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Closing the gap: Improving access to trauma care in New Mexico (2007–2017) ☆

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ABSTRACT

Background: Trauma is a major cause of death and disability in the United States, and significant disparities exist in access to care, especially in non-urban settings. From 2007 to 2017 New Mexico expanded its trauma system by focusing on building capacity at the hospital level.
Methods: We conducted a geospatial analysis at the census block level of access to a trauma center in New Mexico within 1 h by ground or air transportation for the years 2007 and 2017. We then examined the characteristics of the population with access to care. A multiple logistic regression model assessed for remaining disparities in access to trauma centers in 2017.
Results: The proportion of the population in New Mexico with access to a trauma center within 1 h increased from 73.8% in 2007 to 94.8% in 2017. The largest increases in access to trauma care within 1 h were found among American Indian/Alaska Native populations (AI/AN) (35.2%) and people living in suburban areas (62.9%). In 2017, the most rural communities (aOR 58.0), communities on an AI/AN reservation (aOR 25.6), communities with a high proportion of Hispanic/Latino persons (aOR 8.4), and a high proportion of elderly persons (aOR 3.2) were more likely to lack access to a trauma center within 1 h.
Conclusion: The New Mexico trauma system expansion significantly increased access to trauma care within 1 h for most of New Mexico, but some notable disparities remain. Barriers persist for very rural parts of the state and for its sizable American Indian community.

1. Background

Trauma is a leading cause of death in the United States, and there are consistent disparities in outcomes for people who live in rural and impoverished communities, for people of color, and elderly populations [1-8]. Dedicated trauma centers have been shown to improve mortality, but many vulnerable communities remain without adequate access to dedicated trauma care [9-13]. Additionally, trauma centers closures nationally may worsen existing disparities, especially in rural communities [10]. The "golden hour" for trauma care is widely used in the literature as a marker of trauma access for communities at a state and national level [9,10,14].

In the mid 2000s, New Mexico had the highest mortality rate for unintentional injuries in the United States [15]. While much of the population in New Mexico is clustered in a small number of urban and suburban areas, New Mexico's populace also includes high numbers of two subpopulations that experience some of the highest disparities in trauma care: rural populations and American Indians/Alaskan Natives (AI/AN) [4,8]. Emergency and acute care for the AI/AN community faces significant barriers, and improving access to trauma care for rural populations has been similarly challenging [16].

Recognizing the scope of these challenges, New Mexico dedicated specific funding in 2007 through the Trauma System Funding Authority for the expansion of trauma centers in the state in an effort to address these health disparities [17]. As a result of this funding, the New Mexico trauma system expanded from three designated trauma centers in 2007, to thirteen designated trauma cen-

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ters in 2017. The trauma center expansion was primarily through state-level certification of level III and IV trauma centers. New Mexico level III and IV trauma centers have formal trauma policies and procedures in place, a quality improvement program, injury prevention initiatives, and transfer agreements and protocols with level I or II trauma centers that provide a higher level of care. This model of an inclusive trauma system, where a large proportion of acute care hospitals participate, has been shown to improve mortality, and may reduce cost and the need for interfacility transfer [18-21].

1.1. Purpose

While the dedicated expansion of trauma centers in New Mexico between 2007 and 2017 is known to have increased the number of trauma centers active in New Mexico, it is not known how the expansion of these trauma centers translates into improved access to trauma care at the population level. Here, we hypothesize that the expansion resulted in significantly increased access to trauma care in general for residents of New Mexico, but that disparities in access still exist in rural and AI/AN communities.

2. Methods

2.1. Study design and population

We performed a retrospective cross-sectional analysis comparing access to dedicated trauma care for the population of New Mexico between 2007 and 2017. Access to trauma centers was analyzed at the level of the census block, the most granular subunit of census data available, which consist of an average of 39 people per block in New Mexico. Socio-economic and demographic data is only available at the block group level, which consist of an average of 1437 people per block group in New Mexico.

Our primary outcome is the proportion of the population of New Mexico with access to a trauma center in 2007 compared to 2017, and was conducted at the block level for spatial analysis. For secondary outcomes examining socio-economic and demographic trends in trauma center access, we created a population weighted analysis at the block group level using our primary spatial analysis at the block level. This study was deemed not human subjects research by the institutional review board at the University of Southern California.

2.2. Geospatial data acquisition

Data on the location and shape of census blocks in New Mexico were obtained from the IPUMS National Historical Geographic Information System server, along with block level population from the 2010 United States Census [22]. For the purposes of distance calculations, the population of a census block was assumed to reside at the geographic centroid of that block. Trauma centers were identified using the Trauma Information Exchange Program, and cross referenced with the New Mexico Department of Health State Trauma Coordinator to verify trauma designation status at the end of 2017 [23,24]. We included all trauma centers located in New Mexico, as well as two centers in Texas that serve New Mexico according to the New Mexico Department of Health Trauma Care Program. Trauma centers were geocoded using the Google Geocoding API using the "RCurl" and "RJSONIO" software packages in the "R" programming language, following the methods of Bently [25]. Spatial transformations between coordinate systems was performed using the "SP" spatial analysis package in R. Maps were created using QGIS software.

