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Crossing the line: access to trauma care across state borders

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ABSTRACT

Objective This study investigates the challenge posed by state borders by identifying the population, injury, and geographic scope of areas of the country where the closest trauma center is out-of-state, and by collating state emergency medical services (EMS) policies relevant to cross-border trauma transport.

Methods We identified designated levels I, II, and III trauma centers using data from American Trauma Society. ArcGIS was used to map the distance between US census block groups and trauma centers to identify the geographic areas for which cross-border transport may be most expedient. National Highway Traffic Safety Administration data were queried to quantify the proportion of fatal crashes occurring in the areas of interest. State EMS protocols were categorized by stance on cross-border transport.

Results Of 237 596 included US census block groups, 18 499 (7.8%) were closest to an out-of-state designated level I or II trauma center. These census block groups accounted for 6.9% of the US population and 9.5% of all motor vehicle fatalities. With the inclusion of level III trauma centers, the number of US census block groups closest to an out-of-state designated level I, II, or III trauma center decreased to 13 690 (5.8%). These census block groups accounted for 5.1% of the US population and 7.1% of all motor vehicle fatalities. Of the 48 contiguous states, 30 encourage cross-border transport, 2 discourage it, 12 are neutral, and 4 leave it to local discretion.

Conclusion Cross-border transport can expedite access to care in at least 5% of US census block groups. While few states discourage this practice, more robust policy guidance could reduce delays and enhance care.

Level of Evidence III, Epidemiological.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The role of state borders in access to definitive trauma care has not been robustly examined thus far.

WHAT THIS STUDY ADDS

⇒ With a unique methodology, this study leverages both geospatial and policy analyses to inform the discussion on prehospital cross-border transport of acutely injured patients.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Findings have direct relevance to state-level and national-level policy and align with *TSACO*'s goal to promote public health and enhance care across contexts.

INTRODUCTION

In the USA, trauma is the fourth leading cause of death across all age groups and accounts for over 3 million non-fatal injuries and 150 000 fatalities annually.[1] The majority of preventable fatal injuries are attributable to hemorrhage or brain injury, making expedient access to definitive trauma care paramount.[1] Policies that support rapid patient transport have the potential to save lives. Because trauma systems and emergency medical services (EMS) protocols are organized on the state level, rather than national level, state borders may pose an obstacle to optimal and expedient access to care.

Trauma patients needing emergent care are directed to designated trauma centers meeting established standards for resources and personnel. In the event of traumatic injury, EMS providers are empowered to bypass closer hospitals in favor of designated trauma centers where geography permits and situational context is appropriate.[2] Since longer prehospital times are associated with increased risk of complications and mortality,[3 4] the geographic distribution of trauma centers plays a key role in patient outcomes. However, trauma centers are not necessarily located or designated based on population distribution or need, leading to geographic inequities in access to care. While the number of designated trauma centers has increased over time, designating additional higher-level trauma centers does not always increase population access. New centers often serve the same geographic areas as already-existing centers leaving underserved areas elsewhere.[5]

Geographic proximity is not the only determinant of access, however. State policies and protocols may play a role. For patients living near state borders, the nearest trauma center may be out-of-state rather than in-state. Barriers to obtaining care at these centers may include EMS regulations and licensing models; payment concerns; and patient preferences. EMS agencies, regulated by state and local governing bodies, may not be permitted to transport patients across state lines. EMS providers may not be licensed to practice in adjacent states, making care provided en route a legal risk. Patients' insurance policies may not cover out-of-state treatment, and state trauma funds may not address care provided across the border. Preferentially transporting patients to designated trauma centers only within their state of injury may increase transport

Table 1 Characteristics of US census block groups according to location of closest level I or II TC

