Geographic Discordance Between Patient Residence and Incident Location in Emergency Medical Services Responses

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Study objective: The location of a patient's residence is often used for emergency medical services (EMS) system planning. Our objective is to evaluate the association between patient residence and emergency incident zip codes for 911 calls.

Methods: We used data from the 2013 National Emergency Medical Services Information System (NEMSIS) Public-Release Research Dataset. We studied all 911 calls with a valid complaint by dispatch, identifying zip codes for both the residence and incident locations (n=12,376,784). The primary outcomes were geographic and distance discordances between patient residence and incident zip codes. We used a multivariate logistic regression model to determine geographic discordance between residence and incident zip codes by dispatch complaint, age, and sex. We also measured distances between locations with geospatial processing.

Results: The overall proportion of geographic discordance for all 911 calls was 27.7% (95% confidence interval [CI] 27.7% to 27.8%) and the median distance discordance was 11.5 miles (95% CI 11.5 to 11.5 miles). Lower geographic discordance rates were found among patients aged 65 to 79 years (20.2%; 95% CI 20.1% to 20.2%) and 80 years and older (14.5%; 95% CI 14.5% to 14.6%). Motor vehicle crashes (63.5%; 95% CI 63.5% to 63.6%), industrial accidents (59.3%; 95% CI 58.0% to 60.6%), and mass casualty incidents (50.6%; 95% CI 49.6% to 51.5%) were more likely to occur outside a patient's residence zip code. Median network distance between home and incident zip centroid codes ranged from 8.6 to 23.5 miles.

Conclusion: In NEMSIS, there was geographic discordance between patient residence zip code and call location zip code in slightly more than one quarter of EMS responses records. The geographic discordance rates between residence and incident zip codes were associated with dispatch complaints and age. Although a patient's residence might be a valid proxy for incident location for elderly patients, this relationship holds less true for other age groups and among different complaints. Our findings have important implications for EMS system planning, resource allocation, and injury surveillance. [Ann Emerg Med. 2016;■:1-8.]

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INTRODUCTION

Background

Approximately 240 million calls for all emergency services (911) are made in the United States every year.[1] Each year, emergency medical services (EMS) personnel treat approximately 20 million patients who experience medical emergencies.[2] Resulting data on the geographic location of injuries and medical emergencies inform administrative decisions to help ensure effective and timely emergency care delivery. These decisions include determination of geographic sites of trauma centers and ambulances, and the implementation of appropriate patient triage guidelines and transfer arrangements.[3] Because out-of-hospital providers, hospitals, and health care systems need to appropriately allocate their resources according to the underlying epidemiology of disease, it is crucial to obtain accurate data in regard to how the incidence of the emergency call may differ geographically from the patient's location. In fact, several studies have examined the inaccuracies of recording incident locations and have stated the importance of evaluating geocoding to better understand the distribution of health and accurate locations of out-of-hospital emergency incidents.[4-6]

Importance

Current literature has cited that standardized data on 911 emergency locations are limited or unavailable,[3,7] and thus administrative databases have relied on patient residence as a proxy for incident location. However, out-of-hospital emergency events often occur away from a person's residence. Although select studies suggested that a predominant number of certain emergency conditions,

Editor's Capsule Summary

What is already known on this topic

Geographic analysis is important for emergency medical services (EMS) system planning.

What question this study addressed

Is EMS patient residence location an accurate proxy for EMS incident location?

What this study adds to our knowledge

In this study of more than 12 million EMS activations, patient residence and incident zip code were discordant in one fourth of cases.

How this is relevant to clinical practice

Instead of patient residence, EMS planners should use more sophisticated approaches for system geographic analysis.

such as pedestrian injuries or fatal injuries, occur near a patient's home, these studies were limited to injury deaths, predefined regions, or injury-specific conditions. The concordance between location of residence and out-of-hospital emergency incidents has not been tested on a national level in the United States.[3,7-10]

Goals of This Investigation

The objective of this study was to characterize the geographic discordance between home and incident location among EMS responses in the United States. Given the long history and precedence of using zip code as a proxy for location,[11-13] we similarly used zip codes as the basis for this study.

MATERIALS AND METHODS

Study Design

We performed a retrospective, descriptive study of all 911-initiated EMS activations in the 2013 National Emergency Medical Services Information System (NEMSIS) Public-Release Research Dataset. This study was deemed exempt by the University of California, San Francisco Committee on Human Research.

Selection of Participants and Data Collection and Processing

The NEMSIS registry is a data set encompassing the majority of EMS responses in the United States. Overseen by the NEMSIS Technical Assistance Center, NEMSIS consists of 78 data elements submitted by participating EMS agencies to state repositories and then passed on to the national registry. Data submitted by agencies primarily characterize EMS ground activations, based on 911 requests for emergency care, although several states also submit interfacility or acute care transports, or air medical transports. This database comprises clinical data elements including patient and EMS agency characteristics, information about EMS response to 911 calls, and location and times of these calls.[14] A detailed description of the NEMSIS annual data set can be found elsewhere.[15] During 2013, 42 states, including Alaska and Hawaii, and 3 territories (Guam, Northern Mariana Islands, and the Virgin Islands) submitted EMS activations to the National EMS Database.[16,17] The combined territories contributed just over 23,000 records in 2013, representing less than one tenth of 1% of the overall study population.

We included all EMS activations resulting from a 911 call. We excluded interfacility transfers and limited the study to EMS run reports that included both a residence and incident zip code.

Outcome Measures

Geographic discordance was defined as disagreement between the patient residence and out-of-hospital incident zip codes. The incident zip code was defined as the zip code of the location in which the out-of-hospital incident or medical emergency occurred, assumed to be the same as the zip code from which the 911 call was placed. A 5-digit zip code is an element that each EMS provider is required to list at the incident and submit to the NEMSIS database. Patient home zip codes were recorded by the responding EMS providers according to patient or bystander report. An EMS provider may also record a patient home zip code based on other information (eg, software generated) if needed.

