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Original Article

Preliminary results of 2009 pandemic influenza surveillance in the United States using the Aggregate Hospitalization and Death Reporting Activity

Michael A. Jhung, Heidi Davidson, Anne McIntyre, William J. Gregg, Sharoda Dasgupta, Tiffany D'Mello, Victoria White, Ashley Fowlkes, Lynnette Brammer, Lyn Finelli

Influenza Division, Centers for Disease Control and Prevention, Atlanta, GA, USA.
Correspondence: Michael A. Jhung and Lyn Finelli, 1600 Clifton Road, MS-A32, Atlanta, GA 30333, USA. E-mail: mjhung@cdc.gov, lyf8@cdc.gov

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Background To augment established influenza surveillance systems in the United States, the Centers for Disease Control and Prevention and the Council of State and Territorial Epidemiologists implemented the Aggregate Hospitalization and Death Reporting Activity (AHDRA) in August 2009. The AHDRA was designed to meet increased demands for timely and detailed information describing illness severity during the 2009 H1N1 influenza A (pH1N1) pandemic response.

Objectives We describe the implementation of AHDRA and provide preliminary results from this new surveillance activity.

Methods All 50 US states were asked to report influenza-associated hospitalizations and deaths to AHDRA each week using either a laboratory-confirmed or syndromic surveillance definition. Aggregate counts were used to calculate age-specific weekly and cumulative rates per 100 000, and laboratory-confirmed reports were used to estimate the age distribution of pH1N1 influenza-associated hospitalizations and deaths.

Results From August 30, 2009, through April 6, 2010, AHDRA identified 41 689 laboratory-confirmed influenza-associated hospitalizations and 2096 laboratory-confirmed influenza-associated deaths. Aggregate Hospitalization and Death Reporting Activity rates peaked earlier than hospitalization and death rates seen in previous influenza seasons with other surveillance systems, and the age distribution of cases revealed a tendency for hospitalizations and deaths to occur in persons <65 years for age.

Conclusions Aggregate Hospitalization and Death Reporting Activity laboratory-confirmed reports provided important information during the 2009 pandemic response. Aggregate Hospitalization and Death Reporting Activity syndromic reports were marked by low representativeness and specificity and were therefore less useful. The AHDRA was implemented quickly and may be a useful surveillance system to monitor severe illness during future influenza pandemics.

Keywords H1N1 influenza, pandemic, surveillance.

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Introduction

Multiple surveillance systems are used in the United States each year to characterize seasonal influenza epidemics and to detect unusual events such as infections with novel viruses or those with pandemic potential. These systems track a variety of outcomes, including laboratory-confirmed influenza hospitalizations, outpatient visits for influenza-like illness (ILI), pneumonia and influenza-coded deaths for all ages, pediatric laboratory-confirmed deaths, and positive laboratory samples.[1] Despite the utility of these existing systems, additional data to estimate disease severity and track illness at the state level were needed during the 2009 H1N1 pandemic, as timely and representative information describing 2009 pandemic influenza A (H1N1) (pH1N1) activity was needed for pandemic decision-making and resource allocation. In August 2009, the Centers for Disease Control and Prevention (CDC) and the Council of State and Territorial Epidemiologists (CSTE) established the Aggregate Hospitalization and Death Reporting Activity (AHDRA) as part of an overall national surveillance strategy implemented to collect timely and representative data describing pH1N1 infections in the United States. The AHDRA was designed to (i) track severe disease within states and territories to better characterize the focal nature of the pandemic, (ii) track disease trends over brief periods of time to facilitate rapid public health responses to changes in pH1N1 epidemiology, and (iii) accommodate variation in local resources by providing a simple, flexible method that allowed reliable report-

ing by all states and territories without overwhelming health departments during the pandemic response. In this report, we describe the methods and implementation of AHDRA and provide preliminary results from this new surveillance activity.

