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The Utility of a Novel Definition of Health Care Regions in the United States in the Era of COVID-19: A Validation of the Pittsburgh Atlas Using Pneumonia Admissions

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Study objective: The COVID-19 pandemic in the United States has underscored the need to understand health care in a regional context. However, there are multiple definitions of health care regions available for conducting geospatial analyses. In this study, we compare the novel Pittsburgh Atlas, which defined regions for emergency care, with the existing definitions of regions, counties, and the Dartmouth Atlas, with respect to nonemergent acute medical conditions using pneumonia admissions.

Methods: We identified patients hospitalized with a primary diagnosis of pneumonia or a primary admitting diagnosis of sepsis with a secondary diagnosis of pneumonia in the Agency for Healthcare Research and Quality’s State Inpatient Databases. We calculated the percentage of region concordant care, the localization index, and market share for 3 definitions of health care regions (the Pittsburgh Atlas, Dartmouth Atlas, and counties). We used logistic regression identified predictors of region concordant care.

Results: We identified 1,582,287 patients who met the inclusion criteria. We found that the Pittsburgh Atlas and Dartmouth Atlas definitions of regions performed similarly with respect to both localization index (92.0 [interquartile range 87.9 to 95.7] versus 90.3 [interquartile range 81.4 to 94.5]) and market share (8.5 [interquartile range 5.1 to 13.6] versus 9.4 [interquartile range 6.7 to 14.1]). Both atlases outperformed the localization index (67.5 [interquartile range 49.9 to 83.9]) and market share (20.0% [interquartile range 11.4 to 31.4]) of the counties. Within a given referral region, the demographic factors, including age, sex, race/ethnicity, insurance status, and the level of severity, affected concordance rates between residential and hospital regions.

Conclusion: Because the Pittsburgh Atlas also has the benefit of respecting state and county boundaries, the use of this definition may have improved policy applicability without sacrificing accuracy in defining health care regions for acute medical conditions.

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Please see page 519 for the Editor’s Capsule Summary of this article.

INTRODUCTION

The COVID-19 pandemic has brought parts of the US health care system to the brink, highlighting the fragmented nature of health care delivery in the United States. One of the hallmarks of this fragmented care system is geographic variation, as demonstrated by variation in regional COVID-19 strategies for managing patient flows and the allocation of health care resources, such as personal protective equipment and ventilators. Because public health powers in the United States are vested in the states, COVID-19 patient surge strategies varied from state to state. Additionally, public health orders issued by state governors, such as mask mandates and shelter-in-place orders, are often confined to individual state borders, creating a scenario where the residents of different states are subject to different sets of exposures. The ability to both understand and predict where patients will present for care within administratively actionable boundaries is critical for developing infrastructure and allocating finite health care resources.

One of the greatest limitations to our ability to understand and improve regionalized care is how we define the regions themselves. Early research has shown that state-level COVID-19–related analyses can be too generalized, smoothing over
Editor’s Capsule Summary

What is already known on this topic
Knowing regional resources and utilization is key to meeting populations’ health care needs.

What question this study addressed
How do two approaches to assessing regional health care capacity fare compared to by-county assessments in those with pneumonia or sepsis?

What this study adds to our knowledge
In over 1.5 million patient care episodes, the Pittsburgh and the Dartmouth atlas approaches performed similarly and better than county-level assessments using common markers of capacity.

How this is relevant to clinical practice
This doesn’t change care on arrival but can help regions prepare for acute care demands by having a clearer view of use and capacity.

The COVID-19 pandemic has underscored the need for understanding health care systems in a regional context. Because patients with acute medical conditions, such as COVID-19, are increasingly being admitted through the emergency department rather than through direct admissions, we hypothesize that patients with these conditions have care-seeking patterns more similar to emergency conditions than semielective major surgical care referral patterns. In this context, we sought to compare the performance of the time-sensitive, emergency condition-focused Pittsburgh Atlas with the tertiary care-focused Dartmouth Atlas in the prediction of inpatient hospitalizations pneumonia, which we considered a proxy for COVID-19.

