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Original Article

Pediatric Trauma Patterns and Prevention Strategies in West Texas: Implications for Emergency Medicine and Community Outreach

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Abstract

Background: Pediatric trauma is the leading cause of mortality among U.S. children and adolescents. Rural populations experience disproportionately high injury burden due to geographic isolation, prolonged transport times, and increased exposure to off-road vehicle (ORV) use. However, broad rural–urban classifications may obscure important regional variability. West Texas and Eastern New Mexico represent a unique catchment area with expansive rural zones, long transport distances, and significant reliance on regional trauma referral networks.

Objectives: The primary objective of this study was to characterize pediatric trauma patterns and Injury Severity Score (ISS) distribution among children presenting to a Level 1 trauma center serving West Texas and Eastern New Mexico. Secondary objectives included evaluating differences in mechanism of injury (MOI) between rural and urban populations, comparing injury severity across geographic classifications, and assessing predictors of ORV-related trauma.

Methods: This retrospective observational cohort study analyzed pediatric trauma registry data from University Medical Center (UMC) in Lubbock, Texas. Patients younger than 18 years evaluated for traumatic injury during the study period were included. Counties were categorized using Rural–Urban Continuum Codes (RUCC), with metropolitan counties defined as RUCC 1–3 and nonmetropolitan counties defined as RUCC 4–9. Additional regional stratification was performed using Regional Advisory Council (RAC) trauma service designations. Demographic variables, mechanism of injury, and Injury Severity Score were analyzed using descriptive statistics, chi-square analysis, and logistic regression.

Results: A total of 2,720 pediatric trauma patients were included. Injury severity distribution demonstrated a strong right-skewed pattern, with most injuries classified as mild (ISS 1–8). Rural and urban populations showed no statistically significant differences in overall mechanism of injury distribution or ISS categories. However, significant regional differences in trauma severity emerged when patients were stratified according to RAC region. ORV-related injuries demonstrated significant associations with specific RUCC categories, age, and sex. Compared to RUCC 2 counties, RUCC 6 counties demonstrated significantly higher odds of ORV injury after adjustment for demographic factors.

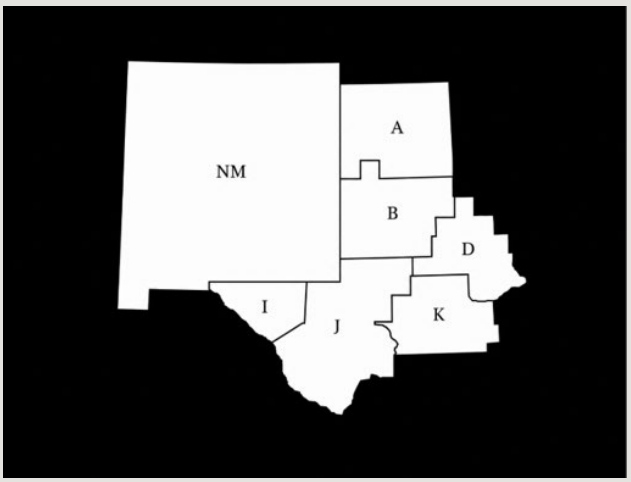
Conclusions: Broad rural–urban classifications may inadequately capture meaningful geographic variation in pediatric trauma patterns. Regional heterogeneity within West Texas suggests the need for localized prevention initiatives, improved EMS protocols, and targeted outreach programs emphasizing ORV safety and rapid trauma transport. Data-driven understanding of local epidemiology may improve both pediatric trauma prevention and acute trauma system performance.

Keywords: pediatric trauma, rural health, injury severity score, off-road vehicle injuries, emergency medicine, trauma systems, West Texas, Rural-Urban Continuum Codes