Variable label	Variable levels	Closest TC I–II in-state Mean (±SD) N=219 092	Closest TC I–II out-of-state Mean (±SD) N=18 499	P value
Rural-urban continuum code*	1	120 393 (55.0%)	4739 (25.6%)	<0.001
	2	47 579 (21.7%)	1960 (10.6%)	
	3	19 435 (8.9%)	2859 (15.5%)	
	4	9824 (4.5%)	1639 (8.9%)	
	5	3045 (1.4%)	955 (5.2%)	
	6	10.374 (4.7%)	2710 (14.6%)	
	7	5168 (2.4%)	2310 (12.5%)	
	8	1518 (0.7%)	519 (2.8%)	
	9	1756 (0.8%)	808 (4.4%)	
Block population		1253.0 (882.0–1739.0)	1088.0 (783.0–1500.0)	<0.001
Population density		2731.3 (530.6–6348.1)	376.5 (56.2–2029.1)	<0.001
White (%)		69.4 (36.2–88.5)	87.0 (66.7–95.5)	<0.001
Black (%)		2.6 (0.0–14.3)	0.9 (0.0–8.4)	<0.001
Native (%)		0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.69
Asian/Pacific Islander (%)		0.7 (0.0–5.4)	0.0 (0.0–1.0)	<0.001
Latinx (%)		7.2 (1.4–23.1)	2.2 (0.0–8.5)	<0.001
Graduated college (%)		27.4 (15.0–46.1)	19.7 (11.8–31.4)	<0.001
Unemployment rate (%)		3.8 (1.1–7.8)	3.8 (1.0–7.8)	0.73
Median household income		65 000.0 (46 250.0–92 210.0)	54 778.0 (41 131.0–72 500.0)	<0.001
Family poverty rate		5.2 (0.0–14.5)	7.0 (1.2–16.1)	0.016
Children living in a single parent household (%)		23.8 (6.9–48.9)	26.4 (9.4–50.3)	0.15
Under 18 years (%)		21.4 (15.2–27.6)	21.0 (15.4–26.5)	<0.001
Over 65 years (%)		15.1 (9.4–22.1)	18.3 (12.7–24.9)	<0.001
Average household size		2.6 (2.2–3.0)	2.4 (2.2–2.7)	<0.001

*Rural-urban continuum codes variable levels: (1) counties in metro areas of 1 million population or more; (2) counties in metro areas of 250 000 to 1 million population; (3) counties in metro areas of fewer than 250 000 population; (4) urban population of 20 000 or more, adjacent to a metro area; (5) urban population of 20 000 or more, not adjacent to a metro area; (6) urban population of 2500–19 999, adjacent to a metro area; (7) urban population of 2500–19 999, not adjacent to a metro area; (8) completely rural or fewer than 2500 population, adjacent to a metro area; (9) completely rural or fewer than 2500 urban population, not adjacent to a metro area.
TCC, trauma center.

distance, leading to longer prehospital time and increased mortality.

To investigate the role of state borders in access to trauma care in cross-border areas, we identified the population, injury, and geographic scope of areas of the USA where the closest trauma center is out-of-state, and collated state EMS policies relevant to cross-border trauma transport. The goal of this research is to identify opportunities for trauma system and policy interventions that optimize expedient access to care where state borders might interfere. We sought to determine what proportion of US census block groups and population were located closer to an out-of-state rather than in-state trauma center, and therefore at risk of potentially delayed care due to local policies on cross-border transport of acutely injured patients.

METHODS

Study population

Trauma centers are designated as level I through level V depending on availability of resources and patient volume. Designation is overseen by state or local regulatory bodies and verified in many, but not all, states by the American College of Surgeons-Committee on Trauma (ACS-COT) with up to five levels. Levels I and II centers provide comprehensive trauma care and must meet requirements regarding in-house staffing of key surgical services and timeframes of availability for other resources.[6] Level III centers may not provide definitive care for all injuries but provide most care in a short timeframe and have surgical and critical care resources required for stabilization. Levels IV and V trauma centers are part of the trauma system but have fewer required resources and provide less comprehensive care, levels I and II trauma centers offer comprehensive care, while level III centers provide stabilization and initial management of injury. Levels I, II, and III centers are the focus of this study.