The distance between patients' home zip code and the emergency incident zip code was defined as the road network distance, in miles, between the centroids of respective zip codes. The network (or "road network") distance is distinct from Euclidean distance ("as the crow flies") in that this approach accounts for roads and topologic obstacles between 2 geographic locations.[18] A zip code centroid refers to the geographic center of the zip code. The median of network distances between zip codes was calculated with the median distance among all identified zip code combinations.

A patient's age is listed in the NEMSIS data set as an integer provided by an EMS provider, and it is either calculated from date of birth or best approximation. When patient age was considered, records were categorized into the following 4 groups for analysis: 0 to 17 years (children), 18 to 64 years (adults), 65 to 79 years, and 80 years and older. A patient's sex was analyzed as a binary field, with the codes "female" or "male" reported by an EMS provider.

Patient complaints were obtained from NEMSIS as they were reported by dispatch to the responding EMS unit. Each 911 call was coded in the data set as provided by an EMS provider and was categorized into one of 33 complaint categories for this study (Table 1).

Primary Data Analysis

We used a multivariable logistic regression model to examine measures of geographic discordance. Geographic discordance was measured for 3 different models or subgroups: discordance by dispatch complaint, by age group, and by both dispatch complaint and age group. Each category was calculated as a percentage difference between patient residence and incident zip codes. Dispatch complaints were entered into the model as a dummy variable, using discordance between home and incident zip codes for the complaint category "cardiac arrest" as the reference value, which we chose because studies have reported that approximately 70% to 80% of cardiac arrests occur at home.[19,20] We adjusted the model for patient age (as a continuous element) and sex. The resulting adjusted odds ratios (ORs) indicated the degree to which the residence and incident zip codes varied compared with those for cardiac arrest incidents, controlling for confounding caused by patient age and sex. We also stratified these results by age group and chief complaint.

For each pair of discordant residence and incident zip codes, we determined the shortest route between zip code centroids, using Dijkstra's algorithm; this widely used algorithm determines the shortest path along an existing road network.[21] We determined the median distance discordance by complaint category and age group in stratified analyses.

All statistical analyses were performed with SAS (version 9.3; SAS Institute, Inc., Cary, NC). Network distance calculations were performed using ArcGIS Network Analyst (version 10.0; Environmental Systems Research Institute, Inc., Redlands, CA).

RESULTS

All EMS activations reported in the 2013 NEMSIS data set were initially considered for inclusion in this study (n=23,897,211). The study sample was then limited to EMS activations resulting from a 911 call (n=18,556,165) and excluded interfacility transfers (n=542,282), resulting in 18,013,883 EMS activations. We further limited the study to EMS run reports including a residence and incident zip code (n=14,598,884). Our final sample included a total of 12,376,784 EMS activations with a valid complaint by dispatch (Figure 1). Sample characteristics are presented in Table 1. Our study population included 67.5% non-Hispanic whites, 55.2% aged between 18 and 64 years, and 32.5% Medicare beneficiaries. The most common complaints reported by dispatch included sickness (16.5%), breathing problems (11.7%), falls (10.4%), chest pain (8.8%), and motor vehicle crashes (8.1%).

The overall proportion of geographic discordance for all 911 calls was 27.7% (95% confidence interval [CI] 27.7% to 27.8%). The median distance discordance was 11.5 miles (95% CI 11.5 to 11.5 miles) (excluding those without discordance).

When stratified by dispatch complaint, the majority of motor vehicle crashes, industrial accidents, and mass casualty incidents occurred outside a patient's residence zip code (Figure E1, available online at http://www.annemergmed.com). These 3 complaints were shown to have a 63.5% (95% CI 63.5% to 63.6%), 59.3% (95% CI 58.0% to 60.6%), and 50.6% (95% CI 49.6% to 51.5%) rate of geographic discordance, respectively. Heat or cold exposure, drowning, and traumatic injuries were the next most likely complaints to show high geographic discordance (ranging from 42.4% to 44.9% discordance rates), in contrast to complaints such as cardiac arrest, back pain, choking, fall, breathing problems, and stroke or cerebrovascular accidents, which were less likely to show geographic discordance between residence and incident zip codes (ranging between 18.1% and 20.1%).

Children and adults were more likely to be injured in areas outside their residence zip code than elderly patients (Figure E2, available online at http://www.annemergmed.com). Age groups 0 to 17 and 18 to 64 years showed the greatest geographic discordance, 32.5% (95% CI 32.4% to 32.6%) and 34.2% (95% CI 34.2% to 34.3%), respectively. Elderly patients were less likely to show geographic discordance between residence and incident zip codes, with a 20.2% geographic discordance rate (95% CI 20.1% to 20.2%) among individuals aged 65 to 79 years and an even lower rate of 14.5% (95% CI 14.5% to 14.6%) among patients aged 80 years and older.

When stratified by both complaint and age, motor vehicle crashes, industrial accidents, mass casualty incidents, traumatic injuries, heat or cold exposure, and drowning were among the complaints with the highest geographic discordance for each age group (Figure 2). Across age groups, the rates of geographic discordance of these 6 complaints were much higher for aged 18 to 64 years (ranging from 46.1% to 65.9%) compared with aged

Table 1. Descriptive characteristics of study sample.