Methods

From August 30, 2009, through April 6, 2010, CDC requested weekly reporting of influenza-associated hospitalizations and deaths from all 50 US states, the District of Columbia, New York City, and six US territories. States and territories were asked to identify hospitalizations and deaths in their jurisdictions according to either a laboratory-confirmed or syndromic surveillance definition and could use either definition to report hospitalizations or deaths. Laboratory-confirmed cases included those identified by rapid influenza diagnostic test, reverse transcriptase–polymerase chain reaction (RT-PCR) testing, direct fluorescent antigen testing (DFA), immunofluorescent antigen testing, or viral culture; identification of influenza type or subtype was not required. Syndromic reports included cases of pneumonia and influenza based on clinical syndrome, admission or discharge data, or a combination of data elements that could include diagnostic laboratory test results. Prior to the first reporting period, 33 jurisdictions indicated they intended to submit laboratory-confirmed hospitalizations, and 20 indicated they would submit syndromic hospitalizations. Thirty-six jurisdictions intended to submit laboratory-confirmed death reports, and 17 indicated they would submit syndromic deaths; information describing method of reporting was unavailable for one state and four territories. Jurisdictions were instructed to submit aggregate counts each week by age group (0–4, 5–18, 19–24, 25–49, 50–64, and ≥65 years).

Aggregate counts were used to calculate age-specific weekly and cumulative rates per 100 000 according to 2008 post-censal US population estimates. Laboratory-confirmed and syndromic data were analyzed for relative increase or decrease by state each week, and laboratory-confirmed cumulative rates were used to describe the age distribution of pH1N1 influenza-associated hospitalizations and deaths. Owing to differences between laboratory-confirmed and syndromic reporting definitions, we calculated two national incidence estimates of pH1N1 influenza-associated hospitalizations and deaths: one extrapolating reports from laboratory-confirmed jurisdictions to the entire country and one extrapolating reports from syndromic jurisdictions to the entire country. Calculation of rates involving laboratory-confirmed influenza-associated hospitalizations and deaths used the populations of states reporting laboratory-confirmed cases as a denominator; calculations involving syndromic influenza-associated hospitalizations and deaths used the populations of states reporting syndromic cases as a denominator.

Laboratory-confirmed reports from AHDRA were used to estimate weekly, age group-specific national influenza-associated death-to-hospitalization ratios. These ratios were incorporated into a model used to estimate the national illness burden of influenza-associated cases, hospitalizations and deaths during the pandemic, accounting for variation in medical care-seeking, laboratory practice and detection capability, and under-reporting of confirmed cases.[2]

All data were maintained in a database on a secure server at CDC, and all analyses were performed using Microsoft Excel and sas v 9.1 (SAS Institute, Cary, NC, USA). This activity was determined by CDC to be part of routine public health practice and was not subject to institutional review board approval for human research protections.

Results

The median number of jurisdictions reporting laboratory-confirmed hospitalizations each week was 36 (range 29–38), and the median number of jurisdictions reporting syndromic hospitalizations each week was 18 (range 12–19). The median number of jurisdictions reporting laboratory-confirmed deaths each week was 39 (range 30–40), and the median number of jurisdictions reporting syndromic deaths each week was 14 (range 8–16). With the exception of 1–2 weeks at the beginning and end of the surveillance period, reporting was consistent for both laboratory-confirmed and syndromic reporters (Figure 1). Only two jurisdictions changed their surveillance definition during the reporting period (one from laboratory confirmed to syndromic and one from syndromic to laboratory confirmed), and only two jurisdictions failed to report for more than 1 week during the reporting period.

