Influenza-Associated Pediatric Deaths in the United States, 2010–2016

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abstract

BACKGROUND: Influenza-associated pediatric deaths became a notifiable condition in the United States in 2004.

METHODS: We analyzed deaths in children aged <18 years with laboratory-confirmed influenza virus infection reported to the Centers for Disease Control and Prevention during the 2010–2011 to 2015–2016 influenza seasons. Data were collected with a standard case report form that included demographics, medical conditions, and clinical diagnoses.

RESULTS: Overall, 675 deaths were reported. The median age was 6 years (interquartile range: 2–12). The average annual incidence was 0.15 per 100 000 children (95% confidence interval: 0.14–0.16) and was highest among children aged <6 months (incidence: 0.66; 95% confidence interval: 0.53–0.82), followed by children aged 6–23 months (incidence: 0.33; 95% confidence interval: 0.27–0.39). Only 31% (n = 149 of 477) of children aged ≥6 months had received any influenza vaccination. Overall, 65% (n = 410 of 628) of children died within 7 days after symptom onset. Half of the children (n = 327 of 654) had no preexisting medical conditions. Compared with children with preexisting medical conditions, children with none were younger (median: 5 vs 8 years old), less vaccinated (27% vs 36%), more likely to die before hospital admission (77% vs 48%), and had a shorter illness duration (4 vs 7 days; P < .05 for all).

CONCLUSIONS: Each year, influenza-associated pediatric deaths are reported. Young children have the highest death rates, especially infants aged <6 months. Increasing vaccination among children, pregnant women, and caregivers of infants may reduce influenza-associated pediatric deaths.

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Ms Shang performed the statistical analysis, interpreted the data, and drafted and revised the manuscript; Mrs Blanton acquired and interpreted the data and revised the manuscript; Ms Brammer acquired data, supervised data collection, interpreted the data, and revised the manuscript; Drs Olsen and Fry conceptualized and designed the study, interpreted the data, and revised the manuscript; and all authors approved the final manuscript as submitted.

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WHAT'S KNOWN ON THIS SUBJECT: In 2004, influenza-associated pediatric mortality became a notifiable condition, and deaths are reported annually. Young children and children with preexisting conditions, particularly neurologic disorders, are overrepresented among influenza-associated pediatric deaths. Influenza vaccination for all children ≥6 months old is recommended.

WHAT THIS STUDY ADDS: From 2010 to 2016, young children continued to be at the greatest risk for influenza-associated pediatric deaths. Children without preexisting medical conditions accounted for half of all deaths. Vaccination coverage was low among influenza-associated pediatric deaths.

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In 2004, after a particularly severe influenza season with 153 reported pediatric deaths, influenza-associated pediatric deaths became a nationally notifiable disease, and the Influenza-Associated Pediatric Mortality Surveillance System was implemented in the United States.[1,2] Since 2004, surveillance data have been used to describe the burden and risk factors associated with both seasonal and pandemic influenza-associated pediatric deaths.[3–8] Previous results that were summarized from this surveillance system have contributed to evidence used by the Advisory Committee on Immunization Practices for influenza vaccination recommendations for children.[9,10] In this report, we update previous reports and describe influenza-associated pediatric deaths for the 6 seasons after the 2009 (H1N1)pdm09 pandemic, from the 2010–2011 season to the 2015–2016 season.

METHODS

Data Source

We analyzed data from the Influenza-Associated Pediatric Mortality Surveillance System for 6 influenza seasons, 2010–2011 to 2015–2016. For this analysis, an influenza season was defined as October 1 through September 30 of the following year. This system has been described in detail previously.[3,6–8] Briefly, an influenza-associated pediatric death is defined as a death resulting from a clinically compatible illness in a US resident aged <18 years with laboratory-confirmed influenza virus infection, with no period of complete recovery between the illness and death. State and territorial health departments report deaths to the Centers for Disease Control and Prevention using a standard case report form and transmit the information through a secure, Web-based interface. The form is used to collect information on demographics, dates of illness onset and death, hospital admissions, complications, location of death, preexisting medical conditions, influenza virus testing and results, and influenza vaccination status. In addition, states report whether bacterial testing was performed on specimens from sterile sites after illness onset or from postmortem tissue (if the specimen was collected within 24 hours after death) and results.