Characteristic	Frequency No.	%
Age, y		
0–17	888,864	7.2
18–64	6,795,346	55.2
65–79	2,350,603	19.1
≥80	2,268,529	18.4
Sex		
Male	5,616,452	45.8
Female	6,658,581	54.2
Race		
Non-Hispanic white	5,656,443	67.5
Non-Hispanic black	1,944,385	23.2
Hispanic	560,636	6.7
Non-Hispanic Asian	64,090	0.8
Other	155,902	1.9
Primary method of payment		
Commercial insurance	1,000,606	25.6
Medicaid	602,869	15.4
Medicare	1,270,068	32.5
Self-pay	710,503	18.2
Other (other government, not billed, worker's compensation, payment by facility, community network, contracted payment, no insurance identified, and other payment option)	324,781	8.3
Type of service requested		
911 Response (scene)	12,376,784	100.0
Response mode to scene		
Emergency (immediate response)	9,709,819	78.5
Emergency downgraded to nonemergency	213,859	1.7
Nonemergency	2,355,952	19.0
Nonemergency upgraded to emergency	97,154	0.8
Complaints reported by dispatch		
Abdominal pain	524,836	4.2
Allergies	99,571	0.8
Animal bite	23,259	0.2
Assault	210,527	1.7
Back pain	170,233	1.4
Breathing problem	1,444,253	11.7
Burns	76,748	0.6
Carbon monoxide poisoning/hazmat	13,737	0.1
Cardiac arrest	158,919	1.3
Chest pain	1,084,328	8.8
Choking	42,250	0.3
Convulsions/seizure	489,781	4.0
Diabetic problem	307,877	2.5
Drowning	5,159	0.04
Electrocution	3,748	0.03
Eye problem	14,282	0.1
Fall victim	1,290,488	10.4
Headache	91,588	0.7
Heart problems	167,943	1.4
Heat/cold exposure	22,194	0.2
Hemorrhage/laceration	267,737	2.2
Industrial accident/inaccessible incident/other entrapments (nonvehicle)	5,164	0.04
Ingestion/poisoning	215,624	1.7
Pregnancy/childbirth	109,467	0.9
Psychiatric problem	357,154	2.9
Sick person	2,035,744	16.5
Stab/GSW	39,657	0.3
Stroke/CVA	297,015	2.4
Motor vehicle crash	999,927	8.1
Traumatic injury	400,601	3.2
Unconscious/fainting	715,174	5.8
Unknown problem, man down	681,971	5.5
MCI	9,828	0.1
Cardiac arrest		
No	8,540,886	98.4
Yes, before EMS arrival	122,110	1.4
Yes, after EMS arrival	21,260	0.2
Incident/patient disposition		
Cancelled	54,318	0.4
Dead at scene	126,028	1.0
No patient found	19,455	0.2
No treatment required	351,623	2.8
Patient refused care	1,154,005	9.3
Treated and released	399,692	3.2
Treated, transferred care	508,872	4.1
Treated, transported by EMS	9,725,251	78.6
Treated, transported by law enforcement	15,201	0.1
Treated, transported by private vehicle	22,339	0.2
EMS transport method		
Ground-ambulance	6,967,629	99.7
Air medical (fixed wing or rotorcraft)	24,629	0.3

Hazmat, Hazardous materials; *GSW*, gunshot wound; *CVA*, cerebrovascular accident; *MCI*, mass casualty incident.

0 to 17 years (44.6% to 54.7%), 65 to 79 years (31.0% to 61.7%), and 80 years and older (16.7% to 53.6%). This trend was found among all other complaints, in which adults consistently had higher geographic discordance rates compared with all other age groups. Less than 20% geographic discordance was found in 16 of all 33 complaints for aged 65 to 79 years and in 29 of the 33 complaints for aged 80 years and older, whereas children and adults showed more than 20% geographic discordance in 30 and 33 of all complaints, respectively. Table E1 (available online at http://www.annemergmed.com) provides a complete list of zip code discordance rates for all complaints across all age groups.

When stratified by complaint, the median network distance between 2 discordant zip codes ranged from 8.6 miles (95% CI 8.5 to 8.8 miles) to 23.5 miles (95% CI 22.0 to 25.5 miles) for all complaints among all age groups, with stab or gunshot wounds accounting for the shortest median distance and drowning having the longest median distance (Figure 3). When stratified by age, distance discordance remained relatively consistent across all ages, albeit slightly lower for patients aged 80 years and older, particularly for drowning (15.6%; 95% CI 9.4% to 23.5%), traumatic injuries (10.7%; 95% CI 10.4% to 11.1%), and heat or cold exposure (13.2%; 95% CI 12.0%

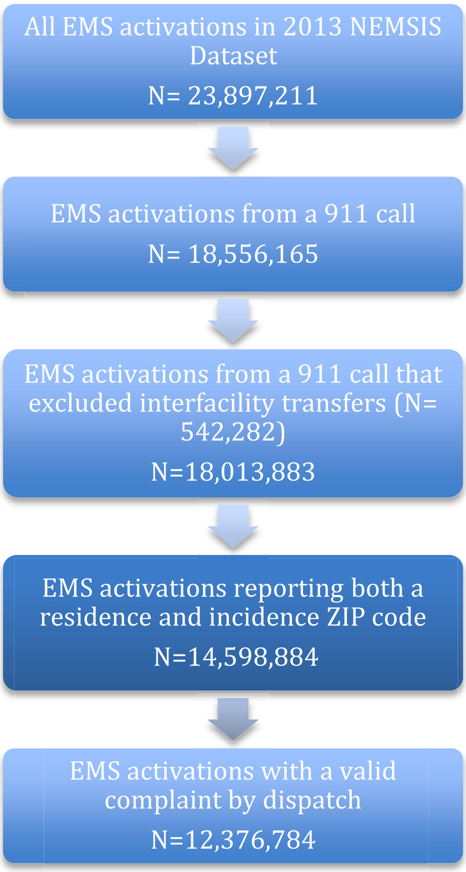

Figure 1. Flowchart of the study sample.

to 14.4%). Table E2 (available online at http://www.annemergmed.com) provides more detailed results on the median network distance between residence and incident zip codes, stratified by both complaint and age.

Geographic discordance was highest for motor vehicle crashes, industrial accidents, and mass casualty incidents, with an OR of 5.79 (95% CI 5.71 to 5.87), 5.02 (95% CI 4.74 to 5.32), and 3.67 (95% CI 3.51 to 3.83), respectively, compared with that of cardiac arrest complaints (Table 2). Drowning, electrocution, heat or cold exposure, and traumatic injuries had the next highest OR (ranging from 2.40 to 3.01) compared with cardiac complaints. Geographic discordance was less likely for abdominal pain (OR 0.97; 95% CI 0.96 to 0.98), back pain (OR 0.93; 95% CI 0.91 to 0.94), and carbon monoxide poisoning or hazardous materials (OR 0.93; 95% CI 0.89 to 0.97) compared with cardiac complaints. Geographic discordance was lower for patients aged 80 years or older.