In 27 of 36 jurisdictions reporting laboratory-confirmed hospitalizations for which information was available, the median proportion of hospitals under surveillance was 100% of all hospitals within the jurisdiction (range 18–100%). For 16 of 18 jurisdictions using a syndromic hospitalization definition, the median proportion of hospitals under surveillance was 45% of all hospitals within the jurisdiction (range 9–100%). Information regarding the type of diagnostic test used to identify cases was available for 24 jurisdictions reporting laboratory-confirmed hospitalizations and 22 jurisdictions reporting laboratory-confirmed deaths from September 8 to October 6, 2009. Sixteen of 24 (67%) jurisdictions employed RT-PCR, viral culture, or DFA testing to identify the majority of reported hospitalizations (at least 75% of reported cases in each jurisdiction), and 18 of 22 (82%) jurisdictions used one of these methods to identify the majority of reported deaths.

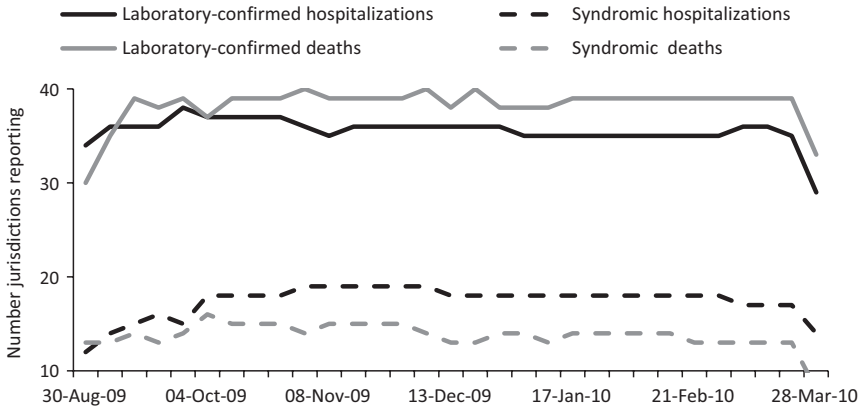

Figure 1. Number of jurisdictions reporting to the Aggregate Hospitalization and Death Reporting Activity by surveillance definition and by week – August 30, 2009 to April 6, 2010.

Laboratory-confirmed cases not identified by RT-PCR, DFA, or viral culture were identified using rapid antigen testing or an unspecified diagnostic test.

A total of 41 689 laboratory-confirmed hospitalizations and 2096 laboratory-confirmed deaths were reported from August 30, 2009, through April 6, 2010. Weekly laboratory-confirmed hospitalizations peaked at >5000 during the last week of October 2009 and declined from that date to <200 by the end of March 2010 (Figure 2). Weekly laboratory-confirmed deaths peaked at nearly 200 during the same week as the laboratory-confirmed hospitalization peak, before declining to <20 per week by the end of March 2010 (Figure 2). The highest laboratory-confirmed hospitalization rate was observed in the 0- to 4-year-old age group, which had a rate 2- to 3-fold higher than those observed in the other age groups (Figure 3). The majority of laboratory-confirmed hospitalizations (>70%) reported to AHDRA were in patients <50 years of age, and fewer than 10% were in patients 65 years of age or older. The AHDRA weekly laboratory-confirmed death rate peaked in October 2009 at 0·078 and fell to <0·001 per 100 000 persons by March 2010. The highest laboratory-confirmed death rate was seen in the 50–64 year old age group, and 69% of laboratory-confirmed deaths occurred in patients between 25 and 64 years of age (Figure 3).

A total of 134 441 syndromic hospitalizations and 13 983 syndromic deaths were reported to AHDRA. Weekly syndromic hospitalizations peaked at nearly 7000 during the last week of October 2009 and were distributed in a pattern similar to the weekly laboratory-confirmed hospitalization curve. Weekly syndromic deaths peaked at 605 approximately 1 month later but did not show a pattern resembling the weekly laboratory-confirmed death curve (Figure 2). The highest rates of syndromic hospitalizations were reported in patients ≥65 years of age (399 per 100 000), and in patients 0–4 years of age (255 per 100 000). Greater than 80% of all syndromic deaths reported were in patients ≥65 years of age, and fewer than 2% were in patients <25 years of age (Figure 3).