2.3. Demographic information

The American Community Survey is conducted by the U.S. Census Bureau that creates population estimates of racial, economic, and social characteristics at the block group level. We used the most recent 5-year estimates from 2016, to examine demographic characteristics and disparities in access to care at the population level.

We used the Area Deprivation Index Score which was derived from the American Community Survey in order to incorporate a standardized scale for social determinants of health and social vulnerability. The Area Deprivation Index includes the domains of income, education, employment, and housing quality, and divides each state into deciles of socioeconomic disadvantage with 1 being the least disadvantaged community and 10 being the most disadvantaged [26,27].

Finally, we defined urbanicity and rurality using the 2013 U.S. Department of Agriculture Rural-Urban Continuum codes (RUCC) by county [28]; the continuum defines counties from the most densely populated as a 0 and the least densely populated as a 9. Similar to prior work in trauma access, we define rural block groups as those with a RUCC code of 9; suburbs, as block groups with RUCC codes 4–7; and minor cities as block groups with RUCC codes 2 and 3 [9]. There are no counties with RUCC codes of 0 or 1 in New Mexico, which would be typically defined as a "major city", and there are no counties in New Mexico with a RUCC code of 8.

2.4. Distance and driving time calculations

Distances between census blocks and trauma hospitals were approximated as straight-line distances between the centroid of each census block and the trauma hospital using the Vincenty Ellipsoid method [29]. To estimate ground transport times between centroids and hospitals, we calculated the single direction drive time starting at each block centroid and ending at the closest trauma hospital using the Google Distance Matrix API which estimates actual drive times along the network of roads rather than simply converting straight line distances. We then followed the example of Barnas et al. and defined the total ground transport time as a multiple of the single direction drive time plus an on scene time [14]. To account for differences in transportation in rural and urban areas, we adjusted the drive time multiple and on-scene time estimates by rural urban and rural designation as in Branas et al. [14] Census blocks were defined as having access by ground transportation if their total ground transport time to the closest trauma hospital was less than or equal to 60 min.

2.5. Flight time calculations

Transport time by helicopter was defined as the sum of flight time from helicopter base to block centroid, on scene time, and flight time from block centroid to the closest trauma hospital. Locations of helicopter bases in 2007 and 2017, as well as information on the average flight speed of rescue helicopters in New Mexico (4.1 m/s), were obtained from the Atlas and Database of Air Medical Services (ADAMS) of the Association of Air Medical Services. Component flight times were calculated using the Vincenty Ellipsoid, and on scene time was set at 21.6 min [14]. Census blocks were defined as having access by air transportation if their total helicopter transport time to the closest trauma hospital was less than or equal to 60 min.

2.6. Statistical analyses

Census blocks were defined as having access to dedicated trauma care if the centroid of the census block was 60 min by either car or helicopter from the closest trauma center. We then created a population weighted estimate for block groups using

our block level analysis, and defined a block group with access to care if more than 80% of the population within the block group had access to a trauma center within 1 h. For the analysis at the block group level, we compared the proportion of the population with access to a trauma center within 1 h in 2007 to 2017. Statistical analysis was performed in STATA (version 13.1).

To assess for remaining disparities in access to a trauma center after implementation, we performed a multivariable logistic regression model with predictive margins to estimate access to trauma care within 1 h in 2017 for vulnerable populations (predictor variables). We chose predictor variables based on prior trauma disparities research, including age, gender, race/ethnicity, payor, urban/rural status, and communities on American Indian reservations. We additionally utilized the Area Deprivation Index as a surrogate for social determinants of health not otherwise captured in our model. Similar to prior work with trauma center access disparities, we divided block groups by proportion of a given population to examine disparities in access to trauma centers [9,10]. Census tracks do not coincide with reservation boundaries, so we created a surrogate variable for block groups on AI/AN reservations if more than 75% of the population of the block group was AI/AN.

3. Results

3.1. Access to dedicated trauma care

Using the census block as the unit of geospatial analysis for our primary outcome, the trauma center expansion increased the proportion of the population in New Mexico with access to a trauma center within 1 h from 73.8% in 2007 to 94.8% in 2017 (difference in proportions 21.0%; 95% confidence interval [CI] 20.9% to 21.1%). Using a population weighted estimate for proportion of the population with access to a trauma center within 1 h at the block group level yielded nearly identical proportions, with 73.7% with access to a trauma center in 1 h in 2007 compared to 94.5% in 2017 (difference in proportions 20.8%; 95% CI 20.7% to 20.9%).

Table 1 shows the results of the analysis using our population weighted estimates at the block group level for people living in New Mexico who had access to a trauma center in 2007 compared to 2017. The largest increases in access to trauma care within 1 h were found in AI/AN (35.2%, 95% CI 35.0% to 35.4%), suburban areas (62.9%, 95% CI 62.8% to 63.0%), and the four highest deciles of vulnerable communities on the Area Deprivation Index scale (deciles 7 and 8: 28.3%, 95% CI 28.1% to 28.5%; and deciles 9 and 10: 33.2%, 95% CI 33.0% to 33.4%). Fig. 1 shows maps of census blocks with access to a trauma center within 1 h by air or ground transportation in New Mexico in 2007 and in 2017, as well as a population density map at the block level for reference. As seen in Fig. 1, while the trauma system expansion did increase access to trauma care, there are still areas where access to trauma care is limited in 2017, mainly in the more remote parts of the state. Fig. 2 shows the cumulative distribution of the population in New Mexico with access to a trauma center in 2007 and 2017.

