Quality Through Coopetition: An Empiric Approach to Measure Population Outcomes for Emergency Care–Sensitive Conditions

Brendan G. Carr, MD, MS*; Austin S. Kilaru, MD; David N. Karp, MUSA; M. Kit Delgado, MD, MS; Douglas J. Wiebe, PhD

*Corresponding Author. E-mail: brendan.carr@jefferson.edu, Twitter: @Dr_BrendanCarr.

Study objective: We develop a novel approach for measuring regional outcomes for emergency care–sensitive conditions.

Methods: We used statewide inpatient hospital discharge data from the Pennsylvania Healthcare Cost Containment Council. This cross-sectional, retrospective, population-based analysis used *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis codes to identify admissions for emergency care–sensitive conditions (ischemic stroke, ST-segment elevation myocardial infarction, out-of-hospital cardiac arrest, severe sepsis, and trauma). We analyzed the origin and destination patterns of patients, grouped hospitals with a hierarchical cluster analysis, and defined boundary shapefiles for emergency care service regions.

Results: Optimal clustering configurations determined 10 emergency care service regions for Pennsylvania.

Conclusion: We used cluster analysis to empirically identify regional use patterns for emergency conditions requiring a communitywide system response. This method of attribution allows regional performance to be benchmarked and could be used to develop population-based outcome measures after life-threatening illness and injury. [Ann Emerg Med. 2018;72:237-245.]

Please see page 238 for the Editor's Capsule Summary of this article.

0196-0644/$-see front matter

https://doi.org/10.1016/j.annemergmed.2018.03.004

INTRODUCTION

Background

The dominant framework for defining population health focuses on patient panels (accountable care organizations and patient-centered medical homes) or the payer's perspective of covered lives.[1-4] The National Academy of Medicine, however, noted that "[a]lthough the healthcare delivery system is increasingly focused on population health, the committee found that focus reflects a relatively narrow interpretation of the term—populations as the patient panel or group of covered lives" and instead recommended that the more inclusive term *total population health* be used to refer to "the health of all people living in a geographic area."[5] The National Academy of Medicine perspective offers an opportunity to measure outcomes differently, and critical illnesses and injuries that require a regional response represent a compelling case for this approach.

Patients with unplanned critical illness and injury are inherently linked to hospitals by geography rather than by health system network affiliations because of the time-sensitive nature of care.[6-13] Optimizing outcomes for emergency care–sensitive conditions[14] such as trauma, stroke, ST-segment elevation myocardial infarction, cardiac arrest, and sepsis requires an inclusive systems-based approach that aligns incentives across multiple components of the health care delivery system.[15-18] Regionalization of care improves clinical outcomes for emergency care–sensitive conditions[19-22] through the use of strategic emergency medical services (EMS) design, interfacility transfer agreements, and the designation of specialty centers (eg, trauma centers).

To date, however, no regional performance benchmarking or incentive to improve "total population health" for emergency care–sensitive conditions exists. This is due in part to the absence of a geographic unit that accurately captures health care use for unplanned critical illness.[11,13,23] The Dartmouth Atlas of Health Care[24] has led efforts to describe the relationship between geography and health, but hospital service areas and hospital referral

Editor's Capsule Summary

What is already known on this topic

Regionalization of care is needed to optimize outcomes after unplanned critical illness.

What question this study addressed

The authors used 2011 Pennsylvania inpatient claims for 5 time-sensitive conditions to develop emergency care service regions by clustering hospitals that provided care to patients residing in similar zip codes and attributing each zip code to one or more hospital clusters based on the proportion of patients treated by the hospitals in that cluster.

What this study adds to our knowledge

Empiric emergency care patterns resulted in 10 emergency care service regions, with some area overlap (15% to 41%), mainly at geographic borders.

How this is relevant to clinical practice

A regional system could be used to provide incentive to health care stakeholders to develop an integrated network of coordinated emergency care.

regions were created from Medicare hospitalization records more than 20 years ago and were based on where patients received cardiovascular and neurologic surgeries. Primary care service areas were developed in the mid-1990s as a part of a contract by the Health Resources and Services Administration to understand use patterns for primary care. Both primary care and referral surgeries are market based, and patients can determine their own willingness to travel for care. No method of geographic attribution akin to existing models for attribution to an Accountable Care Organization or a patient panel exists, and thus no incentive program (quality tied to reimbursement) has been developed to improve population-level outcomes for threats to life and limb. In their report focused on regionalized EMS, the National Quality Forum concluded that "…more research is needed to appropriately define regional units of measurement which would become the basis for regional emergency preparedness and response."[13]

A population-based approach to measuring outcomes for emergency care–sensitive conditions would encourage cooperation in competitive health care environments and is consistent with the developing concept of "accountable health communities."[25,26] Although a coordinated approach to system building exists in some markets that are saturated by a single dominant system (eg, large integrated delivery systems), population-level incentives provide an alternative to market consolidation as a means to create coordinated care delivery. By creating a common empiric geographic attribution model, our approach provides incentive to the multiple stakeholders involved in the delivery of care to work collaboratively toward a common regional goal.

