MORTALITY FROM PNEUMONIA IN CHILDREN IN THE UNITED STATES, 1939 THROUGH 1996

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ABSTRACT

Background and Methods Pneumonia remains an important cause of childhood deaths throughout the world, but in developed countries, the mortality rate is decreasing. We reviewed death records for children in the United States from 1939 through 1996. A plot of the annual rates of change in the number of deaths from pneumonia was used to generate hypotheses about the influence of various events and interventions. We used data from the National Hospital Discharge Survey, the Medicaid program, and published reports to test these hypotheses.

Results During the 58-year study period, the number of children who died from pneumonia declined by 97 percent, from 24,637 in 1939 to 800 in 1996. During the same period, the rate of mortality from other causes declined by 82 percent. There were steep declines in the mortality rates for pneumonia from 1944 to 1950, although the rate increased among older children in 1957, and there were sustained declines in all age groups from 1966 to 1982. From 1966 to 1982, the mortality declined by an average of 13.0 percent annually, and these decreases coincided with increases in the proportion of poor children covered by Medicaid, increases in rates of hospitalization for pneumonia, a narrowing of the gap between the mortality rate for black children and the rate for white children, and a convergence between the mortality rate in the South and the rates in the other three census regions.

Conclusions Since 1939, the rate of mortality from pneumonia in children in the United States has declined markedly. We hypothesize that the steep declines in the late 1940s are attributable to the use of penicillin, that the peak in 1957 was due to the influenza A pandemic, and that the sustained decline from 1966 through 1982 may be attributable in part to improved access to medical care for poor children. (N Engl J Med 2000;342:1399-407.)

PNEUMONIA remains a leading cause of death among children throughout the world. Each year, an estimated 4 million children, primarily in developing countries, die from pneumonia.[1] Efforts to reduce the rate of mortality from childhood pneumonia in developing countries have focused on vaccination against measles and pertussis and on the use of simple algorithms and empirical treatment for presumed pneumonia by village health workers.[1,2] In the United States, pneumonia remains a common and occasionally severe childhood infection, but new vaccines against *Streptococcus pneumoniae* and influenzavirus offer promise for reducing its incidence.[3-5] Recently legislated expansion of medical insurance coverage for children may also lead to reductions in the rate of mortality from pneumonia if there is earlier or improved care.[6,7]

We reviewed the decline in the rate of mortality from pneumonia among U.S. children since 1939 to identify factors that may have contributed to the decline and to speculate on the potential effects of new vaccines, expanded access to care, and other future developments.

METHODS

Sources of Data on Deaths

We used death-certificate data reported to the U.S. Vital Statistics System from 1939 through 1996 to identify underlying causes of deaths attributed to pneumonia or influenza in children (defined as persons under the age of 15 years for the purpose of this study). We excluded years before 1939 because the cause-of-death portion of the death certificate was substantially different in earlier years.[8] Data on the cause of death were available for more than 99 percent of all deaths in the United States, except for 1972, when a 50 percent sample was used to estimate the number of deaths.[8] Except for the addition in 1989 of a fuller description of the chain of events leading to death, no major changes were made to death certificates after 1949. To calculate mortality rates, we used birth data as the population denominators for infants (children less than 1 year old), and census data as the population denominators for preschool children (1 to 4 years old) and school-age children (5 to 14 years old).

Deaths were classified as due to pneumonia on the basis of the *International Classification of Diseases* (ICD) codes for pneumonia and influenza in the editions of the ICD that were current during the study period. In addition, we used a code for pneumonia in newborns (children less than four weeks old) that was introduced in the sixth edition of the ICD. The eighth edition deleted the code for pneumonia in newborns and introduced a code for sudden death from an unspecified cause. In the ninth edition, a code was introduced for pneumonitis due to aspiration of solids and liquids, and a specific code for the sudden infant death syndrome was added. Beginning with the sixth edition of the ICD, comparability studies were performed in which deaths in a particular year were classified according to the codes in the

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new edition and according to the codes in the preceding edition.[9-12] The comparability ratio was 0.86 for the fifth and sixth editions, 0.94 for the sixth and seventh, 0.96 for the seventh and eighth, and 0.93 for the eighth and ninth.

Changes in the Mortality Rate

To reduce the influence of random fluctuations in the number of pneumonia-associated deaths, we calculated the annual percentage change in the mortality rate by using a three-year moving average, so that the percentage for each year was an average of the change in the rate for that year and for the previous and subsequent years.