3.2. Logistic regression

Because approximately 99% of the population of New Mexico that resides in urban areas had access to a trauma center both in

Table 1
Individuals with access to a trauma center within 1 h by flying or driving in New Mexico in 2007 compared to 2017.

	Total population[a]	Access to trauma center in 2007 N (%)	Access to trauma center in 2017 N (%)	Difference in proportions (95% CI)
Total	2,082,669	1,532,145 (73.7)	1,968,763 (94.5)	20.8 (20.7 to 20.9)
Age				
Age 0 to 10	267,468	197,676 (73.9)	264,266 (98.8)	24.9 (24.7 to 25.1)
Age 11 to 19	282,662	204,221 (72.2)	268,272 (94.9)	22.7 (22.5 to 22.9)
Age 20 to 29	289,801	216,326 (74.6)	277,946 (95.9)	21.3 (21.1 to 21.5)
Age 30 to 39	260,579	196,455 (75.4)	249,231 (95.6)	20.2 (20.0 to 20.4)
Age 40 to 49	244,346	184,085 (75.3)	230,749 (94.4)	19.1 (18.9 to 19.3)
Age 50 to 59	280,363	209,193 (74.6)	262,691 (93.7)	19.1 (18.9 to 19.3)
Age 60 to 69	239,044	174,549 (73.0)	222,085 (92.9)	19.9 (19.7 to 20.1)
Age 70 to 79	135,013	96,784 (71.7)	124,254 (92.0)	20.3 (20.0 to 20.6)
Age over 80	74,393	52,856 (71.0)	69,269 (93.1)	22.1 (21.7 to 22.5)
Gender				
Female	1,051,229	776,618 (73.9)	995,174 (94.7)	20.8 (20.7 to 20.9)
Male	1,031,440	755,527 (73.2)	973,589 (94.4)	21.2 (21.1 to 21.3)
Race/ethnicity				
Hispanic/Latino	995,831	754,275 (75.7)	934,069 (93.8)	18.1 (18.0 to 18.2)
Non-Hispanic White	534,805	379,667 (71.0)	519,389 (97.1)	26.1 (26.0 to 26.2)
AI/AN	193,295	113,642 (58.8)	181,698 (94.0)	35.2 (35.0 to 35.4)
Black	41,957	32,248 (76.9)	40,820 (97.3)	20.4 (20.0 to 20.8)
Asian	29,168	25,699 (88.1)	28,511 (97.7)	9.6 (9.2 to 10.0)
Hawaiian/Pacific Islander	1340	1026 (76.6)	1269 (94.7)	18.1 (15.5 to 20.7)
Rurality[b], % (95% CI)				
RUCC 2–3	1,388,168	1,372,833 (98.9)	1,383,410 (99.7)	0.8 (0.8 to 0.8)
RUCC 4–7	674,991	157,380 (23.3)	581,658 (86.2)	62.9 (62.8 to 63.0)
RUCC 9	19,510	1932 (9.9)	3695 (18.9)	9.0 (8.3 to 9.7)
Insurance				
Private	1,161,277	881,532 (75.9)	1,101,775 (94.9)	19.0 (18.9 to 19.1)
Medicaid	492,265	340,164 (73.2)	460,819 (93.6)	20.4 (20.3 to 20.5)
Uninsured	294,187	208,096 (70.7)	278,820 (94.8)	24.1 (23.9 to 24.3)
Medicare	111,497	81,209 (72.8)	102,322 (91.8)	19.0 (18.7 to 19.3)
Area Deprivation Index Score				
Quintile 1	461,560	423,586 (91.8)	453,064 (98.2)	6.4 (6.3 to 6.5)
Quintile 2	428,357	331,682 (77.4)	407,490 (95.1)	17.7 (17.6 to 17.8)
Quintile 3	427,842	315,939 (73.8)	397,703 (93.0)	19.2 (19.0 to 19.4)
Quintile 4	385,853	247,243 (64.0)	355,978 (92.3)	28.3 (28.1 to 28.5)
Quintile 5	379,057	213,695 (60.3)	354,528 (93.5)	33.2 (33.0 to 33.4)

[a] From population weighted analysis of block groups using the block level spatial analysis.
[b] New Mexico does not have areas defined with a RUCC of 0, 1, or 8.