Importance

Hospital-level incentives (eg, penalties or bonuses tied to outcomes) are useful for conditions requiring hospital-level interventions (eg, central line infection rates), but have not been used to provide incentive for the development of the communitywide systems of care that are needed for emergency care–sensitive conditions. Planning for emergency care–sensitive conditions at the population level has been endorsed by experts,[10,12,15-18,27-29] but outcomes are assessed at the facility level, so little incentive exists for cooperative system building to address the needs of "all people living in a geographic area."[5,30-35] In addition, no population-level reporting exists, so communities have no way to know the performance of their local emergency care system (eg, population-based injury outcomes, cardiac arrest survival rate), limiting the ability for consumer advocacy or traditional market forces to improve health outcomes.

We describe a method by which patient use patterns rather than financial affiliations of health systems empirically define the community. The Center for Medicare & Medicaid Innovation program uses incentives to improve health outcomes, and the Institute of Medicine has recommended that these efforts extend to emergency conditions.[5,36] Our method allows communities to be attributed to the health care system in a manner that could, for the first time, be tied to outcomes and payment.[30-32] Solutions may include additional resources at referral centers, modified EMS protocols, or telemedicine solutions, each customized to meet needs specific to the region and aimed at providing incentive for cooperation across payers, hospitals, and other system stakeholders (eg, EMS providers).

Goals of This Investigation

We sought to create a method for empirically attributing patients with emergency care–sensitive conditions to the hospitals that they depend on to provide lifesaving and limb-saving interventions. Our ultimate goal is to benchmark regional outcomes so that shared incentives (or penalties) could be developed across historically unaffiliated stakeholders to encourage competitive cooperation (coopetition) focused on improving population-based outcomes.

MATERIALS AND METHODS

Study Design and Setting

We conducted a 1-year cross-sectional analysis of emergency department (ED)–based hospital admissions for 5 time-sensitive conditions in Pennsylvania. The institutional review board at the University of Pennsylvania approved the study as exempt from review.

Data Collection and Processing

We used statewide administrative claims data from the 2011 Pennsylvania Inpatient Discharge Data File (Pennsylvania Health Care Cost Containment Council, Harrisburg, PA). The incident-level data include all hospital discharges for 1 year, the patient's residential zip code, the facility where the patient was admitted, the source of admission, and primary and secondary discharge diagnoses (including an indicator for "present on admission"). We obtained hospital location from the 2011 Annual Hospital Survey (American Hospital Association, Chicago, IL). We limited our analysis to general acute care hospitals (158 of 244).

Selection of Participants

We selected inpatient admissions to general acute care hospitals for 5 emergency care–sensitive conditions: trauma, ischemic stroke, severe sepsis, out-of-hospital cardiac arrest, and ST-segment elevation myocardial infarction,[31] using validated *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* codes, in which any one of the 5 discharge diagnoses conditions was "present on admission"[37-40] (n=178,457) (see Table E1 [available online at http://www.annemergmed.com] for a list of codes). We excluded inpatient records with an admission source other than "home" (ie, interfacility transfers) (n=14,311), pediatric patients (<18 years old) (n=2,854), and patients without a valid residential zip code in Pennsylvania (n=7,751).

Outcome Measures

The outcome of our analyses was a set of hospital clusters that reflected how geographies can be attributed to hospitals for a set of emergency care–sensitive conditions. We report these clusters in terms of mapped geographic boundaries that we term emergency care service regions. Our complete methods are presented in Appendix E1-E3 (available online at http://www.annemergmed.com), with programming code and documentation. Additional analyses and alternative methods are presented in Figure E1 and E2, and Table E2 (available online at http://www.annemergmed.com).

Primary Data Analysis

Our methods involved grouping hospitals into distinct clusters based on use patterns for unplanned critical illness, and then attributing zip codes to one or more clusters to define the geographic boundary of the emergency care service region for each set of hospitals. This first part was accomplished by summarizing origin-destination linkages between patient residence and facility location for each hospital, and then by using a hierarchical clustering algorithm to group hospitals based on the degree to which they serve patients from similar geographies. In the second part, we assigned every zip code in the state to at least one hospital cluster according to a standard attribution rule, given the proportion of resident patients who were treated at any of the hospitals in that cluster. Statistical analyses were performed with Stata (version 14.0; StataCorp, College Station, TX), and geoprocessing tasks were conducted in ArcGIS (version 10.1; ESRI, Redlands, CA) with Python 2.7 ArcPy scripting libraries.

