indicated that their health issues were not serious enough to seek medical attention (McCarty et al., 2016). People also might not report HAB exposure to their healthcare provider or know to mention it during their medical visit.

While the findings from this data set are enlightening, limitations within the data set made us unable to verify that we had correctly classified people with HAB exposure codes. First, an exploration of the proximate events that occurred on the same day as the HAB exposure codes showed several conditions that would be unrelated to HAB exposure such as “diabetes mellitus without mention of complication,” “tobacco use disorder,” or “routine gynecological examination.” It is likely these codes were used to describe the patient’s status overall; however, it is unclear whether these codes were related to the symptoms presented at the medical visit. Several people also had a diagnostic code for fever, which, while unexpected based on what we know about HAB toxin exposure, should be explored further.

Second, several codes were used to describe injuries or lacerations, which could be unrelated to an actual HAB exposure. In addition, other codes sometimes were used that corresponded to potentially different exposures or indicated that the person might have been exposed to multiple substances: “Contact with and exposure to other hazardous aromatic compounds” or “contact with and exposure to other potentially hazardous chemicals.” While these other exposure codes might be related to an HAB exposure event, it is unclear if these codes were indicative of the HAB exposure itself or another substance in the environment at the same time as the HAB event condition. Finally, because we were able to search only through records with ICD codes, we might have missed patients whose exposure to an HAB was documented elsewhere in the record.

Despite these limitations, exploring large scale EHR systems—and in particular those such as MarketScan that have primary care medical visits documented along with hospital visits —can help researchers estimate the occurrence of HAB-related illness across the U.S. Defining HAB exposure and related illness can be challenging because of misdiagnoses, failure of the patient fully disclosing exposures they might have had leading up to the health events (either because they fail to see the importance of the connection or fail to remember), or lack of general knowledge about HAB-related illness or use of HAB exposure codes by healthcare professionals.

As the symptoms associated with HABs are common among other illnesses and disorders, it is important to have exposure diagnostic code classifications to differentiate HAB-related illness from other exposures. Our findings can inform future medical education on the importance of using specific ICD codes for HAB exposures. Patients should also be encouraged to tell their physicians about their environmental exposures, specifically when HABs are present. Once there is increased knowledge by healthcare professionals regarding environmental exposures such as HABs, EHR databases will be much more useful for tracking environmental exposures and associated health effects.

Conclusion

In this initial evaluation of the MarketScan databases, we found that although HAB exposure codes were used infrequently, they were most often recorded during bloom seasons in warmer months. The most common health outcomes associated with these codes were respiratory symptoms. These findings suggest that EHR databases, though far from perfect, can be useful in examining trends in HAB-related illness reports in the U.S.

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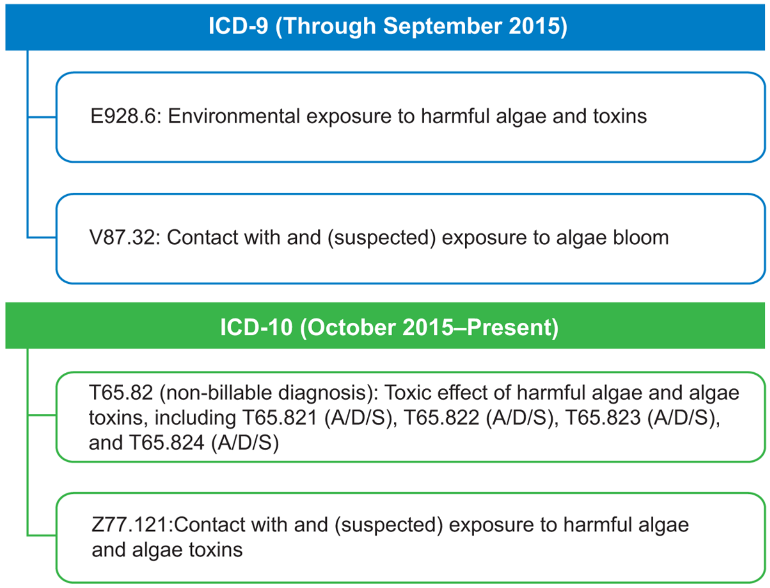

FIGURE 1. ICD Codes for Harmful Algal Bloom Exposure

ICD = International Classification of Diseases; A = initial encounter; D = subsequent encounter; S = sequela.