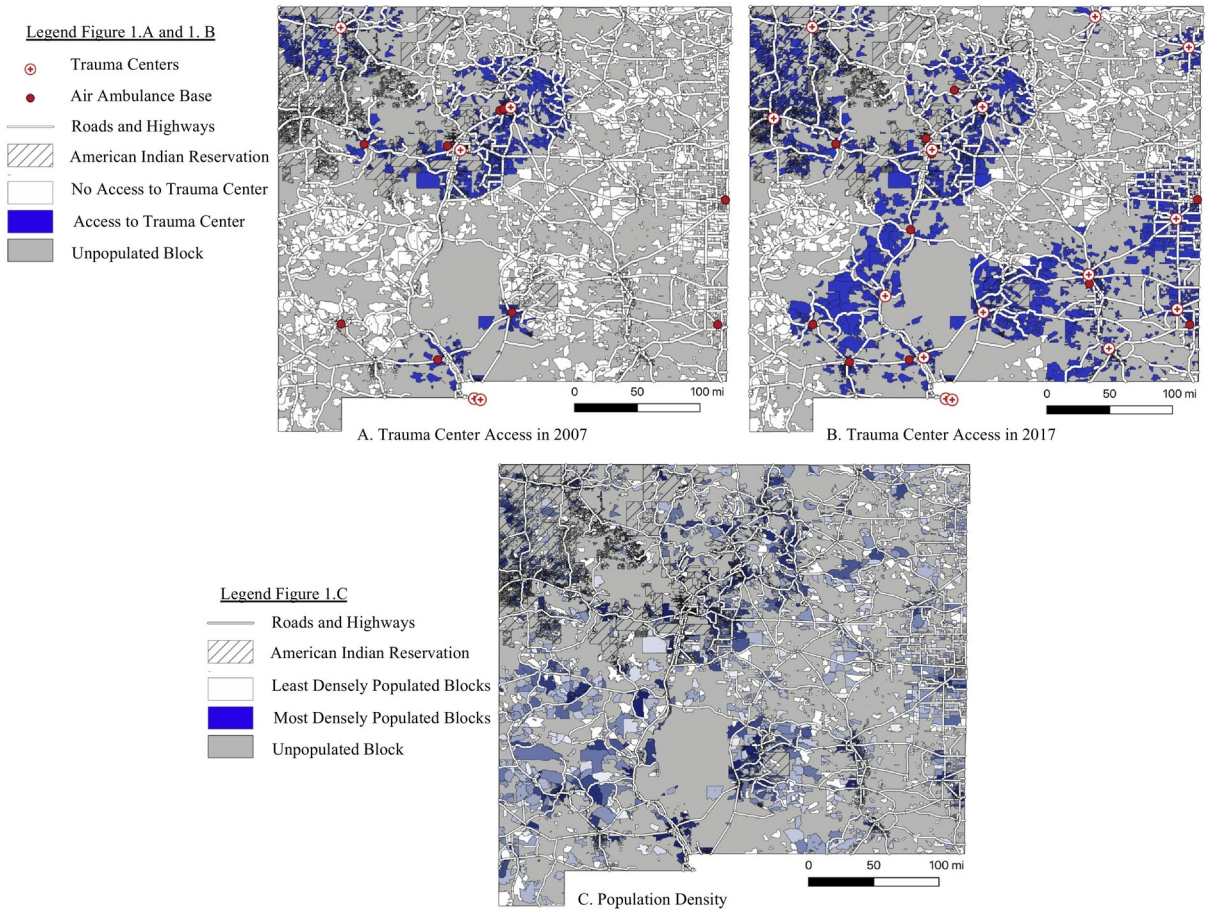

Fig. 1. Figure 1.A. shows the block level access to a trauma center in 2007. Figure 1.B. shows the block level access to a trauma center in 2017. Figure 1.C. shows the population density of blocks in New Mexico, with white being the least densely populated block and the darkest blue being the most densely populated.

2007 and 2017, we performed the regression analysis assessing for disparities in access to a trauma center only for rural and suburban communities (Table 2). We found that in communities with the highest proportion of the population over 60 years (adjusted odds ratio [aOR] 3.2, 95% CI 1.2 to 8.4), communities with the two highest thirds proportion Hispanic/Latino population (aOR 3.7, 95% CI 1.5 to 9.4; aOR 8.4, 95% CI 3.2 to 21.8), communities with the highest proportion of AI/AN (defined as on-reservation) (aOR 25.6, 95% CI 5.2 to 126.5), and communities in the two most rural counties (aOR 5.3, 95% CI 2.1 to 13.8; aOR 58.0, 95% CI 11.8 to 284.2 respectively), had the highest odds of lacking access to a trauma center within 1 h.

4. Limitations

In modeling population level access to dedicated trauma centers, we made certain assumptions that might not conform to actual access patterns, especially in rural areas. First, our models assumed the most efficient dispatch of ambulances, with a ground ambulance dispatched from the nearest hospital to the trauma scene and then back to the nearest trauma center, which might not be the actual protocol at all facilities. Second, since there are only a set number of ambulances, especially in rural areas, if a particular ambulance is already on a call (trauma related or otherwise) then the closest responding unit might require a farther travel distance to reach the trauma scene. These assumptions are consistent with prior work in modeling trauma center access, but further work should examine the effect of variable rural EMS dispatch times and staffing practices on access to timely prehospital and hospital-based care. Third, Tribal EMS agencies will likely have increased dispatch and transport times even compared to EMS agencies in other rural environments due to poor road conditions and lack of exact addresses on many parts of AI/AN reservations, which we were unable to quantify or account for in our analysis.