Figure 1*A* shows a sample utilization matrix, which consists of zip codes and hospitals, creating an origin-destination table that summarizes the proportion of a hospital's patients who reside in each zip code. This represents the relative contribution of patients from each zip code to a given hospital. These values were used to compute a similarity matrix, which describes the degree of similarity between each pair of hospitals (Figure 1*B*). These values, standardized to range 0 to 1, describe how dissimilar (0) or similar (1) each pair of hospitals' patient catchments are to each other, indicating the extent to which 2 hospitals share accountability for a given community. Finally, we applied an agglomerative hierarchical clustering algorithm to these data to identify distinct clusters of hospitals. We defined clusters as groups of hospitals that treat patients from a similar geography. This process produced multiple nested subgroups, in which a more generous grouping criterion (permitting lower similarity between hospitals) resulted in a smaller number of larger clusters (more hospitals per cluster), and a more stringent grouping criterion (requiring higher similarity between hospitals) resulted in a larger number of smaller clusters (fewer hospitals per cluster). Figure 1*C* demonstrates a dendrogram (tree diagram), which we used to visualize the nested structure of all possible configurations, in which each branch contains a subgroup of hospitals and the *y* axis represents the degree of similarity for a given configuration. We evaluated 2 statistical stopping rules to determine the goodness-of-fit for each solution, Calinski-Harabasz pseudo-F and Duda-Hart Je2/Je1.[41-43] We selected an optimal configuration in which within-cluster similarity was maximized, while between-cluster similarity was

A Utilization Matrix

ZIP code	Hospital A	Hospital B	Hospital C
X	50 % of Hospital A patients live in X	50%	10%
Y	40%	35%	10%
Z	10%	15%	80%

B Similarity Matrix

	Hospital A	Hospital B	Hospital C
Hospital A	--		
Hospital B	High Similarity	--	
Hospital C	Low Similarity	Low Similarity	--

C Dendrogram

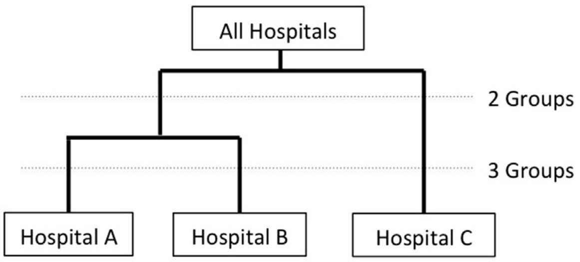

Figure 1. Model of hierarchical cluster analysis methodology. The simple model depicts the 3 steps of part 1 of our analysis. For demonstration, 3 hospitals (A, B, and C) and 3 zip codes (X, Y, and Z), are included in 3 panels: the utilization matrix (*A*) shows the distribution of each hospital's patients by zip code; the similarity matrix (*B*) shows the degree of similarity, based on utilization index values, for each pair of hospitals; and the dendrogram (*C*) shows the results of the cluster analysis in a nested "tree diagram." The 3 hospitals form 1, 2, or 3 groups, depending on the "cut" point. The dashed lines represent potential grouping configurations at various levels of similarity. At perfect similarity, there are 3 clusters consisting of individual hospitals. Hospitals A and B are highly similar in regard to patient origin; therefore, in an agglomerative clustering method, they cluster together at a higher similarity threshold before they cluster with hospital C at a lower level of similarity.

minimized, or where optimal configurations were those that were the most discrete.

We next defined the geographic area corresponding to each group of hospitals, which we term emergency care service regions. Zip codes were attributed to each emergency care service region if at least 25% of resident patients were treated at any hospital in the associated cluster. The denominator for zip code attribution is the total number of patient admissions from each zip code, whereas total hospital admissions were used as the denominator for the utilization matrix in part 1 above. This part of the analysis took into account the relevance of the cluster of hospitals to each zip code as a criterion for including it in the emergency care service region. This approach to building emergency care service regions allowed zip codes to be assigned to multiple clusters (depending on the selected attribution threshold), creating emergency care service regions with overlapping, or "fuzzy," boundaries. The sharing of geographic areas was permitted to capture the true dynamics of patient use patterns and to reduce the proportion of a zip code's patients being attributed to the wrong emergency care service region.[24,44]

RESULTS

We identified 153,595 hospital admissions for 5 emergency care–sensitive conditions during 2011 in Pennsylvania. Of these, 24,037 admissions (15.7%) were for stroke, 18,598 (12.1%) for ST-segment elevation myocardial infarction, 3,055 (2.0%) for cardiac arrest, 28,129 (18.3%) for sepsis, and 85,504 (55.7%) for trauma. Admissions to 157 general acute care hospitals originated from 1,743 zip codes. Fifty-five zip codes had no admissions. One hospital had a single admission and was excluded from the analysis.