LIMITATIONS

NEMSIS is a registry of EMS activations rather than a repository of patients receiving care. Multiple emergency resources responding to the same 911 call may submit data to a state data repository. Thus, geographic discordance rates indicate the frequency with which EMS resources respond to the same (or different) zip code regions. However, the effect of this limitation on the current study is minimal because we used medians and ratios to report findings rather than counts.

We excluded EMS run reports that did not have both a residence and incident zip code. When comparing the distributions of dispatch complaint types for EMS activations with and without valid home and incident zip codes, the distributions were largely similar. However, dispatch complaints most likely to occur away from home were more prevalent among EMS activations without both valid zip codes. For example, motor vehicle crashes represented 16% of activations with missing valid zip codes compared with only 8% with valid ones. These findings suggest that our results are most likely biased in a conservative direction.

Race was not included in the regression model because it is often missing and unreliable in emergency situations. The inclusion criteria used by states to characterize EMS activations aggregated in state repositories vary. Although some states mandate reporting every EMS activation, others require only activations resulting in a patient contact or transport. Finally, the use of zip codes to analyze geographic discordance among patient residence and out-of-hospital incident location can introduce barrier bias. For example, an individual may live at the edge of a zip code such that he or she could be close to home but experience an EMS event classified in another zip code. Additionally, a person could experience an EMS event much farther from home but still in the same zip code location. Although the use of zip codes does not provide an exact location, the margin of error may not have practical ramifications for EMS and trauma systems because hospital catchment areas generally serve more than 1 zip code. Distance measurements would be limited in the same way. The analysis attempted to mitigate these potential biases by relying on median distances from centroids to represent the natural distribution of all 911 calls within each zip code.

DISCUSSION

To test the assumption that a patient's residence can serve as a proxy for incident location for 911 calls, this study analyzed the rate of geographic discordance between residence and incident zip codes among more than 12 million EMS activations. Our analysis showed that the rate of geographic discordance varied significantly across age and complaint categories. By studying the geographic distribution of out-of-hospital incident locations, emergency care or trauma systems could be more prepared

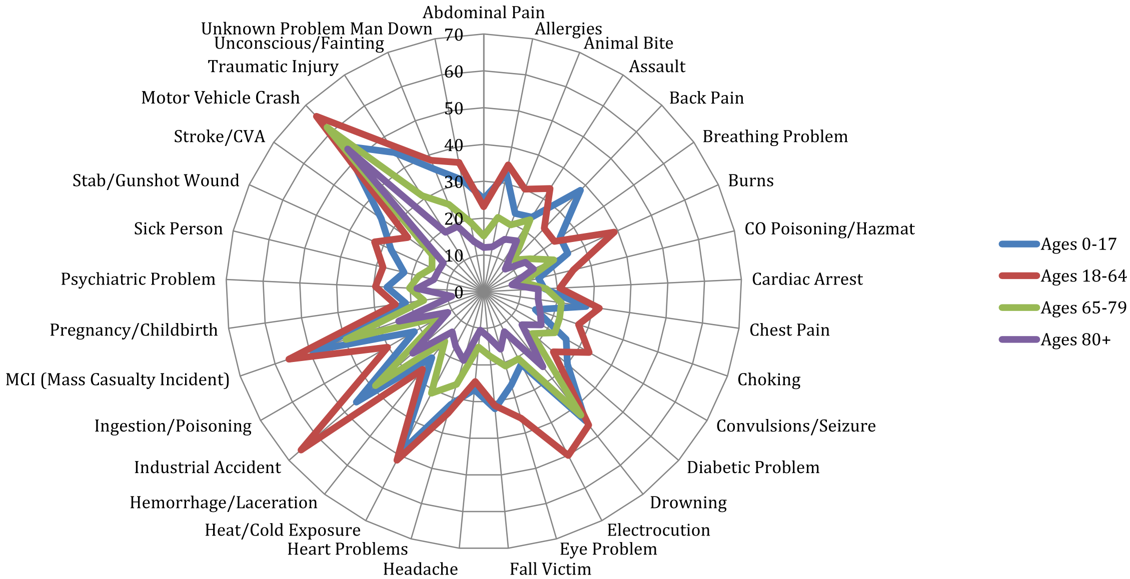

Figure 2. Rate of zip code discordance (%) by dispatch complaint and age.

to determine the distribution of resources or create effective triage and transfer guidelines to treat patients, given the geographic mismatch in residence and out-of-hospital incident locations.

Our analysis quantified the degree of distance discordance rates calculated for each complaint and age group. Most complaints occurred approximately 8.6 to 23.5 miles from the patient's residence. Although these distances are far enough to potentially skew our understanding of need-based EMS resource allocation and geographic distribution, they may not necessarily prohibit access to care. When disparate zip codes are examined by distance, it is not surprising that complaints potentially associated with travel, such as heat or cold exposure or drowning, on average occurred at a much greater distance away from home. These distances may be far enough to suggest that the place of residence is an inaccurate approximation of incident location compared with other complaints with shorter disparate geographic distances.

