Influenza-Associated Hospitalizations in the United States

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Context Respiratory viral infections are responsible for a large number of hospitalizations in the United States each year.

Objective To estimate annual influenza-associated hospitalizations in the United States by hospital discharge category, discharge type, and age group.

Design, Setting, and Participants National Hospital Discharge Survey (NHDS) data and World Health Organization Collaborating Laboratories influenza surveillance data were used to estimate annual average numbers of hospitalizations associated with the circulation of influenza viruses from the 1979-1980 through the 2000-2001 seasons in the United States using age-specific Poisson regression models.

Main Outcome Measures We estimated influenza-associated hospitalizations for primary and any listed pneumonia and influenza and respiratory and circulatory hospitalizations.

Results Annual averages of 94 735 (range, 18 908-193 561) primary and 133 900 (range, 30 757-271 529) any listed pneumonia and influenza hospitalizations were associated with influenza virus infections. Annual averages of 226 054 (range, 54 523-430 960) primary and 294 128 (range, 86 494-544 909) any listed respiratory and circulatory hospitalizations were associated with influenza virus infections. Persons 85 years or older had the highest rates of influenza-associated primary respiratory and circulatory hospitalizations (1194.9 per 100 000 persons). Children younger than 5 years (107.9 primary respiratory and circulatory hospitalizations per 100 000 persons) had rates similar to persons aged 50 through 64 years. Estimated rates of influenza-associated hospitalizations were highest during seasons in which A(H3N2) viruses predominated, followed by B and A(H1N1) seasons. After adjusting for the length of each influenza season, influenza-associated primary pneumonia and influenza hospitalizations increased over time among the elderly. There were no significant increases in influenza-associated primary respiratory and circulatory hospitalizations after adjusting for the length of the influenza season.

Conclusions Significant numbers of influenza-associated hospitalizations in the United States occur among the elderly, and the numbers of these hospitalizations have increased substantially over the last 2 decades due in part to the aging of the population. Children younger than 5 years had rates of influenza-associated hospitalizations similar to those among individuals aged 50 through 64 years. These findings highlight the need for improved influenza prevention efforts for both young and older US residents.

JAMA. 2004;292:1333-1340 www.jama.com

NATIONAL ESTIMATES OF INfluenza-associated mortality have been important for understanding the epidemiology of influenza over time and for resource planning for influenza epidemics and future influenza pandemics.[1-4] However, mortality incompletely reflects the severity of influenza infections because many severe illnesses do not result in death. In addition, influenza types and subtypes have differential effects on morbidity and mortality. For example, during some seasons, influenza A(H1N1) and B viruses are associated with substantial numbers of hospitalizations and outpatient visits but small increases in mortality.[5-7] Furthermore, influenza-associated hospitalizations contribute an important proportion of the total health burden and economic costs of influenza epidemics and pandemics.[2,8-10]

Previous studies have estimated numbers and rates of influenza-associated hospitalizations by age group, risk status, influenza type and subtype, and vaccine status.[11-20] However, only 2 studies, both using National Hospital Discharge Survey (NHDS) data, have provided national estimates of influenza-associated hospitalizations in the United States.[11,13] Barker[11] estimated influenza-associated hospitalizations from 1970 through 1978 in 3 age groups using 3 mutually exclusive hospital outcomes: all-cause pneumonia and influenza, respiratory disease excluding all-cause pneumonia and influenza, and acute cardiac failure. The assessment of influenza-associated hospitalizations was limited to seasons in which influenza A(H3N2) viruses predominated and the assessment used winter seasons in which in-

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fluenza A(H1N1) and B viruses predominated as the baseline period from which to estimate A(H3N2) excess hospitalizations. In the second study, Simonsen and colleagues[13] estimated annual numbers of influenza-associated hospitalizations by virus type and subtype from the 1969-1970 through 1994-1995 seasons for primary pneumonia and influenza hospitalizations for 2 age groups ($<$64 years and $\geq$65 years). In most seasons, November hospitalizations were used as the baseline for estimating influenza-associated hospitalizations. In 6 seasons when the influenza circulation began late, a December baseline was used to estimate such hospitalizations.