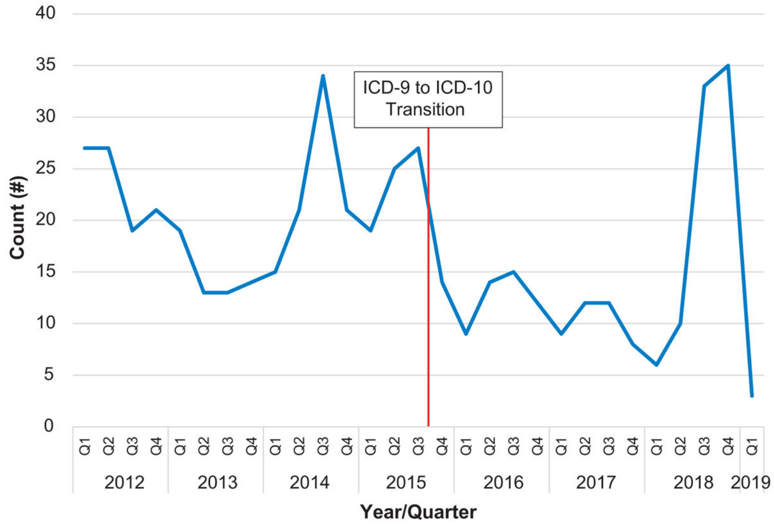

FIGURE 2. Count of Harmful Algal Bloom ICD Codes by Year From January 1, 2012–April 30, 2019, MarketScan Data

ICD = International Classification of Diseases; Q1 = January–March; Q2 = April–June, Q3 = July–September; Q4 = October–December.

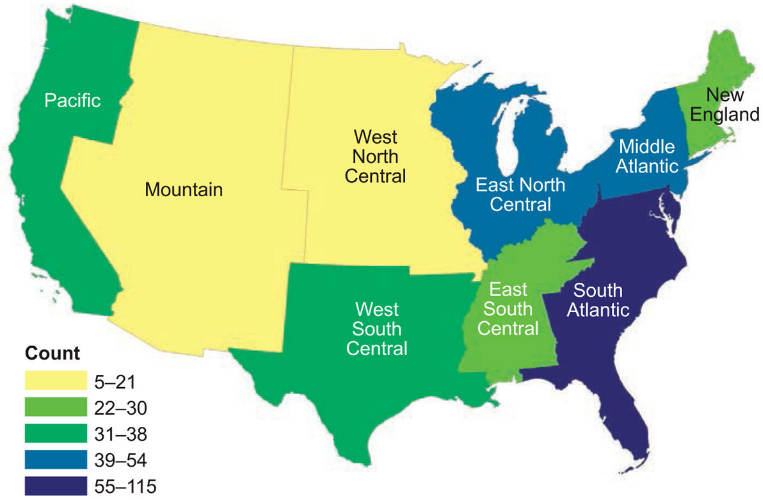

FIGURE 3. Count of Harmful Algal Bloom ICD Codes by Region From January 1, 2012–April 30, 2019, MarketScan Data

ICD = International Classification of Diseases.

TABLE 1

Demographic Characteristics of MarketScan Data Cohorts With Harmful Algal Bloom Exposure (ICD) Codes

Characteristic	Commercial Claims[a] January 1, 2012-April 30, 2019		Medicaid Claims[a] January 1, 2009-December 31, 2018	
	Count (N = 380)	Frequency (%)	Count (N = 178)	Frequency (%)
Age				
0–17	63	16.6	111	62.3
18–44	125	32.9	45	25.3
45–64	167	43.9	22	12.4
≥65	25	6.6	–	–
Sex				
Female	204	53.7	94	52.8
Male	176	46.3	84	47.2
Race				
Black	–	–	43	24.2
Hispanic	–	–	_[b]	_[b]
White	–	–	100	56.2
Other	–	–	_[b]	_[b]
Region				
East North Central	54	14.2	–	–
East South Central	30	7.9	–	–
Middle Atlantic	53	13.9	–	–
Mountain	21	5.5	–	–
New England	25	6.6	–	–
Pacific	34	8.9	–	–
South Atlantic	115	30.3	–	–
West North Central	_[b]	_[b]	–	–
West South Central	38	10.0	–	–
Urban/rural				

Urban	326	85.8	–	–
Rural	49	12.9	–	–
Inpatient or emergency visits	66	17.4	78	43.8
	Median	**Interquartile Range**	**Median**	**Interquartile Range**
Cost of medical visit (U.S. dollars)	$122.34	$75.69-$200.82	$61.16	$8.99-$105.09
Length of hospital stay (days)[c]	4	3–7	–	–

ICD = International Classification of Diseases.

[a]The Commercial claims database did not have data on race; the Medicaid claims database did not have data on region or urban/rural residence.

[b]Data suppressed due to small sample size.

[c]Length of stay for any visits resulting in hospitalization. Only one person in the Medicaid database was hospitalized (4 days total).

TABLE 2

Top 5 ICD-9 and ICD-10 Health Diagnostic Codes Associated With a Harmful Algal Bloom Exposure Visit

Event Name	# of Individuals	Frequency (%)
ICD-9		
786.2: Cough	42	7.5
995.3: Allergy, unspecified	38	6.8
780.79: Other malaise and fatigue	16	2.9
784.0: Headache	12	2.2
V70.0: Routine general medical examination at a healthcare facility	12	2.2
ICD-10		
R05: Cough	37	6.6
R0602: Shortness of breath	12	2.2
I10: Essential (primary) hypertension	11	2.0
J029: Acute pharyngitis, unspecified	11	2.0
J069: Acute upper respiratory infection, unspecified	11	2.0

ICD = International Classification of Diseases.