

## Geographic Variation in Pneumonia and Influenza in Long-Term Care Facilities: A National Study

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There is large county-level geographic variation in pneumonia and influenza hospitalizations among short-stay and long-stay long-term care facility residents in the United States. Long-term care facilities in counties in the Southern and Midwestern regions had the highest rates of pneumonia and influenza from 2013 to 2015. Future research should identify reasons for these geographic differences.

**Keywords.** pneumonia; influenza; Medicare; long-term care; spatial analysis.

Between 2015 and 2016, 50% of influenza-associated hospitalizations and 64% of deaths related to pneumonia and influenza (P&I) occurred among Medicare-eligible adults aged  $\geq 65$  years, many of whom live in long-term care facilities (LTCFs) [1]. A growing body of evidence has documented the particularly high risk of respiratory infections among the 1.3 million frail older adults residing in LTCFs annually [2–5]. P&I infections increase the risk of hospitalization for these older adults, leading to many adverse outcomes and increased health-care costs [6].

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No studies have employed national data to identify geographic patterns in the incidence of P&I in LTCFs across all counties in the United States (US). Our prior work described LTCF factors affecting P&I incidence across LTCFs for short-stay and long-stay LTCF populations, each receiving post-acute and long-term care, respectively [4]. One might expect differences in P&I between the short and long-stay LTCF populations because of differences in clinical acuity, staffing, and LTCF resources. Quantifying the county-level burden of P&I in LTCFs is critically important to help identify geographic differences and opportunities for interventions to reduce respiratory infections. Such information is highly relevant to local public health leaders and clinicians responsible for making decisions about resource allocation, treatment efforts, and infection control interventions to improve health outcomes for the vulnerable LTCF population.

Geospatial analyses incorporate geographic information to explore variation that might be due to differences in location. We extend our prior work by conducting a geospatial analysis to (1) determine how P&I hospitalization rates from LTCFs vary across US counties adjusting for LTCF resident characteristics, and (2) identify clusters of counties with similarly high and low P&I rates. We hypothesized that there would be wide variation in rates across counties for both short-stay and long-stay LTCF populations.

### METHODS

This was a retrospective cohort study derived from a national population of  $> 7.2$  million Medicare beneficiaries residing in 15 887 LTCFs between 1 January 2013 and 31 December 2015. In brief, we used 100% of 2013–2015 Medicare claims, Minimum Data Set clinical assessments, and facility-level data to identify eligible short-stay ( $< 100$  days) and long-stay ( $\geq 100$  days) LTCF residents (Supplementary Table 1) [4]. We identified all US counties using Federal Information Processing Standards county codes and aggregated resident covariates to the county level. County was the chosen unit of analysis because counties are often the smallest geographic unit with policy implications and the unit at which Medicare beneficiaries typically select LTCFs. P&I was identified by the presence of an *International Classification of Diseases, Clinical Modification, Ninth Revision* or *Tenth Revision* diagnosis code for pneumonia or influenza-like illness (480–488.XX, J09–J18) in the principal position on the hospitalization claim [7]. We calculated crude P&I hospitalization incidence rates (IRs) and risk-standardized incidence rates (RSIRs) in each county to adjust for resident-level differences. We used risk-standardization via hierarchical Poisson modeling adapted from Centers for Medicare and Medicaid Services methodology (Supplementary Text 1 and Supplementary Table 2) [4].

Geospatial analyses were employed to explore geographic patterns in the crude IRs and RSIRs. We identified the degree to which county RSIRs are related to neighboring county's rates across all counties by calculating a global Moran's *I* statistic (Supplementary Text 2). We further explored patterns by calculating an Anselin local Moran's *I* statistic to identify clusters of counties with similarly high or low P&I rates (high-high or low-low clusters), or outlier counties (high-low or low-high outliers) with rates differing from neighboring counties (Supplementary Text 2). Hawaii and Alaska are geographic outliers from the continental US and were excluded. Choropleth maps were used to plot the quintiles of crude IRs and RSIRs across counties. Data were analyzed using SAS version 9.4 (SAS Institute, Cary, North Carolina), R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria), and ArcMap 10.5.1 (ESRI, Redlands, California) software. The institutional review board at Brown University approved the study protocol.