We estimated annual numbers of influenza-associated hospitalizations from the 1979-1980 through the 2000-2001 respiratory seasons, a 22-year period for which national influenza laboratory surveillance data were available. We modified Poisson regression methods previously used to estimate influenza-associated mortality in the United States[21] to estimate numbers and rates of influenza-associated hospitalizations.

METHODS

Definition of Respiratory Season

Influenza viruses typically circulate during winter months and across calendar years. Therefore, we defined July 1 through June 30 of the following year as a respiratory season so that an entire influenza season was studied.

National Viral Surveillance Data

In the United States, laboratory-based surveillance for influenza viruses is conducted from October through mid May (calendar week 40 through week 20). For the influenza virus surveillance periods from the 1979-1980 through 2000-2001 seasons, we obtained numbers of respiratory specimens that tested positive for influenza. Specimens are reported weekly by 50 to 75 US-based World Health Organization (WHO) collaborating virology laboratories to the Centers for Disease Control and Prevention. The laboratories provide numbers of total respiratory specimens tested for influenza and positive influenza tests by virus type and subtype.[22] The monthly percentages of specimens that tested positive for influenza viruses were used in estimating the effect of influenza circulation on monthly hospitalizations in the United States. For summary purposes, we defined a predominant influenza virus type or subtype for each season based on whether the influenza type or subtype constituted more than 20% of the total influenza specimens that had tested positive in a given season.

NHDS Hospital Discharge Diagnoses

Hospital discharge diagnosis records were obtained from the NHDS[23-28] for the 1979-1980 through 2000-2001 seasons. National Hospital Discharge Survey hospital discharge data are collected and reported by month for approximately 270 000 inpatient records sampled from approximately 500 hospitals. These records represent approximately 1% of all inpatient hospitalizations in the United States.[29,30] The sampling design assigns a discharge weight to each hospital record. The discharge weight is the number of hospitalizations that the hospital record represents, and use of these weights permits calculations of nationally representative numbers of hospitalizations. We summed the corresponding discharge weights by month to obtain nationally representative numbers of hospitalizations.

International Classification of Diseases, Ninth Revision, Clinical Modification (*ICD-9-CM*) codes[31] were used to categorize hospitalizations. Monthly hospitalizations were summarized by both first-listed and any-listed *ICD-9-CM* discharge codes. We considered the first-listed discharge code as the primary discharge diagnosis. We examined 2 diagnostic categories: pneumonia and influenza hospitalizations (*ICD-9-CM* codes 480-487) and respiratory and circulatory hospitalizations (*ICD-9-CM* codes 390-519). Thus, pneumonia and influenza hospitalizations were a subset of respiratory and circulatory hospitalizations.

Statistical Analyses

We modified methods developed for estimating US influenza-associated mortality[21] to estimate influenza-associated hospitalizations with NHDS data. One advantage of this method is that it permitted the effect of influenza circulation to vary by month, and therefore hospitalization estimates could also fluctuate with influenza activity. Poisson regression models were fit to 8 age groups: younger than 5 years, 5 through 49 years, 50 through 64 years, 65 through 69 years, 70 through 74 years, 75 through 79 years, 80 through 84 years, and 85 years or older. Influenza virus circulation terms representing the percentages of specimens testing positive for influenza A(H1N1), A(H3N2), and B viruses during each month in the study period were included in all models.

The age-specific Poisson regression models we used can be written as

$$Y = \alpha \exp(\beta_0 + \beta_1[t] + \beta_2[t^2] + \beta_3[t^3] + \beta_4[\sin(2t\pi/12)] + \beta_5[\cos(2t\pi/12)] + \beta_6[A(H1N1)] + \beta_7[A(H3N2)] + \beta_8[B]$$

