Trends in Pathogens Among Patients Hospitalized for Pneumonia From 1993 to 2011

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Abstract

The Nationwide Inpatient Sample aggregated data from approximately 20% of US hospital admissions from 1993 to 2011. Prior literature found that pneumonia admissions decreased following the introduction of the pneumococcal vaccine in 2000.[1] The *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*), codes provide information regarding pneumonia pathogens, but no studies, to our knowledge, have used these codes to analyze longitudinal trends in the pathogens documented during hospitalizations for pneumonia.

METHODS

We selected patients 18 years or older admitted for pneumonia based on a principal diagnosis of pneumonia (*ICD-9-CM* codes 480.0–480.3, 480.8, 480.9, 481, 482.0–482.9, 483.0–483.8, 485, 486, and 487). Consistent with recent literature,[2] we also selected hospitalizations with pneumonia as a secondary diagnosis if the principal diagnosis was sepsis (*ICD-9-CM* codes 038.8, 038.9, 785.52, 995.91, and 995.92) or respiratory failure (*ICD-9-CM* codes 518.81, 518.82, 518.84, and 799.1). For each pathogen, we used a linear regression model with year of hospitalization as the explanatory variable and the percentage

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of cases coded with that pathogen as the dependent variable. We obtained annual population estimates from the US Census Bureau.[3]

RESULTS

From January 1, 1993, to December 31, 2011, hospitalizations for pneumonia increased from 910 676 to 1 378 551 (350.4 to 442.4 per 100 000 US population; $P < .001$) (Table and Figure). The proportion of admissions with no reported pathogen increased from 65.9% to 83.9% ($P < .001$). Admissions with the nonpneumonia principal diagnoses were more likely to have pathogens documented (odds ratio, 1.28; 95% CI, 1.25–1.30; $P < .001$). From 1993 to 2011, there were declines in the coding of streptococcal species (from 7.1% to 2.3%; $P < .001$), *Pseudomonas* (from 3.9% to 2.3%; $P < .001$), and *Haemophilus influenzae* (from 3.6% to 0.4%; $P < .001$); however, the coding of *Staphylococcus aureus* increased (from 3.6% to 3.9%; $P = .004$).

Streptococcal species, especially *Streptococcus pneumoniae*, were the most frequently coded pathogens in 1993. There were decreases in the documentation of streptococcal species, *Haemophilus influenzae*, and *Pseudomonas*, whereas documentation of *Staphylococcus aureus* increased modestly.

Unadjusted inpatient mortality did not change significantly (from 8.7% to 7.8%; $P = .40$). Cases coded with *S aureus* had the highest mortality (12.0%).

DISCUSSION

To our knowledge, this is the first analysis of trends in the microbiologic pathogens in patients hospitalized for pneumonia based on nationally representative data spanning nearly 2 decades.

Streptococcus pneumoniae has been reported to be the most common cause of community-acquired pneumonia.[4] Declines in cases of adult pneumonia due to *S pneumoniae* may be related to more frequent and effective vaccination as well as to herd immunity from increased pediatric vaccination after 2000.[1] In addition to prevention, vaccination reduces the risk of invasive pneumococcal disease and bacteremia. We hypothesize that this reduced risk may have resulted in less-frequent coding because more thorough diagnostic evaluations accompany a higher severity of disease.[5] We observed a reduction in *Streptococcus*, despite the addition of urine antigen testing.[6] Furthermore, quality improvement initiatives to reduce the time from presentation to antibiotic administration may also have reduced the yield of traditional culture-based diagnostics. We cannot know with certainty how the contributions of vaccination and changes in diagnostic tests affected the trends that we describe. However, we believe that our findings suggest important changes in pneumonia pathogens.

Streptococcuspneumoniae was the most frequent pathogen in 1993 and *S aureus* was the most frequent in 2011, most of which was methicillin-resistant *S aureus* (MRSA). Because we included hospitalizations with certain alternative principal diagnoses, it is likely that our case definition included some patients with health care–associated pneumonia, which may have increased our identification of MRSA. Despite the trends observed, the low incidence

of *S aureus* (<4%) suggests that MRSA coverage is not routinely indicated for patients with community-acquired pneumonia.[7]

We have described changes in pneumonia pathogens from hospital admissions during 2 decades. We believe that these changes should be considered for public health monitoring and care for pneumonia, which is the leading cause of infectious death in the United States.