MATERIALS AND METHODS

Data Sources and Population
Using the Healthcare Costs and Utilization Project State Inpatient Databases for all 15 states that provide both patient residence and the admitting facility locations (Arkansas, Arizona, Colorado, Iowa, Kentucky, Minnesota, Mississippi, North Carolina, Nebraska, New Jersey, New York, Oregon, Rhode Island, Utah, and Vermont) and the International Classification of Disease, 9th Edition, Clinical Modification diagnosis codes (Table E1, available at http://www.annemergmed.com), we identified all patients admitted for inpatient treatment of pneumonia between January 1, 2014, and December 31, 2014. Patients were included if their primary admitting diagnosis was pneumonia or if it was sepsis with a secondary diagnosis of pneumonia.

The inpatient records were linked with the American Hospital Association annual survey using the American Hospital Association identification numbers in the State Inpatient Databases. The American Hospital Association survey was used to determine hospital characteristics and to identify the Dartmouth Atlas hospital referral region of the hospital. The records were then linked with the Pittsburgh Atlas emergency medicine referral region of the hospital using the hospital counties reported in the State Inpatient Databases. The patients’ hospital referral region and Pittsburgh Atlas emergency medicine referral region of residence were determined on the basis of the residential zip code and county, as reported in the State Inpatient Databases. The county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region population characteristics were derived from the US Census Bureau American Community Survey and were linked with records based on the geographic location of the hospital.

the real variation within parts of a state. Conversely, the counties may be too small of a standalone unit of geographic analysis and can vary in their structure, size, constituency, and resources both within and between states.

The Dartmouth Atlas of Health Care, which divides the country into health care markets on the basis of geographic patterns of tertiary medical care, is the current standard for the geographical analysis of health care utilization and spending in the United States. The main geographic unit of analysis in the Dartmouth Atlas is the hospital referral region, originally devised by identifying where the residents of their smaller geographic units, hospital service areas, underwent major cardiovascular procedures and received neurosurgical care. Thus, although hospital referral region has a good predictive capacity with regard to the location of tertiary care services, its utility is limited in urgent or emergency conditions and routine nonelective hospitalization.

In 2018, Wallace et al introduced the Pittsburgh Atlas, a new set of geographic regions focusing on where patients sought care for acute, time-sensitive conditions. The Pittsburgh Atlas was created by aggregating the counties into regions that respect state boundaries, minimizing the number of decision makers and political stakeholders in a given region while maximizing the responsibility each has for that region. The Pittsburgh Atlas has previously been examined as a tool for defining trauma referral regions and has been operationalized in studies of emergency care systems.
Variable Definitions

The primary measures of interest for this analysis were concordance between the residential and the treatment region and the localization and market share of pneumonia admission, calculated at the county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region level. Measured at the patient level, concordance was coded as “yes” for patients treated in the same region as their residence and as “no” for patients treated in a region other than their residence. At the regional level, localization measures the extent to which the residents of a region receive medical care within that region and is calculated as the percentage of all regional residents with a pneumonia diagnosis who are treated within their region of residence. Also, at the regional level, market share measures the tendency for patients to travel to a different region for treatment and is calculated as the percentage of nonresidents treated in a region divided by the total number of patients with pneumonia treated in the region. Well-designed health care delivery regions should have high concordance between residential and treatment regions at the individual level, and the region level localization should approach 100% while the market share approaches 0%.

The patient-level variables assessed in regression analyses included age, sex, race/ethnicity, rural residence, insurance status, sepsis diagnosis, and the need for mechanical ventilation. Age (years) and sex (male or female) were used as reported in the State Inpatient Databases. Race/ethnicity was coded as non-Hispanic White, non-Hispanic Black, Hispanic, and other race/ethnicity. A residence was coded as rural (micropolitan or noncore) or nonrural (large central, large fringe, medium, or small metropolitan) based on the National Center for Health Statistics urban-rural classification of the patient’s county of residence. The insurance status was determined based on primary payer reported in the State Inpatient Databases and coded as Medicare, Medicaid, private insurance, self-pay/uninsured, or other. The patients with a primary admitting diagnosis of sepsis were coded as having a sepsis diagnosis. Patients with at least one International Classification of Disease, 9th Edition, Clinical Modification procedure code for continuous invasive mechanical ventilation (96.7X) were coded as requiring mechanical ventilation.