where Y represents the number of hospitalizations during a particular month for a specific age group. The term α was the population offset. The term t was the number of months in a time series from July 1979 through June 2001. We estimated the following β coefficients: β_0 was the intercept, β_1 accounted for the linear time trend in months, β_2 and β_3 accounted for nonlinear time trends, β_4 and β_5 accounted for seasonal changes in hospitalizations, and β_6 through β_8 were coefficients associated with the percentages of specimens testing positive for specific influenza viruses in a given month. Estimates of monthly US age-specific populations were used to account for changes in population trends over time and were obtained from the Census Bureau.[32] Attempts to include a term for respiratory syncytial virus in these models were unsuccessful because of the high correlation between the cosine term and the respiratory syncytial virus term (r=0.90) when the data were modeled on a monthly rather than on a weekly basis as was done in our recent mortality analyses.[21] All analyses were performed using SAS statistical software version 8.2 (PROC GENMOD, SAS Institute Inc, Cary, NC). Because NHDS data sets are deidentified public-use data sets, their use does not require formal institutional review board approval.

We determined the number of weeks during each respiratory season for which at least 10% of specimens tested positive for influenza. We used these numbers in analyses to control for the length of the influenza season when examining trends in influenza hospitalization rates.

RESULTS

Annual Influenza Laboratory Surveillance

For the 1979-1980 through 2000-2001 seasons, an annual average of 30 936 specimens (range, 14 804-53 427) were tested for influenza. During months in which specimens were tested for influenza, an average of 13.3% of specimens tested positive for influenza. Influenza A(H1N1), A(H3N2), and B viruses were detected in 2.1%, 7.9%, and 3.3% of the total specimens tested, respectively. During the 22 respiratory seasons included in this study, A(H1N1), A(H3N2), and B viruses predominated in 7, 15, and 11 respiratory seasons, respectively. There were 11 seasons in which more than 1 virus type or subtype predominated. The average number of months in which at least 10% of specimens tested positive for influenza during each respiratory season was 2.8 months (range, 0-4 months).

Annual Trends in Primary Hospital Discharge Diagnoses

During the study period, there were annual averages of 1 097 564 primary and 1 681 449 any listed pneumonia and influenza hospitalizations (TABLE 1). There were annual averages of 8 843 498 primary and 14 722 488 any listed respiratory and circulatory hospitalizations. Primary pneumonia and influenza hospitalizations represented 12.4% of the primary respiratory and circulatory hospitalizations. The total numbers of primary pneumonia and influenza hospitalizations increased in a linear fashion from the 1979-1980 through the 2000-2001 respiratory seasons (FIGURE). The total numbers of primary respiratory and circulatory hospitalizations decreased from the 1982-1983 through 1990-1991 respiratory seasons but increased from the 1991-1992 through 1999-2000 respiratory seasons.

Annual Estimates of Influenza-Associated Hospitalizations

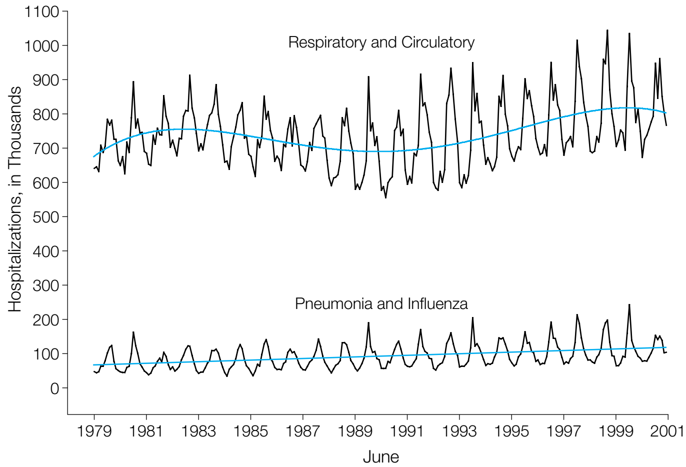
We estimated annual averages of 94 735 (range, 18 908-193 561) primary and 133 900 (range, 30 757-271 529) any listed pneumonia and influenza hospitalizations were associated with influenza viruses in the United States during the 1979-1980 through 2000-2001 respiratory seasons (TABLE 2). These influenza-associated hospitalization estimates represented 8.6% of all primary and 8.0% of any listed pneumonia and influenza hospitalizations. Similarly, we estimated annual averages of 226 054