We identified ACS-COT verified levels I, II, and III trauma centers for 48 contiguous US states using the American Trauma Society's Trauma Information Exchange Program (2020).[7] We also included state-designated trauma centers without ACS verification in our analysis. We excluded trauma centers in Alaska, Hawaii, and Washington DC because the role of cross-border trauma transport differs for non-contiguous states and federal districts. Geographic coordinates for trauma centers were encoded using GeoApify's Geocoding Application Programming Interface. ArcGIS Desktop V.10.8 (Esri) was used to map the distribution of trauma centers across the USA.

Geospatial analysis

All US census block groups, except those in non-contiguous states and federal districts, were included in this analysis (237,596). Population-weighted census block group centroids were determined for each included census block group using geographic data from the US Census Bureau (2020). National road network data were obtained from the US Bureau of Transportation Statistics. These data were used in conjunction with the ArcGIS Network Analysis tool

Table 2 Characteristics of US census block groups according to location of closest level I, II, or III TC

Variable label	Variable levels	Closest TC I–II in-state Mean (±SD) N=224 270	Closest TC I–II out-of-state Mean (±SD) N=13 321	P value
Rural-urban continuum code*	1	121 566 (54.2%)	3566 (26.8%)	<0.001
	2	48 221 (21.5%)	1318 (9.9%)	
	3	20 356 (9.1%)	1938 (14.5%)	
	4	10 125 (4.5%)	1338 (10.0%)	
	5	3546 (1.6%)	454 (3.4%)	
	6	11 028 (4.9%)	2056 (15.4%)	
	7	5871 (2.6%)	1607 (12.1%)	
	8	1566 (0.7%)	471 (3.5%)	
	9	1991 (0.9%)	573 (4.3%)	
Block population		1248.0 (879.0–1734.0)	1091.0 (789.0–1499.0)	<0.001
Population density		2669.2 (502.3–6252.3)	295.9 (52.4–1758.8)	<0.001
White (%)		69.8 (36.9–88.7)	88.5 (68.6–96.1)	<0.001
Black (%)		2.5 (0.0–14.1)	0.9 (0.0–8.6)	<0.001
Native (%)		0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.69
Asian/Pacific Islander (%)		0.7 (0.0–5.2)	0.0 (0.0–0.9)	<0.001
Latinx (%)		7.1 (1.4–22.8)	1.7 (0.0–6.7)	<0.001
Graduated college (%)		27.1 (14.9–45.8)	19.7 (11.7–31.1)	<0.001
Unemployment rate (%)		3.8 (1.1–7.8)	3.9 (1.1–7.8)	0.73
Median household income		64 664.0 (46 141.0–91 705.0)	54 519.0 (40 646.0–72 344.0)	<0.001
Family poverty rate		5.3 (0.0–14.5)	7.1 (1.4–16.5)	0.016
Children living in a single parent household (%)		23.9 (7.0–48.9)	26.7 (9.4–50.7)	0.15
Under 18 years (%)		21.4 (15.2–27.5)	20.8 (15.4–26.3)	<0.001
Over 65 years (%)		15.2 (9.4–22.2)	18.3 (12.6–24.8)	<0.001
Average household size		2.6 (2.2–3.0)	2.4 (2.2–2.7)	<0.001

*Rural-urban continuum codes variable levels: (1) counties in metro areas of 1 million population or more; (2) counties in metro areas of 250 000 to 1 million population; (3) counties in metro areas of fewer than 250 000 population; (4) urban population of 20 000 or more, adjacent to a metro area; (5) urban population of 20 000 or more, not adjacent to a metro area; (6) urban population of 2500–19 999, adjacent to a metro area; (7) urban population of 2500–19 999, not adjacent to a metro area; (8) completely rural or fewer than 2500 population, adjacent to a metro area; (9) completely rural or fewer than 2500 urban population, not adjacent to a metro area.
TC, trauma center.

to identify the nearest designated (1) level I or II trauma center and (2) level I, II, or III trauma center to each census block group by drive-time distance. Since time values associated with each road or route is not available, minimum drive-time values were calculated by dividing road-segment lengths by their respective speed limits. For both levels I–II and levels I–III trauma centers, we located the nearest in-state and out-of-state trauma center to each census block group centroid based on drive-time distance. The drive-time difference between the nearest in-state and out-of-state trauma center for a given census block group was also calculated.