The health system characteristics assessed in regression analyses included the total number of medical/surgical inpatient beds and the total number of medical/surgical intensive care unit beds. The bed counts were derived from the American Hospital Association annual survey and aggregated to the county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region level based on hospital location. The population characteristics were derived from the US Census Bureau American Community Survey. The county-level characteristics were derived directly from the census data and aggregated to the Pittsburgh Atlas emergency medicine referral region level. The hospital referral region–level characteristics were aggregated from zip code tabulation area data. The population characteristics included in the analysis were the proportion of the population identified as White, proportion with at least a college education, proportion without health insurance, and median household income.

Analytic Approach

Individual patient characteristics were described at the county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region level using the mean (standard deviation) of continuous measures and the distribution of categoric variables. The region-level characteristics were described with the median (interquartile range [IQR]) of each variable. The localization index and market share were described at the county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region level using the mean (standard deviation), median (IQR), and range of each value. Bivariable and multivariable linear regression were used to assess the relationship between localization index, market share, and regional characteristics.

The sensitivity analyses examined the county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region–level distributions of localization index and market share for patients with a primary diagnosis of sepsis and for patients requiring mechanical ventilation.

This study was approved by the Partners Healthcare Human Research Committee [approval number 2015P001722]. All analyses were performed using Stata 14 (StataCorp).

RESULTS

Patient Population and Characteristics of Referral Regions

Our analysis included a total of 15 states yielding a total study population of 1,582,287 people admitted for a diagnosis of pneumonia. The mean (standard deviation) age of the population was 65.7 (22.8) years, and 49.6% were women. The median (IQR) population of a single Pittsburgh Atlas emergency medicine referral region was 549,137 (IQR 303,834 to 1,191,011), which did not differ significantly from the size of a given hospital referral region (651,915 [IQR 355,939 to 1,408,340]). As expected, both referral regions are much larger than the counties, which have a median population of 35,410 (IQR 15,964 to

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The demographic and clinical characteristics were similar between the hospital referral regions and the Pittsburgh Atlas emergency medicine referral regions (Table E1).

**Pittsburgh Atlas Performance and Validation**

In contrast to hospital referral regions, the Pittsburgh Atlas emergency medicine referral regions do not cross local or state boundaries (Figure 1). The Pittsburgh Atlas emergency medicine referral regions and the hospital referral regions performed similarly in 2 measures of geospatial accuracy—localization index and market share. The localization index reflects the extent to which the location of a patient’s medical care is concordant with the patient’s region of residence (percentage of regional residents with given diagnosis treated within their home region). The Pittsburgh Atlas emergency medicine referral regions performed similar to the hospital referral regions based on the localization index, with a median (IQR) of 92.0% (87.9% to 95.7%) versus 90.3% (81.4% to 94.5%), respectively. Both were superior to the counties with respect to the localization index as expected, which had a localization index of 67.5 (IQR 49.9 to 83.9) (Table 1 and Figure 2). The market share, or the percentage of nonresidents treated in a given referral region for a stated condition, was the lowest for the Pittsburgh Atlas emergency medicine referral regions (8.5 [5.1 to 13.6]) compared with the hospital referral regions (9.4 [6.7 to 14.1]) and the county (20.0 [11.4 to 31.4]). A sensitivity analysis examining patients with pneumonia with a primary diagnosis of sepsis and those requiring mechanical ventilation showed that localization index and market share were similar for the hospital referral regions and Pittsburgh Atlas emergency medicine referral regions, which were both superior to the counties (Table E2, available at [http://www.annemergmed.com](http://www.annemergmed.com)).