Table 1. Annual Numbers of Hospitalizations*

Season	Predominant Type or Subtype	Pneumonia and Influenza: Primary	Pneumonia and Influenza: Any Listed	Respiratory and Circulatory: Primary	Respiratory and Circulatory: Any Listed
1979-1980	B	865 831	1 287 370	8 439 463	12 481 589
1980-1981	A(H3N2) and A(H1N1)	919 527	1 397 719	8 731 481	13 016 836
1981-1982	B and A(H1N1)	798 497	1 244 653	8 764 245	13 274 939
1982-1983	A(H3N2)	969 494	1 461 657	9 200 449	14 011 837
1983-1984	A(H1N1) and B	911 404	1 441 032	9 159 882	14 293 230
1984-1985	A(H3N2)	897 709	1 410 075	8 719 647	13 775 287
1985-1986	B and A(H3N2)	965 195	1 512 549	8 656 732	13 615 762
1986-1987	A(H1N1)	949 472	1 469 651	8 531 884	13 552 625
1987-1988	A(H3N2)	1 015 771	1 538 481	8 558 141	13 811 340
1988-1989	B and A(H1N1)	1 007 311	1 535 909	8 205 538	13 529 005
1989-1990	A(H3N2)	1 121 925	1 665 437	8 143 846	13 490 326
1990-1991	B	1 052 748	1 593 078	7 966 791	13 377 130
1991-1992	A(H3N2)	1 140 515	1 720 867	8 682 815	14 675 059
1992-1993	B and A(H3N2)	1 164 851	1 752 072	8 581 400	14 755 415
1993-1994	A(H3N2)	1 203 076	1 801 235	8 567 533	14 904 193
1994-1995	A(H3N2) and B	1 218 022	1 835 374	8 752 360	15 139 232
1995-1996	A(H1N1) and A(H3N2)	1 222 394	1 888 145	9 140 502	16 062 778
1996-1997	A(H3N2) and B	1 313 052	2 014 834	9 263 679	16 214 492
1997-1998	A(H3N2)	1 358 560	2 104 097	9 613 565	17 125 197
1998-1999	A(H3N2) and B	1 402 983	2 127 729	9 648 804	17 306 149
1999-2000	A(H3N2)	1 323 393	2 088 237	9 618 752	17 451 112
2000-2001	A(H1N1) and B	1 324 683	2 101 675	9 609 444	18 031 197
Mean (SD)		1 097 564 (180 045)	1 681 449 (280 113)	8 843 498 (496 483)	14 722 488 (1 616 326)

*Estimates are based on weighted monthly data.

Figure. Monthly Numbers of Hospitalizations by Primary Discharge Type From the 1979-1980 Through 2000-2001 Respiratory Seasons



The curve plotting the respiratory and circulation data is a fourth-order polynomial curve, and the pneumonia and influenza curve represents a straight linear regression line.

(range, 54 523-430 960) primary and 294 128 (range, 86 494-544 909) any listed respiratory and circulatory hospitalizations were associated with influenza viruses. For the respiratory and circulatory hospitalizations, these estimates represented 2.6% of all primary and 2.0% of any listed hospitalizations during the study period.

When we examined the year-to-year variability in influenza-associated hospitalizations, we noted a substantial increase in hospitalizations during the 1996-1997 through 1999-2000 influenza seasons, a period when A(H3N2) viruses predominated. Influenza-associated hospitalizations in the 2000-2001 season were the lowest since the 1995-1996 influenza season, and this corresponded with circulation of A(H1N1) viruses.

A summary of the numbers and rates of influenza-associated hospitalizations by discharge diagnosis and age group are presented in TABLE 3. Among children younger than 5 years, we estimated annual averages of 3454 (18.5 hospitalizations per 100 000 person-years) primary and 4916 (26.3 hospitalizations per 100 000 person-years) any listed pneumonia and influenza hospitalizations. For the same age group, we estimated 20 031 (107.9 hospitalizations per 100 000 person-years) primary and 21 156 (113.9 hospitalizations per 100 000 person-years) any listed respiratory and circulatory hospitalizations. Persons aged 5 through 49 years had the lowest rates of influenza-associated hospitalizations. Influenza-associated hospitalization rates increased dramatically with age. For example, among persons aged 85 years and older, we estimated annual averages of 21 788 (628.6 hospitalizations per 100 000 person-years) primary and 26 988 (777.3 hospitalizations per 100 000 person-years) any listed pneumonia and influenza hospitalizations. In this age group, we estimated annual averages of 40 813 (1194.9 hospitalizations per 100 000 person-years) primary and 57 350 (1669.2 hospitalizations per 100 000 person-years) any listed respiratory and circulatory influenza-associated hospitalizations.