Fourth, New Mexico EMS protocol for air ambulances utilization is more complicated than our current model was able to incorporate. For example, activation of an air ambulance is often, but not always, sequential rather than simultaneous with activation of ground transport. In many cases, a ground ambulance is dispatched to evaluate the trauma scene and the ground ambulance crew in conjunction with an EMS base station makes the determination to launch and air ambulance. This protocol would result in a longer than modeled transport time via air ambulance. Similarly, patients will at times bypass a level IV trauma center in New Mexico by air ambulance in certain situations, a practice less often utilized by ground ambulances in remote areas due to significantly longer transport times. Finally, while using Google drive times to estimate distances is likely more accurate that estimations based on straight line distances, it does not account for all factors a ground transport would encounter such as an ambulance with lights and sirens or traffic patterns at different times of day.

5. Discussion

Overall the New Mexico trauma system expansion supported by the Trauma System Funding Authority resulted in the development

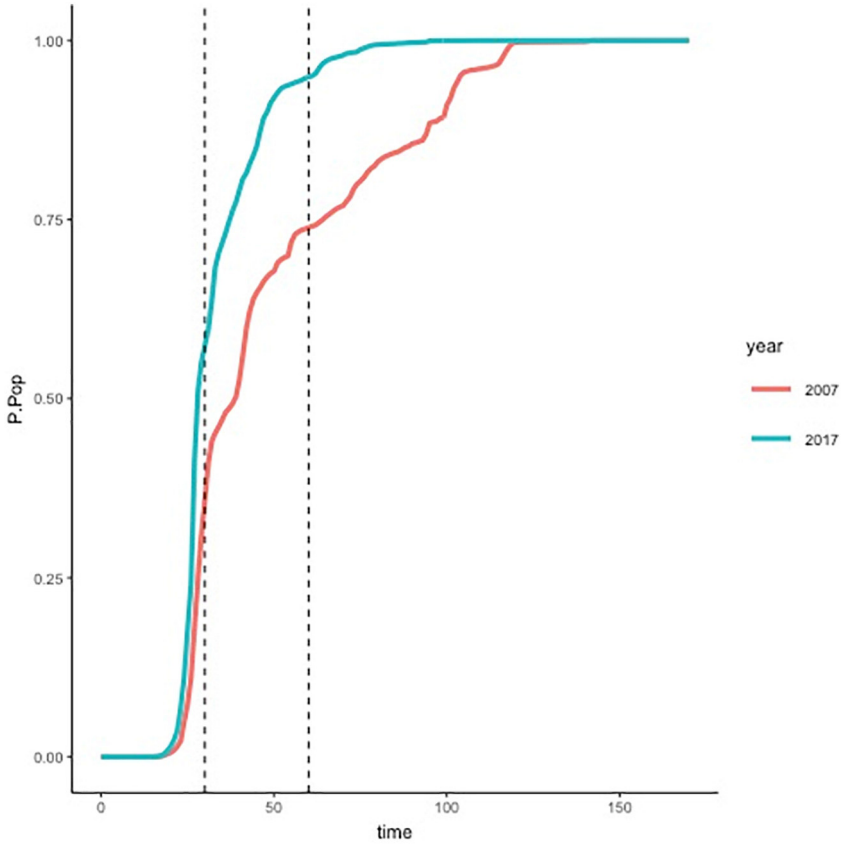

Fig. 2. Distribution of New Mexico population with access to a trauma center by time.Plot of the proportion of the population of New Mexico with access to a trauma center over time (minutes). The x-axis shows travel times to a designated trauma center in minutes, and the y-axis shows the corresponding cumulative percent of population with access within as many minutes (by driving or helicopter). The red curve shows the cumulative distribution in 2007 and the blue curve shows the cumulative distribution in 2017. Dashed lines show time cutoffs of 30 and 60 min. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

of an inclusive trauma system, with an estimated 94.8% of New Mexicans that live in communities with access to a trauma center within 1 h in 2017. This increase of more than 20% from 2007 was largely due to significant increases in access in suburban parts of the state. The ten year investment in trauma centers by the state increased access to trauma care for nearly every subpopulation we examined, with the exception of urban areas where access was already nearly universal in 2007.

Our results align well with previous work by Carr et al., who performed a national analysis of access in 2010 to Level I or II trauma centers at the census block group level and also found low rates of access in New Mexico in a similar geospatial pattern as well as lower access in more rural areas [9]. Branas et al. also found similar results at the census block group level in 2005 in terms of both geospatial patterns of access in New Mexico and decreased access in general in rural areas [14]. We extend these analyses in several key directions. First, we examine a natural experiment in the comparison of access in New Mexico before and after the institution of a given policy which allows us to examine changes in access in a highly rural environment. Second, we utilize census blocks (with an average of 39 people) for our spatial analysis which are an order of magnitude more granular than the block groups (with an average of 1437 people) used previously. To our knowledge, this is the highest granularity spatial analysis of access to trauma care that has been performed. Finally, we used multivariable regression analysis to highlight continuing disparities in the trauma care system, particularly in areas which are more rural and have high proportions of the population who are AI/AN, Hispanic/Latino, as well as elderly patients.