To determine whether reductions in the mortality rate during certain periods were more pronounced for bacterial pneumonia than for viral pneumonia, we classified two codes in the ninth revision of the ICD as representing possible bacterial pneumonia (codes 481 and 482) and two as representing possible viral pneumonia (codes 480 and 487). Similarly, for the period from 1944 to 1950, we compared the code for lobar pneumonia (more likely to have a bacterial cause than a nonbacterial cause; code 108 in the fifth edition of the ICD) with the codes for bronchopneumonia and influenza (more likely to have a nonbacterial cause; codes 107 and 33).

Hospitalizations

Data from the National Hospital Discharge Survey, which were available for the period from 1970 through 1996, were analyzed according to previously reported methods.[13] For children under the age of 15 years, we compared the estimated number of hospital discharges after a diagnosis of pneumonia per 10,000 children with the number after all other diagnoses during the period when there were steep declines in the rate of mortality from pneumonia (1970 through 1982).

Medicaid Data

Using data from the Health Care Financing Administration, we calculated the ratio of the number of children covered by Medicaid to the number of persons under the age of 18 years who were living in poverty, for the period from the inception of the program, in 1965, through 1985. Estimates of the total number of Medicaid recipients were not available for 1966 or 1967, and estimates of the number of children covered by Medicaid were unavailable for the period from 1968 through 1974. To estimate the number of children covered by Medicare in these years, we used the average ratio of the number of children covered to the total number of covered persons for the period from 1975 through 1984 (0.43; range, 0.42 to 0.49) and applied it to the total number of recipients each year from 1968 through 1974. Data on persons under the age of 18 years who were living in poverty were obtained from census estimates (http://www.census.gov/hhes/poverty/histpov/hstpov03.txt).

RESULTS

Rates of mortality from childhood pneumonia in the United States declined by 97 percent in the 58-year period from 1939 through 1996. This decline paralleled but exceeded the 82 percent decline in overall childhood mortality (Fig. 1). The number of deaths ascribed to pneumonia dropped from 24,637 in 1939 to 800 in 1996, an absolute difference of 23,837 deaths, despite the substantial increase in the population during this period. Mortality rates declined by 98 percent for infants (children under the age of 1 year), by 99 percent for preschool children