We compared the relative proportion of influenza A and B viruses detected among pediatric deaths with the proportions detected in persons aged ≤24 years as reported by the US Influenza Virologic Surveillance System. The Influenza Virologic Surveillance System collects data from ∼100 public health and 300 clinical laboratories in the United States through either the US World Health Organization Collaborating Laboratories System or the National Respiratory and Enteric Virus Surveillance System.[11] Each week, these laboratories report to the Centers for Disease Control and Prevention the total number of respiratory specimens tested, the number that are positive for influenza viruses by virus type, and the (when available) influenza A virus subtypes and influenza B virus lineage. In addition, the World Health Organization collaborating laboratories report on the age or age group (0–4 years, 5–24 years, 25–64 years, and ≥65 years) of the person tested.[12]

Definitions

Children aged ≥6 months at the date of illness onset were considered eligible for vaccination. Children aged 6 months to 8 years were considered fully vaccinated if they were reported to have received the recommended doses of the influenza vaccine ≥14 days before illness onset in that season[13–18]; they were considered partially vaccinated if they were reported to have received 1 dose of the vaccine ≥14 days before illness onset but no vaccination in the immediate-previous season or if they received 2 doses in the current season but the interval between the 2 doses was <28 days or the interval between the second dose and illness onset was <14 days. Data on maternal vaccination were not collected. Children with ≥1 of the following conditions before illness onset were considered to have a preexisting medical condition: asthma and/or reactive airway disease, cancer, cardiac and congenital heart diseases, cerebral palsy, chronic pulmonary diseases, cystic fibrosis, chromosomal diseases, moderate to severe developmental delay, diabetes mellitus, endocrine disorders, febrile seizures, immunosuppressive conditions, metabolic diseases, mitochondrial disorder, neurologic or neurodevelopmental disorders, neuromuscular disorder, premature at birth, pregnancy, renal diseases, or seizure disorder.

Statistical Analysis

A Wilcoxon rank test was used to compare medians, and a χ^2 test was used to compare proportions among different groups. A Cochran-Armitage trend test was used for trend analysis. Population estimates from the US Census Bureau (2011–2015) were used to calculate minimum mortality rates.[19] Population estimates for 2016 were not available at the time of this analysis, so the population estimates of 2015 were used for 2016 population calculation. Although the true burden was likely underestimated, the mortality rates allowed us to compare the burden across different groups. Exact 95% confidence intervals were calculated with Poisson distribution. All *P* values were 2 sided, and *P* values <.05 were considered statistically significant. Data were analyzed with SAS 9.3 (SAS Institute, Inc, Cary, NC).

TABLE 1 Demographic Characteristics Among Influenza-Associated Pediatric Deaths in the United States, 2010–2016

Characteristic	No. Children (%)	Average Annual Incidence of Deaths per 100 000 Children (95% CI)
All ages[a]	675 (100)	0.15 (0.14–0.16)
<6 mo	78 (12)	0.66 (0.53–0.82)
6–23 mo	116 (17)	0.33 (0.27–0.39)
24–59 mo	103 (15)	0.14 (0.12–0.17)
5–8 y	131 (19)	0.13 (0.11–0.16)
9–12 y	117 (17)	0.12 (0.10–0.14)
13–17 y	130 (19)	0.10 (0.09–0.12)
Race[b]		
White	435 (72)	0.13 (0.12–0.15)
African American	111 (18)	0.17 (0.14–0.20)
Asian American	29 (5)	0.13 (0.09–0.19)
Native Hawaiian and/or Pacific Islander	8 (1)	0.64 (0.32–1.30)
American Indian and/or Alaskan native	20 (3)	0.29 (0.18–0.44)
Ethnicity[c]		
Non-Hispanic, non-Latino	436 (76)	0.13 (0.12–0.14)
Hispanic or Latino	141 (24)	0.13 (0.11–0.14)
Sex		
Male	351 (52)	0.16 (0.14–0.17)
Female	324 (48)	0.15 (0.13–0.17)
Geographic census region[d]		
South	263 (39)	0.16 (0.14–0.18)
West	173 (26)	0.16 (0.14–0.19)
Northeast	97 (14)	0.14 (0.11–0.17)
Midwest	140 (21)	0.15 (0.12–0.17)

The overall national incidence rate, incidence rates by sex, and incidence rates by census regions are adjusted by age group. CI, confidence interval.

[a] Age at date of death.