Influenza-Associated Hospitalizations by Predominant Influenza Type and Subtype

In seasons during which A(H1N1) viruses predominated, 22.6 primary pneumonia and influenza and 55.9 primary respiratory and circulatory hospitalizations per 100 000 person-years were associated with influenza virus circulation. For B viruses, we estimated 37.7 and 81.4 influenza-associated hospitalizations per 100 000 person-years for primary pneumonia and influenza and primary respiratory and circulatory hospitalizations, respectively. A(H3N2) viruses were associated with the highest annual rates of influenza-associated hospitalizations. During seasons in which A(H3N2) viruses predominated, there were 43.5 primary pneumonia and influenza and 99.0 primary respiratory and circulatory hospitalizations per 100 000 person-years associated with influenza viruses.

Age-Specific Trends in Influenza-Associated Hospitalization Rates

Influenza-associated hospitalization rates increased annually during the study period among persons aged 50 through 64 years, 65 through 69 years, 70 through 74 years, 75 through 79 years, 80 through 84 years, and 85 years and older ($P<.01$ for each trend). After controlling for the length of the influenza season, a significant increase in the rates over time was still found among persons aged 65 through 69 years, 70 through 74 years, 75 through 79 years, 80 through 84 years, and 85 years and older ($P<.05$ for each trend).

Significant increases in influenza-associated hospitalization rates for respiratory and circulatory hospitalizations were found among persons younger than 5 years and those aged 65 through 69 years, 70 through 74 years, 75 through 79 years, 80 through 84 years, and 85 years and older ($P<.05$ for each trend). However, after controlling for the length of the influenza season, there were no significant increases in trends over time.

Length of Hospital Stay by Age Group and Diagnosis

Length of hospital stay varied by diagnosis and age group (TABLE 4). The median length of stay for primary pneumonia and influenza hospitalizations increased with age. The median length of stay was 3 days for those younger than 5 years; 4 days for those aged 5 through 49 years; 6 days for those aged 50 through 64, 65 through 69, and 70 through 74 years; and 7 days for those aged 75 through 79, 80 through 84, and 85 years and older. The median length of stay for primary respiratory and circulatory hospitalizations was 3 days for those younger than 5 years and those aged 5 through 49 years; 4 days for