We calculated the proportion of census block groups that were located closer to an out-of-state designated (1) level I or II or (2) level I, II, or III trauma center, and the corresponding population numbers for these census block groups. We used data from the US Census Bureau's American Community Survey 5-year dataset (2020) to determine the demographic characteristics of affected groups. The United States Department of Agriculture rural-urban continuum codes were used to categorize census block groups as either urban or rural, with blocks coded as 1–3 classified as urban and blocks coded as 4–9 broadly classified as rural.[8]

This study was designated exempt from review by our affiliated Institutional Review Board.

Policy analysis

We reviewed most-recent publicly available documents from local governing and state governing bodies to collect state EMS protocols. These were obtained online from the official websites of governing bodies. The format and policy language in available documents regarding cross-border transport varies between regions. We classified state EMS protocols into four categories: encourages cross-border transport, discourages cross-border transport, neutral on cross-border transport, or leaves the matter of cross-border transport to local discretion. If state protocols explicitly cited policies permitting cross-border transport, in reference to a specific state or in general, the state was categorized as 'encouraging cross-border transport'. If protocols explicitly prohibited cross-border transport, the state was categorized as 'discouraging cross-border transport'. If a state offered no official stance on the matter, it was categorized as 'neutral'. Lastly, if a state offered language indicating cross-border transport was feasible in some instances, it was categorized as 'leaving the matter to local discretion'.

Motor vehicle crash fatalities

To estimate the burden of serious injuries occurring in the areas of concern, we used national data on motor vehicle crash fatalities. Data were extracted from the National Highway Traffic Safety Administration Fatality Analysis Report System (FARS)

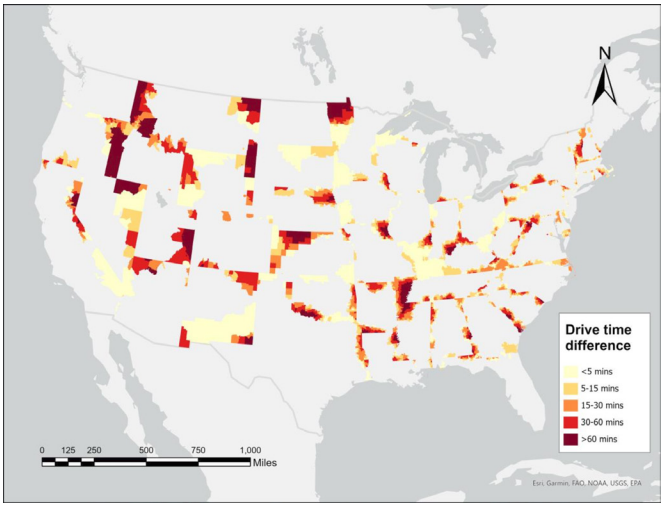

Figure 1 US census block groups classified by drive time difference between nearest in-state and out-of-state levels I–II trauma center.

(2020). FARS assesses fatal injuries suffered in motor vehicle traffic crashes in the USA and provides data at the national, state, and local level. Based on geographic designations and person-level data in FARS, we calculated the number and proportion of fatal crashes occurring in census block groups closer to an out-of-state versus in-state trauma center.

RESULTS

Of 237 596 US census block groups included, 18 499 (7.8%) were closest to an out-of-state designated level I or II trauma center. These census block groups accounted for 6.9% of the US population. These census block groups also accounted for 9.5% of all motor vehicle fatalities reported on FARS in 2020. With the inclusion of level III trauma centers, the number of US census block groups closest to an out-of-state designated level I, II, or III trauma center decreased to 13 690 (5.8%). These census block groups accounted for 5.1% of the US population as well as 7.1% of all motor vehicle fatalities reported on FARS in 2020. Tables 1 and 2 show the characteristics of these census block groups.

