Deaths From Pneumonia—New York City, 1999–2015

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Background. “Pneumonia and influenza” are the third leading cause of death in New York City. Since 2012, pneumonia and influenza have been the only infectious diseases listed among the 10 leading causes of death in NYC. Most pneumonia and influenza deaths in NYC list pneumonia as the underlying cause of death, not influenza. We therefore analyzed death certificate data for pneumonia in NYC during 1999–2015.

Methods. We calculated annualized pneumonia death rates (overall and by sociodemographic subgroup) and examined the etiologic agent listed.

Results. There were 41,400 pneumonia deaths during the study period, corresponding to an annualized age-adjusted death rate of 29.7 per 100,000 population. Approximately 17.5% of pneumonia deaths specified an etiologic agent. Age-adjusted pneumonia death rate declined over the study period and across each borough. Males had an annualized age-adjusted pneumonia death rate 1.5 (95% confidence interval [CI], 1.5–1.5) times that of females. Non-Hispanic blacks had an annualized age-adjusted pneumonia death rate 1.2 (95% CI, 1.2–1.2) times that of non-Hispanic whites. The annualized pneumonia death rate increased with age group above 5–24 years and neighborhood-level poverty. Staten Island had an annualized age-adjusted pneumonia death rate 1.3 (95% CI, 1.2–1.3) times that of Manhattan. In the multivariable analysis, pneumonia deaths were more likely to occur among males, non-Hispanic blacks, persons aged ≥65 years, residents of neighborhoods with higher poverty levels, and in Staten Island.

Conclusions. While the accuracy of death certificates is unknown, investigation is needed to understand why certain populations are disproportionately recorded as dying from pneumonia in NYC.

Keywords. mortality; New York City; pneumonia.

Pneumonia is a clinical syndrome characterized by pulmonary infection. There are numerous infectious etiologies of pneumonia, though an etiology is not identified in the majority of cases even after extensive diagnostic evaluation [1]. An important contributor to pneumonia is infection with influenza virus, a common seasonal pathogen that can cause pneumonia through primary pulmonary infection or secondary bacterial complications [2]. Because of their association, pneumonia and influenza are often grouped together when analyzing death certificate data.

“Pneumonia and influenza” have ranked as the third leading cause of death in New York City since 1998 [3]. Since 2012, pneumonia and influenza have been the only infectious diseases listed among the 10 leading causes of death in NYC; HIV, which was previously among the 10 leading causes of death, has now fallen from the list [3]. These statistics are generated annually in NYC using death certificate data processed via a standard definition that is also used nationally, but these statistics have 2 notable limitations for understanding pneumonia burden in NYC.

First, the International Classification of Diseases, Tenth Revision (ICD-10), codes that the standard definition uses to identify pneumonia and influenza (ICD-10 codes J09–J18) are not inclusive of all forms of pneumonia that might be contributing to the overall burden of pneumonia in NYC. For example, newborns can experience pneumonia, yet congenital pneumonias (ICD-10 codes P23.1–P23.6) are not part of the standard definition, nor are pneumonias following aspiration events (ICD-10 code J69.0) [4, 5]. Furthermore, this standard definition does not fully reflect local epidemiologic circumstances for pneumonia. The pneumonia and influenza diagnoses (ICD-10 codes J09–J18) used by this standard definition notably do not include Legionnaires’ disease (ICD-10 code A48.1), a severe pneumonia caused by Legionella bacteria whose incidence is rising in NYC and which has been responsible for severe outbreaks in NYC [4, 6–8].

Second, while grouping pneumonia and influenza together is accurate in some cases, the 2 conditions are not always associated, and combining them might obscure differences in epidemiology. Within the category pneumonia and influenza (ICD-10 codes J09–J18), there are substantially more deaths recorded for pneumonia (ICD-10 codes J12–J18) than deaths
recorded for influenza (ICD-10 codes J09–J11). For example, in NYC during 1999–2015, pneumonia was listed as the underlying cause of death in 99.3% of all pneumonia and influenza deaths, whereas influenza was listed as the underlying cause of death in only 0.7%.

There are limited published data on the epidemiology of pneumonia in NYC [9]. Understanding the aggregate burden of pneumonia in NYC, as well as burden for various sociodemographic groups, could inform clinical and public health interventions. Thus, we analyzed death certificate data in NYC during 1999–2015 in which pneumonia was listed as a cause of death.