While the trauma center expansion was largely successful in increasing access to dedicated trauma care for most of New Mexico, we did find some remaining disparities in access to care for some communities in the state in 2017. While much of the focus on access to trauma care has been on improving care in rural areas, our analysis found disparities in several communities despite taking into account a variety of factors including rural residence. We identified communities with the highest proportion of elderly people, Hispanic/Latinos, American Indian/Alaska Natives, and the most rural areas all were independently associated with not having access to a trauma center within 1 h in 2017. These are important populations to focus on, as the elderly, people of color, and people living in rural areas all have disparities in mortality from trauma as well [1-6]. A strength of our analysis of remaining disparities 2017 is that we considered factors beyond demographics and incorporated social determinants of health using the Area Deprivation Index. The Area Deprivation Index ranks each block group in a state by social vulnerability, incorporating metrics collected on the American Community Survey such as income, education, and employment [26]. Our analysis did not find that social vulnerability was independently associated with disparities in access to trauma centers in 2017.

Compared to patients in urban environments, rural trauma patients are more likely to die in the prehospital setting [4]. Elderly patients and people of color have also been shown to have disproportionately high mortality from trauma [5]. While access did improve for these populations during the study period, it is not clear that access to trauma centers alone will improve disparities in mortality from trauma for these communities. Prior work on

Table 2
Likelihood that a suburban or rural community remains without access to a trauma center within 1 h in New Mexico in 2017.

Characteristics	Odds ratio, no access in 2017	95% confidence interval	Predictive margin	95% confidence interval
Age over 60				
Lowest 1/3	Ref	Ref	0.12	0.05 to 0.18
Middle 1/3	1.2	0.5 to 3.1	0.13	0.08 to 0.17
Highest 1/3	3.2	1.2 to 8.4	0.23	0.18 to 0.28
Female population				
Lowest 1/3	Ref	Ref	0.17	0.13 to 0.22
Middle 1/3	1.1	0.5 to 2.1	0.18	0.14 to 0.23
Highest 1/3	0.9	0.4 to 1.7	0.16	0.12 to 0.21
Hispanic/Latino population				
Lowest 1/3	Ref	Ref	0.08	0.05 to 0.12
Middle 1/3	3.7	1.5 to 9.4	0.19	0.13 to 0.24
Highest 1/3	8.4	3.2 to 21.8	0.28	0.21 to 0.34
Black population				
Lowest 1/3	Ref	Ref	0.18	0.14 to 0.21
Middle 1/3	0.7	0.3 to 1.4	0.14	0.08 to 0.19
Highest 1/3	1.3	0.6 to 2.7	0.20	0.14 to 0.26
Reservation				
Off reservation	Ref	Ref	0.16	0.14 to 0.19
On reservation	25.6	5.2 to 126.5	0.54	0.35 to 0.72
Rurality (RUCC)*				
RUCC 4 (most suburban)	Ref	Ref	0.11	0.04 to 0.18
RUCC 5	0.2	0.1 to 0.7	0.02	0.00 to 0.05
RUCC 6	2.5	0.95 to 6.7	0.22	0.14 to 0.30
RUCC 7	5.3	2.1 to 13.8	0.34	0.25 to 0.44
RUCC 8	–	–	–	–
RUCC 9 (most rural)	58.0	11.8 to 284.2	0.79	0.60 to 0.98
Medicare				
Lowest 1/3	Ref	Ref	0.13	0.07 to 0.19
Middle 1/3	1.7	0.7 to 4.1	0.18	0.13 to 0.23
Highest 1/3	1.9	0.8 to 4.5	0.19	0.15 to 0.23
Medicaid				
Lowest 1/3	Ref	Ref	0.19	0.12 to 0.25
Middle 1/3	0.8	0.3 to 1.8	0.16	0.12 to 0.20
Highest 1/3	0.9	0.4 to 2.3	0.18	0.13 to 0.23
Uninsured				
Lowest 1/3	Ref	Ref	0.20	0.15 to 0.25
Middle 1/3	0.7	0.4 to 1.4	0.16	0.12 to 0.21
Highest 1/3	0.7	0.3 to 1.5	0.16	0.11 to 0.21
Area Deprivation Index				
Quintile 1	Ref	Ref	0.26	0.13 to 0.38
Quintile 2	0.6	0.2 to 2.0	0.20	0.12 to 0.27
Quintile 3	0.6	0.2 to 2.0	0.20	0.14 to 0.26
Quintile 4	0.3	0.1 to 1.2	0.14	0.10 to 0.19
Quintile 5	0.4	0.1 to 1.4	0.16	0.10 to 0.21

The distribution of AI/AN population was bimodal, and a block group was defined as on a reservation if the AI/AN population was greater than 75% based on visualization of the data. Rurality was treated as a categorical variable using USDA RUCC codes. The Area Deprivation Index divides block groups into deciles, and for our analysis was grouped into quintiles. All other characteristics are divided into thirds by the proportion of the characteristic analyzed in a given community, with the 3rd tertile being the highest.

trauma system expansions have suggested that an inclusive trauma system design, one in which most acute care hospitals participate, improve patient outcomes and mortality [18-21], but future work should examine patient oriented outcomes for trauma patients served at level III and IV trauma centers. Future work focused on the community burden of trauma and barriers to accessing trauma care should also focus vulnerable rural populations in New Mexico. For critically injured patients coming from rural environments, transfer might be required to a level I or level II trauma center, which adds considerably to the total time required to access definitive care.