Table 2. Annual Numbers and Rates of Influenza-Associated Hospitalizations*

		Pneumonia and Influenza Hospitalizations				Respiratory and Circulatory Hospitalizations			
		Primary		Any Listed		Primary		Any Listed	
Season	Predominant Type or Subtype	No. of Cases	Rate†	No of Cases	Rate†	No. of Cases	Rate†	No. of Cases	Rate†
1979-1980	B	44 871	19.7	61 237	26.9	120 929	53.2	151 544	66.7
1980-1981	A(H3N2) and A(H1N1)	44 488	19.4	67 710	29.5	167 812	73.1	189 048	82.4
1981-1982	B and A(H1N1)	21 806	9.4	30 983	13.4	61 211	26.4	86 494	37.3
1982-1983	A(H3N2)	62 577	26.8	93 660	40.0	213 256	91.2	245 524	105.0
1983-1984	A(H1N1) and B	55 941	23.7	81 225	34.4	148 277	62.8	226 551	96.0
1984-1985	A(H3N2)	96 941	40.7	143 532	60.2	303 390	127.3	333 024	139.8
1985-1986	B and A(H3N2)	71 141	29.6	98 431	40.9	169 359	70.4	212 129	88.2
1986-1987	A(H1N1)	18 908	7.8	30 757	12.7	54 523	22.5	121 678	50.1
1987-1988	A(H3N2)	61 510	25.1	89 242	36.4	172 151	70.3	207 454	84.7
1988-1989	B and A(H1N1)	81 471	32.9	114 112	46.1	175 998	71.2	273 273	110.5
1989-1990	A(H3N2)	90 396	36.2	130 204	52.1	241 456	96.7	278 118	111.4
1990-1991	B	78 075	31.0	104 821	41.6	157 911	62.6	221 412	87.8
1991-1992	A(H3N2)	104 245	41.0	149 944	58.9	263 614	103.6	326 331	128.2
1992-1993	B and A(H3N2)	110 926	43.2	149 157	58.0	226 541	88.1	304 898	118.6
1993-1994	A(H3N2)	114 049	43.9	160 482	61.8	271 655	104.6	322 736	124.3
1994-1995	A(H3N2) and B	101 480	38.7	140 105	53.4	226 657	86.4	288 417	109.9
1995-1996	A(H1N1) and A(H3N2)	87 497	33.0	124 205	46.9	196 502	74.1	296 312	111.8
1996-1997	A(H3N2) and B	180 214	67.3	248 557	92.8	382 969	142.9	490 246	182.9
1997-1998	A(H3N2)	193 561	71.4	271 529	100.2	430 960	159.1	530 225	195.7
1998-1999	A(H3N2) and B	190 331	69.5	263 270	96.1	390 446	142.5	503 894	183.9
1999-2000	A(H3N2)	184 098	66.4	265 300	95.7	426 662	153.9	544 909	196.6
2000-2001	A(H1N1) and B	89 636	32.0	127 328	45.4	170 899	60.9	316 588	112.9
Mean (SD)		94 735 (51 549)	36.8 (18.2)	133 900 (71 496)	52.0 (25.2)	226 054 (106 463)	88.4 (37.9)	294 128 (126 583)	114.8 (43.6)

*Estimates are based on weighted monthly data.
†Rate per 100 000 person-years.

Table 3. Age-Specific Annual Average Numbers and Rates of Influenza-Associated Hospitalizations*

	Age Groups, y								
Variable	<5	5-49	50-64	65-69	70-74	75-79	80-84	≥85	Total
Pneumonia and influenza hospitalizations									
Primary									
Number	3454	11 431	13 476	6871	10 609	14 226	12 879	21 788	94 735
Rate†	18.5	6.8	37.9	71.1	127.8	219.5	302.2	628.6	36.8
Any listed									
Number	4916	19 442	18 917	10 283	17 209	20 185	15 959	26 988	133 900
Rate†	26.3	11.5	53.3	106.4	207.4	312.2	376.2	777.3	52.0
Respiratory and circulatory hospitalizations									
Primary									
Number	20 031	34 867	29 447	18 301	26 501	27 516	28 578	40 813	226 054
Rate†	107.9	20.8	83.8	189.7	321.2	431.1	686.1	1194.9	88.4
Any listed									
Number	21 156	47 745	39 198	22 168	40 552	31 319	34 640	57 350	294 128
Rate†	113.9	28.3	111.3	229.7	491.9	489.4	829.1	1669.2	114.8

*Estimates are based on weighted monthly data.
†Rate is per 100 000 person-years.

those aged 50 through 64 years; 5 days for those aged 65 through 69, 70 through 74, and 75 through 79 years; 6 days for those aged 80 through 84 years and those 85 years and older.

COMMENT

We used monthly influenza surveillance data and nationally representative hospital discharge data to estimate influenza-associated hospitalizations in the United States by discharge category, discharge type, and age group. We found that the numbers and rates of influenza-associated hospitalizations generally increased during the study period.

Our results are consistent with our recent mortality analyses, which found substantial increases in influenza-associated mortality among persons 65 years and older during the 1990s.[21] We postulate that these increases in influenza-associated hospitalizations and deaths were due to several factors, including the aging of the population, the predominance of A(H3N2) viruses in many recent seasons, and the general trend for influenza viruses to circulate or to be detected for longer periods in respiratory seasons during the 1990s.