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**Figure 1.** Map of hospital referral regions and Pittsburgh Atlas emergency medicine referral regions with state boundaries in bold lines (states contributing data to this study are shaded).
Factors Associated With Concordance Between the Residential and Hospital Regions

The demographic and clinical characteristics of patients with concordant versus nonconcordant residential and hospital geographical regions are listed in Table 2. Within a given referral region, the demographic factors, including age, sex, race/ethnicity, insurance status, and the level of severity, affected concordance rates between residential and hospital regions. Female sex was associated with a slightly increased likelihood of remaining in one’s residential region.

Black or Hispanic race/ethnicity was associated with increased concordance between residential and hospital regions at all 3 levels of analysis (county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region). In other words, Black and Hispanic patients in this study were less likely than White patients to leave their region. This finding held true at all 3 levels of geographical analysis in both unadjusted and adjusted analysis.

Insurance status was also associated with staying within one’s residential region for care. The patients with private insurance were more likely to be hospitalized outside their residential region at all 3 levels of analysis compared with those with Medicare insurance. In contrast, the patients with Medicaid as primary insurance were more likely to receive care within their residential region.

In each geographical region, patients requiring mechanical ventilation (ie, higher level of care) or presenting with sepsis as a primary diagnosis were less likely to be hospitalized in their geographical region of residence in all 3 areas of analysis.

Population Characteristics Associated With Patient Flow

Using logistic regression modeling to identify the regional characteristics that affect patient flows, we found that the population size and hospital resources have significant effect on both localization index and market share (Table E3, available at http://www.annemergmed.com). These measures indicate that patients are likely to seek region nonconcordant care when the health care resources are inadequate compared with the resident population. These associations were large in magnitude at the county level but were dampened or nonexistent when

![Figure 2. Dot plot showing the distribution of the localization index and market share by county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region. HRR, hospital referral region; PRR, Pittsburgh Atlas emergency medicine referral region.](image-url)
LIMITATIONS

This study must be interpreted in the context of its limitations. We used data from 15 states, representing a diversity of the states in the United States in terms of geography, population, and insurance status. The Healthcare Cost and Utilization Project does not include all states, and many states lack the data elements necessary to complete the necessary analysis. Although our study includes data from all states with the necessary data, our analysis is still limited by the number of states included in the analysis. The hospital referral regions, but not the Pittsburgh Atlas emergency medicine referral regions, cross state boundaries, and the State Inpatient Databases do not include data from the adjacent states. For regions that spanned multiple states and had incomplete data capture, we performed our analysis using all available data for the region. To account for limitations due to border crossing, we completed an additional sensitivity analysis showing that areas that included a state border did not behave differently than those within the middle of the state. This is somewhat exacerbated by a lack of complete national data and contiguous state data in some regions. We utilized 2014 data in our analyses and the data therefore reflect the demographics and health care utilization at that time, which may have changed over time as populations shift across the country. There have also been significant changes in the health care landscape between 2014 and today, such the implementation of the Patient Protection and Affordable Care Act; other work has shown the little effect of these changes on overall hospital admissions. The implementation of the International Statistical Classification of Diseases, Tenth Revision coding standard in 2015 may affect the generalizability as the changes in coding practice may have implications for our cohort definition. Additionally, we should note that neither the Dartmouth Atlas nor the Pittsburgh Atlas has undergone a major revision since their creation and may suffer accuracy degradation over time as populations shift and health care facilities change over time. Although the Pittsburgh Atlas is relatively new, it has been more than 20 years since the publication of the Dartmouth Atlas.