The utilization index for each hospital–zip code pair ranged from 0% to 100%; each hospital drew on average 32.1% (SD=17.8%) of patients from any one zip code. Similarity values for each hospital-hospital pair ranged from 0 to 0.85 (mean=0.34; SD=0.20). The similarity index for an individual sample hospital is mapped in Figure 2, showing the geographic distribution of values relative to the index hospital. The figure demonstrates that hospital-to-hospital similarity is generally a function of distance, although not uniformly.

The cluster analysis generated multiple, nested solutions for grouping hospitals (Figure 3). In accordance with goodness-of-fit statistics (Calinski-Harabasz=0.62; Duda-Hart=1.0), we identified 10 clusters as the most robust. We considered additional groupings for 5-, 10-, and 20-cluster maps to understand change in geographic scale. The 10-cluster solution had a median of 11.5 hospitals per group (range=4 to 39; interquartile range [IQR]=9 to 22). Total emergency care–sensitive conditions admissions per cluster ranged from 1,755 to 46,820 (median=6,554; IQR=4,520 to 22,683). For each cluster, the average distance between hospital pairs ranged from 13.3 to 47.9 miles (median=29.4; IQR=26.7 to 35.6).

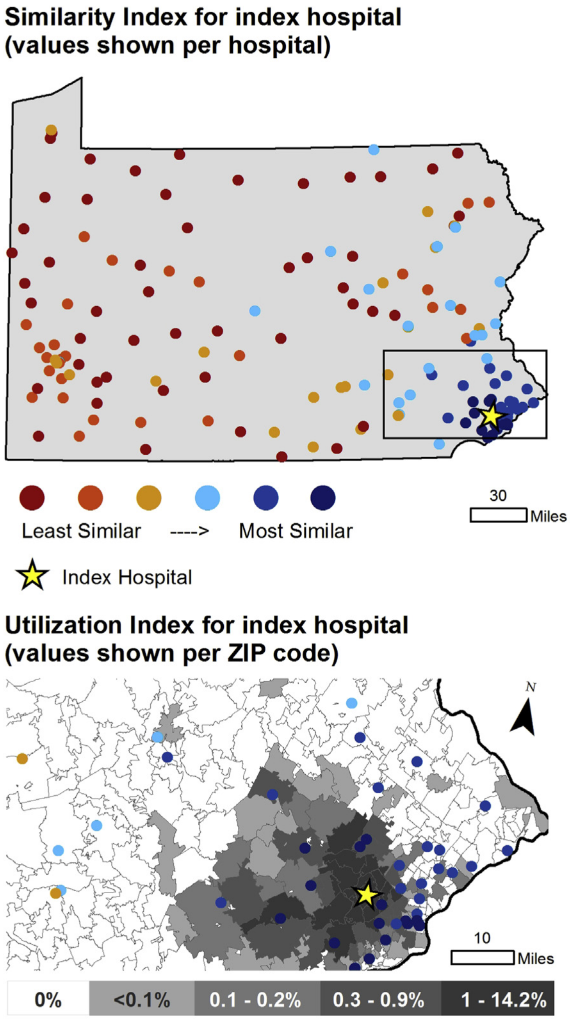

Figure 2. Map of similarity index values. The figure shows the resulting spatial distribution of similarity values. The map highlights the southeastern region of Pennsylvania; use values and similarity values are displayed for a randomly selected "index hospital" in Philadelphia. The thematic base map of zip codes shows the index hospital's patient catchment (utilization index: proportion of the hospital's patients who reside in each zip code). Similarity values for each hospital–index hospital pair are displayed at the location of the paired hospital (symbolized on the map with colored dots; colors indicate the value of the similarity coefficient (0 to 1).

The map of emergency care service regions (10-cluster solution) is shown in Figure 4. Cluster names were assigned according to major metropolitan areas. Two hundred twenty (12.35%) zip codes were attributed to 2 or more emergency care service regions (overlapping areas). Zip codes with zero admissions were added to an emergency care service region by using a geoprocessing algorithm to fill gaps in otherwise contiguous groups of zip codes. The percentage of land area overlap between emergency care service regions ranged from 14.9% to 41.0% (median=23.3%; IQR=16.5% to 27.3%). Seven

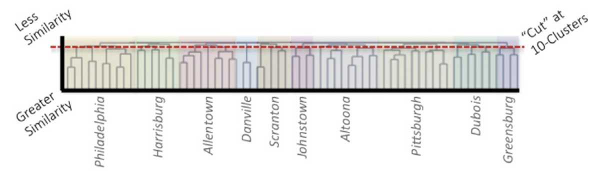

Figure 3. Dendrogram of cluster results. The dendrogram ("tree diagram") displays the nested structure of multiple clustering configurations resulting from the cluster analysis. The *y* axis indicates the threshold at which hospitals are "grouped," or merged into a new, larger cluster, based on the degree of similarity between each hospital's utilization index (ie, similar patient catchments). The *dotted red line* is the "cut" point along the similarity scale for the selected 10-cluster configuration. Shaded groups correspond to the mapped regions shown in Figure 4.

thousand five hundred eighty patients lived in an overlapping area; the median was 510.5 per emergency care service region (range=118 to 2,056; IQR=259 to 865.3).