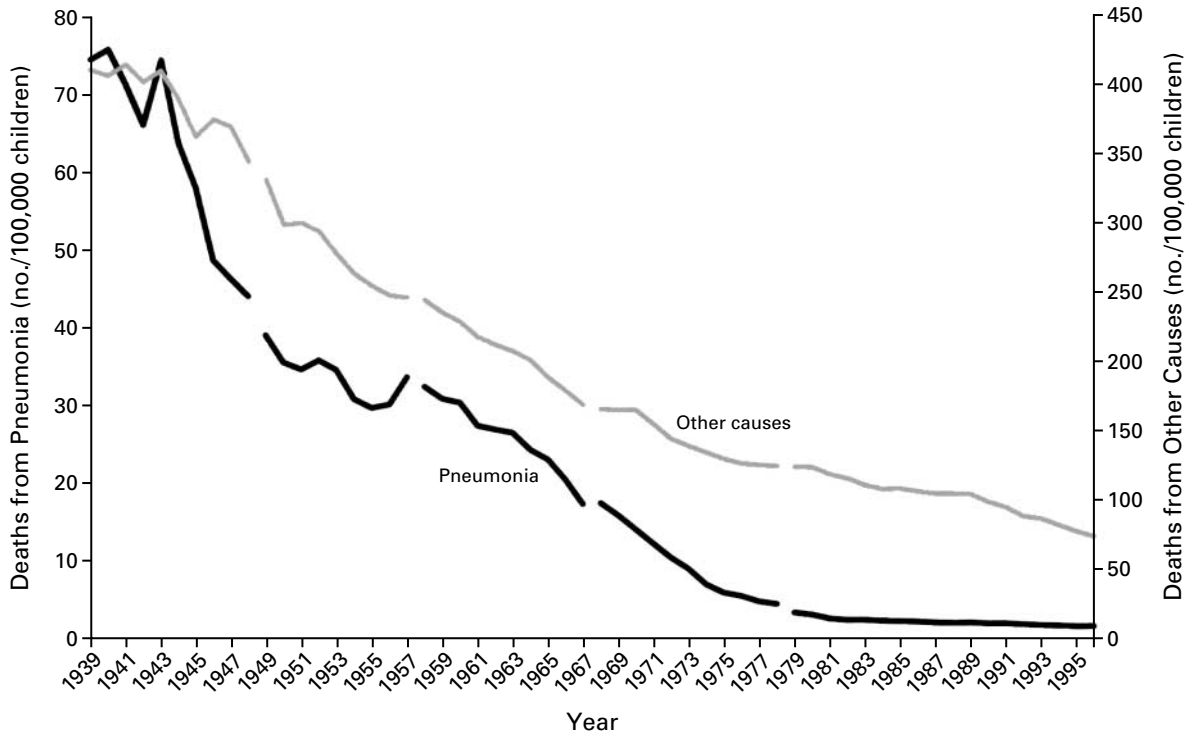

Figure 1. Deaths from Pneumonia and from Other Causes in Childhood, from 1939 through 1996.
Gaps in the curves indicate changes in the *International Classification of Diseases* codes.

(1 to 4 years old), and by 97 percent for school-age children (5 to 14 years old).

The reduction in the numbers of deaths from pneumonia over the 58-year period represented an average annual decline of 6.8 percent, as compared with 3.0 percent for deaths from other causes. However, variations in the rate of decline were apparent when the smoothed annual rates of change were examined (Fig. 2). The curves for the rate of mortality from pneumonia were distinct from that for the rate of mortality from other causes at three times during the study period: from 1944 to 1950, when the rate of mortality from pneumonia declined steeply; in 1957, when there was a sharp increase; and from 1966 to 1982, when there was a sustained decline.

The average annual decline in the rate of mortality from pneumonia for the seven years from 1944 to 1950 was 9 percent for infants, 14 percent for preschool children, and 13 percent for school-age children. The annual declines were similar for lobar pneumonia (14 percent), bronchopneumonia (10 percent), and influenza (10 percent).

The peak in the rate of mortality from pneumonia in 1957 was principally the result of an increased number of deaths among school-age children. Among these children, deaths from pneumonia increased by 69 percent, from 736 in 1956 to 1241 in 1957, as compared with a 22 percent increase for preschool children and an 11 percent increase for infants. The increase in the mortality rate among school-age children in 1957 was similar to the increases in the rates among persons who were 15 to 25 years old and those who were over the age of 65 years (data not shown).

From 1966 through 1982, the annual rate of mortality from pneumonia declined by an average of 15 percent for infants and by an average of 11 percent for children 1 to 14 years old. The decline in infant deaths coded as pneumonia (from 226 per 100,000 births in 1968 to 21 per 100,000 in 1982) coincided with a steep increase in deaths coded as due to the sudden infant death syndrome (from 20 per 100,000 births in 1968 to 141 per 100,000 in 1982). By definition, no deaths among preschool or school-age children were coded as the sudden infant death syndrome.