**METHODS**

**Data Source**
We analyzed death certificate data reported to the NYC Department of Health and Mental Hygiene (DOHMH) for NYC residents during 1999–2015. Underlying cause of death (the primary condition reported as most responsible for an individual’s death) and multiple causes of death (all conditions on the death certificate that were reported to have contributed to an individual’s death) data were included in this analysis. DOHMH determined that this investigation does not involve human subjects, and the Centers for Disease Control and Prevention determined this investigation to be public health nonresearch.

**Definitions**
We defined a pneumonia death as a death in which an ICD-10 code for pneumonia was listed as the underlying cause of death on the death certificate. A pneumonia-related death was one in which an ICD-10 code for pneumonia was listed among any of the conditions on the death certificate that might have contributed to the individual’s death. ICD-10 codes for pneumonia were identified by searching the ICD-10 diagnostic code index for any diagnoses that included the word pneumonia [4]. Table 1 lists 41 pneumonia ICD-10 codes identified plus 2 additional codes for Legionnaires’ disease and pneumonitis due to food and vomit [4].

Pneumonia and pneumonia-related deaths were subcategorized as having a specified etiology if an etiologic agent was identified on the death certificate (influenza viral pneumonia, noninfluenza viral pneumonia, bacterial pneumonia, or other specified pneumonia) or as having an unspecified etiology if an etiologic agent was not identified.

**Data Analysis**
The unit of analysis was a person. We calculated the count and percentage of pneumonia and pneumonia-related deaths using underlying cause of death and multiple cause of death data, respectively.

Annualized pneumonia and pneumonia-related death rates were derived 2 ways. First, we divided the annual age-specific number of pneumonia and pneumonia-related deaths, respectively, by the corresponding population using intercensal population estimates from the US Census for each year [10]. Second, we multiplied the monthly counts for pneumonia and pneumonia-related deaths by 12 to annualize the rates. In both cases, the death rates were expressed per 100,000 population. Pneumonia deaths were also categorized into 7 age groups (<5, 5–24, 25–44, 45–64, 65–74, 75–84, ≥85 years). Where applicable, we age-adjusted the annualized death rates to the 2000 projected US population using direct standardization (see the Supplementary Methods for details) [10].

We calculated annualized age-adjusted pneumonia and pneumonia-related death rates for each year and by month. We assumed a Poisson process in the generation of death counts and related standard errors. Rate ratios (RRs) and 95% confidence intervals (CIs) were calculated by sex, age categories, race/ethnicity groups, neighborhood-level poverty, and borough [11].

We assessed neighborhood-level poverty using underlying cause of death data and residential Census tract information available at the time of death. Neighborhood-level poverty was defined as the percentage of residents with an income below the federal poverty level within a defined Census tract [12]. Poverty data were obtained from the 2000 Census and the American Community Surveys from 2005–2014 [12, 13]. Neighborhood-level poverty for each Census tract was aggregated and categorized into 4 groups: low (<10% of residents living below the federal poverty level), medium (10 to <20%), high (20 to <30%), and very high (≥30%) [12]. Data before 2000 were excluded from the neighborhood-level poverty analysis due to the lack of consistently constructed Census tract poverty data.

We examined accompanying information on death certificates, such as place of death, type of institution where death occurred, autopsy performed, tobacco use contributing to death, pregnancy status at time of death, birthplace, premature death (death in a person aged <65 years), and education level. Some death certificates had missing information on place of death (0.3%), type of institution where death occurred (0.3%), autopsy performed (5.4%), tobacco use contributing to death (70.7%), pregnancy status at time of death (52.3% among female decedents), birthplace (1.8%), and education level (3.7%). For all accompanying information, we calculated the proportion of pneumonia deaths of specified and unspecified etiology and used the chi-square test to assess the difference in proportion [11]. For pneumonia-related deaths, we identified the 10 leading underlying causes of death listed on the death certificate.