LIMITATIONS

Our study has limitations related to data, approach, and analytic methods. We used administrative data to identify *ICD-9-CM* codes for patients with 5 emergency care–sensitive conditions and recognize the limits of administrative data to identify clinical scenarios.[45] We used the "present on admission" flag (ie, illness occurred outside of the hospital setting) to identify admissions from the ED. Although the emergency care–sensitive conditions we used typically warrant admission, patients who died before admission are missing from our analysis, and patients who

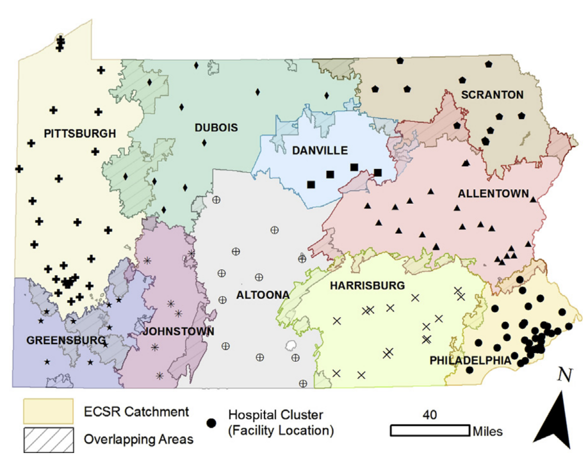

Figure 4. Map of 10-cluster solution: hospital clusters and emergency care service regions. The figure shows a map of the geographic boundaries for ECSRs corresponding to the set of 10 hospital clusters. Each point symbol represents the location of a hospital; symbols of the same type represent hospitals within the same cluster. The area of coverage for each ECSR is denoted by a unique color. The map demonstrates overlapping areas between ECSRs, denoted by the superimposed boundary layers. *ECSR*, Emergency care service region.

were transferred ED to ED may have been misclassified because our data cannot capture patients treated in an ED and then directly transferred to an inpatient facility. The exclusion of interfacility transfers may affect the shape of the service regions we developed. Our data were limited to residential zip code, limiting their precision compared with address-level data. A preferred solution, should these methods be adopted by the Centers for Medicare & Medicaid Services, would be to use patient address or small units of analysis (block groups or census tracts). Although administrative data do not identify location of event, previous work demonstrates that the majority of injury, stroke, and cardiac arrest occurs at or near home.[46-48]

Our approach has limits as well. We recognize that we did not directly account for EMS destination protocols and hospital diversion practices and that the patterns we identified may be related to these policies. Our methods capture use patterns because they empirically exist in the data; areas with poor population-level outcomes will need to consider the role of existing protocols on outcomes. We excluded pediatric patients, given the unique resources and systems of care required for this population. Children are infrequently treated for most of the conditions that we addressed, other than trauma, and, given the need for specialized pediatric care, we believe that population-based outcomes for children are beyond the scope of this study. Finally, we focused only on select, high-consequence conditions that required a coordinated system response; the geographic boundaries we created are likely not appropriate for benchmarking all unscheduled or emergency care.

Finally, there are analytic limitations related to the cluster analysis that we describe. The statistical stopping rules used for identifying optimal configurations use only one criterion (similarity of origin-destination patterns). Additional research and stakeholder input would help to determine additional factors, such as optimal number of hospitals per cluster, or travel or transportation times. These criteria may be context specific, depending on the research, planning, or policy application. Our results are intended to demonstrate the method and concept rather than to serve as a definitive identification of clusters in Pennsylvania. The ability to easily scale the cluster size up and down and the ability to rapidly recalculate service regions to reflect current use are key innovations of this approach. Future emergency care service region calibration may benefit from consideration of transfers and revisits and inclusion of patients and hospitals in neighboring states.

DISCUSSION

This study aimed to develop a geographic attribution method that is empirically derived, specific to select conditions requiring a regional system of care, easily updated to reflect system changes, and actionable for measuring outcomes at the population level. Achieving optimal outcomes for the conditions we describe requires that multiple stakeholders in a community, including unaffiliated or competing sectors of the health community, work together to build an integrated network of regionalized, coordinated care. Our methods allow patient use to define both the community and the providers that they depend on for their lifesaving and limb-saving care. The long-term goal of this work is to operationalize the Institute of Medicine's definition of total population health by providing a means by which to objectively define system building and provide incentive for using it.