These findings contribute significantly to our current body of knowledge, given the lack of or limited data available on location of out-of-hospital incidents.[3,7] Although several studies have examined the relationship between out-of-hospital incidents and residence locations, they have been limited to injury deaths, specific predefined regions, or injury-specific conditions such as automobile-

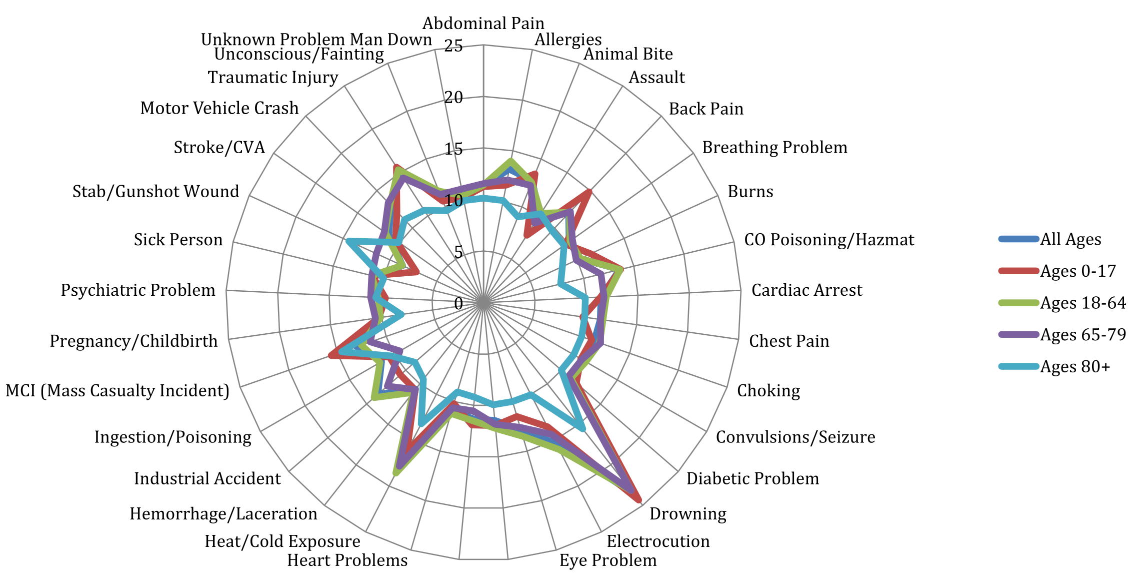

Figure 3. Median network distance between residence and incident zip codes (miles) by dispatch complaint and age.

Table 2. Multivariable predictors of geographic discordance.

Predictors	Adjusted OR (95% CI)
Abdominal pain*	0.97 (0.96–0.98)
Allergies	1.67 (1.64–1.71)
Animal bite	1.26 (1.22–1.30)
Assault	1.39 (1.37–1.41)
Back pain	0.93 (0.91–0.94)
Breathing problem	1.09 (1.07–1.10)
Burns	1.79 (1.76–1.83)
Carbon monoxide poisoning/hazmat	0.93 (0.89–0.97)
Chest pain	1.51 (1.49–1.53)
Choking	1.16 (1.17–1.19)
Convulsions/seizure	1.48 (1.46–1.50)
Diabetic problem	1.13 (1.11–1.15)
Drowning	2.97 (2.77–3.11)
Electrocution	2.40 (2.25–2.57)
Eye problem	1.61 (1.55–1.67)
Fall victim	1.34 (1.32–1.36)
Headache	1.03 (1.01–1.05)
Heart problems	1.84 (1.81–1.87)
Heat/cold exposure	3.01 (2.92–3.10)
Hemorrhage/laceration	1.16 (1.14–1.18)
Industrial accident	5.02 (4.74–5.32)
Ingestion/poisoning	1.22 (1.21–1.24)
MCI	3.67 (3.51–3.83)
Pregnancy/childbirth	0.90 (0.88–0.92)
Psychiatric problem	1.26 (1.24–1.28)
Sick person	1.27 (1.25–1.29)
Stab/GSW	1.29 (1.26–1.33)
Stroke/CVA	1.20 (1.19–1.22)
Motor vehicle crash	5.79 (5.71–5.87)
Traumatic injury	2.64 (2.61–2.68)
Unconscious/fainting	1.96 (1.93–1.98)
Man down	1.61 (1.59–1.63)
Age, y	
0–17†	2.01 (2.00–2.02)
18–64	2.50 (2.49–2.51)
65–79	1.41 (1.41–1.42)
Sex, male	1.16 (1.16–1.16)

*For patient complaints, adjusted odds illustrate the odds that a 911 emergency occurs in a zip code other than home zip code compared with patient complaint "cardiac arrest."

†For patient age groups, adjusted odds illustrate the odds that a 911 emergency occurs in a zip code other than home zip code compared with patients aged 80 years or older.

pedestrian collisions. To our knowledge, this is the first article in the United States to test the assumption that residence location can be used as a proxy for the location of other out-of-hospital incidents, using comprehensive national data. A recent article[7] analyzed the relationship between site of out-of-hospital injury and residence in Canada, but focused on a specific predefined region. It differs from our study by supporting the assumption mentioned above and concluding that a majority of injuries occurred near a patient's residence, regardless of mechanism of injury or age, with a median distance of 0.2 miles between out-of-hospital injury and residence locations, compared with 11.5 miles in our study. Our results question the assumption that location of residence is a usable proxy for incidence of 911 calls, particularly for certain conditions.

Our study has direct relevance to out-of-hospital and hospital and trauma system planning and resource allocation, providing insights on how to best improve access and availability of emergency care for specific populations and injuries in a given area. Examining the geographic distribution of injuries helps EMS understand how to best serve at-risk populations, particularly those that might lack access to emergency and trauma care, and allows them to allocate or distribute services and resources appropriately within specific locations. For example, recently the American College of Surgeons developed the Needs Based Assessment of Trauma Systems tool to create a framework for allocation decisions of trauma centers. Transport times are a main component of the tool. Overall, determining the location of the incident of 911 calls has the potential to affect the design, implementation, and location of trauma and emergency care systems, and the comprehensive scope of our study provides evidence-based research to support such decisions.