Introduction

Trauma remains the leading cause of death among pediatric patients in the United States and represents a substantial source of long-term disability, healthcare utilization, and socioeconomic burden[1,2]. According to the Centers for Disease Control and Prevention (CDC), unintentional injuries account for most pediatric mortality beyond infancy, with motor vehicle crashes, recreational injuries, falls, and firearm-related trauma contributing significantly to morbidity and mortality across childhood and adolescence[2–5]. Prior literature suggests that while pediatric trauma affects all geographic regions, rural communities consistently experience worse outcomes than urban populations[6–8]. The disparity between rural and urban trauma outcomes is multifactorial as rural communities frequently face reduced access to pediatric trauma centers, increased reliance on volunteer emergency medical services, limited availability of subspecialty surgical care, and prolonged transport times[8–12]. Additionally, rural children often experience increased exposure to high-risk mechanisms of injury associated with agricultural work, recreational vehicle use, livestock handling, and outdoor activities[7]. Prior studies have demonstrated that ATV and offroad vehicle (ORV)-related injuries occur at significantly higher rates among rural pediatric populations and are associated with severe orthopedic injuries, traumatic brain injury, and increased mortality[13–15]. Despite extensive national-level trauma research, broad geographic classifications may inadequately represent the variability that exists within individual trauma systems[16–18]. Rural designation alone may not meaningfully capture differences in injury epidemiology, EMS infrastructure, transportation barriers, or healthcare access[4,10–12,16,18]. Trauma mortality risk varies substantially across geographic regions and suggested that more granular spatial analyses are necessary to identify localized disparities and optimize trauma system performance[6,18]. West Texas and Eastern New Mexico provide a unique setting for pediatric trauma analysis as the region encompasses large geographic distances, multiple rural counties, agricultural economies, oilfield industries, and recreational ORV activity[7,9,13,14]. University Medical Center in Lubbock serves as the primary Level 1 trauma center for a broad catchment area extending across West Texas and portions of Eastern New Mexico (Figure 1). Given the diversity of regional populations and trauma mechanisms, a more detailed understanding of pediatric trauma patterns may provide valuable insight for emergency medicine physicians, trauma surgeons, EMS agencies, and public health organizations[6,7]. The present study sought to characterize pediatric trauma patterns within this regional trauma network. The primary objective was descriptive in nature and aimed to evaluate Injury Severity Score distribution and mechanism of injury trends among pediatric trauma patients. Secondary objectives included comparison of rural versus urban injury mechanisms, assessment of regional differences in trauma severity, and evaluation of predictive factors associated with ORV-related trauma.

Figure 1: UMC Service Area



Background

Pediatric trauma research has consistently demonstrated disparities between rural and urban populations[6–9]. Children living in rural communities are more likely to experience delayed access to definitive trauma care, increased prehospital transport times, and reduced availability of pediatric specialty services[7,9,11,19]. These limitations contribute to increased mortality rates even when injury severity appears similar between geographic groups[6,8,20,21]. Several mechanisms contribute to

increased pediatric trauma risk in rural environments. Recreational ORV use represents one of the most important contributors to severe pediatric injury in agricultural regions[13,14,22,23]. Children and adolescents in rural communities are frequently exposed to ATVs, utility terrain vehicles, dirt bikes, and other recreational vehicles beginning at young ages[13,14]. Limited helmet use, lack of formal safety training, and operation on unregulated terrain substantially increase the risk of traumatic brain injury, spinal trauma, thoracic injury, and extremity fractures[13,14,24–26]. In addition to recreational injury exposure, rural communities often face infrastructural limitations affecting trauma outcomes[7–9,11,19,21]. EMS response times may be prolonged by geographic distance, workforce shortages, or adverse weather conditions[27–33]. Helicopter transport availability may also vary significantly across rural regions[34,35]. Consequently, mortality differences may emerge even in the absence of major differences in injury severity distributions[6,8,9,21,36]. Existing literature has emphasized the importance of geographic specificity in trauma analysis[8,37–39]. Traditional metropolitan vs. non-metropolitan classifications may oversimplify trauma epidemiology by grouping together populations with substantially different risk profiles[8,21,38,39]. For example, a county classified as non-metropolitan may contain agricultural communities, oilfield regions, recreational tourism centers, or frontier populations with very different mechanisms of injury and healthcare access challenges[38,40,41]. The Rural–Urban Continuum Code system developed by the United States Department of Agriculture offers a more nuanced method for categorizing counties according to population size and proximity to metropolitan areas[6,40,42]. Combining RUCC classification with regional trauma service designations may provide greater insight into pediatric injury patterns than broad rural–urban grouping alone[6,19,38,43]. Understanding local epidemiology is particularly important for trauma prevention efforts[44]. Community outreach strategies targeting helmet use, ORV safety, and injury prevention education are most effective when tailored to the specific risks of a given population[14,44–46]. Similarly, trauma response systems benefit from data-driven resource allocation, EMS protocol development, and transport optimization[36,37,47,48]. This study contributes to the growing body of literature emphasizing localized pediatric trauma analysis and may inform future prevention strategies throughout West Texas and similar rural populations.

Table 1. Cohort characteristics and injury severity

Population Characteristics	*Overall (N = 2,720)*
Age, years	
Mean ± SD	7.04 +/- 4.56
Median (IQR)	7 (8)
Sex, n (%)	
Male	1691 (62.2)
Female	1029 (37.8)
Ethinicity, n (%)	
White	2420 (89.0)
Asian	12 (0.4)
Native American	5 (0.2)
Black	139 (5.1)
Other/Unknown	141 (5.3)
Geographic classification, n (%)	
Urban	1381 (50.8)
Rural	1339 (49.2)
ISS	
Mean ± SD	7.04
Median	4
ISS category, n (%)	
Mild (1–8)	1,850 (68.0)
Moderate (9–15)	594 (21.8)
Severe (16–24)	153 (5.6)
Very severe (25–75)	123 (4.5)