American Indian/Alaska Native citizens make up over 10% of the state's population, compared to just over 1% in the United States as a whole, and have significant disparities in mortality from accidental and intentional injuries [8,30]. While AI/ANs had the highest proportional increase in access to trauma centers from 2007 to 2017, resulting access was still lower than the rest of the state. We found that communities with the highest proportion of AI/ANs (defined as communities on reservations) had remaining disparities in access to trauma centers in 2017. Gallup Indian Medical Center is the only Indian Health Service or Tribal hospital that is also a designated trauma center in New Mexico, leaving some AI/AN communities living on reservations in New Mexico without a trauma center either nearby or within their medical system. While most reservations in the state are in rural areas, the fact that we find that reservations, even when controlling for rural residence, have disparities in care raises some concerning questions. The Indian Health Service is underfunded and understaffed when it comes to acute care services [31], and because the government is bound by treaty to provide healthcare for AI/ANs, any disparities in care are critical to address and are the responsibility of the federal government to support. Future work on access to care should also focus on rural IHS and Tribal EDs to identify the unique trauma burdens, barriers to care, and systems-level needs AI/AN communities face, especially for communities on reservations.

When considering specific vulnerabilities of rural population and the AI/AN population in New Mexico, it is also important to consider the sustainability of level III and IV trauma centers, which accounted for much of the improved access for these communities during the study period. Level III and IV trauma centers are integral to inclusive trauma systems, and even if a patient is transferred to a higher level of care, the stabilization services provided by level III

and IV trauma centers are critical to the trauma care infrastructure. Rural hospitals face significant financial barriers and the trend nationally of rural hospital closures is concerning. The trauma certification process requires investment at the hospital level for education, supplies, and staffing which is partially supported at this time by the Trauma System Funding Authority. This funding, however, is not indefinite and my not be sustainable in the long run. Additionally, level IV trauma centers are primarily focused on emergency department care (the presence of a general surgeon is "desired" but not "mandatory" for level IV designation in New Mexico), and staffing shortages among qualified emergency physicians in rural areas are significant. These staffing shortages are even more pronounced among IHS and tribal hospitals, making them even more vulnerable to funding and staffing shortages [16].

An alternative approach to addressing health disparities for rural trauma patients is in capacity building of the pre-hospital system. In one study in Northern California, a rural trauma program focusing on increasing the capacity of EMS teams showed an improvement in patient outcomes regardless of whether or not a patient was treated at a level III/IV trauma center or at another rural hospital [6]. It is likely that each state will face specific challenges, and in some cases it may make more sense to bypass a level III or IV trauma center with a highly trained prehospital team in favor of a level I or II trauma center. Importantly, prehospital providers in rural New Mexico are often EMTs and face transfer distances of hundreds of miles, many times on dirt roads of variable quality, and an incomplete address system in remote communities and on reservations. Given the constraints on Level III and IV trauma centers, future work on expanding access to trauma care should examine patterns of care for patients injured near level III and level IV trauma centers, as well as strategies aimed at increasing training and capacity of prehospital providers.

6. Conclusion

We found that between 2007 and 2017, the New Mexico trauma system expansion did significantly increase access to dedicated trauma care for people living in New Mexico. Despite this progress, we also found that barriers to trauma care remain for rural parts of the state, elderly communities, and for its sizable Hispanic/Latino and American Indian communities. Future trauma system efforts should focus on the best ways to improve access to care for these vulnerable communities, with a focus on quality of care and transfer patterns of level III and IV trauma centers.

References

[1] Greene WR, Oyetunji TA, Bowers U, Haider AH, Mellman TA, Cornwell EE, et al. Insurance status is a potent predictor of outcomes in both blunt and penetrating trauma. Am J Surg 2010;199(4):554–7. , https://doi.org/10.1016/j.amjsurg.2009.11.005.

[2] Haider, A. H., Chang, D. C., Efron, D. T., Haut, E. R., Crandall, M., & Cornwell, E. E. (2008). Race and insurance status as risk factors for trauma mortality, Arch Surg, 143(10), 945–949. https://doi.org/10.1001/archsurg.143.10.945

[3] Harris AR, Fisher GA, Thomas SH. Homicide as a medical outcome: racial disparity in deaths from assault in US level I and II trauma centers. J Trauma Acute Care Surg 2012;72(3):773–82. , https://doi.org/10.1097/TA.0b013e318226eb39.

[4] Jarman MP, Castillo RC, Carlini AR, Kodadek LM, Haider AH. Rural risk: geographic disparities in trauma mortality. Surgery 2016;160(6):1551–9. , https://doi.org/10.1016/j.surg.2016.06.020.

[5] Lehmann, R., Beekley, A., Casey, L., Salim, A., & Martin, M. (2009). The impact of advanced age on trauma triage decisions and outcomes: a statewide analysis. Am J Surg, 197(5), 571–4– discussion 574–5. https://doi.org/10.1016/j.amjsurg.2008.12.037

[6] Lipsky AM, Karsteadt LL, Gausche-Hill M, Hartmans S, Bongard FS, Cryer HG, et al. A comparison of rural versus urban trauma care. J Emerg Trauma Shock 2014;7(1):41–6. , https://doi.org/10.4103/0974-2700.125639.