In contrast to patients aged 18 to 64 years who showed greater than 20% geographic discordance, the use of residence for proxy may be appropriate for patients aged 65 to 79 years and 80 years and older who were found to have less than a 20% geographic discordance between zip codes. This was not surprising, given that previous studies found that older groups are injured closer to home.[8] The assumption of using residence zip codes as a proxy for EMS location may be a reasonable predictor for geriatric care planning. More caution about the accuracy of this proxy may be warranted, however, for certain complaints, such as motor vehicle crashes, industrial accidents, mass casualty incidents, traumatic injuries, and drowning, because they demonstrated a high rate of geographic discordance across all ages, including the elderly.

The implications of our article are not to offer a solution to replace zip codes with another more granular way of recording geography, but rather an admonition to be cautious when making such assumptions. Future directions could include potentially incorporating out-of-hospital incident zip codes into administrative data for patients who arrive at hospitals by ambulance, for example. In some states, EMS agencies have detailed geographic information and record the longitudes and latitudes of incidents and transport destinations. Exact patient home and incident addresses are often available to responding EMS providers from patients, bystanders, 911 call centers, or global positioning systems. The NEMSIS standard includes data elements to capture an exact address for each patient and incident location. Elements capturing exact addresses are available to local EMS agencies; they may be aggregated at a state level, if permitted, but are not included in the National EMS Registry because of privacy issues. This information highlights the idea that this study could be replicated, using state or local data, to tailor findings to specific geographic regions.

In conclusion, our results challenge the validity of the blanket assumption that residence and incident zip codes can be considered interchangeable for all patients. The geographic discordance of zip codes highlights the need for more sophisticated approaches to EMS geographic modeling and resource allocation, which EMS providers and administrators can use to best treat patients. This study has important implications for EMS planning and has the potential to affect the design, implementation, and location of trauma and emergency care systems.

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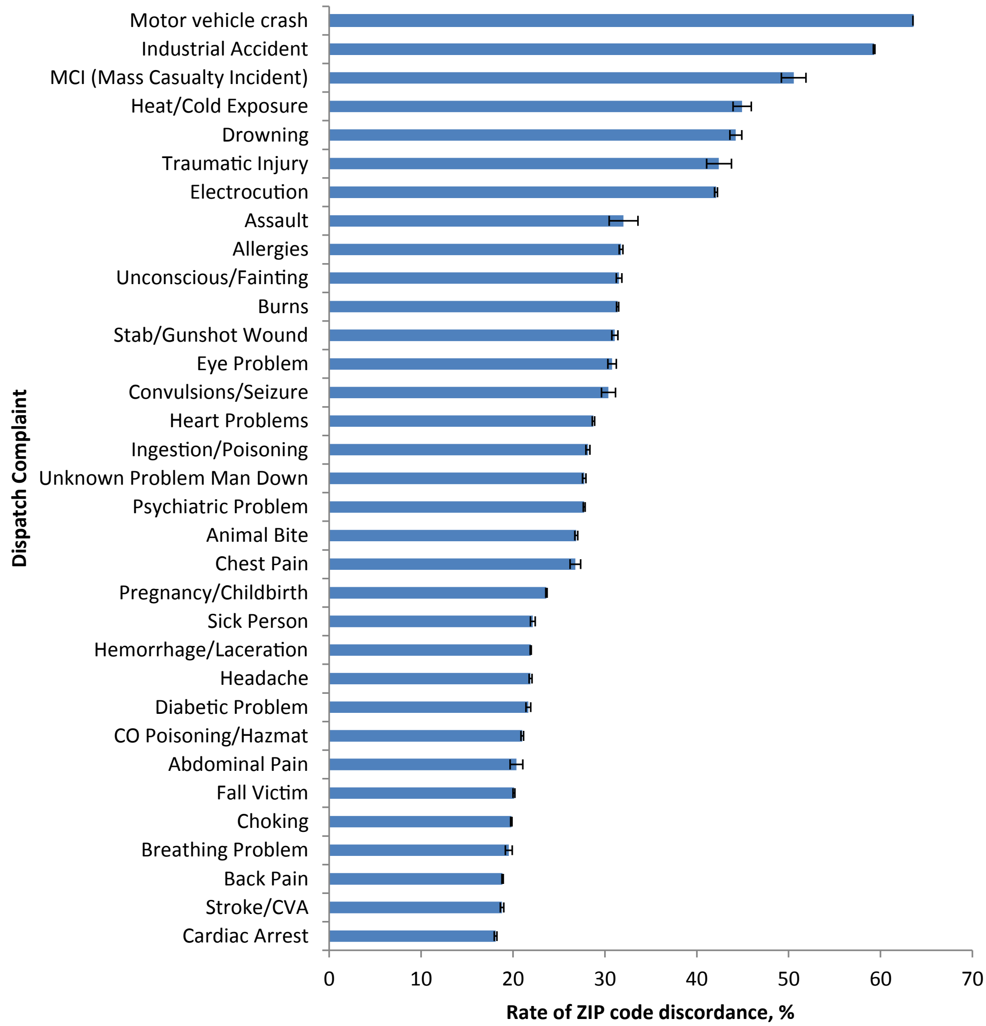

Figure E1. Rate of zip code discordance (%) by dispatch complaint. Whiskers represent CIs.

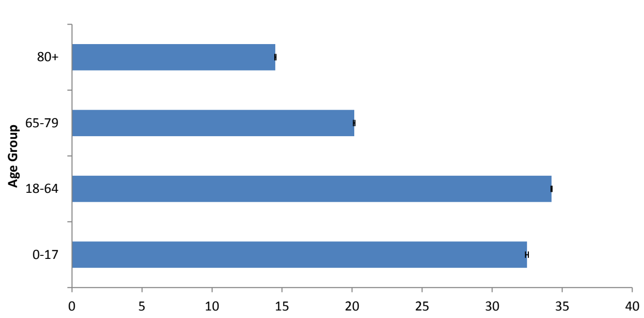

Figure E2. Rate of zip code discordance (%) by age. Whiskers represent CIs.

Table E1. Rate of zip code discordance (%) by dispatch complaint and age.