Methods

This study was conducted as a retrospective observational cohort analysis of pediatric trauma patients evaluated at University Medical Center (UMC) in Lubbock, Texas. UMC serves as a

Level 1 trauma center and receives referrals from a broad geographic region encompassing West Texas and Eastern New Mexico. The study was designed primarily as a descriptive investigation intended to generate hypotheses

regarding regional pediatric trauma patterns. The study met criteria for exemption from formal institutional review board review in accordance with 45 CFR 46.104(d)(4)(iii) as designated by the Texas Tech University Health Sciences Center Institutional Review Board for the Protection of Human Subjects. Pediatric patients younger than 18 years who were evaluated for traumatic injury and entered the institutional trauma registry during from January 1, 2016 to December 31, 2024 were eligible for inclusion. Patients represented both metropolitan and nonmetropolitan communities across West Texas and Eastern New Mexico. Patients with incomplete geographic information or missing Injury Severity Score data were excluded from subgroup analyses when appropriate; this accounted for 175 patients or 6% of the original raw data. County-level geographic classification was performed using Rural–Urban Continuum Codes (RUCC). Metropolitan counties were defined as RUCC categories 1 through 3, while nonmetropolitan counties were defined as RUCC categories 4 through 9. Additionally, patients were assigned as either Rural or Urban based on USDA classification of their county. Additional stratification was performed using Regional Advisory Council (RAC) trauma service regions. Patients were grouped according to Region A (Panhandle), Region B (Lubbock area), Region NM (New Mexico), and combined Regions D, I, J, and K (surrounding regions of Lubbock/Region B) as seen in Figure 1. Lower-volume regions were combined to improve statistical stability and reduce the influence of sparse subgroup counts. Demographic variables included age and sex. Injury-related variables included mechanism of injury and Injury Severity Score (ISS). ISS values were analyzed both continuously and categorically. Standard ISS categories were defined as follows: Mild injury: ISS 1–8, Moderate injury: ISS 9–14, Severe injury: ISS 16–24, Very severe injury: ISS 25–75.[49]

All statistical analyses were conducted using IBM SPSS Statistics (Version 31.0; IBM Corp., Armonk, NY). The primary descriptive outcome involved characterization of ISS distribution across the study population. Descriptive statistics were used to summarize demographic and injury characteristics. Continuous variables were evaluated for normality using histogram analysis and visual inspection. ISS demonstrated a non-normal right-skewed distribution, with a median score of 4 and mean score of 7, reflecting the predominance of lower-severity trauma. Chi-square analysis was used to compare mechanism of injury distributions and ISS severity categories between geographic groups. Logistic regression analysis was performed to evaluate predictors of ORV-related trauma while controlling for age and sex. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 2,720 pediatric trauma patients were included in the analysis. The study population represented a broad geographic catchment area spanning metropolitan and nonmetropolitan counties across western Texas as demonstrated in Table 1. Injury Severity Score (ISS) distribution demonstrated substantial right skew, reflecting predominance of lower-acuity trauma within the cohort. Mild injuries (ISS 1–8) accounted for 68.0% of all cases (n = 1,850), while moderate injuries (ISS 9–14) comprised 21.8% (n = 594). Severe injuries (ISS 16–24) represented 5.6% of cases (n = 153), and very severe injuries (ISS 25–75) accounted for 4.5% (n = 123). The median ISS was 4, whereas the mean ISS was 7.04, further demonstrating a non-normal distribution driven by a large proportion of mild injuries.

Chi-square analysis comparing mechanisms of injury between RUCC Rural and Urban populations demonstrated no statistically significant differences (χ^2 (df) = 19.5(13), p = 0.109) as demonstrated in Table 2. Mechanisms of injury were proportionally distributed across both geographic categories, with no major variation identified between rural and urban patient populations.

Comparison of ISS severity categories between Rural and Urban populations similarly

demonstrated no statistically significant differences (χ^2 (df) = 4.9(3), p = 0.183). Mild, moderate, severe, and very severe injuries occurred at proportionally comparable rates as seen in Table 2. These findings indicate that injury severity distributions were largely similar when analyzed using broad rural–urban geographic groupings.

When patients were stratified according to Regional Advisory Council (RAC) trauma service regions rather than broad rural–urban classification, significant variation in injury severity distribution emerged (χ^2 (df) = 58.9(9), p < 0.001). Region B, corresponding to the greater Lubbock metropolitan area, demonstrated a higher proportion of mild injuries relative to other regions. In contrast, Region A demonstrated a greater proportion of moderate injuries, while combining Regions D, I, J, and K demonstrated variable distributions of severe and very severe trauma. These findings are demonstrated in Table 3.