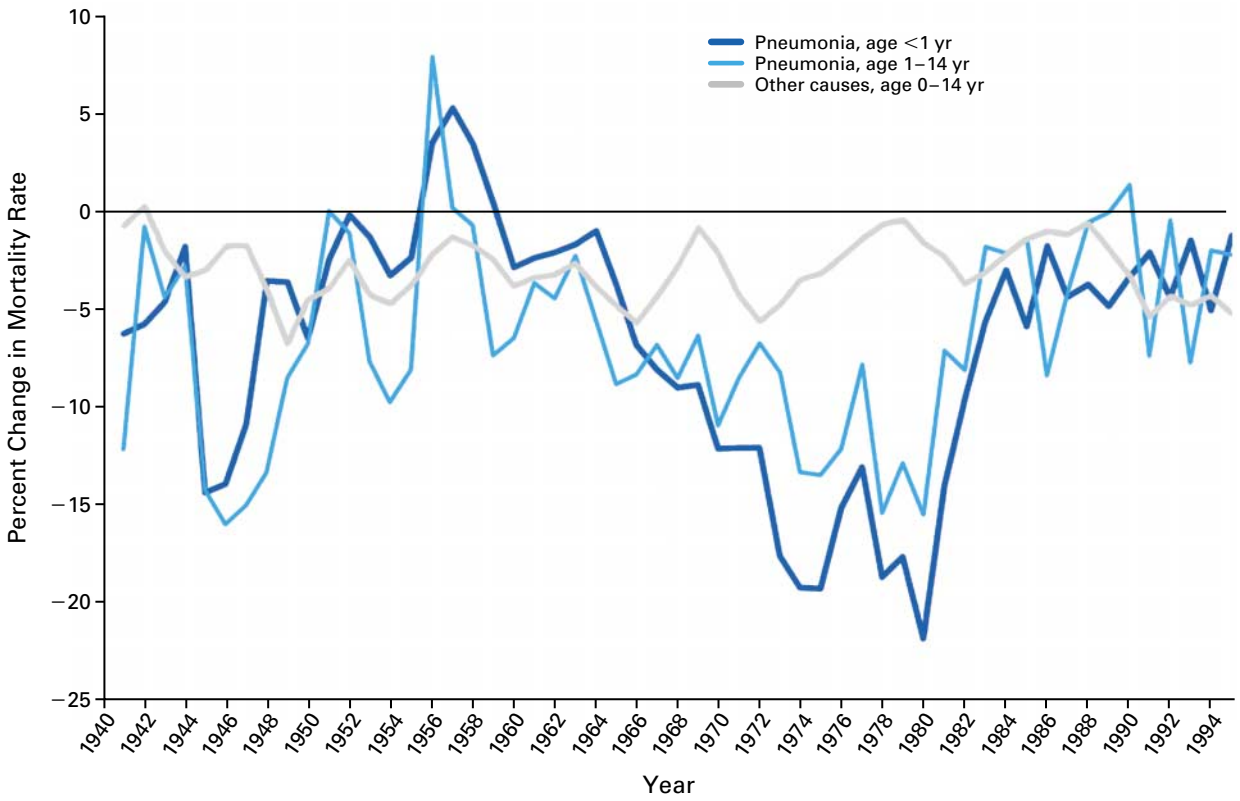

Figure 2. Annual Percent Change in Rates of Mortality from Pneumonia and from Other Causes in Infants and Older Children, from 1939 through 1996.

The curves were smoothed by using a three-year moving average (i.e., the percent change for each year is an average of the changes for that year and for the previous and subsequent years).

An etiologic agent was not specified for most deaths from pneumonia during the period from 1966 through 1982. In 1980, for example, 75 percent of deaths from pneumonia were coded as either pneumonia, type unspecified, or bronchopneumonia. For deaths from pneumonia that were attributed to viruses, the annual rate of decline was 13 percent, which was similar to the rate of decline for deaths attributed to bacterial pneumonia (11 percent).

We evaluated other causes of death to determine whether coding practices might have influenced changes in the rate of mortality from pneumonia during this period. For example, among school-age children, the number of deaths attributed to asthma increased from 139 in 1970 to 191 in 1995, an increase that was less than 5 percent of the number of deaths attributed to pneumonia and influenza in the same period. Similarly, changes in mortality rates for respiratory failure (codes 518.4 and 518.8 in the ninth edition of the ICD) and sepsis (code 038) were not associated with the observed declines in mortality rates for pneumonia. Among deaths for which pneumonia was listed anywhere on the death certificate, the proportion coded as due to pneumonia was highest for infants (74 percent in 1968) and lowest for school-age children (39 percent), and the proportion declined by an average of 2 percent annually from 1968 through 1982.

We estimated that the ratio of children covered by Medicaid to all children living in poverty increased from 0 in 1965, when the program started, to 0.97 in 1976 and then declined to 0.70 in 1982 (Fig. 3A).

A review of National Hospital Discharge Survey data for the period from 1970 through 1985 showed that rates of hospitalization due to pneumonia among children did not decline in parallel with mortality rates for pneumonia (Fig. 3B). In fact, rates of hospitalization for pneumonia increased, whereas rates of hospitalization for all other disorders remained stable. The introduction of new codes in the ninth ICD revision in 1979 led to an increase in the rate of hospitalization for pneumonia (indicated by the gaps in the curves). However, between 1970 and the implementation of the new codes in 1979, the rate of hospitalization for pneumonia increased by 19 percent, whereas the rate of hospitalization for other disorders decreased by 1 percent. We could not directly examine the rate of hospitalization for pneumonia among poor children because data on insurance coverage were missing in up to 25 percent of records.