[7] R.Y.J. Hsia and Y.C. Shen, Possible Geographical Barriers to Trauma Center Access for Vulnerable Patients in the United States. Arch Surg. 146(1)46. 10.1001/archsurg.2010.299

[8] Burwell S, McSwain RG, Frazier F, et al. Indian Health Service Trends in Indian Health 2014 Edition. Rockville MD: Indian Health Service; 2014.

[9] Carr BG, Bowman AJ, Wolff CS, Mullen MT, Holena DN, Branas CC, et al. Disparities in access to trauma care in the United States: a population-based analysis. Injury 2017;48(2):332–8. https://doi.org/10.1016/j.injury.2017.01.008.

[10] Hsia RYJ, Shen YC. Rising closures of hospital trauma centers disproportionately burden vulnerable populations. Health Aff 2011;30(10):1912–20. , https://doi.org/10.1377/hlthaff.2011.0510.

[11] MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, et al. A national evaluation of the effect of trauma-center care on mortality. N Engl J Med 2006;354(4):366–78. , https://doi.org/10.1056/NEJMsa052049.

[12] Newgard CD, Fu R, Bulger E, Hedges JR, Mann NC, Wright DA, et al. Evaluation of rural vs urban trauma patients served by 9-1-1 emergency medical services. JAMA Surg 2017;152(1):11. , https://doi.org/10.1001/jamasurg.2016.3329.

[13] Rogers, F. B., Shackford, S. R., Hoyt, D. B., Camp, L., Osler, T. M., Mackersie, R. C., & Davis, J. W. (1997). Trauma deaths in a mature urban vs rural trauma system. A comparison. Arch Surg, 132(4), 376–81– discussion 381–2.

[14] Branas CC, MacKenzie EJ, Williams JC, Schwab CW, Teter HM, Flanigan MC, et al. Access to trauma centers in the United States. Jama 2005;293(21):2626–33. , https://doi.org/10.1001/jama.293.21.2626.

[15] Centers for Disease Control and Prevention (CDC). State-specific unintentional-injury deaths—United States, 1999–2004. Morb Mortal Wkly Rep 2007;56(43):1137–40.

[16] Bernard K, Hasegawa K, Sullivan A, et al. A profile of Indian Health Service emergency departments. Ann Emerg Med 2017;69:705–10. , https://doi.org/10.1016/j.annemergmed.2016.11.031.

[17] New Mexico Trauma System Funding Strategy. New Mexico trauma system funding strategy, 1–55, 2017.

[18] Tinkoff, G. H., O'Connor, R. E., Alexander, E. L., & Jones, M. S. (2007). The Delaware trauma system: impact of level III trauma centers. J Trauma, 63(1), 121–6– discussion 126–7. https://doi.org/10.1097/TA.0b013e3180686548

[19] Tinkoff GH, Reed JF, Megargel R, Alexander EL, Murphy S, Jones MS. Delaware's inclusive trauma system: impact on mortality. J Trauma 2010;69(2):245–52. , https://doi.org/10.1097/TA.0b013e3181e493b9.

[20] Vanni AJ, Hotaling J, Hamlat C, Jurkovich GJ, Voelzke BB. Do inclusive trauma systems improve outcomes after renal trauma? J Trauma 2012;72(2):385–9. , https://doi.org/10.1097/TA.0b013e3182411c67.

[21] Galanis DJ, Steinemann S, Rosen L, Bronstein AC, Biffl W. Rural level III centers in an inclusive trauma system reduce the need for interfacility transfer. J Trauma Acute Care Surg 2018;85(4):747–51. , https://doi.org/10.1097/TA.0000000000002033.

[22] IPUMS, Manson S, Schroeder J, Van Riper D, Ruggles S. IPUMS National Historical Geographic Information System: Version 12.0 [Database]. Minneapolis: University of Minnesota; 2017. , http://doi.org/10.18128/D050.V12.0 [Accessed: 06/2018].

[23] Trauma information exchange Available at https://www.amtrauma.org/page/tiep [Accessed 6/2018].

[24] Email communication, New Mexico State Trauma Coordinator Michael Guinn, 6/4/2018.

[25] Bentley B. "Geocoding with Google in R" RPubs. 2017. Available; https://rpubs.com/blentley/geocoding Accessed 06/2018.

[26] Kind AJH, Buckingham WR. Making neighborhood-disadvantage metrics accessible - the neighborhood Atlas. N Engl J Med 2018;378(26):2456–8. , https://doi.org/10.1056/NEJMp1802313.

[27] Neighborhood Atlas Available at https://www.neighborhoodatlas.medicine.wisc.edu.

[28] United States Department of Agriculture. Rural urban continuum codes Available at https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/.

[29] Hijmans Robert J. geosphere: spherical trigonometry. R package version 1.5-5, https://CRAN.R-project.org/package=geosphere, ; 2016 [Accessed 06/2018].

[30] Sarche, M., Spicer, P. (2008). Poverty and Health Disparities for American Indian and Alaska Native Children. Annals of the New York Academy of Sciences, 1136(1), 126–136. https://doi.org/10.3102/00346543067003339

[31] Anderson ES, D'Andrea S. Emergency medicine and the Indian Health Service: overburdened and understaffed. Ann Emerg Med 2017;69:711–3. https://doi.org/10.1016/j.annemergmed.2017.03.065.