Logistic regression analysis was performed to evaluate predictors associated with ORV-related trauma as seen in Table 4. After adjustment for age and sex, overall RUCC classification was significantly associated with ORV-related injury patterns (Wald χ^2 (df) = 18.3(7), p = 0.011). Compared with RUCC 2 counties, patients from RUCC 6 counties demonstrated significantly greater odds of ORV-related injury (OR 2.5, p < 0.001), while RUCC 7 counties also demonstrated increased odds of ORV-related trauma (OR 2.5, p = 0.021). No statistically significant differences were identified for RUCC 3, 4, 5, 8, or 9 counties relative to the reference group. Female sex was independently associated with increased odds of ORV-related trauma compared with males (OR 1.6, p = 0.007). Increasing age was also associated with greater likelihood of ORV-related injury, with each additional year of age corresponding to an increase in odds of ORV trauma (OR 1.3, p < 0.001).

Discussion

The present study provides insight into pediatric trauma epidemiology within a large rural trauma catchment area encompassing West Texas and Eastern New Mexico. Several important findings emerged from the analysis. First, pediatric trauma patterns demonstrated greater similarity between metropolitan and nonmetropolitan populations than initially anticipated. Mechanism of injury distributions and Injury Severity Score categories did not significantly differ between broad rural and urban classifications. This finding contrasts with portions of the existing literature suggesting substantially higher trauma burden among rural pediatric populations[8,21,38]. However, it may reflect the limitations of broad geographic classification systems in capturing the complexity of regional trauma epidemiology[6,8,38–40]. The absence of significant rural–urban differences does not necessarily imply equivalent trauma risk across

Table 3. Injury Severity by RAC Region

ISS category	Region A	Region B	Regions D/I/J/K	New Mexico	Total
Mild (1–8)	231 (59.1%)	791 (73.9%)	479 (62.9%)	349 (70.4%)	1,850 (68.0%)
Moderate (9–14)	119 (30.4%)	185 (17.3%)	189 (24.8%)	101 (20.4%)	594 (21.8%)
Severe (16–24)	31 (7.9%)	41 (3.8%)	55 (7.2%)	26 (5.2%)	153 (5.6%)
Very severe (25–75)	10 (2.6%)	54 (5.0%)	39 (5.1%)	20 (4.0%)	123 (4.5%)
Total	**391 (100%)**	**1,071 (100%)**	**762 (100%)**	**496 (100%)**	**2,720 (100%)**

communities. Rather, it suggests that trauma exposure and injury patterns within West Texas may be influenced by localized cultural, economic, and environmental factors extending beyond conventional population-density metrics. Second, regional stratification using RAC designations revealed meaningful geographic variation in injury severity. This observation supports the hypothesis that localized analysis may identify disparities obscured by broader classifications. Regions characterized by greater transport distances, reduced EMS density, or increased recreational ORV exposure may experience distinct trauma patterns despite sharing similar RUCC categories.

The finding that Region B demonstrated a greater proportion of mild injuries may reflect proximity to tertiary care resources and lower thresholds for emergency evaluation within metropolitan settings[50]. Additionally, Region B, where study site is located, would not attract mild injuries from other surrounding areas as they can be well managed without a referral for greater resources. This claim is similarly reflected by Region A having significantly more Moderate injuries as they would require referral for a higher level of care. Conversely, rural regions may experience selective referral bias in which only higher-acuity patients are transferred to tertiary centers[9,51,52]. The ORV-specific findings are particularly important for pediatric injury prevention efforts. Although ORV-related injuries were anticipated to occur more frequently in rural regions, broad metropolitan versus nonmetropolitan categorization did not reveal substantial differences in overall mechanism patterns. ORV trauma continues to represent a major source of pediatric morbidity in rural environments[14,26,53]. Increased odds of ORV injury among RUCC 6 counties suggest that certain semi-rural or isolated communities may experience especially high exposure risk. Collectively, these findings suggest that ORV-related trauma patterns vary according to more granular geographic and demographic characteristics rather than broad rural–urban designation alone.

The association between increasing age and ORV injury is consistent with prior literature demonstrating elevated risk-taking behaviors among adolescents[14,54,55]. Older pediatric patients may engage in independent vehicle operation with limited supervision, increasing the likelihood of high-energy trauma[14]. The finding that female sex was independently associated with increased odds of ORV injury after adjustment was unexpected and may reflect regional recreational participation patterns or sampling characteristics. Further investigation is warranted to clarify this relationship. Prior literature suggests that rural pediatric trauma patients may experience increased mortality despite comparable injury severity[8,9,20,21]. Literature suggests that factors such as prolonged EMS response intervals, delayed access to blood products, limited pediatric airway expertise, and lengthy transport times contribute to these disparities[7,9,56–60]. These findings have important implications for emergency medicine and public health policy. Region-specific injury prevention programs may be more effective than broad statewide initiatives. Community outreach through schools, 4-H organizations, Future Farmers of America chapters, and recreational organizations may improve helmet utilization while riding and parental supervision practices[44,46,54]. Additionally, trauma systems serving rural populations should prioritize optimization of prehospital care protocols. Strategies such as rapid transport, expanded airway management training, telemedicine consultation, and improved access to prehospital blood products may reduce preventable mortality[36,60,61].