As Medicaid coverage increased and the rate of hospitalization for pneumonia rose, the difference between the rate of mortality from pneumonia in the South and the rates in other regions narrowed (Fig. 4A), as did the difference between the rates for black children and for white children (Fig. 4B). Census data on children were not available according to region for the period from 1965 through 1969, and we were therefore unable to calculate mortality rates according to region for this period.

DISCUSSION

The 97 percent decline in rates of mortality from pneumonia among U.S. children over the past half century is a notable achievement in medicine and public health. With the developed countries currently preparing to introduce a battery of new pneumonia vaccines and with an opportunity to expand Medicaid coverage of uninsured children, it is appropriate to examine the rates of mortality from childhood pneumonia in earlier eras. We examined three periods when changes in the rate of mortality from pneumonia were distinct from changes in the rate of mortality from other causes, and we speculated on possible explanations for these changes. These periods were the 1940s, immediately after the introduction of penicillin; the year 1957, when the influenza pandemic occurred; and the 1960s and 1970s, when the War on Poverty expanded access to medical care for millions of people.

New Antimicrobial Agents

Penicillin became available for widespread use in the mid-1940s. Its predecessors, sulfanilamide and sulfapyridine, were less effective in treating pneumonia.[14,15] Analysis of data available in the 1950s led some authorities to conclude at the time that the newer antimicrobial agents had profoundly influenced rates of mortality from pneumonia.[16,17] The greatest reduction in the rate of mortality from pneumococcal pneumonia was among patients who were 12 to 29 years old, with progressively smaller reductions among older patients.[15] We found steep declines in the rates of mortality from pneumonia during the period from 1944 through 1950, which may be attributable to the increased availability of antimicrobial agents; however, we did not find that the new agents led to substantially larger reductions in the number of deaths from lobar pneumonia than in the number from bronchopneumonia.

A series of new antimicrobial agents have been introduced since the 1940s for the treatment of pneumonia in children, but we found no association between reductions in mortality rates and the introduction of these agents. For example, there were steep declines in mortality rates during the 1970s, a time when several new cephalosporins with β-lactamase stability became available.[18,19] However, we found no clear evidence that mortality rates for bacterial pneumonia declined more steeply than those for viral pneumonia.

The 1957 Influenza Pandemic

The 1957 influenza pandemic had a dramatic influence on rates of mortality from childhood pneumonia. The pandemic, associated with the appearance