## RESULTS

### Study Cohorts and Pneumonia and Influenza Incidence Rates

The final study cohort consisted of 1 771 960 short-stay residents (14 306 LTCFs) across 2745 counties, and 922 724 long-stay residents (14 536 LTCFs) across 2784 counties (Supplementary Figure 1 and Supplementary Table 2). During the study period, the average county-level crude IR per 1000 person-years among short-stay residents was 163.7 (standard deviation [SD], 218.3) with a minimum of 0.0 and maximum of 2463.8. The average county-level crude IR among long-stay residents was 116.9 (SD, 82.1) with a minimum of 0.0 and maximum of 873.2. Short-stay county-level RSIRs per 1000 person-years were a mean of 110.6 (SD, 29.8) with a minimum of 32.7 and maximum of 340.9 (Figure 1). Long-stay county-level RSIRs were a mean of 100.5 (SD, 50.2) with a minimum of 19.7 and maximum of 685.4 (Figure 1).

### Geospatial Analysis of Pneumonia and Influenza Incidence Rates

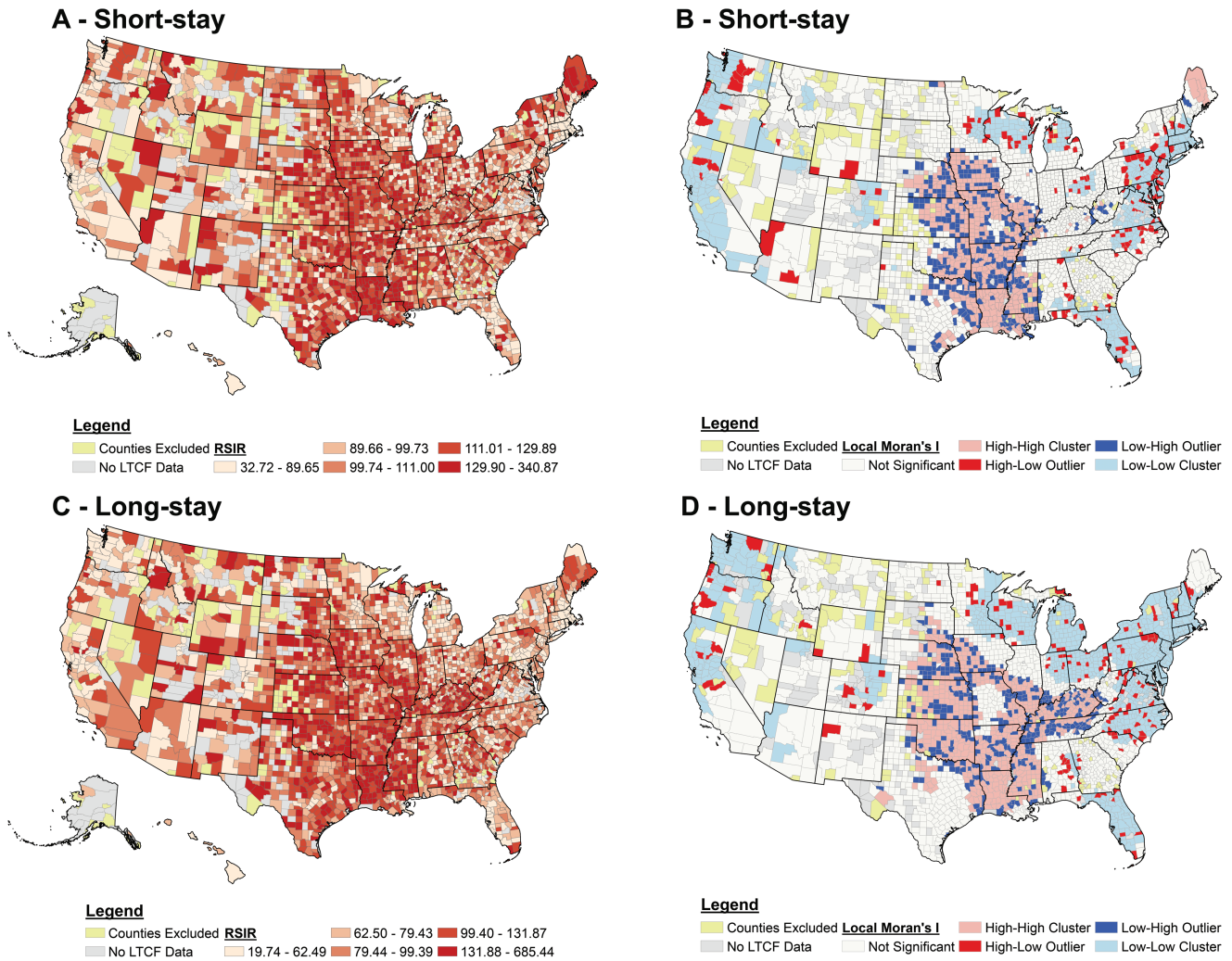
The highest crude IRs and RSIRs were concentrated among counties in the Midwestern and Southern US for both short-stay and long-stay residents (Supplementary Figure 2, Supplementary Figure 3, and Figure 1). Positive spatial autocorrelation of county-level RSIRs was observed for short-stay residents (Moran's  $I = 0.14$ ,  $P < .01$ ) and long-stay residents (Moran's  $I = 0.23$ ,  $P < .01$ ). Clusters of counties with short-stay residents with high-high RSIRs were observed in the Southern and Midwestern US, with low-low clusters along the East and West Coasts (Figure 1). A similar pattern of county-level P&I events was observed for counties with long-stay residents, though the high-high clusters extended further east and the low-low clusters extended further from east to west (Figure 1). Outlier counties differed between the short-stay and long-stay populations.