Several limitations should be considered when interpreting the findings of this study. Firstly, the retrospective observational design limited the ability to establish causal relationships between geographic factors and trauma outcomes. The study was intended primarily as a descriptive and hypothesis-generating investigation. Secondly, the analysis relied on trauma registry data from a single Level 1 trauma center. Although UMC serves a large regional catchment area, findings may not be generalizable to other trauma systems with different demographic or geographic characteristics. Thirdly, the absence of significant rural–urban differences in ISS

distribution may partly reflect referral bias. Rural patients managed at local facilities without transfer to UMC are not captured in this dataset, which likely enriches the rural cohort for higher-acuity injuries and may mask true differences in injury severity between geographic groups. Relatedly, the study focused primarily on patients who survived long enough to reach definitive trauma care; prehospital fatalities and patients treated at outside institutions may not have been fully captured. Fourthly, broad grouping of RAC regions may have obscured additional local variation. Lower-volume regions were combined to improve analytic stability, but this may have reduced sensitivity for detecting smaller geographic differences. Fifthly, this study did not include outcomes such as mortality, length of stay, or discharge disposition. This is an important limitation because prior literature suggests that rural patients may experience worse outcomes even when injury severity is comparable to that of urban patients. The present analysis is therefore unable to determine whether the absence of measurable differences in injury severity translates into equivalent clinical outcomes across geographic groups. Additionally, certain variables relevant to trauma outcomes were not available for analysis, including transport times, EMS response intervals, helmet utilization, socioeconomic status, and more detailed injury mechanism characteristics. Finally, ORV-related injuries likely encompass heterogeneous vehicle types, including ATVs, dirt bikes, and utility terrain vehicles, which could not be reliably distinguished within the registry.

Future investigations should focus on more detailed characterization of regional pediatric trauma epidemiology across West Texas and Eastern New Mexico. Prospective studies incorporating prehospital transport metrics, EMS response intervals, helicopter utilization, and mortality outcomes may provide greater insight into the relationship between geography and pediatric trauma survival. Additional work should evaluate the effectiveness of region-specific injury prevention initiatives. Community-based programs targeting helmet use, age-appropriate ORV supervision, and safe recreational practices may substantially reduce pediatric injury burden. Partnerships with school districts, 4-H organizations, agricultural associations, and community outreach programs may improve dissemination of injury prevention education. Future research should also evaluate opportunities to optimize rural trauma system performance through advanced airway training, telemedicine integration, prehospital blood product availability, and rapid transfer protocols. More granular geographic analyses incorporating GIS mapping and county-level socioeconomic indicators may further improve understanding of localized trauma risk. Ultimately, data-driven regional trauma analysis may improve both pediatric injury prevention and emergency trauma care delivery throughout rural healthcare systems.

Conclusion

Pediatric trauma patterns within West Texas and Eastern New Mexico demonstrated greater similarity between metropolitan and nonmetropolitan populations than initially expected. However, meaningful regional differences emerged when trauma severity was analyzed using more granular geographic stratification. ORV-related injuries demonstrated identifiable demographic and geographic associations, emphasizing the importance of targeted prevention strategies in rural communities. These findings support the need for region-specific trauma prevention initiatives, optimized EMS transport protocols, and continued investigation into localized pediatric injury epidemiology. Broad rural–urban classifications alone may inadequately characterize trauma risk within large regional trauma systems. A more nuanced, data-driven approach may improve both preventive interventions and acute pediatric trauma outcomes.

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References

1. Sleet DA, Ballesteros MF, Borse NN. A Review of Unintentional Injuries in Adolescents. *Annu Rev Public Health*. 2010;31(1):195-212. doi:10.1146/annurev.publhealth.012809.103616

2. FastStats - Child Health. February 2026. https://www.cdc.gov/nchs/fastats/child-health.htm.

3. Cunningham RM, Walton MA, Carter PM. The Major Causes of Death in Children and Adolescents in the United States. *N Engl J Med*. 2018;379(25):2468-2475. doi:10.1056/NEJMsr1804754

4. Grossman DC. The history of injury control and the epidemiology of child and adolescent injuries. *Future Child*. 2000;10(1):23-52.