[b] Races of 72 children are unknown

[c] Ethnicity of 98 children is unknown.

[d] Two cases from Puerto Rico were excluded from the calculation because of their geographic census region.

RESULTS

From October 2010 to September 2016, 675 influenza-associated pediatric deaths were reported by 49 states and Puerto Rico. The median age was 6 years (interquartile range [IQR]: 2–12 years). The average annual mortality rate was 0.15 deaths per 100 000 children (Table 1). Children aged <6 months had the highest mortality rate (0.66 deaths per 100 000 children). Compared with children aged 13 to 17 years, infants aged <6 months were >6 times as likely to have an influenza-associated death, and children aged 6 to 23 months were >3 times as likely to have an influenza-associated death. During the 6 seasons examined, annual mortality rates were consistently the highest in children <6 months and children 6 to 23 months. Native Hawaiian and/or Pacific Islander and American Indian and/or Alaskan native children had higher mortality rates than children who were white, African American, or Asian American.

The annual average number of influenza-associated pediatric deaths from 2010 to 2016 was 113; the 2012–2013 season had the highest number of pediatric deaths reported (n = 171), and the 2011–2012 season had the lowest number (n = 37; Fig 1).[12] Overall, 65% (n = 436 of 675) of pediatric deaths coincided with an influenza A virus infection, 33% (n = 225 of 675) of case patients had an influenza B virus infection reported, <1% (n = 5 of 675) had A and B viruses coinfections, and 1% (n = 9 of 675) were not typed. This relative proportion of A and B viruses for each season was similar to that seen among all persons aged ≤24 years in the virologic surveillance (except for the 2012–2013 season, during which influenza A viruses [48%] were detected less frequently than B viruses [52%] among pediatric deaths). In virologic surveillance, influenza A viruses were predominant (>65%) during all 6 seasons. The actual proportion of influenza B viruses detected in pediatric deaths was higher than the proportion of influenza B viruses detected in children of a similar age (≤24 years old) from virologic surveillance for each of the 6 seasons. This finding remained when we limited the analysis to children aged <5 years in both surveillance systems (data not shown). Overall, among the 4 age groups of children who died (<6 months, 6 to 23 months, 24 to 59 months, and 5–17 years), young children had a higher proportion of influenza A viruses detected than older children; 83% (n = 63 of 76) of children aged <6 months had influenza A viruses detected compared with 58% (n = 216 of 371) of children aged 5 to 17 years (test for trend P < .01).

Half of the children who died had ≥1 preexisting medical condition before illness onset (Table 2). Neurologic disorders (27%) were the most commonly reported conditions, followed by asthma and/or reactive airway disease, cardiac or congenital heart disease, and chronic pulmonary diseases. Of the 477 children who were eligible for vaccination and for whom vaccination information was available, 31% had evidence of any influenza vaccination, and 22% had evidence of full vaccination. Two of the children who were partially vaccinated were <7 months of age and therefore did not have time for full vaccination before death. The median time from symptom onset to death was 5 days (IQR: 2–11 days). The majority of children (65%) died within 7 days of illness onset, and 13% died within 1 day of illness onset. Thirty-eight percent