Extrapolating AHDRA reports to the entire country yielded cumulative counts of hospitalizations and deaths that estimate what may have been observed had all jurisdictions reported using either a laboratory-confirmed or syndromic surveillance definition (Table 1).

Although the weekly laboratory-confirmed death-to-hospitalization ratio demonstrated considerable variability espe-

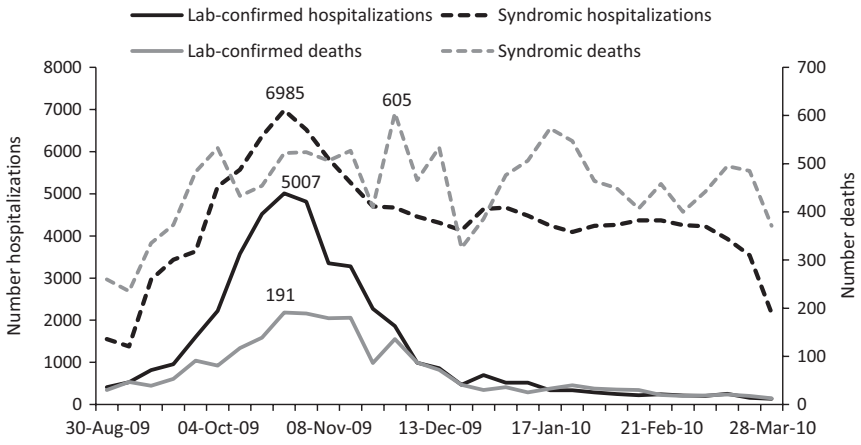

Figure 2. Weekly laboratory-confirmed and syndromic pH1N1 hospitalizations and deaths reported to the Aggregate Hospitalization and Death Reporting Activity – August 30, 2009 to April 6, 2010.

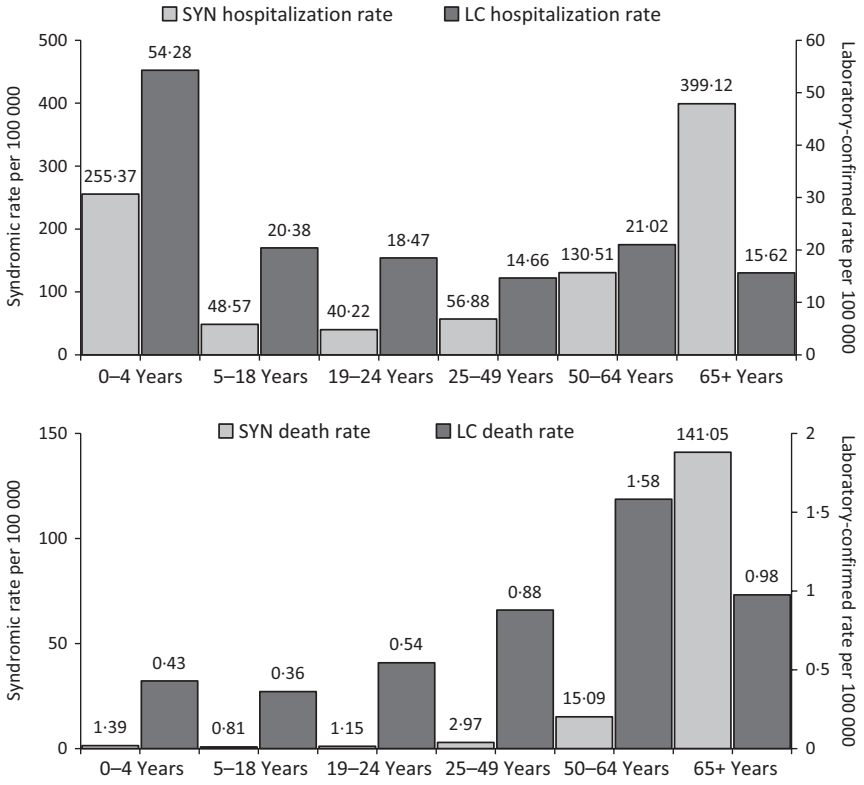

Figure 3. Estimated rates per 100 000 persons of laboratory-confirmed and syndromic pH1N1 hospitalizations and deaths reported to the Aggregate Hospitalization and Death Reporting Activity, by age group, August 30, 2009 to April 6, 2010.