Table 2. Characteristics of patients seeking county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region concordant care.

| Variable                      | Total Population | County Concordant | Hospital Referral Region Concordant | Pittsburgh Atlas Emergency Medicine Referral Region Concordant |
|-------------------------------|------------------|-------------------|-------------------------------------|---------------------------------------------------------------|
|                               | N = 527,429      | Yes (N = 398,870) | Yes (N = 477,067)                   | Yes (N = 486,491)                                             |
| Age, mean (SD) (y)            | 65.7 (22.8)      | 66.4 (22.6)       | 63.8 (23.1)                         | 62.5 (24.1)                                                  |
| Female (%)                    | 49.6             | 50.2              | 47.9                                | 49.9                                                         |
| Race (%)                      |                  |                   |                                     |                                                               |
| White                         | 68.7             | 68.1              | 70.7                                | 68.7                                                         |
| Black                         | 11.0             | 11.7              | 8.9                                 | 11.2                                                         |
| Hispanic                      | 7.5              | 8.3               | 5.2                                 | 7.6                                                          |
| Other                         | 12.7             | 11.9              | 15.2                                | 12.4                                                         |
| Rural (%)                     | 20.4             | 16.0              | 34.2                                | 19.6                                                         |
| Primary payer (%)             |                  |                   |                                     |                                                               |
| Medicare                      | 65.4             | 66.5              | 62.2                                | 65.9                                                         |
| Medicaid                      | 12.8             | 13.0              | 12.1                                | 12.8                                                         |
| Private insurance             | 16.7             | 15.5              | 20.6                                | 16.3                                                         |
| Self-pay                      | 2.9              | 2.9               | 2.8                                 | 2.9                                                          |
| Other                         | 2.1              | 2.1               | 2.4                                 | 2.1                                                          |
| Sepsis as primary (%)         | 35.7             | 35.3              | 37.2                                | 35.6                                                         |
| Mechanical ventilator (%)     | 10.3             | 9.7               | 12.2                                | 10.0                                                         |

SD, standard deviation.
Finally, we must acknowledge the ways in which the COVID-19 pandemic has changed the healthcare system overall. Changes in the healthcare delivery system, including changes in interfacility transfer policies and practice, out-of-hospital emergency medical services triage and treat-and-release guidelines, and the emergence of telehealth, may have led to changes in the healthcare utilization patterns, including if and where patients are admitted to the hospital.

**DISCUSSION**

In this study of patients admitted with a diagnosis of pneumonia, we found that Pittsburgh Atlas emergency medicine referral regions, a novel set of referral regions that respect county and state borders, were equivalent or slightly superior in key geospatial metrics, localization, and market share compared with the existing standard for defining healthcare regions, the hospital referral regions. The overall population size within a Pittsburgh Atlas emergency medicine referral region was similar to that of a hospital referral region. Disease severity affected the likelihood of remaining in one's region for admission. Patients requiring mechanical ventilation or presenting with sepsis were more likely to leave their residential region to seek care on all 3 levels of analysis. Within this patient population, decreased concordance may reflect the need to travel for a higher level of care (ie, an intensive care unit). Additionally, patients with social vulnerabilities were less likely to leave their region for care at the county, hospital referral region, and Pittsburgh Atlas emergency medicine referral region levels. Patients with Medicaid as primary insurance and non-White race were most likely to receive care within their region of residence.

With roughly equivalent patient flow metrics, the Pittsburgh Atlas offers a potential advantage over the Dartmouth Atlas in practical application. Efforts to support regionalized care programs are inherently dependent on stakeholder support. The Dartmouth Atlas contains many regions that cross state borders and several regions that include residents of up to 4 different states. With an increasing number of stakeholders in a region, each individual's share of responsibility and accountability decreases, which may temper levels of interest and investment. Additionally, political units (such as counties and states) only have authority within the borders of their region and have no direct control of what happens in adjacent places. Because Pittsburgh Atlas emergency medicine referral regions are aggregates of counties and bounded within states, the number of stakeholders is minimized, but each has significantly more at stake. For example, there is one state governor in each Pittsburgh Atlas emergency medicine referral region, but that governor has 100% responsibility for the Pittsburgh Atlas emergency medicine referral region. Additionally, Pittsburgh Atlas emergency medicine referral regions can easily be aggregated to evaluate established multistate regions. While care needs to be taken to choose the most appropriate geographic unit of analysis, especially in border and metropolitan regions, these characteristics may make the Pittsburgh Atlas emergency medicine referral region an attractive alternative to the hospital referral region as a regional unit in studies and evaluations of government-based policy impacts.