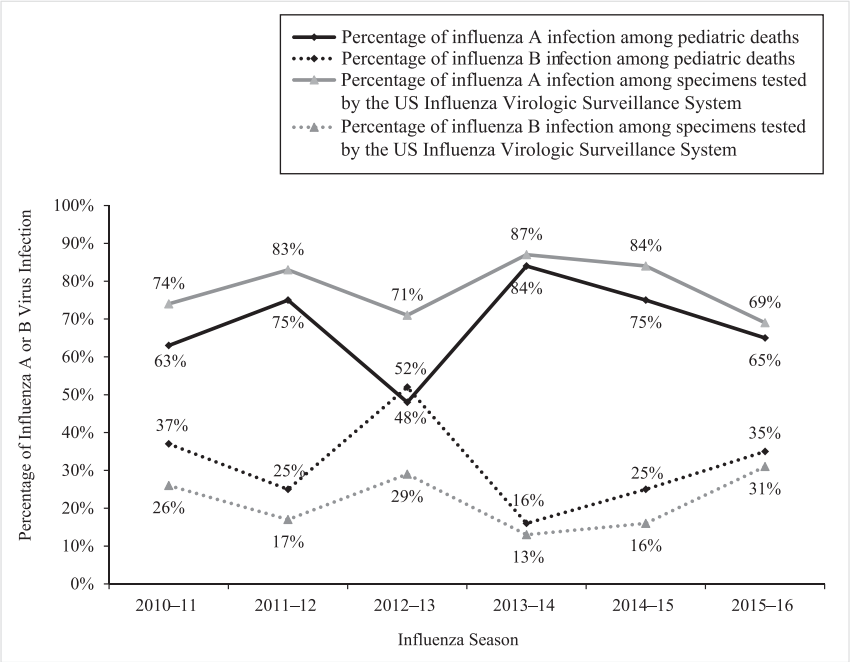

FIGURE 1

Comparison of influenza A and B viruses detected among influenza-associated pediatric deaths and persons aged ≤24 years by the Influenza Virologic Surveillance System in the United States (2010–2016). The number of specimens that were able to be typed as either influenza A or B infection among pediatric deaths were as follows: 2010–2011 season, 123 of 123; 2011–2012 season, 36 of 37; 2012–2013 season, 168 of 171; 2013–2014 season, 107 of 111; 2014–2015 season, 145 of 148; and 2015–2016 season, 82 of 85. *P* values for the difference in the proportions of influenza B viruses between the 2 systems were as follows: 2010–2011 season, $P < .01$; 2011–2012 season, $P = .06$; 2012–2013 season, $P < .01$; 2013–2014 season, $P = .38$; 2014–2015 season, $P = .01$; 2015–2016 season, $P < .01$; and from 2010 to 2016, $P < .01$. Data were downloaded from FluView.[20]

(*n* = 255 of 665) of the children died in the community or emergency department (ED) before hospital admission.

Specimens from normally sterile sites were collected from 362 children for bacterial testing, among these, blood or blood combined with other samples (85%) were the most frequently reported. Overall, 43% had bacteria detected. Of those, β-hemolytic *Streptococcus* (19%) and *Staphylococcus aureus* (17%) were the most commonly reported bacterial coinfections (Table 2). The majority (66%; *n* = 31 of 47) of *S aureus* isolates that had sensitivity testing performed on them were antibiotic resistant. We found no difference in the proportion of bacterial coinfections that were detected among children who died within 5 days of illness onset compared with children who died later in their illnesses ($P = .39$). In 13% (*n* = 62 of 488) of influenza-associated pediatric deaths, coinfection with another virus was reported, with respiratory syncytial virus (40%) being the most frequently identified.

Overall, clinical complications before death were reported for 75% of the children (Table 2). The most frequently reported complications were pneumonia (41%), sepsis or shock (31%), and acute respiratory distress syndrome (ARDS) (29%). We did not detect a higher proportion of invasive bacterial infections among patients with pneumonia complications compared with nonpneumonia patients (43% [*n* = 73 of 167] vs 40% [*n* = 53 of 133]; $P = .50$). In addition to the syndromes that are typically recognized as complications, 22 (4%) and 17 (3%) deaths had bronchiolitis and croup reported, respectively. Antiviral treatment was reported in 53% (*n* = 321 of 611) of pediatric deaths; as expected, most antiviral use (*n* = 282; 88%) was among children who were admitted to the hospital. Antibiotic treatment was reported in 51% (*n* = 310 of 611) of pediatric deaths, and most antibiotic use (*n* = 266; 86%) was among children who were admitted to the hospital.

Children who died with and without preexisting medical conditions differed by age, vaccination status, bacterial coinfections, clinical complications, illness duration, antiviral treatment, and location of death (Table 3). Preexisting medical conditions were more common among older children, and the proportion of children who died with preexisting medical conditions increased with age; of children <6 months old, 29% had preexisting medical conditions, but 60% of children aged 9 to 17 years had preexisting medical conditions (*P* for trend <.01). Children without preexisting medical conditions were less likely to be vaccinated, have clinical complications, receive antiviral treatment, and to be admitted to a hospital, but they were more likely to have bacterial coinfections or die more quickly than children with preexisting medical conditions. Among the children who died before hospital admission, the median number of days from illness onset to death was the same for children with or without preexisting medical conditions (Fig 2). Among children who were admitted to the hospital before death, the time between illness onset and death among those with preexisting medical conditions was longer compared with those without preexisting medical conditions. However, the time from illness onset to admission was the same for these 2 groups (median: 2 days; $P = .10$).