We performed 2 multivariable analyses, using a negative binomial regression, to assess the direct effects of demographic factors on pneumonia death rate, while adjusting for potential confounders. Model 1 adjusted for borough and included data from 1999–2015; model 2 adjusted for neighborhood-level poverty and included data from 2000–2015. We used the negative
Table 1. Number and Frequency of Pneumonia and Pneumonia-Related Deaths—New York City, 1999–2015

| Pneumonia Disease Category | ICD-10 Code | Pneumonia Deaths | Pneumonia Death, % | Pneumonia-Related Deaths | Pneumonia-Related Death, % |
|----------------------------|-------------|-------------------|--------------------|--------------------------|---------------------------|
| Total                      | N/A         | 41,400            | 100.0              | 78,351                   | 100.0                     |
| Specified                  | N/A         | 7236              | 17.48              | 12,343                   | 15.75                     |
| Influenza viral pneumonia  | J11.0       | 61                | 0.15               | 59                       | 0.08                      |
| Influenza with pneumonia, influenza virus identified | J10.0 | 31 | 0.07 | 23 | 0.03 |
| Influenza with pneumonia, virus not identified | J12.0 | 6 | 0.01 | 8 | 0.01 |
| Noninfluenza viral pneumonia | N/A | 98 | 0.24 | 163 | 0.21 |
| Adenoviral pneumonia       | J12.1       | 7                 | 0.02               | 11                       | 0.01                      |
| Respiratory syncytial virus pneumonia | J12.2 | 3 | 0.01 | 6 | 0.01 |
| Parainfluenza virus pneumonia | J12.3 | 1 | 0.00 | 2 | 0.00 |
| Human metapneumovirus pneumonia | J12.8 | 4 | 0.01 | 2 | 0.00 |
| Other viral pneumonia      | J12.9       | 66                | 0.16               | 109                      | 0.14                      |
| Viral pneumonia, unspecified | B10.2 | 2 | 0.00 | 3 | 0.00 |
| Measles complicated by pneumonia | B05.2 | 0 | 0.00 | 0 | 0.00 |
| Cytomegaloviral pneumonia  | B25.0       | 7                 | 0.02               | 18                       | 0.02                      |
| Congenital pneumonia due to viral agent | P23.0 | 2 | 0.00 | 4 | 0.01 |
| Bacterial pneumonia        | N/A         | 6,293             | 15.20              | 11,623                   | 14.83                     |
| Pneumonia due to *Streptococcus pneumoniae* | J13 | 108 | 0.26 | 156 | 0.20 |
| Pneumonia due to *Haemophilus influenzae* | J14 | 5 | 0.01 | 6 | 0.01 |
| Pneumonia due to *Klebsiella pneumoniae* | J15.0 | 426 | 1.03 | 728 | 0.93 |
| Pneumonia due to *Pseudomonas* | J15.1 | 218 | 0.53 | 379 | 0.48 |
| Pneumonia due to *Staphylococcus* | J15.2 | 348 | 0.84 | 615 | 0.78 |
| Pneumonia due to *Streptococcus*, group B | J15.3 | 0 | 0.00 | 0 | 0.00 |
| Pneumonia due to other *Streptococci* | J15.4 | 104 | 0.25 | 209 | 0.27 |
| Pneumonia due to *Escherichia coli* | J15.5 | 15 | 0.04 | 25 | 0.03 |
| Pneumonia due to other aerobic Gram-negative bacteria | J15.6 | 47 | 0.11 | 81 | 0.10 |
| Pneumonia due to *Mycoplasma pneumoniae* | J15.7 | 6 | 0.01 | 8 | 0.01 |
| Other bacterial pneumonia | J15.8 | 74 | 0.18 | 139 | 0.18 |
| Bacterial pneumonia, unspecified | J15.9 | 4873 | 11.77 | 9207 | 11.75 |
| Chlamydial pneumonia       | J16.0       | 0                 | 0.00               | 0                        | 0.00                      |
| Legionnaires’ disease      | A48.1       | 63                | 0.15               | 63                       | 0.08                      |
| Congenital pneumonia due to *Chlamydia* | P23.1 | 0 | 0.00 | 0 | 0.00 |
| Congenital pneumonia due to *Staphylococcus* | P23.2 | 0 | 0.00 | 0 | 0.00 |
| Congenital pneumonia due to *Streptococcus*, group B | P23.3 | 0 | 0.00 | 0 | 0.00 |
| Congenital pneumonia due to *Escherichia coli* | P23.4 | 0 | 0.00 | 0 | 0.00 |
| Congenital pneumonia due to *Pseudomonas* | P23.5 | 1 | 0.00 | 1 | 0.00 |
| Congenital pneumonia due to other bacterial agents | P23.6 | 5 | 0.01 | 6 | 0.01 |
| Other specified pneumonia  | N/A         | 753               | 1.82               | 475                      | 0.61                      |
| Pneumonia due to other specified infectious organisms | J16.8 | 0 | 0.00 | 4 | 0.01 |
| HIV disease with *Pneumocystis carinii* pneumonia | B20.8 | 751 | 1.81 | 471 | 0.60 |
| Congenital pneumonia due to other organisms | P23.8 | 2 | 0.00 | 0 | 0.00 |
| Unspecified                | N/A         | 34,164            | 82.52              | 66,008                   | 84.25                     |
| Bronchopneumonia, unspecified | J18.0 | 1788 | 4.32 | 5744 | 7.33 |
| Lobar pneumonia, unspecified | J18.1 | 10,942 | 26.43 | 15,818 | 20.19 |
| Hypostatic pneumonia, unspecified | J18.2 | 2 | 0.00 | 78 | 0.10 |
| Other pneumonia, organism unspecified | J18.8 | 20 | 0.05 | 99 | 0.13 |
| Pneumonia, unspecified     | J18.9       | 20,542            | 49.62              | 41,291                   | 52.70                     |
| Abscess of lung with pneumonia | J85.1 | 18 | 0.04 | 81 | 0.10 |
| Congenital pneumonia, unspecified | P23.9 | 32 | 0.08 | 57 | 0.07 |
| Pneumonitis due to food and vomit | J69.0 | 820 | 1.98 | 2840 | 3.62 |