We determined that census block groups closer to an out-of-state trauma center were more likely rural (48.4% for levels I–II and 48.7% for levels I–III trauma centers, p<0.001). In addition, these census block groups had smaller populations (p<0.001), lower population density (p<0.001), lower median household incomes (p<0.001), and higher rates of family poverty (p<0.001).

Broadly, the average rate of motor vehicle fatalities per 100 000 for census block groups closest to an in-state trauma center was 11.5 for levels I–II and 11.6 for levels I–III. The average rate of motor vehicle fatalities per 100 000 in census block groups closest to an out-of-state trauma center was 16.4 for levels I–II and 16.6 for levels I–III.

For census block groups closest to an out-of-state levels I–II trauma center, the average rate of motor vehicle fatalities per 100 000 was 16.4 in states that approved of cross-border transport and 16.2 in states that either discouraged cross-border transport, remained neutral regarding cross-border transport, or left the matter of cross-border transport to local discretion.

Similarly, for census block groups closest to an out-of-state levels I–III trauma center, the average rate of motor vehicle fatalities per 100 000 was 16.2 in states that approved of cross-border transport and 17.5 in states classified under the remaining categories.

Figures 1 and 2 show the stratification of drive time distance between in-state and out-of-state trauma centers across US census block groups. Of the 18 499 census block groups in which the nearest level I or II trauma center was out-of-state, 7463 (40.3%) census block groups had a drive time difference <5 min; 3716 (20.1%) census block groups had a drive time difference between 5 and 15 min; 3124 (16.9%) census block groups had a drive time difference between 15 and 30 min; 2907 (15.7%) census block groups had a drive time difference between 30 and 60 min; and 1289 (6.9%) census block groups had a drive time difference >60 min.

Of the 13 690 census block groups in which the nearest level I, II, or III trauma center was out-of-state, 6151 (44.9%) census block groups had a drive time difference <5 min; 3703 (27.0%) census block groups had a drive time difference between 5 and 15 min; 1776 (12.9%) census block groups had a drive time difference between 15 and 30 min; 1768 (12.9%) census block groups had a drive time difference between 30 and 60 min; and 292 (2.1%) census block groups had a drive time difference >60 min.

Of the 48 contiguous states, 30 encourage cross-border transport, 2 discourage it, 12 are neutral, and 4 leave it to local discretion. Online supplemental table 1 shows the cross-border policy status in all contiguous US states. Figure 3 classifies states by cross-border EMS transport policy.

For US census block groups closest to a level I–II out-of-state trauma center, 4729 census block groups are in states with policies that either discourage cross-border transport, remain neutral regarding cross-border transport, or leave the matter of cross-border transport to local discretion, affecting approximately 6 074 610 US residents. For US census block groups closest to a level I–III out-of-state trauma center, 4709 census block groups are in states with policies that either discourage cross-border transport, remain neutral regarding cross-border transport, or leave the matter of cross-border transport to local discretion, affecting approximately 4 712 031 US residents.

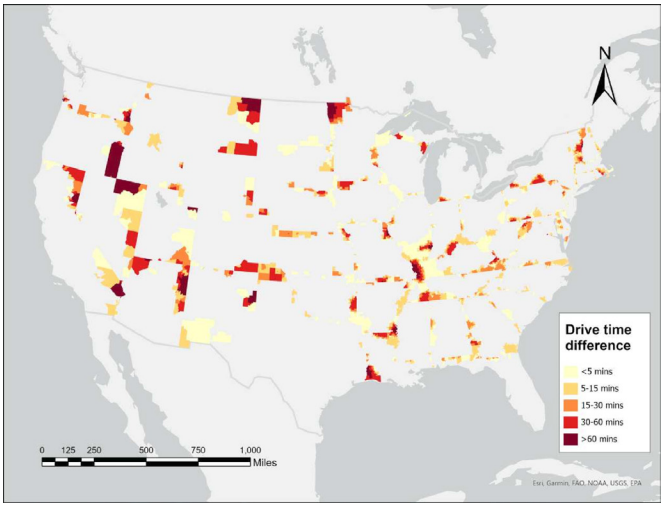

Figure 2 US census block groups classified by drive time difference between nearest in-state and out-of-state levels I–III trauma center.