TABLE 2 Characteristics of Influenza-Associated Pediatric Deaths in the United States, 2010–2016

Characteristics	Value, *n*/*N* (%)
Preexisting medical conditions	
≥1 preexisting medical conditions[a]	327/654 (50)
Neurologic disorders[b]	178/654 (27)
Asthma, reactive airway disease	78/654 (12)
Cardiac and congenital heart diseases	76/654 (12)
Pulmonary diseases[c]	65/654 (10)
Endocrine diseases[d]	37/654 (6)
Premature at birth	33/654 (5)
Immunosuppressive conditions[e]	30/654 (5)
Renal diseases	15/654 (2)
Other conditions[f]	10/654 (2)
No information reported	23/677 (3)
Information reported	654/677 (97)
Influenza vaccination status	
Ineligible for vaccination	81/675 (12)
Eligible but no information reported	117/594 (20)
Eligible and with information reported	477/594 (80)
No vaccination	328/477 (69)
Any vaccination	149/477 (31)
Full vaccination	105/477 (22)
Days from symptom onset to death	
≤1	83/628 (13)
2–7	327/628 (52)
>7	218/628 (35)
No information reported	47/675 (7)
Information reported	628/675 (93)
Location of death	
Community	116/665 (17)
ED	139/665 (21)
Inpatient ward or ICU	410/665 (62)
No information reported	10/675 (1)
Information reported	665/675 (99)
Bacterial coinfections from normally sterile sites	
≥1 bacterial coinfections[a]	156/362 (43)
β-hemolytic *Streptococcus*	69/362 (19)
S aureus[g]	63/362 (17)
Streptococcus pneumoniae	30/362 (8)
Pseudomonas aeruginosa	11/362 (3)
Escherichia coli	8/362 (2)
Other Gram-negative bacteria[h]	25/362 (7)
No information reported	313/675 (46)
Information reported	362/675 (54)
Clinical complications during acute illness phase	
≥1 clinical complications[a]	451/601 (75)
Pneumonia	245/601 (41)
Sepsis or shock	185/601 (31)
ARDS	175/601 (29)
Seizures	79/601 (13)
Encephalopathy or encephalitis	56/601 (9)
Cardiomyopathy, myocarditis	45/601 (7)
Hemorrhagic pneumonia, pneumonitis	31/601 (5)
Other complications	176/601 (29)
No information reported	74/675 (11)
Information reported	601/675 (89)
Mechanical ventilation	
No information reported	41/675 (6)
Information reported	634/675 (94)
With mechanical ventilation treatment	354/634 (56)

[a] The categories shown are not mutually exclusive because some children had ≥1 preexisting medical condition, infection, or complication.

[b] Neurologic disorders included moderate to severe developmental delay (*n* = 141), chromosomal diseases (*n* = 81), seizure disorder (*n* = 93), neurodevelopmental disorder (*n* = 83), cerebral palsy (*n* = 50), neuromuscular disorder (*n* = 12), and mitochondrial disorder (*n* = 8).

DISCUSSION

During influenza seasons 2010–2011 to 2015–2016, an average of 113 influenza-associated pediatric deaths were reported each year. This number is likely an underestimate, with the true number perhaps being as much as twofold higher.[21] Half of the reported deaths were among children with preexisting medical conditions, with neurologic disorders being the most commonly reported. Children aged <6 months were >4 times as likely and children aged 6 to 23 months were >2 times as likely to die compared with children aged 2 to 17 years. Young children <2 years of age were less likely to have preexisting medical conditions compared with older children who died. Reported influenza vaccination coverage levels among pediatric deaths for all age groups were below the nationally reported level of 59% during the 2015–2016 influenza season.[22] Our results reinforce the need to continue efforts to improve vaccination coverage among all children aged ≥6 months as well as pregnant women and household members who care for infants aged <6 months to meet the Healthy People 2020 goal of 70%.[23]

Young children are at an increased risk for severe influenza infections. In addition to high rates of influenza-associated deaths, young children also had the highest rates of influenza-associated pediatric hospitalization from 2003 to 2009 and pediatric hospitalizations because of lower respiratory tract infections from 2007 to 2011.[24–27] Also, most young children who were hospitalized had no preexisting medical conditions.[25,26,28,29] For children aged ≥6 months, influenza vaccination has been estimated to reduce the risk of pediatric deaths by half among children with preexisting medical conditions and by nearly two-thirds among children without preexisting medical conditions from 2010 to 2014.[30] Vaccination

TABLE 2 Continued

[c] Pulmonary diseases included chronic pulmonary disease (n = 62) and cystic fibrosis (n = 3).