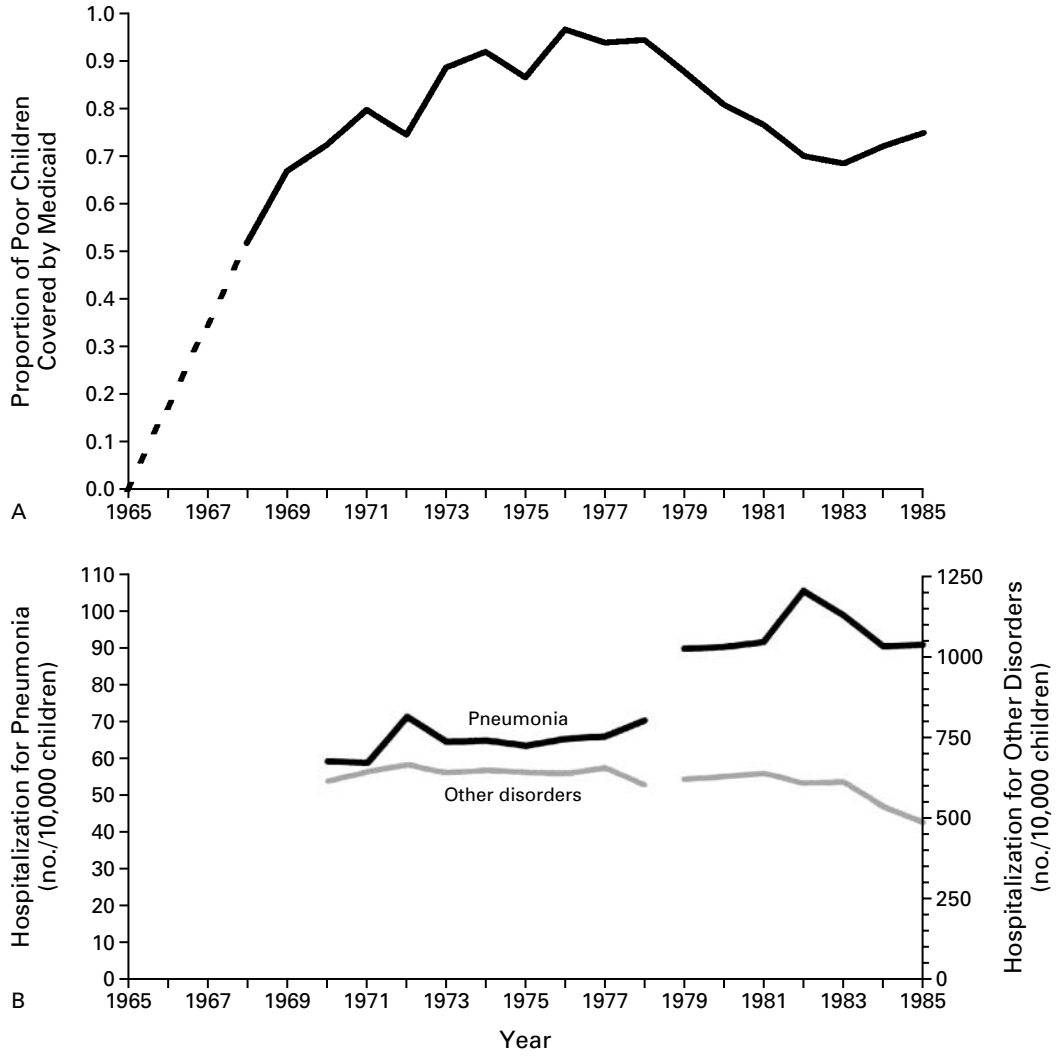

Figure 3. Medicaid Coverage and Rates of Hospitalization for Pneumonia, from 1965 through 1985.

Panel A shows the ratio of the number of children covered by Medicaid to the number of persons under the age of 18 years and living in poverty. The Medicaid program started in 1965. No national data on numbers of enrollees were available for 1966 or 1967 (indicated by the broken lines). We estimated the proportions of children covered from 1968 to 1974, since specific data on the coverage of children were not available for these years. Panel B shows rates of hospitalization for pneumonia and for all other disorders, on the basis of data from the National Hospital Discharge Survey, which began in 1970. The gaps in the curves indicate changes in the *International Classification of Diseases* codes.

of the so-called Asian influenza caused by influenza A (H2N2) virus, caused an estimated 69,800 excess deaths from pneumonia and influenza in the United States.[20] Our finding that the number of deaths from pneumonia increased disproportionately among children who were 5 to 14 years old is consistent with the observations of others. In an analysis of deaths from pneumonia and influenza during the period from October through December 1957, the rate of excess mortality (the observed mortality rate in relation to the expected age-specific rate) among persons 5 to 20 years old peaked at 400 percent, a rate that was two to three times as high as that in any other age group.[21]

Increased Access to Medical Care

One of the most striking changes in the rates of mortality from childhood pneumonia was the annual decrease in the rates between 1966 and 1982. We considered several potential explanations for this sustained decline.

The reduction in the rates of mortality from pneumonia among infants is attributable in part to the introduction of a new code for sudden death in infants.