Pneumonia deaths: the primary condition reported as most responsible for an individual’s death; pneumonia-related deaths: all conditions reported on the death certificate that contributed to an individual’s death.

Abbreviations: ICD-10, International Classification of Diseases, Tenth Revision; N/A, not applicable.
binomial model because it provided an improved fit compared with the Poisson regression as well as addressing the issue of overdispersion in our data. RRs and 95% CIs were calculated. All analyses were done using SAS 9.4 software. A P value <.05 was considered statistically significant.

RESULTS
During 1999–2015, there were 41,400 pneumonia deaths in NYC, corresponding to a mean of 2,435 pneumonia deaths per year or an annualized age-adjusted pneumonia death rate of 29.7 (95% CI, 29.4–30.0) per 100,000 population. (Table 2) The annualized age-adjusted pneumonia death rate declined from 32.3 (95% CI, 31.6–33.0) per 100,000 population during 1999–2001 to 24.7 (95% CI, 24.1–25.3) per 100,000 population during 2013–2015; Figure 1A shows the trend over the study period. This downward trend in annualized age-adjusted death rate was also observed for pneumonia-related deaths, from 67.6 (95% CI, 66.6–68.7) per 100,000 population during 1999–2001 to 50.5 (95% CI, 49.6–51.3) per 100,000 population during 2013–2015; Figure 1B shows the trend over the study period. Pneumonia deaths (Supplementary Figure 1) and pneumonia-related deaths (data not shown) varied by season, with the highest pneumonia death rates occurring during winter months.

Etiology of Pneumonia Deaths
Pneumonia deaths of specified etiologies accounted for 17.5% (n = 7,236) of all pneumonia deaths. The remaining 82.5% (n = 34,164) of pneumonia deaths were due to unspecified etiologies. Of all deaths with pneumonia as the underlying cause, 15.2% were attributed to bacterial infection, which was the most common etiologic agent listed among all specified etiologies. Of the 6,293 bacterial pneumonia deaths, 63 (1.0%) were attributed to Legionnaires’ disease (Table 1). The annualized age-adjusted pneumonia death rate for pneumonias of unspecified etiology declined from 27.3 (95% CI, 26.6–28.0) per 100,000 population during 1999–2001 to 20.3 (95% CI, 19.8–20.9) per 100,000 population during 2013–2015. Conversely, the annualized age-adjusted pneumonia death rate for pneumonias of specified etiology remained statistically (weakly) unchanged from 5.0 (95% CI, 4.7–5.3) per 100,000 population during 1999–2001 to 4.4 (95% CI, 4.2–4.7) per 100,000 population during 2013–2015.