5. West BA, Rudd RA, Sauber-Schatz EK, Ballesteros MF. Unintentional injury deaths in children and youth, 2010-2019. *J Safety Res*. 2021;78:322-330. doi:10.1016/j.jsr.2021.07.001

6. Jarman MP, Castillo RC, Carlini AR, Kodadek LM, Haider AH. Rural risk: Geographic disparities in trauma mortality. *Surgery*. 2016;160(6):1551-1559. doi:10.1016/j.surg.2016.06.020

7. Pai PK, Klinkner DB. Pediatric trauma in the rural and low resourced communities. *Semin Pediatr Surg*. 2022;31(5):151222. doi:10.1016/j.sempedsurg.2022.151222

8. Butler EK, Johnson R, Saltzman DA, Segura BJ, Minneapolis, Minnesota. Beyond rural versus urban: A gradient of mortality risk among injured children across a four-level rurality scale. *J Trauma Acute Care Surg*. March 2026. doi:10.1097/TA.0000000000004977

9. Hernandez N, Zagales R, Awan MU, et al. Factors contributing to disparities in trauma care between urban vs rural trauma centers: Towards improving trauma care access and quality of care delivery. *Injury*. 2024;55(12):112017. doi:10.1016/j.injury.2024.112017

10. Ashburn NP, Hendley NW, Angi RM, et al. Prehospital Trauma Scene and Transport Times for Pediatric and Adult Patients. *West J Emerg Med*. 2020;21(2):455-462. doi:10.5811/westjem.2019.11.44597

11. Burdick KJ, Lee LK, Mannix R, Monuteaux MC, Hirsh MP, Fleegler EW. Racial and Ethnic Disparities in Access to Pediatric Trauma Centers in the United States: A Geographic Information Systems Analysis. *Ann Emerg Med*. 2023;81(3):325-333. doi:10.1016/j.annemergmed.2022.08.454

12. Bohnhoff JC, Cutler A, Hagenbuch S, Kurland K. Pediatric subspecialty outreach clinics: reach and impact on access to care. *BMC Pediatr*. 2024;24(1):519. doi:10.1186/s12887-024-04995-6

13. Ganga A, Kim EJ, Araia ES, et al. Pediatric all-terrain vehicle (ATV) related head injury rates and patterns: A 10-year nationwide analysis. *Am J Emerg Med*. 2023;67:56-62. doi:10.1016/j.ajem.2023.02.007

14. Jennissen CA, Denning GM, Aitken ME, et al. American Academy of Pediatrics Recommendations for the Prevention of Pediatric ATV-Related Deaths and Injuries. *Pediatrics*. 2022;150(4):e2022059279. doi:10.1542/peds.2022-059279

15. Hadad I, Goldman RD. All-terrain vehicle injuries in children and adolescents. *Can*

Fam Physician Med Fam Can. 2025;71(2):112-114. doi:10.46747/cfp.7102112

16. Beiriger J, Silver D, Lu L, et al. The Geography of Injuries in Trauma Systems: Using Home as a Proxy for Incident Location. *J Surg Res*. 2023;290:36-44. doi:10.1016/j.jss.2023.04.004

17. Ordoobadi AJ, Castillo-Angeles M, Tabata-Kelly M, et al. System-Level Variability in Trauma Center Utilization for Seriously Injured Older Adults. *J Surg Res*. 2025;305:10-18. doi:10.1016/j.jss.2024.10.047

18. Zogg CK, Becher RD, Dalton MK, et al. Defining Referral Regions for Inpatient Trauma Care: The Utility of a Novel Geographic Definition. *J Surg Res*. 2022;275:115-128. doi:10.1016/j.jss.2021.12.050

19. Melhado C, Hancock C, Wang H, et al. Pediatric Readiness and Trauma Center Access for Children. *JAMA Pediatr*. 2025;179(4):455. doi:10.1001/jamapediatrics.2024.6058

20. Sadoway A, Kinden R, Erdogan M, et al. Epidemiology and factors associated with mortality among pediatric major trauma patients in Nova Scotia: A 17-year retrospective analysis. *Injury*. 2024;55(6):111484. doi:10.1016/j.injury.2024.111484

21. Holter JA, Jeppesen E, Dehli T, Ohm E, Wisborg T. Urban-rural disparities in fatal and non-fatal paediatric injuries after trauma - A national retrospective cohort study. *Injury*. 2024;55(12):111968. doi:10.1016/j.injury.2024.111968

22. Gilblom EA, Johnson AB, Sahr S, Syverson D, Sang HI. Children and youth agricultural injuries: A retrospective analysis of pediatric trauma admissions in North Dakota. *Heliyon*. 2023;9(6):e16626. doi:10.1016/j.heliyon.2023.e16626

23. Weichelt BP, Gorucu S, Burke RR, Salzwedel MA, Murphy DJ, Lee BC. Agricultural youth injuries: An updated review of cases from U.S. news media reports, 2016-2021. *Front Public Health*. 2022;10:1045858. doi:10.3389/fpubh.2022.1045858