Using the nationally representative estimates of influenza-associated hospitalizations from this study and of deaths from our mortality study,[21] we can estimate relative risks (RRs) describing the risk of an influenza-associated hospitalization compared with the risk of an influenza-associated death. For example, among children younger than 5 years, the RR for an influenza-associated hospitalization relative to death is 270; while among persons aged 50 through 64 years, the RR is 11. Young children are at much greater risk for an influenza-associated hospitalization compared with an influenza-associated death; this difference greatly diminishes with increasing age. These results will be useful for national cost-effectiveness and policy analyses which assess the pros and cons of alternative vaccination strategies to reduce the morbidity and mortality from influenza, including vaccinating all children or universal immunization.

An important implication of our results is that the use of primary pneumonia and influenza discharges to estimate influenza-associated hospitalizations does not fully capture the total effect of influenza virus activity on morbidity in the United States. Our estimates of any listed respiratory and circulatory hospitalizations were about 3 times as high as our estimates of primary pneumonia and influenza hospitalizations. Other studies also suggest that influenza virus activity is associated with an increase in hospitalizations for a broad range of cardiopulmonary diagnoses, and not just primary pneumonia and influenza discharges.[11,19]

Generally, our estimated annual numbers and rates of influenza-associated hospitalizations are similar to previous national estimates made using NHDS data. Barker[11] estimated 370 influenza-associated pneumonia and influenza hospitalizations per 100 000 persons who were at least 65 years during 5 A(H3N2) seasons in the 1970s while we estimated 281 any listed pneumonia and influenza hospitalizations per 100 000 persons during the 1979-1980 through 2000-2001 respiratory seasons for this age group. Barker's estimate for the sum of influenza-associated hospitalizations for respiratory disease and acute cardiac failure was an annual average of 419 hospitalizations per 100 000 persons who were at least 65 years. We estimated 581 any listed respiratory and circulatory hospitalizations per 100 000 annually, which was slightly higher but would be expected given the continued aging of this age group.

In the other study that used NHDS data, Simonsen and colleagues[13] estimated 49 influenza-associated primary pneumonia and influenza hospitalizations per 100 000 persons for all ages, while we estimated 37 hospitalizations per 100 000 person-years for the same outcome. Comparing the results from these 2 studies during overlapping seasons (1979-1980 through 1994-1995), the annual estimates of influenza-associated pneumonia and influenza hospitalizations were highly correlated ($r=0.73$, $P<.01$). Across the entire study period, Simonsen and colleagues[13] estimated higher rates of primary pneumonia and influenza hospitalizations among persons younger than

Table 4. Descriptive Statistics for Length of Stay

No. of Days	Age Groups, y							
	<5	5-49	50-64	65-69	70-74	75-79	80-84	≥85
Pneumonia and influenza hospitalizations								
Primary								
Median	3	4	6	6	6	7	7	7
Average	4.3	5.8	7.5	8.0	8.4	8.7	9.0	8.9
Any listed								
Median	3	5	7	7	7	7	8	7
Average	4.9	7.5	10.0	10.5	10.6	10.8	10.6	10.0
Respiratory and circulatory hospitalizations								
Primary								
Median	3	3	4	5	5	5	6	6
Average	3.7	4.8	6.6	7.4	7.7	7.8	8.0	8.1
Any listed								
Median	3	3	5	5	6	6	6	6
Average	4.5	5.8	7.1	7.8	8.1	8.3	8.5	8.6

65 years relative to our study (33 vs 13 hospitalizations per 100 000 persons, respectively). Conversely, we estimated higher rates of primary pneumonia and influenza hospitalizations among persons who were aged at least 65 years (174 vs 205 per 100 000 persons, respectively). The difference in rates among those younger than 65 years in the study by Simonsen et al most likely reflect the increased influenza morbidity found among younger individuals during the 1968-1969 pandemic period.