Pneumonia Death Rate by Sex, Race/Ethnicity, Neighborhood-Level Poverty, and Borough of Residence
The annualized age-adjusted pneumonia death rate was greater in males than females (RR, 1.5; 95% CI, 1.5–1.5) (Table 2). Non-Hispanic blacks (RR, 1.2; 95% CI, 1.2–1.2) had significantly higher annualized age-adjusted pneumonia death rates compared with non-Hispanic whites. Non-Hispanic Asians/Pacific Islanders (RR, 0.8; 95% CI, 0.8–0.8) had a significantly lower annualized age-adjusted pneumonia death rate compared with non-Hispanic whites. The annualized age-adjusted pneumonia death rate for Hispanics was not significantly different from that of non-Hispanic whites (RR, 1.0; 95% CI, 1.0–1.1). Neighborhoods with a very high poverty level had an annualized age-adjusted pneumonia death rate 1.6 (95% CI, 1.6–1.6) times that of neighborhoods with a low poverty level.

By borough, the highest (38.3; 95% CI, 36.9–39.7; per 100,000 population) and lowest (23.0; 95% CI, 22.5–23.4; per 100,000 population) annualized age-adjusted pneumonia death rates occurred in Staten Island and Queens, respectively (Table 2). The annualized age-adjusted pneumonia death rate was highest in Staten Island at 49.8 (95% CI, 47.6–52.1) per 100,000 population during 1999–2007, but was later equal to or surpassed by the annualized age-adjusted pneumonia death rate of 32.5 (95% CI, 31.4–33.6) per 100,000 population in the Bronx during 2008–2015. In contrast, Queens had the lowest annualized age-adjusted pneumonia death rate during both time periods, at 23.1 (95% CI, 22.5–23.8) in 1999–2007 and 22.8 (95% CI, 22.2–23.5) in 2008–2015 (Figure 2).

Pneumonia Death Rate by Age Group
Annualized pneumonia death rates increased with each age group above the 5–24-year age group, and most deaths were not premature (85.6%). However, persons aged <5 years (RR, 5.3; 95% CI, 4.3–6.6) had a higher annualized pneumonia death rate compared with persons aged 5–24 years.

Multivariable Regression Estimates
Among persons of all age groups, pneumonia death RRs were attenuated after adjusting for sex, race/ethnicity, and borough for model 1 (which adjusted for borough), and were attenuated for those aged ≤64 years after adjusting for sex, race/ethnicity, and neighborhood-level poverty for model 2 (which adjusted for neighborhood-level poverty). Additionally, in both multivariable models, pneumonia death RRs for non-Hispanic blacks and males were larger compared with unadjusted RRs. In model 1, both Staten Island and the Bronx had the highest RR (RR, 1.2; 95% CI, 1.1–1.4; and RR, 1.3; 95% CI, 1.1–1.4; respectively), whereas Queens had the lowest RR (RR, 0.8; 95% CI, 0.7–0.9), relative to Manhattan, after controlling for sex, race/ethnicity, and age (Table 3). In model 2, we observed an increasing gradient in RR by neighborhood-level poverty, even after adjusting for demographic characteristics (Supplementary Table 1).

Accompanying Data on Death Certificates
Among persons who experienced a pneumonia death, 34.1% were born outside of the United States. The majority of pneumonia deaths occurred during an inpatient hospital stay (86.7%). More than half of pneumonia deaths (53.8%) occurred among persons with a high school diploma/general educational development certificate or some college. An autopsy was performed in 4.4% of pneumonia deaths (Supplementary Table 2).

Pneumonia-Related Deaths
A total of 78,351 pneumonia-related deaths were reported during 1999–2015, with 15.8% of these deaths due to pneumonias
## Table 2. Annualized Age-Adjusted Pneumonia Death Rates in Bivariate Analysis—New York City, 1999–2015