We believe that the approach we suggest is immediately actionable. As we described above, existing geographic models (eg, Dartmouth Atlas of Health Care) focus on referral care and primary care rather than emergency care, are not meant to be redrawn frequently to reflect changing use patterns, and as a result cannot be used for quality measurement. Our clusters can be re-created frequently to allow changes in use to be reflected in attribution in a manner similar to the way that patients are attributed to Accountable Care Organizations. In this way, payment incentives can be created that align community expectations with health system priorities. Another advantage of our approach is the scalability of clusters. Depending on the application—such as developing population-based payment initiatives, networks for clinical trials, data and resource sharing, and regional emergency preparedness planning—this analysis provides solutions for many potential cluster sizes and nested subclusters. Finally, our methods allow emergency care service regions to overlap. Although previous geographic models have established rigid, nonoverlapping boundaries, these clusters reveal fuzzy boundaries in which patients and ambulances choose between many destinations for care, allowing an examination of gaps in coverage or diffusion of responsibility for care.

Other studies have considered cluster analysis as a tool for health systems research.[42,43,49] Delamater et al[49] applied a clustering methodology to identify hospital groups for managing volume capacity in Michigan. Our methods differ in our ability to identify multiple nested configurations simultaneously; smaller clusters are merged into larger clusters in an agglomerative process. This nested configuration informs the "hub and spoke" networks similar to those used in trauma and other systems of care.

Finally, our work has important implications for quality measurement and payment incentive programs. Hospital-based quality measurement programs fail to provide incentive for the regional planning that is necessary for threats to life and limb. For example, the American College of Surgeons currently benchmarks outcomes at trauma centers participating in the Trauma Quality Improvement Program. This approach is useful for improving quality at participating centers, but fails to provide incentive for coordination between nontrauma-center hospitals and trauma centers, between trauma centers within a region, and with local EMS and public health systems. A concrete example of how this work could be applied is to benchmark regional injury survival rates, to transmit them to the public (as is done for other hospital-based conditions on https://www.medicare.gov/hospitalcompare/), and to connect outcomes to a shared reimbursement incentive for all involved parties (as has been done in advanced alternative payment models). A shared incentive to improve regional triage to trauma centers or regional injury survival could fundamentally change health system behavior by creating an incentive to cooperate. An important next step is to use emergency care service regions to measure outcomes for acute care and to assess regional variability. Overlapping boundaries allows an improved understanding of how competition affects system building and outcomes for emergency care–sensitive conditions.[50]

In summary, we introduce the concept of an accountable geographic unit specific to emergency care–sensitive conditions that could be used to create coopetition to improve total population health outcomes for threats to life and limb. Existing standards for defining populations have resulted in poorly coordinated efforts and fragmented care. "Productive collective action" can only "emerge from the factional divisions" when a common unit of analysis and a common goal are identified.[51] Our proposed unit, emergency care service region, is defined by the population's hospital use patterns rather than by payers or providers. These geographic units serve as a basis for establishing emergency care communities designed to test innovative policy incentives, including payment structures, systems planning, and health interventions aimed at improving health outcomes. This approach has potential to align interests of health care stakeholders, facilitate collaboration between competitive components of the health care system, and ultimately improve population-level emergency care system performance.

The authors acknowledge Jennifer Love, MD, for contributing to discussions in early stages of project development.

Supervising editor: Melissa L. McCarthy, ScD, MS

Author affiliations: From the Department of Emergency Medicine, Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, PA (Carr, Karp); the Department of Emergency Medicine, Highland Hospital, Oakland, CA (Kilaru); and the Department of Emergency Medicine (Delgado) and Department of Biostatistics, Epidemiology, and Informatics (Karp, Wiebe), Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA.

Author contributions: BGC, ASK, and DJW conceived the study, obtained research funding, and drafted the article. DNK and DJW designed the analysis. ASK, DNK, and DJW performed the analysis. MKD provided critical input and feedback throughout various steps in the analysis. All authors contributed substantially to article revision. BGC takes responsibility for the paper as a whole.

All authors attest to meeting the four ICMJE.org authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist. This project was supported by a pilot award from the Robert Wood Johnson Health & Society Scholars Program and the Leonard Davis Institute for Health Economics, University of Pennsylvania, and an R01 award from the Agency for Healthcare Research and Quality (1R01HS023614-01). Dr. Carr spends a portion of his time as the director of the Emergency Care Coordination Center in the Office of the Assistant Secretary for Preparedness and Response.