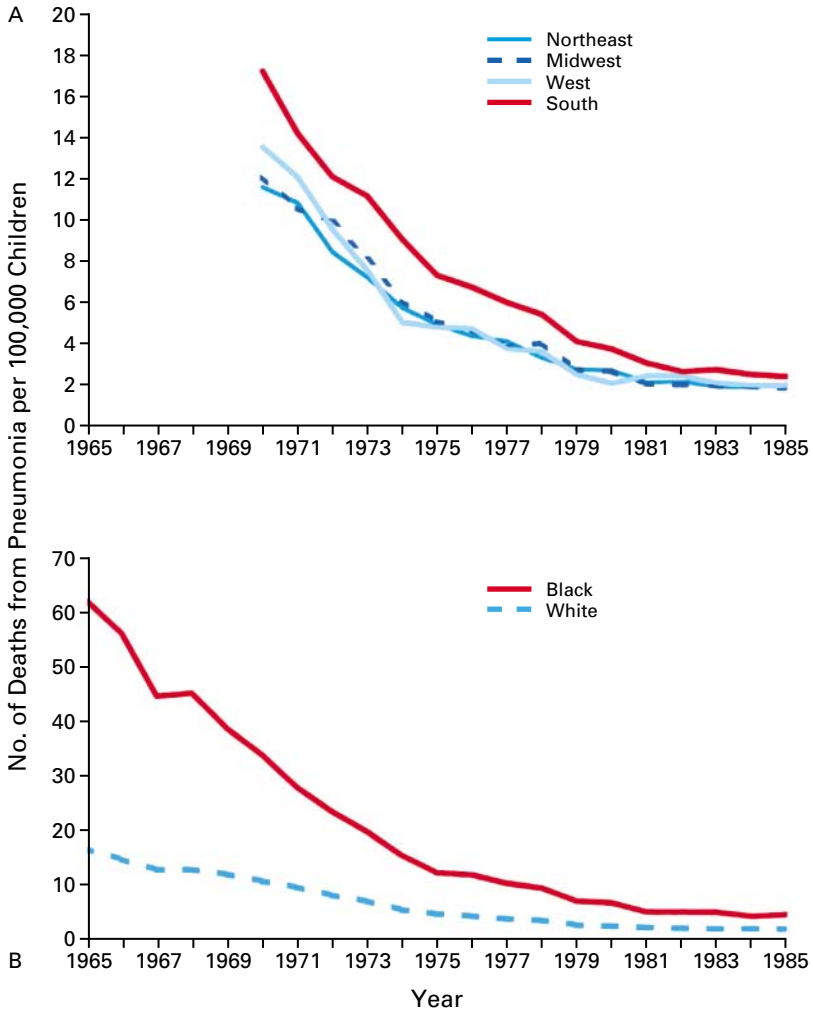

Figure 4. Rates of Mortality from Childhood Pneumonia According to Region and Race, from 1965 through 1985.

Panel A shows mortality rates for the four census regions of the United States. Data on deaths among children under the age of 15 years were not available according to census region before 1970. Panel B shows mortality rates for black children and for white children.

A series of exploratory analyses, however, showed no convincing evidence that the declines among infants that were not due to the new codes or the substantial declines among preschool and older children were attributable to improved treatment of bacterial infections, changes in the use of antimicrobial agents, changes in the distribution of pathogens, regional differences in medical care, earlier or improved care of critically ill children, or coding artifacts. The mortality rate for bacterial pneumonia did not decline more steeply than the rate for viral pneumonia, as might have been expected if earlier or improved antimicrobial treatment had been responsible for the declines. The introduction of the Women, Infants, and Children program in 1972 may have led to improvements in nutritional status, but it is not clear that malnutrition of the severity associated with fatal pneumonia was widespread in the United States in the 1970s.[22] The declines in mortality rates also could not be attributed to the introduction of ICD codes for deaths from asthma, respiratory failure, sepsis, or other disorders apart from pneumonia.

Among preschool children, the rate of mortality from pneumonia declined steeply during the period from 1963 through 1968 (data not shown). This decline, which immediately preceded and overlapped the overall reduction in mortality from pneumonia, coincided with the availability of the measles vaccine. Measles may be the leading preventable cause of death from childhood pneumonia throughout the

world.[23,24] Currently, measles accounts for approximately 1 million deaths per year, mostly among children in developing countries who are 9 to 24 months old.[24,25] Measles vaccine was introduced in the United States in 1963, and vaccination programs resulted in a 95 percent reduction in reported cases of measles, from 481,530 in 1962 to 22,231 in 1968.[26] Thus, the decline in the rate of mortality from pneumonia among preschool children occurred at the time and in the age group in which measles vaccination was likely to have had the greatest effect. However, except for a more prominent decline in this age group, it is difficult to separate the decline between 1963 and 1968 from the sustained decline during the period from 1966 through 1982.

The relative decline in rates of mortality from pneumonia among children of all ages from 1966 through 1982 may be attributable to improved access to medical care among poor children, primarily as a result of the Medicaid program. Evidence from several sources supports this hypothesis. Title XIX of the Social Security Act (the Medicaid program) was enacted in 1965 and ushered in a 15-year era of expanded federal health care programs for poor children that was unique in the 20th century (Table 1).[27-29] These programs were scaled back with the passage of the Omnibus Budget Reconciliation Act in 1981, although access to care has again improved since 1990.[30] From 1965 through 1976, the proportion of poor children who were covered by Medicaid increased dramatically. Others have also found that Medicaid benefits were introduced incrementally during this period.[29,31] The sustained decline in the rate of mortality from childhood pneumonia between 1966 and 1982 thus coincides with the introduction and expansion of federally mandated coverage of medical care for poor children.