| Category                  | Overall | Specified Etiology | Unspecified Etiology |
|---------------------------|---------|--------------------|----------------------|
|                           | No.     | %                  | Death Rate<sup>a</sup> | Rate Ratio 95% CI | No.     | %                  | Death Rate<sup>a</sup> | Rate Ratio 95% CI | No.     | %                  | Death Rate<sup>a</sup> | Rate Ratio 95% CI |
| Total                     | 41 400  | 100.0              | 29.7                 | -                | 7236    | 17.5              | 5.2               | -               | 34 164  | 82.5              | 24.5               | -               |
| Sex                       |         |                    |                      |                  |         |                    |                   |                |         |                    |                    |                |
| Male                      | 19 041  | 46.0               | 37.4                 | 1.5              | 1.5–1.5 | 3525               | 48.7             | 6.6            | 1.5               | 1.5–1.6            | 15 516  | 45.4              | 30.8             | 1.5          |
| Female                    | 22 359  | 54.0               | 24.9                 | Ref              | Ref     | 3711               | 51.3             | 4.3            | Ref              | Ref               | 18 648  | 54.6              | 20.7             | Ref          |
| Age category, y<sup>b</sup> |         |                    |                      |                  |         |                    |                   |                |         |                    |                    |                |
| <5                        | 201     | 0.5                | 2.2                  | 5.3              | 4.3–6.6 | 77                 | 1.1             | 0.8            | 5.5               | 3.9–7.8            | 124     | 0.4               | 14.8          | 5.2          |
| 5–24                      | 149     | 0.4                | 0.4                  | Ref              | Ref     | 55                 | 0.8             | 0.2            | Ref              | Ref               | 94      | 0.3               | 0.3            | Ref          |
| 25–44                     | 993     | 2.4                | 2.2                  | 5.4              | 4.6–6.4 | 452                | 6.2             | 1.0            | 6.7               | 5.1–8.9            | 541     | 1.6               | 1.2            | 4.7          |
| 45–64                     | 4615    | 11.1               | 14.2                 | 34.4             | 29.2–40.5 | 1234              | 17.1            | 3.8            | 24.9              | 19.0–32.6          | 3381    | 9.9               | 10.4            | 39.9         |
| 65–74                     | 5343    | 12.9               | 59.2                 | 143.4            | 121.9–168.7 | 1023              | 14.1            | 11.3           | 74.4              | 56.7–97.6          | 4320    | 12.6              | 47.8            | 183.8        |
| 75–84                     | 11 513  | 27.8               | 206.1                | 499.3            | 424.8–586.9 | 1820              | 25.2            | 32.6           | 213.8             | 163.5–279.6        | 9693    | 28.4              | 173.5           | 666.4        |
| ≥85                       | 18 586  | 44.9               | 803.9                | 1947.8           | 1657.8–2288.6 | 2575              | 35.6            | 111.4          | 731.1             | 559.7–954.9        | 16 011  | 46.9              | 692.6           | 2659.8       |
| Race/ethnicity            |         |                    |                      |                  |         |                    |                   |                |         |                    |                    |                |
| Non-Hispanic Asian/PI     | 2456    | 5.9                | 22.6                 | 0.8              | 0.8–0.8 | 342                | 4.7             | 3.0            | 0.7               | 0.6–0.8            | 2114    | 6.2               | 19.6            | 0.8          |
| Non-Hispanic black        | 9579    | 23.1               | 33.8                 | 1.2              | 1.2–1.2 | 2184               | 30.3            | 7.4            | 1.8               | 1.7–1.9            | 7385    | 21.6              | 26.3            | 1.1          |
| Hispanic                  | 6866    | 16.6               | 29.2                 | 1.0              | 1.0–1.1 | 1392               | 19.2            | 5.5            | 1.3               | 1.2–1.4            | 5474    | 16.0              | 23.7            | 1.0          |
| Non-Hispanic white        | 21 702  | 52.4               | 28.3                 | Ref              | Ref     | 3131               | 43.3            | 4.2            | Ref              | Ref               | 18 571  | 54.4              | 24.1            | Ref          |
| Other/unknown             | 797     | 1.9                | -                    | -                | -       | 177                | 2.4             | -              | -                 | -                 | 620     | 1.8               | -              | -            |
| Neighborhood-level poverty<sup>c</sup> |         |                    |                      |                  |         |                    |                   |                |         |                    |                    |                |
| Low: <10%                 | 11 333  | 29.3               | 24.1                 | Ref              | Ref     | 1567               | 23.4            | 3.4            | Ref              | Ref               | 9746    | 30.6              | 20.7            | Ref          |
| Medium: 10–<20%           | 10 846  | 28.1               | 27.8                 | 1.2              | 1.1–1.2 | 1802               | 26.5            | 4.6            | 1.3               | 1.3–1.4            | 9044    | 28.4              | 23.1            | 1.1          |
| High: 20–<30%             | 7877    | 20.4               | 32.3                 | 1.3              | 1.3–1.4 | 1472               | 21.7            | 5.9            | 1.7               | 1.6–1.9            | 6405    | 20.1              | 26.3            | 1.3          |
| Very high: ≥30%           | 8560    | 22.2               | 38.7                 | 1.6              | 1.6–1.6 | 1933               | 28.5            | 8.5            | 2.5               | 2.3–2.6            | 6627    | 20.8              | 30.2            | 1.5          |
| Borough of residence during time of death |         |                    |                      |                  |         |                    |                   |                |         |                    |                    |                |
| Bronx                     | 7220    | 17.4               | 35.5                 | 1.2              | 1.1–1.2 | 1825               | 25.2            | 8.9            | 1.9               | 1.7–2.0            | 5393    | 15.8              | 26.6            | 1.0          |
| Brooklyn                  | 12 912  | 31.2               | 31.4                 | 1.0              | 1.0–1.1 | 2299               | 31.8            | 5.6            | 1.2               | 1.1–1.2            | 10 613  | 31.1              | 25.8            | 1.0          |
| Manhattan                 | 8850    | 21.4               | 30.2                 | Ref              | Ref     | 1385               | 19.1            | 4.8            | Ref              | Ref               | 7465    | 21.9              | 25.5            | Ref          |
| Queens                    | 9399    | 22.7               | 23.0                 | 0.8              | 0.7–0.8 | 1319               | 18.2            | 3.2            | 0.7               | 0.6–0.7            | 8080    | 23.7              | 19.7            | 0.8          |
| Staten Island             | 3019    | 7.3                | 38.3                 | 1.3              | 1.2–1.3 | 408                | 5.6             | 5.1            | 1.1               | 1.0–1.2            | 2611    | 7.6               | 33.2            | 1.3          |