## DISCUSSION

In this national study of LTCF residents, we found marked geographic variation in the rates of P&I for both short-stay and long-stay populations. For both populations, higher RSIRs were observed for counties in the Southern and Midwestern US, with lower RSIRs in counties along the East Coast and West Coast. Clustering of counties with similar P&I rates was present for all LTCF residents, but particularly pronounced for long-stay residents. The clustering of adjacent counties with high and low P&I rates suggests that important factors influencing LTCF P&I rates may exist at the county level, with differences in outlier counties reinforcing that possibility. Counties with the highest and lowest rates might be particularly influenced by geographically varying characteristics such as hospital proximity or similar policies across chain-affiliated LTCFs. Outlier counties with low rates might have unique programs to manage P&I within LTCFs, while those with high rates might lack formal infection prevention and management policies [8]. Similarities between county-level short-stay and long-stay P&I rates may result from the co-location of residents in the same LTCF, with rates reduced by similar infection prevention programs. Conversely, differences may reflect the intensity of services provided for the short-stay population, reflecting less need to hospitalize for P&I compared to the long-stay population. Our study provides foundational evidence to inform strategic efforts at the county level to improve health outcomes of older adults by reducing and managing LTCF P&I infections.

When considering factors that may affect P&I, differences in county-level quality of care and LTCF practices may explain some of the observed geographic variation [4]. LTCF staffing hours and the presence of skilled staff, such as nurse practitioners or physician assistants, have been associated with reduced P&I event rates and likely vary by county [4, 9]. LTCF resident pneumococcal and influenza vaccination rates also vary geographically and could be explanatory [2, 10]. Additionally, state departments of health may influence vaccination rates by providing vaccines directly to LTCFs, reducing supply disruptions [11]. Hospitals may have also established relationships with LTCFs specifically to reduce infections or resident hospitalizations [12]. Such relationships may lead to distinct patterns of P&I across counties served by specific hospitals. These findings suggest more research is necessary to identify and understand the factors affecting geographic variation in P&I rates among LTCF residents.