DISCUSSION

Longer prehospital time is associated with poorer patient outcomes and increased mortality after serious injury.[4 9] In a state-based EMS and trauma system, we found that individuals

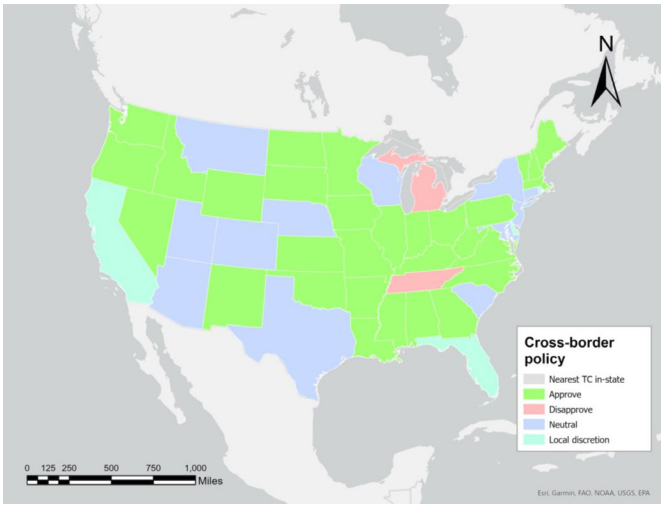

Figure 3 US states categorized by policy-state on cross-border transport. TC, trauma center.

injured in at least 5% of US census block groups live closest to out-of-state trauma care and may benefit from enhanced access to care. EMS and prehospital injury response continues to be coordinated at local and/or state levels and typically offers little guidance on the role or viability of cross-border transport in trauma care.[10]

While the transport of severely injured patients to non-designated or lower-level designated trauma centers may be necessary in some instances, it at times delays definitive care.[11 12]

Our work underscores that the lack of clarity regarding cross-border transport is suboptimal. Approximately 22 million US residents live closer to a level I or II trauma center in an adjacent state rather than one in their own state. Similarly, approximately 16 million US residents live closer to a level I, II, or III trauma center in an adjacent state rather than one in their own state. In the event of injury, a significant proportion of the US population reside in areas that may not receive the most efficient or timely prehospital care due to unclear guidance from governing bodies.

Access to designated trauma centers, which is the gold standard, has improved over time. As of 2019, 90% of US residents lived within 1 hour of a designated level I or II trauma center, representing a 15% increase from 2013.[13] While this is important in facilitating more timely access to definitive hospital care, geographic differences and inequities in access to care continue to persist. Hospitals may seek and receive trauma center designation for a range of reasons. The American College of Surgeons developed the Needs-Based Assessment of Trauma Systems (NBATS) to provide need-based recommendations for trauma center designation, taking into account geography, injury incidence and severity, transport time, and existing resources.[14] While NBATS demonstrates need for additional trauma centers throughout the USA, it has some limitations.[15] For example, it excludes prehospital deaths in its assessment of a given region's trauma patient volume[15]—an oversight that could inaccurately portray the existing needs as it relates to trauma care. This further underscores that the existing approach to trauma center designation and distribution likely contributes to the existing fragmented nature of the US trauma system at large.

Of those nearest to an out-of-state trauma center, the differential distance between the nearest and second-nearest trauma center is <5 min for most affected census block groups. While these distances may seem negligible, even the slightest variation in prehospital transit distance can worsen patient outcomes.[16] For example, in Chicago—where there are seven Illinois-verified level 1 adult trauma centers—gunshot wound patients shot more than a mere five miles from an appropriate trauma center had an increased risk of mortality.[17] In this context, longer prehospital distances are doubly concerning. In our work, 6.9% of census block groups closest to an out-of-state level I or II trauma center and 2.1% of census block groups closest to an out-of-state level I, II, or III trauma center have a differential distance between the nearest and second-nearest trauma center that is >60 min. This is a notable gap and contributes to significant additional prehospital transit time.