Abbreviations: CI, confidence interval; PI, Pacific Islander; Ref, reference.

<sup>a</sup>Rate expressed as annualized age-adjusted and age-specific death rate per 100,000 population of the corresponding population per year.

<sup>b</sup>Age-specific pneumonia death rates.

<sup>c</sup>For neighborhood-level poverty, the number of pneumonia deaths was calculated for only those deaths with available Census tract data during 2000–2015.
of specified etiology. During this period, the 5 most common underlying causes of death among pneumonia-related deaths were (in descending order): chronic ischemic heart disease, unspecified dementia, other chronic obstructive pulmonary disease, malignant neoplasm of bronchus and lung, and stroke, not specified as hemorrhage or infarction (Supplementary Table 3).

**DISCUSSION**

We conducted an exploratory analysis of pneumonia deaths in NYC using death certificate data, given that pneumonia is a leading cause of death in NYC. The data presented here are not routinely presented in mortality reports for NYC [14]. We found that the death rate from pneumonia declined in NYC during 1999–2015 and that an average of 2400 New Yorkers were reported to have died from pneumonia annually. We also observed differences in pneumonia death rates by various sociodemographic subgroups. Most pneumonia deaths had no etiology specified on the death certificate.

Health disparities by age, sex, and race/ethnicity have been previously documented in NYC, and we observed similar disparities for pneumonia deaths in our analysis [15–17]. For example, older adults and males experienced higher pneumonia death rates in NYC compared with younger persons and...
females, respectively, even after adjusting for confounding factors, and this is consistent with national data [18]. Similarly, we found that non-Hispanic blacks had a higher pneumonia death rate compared with non-Hispanic whites (also consistent with national data) in both the unadjusted and adjusted models [18].

We also found that neighborhoods characterized by higher levels of poverty had higher pneumonia death rates relative to neighborhoods characterized by lower levels of poverty, even after adjusting for individual sociodemographic characteristics. Additional investigation of risk factors at the neighborhood level could potentially reveal some that are modifiable. For example, air pollution levels in NYC vary by neighborhood; they are higher in higher-poverty than lower-poverty neighborhoods and have been linked to higher hospitalization rates for respiratory disease and higher risk of pneumonia death [19–21]. Thus, strategies that target neighborhood-level risk factors for pneumonia deaths such as air pollution might have an indirect impact in NYC.