If expanded access to medical care contributed to the decline in mortality rates during the 1970s, the steepest decline would be expected among poor children. However, death certificates do not include information about family income and insurance coverage. The narrowing of the gap between the mortality rates for black children and for white children and between the rates in the South and in other regions in the 1970s constitutes evidence of the role of expanded access to care. Black race has been used as a crude surrogate for poverty, as has residence in the South.[29] During the 1970s, the South had the largest population of poor children (6 million in 1969, as compared with 6.6 million in all other regions combined) and the lowest expenditures for children's health care (a mean expenditure of $24 per poor child, as compared with $36 or $37 per poor child for each of the other regions).[29]

The greatly expanded access to acute medical care among poor children during this period is well documented. Between 1964 and 1975, for example, the annual number of visits to a physician among children in the quartile with the lowest income increased by 70 percent (from 2.7 to 4.6 visits per child), whereas the number of visits for children in the quartile with the highest income decreased by 10 percent (from 5.0 to 4.5 visits per child).[29] Our analysis further demonstrated that rates of hospitalization for pneumonia among children increased in proportion to rates of hospitalization for other disorders during this period. Thus, the steep decline in the rates of mortality from pneumonia cannot be attributed to a decrease in the incidence of pneumonia but may correspond instead to increased access to care.

The Medicaid program was criticized in the 1970s for its excessive costs and for its focus on acute care

TABLE 1. U.S. HEALTH CARE PROGRAMS FOR CHILDREN IN THE 20TH CENTURY.*

YEAR	LEGISLATION OR EVENT	PROGRAM OR RESULT
1909	First White House Conference on the Child	Start of federal involvement in child welfare
1921	Sheppard–Towner Act	Maternal and infant health care
1930	Repeal of the Sheppard–Towner Act with support from the AMA	Formation of the American Academy of Pediatrics
1935	Title V	Maternal health care and care for crippled children
1965	Title XIX (Medicaid)	Medical care for poor children and elderly persons
1967	Early and Periodic Screening, Diagnosis, and Treatment	Increased well-child care
1972	Women, Infants, and Children	Nutritional supplements
1974	Title XX	Child care, family planning, and medical care
1978	Amendment of the Public Health Service Act	Adolescent-pregnancy programs
1981	Omnibus Budget Reconciliation Act	Three-year reduction in federal expenditures for children's health care

*Information is from Oberg,[27] Berkelhamer et al.,[28] and Davis and Schoen.[29] AMA denotes American Medical Association.

at public clinics and hospitals rather than on preventive care.[31,32] In fact, this focus may have reduced mortality from childhood pneumonia and other acute conditions that benefit from prompt access to physicians and hospitals. The number of deaths from diarrhea among children, for example, declined by 75 percent between 1968 and 1985, a change that was also out of proportion to changes in the numbers of deaths from other causes during this period.[33]

Further support for the possibility that increased access to care reduced the rate of mortality from pneumonia comes from a series of placebo-controlled studies showing that improved access to care and early antimicrobial treatment can decrease the rate of mortality from childhood pneumonia by approximately 50 percent.[1,2,34-36] Most of these studies have been conducted in developing countries, where the base-line rates of mortality from pneumonia are at least as high as the rates in the United States in the 1940s.

Limitations of the Study

Our analysis is subject to important limitations inherent in evaluations based on death records. The information contained in such records is quite limited and the documented cause of death may be inaccurate.[37] Our findings provided a useful framework for speculating on the factors that influence rates of mortality from pneumonia, but the events and interventions we proposed as influential factors may have been associated only indirectly with changes in these rates. Coding artifacts probably did not influence mortality rates, except for the effect of the new code for the sudden infant death syndrome on infant mortality rates. Some of the findings in our study are robust and not attributable to artifact, such as the 97 percent decline in the rate of mortality from pneumonia over a period of 58 years and the sustained steep decline among older children between 1966 and 1982.

Conclusions

We believe that some of the largest reductions in rates of mortality from childhood pneumonia during the past 50 years may have resulted from expanded access to medical care for poor children. New vaccines offer opportunities to reduce the incidence and severity of childhood pneumonia, and an additional expansion of health care coverage for poor children who might otherwise not receive prompt clinical attention may further reduce mortality rates.

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