Table 1. Observed and extrapolated* estimates of pH1N1-associated hospitalizations and deaths in the United States reported to the Aggregate Hospitalization and Death Reporting Activity from August 30, 2009 to April 6, 2010

Outcome	Laboratory-confirmed		Syndromic	
	Reported count (rate per 100 000)	Extrapolated count	Reported count (rate per 100 000)	Extrapolated count
Hospitalizations	41 689 (20·76)	63 123	134 441 (139·45)	424 011
Deaths	2096 (0·85)	2584	13 983 (23·82)	72 427

*Extrapolated counts were calculated using the direct method of standardization and represent the number of hospitalizations and deaths that would have occurred in the United States if all states had used either a laboratory-confirmed or a syndromic surveillance definition. Laboratory-confirmed hospitalization and death rates were calculated by dividing the number of cases by the sum of the state populations for states using a laboratory-confirmed definition (207 654 216 for hospitalizations; 245 351 708 for deaths). Syndromic hospitalization and death rates were calculated by dividing the number of cases by the sum of the state populations for states using a syndromic definition (96 405 508 for hospitalizations; 58 708 016 for deaths). Both laboratory-confirmed and syndromic hospitalization and death rates were then applied to the standard population (U.S. Census, July 2008; 304 059 724) to derive extrapolated counts.

cially during the latter part of the surveillance period (3·08–13·76%), the cumulative ratio quickly stabilized near its mean of 5·02% in October 2009 and remained within 1% of this value throughout the remainder of the surveillance period (Figure 4). The cumulative age group-specific laboratory-confirmed death-to-hospitalization ratio was substantially lower for 0- to 18-year-olds compared to older age groups and the overall ratio for all age groups (Figure 4).

Discussion

Laboratory-confirmed data collected by AHDRA helped characterize the epidemiology of pH1N1-associated influenza hospitalizations and deaths in the United States, revealing a time course and illness distribution for pH1N1 that were substantially different from those seen in seasonal influenza epidemics. Aggregate Hospitalization and Death