24. Levy BE, Quattrone M, Castle JT, Doud AN, Draus JM, Worhunsky DJ. Injury Pattern and Outcomes Following All-Terrain Vehicle Accidents in Kentucky Children: A Retrospective Study. *Am Surg*. 2023;89(12):5874-5880. doi:10.1177/00031348231173955

25. Allen JH, Yengo-Kahn AM, Vittetoe KL, et al. The impact of helmet use on neurosurgical care and outcomes after pediatric all-terrain vehicle and dirt bike crashes: a 10-year single-center experience. *J Neurosurg Pediatr*. 2022;29(1):106-114. doi:10.3171/2021.6.PEDS21225

26. Giertych B, Morrow VR, Rizwan U, et al. ATV-Related Trauma in the Pediatric Population. *J Pediatr Orthop*. 2023;43(8):e669-e673. doi:10.1097/BPO.0000000000002447

27. Berry C, Escobar N, Mann NC, et al. Ambulance deserts and inequities in access to emergency medical services care: Are injured patients at risk for delayed care in the prehospital system? *J Trauma Acute Care Surg*. 2025;99(3):484-488. doi:10.1097/TA.0000000000004579

28. Miller KEM, James HJ, Holmes GM, Van Houtven CH. The effect of rural hospital closures on emergency medical service response and transport times. *Health Serv Res*. 2020;55(2):288-300. doi:10.1111/1475-6773.13254

29. Cash RE, Rivard MK, Chrzan K, Mercer CB, Camargo CA, Panchal AR. Comparison of Volunteer and Paid EMS Professionals in the United States. *Prehosp Emerg Care*. 2021;25(2):205-212.

doi:10.1080/10903127.2020.1752867

30. Brown JB, Berry C, Mann NC, Haut ER. Linking EMS and Trauma Registry Data to Improve Outcomes. *JAMA Surg*. 2026;161(5):445. doi:10.1001/jamasurg.2026.0471

31. Fertaly K, Javorka M, Brown D, Holman C, Nelson M, Glover A. Obstetric transport in rural settings: Referral and transport of pregnant patients in a state without a perinatal regionalized system of care. *Health Serv Res*. 2024;59(5):e14365. doi:10.1111/1475-6773.14365

32. Chen X, Gestring ML, Rosengart MR, et al. Logistics of air medical transport: When and where does helicopter transport reduce prehospital time for trauma? *J Trauma Acute Care Surg*. 2018;85(1):174-181. doi:10.1097/TA.0000000000001935

33. Beiriger J, Lu L, Silver D, Brown JB. Impact of patient, system, and environmental factors on utilization of air medical transport after trauma. *J Trauma Acute Care Surg*. 2024;96(1):62-69. doi:10.1097/TA.0000000000004153

34. Brown JB, Gestring ML, Stassen NA, et al. Geographic Variation in Outcome Benefits of Helicopter Transport for Trauma in the United States: A Retrospective Cohort Study. *Ann Surg*. 2016;263(2):406-412. doi:10.1097/SLA.0000000000001047

35. Sborov KD, Gallagher KC, Medvecz AJ, et al. Impact of a New Helicopter Base on Transport Time and Survival in a Rural Adult Trauma Population. *J Surg Res*. 2020;254:135-141. doi:10.1016/j.jss.2020.04.020

36. Newgard CD, Fu R, Bulger E, et al. Evaluation of Rural vs Urban Trauma Patients Served by 9-1-1 Emergency Medical Services. *JAMA Surg*. 2017;152(1):11. doi:10.1001/jamasurg.2016.3329

37. Abraham PJ, Crowley BM, Moore D, et al. Understanding the geography of trauma: Combining spatial analysis and funnel plots to create comprehensive spatial injury profiles. *J Trauma Acute Care Surg*. 2022;93(2):238-246. doi:10.1097/TA.0000000000003468

38. Kallies KJ, Beyer KM, Koehne WJ, et al. Pediatric Traumatic Injury in Rural and Urban Areas of Wisconsin. *Pediatr Emerg Care*. March 2026. doi:10.1097/PEC.0000000000003599

39. Keeves J, Ekegren CL, Beck B, Gabbe BJ. The relationship between geographic location and outcomes following injury: A scoping review. *Injury*. 2019;50(11):1826-1838. doi:10.1016/j.injury.2019.07.013

40. Zahnd WE, Del Vecchio N, Askelson N, et al. Definition and categorization of rural and assessment of realized access to care. *Health Serv Res*. 2022;57(3):693-702. doi:10.1111/1475-6773.13951

41. Zahnd WE, Hung P, Crouch EL, Ranganathan R, Eberth JM. Health care access barriers among metropolitan and nonmetropolitan populations of eight geographically diverse states, 2018. *J Rural Health Off J Am Rural Health Assoc Natl Rural Health Care Assoc*. 2025;41(1):e12855. doi:10.1111/jrh.12855