Acknowledgments

References

1. Griffin MR, Zhu Y, Moore MR, Whitney CG, Grijalva CG. US hospitalizations for pneumonia after a decade of pneumococcal vaccination. N Engl J Med. 2013; 369(2):155–163. [PubMed: 23841730]

2. Lindenauer PK, Lagu T, Shieh MS, Pekow PS, Rothberg MB. Association of diagnostic coding with trends in hospitalizations and mortality of patients with pneumonia, 2003–2009. JAMA. 2012; 307(13):1405–1413. [PubMed: 22474204]

3. US Census Bureau. [Accessed July 21, 2014] US Population by Year. 2013. http://www.multpl.com/united-states-population/table

4. Ruiz M, Ewig S, Marcos MA, et al. Etiology of community-acquired pneumonia: impact of age, comorbidity, and severity. Am J Respir Crit Care Med. 1999; 160(2):397–405. [PubMed: 10430704]

5. Rozenbaum MH, Pechlivanoglou P, van der Werf TS, Lo-Ten-Foe JR, Postma MJ, Hak E. The role of Streptococcus pneumoniae in community-acquired pneumonia among adults in Europe: a meta-analysis. Eur J Clin Microbiol Infect Dis. 2013; 32(3):305–316. [PubMed: 23242464]

6. Sinclair A, Xie X, Teltscher M, Dendukuri N. Systematic review and meta-analysis of a urine-based pneumococcal antigen test for diagnosis of community-acquired pneumonia caused by *Streptococcus pneumoniae*. J Clin Microbiol. 2013; 51(7):2303–2310. [PubMed: 23678060]

7. Wunderink RG. Community-acquired pneumonia versus healthcare-associated pneumonia: the returning pendulum. Am J Respir Crit Care Med. 2013; 188(8):896–898. [PubMed: 24127797]
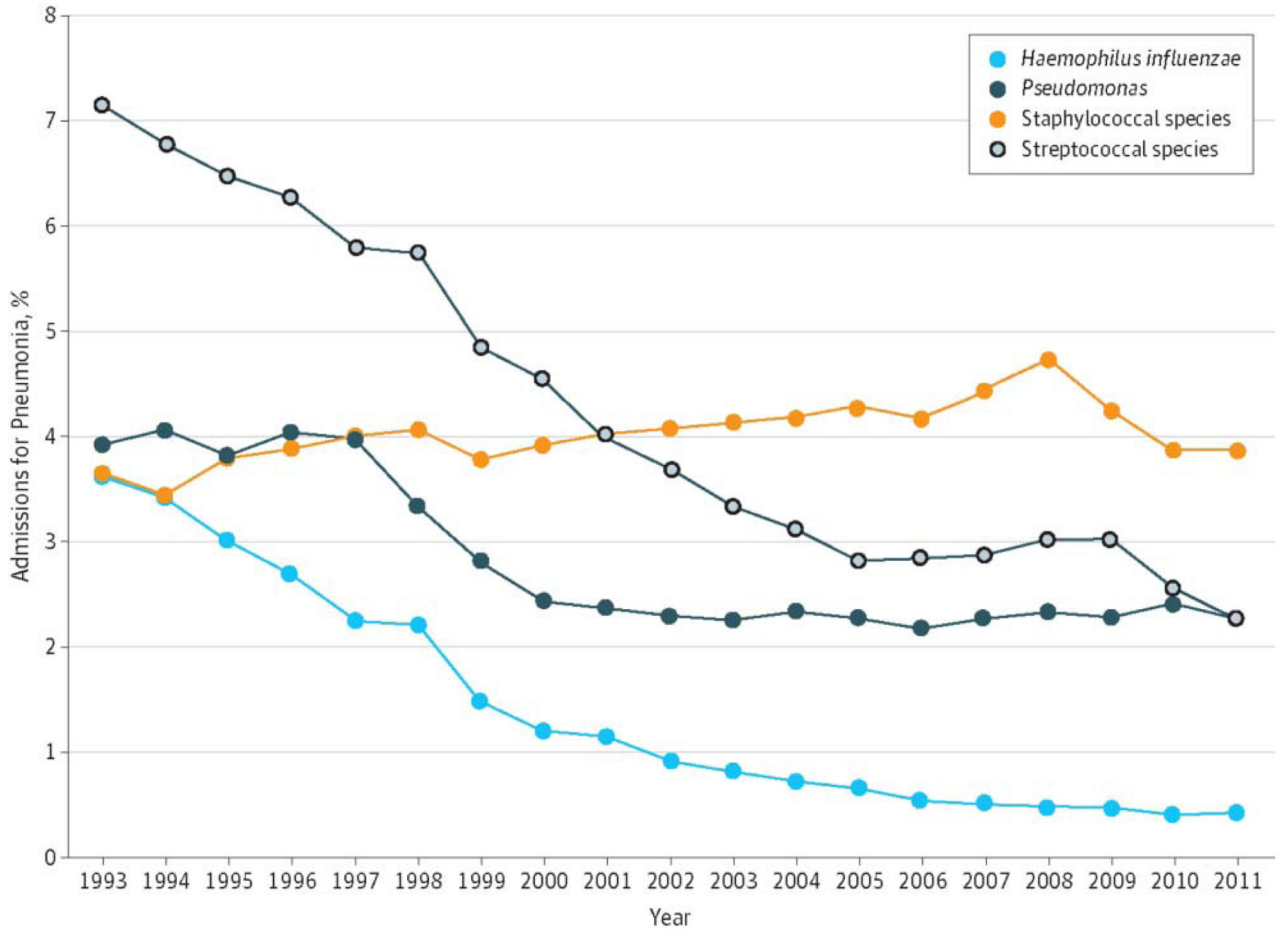
Figure.