[d] Endocrine diseases included endocrine disorder (n = 27) and diabetes mellitus (n = 10).

[e] Immunosuppressive conditions included cancer (n = 17) and immunosuppressive conditions (n = 14).

[f] Other conditions included febrile seizures (n = 4), pregnancy (n = 2), and other nondefined diseases (n = 4).

[g] Sixty-four percent (n = 30 of 47) of *S aureus* isolates were methicillin resistant, 34% (n = 16 of 47) were methicillin sensitive, and 2% (n = 1 of 47) were erythromycin, penicillin, and ampicillin resistant. The drug-resistant status of 16 isolates is unknown.

[h] Other Gram-negative bacteria included *Citrobacter freundii* complex (n = 3), *Enterobacter cloacae* (n = 3), *Burkholderia* spp (n = 1), *Stenotrophomonas maltophilia* (n = 2), *Klebsiella pneumoniae* (n = 3), *Haemophilus influenzae* non–type B (n = 5), *Haemophilus* spp (n = 1), *Moraxella catarrhalis* (n = 2), *Morganella morganii* (n = 1), *Serratia marcescens* (n = 1), *S maltophilia* (n = 1), *Neisseria lactamica* (n = 1), and *Veillonella* species (n = 1).

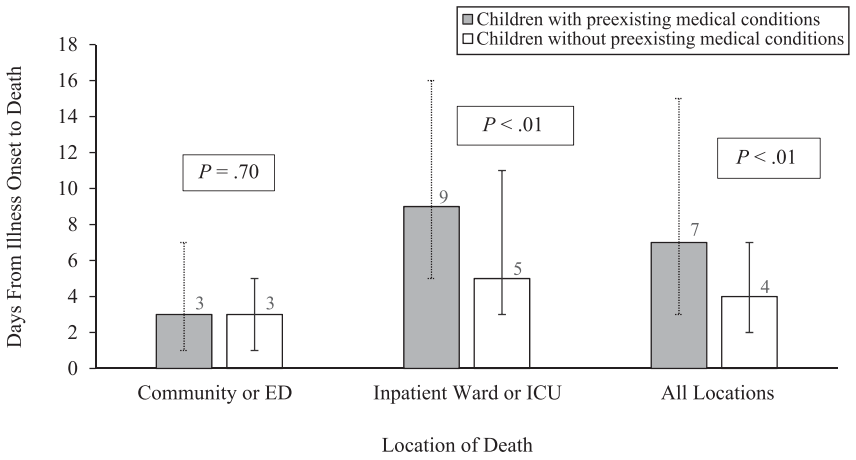

FIGURE 2

Days from illness onset to death for children with influenza-associated pediatric death by presence of preexisting medical conditions and location of death in the United States (2010–2016; N = 647). Days are presented as a median and IQR.

TABLE 3 Selected Characteristics Among Influenza-Associated Pediatric Deaths by Presence of Preexisting Medical Conditions in the United States, 2010–2016 (N = 654)

Characteristic	Children Without Preexisting Medical Conditions (N = 327)	Children With Preexisting Medical Conditions (N = 327)	P
Age[a], y, median (IQR)	5 (1–10)	8 (3–13)	<.01
Vaccination status			
Any	60/225 (27)	88/244 (36)	.01
Full	37/225 (17)	67/244 (27)	—
Invasive bacterial coinfections	91/172 (53)	64/185 (35)	<.01
Clinical complications	214/291 (74)	254/299 (85)	<.01
Pneumonia	102/291 (35)	138/299 (46)	<.01
ARDS	69/291 (24)	104/299 (35)	<.01
Hemorrhagic pneumonia, pneumonitis	21/291 (7)	10/299 (3)	.035
Days from onset to death, median (IQR)	4 (2–7)	7 (3–15)	<.01
≤1	51/307 (17)	29/305 (10)	<.01
2–7	184/307 (60)	134/305 (44)	—
>7	72/307 (23)	142/305 (47)	—
Location of death			
Community	81/323 (25)	29/324 (9)	<.01
ED	86/323 (27)	45/324 (14)	—
Inpatient ward or ICU	156/323 (48)	250/324 (77)	—
Antiviral treatment	127/304 (42)	192/296 (65)	<.01
Mechanical ventilation	148/323 (46)	206/311 (66)	<.01

Unless otherwise specified, data are presented as n/N (%). —, not applicable.