The Pennsylvania Health Care Cost Containment Council (PHC4) is an independent state agency responsible for addressing the problem of escalating health costs, ensuring the quality of health care, and increasing access to health care for all citizens regardless of ability to pay. PHC4 has provided data to this entity in an effort to further PHC4's mission of educating the public and containing health care costs in Pennsylvania. PHC4, its agents, and staff, have made no representation, guarantee, or warranty, express or implied, that the data (financial, patient, payor, and physician specific information) provided to this entity, are error-free, or that the use of the data will avoid difference of opinion or interpretation. This analysis was not prepared by PHC4. This analysis was done by The University of Pennsylvania. PHC4, its agents and staff, bear no responsibility of liability for the results of the analysis, which are solely the opinion of this entity

Publication dates: Received for publication December 18, 2017. Revision received January 29, 2018. Accepted for publication February 28, 2018.

Presented at the Society for Academic Emergency Medicine annual meeting, May 2014, Dallas, TX; the Academy Health annual research meeting, June 2014, San Diego, CA; and the International Medical Geography Symposium, July 2017, Angers, France.

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the US Department of Health and Human Services or its components.

REFERENCES

1. Kindig D, Stoddart G. What is population health? *Am J Public Health*. 2003;93:380-383.
2. Jacobson D, Teutsch S. *An Environmental Scan of Integrated Approaches for Defining and Measuring Total Population Health*. Washington, DC: National Quality Forum; 2012.
3. Stoto MA. *Population Health in the Affordable Care Act Era*. Washington, DC: AcademyHealth; 2013.
4. Chokshi D, Stine N. What is Population Health? Definitions from the Field. 2013. Available at: https://www.rwjf.org/en/culture-of-health/2013/01/defining_population.html. Accessed March 30, 2018.
5. Institute of Medicine. *Toward Quality Measures for Population Health and the Leading Health Indicators*. Washington, DC: National Academies Press; 2013.
6. Institute of Medicine. *Future of Emergency Care: Hospital Based Emergency Care*. Washington, DC: National Academies; 2006.
7. Glickman SW, Kit Delgado M, Hirshon JM, et al. Defining and measuring successful emergency care networks: a research agenda. *Acad Emerg Med*. 2010;17:1297-1305.
8. Shen YC, Hsia RY. Does decreased access to emergency departments affect patient outcomes? analysis of acute myocardial infarction population 1996-2005. *Health Serv Res*. 2012;47:188-210.
9. Lee JE, Sung JH, Ward WB, et al. Utilization of the emergency room: impact of geographic distance. *Geospat Health*. 2007;1:243-253.
10. Branas CC, MacKenzie EJ, Williams JC, et al. Access to trauma centers in the United States. *JAMA*. 2005;293:2626-2633.
11. Klein MB, Kramer CB, Nelson J, et al. Geographic access to burn center hospitals. *JAMA*. 2009;302:1774-1781.
12. Carr BG, Branas CC, Metlay JP, et al. Access to emergency care in the United States. *Ann Emerg Med*. 2009;54:261-269.
13. National Quality Forum. Regionalized Emergency Medical Care Services: Phase 1 2012 Final Report 2012.
14. Carr BG, Conway PH, Meisel ZF, et al. Defining the emergency care sensitive condition: a health policy research agenda in emergency medicine. *Ann Emerg Med*. 2010;56:49-51.
15. Nichol G, Aufderheide TP, Eigel B, et al. Regional systems of care for out-of-hospital cardiac arrest: a policy statement from the American Heart Association. *Circulation*. 2010;121:709-729.
16. Schwamm LH, Pancioli A, Acker JE 3rd, et al. Recommendations for the establishment of stroke systems of care: recommendations from the American Stroke Association's Task Force on the Development of Stroke Systems. *Circulation*. 2005;111:1078-1091.
17. Jacobs AK, Antman EM, Faxon DP, et al. Development of systems of care for ST-elevation myocardial infarction patients. *Circulation*. 2007;116:217-230.
18. Trauma American College of Surgeons Trauma Committee. *Resources for Optimal Care of the Injured Patient 2006*. Chicago, IL: American College of Surgeons; 2006.
19. Concannon TW, Kent DM, Normand S-L, et al. Comparative effectiveness of ST-segment-elevation myocardial infarction regionalization strategies. *Circ Cardiovasc Qual Outcomes*. 2010;3:506-513.
20. Spaite DW, Bobrow BJ, Stolz U, et al. Statewide regionalization of postarrest care for out-of-hospital cardiac arrest: association with survival and neurologic outcome. *Ann Emerg Med*. 2014;64:496-506.e491.