Documentation of Specific Bacterial Pathogens for Pneumonia From 1993 to 2011
Streptococcal species, especially Streptococcus pneumoniae, were the most frequently coded
pathogens in 1993. There were decreases in the documentation of streptococcal species,
Haemophilus influenzae, and Pseudomonas, whereas documentation of Staphylococcus
aureus increased modestly.

Table

Reported Pathogens for Pneumonia Admissions From 1993 to 2011

Year	No. of Admissions per 100 000	%							
		No Organism Specified	Any Streptococcal Species	Streptococcus pneumoniae	Any Staphylococcal Species	MRSA[a]	Pseudomonas	H influenzae	Other Bacteria
1993	350.4	65.9	7.1	5.7	3.6	NA	3.9	3.6	14.0
1994	362.5	66.7	6.8	5.5	3.5	NA	4.1	3.4	14.1
1995	381.9	66.0	6.5	5.3	3.8	NA	3.8	3.0	15.5
1996	380.9	66.8	6.2	5.2	3.9	NA	4.0	2.7	15.0
1997	382.6	69.9	5.8	4.8	4.0	NA	4.0	2.3	12.8
1998	433.2	76.5	5.8	4.8	4.1	NA	3.3	2.2	6.5
1999	453.2	80.8	4.8	4.1	3.8	NA	2.8	1.5	4.2
2000	421.6	82.2	4.6	3.8	3.9	NA	2.5	1.2	3.7
2001	405.3	84.1	4.0	3.3	4.0	NA	2.4	1.2	3.4
2002	421.9	84.9	3.7	3.1	4.1	NA	2.3	0.9	2.9
2003	444.5	84.3	3.3	2.8	4.1	NA	2.3	0.8	3.1
2004	418.3	85.0	3.1	2.6	4.2	NA	2.3	0.7	3.2
2005	468.1	84.8	2.8	2.3	4.3	NA	2.3	0.7	3.0
2006	436.3	85.7	2.9	2.3	4.2	NA	2.2	0.6	2.9
2007	428.1	85.5	2.9	2.3	4.4	NA	2.3	0.5	3.3
2008	439.5	83.4	3.0	2.5	4.7	0.7	2.3	0.5	4.0
2009	429.7	82.7	3.0	2.4	4.3	3.1	2.3	0.5	4.4
2010	411.3	84.8	2.6	2.0	3.9	2.9	2.4	0.4	4.7
2011	442.4	83.9	2.3	1.7	3.9	2.8	2.3	0.4	5.2
P Value	.001	<.001	<.001	<.001	.004	.31	<0.01	<.001	<.001
R^2	0.48	0.70	0.92	0.94	0.40	0.47	0.72	0.87	0.56

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; NA, not available.

[a] *International Classification of Diseases, Ninth Revision, Clinical Modification*, coding was unavailable for years with an NA indication.