[a] At date of death.

in pregnant woman has been demonstrated to reduce laboratory-confirmed influenza among infants in the first 4 to 6 months of life.[31–33]

Children with certain preexisting medical conditions are at an increased risk for influenza complications,[34] including hospitalization or death.[35,36] Among influenza-associated pediatric deaths, neurologic disorders were the most commonly reported conditions, as previously described.[1,7,8] These conditions are rare in the general population but are overrepresented among pediatric deaths and children who are hospitalized with influenza.[37–39] Vaccine coverage was low for these high-risk children, and ongoing educational efforts are needed.

The time from illness onset to death was short for most children in our data set. The majority of children died within 7 days after illness onset, and 13% died within 1 day; this percentage was even higher among children without preexisting medical conditions. Also, ∼40% of the children died in the community or ED before hospital admission. The reasons for such a rapid demise remain unknown, but we cannot rule out that the overall shorter illness duration in previously healthy children may be related to differences in health care–seeking behavior or the timing of health care interventions after illness onset.

During the 6 seasons studied, the proportion of influenza B viruses relative to A viruses detected among pediatric deaths was higher than among children of a similar age in the US Influenza Virologic Surveillance System. This has been documented previously.[1,3,6,8] Thus, both influenza A and B viruses are associated with pediatric deaths, but the relative proportion of B virus infections might be slightly higher among deaths than in general surveillance. Additional studies are underway in an effort to describe this observation

more completely. Some researchers suggest slower age-dependent accumulation in the innate immune response to influenza B relative to influenza A illnesses, although the exact immune system changes are unknown.[40,41]

The children who died experienced a range of complications with pneumonia, sepsis, or shock, and ARDS was reported most commonly, which is similar to what's been revealed in previous reports.[1,8] Pneumonia and ARDS were also frequently reported in hospitalized pediatric patients.[42–44] Consistent with previous reports, *Streptococcus* and *S aureus* were the most commonly identified bacterial coinfections in addition to influenza virus infection.[1,5,8] More bacterial coinfections were identified in children without preexisting medical conditions than in those with preexisting conditions, which is consistent with other reports.[8,37] Information on the receipt of other pediatric vaccines was not collected. However, these results highlight the importance of the receipt of vaccination against other vaccine-preventable diseases among young children and ongoing research to prevent respiratory diseases that currently have no vaccines.

Overall, more than half of the pediatric patients who died were reported to have received antiviral or antibiotic treatment; we do not have information on the timing of treatment relative to death. Antiviral treatment is recommended for all persons with severe illnesses that are suspected to be associated with influenza, such as hospitalized illness, and for illnesses among persons with high-risk conditions.[45]

Our findings are subject to several limitations. First, there is a potential underestimation of mortality numbers and rates because influenza testing was not always performed or was performed later in the illness, when the virus could not be detected anymore. The testing practices may also vary by age and the presence of preexisting medical conditions. In addition to underestimating mortality, these variations in testing practices might also affect the representation of certain children in our data. Second, the misclassification of preexisting medical conditions and vaccination status may have occurred because of the challenges of diagnosing underlying conditions in young children and missing data. Third, we compared the proportion of influenza virus types among pediatric deaths to surveillance data from a larger age group (persons aged ≤24 years) because of the format of surveillance data. Finally, we are unable to assess the effect of antiviral or antibacterial treatment on deaths with the information collected.

CONCLUSIONS

Influenza-associated pediatric deaths are reported each year in the United States. Influenza-associated pediatric mortality was highest among young children aged <2 years. Although many pediatric deaths occurred in children with preexisting medical conditions, half of the deaths were in previously healthy children. This report reinforces the need to improve influenza vaccination coverage to meet the Healthy People 2020 goals. Also, prompt antiviral treatment should be initiated when young children and children with high-risk conditions are suspected to have influenza and when children are hospitalized with suspected influenza.

ABBREVIATIONS

ARDS: acute respiratory distress syndrome
ED: emergency department
IQR: interquartile range

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