21. Edwards JM, Carr BG. Improving patient outcomes from acute cardiovascular events through regionalized systems of care. *Hosp Pract*. 2010;38:54-62.
22. Utter GH, Maier RV, Rivara FP, et al. Inclusive trauma systems: do they improve triage or outcomes of the severely injured? *J Trauma Acute Care Surg*. 2006;60:529-537.
23. Baehr A, Holland T, Biala K, et al. Describing total population health: a review and critique of existing units. *Population Health Management*. 2016.
24. Wennberg J. Appendix on the geography of health care in the United States. *The Dartmouth Atlas of Health Care*. 1999-2012.
25. Martinez R, Carr B. Creating integrated networks of emergency care: from vision to value. *Health Aff (Millwood)*. 2013;32:2082-2090.
26. Fisher ES, Corrigan J. Accountable health communities: getting there from here. *JAMA*. 2014;312:2093-2094.
27. American Heart Association. Mission Lifeline. Vol 20112011.
28. Albright KC, Branas CC, Meyer BC, et al. ACCESS: acute cerebrovascular care in emergency stroke systems. *Arch Neurol*. 2010;67:1210-1218.
29. Poll TH. Harris Interactive: The American Public's Views of and Support for Trauma Systems—A Congressional Briefing: Survey Conducted for The Coalition for American Trauma Care. 2005.
30. Schuur JD, Hsia RY, Burstin H, et al. Quality measurement in the emergency department: past and future. *Health Aff (Millwood)*. 2013;32:2129-2138.
31. Branas CC, Carr BG. *Trauma Center Maps*. Philadelphia, PA: University of Pennsylvania; 2010.
32. Wheatley B. *Regionalizing Emergency Care: Workshop Summary*. Washington, DC: National Academies Press; 2010.
33. McDonald KM. Development of Emergency Department Community Health Indicators. Vol 20142012.
34. Wiebe DDM, Holena D, Carr B. Risk Adjusted Mortality for PTOS Data. A report prepared for the Pennsylvania Trauma Systems Foundation. 2014.
35. American Heart Association. Get with the guidelines. 2016.
36. The National Academies of Sciences, Engineering, and Medicine. *A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury*. Washington, DC: National Academies Press; 2016.
37. Metcalfe A, Neudam A, Forde S, et al. Case definitions for acute myocardial infarction in administrative databases and their impact on in-hospital mortality rates. *Health Serv Res*. 2013;48:290-318.
38. Lagu T, Rothberg MB, Shieh M-S, et al. What is the best method for estimating the burden of severe sepsis in the United States? *J Crit Care*. 2012;27:414.e411-9.
39. Phillips B, Clark DE, Nathens AB, et al. Comparison of injury patient information from hospitals with records in both the National Trauma Data Bank and the Nationwide Inpatient Sample. *J Trauma Acute Care Surg*. 2008;64:768-780.
40. Mullen MT, Kasner SE, Kallan MJ, et al. Joint Commission primary stroke centers utilize more rt-PA in the nationwide inpatient sample. *J Am Heart Assoc*. 2013;2:e000071.
41. Kaufman L, Rousseeuw PJ. *Finding Groups in Data: An Introduction to Cluster Analysis*. Hoboken, NJ: John Wiley & Sons; 2009.
42. Dilts D, Khamalah J, Plotkin A. Using cluster analysis for medical resource decision making. *Med Decis Making*. 1995;15:333-346.
43. Shwartz M, Payne SM, Restuccia JD, et al. Does it matter how small geographic areas are constructed? Ward's algorithm versus the plurality rule. *Health Serv Outcomes Res Methodol*. 2001;2:5-18.
44. Kilaru AS, Wiebe DJ, Karp DN, et al. Do hospital service areas and hospital referral regions define discrete health care populations? *Med Care*. 2015;53:510-516.
45. Kari F, Bryan B, Paul J. The use of claims data in healthcare research. *Open Public Health J*. 2009;2:11-24.

46. Myers SR, Branas CC, Kallan MJ, et al. The use of home location to proxy injury location and implications for regionalized trauma system planning. *J Trauma Acute Care Surg*. 2011;71:1428-1434.
47. Kelly-Hayes MWP, Kase CS, Brand FN, et al. Temporal patterns of stroke onset: the Framingham Study. *Stroke*. 1995;26:1343-1347.
48. Nichol G, Thomas E, Callaway CW, et al. Regional variation in out-of-hospital cardiac arrest incidence and outcome. *JAMA*. 2008;300:1423-1431.
49. Delamater PL, Shortridge AM, Messina JP. Regional health care planning: a methodology to cluster facilities using community utilization patterns. *BMC Health Serv Res*. 2013;13:333.
50. Lewis RJ. Academic emergency medicine and the "tragedy of the commons.". *Acad Emerg Med*. 2004;11:423-427.
51. Berwick DM. Reshaping US health care: from competition and confiscation to cooperation and mobilization. *JAMA*. 2014;312:2099-2100.