Variation in pneumonia death rates were also observed by NYC borough, with Staten Island having the highest and Queens having the lowest annualized age-adjusted pneumonia death rates, independent of individual sociodemographic factors. It is notable that Staten Island had a disproportionately high annualized age-adjusted pneumonia death rate from 1999–2000 and 2003–2006 compared with the other 4 boroughs. In 2005, Staten Island reported its highest annual age-adjusted pneumonia death rate of 68.3 per 100,000 population, which was nearly double and triple the rates of Manhattan and Queens, respectively. After 2007, the annual age-adjusted pneumonia death rate in Staten Island began to approach the rates of other boroughs and was no longer ranked the highest from 2008–2015. The reason for this trend in Staten Island is unknown. One possibility is that there are systematic cause of death reporting issues within medical institutions in different boroughs. Given that there are fewer medical institutions located in Staten Island relative to the other 4 boroughs, any systematic reporting differences concentrated within Staten Island medical institutions would be magnified compared with the other 4 boroughs [22]. To our knowledge, there are no data to confirm this hypothesis, and further investigation is needed.

Similar to prior investigations, we found that the majority of pneumonia deaths were of unspecified etiology, and autopsies were performed only rarely, even though >80% of deaths occurred while inpatient [1, 5]. Because pneumonia can be caused by numerous pathogens, identifying the etiologic agent can help clinicians tailor patient-specific treatment [23]. Additional investigation is needed into the frequency with which appropriate microbiologic diagnostics are performed among patients with pneumonia (such as testing for *Legionella* and respiratory tract viral pathogens), and linking these data to the causes of death listed on death certificates. Moreover, knowing the setting of pneumonia acquisition (community vs hospital) can assist public health authorities in developing targeted interventions to reduce pneumonia deaths [24]. Unfortunately, data
from death certificates currently do not indicate the setting of pneumonia acquisition. Taken together, we suggest that future studies should investigate whether improvements made to identify etiologic agents and the settings of pneumonia acquisition can help to reduce the risk of pneumonia deaths by helping to tailor patient-specific treatments.

There are several limitations to our study. First, the data we used were limited to data reported on the death certificate and did not involve medical chart review. Thus, we did not analyze how cases were managed, such as timing of antibiotic administration, types of antibiotics used, and advanced life support. Second, because we did not review medical charts or autopsy reports, we do not know the accuracy of death certificate data for pneumonia. In NYC, physician training on completion of death certificates is not a requirement, and while DOHMH does offer an electronic learning module, more comprehensive education on completion of death certificates would likely be beneficial [25]. Without any required standard training, it is possible that unorthodox practices of death certificate completion can develop within medical institutions, such as at teaching hospitals where there are clinicians with less experience completing death certificates. For example, a study at an NYC hospital investigating deaths in which unspecified pneumonia (ICD-10 code J18.9) was originally listed as the underlying cause of death found that after amending the death certificate, >90% of these deaths had a change in the assigned underlying cause of death [26]. While this study is not generalizable to all of NYC, it does suggest that hospital-level investigation can be helpful in examining entrenched systematic bias surrounding death certificate completion. Another study of the quality of cause of death reporting in NYC showed that >60% of death certificates listing pneumonia as the underlying cause of death were of limited quality [27]. When completing death certificates, physicians use their best judgment and the medical information available at the time of death to work back from the immediate cause of death to the underlying cause of death [28]. There are situations in which the medical information initially available may be limited and may result in a cause of death being listed that may not accurately describe the chain of events. Finally, although not a limitation, in conducting this investigation we used an expanded set of ICD-10 codes to define pneumonia in such a way that reflects local circumstances (such as Legionnaires’ disease) [6–8]. Because we used an expanded definition for pneumonia deaths, caution should be taken when comparing the rates presented here with those in other studies that use the conventional pneumonia and influenza definition (ICD-10 codes J09–J18). The expanded pneumonia diagnoses that we included only accounted for 2.0% of the total pneumonia deaths reported in our analysis.

In conclusion, pneumonia is an important cause of reported mortality in NYC. More research into the epidemiology of pneumonia in NYC could reveal modifiable risk factors, potential interventions, and gaps or systemic patterns in pneumonia cause of death reporting.

### Supplementary Data

Supplementary materials are available at Open Forum Infectious Diseases online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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