	Age, % (95% CI)			
Dispatch Complaint	**0–17**	**18–64**	**65–79**	**≥80**
Abdominal pain	25.3 (24.6–25.9)	23.1 (23.0–23.2)	15.2 (15.0–15.4)	12.0 (11.8–12.2)
Allergies	32.6 (32.0–33.2)	35.1 (34.7–35.5)	20.6 (19.8–21.3)	12.4 (11.5–13.3)
Animal bite	22.9 (21.9–24.0)	30.0 (29.3–30.8)	19.5 (17.6–21.5)	15.4 (12.8–17.9)
Assault	24.1 (23.5–24.7)	33.3 (33.1–33.6)	23.3 (22.1–24.4)	16.5 (14.9–18.2)
Back pain	38.1 (36.4–39.8)	23.8 (22.9–23.4)	11.9 (11.6–12.3)	8.5 (8.1–8.8)
Breathing problem	25.4 (25.2–25.7)	23.5 (23.4–23.6)	15.4 (15.3–15.5)	13.8 (13.7–14.0)
Burns	25.1 (24.0–26.2)	39.0 (38.5–39.4)	20.9 (20.1–31.6)	14.8 (14.2–15.5)
Carbon monoxide poisoning/hazmat	15.3 (13.9–16.8)	25.0 (24.1–25.9)	11.0 (9.3–12.9)	7.8 (5.8–9.8)
Cardiac arrest	16.5 (15.6–17.4)	20.7 (20.4–21.0)	17.0 (16.6–17.4)	14.9 (14.5–15.2)
Chest pain	28.1 (27.4–28.8)	31.7 (31.6–31.8)	21.3 (21.1–21.4)	14.9 (14.7–15.1)
Choking	14.8 (14.3–15.4)	27.2 (26.5–28.0)	21.8 (20.8–22.8)	16.2 (15.4–17.0)
Convulsion/seizure	25.8 (25.6–26.1)	33.1 (32.9–33.2)	22.3 (21.8–22.7)	18.0 (17.5–18.6)
Diabetic problem	30.0 (29.7–31.4)	25.0 (24.8–25.2)	17.4 (17.1–17.6)	13.7 (13.3–14.1)
Drowning	44.6 (42.4–46.9)	46.1 (44.2–48.0)	42.6 (37.7–47.6)	26.0 (20.0–31.9)
Electrocution	22.2 (18.4–25.9)	50.1 (48.2–51.9)	20.5 (15.5–25.4)	12.2 (7.7–16.7)
Eye problem	26.4 (24.7–28.2)	35.8 (34.8–36.8)	21.1 (19.0–23.2)	16.3 (14.4–18.4)
Fall victim	32.0 (31.6–32.4)	31.1 (31.0–31.3)	17.6 (17.4–17.7)	12.2 (12.2–12.3)
Headache	26.7 (25.4–28.0)	24.5 (24.2–24.9)	15.1 (14.5–15.7)	10.5 (9.9–11.1)
Heart problems	32.0 (30.3–33.7)	34.4 (34.1–34.7)	26.2 (25.8–26.6)	19.5 (19.1–19.9)
Heat/cold exposure	48.8 (46.9–50.7)	51.5 (50.7–52.4)	31.0 (29.4–32.7)	16.7 (15.0–18.3)
Hemorrhage/laceration	22.8 (22.2–23.4)	26.9 (26.7–27.1)	17.1 (16.8–17.4)	13.9 (13.6–14.2)
Industrial accident	45.8 (41.5–50.2)	65.7 (64.2–67.2)	39.0 (34.2–43.9)	25.6 (20.0–31.2)
Ingestion/poisoning	21.8 (21.2–22.3)	30.2 (30.0–30.4)	13.6 (12.9–14.4)	11.2 (10.2–12.3)
MCI	49.0 (46.4–51.6)	56.1 (54.9–57.2)	39.6 (36.0–43.3)	24.5 (20.4–28.5)
Pregnancy/childbirth	21.5 (20.6–22.4)	24.3 (24.0–24.5)	16.5 (14.5–18.6)	8.8 (7.6–10.0)
Psychiatric problem	26.3 (25.9–26.8)	29.4 (29.3–29.6)	20.2 (19.8–20.7)	18.2 (17.7–18.8)
Sick person	22.3 (22.0–22.5)	28.2 (28.1–28.2)	18.2 (18.0–18.3)	14.0 (13.9–14.1)
Stab/GSW	27.7 (26.1–29.4)	32.6 (32.1–33.1)	15.4 (13.6–17.3)	13.6 (11.1–16.4)
Stroke/CVA	34.2 (31.2–37.2)	25.3 (25.1–25.6)	17.3 (17.0–17.5)	13.5 (13.3–13.7)
Motor vehicle crash	54.7 (54.5–55.0)	65.9 (65.8–66.0)	61.7 (61.3–62.0)	53.6 (52.9–54.2)
Traumatic injury	44.9 (44.6–45.3)	47.6 (47.4–47.8)	31.0 (30.6–31.4)	19.2 (18.8–19.6)
Unconscious/fainting	35.9 (35.4–36.3)	38.5 (38.3–38.6)	25.6 (25.4–25.8)	19.1 (18.9–19.3)
Unknown problem, man down	30.9 (30.5–31.4)	35.8 (36.6–35.9)	19.3 (19.4–19.5)	13.8 (13.7–14.0)

Table E2. Median network distance between residence and incidence zip codes (miles) by dispatch complaint and age.