Our study has several limitations. First, while risk standardization of county-level estimates adjusts for differences in person-level characteristics related to P&I risk, it does not adjust for other county-level differences. Second, some counties have a higher number of unique LTCF residents and thus more person-time, which influences the precision of risk-standardized rates across counties. Third, our measure of P&I is



**Figure 1.** A, Risk-standardized incidence rates (RSIRs) of pneumonia and influenza hospitalizations per 1000 resident person-years among short-stay residents in long-term care facilities (LTCFs) by US county (n = 2745). B, Anselin local Moran's *I* county-level clustering of RSIRs among short-stay residents. C, RSIRs of pneumonia and influenza hospitalizations per 1000 resident person-years among long-stay residents in LTCFs by US county (n = 2784). D, Anselin local Moran's *I* county-level clustering of RSIRs among long-stay residents. The following county types can be identified: not significant, the county has nonsignificant clustering with local Moran's *I* ( $P > .05$ ); high-high cluster, a county with a high value surrounded by counties with similarly high values; high-low outlier, a county with a high value surrounded by counties with low values; low-low clusters, a county with a low value surrounded by similarly low values; low-high outlier, a county with a low value surrounded by counties with high values. Abbreviations: LTCF, long-term care facility; RSIR, risk-standardized incidence rate.

subject to error, as coding of P&I on hospital claims varies geographically, and does not disentangle variation in P&I hospitalizations from geographic variation in hospital coding practices. Also, using hospital claims provides a measure that may capture severe incident P&I, but may not capture mild P&I events not requiring hospitalization. Finally, we did not explore seasonality of infections or set outbreak thresholds. Further study of these factors is warranted to shed additional light on regional care practices. Other limitations have been previously described [4].

In conclusion, we found wide variation in county-level P&I hospitalization rates for short-stay and long-stay LTCF residents. Well-defined clusters of high rates for both populations appeared in counties of the midwestern and southern US. These findings can help local public health authorities and clinicians

effectively reduce P&I by targeting resources and efforts to counties with high P&I rates. Additional research is necessary to identify the sources of geographic variation in P&I and support improved health outcomes of frail older adults in LTCFs.

**Supplementary Data**

Supplementary materials are available at *Clinical 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.

**Notes**

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**Potential conflicts of interest.** R. v. A. and A. C. are employed by Sanofi Pasteur. S. G. reports grants from Seqirus and Sanofi, and consulting or speaker fees from Sanofi, Seqirus, Merck, Longeveron, and the Gerontological Society of America related to vaccines or nursing home care quality. V. M. does research in an area related to that of several different paid activities; periodically serves as a paid speaker at national conferences, where he discusses trends and research findings in long-term and post-acute care; and holds stock of unknown value in PointRight, Inc, an information services company providing advice and consultation to various components of the long-term care and post-acute care industry, including suppliers and insurers. PointRight sells information on measurement of nursing home quality to nursing homes and liability insurers; V. M. was a founder of the company but has divested much of his equity in the company and relinquished his seat on the board. V. M. also chairs the Independent Quality Committee for HRC Manor Care, Inc, a nursing home chain, for which he receives compensation; serves as chair of a scientific advisory committee for NaviHealth, a post-acute care service organization, for which he receives compensation; serves as a technical expert panel member on several Centers for Medicare and Medicaid Services quality measurement panels; and is a member of the board of directors of Tufts Health Plan Foundation, Hospice Care of Rhode Island, and The Jewish Alliance of Rhode Island. All other authors report no potential conflicts of interest. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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