For this reason, the Pittsburgh Atlas emergency medicine referral regions may be helpful to adopt for geospatial analysis in situations such as the current COVID-19 pandemic, where decisionmaking is primarily occurring at the state and local levels. Policies regarding issues such as patient triage rules during hospital surges, resource allocation, and other disaster mitigation measures are made at the state and local levels. Furthermore, emergency medical services systems, including the scope of practice, patient triage, and transport destination rules, are controlled at the state and local levels. In addition, public health measures, such as mask mandates, stay-at-home orders, or regulations on which business can open and in what capacity, are dictated at the state and local levels. Decisions about school reopening, in-person instruction, mask mandates, and postexposure quarantines have also been made at the state and local levels. There have also been significant differences in how vaccines have been handled at the state level, including policies addressing cost, distribution, and, more recently, vaccine mandates or bans thereof. Beyond policies aimed directly at disease containment, many other laws, executive orders, and other government directives in the wake of the pandemic may also play a role in altering the state-level health-seeking behavior or outcomes, including provider licensing and credentialing, expanding access to telehealth, changes in insurance regulations, and paid sick leave. An extensive list of such policies and reporting on which states have enacted them has been compiled and made publicly available from the Kaiser Family Foundation. The single-state nature of the Pittsburgh Atlas emergency medicine referral region allows the efficacy of such programs to be tracked and evaluated in the context of other health care and public health data, which are most often collected at the county or state level. Aggregating county-level data into hospital referral regions is more challenging than aggregating data into Pittsburgh Atlas emergency medicine referral regions.
that respect the county boundaries, facilitating rapid analysis of locally available data. In this study, using a common medical condition pertinent to the current COVID-19 health care crisis, we show that Pittsburgh Atlas emergency medicine referral regions perform at least as well as hospital referral regions with respect to capturing natural patient flows while having potentially better utility in producing policy-relevant results in both real-time and post hoc analyses.

Although there are many advantages of Pittsburgh Atlas emergency medicine referral regions, it is important to note that hospital referral regions perform well in key metrics, such as market share and localization index, and significantly outperform counties in these metrics. The aggregation of a more granular base unit (zip codes) into the hospital service areas and then the hospital referral regions may aid in attributing residents to the most appropriate facility-oriented region, especially in areas with an abundance of health care facilities. Additionally, there are certain situations in border regions where the natural patient flow does not respect state boundaries, which may be more accurately reflected by the hospital referral regions.

In conclusion, the Pittsburgh Atlas performed well in this validation study that included admissions for pneumonia with or without sepsis and with or without mechanical ventilation. The Pittsburgh Atlas emergency medicine referral regions have clear potential advantages from a policy standpoint as they respect civic boundaries and therefore may be helpful for county-level, state-level, and interstate planning. In the setting of COVID-19, the use of the Pittsburgh Atlas emergency medicine referral regions may be helpful to inform state-level policy around the regionalization of care, health care utilization, and patient outcomes. Future studies examining COVID-19 in a geospatial context should thoughtfully consider the definition of health care regions that is most relevant to the specific question of interest.

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**Author contributions:**
MKD helped design the study, analyzed the data, and wrote the manuscript. ALM helped design the study and reviewed the manuscript. RWB helped design the study and reviewed the manuscript. CK2 helped design the study and reviewed the manuscript. RS analyzed the data and reviewed the manuscript. EG helped design the study and reviewed the manuscript. MPJ helped design the study, acquired the data, reviewed the manuscript, and takes responsibility for the paper as a whole.

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**Future Meetings of the American College of Emergency Physicians**

The following are the planned sites and dates for the future annual meetings of the American College of Emergency Physicians:

- October 1-4, 2022 San Francisco, CA
- October 9-12, 2023 Philadelphia, PA
- September 29-October 2, 2024 Las Vegas, NV
- October 27-30, 2025 Dallas, TX
- October 5-8, 2026 Chicago, IL
- October 25-28, 2027 Boston, MA
- September 18-21, 2028 Las Vegas, NV