Dispatch Complaint	Age, Miles (95% CI)				
	All	0–17	18–64	65–79	≥80
Abdominal pain	11.3 (11.2–11.4)	11.3 (10.8–11.6)	11.4 (11.3–11.5)	11.5 (11.4–11.8)	10.1 (9.9–10.4)
Allergies	13.2 (13.0–13.4)	11.6 (11.3–12.0)	14.0 (13.7–14.2)	12.1 (11.6–12.8)	10.1 (9.5–11.2)
Animal bite	12.7 (12.3–13.1)	13.5 (12.8–14.6)	12.6 (12.1–13.1)	12.3 (9.9–13.9)	9.0 (7.4–12.3)
Assault	10.1 (9.9–10.1)	7.8 (7.5–8.0)	10.3 (10.2–10.4)	9.2 (8.7–9.9)	10.3 (9.0–12.0)
Back pain	12.0 (11.8–12.1)	14.8 (13.5–16.1)	12.1 (11.9–12.2)	12.2 (11.8–12.7)	9.6 (9.3–10.1)
Breathing problem	10.2 (10.1–10.2)	9.8 (9.6–9.9)	10.3 (10.3–10.4)	10.6 (10.5–10.7)	9.6 (9.5–9.7)
Burns	10.3 (10.1–10.5)	11.4 (10.6–12.2)	10.3 (10.2–10.6)	9.9 (9.2–10.7)	8.4 (7.9–9.2)
Carbon monoxide poisoning/hazmat	13.6 (13.1–14.1)	13.7 (11.4–14.3)	13.6 (13.1–14.3)	11.7 (9.6–15.9)	7.7 (6.2–13.1)
Cardiac arrest	11.4 (11.3–11.6)	11.4 (10.7–11.9)	11.9 (11.7–12.1)	11.7 (11.4–12.0)	9.9 (9.6–10.1)
Chest pain	11.4 (11.4–11.5)	9.7 (9.4–10.1)	11.7 (11.6–11.7)	11.5 (11.4–11.6)	9.9 (9.8–10.0)
Choking	11.4 (11.1–11.7)	11.1 (10.5–11.6)	11.9 (11.5–12.6)	12.0 (11.3–13.0)	10.1 (9.6–10.7)
Convulsions/seizure	11.3 (11.2–11.4)	10.9 (10.7–11.1)	11.4 (11.4–11.5)	11.0 (10.7–11.3)	10.1 (9.7–10.5)
Diabetic problem	11.1 (11.0–11.2)	11.9 (11.1–12.7)	11.2 (11.1–11.3)	10.9 (10.7–11.1)	10.0 (9.8–10.4)
Drowning	23.5 (22.0–25.5)	24.4 (21.0–28.2)	23.2 (21.1–26.9)	23.2 (18.4–28.4)	15.6 (9.4–23.5)
Electrocution	15.4 (14.4–16.5)	13.5 (11.3–17.0)	16.0 (14.6–17.1)	14.4 (11.3–19.0)	10.1 (7.8–15.2)
Eye problem	12.8 (12.5–13.4)	11.5 (10.6–12.8)	13.5 (12.8–13.9)	12.6 (11.1–14.9)	10.0 (8.9–11.5)
Fall victim	11.5 (11.4–11.5)	12.0 (11.8–12.2)	12.2 (12.2–12.3)	11.8 (11.7–12.0)	9.9 (9.9–10.0)
Headache	11.3 (11.1–11.5)	11.9 (11.2–12.8)	11.5 (11.3–11.7)	10.5 (10.2–11.2)	9.2 (8.6–9.8)
Heart problems	10.6 (10.5–10.7)	10.2 (9.5–11.0)	11.2 (11.1–11.3)	10.6 (10.5–10.8)	9.0 (8.9–9.2)
Heat/cold exposure	18.0 (17.4–18.4)	16.2 (14.8–17.7)	18.6 (18.0–19.2)	17.8 (15.9–20.0)	13.2 (12.0–14.4)
Hemorrhage/laceration	10.7 (10.6–10.8)	10.8 (10.4–11.2)	11.1 (10.9–11.1)	10.7 (10.5–11.0)	9.4 (9.2–9.6)
Industrial accident	13.6 (13.0–14.2)	10.7 (9.3–12.5)	14.1 (13.4–14.7)	12.3 (9.8–15.4)	8.8 (8.0–15.3)
Ingestion/poisoning	11.4 (11.3–11.6)	10.5 (10.3–10.9)	11.6 (11.5–11.8)	9.4 (8.8–10.0)	10.3 (8.7–11.3)
MCI	13.0 (12.5–13.5)	15.6 (14.0–17.9)	12.5 (11.9–13.1)	11.6 (10.3–14.2)	14.6 (10.3–19.2)
Pregnancy/childbirth	10.1 (10.0–10.3)	10.3 (9.6–10.8)	10.1 (10.0–10.3)	10.6 (8.1–11.8)	8.1 (7.4–10.6)
Psychiatric problem	10.2 (10.1–10.3)	9.5 (9.4–9.7)	10.2 (10.1–10.3)	11.0 (10.6–11.3)	10.5 (10.1–10.8)
Sick person	11.0 (10.9–11.0)	11.1 (10.9–11.3)	11.2 (11.1–11.2)	11.2 (11.1–11.3)	10.0 (9.9–10.1)
Stab/GSW	8.6 (8.5–8.8)	7.2 (6.8–8.0)	8.7 (8.5–8.8)	11.4 (9.8–13.8)	14.4 (10.9–18.8)
Stroke/CVA	11.3 (11.2–11.4)	10.5 (9.3–12.0)	11.7 (11.6–11.9)	11.8 (11.6–12.0)	10.1 (9.9–10.3)
Motor vehicle crash	13.0 (13.0–13.1)	12.2 (12.1–12.3)	13.2 (13.1–13.2)	13.4 (13.2–13.5)	11.1 (10.9–11.3)
Traumatic injury	15.0 (14.9–15.1)	15.6 (15.3–15.9)	15.3 (15.2–15.5)	14.4 (14.0–14.7)	10.7 (10.4–11.1)
Unconscious/fainting	11.2 (11.2–11.3)	10.6 (10.4–10.8)	11.6 (11.6–11.7)	11.3 (11.2–11.4)	9.6 (9.5–9.8)
Unknown problem, man down	10.6 (10.6–10.7)	10.4 (10.1–10.6)	10.6 (10.5–10.7)	11.2 (11.1–11.4)	10.1 (9.9–10.3)