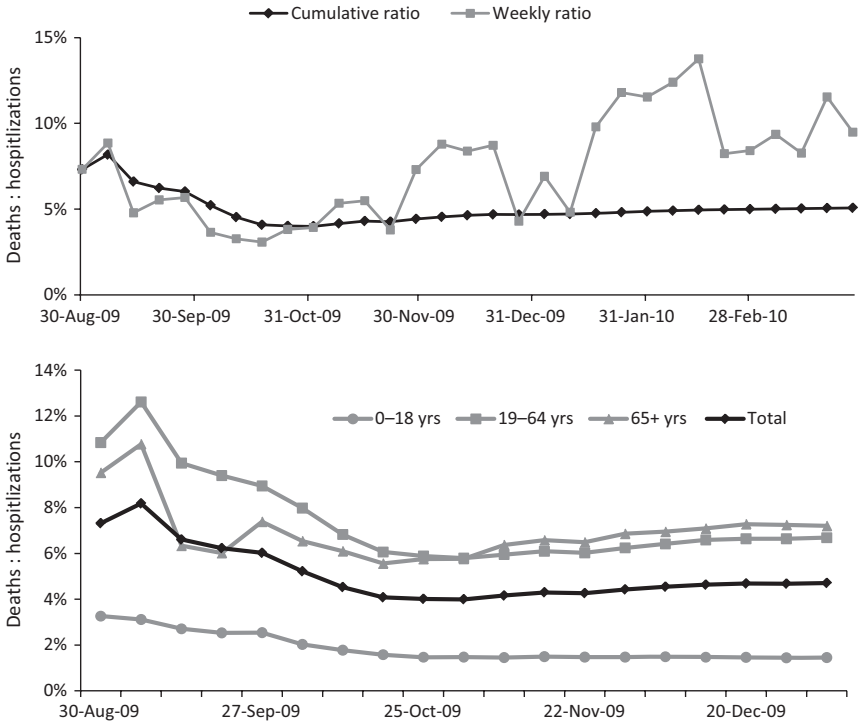

Figure 4. Weekly death-to-hospitalization ratio from laboratory-confirmed reports submitted to the Aggregate Hospitalization and Death Reporting Activity – August 30, 2009 to April 3, 2010. Cumulative death-to-hospitalization ratio by age group from laboratory-confirmed reports submitted to the AHDRA – August 30, 2009 to April 6, 2010.

Reporting Activity laboratory-confirmed peak hospitalizations and deaths occurred much earlier than the typical peak for seasonal influenza activity, which most often occurs during January or February each year.[3,4] Furthermore, the age distribution of laboratory-confirmed hospitalizations reported to AHDRA was markedly different from typical influenza seasons when hospitalizations are more common among persons over 65 years of age.[5–7] Other recent studies corroborate this finding, showing that nearly half of all patients in the United States hospitalized with pH1N1 influenza infections were under the age of 25 years, and <10% were over the age of 65.[5,8] Overall, the age distribution of laboratory-confirmed death rates determined from AHDRA data was also markedly different from that seen in typical influenza seasons. In contrast to typical influenza seasons, when 90% of deaths occur in the elderly,[9,10] 86% of laboratory-confirmed deaths reported to AHDRA were in persons <65 years of age, with the highest rate found in persons aged 50–64 years.

Laboratory-confirmed AHDRA data were also useful in monitoring trends in the distribution of illness and age groups over time in specific jurisdictions. Aggregate Hospitalization and Death Reporting Activity laboratory-confirmed data helped define the beginning and end of the 2009–2010 influenza season and accurately depicted the second wave of pH1N1 illness seen in the fall of 2009;[11] similar double-wave patterns have been seen in previous pandemics.[12–14] AHDRA was also instrumental in the detection of and response to a minor third wave of pH1N1 activity in the Southeast United States in early 2010.[15] AHDRA reporting by state and local health departments allowed tracking of trends in severe disease with greater geographic representativeness than would have been possible with existing systems alone and informed decision-making at the state and national levels. For example, although the Emerging Infections Program (EIP) has conducted population-based surveillance for laboratory-confirmed influenza-associated hospitalizations in the United States since 1995, the EIP network of hospitals conducts surveillance in certain counties in only 16 states.[5] Laboratory-confirmed surveillance via AHDRA during the pandemic was implemented in more than twice the number of states as in the EIP network.

Aggregate Hospitalization and Death Reporting Activity laboratory-confirmed hospitalization and death surveillance was also consistent with data from existing influenza surveillance systems. Emerging Infections Program hospitalizations peaked at approximately the same time in October 2009 as did AHDRA laboratory-confirmed reports, and the age distribution of pH1N1 hospitalizations described by the two systems was similar, with each identifying the highest rate in the 0- to 4-year-old age group and a similar distribution of rates in other age groups.[15] Aggregate Hospitalization and Death Reporting Activity data also accurately reflected outpatient influenza illness during the pandemic. The U.S. Outpatient Influenza-like Illness Surveillance Network (ILINet) collects data from over 3000 healthcare providers each week

on the proportion of patient visits for ILI.* The ILINet weekly percentage peak for the 2009–2010 season (7·7% of all patient visits) occurred 1 week prior to the AHDRA laboratory-confirmed and syndromic hospitalization peaks in October 2009.[15] This approximate 1-week lag between ILI onset and severe outcome (hospitalization or death) has been noted consistently during both annual influenza seasons and during pandemics.[16]