In census block groups closest to an out-of-state level I or II trauma center, there were 3640 (9.4%) motor vehicle fatalities. In census block groups closest to an out-of-state level I, II, or III trauma center, there were 2724 (7.1%) motor vehicle fatalities. We cannot directly evaluate the counterfactual—what would have happened if closer trauma centers were available, or whether state borders impeded care. However, states and regions with limitations in access to care carry a greater burden of prehospital deaths.[18] It is evident that injury is prevalent in affected census block groups. It is therefore imperative that states home to affected census block groups and/or those that lack clarity on the role of cross-border transport find ways to offer explicit guidance so that opportunities to reduce burden of injury and improve care are not lost.

Interventions to build such opportunities are critical. While a national trauma system would ease existing ambiguity in the long-term, current efforts should focus on improving trauma center designation. Strategies that emphasize a needs-based approach to trauma center allocation by balancing both population needs, and geographic constraints can mend existing lapses in access to care.

More granularly, states have a valuable opportunity to innovate as it relates to cross-border trauma care. Our work indicates that there are areas and patient populations that are underserved in their access to expedient and appropriate trauma care. By engaging payer networks, EMS agencies, trauma systems, and federal, state, and local governing bodies, there is room for state-to-state collaboration in assessing synergies and needs between respective trauma systems and implementing solutions to improve care. In addition, there is variety in patient insurance status and coverage. For those who are uninsured or are on private insurance, there is greater risk of financial toxicity when receiving care from out-of-network providers, regardless of whether they are receiving care at an in-network or out-of-network healthcare center.[19] In the context of traumatically injured patients, these determinants should be further evaluated and optimized to better protect patients from financial toxicity and potential sequalae like depression, post-traumatic stress disorder, and lower health-related quality of life.[20]

Limitations

This study has several limitations. Official state policies on cross-border transport may not reflect real-life practice or patient preferences.

We are not able to assess what form of transport would be most likely to be used in the various census block groups we identify. While drive time distances are considered a reliable proxy for prehospital transit distance, such distances may not provide an accurate assessment of prehospital transport. Ground and air transport are subject to several fluctuating variables, including ground or air traffic patterns, which can influence prehospital

transit time. Hence, our measures may yield more conservative estimates than those estimated via alternative methods.

Although the available road network dataset was robust, it may not fully reflect smaller roads or routes that may offer more expedient transit. In addition, since transit is influenced by several variables, ArcGIS network analysis may skew towards lower drive times. Moreover, this bias may be associated with the distance of block group centroids from the road network. We aimed to minimize the effect of this potential bias by using population-weighted block group centroids in our analysis.

Lastly, while FARS provides important annual data regarding fatal injuries suffered in motor vehicle traffic crashes, it is not comprehensive, or population-based. FARS captures collisions in which there is at least one fatality within 30 days of the event but does not record geographic data. However, no other datasets that are population-based or include geographic data (eg, NEMSIS [The National Emergency Medical Services Information System]) were readily available so the use of FARS was necessary for our study.

CONCLUSION

This study demonstrates that 22 million US residents live closer to a level I or II trauma center in an adjacent state and 16 million US residents live closer to a level I, II, or III trauma center in an adjacent state. Cross-border prehospital transport of injured patients has the potential to expedite access to care at least 5% of US census block groups. While few state EMS protocols explicitly discourage this practice, more robust policy guidance could reduce delays and bridge gaps in care.

Contributors Conception and design: EK, SK; acquisition of data: EK, SK, JS; analysis and interpretation of data: EK, SK, JS; drafting the article: EK, SK; critically revising the article: EK, SK; reviewed submitted version of manuscript: EK, SK, JS, DGB, ETD, DNH, PMR. All authors reviewed the results and approved the final version of the manuscript. Guarantor: EJK.

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