The results of this study are also consistent with several studies of influenza-associated hospitalizations restricted to young children. These studies found high rates of hospitalizations among both high-risk and healthy young children.[16,33-35] Although none of these previous studies were nationally representative, the estimated rates are in general quite similar. For example, for all children younger than 5 years, Mullooly and Barker[12] estimated 1.2 hospitalizations per 1000 person-years, Neuzil and colleagues[16] estimated 2.6 hospitalizations per 1000 person-years among healthy children, and Izurieta and colleagues[35] estimated 0.9 hospitalizations per 1000 person-years among healthy children. In our study, we estimated an annual average of 1.1 hospitalizations per 1000 person-years among all children younger than 5 years, which also compares favorably with a recent study that found a laboratory-confirmed influenza hospitalization rate of 0.6 per 1000 among children younger than 5 years during a single mild influenza season.[36]

This study has several limitations. Because NHDS data do not include previous health information, it was not possible to determine which individuals were at risk for influenza complications due to underlying conditions (eg, asthma, heart disease, etc) or to control for changes in the prevalence of these conditions over time. Nor was it possible to identify individuals who had received influenza vaccine prior to the respiratory season in which the individual was hospitalized in order to assess vaccine effectiveness. Although our influenza mortality estimates were made using similar methods and weekly death data, in this study we were limited to making hospitalization estimates using monthly hospital discharge data. Use of weekly hospitalization and influenza circulation information would have permitted fluctuations in both data sources to be more closely associated and would have provided more precise estimates of influenza-associated hospitalizations. We were also not able to control for the circulation of respiratory syncytial virus, which is known to circulate at similar times as influenza viruses and is often associated with significant morbidity and mortality. Finally, we were unable to stratify data further for children younger than 5 years due to the few numbers of hospitalizations that occurred for children aged 2 to 4 years. Despite these limitations, our use of NHDS data provided nationally representative annual estimates of influenza-associated hospitalizations that can be compared over 2 decades. Smaller data sources often used to assess influenza vaccine effectiveness cannot offer these advantages.

Currently, we estimate that more than 200 000 respiratory and circulatory hospitalizations are associated with influenza each year in the United States, substantially more than estimates of pneumonia and influenza hospitalizations.[13] As noted in our report describing influenza-associated mortality, the aging of the US population is an important contributor to the increasing numbers of influenza-associated hospitalizations and deaths.[21] For example, between 1976 and 2001 the number of US citizens aged 85 and older had more than doubled.[32,37] Based on US census estimates, the numbers of very elderly people in the United States will continue to increase and thus we expect that the numbers of influenza-associated hospitalizations and deaths will likely increase over time. Additional efforts are needed to ensure that current recommendations for influenza vaccination for all high-risk individuals, household contacts of high-risk individuals, health-care workers, and young children are fully implemented. Recent observational studies have suggested that influenza vaccination may reduce respiratory and circulatory hospitalizations substantially, particularly among the elderly.[19,38-39] Efforts to vaccinate older Americans and their contacts annually must continue to be a priority for immunization programs. Consideration should also be given to other influenza prevention methods for older Americans given the potential for decreased immune responsiveness to vaccines in the very elderly.[40,41]

After the elderly, the second highest rates of influenza-associated hospitalizations are found in young children. This point was highlighted during the 2003-2004 A(H3N2)–influenza season, which may have been particularly severe among children. Through July 2004, data on 152 deaths among children with laboratory-confirmed influenza virus infection during the last influenza season has been collected nationally.[42] The Council of State and Territorial Epidemiologists voted in June 2004 to add deaths of children with evidence of influenza virus infection to its list of nationally reportable conditions. Clearly, new measures to prevent influenza-associated morbidity and mortality among young children are needed.

Author Contributions: Dr Thompson had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Thompson, Shay, Weintraub, Cox, Fukuda.
Acquisition of data: Weintraub, Brammer, Cox.
Analysis and interpretation of data: Thompson, Shay, Weintraub, Brammer, Bridges, Cox, Fukuda.
Drafting of the manuscript: Thompson, Shay.
Critical revision of the manuscript for important intellectual content: Thompson, Shay. Weintraub, Brammer, Bridges, Cox, Fukuda.
Statistical analysis: Thompson, Weintraub, Brammer.
Administrative, technical, or material support: Thompson, Weintraub, Bridges.
Study supervision: Thompson, Shay, Cox, Fukuda.

Funding/Support: This project did not receive any dedicated funding.
Acknowledgments: We thank Ericka Sinclair, Erin Murray, and Alicia Postema for assistance in organizing the WHO influenza isolate data.

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