Despite its usefulness during the pandemic, AHDRA was noted to have several limitations. First, jurisdictions were permitted to report according to different surveillance criteria (e.g., use of a laboratory-confirmed or syndromic case definition, multiple diagnostic testing methods) and results therefore did not measure identical outcomes. This disparity is evident in the age distributions of laboratory-confirmed and syndromic hospitalization rates – although both reporting methods show similar peaks in the hospitalization rate for the youngest age group, laboratory-confirmed rates thereafter generally decline with increasing age, while syndromic rates initially decline but then show a dramatic increase for the ≥65-year-old age group. Presumably, the difference is largely because of the relatively low specificity of a syndromic compared to a laboratory-confirmed definition of influenza infection. Syndromic reporting likely captures many hospitalizations associated with non-influenza respiratory illness, which often occur with greater frequency in young children and the elderly,[6,17–19] while laboratory-confirmed reporting is much more likely to identify only cases of influenza illness. Thus, it is inappropriate to make comparisons between reporting jurisdictions in AHDRA without adjusting for differences in reporting methods and practices. Instead, AHDRA's best use may have been to track the progression of the epidemic within each state, a goal consistent with the original intent of the system.

A more important consequence of the decision to allow two surveillance definitions in AHDRA is the inherent limitation of using a syndromic definition to conduct national surveillance for influenza-associated infections. Although AHDRA syndromic data were useful to track trends of disease within those jurisdictions submitting syndromic reports, they may not otherwise accurately reflect the burden or severity of influenza-associated hospitalizations and deaths in the United States. Because the proportion of syndromic respiratory hospitalizations and deaths attributable to influenza is small,[20] it is unclear whether syndromic findings in AHDRA represent influenza infections or hospitalizations and deaths caused by other respiratory illnesses. Interpretation of syndromic data was further complicated by the limited number of hospitals included in syndromic reports (a median of 45% of all hospitals within each reporting jurisdiction).

*For this system, ILI is defined as fever [temperature of 100°F (37.8°C) or greater] and a cough and/or a sore throat in the absence of a known cause other than influenza.

A further limitation of AHDRA is that the system does not collect several potentially useful data elements, such as population denominator information and influenza type or subtype (although >99% of circulating influenza viruses during the surveillance period were pH1N1). Also, the additional effort required of reporting jurisdictions to conduct AHDRA surveillance may be high and may exhaust state and local health department resources during a pandemic. Finally, extrapolated burden estimates derived from AHDRA data do not account for variations in medical care-seeking, laboratory practice and detection capability, degree of under-reporting of confirmed cases, and other population differences across jurisdictions. However, AHDRA laboratory-confirmed data were important components of model-based estimates that do account for these sources of underestimation.[2]

Conclusion

Understanding the impact of pH1N1 influenza hospitalizations and deaths was important to guide the pandemic response and will be important to inform preparedness and response plans for future public health crises. The AHDRA was an important component of US influenza surveillance efforts during the pandemic and provided a level of geographic representativeness and timeliness for reporting of severe influenza-associated outcomes that was not available from existing national surveillance systems. Laboratory-confirmed reporting in AHDRA supplied valuable information to public health practitioners during the pandemic and should inform refinements to seasonal surveillance activities in the coming seasons, as well as revisions of pandemic surveillance plans. Although useful in monitoring trends within jurisdictions, AHDRA syndromic reports, as a measure of influenza-associated hospitalizations and deaths, were difficult to interpret. These data were complicated by limited representativeness and a low specificity for detecting influenza-attributable hospitalizations and deaths among events associated with respiratory illness. Using only syndromic surveillance data to monitor epidemic or pandemic influenza is thus not recommended, particularly in a setting like the 2009 H1N1 pandemic when elderly persons were largely immune because of prior exposures to antigenically related influenza viruses.[21] Because AHDRA was implemented within a few weeks time, the system may prove particularly useful as a prototype for a pandemic or epidemic respiratory infection surveillance system that needs to be implemented quickly and efficiently on a national scale.

Conflicts of interest

None.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the CDC.

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