42. Kosar CM, Loomer L, Ferdows NB, Trivedi AN, Panagiotou OA, Rahman M. Assessment of Rural-Urban Differences in Postacute Care Utilization and Outcomes Among Older US Adults. *JAMA Netw Open*. 2020;3(1):e1918738. doi:10.1001/jamanetworkopen.2019.18738

43. Byrne JP, Nance ML, Scantling DR, et al. Association between access to pediatric trauma care and motor vehicle crash death in children: An ecologic analysis of United States counties. *J Trauma Acute Care Surg*. 2021;91(1):84-92. doi:10.1097/TA.0000000000003110

44. Pulliam K, Gardner D, Edmunds P, et al. Partnering with High-Risk Communities to Successfully Reduce Pediatric Injury Over Time. *J Pediatr Surg*. 2023;58(8):1506-1511. doi:10.1016/j.jpedsurg.2022.12.005

45. Howard KA, Griffin SF, Stuenkel M, Sease KK. Community features' varying insight into emergency department use for different childhood injuries. *J Safety Res*. 2023;86:209-212. doi:10.1016/j.jsr.2023.05.011

46. Goodon H, Gawaziuk JP, Comaskey B, et al. Social Determinants of Health and Injury Among Children. *JAMA Netw Open*. 2025;8(6):e2513584. doi:10.1001/jamanetworkopen.2025.13584

47. Ben Beck null, Tack G, Cameron P, Smith K, Gabbe B. Optimizing Trauma Systems: A Geospatial Analysis of the Victorian State Trauma System. *Ann Surg*. 2023;277(2):e406-e417. doi:10.1097/SLA.0000000000004904

48. Dooley JH, Ozdenerol E, Sharpe JP, Magnotti LJ, Croce MA, Fischer PE. Location, location, location: Utilizing Needs-Based Assessment of Trauma Systems-2 in trauma system planning. *J Trauma Acute Care Surg*. 2020;88(1):94-100. doi:10.1097/TA.0000000000002463

49. VanDerHeyden N, Cox TB. Trauma Scoring. In: Asensio JA, Trunkey DD, eds. Current Therapy of Trauma and Surgical Critical Care. Mosby; 2008:26-32. doi:10.1016/B978-0-323-04418-9.50010-2

50. Tillmann BW, Nathens AB, Guttman MP, et al. The impact of referring hospital resources on interfacility overtriage: A population-based analysis. *Injury*. 2024;55(3):111332. doi:10.1016/j.injury.2024.111332

51. Savard S, Ready LV, Mondal P, Sothilingam N, Davis P. A comparison of trauma patients in urban and rural areas presenting to a Canadian tertiary care centre. *Can J Surg J Can Chir*. 2024;67(4):E313-E317. doi:10.1503/cjs.013623

52. Min JG, Smith M, Englehart MS, et al. The Golden Hour is elusive in rural trauma: A 10-year analysis from a Level I trauma center in Montana. *Am J Emerg Med*. 2026;103:127-131. doi:10.1016/j.ajem.2026.01.053

53. Elzaim HS, Vatcheva K, Torres-Reveron A, Pequeno G, Betancourt-Garcia MM. Comparative analysis of all-terrain vehicles, motorcycle and automobile-related trauma in a rural border community of the USA. *BMJ Open*. 2022;12(9):e054289. doi:10.1136/bmjopen-2021-054289

54. Jennissen CA, Denning GM, Aitken ME, THE COUNCIL ON INJURY, VIOLENCE, AND POISON PREVENTION. A Comprehensive Report on All-Terrain Vehicles and Youth: Continuing Challenges for Injury Prevention. *Pediatrics*. 2022;150(4):e2022059280. doi:10.1542/peds.2022-059280

55. MacDougall W, Jiang X, Sobhan S, et al. Severity of All-Terrain Vehicle–Related Injuries by Age in Canada, 2002-2019. *JAMA Netw Open*. 2023;6(5):e2316060. doi:10.1001/jamanetworkopen.2023.16060

56. Goodman LF, Martino AM, Schomberg J, et al. Basic is Better? An Assessment of National Outcomes in Prehospital Airway Management in Critical Acuity Pediatric Trauma. *J Emerg Med*. 2025;70:68-79. doi:10.1016/j.jemermed.2024.08.016

57. Pusateri AE, Moore EE, Moore HB, et al. Association of Prehospital Plasma Transfusion With Survival in Trauma Patients With Hemorrhagic Shock When Transport Times Are Longer Than 20 Minutes: A Post Hoc Analysis of the PAMPer and COMBAT Clinical Trials. *JAMA Surg*. 2020;155(2):e195085. doi:10.1001/jamasurg.2019.5085

58. Hung G, Wang T, Hsieh E, Burjonrappa S. Comparing complications in pediatric trauma patients transported before and after 30 minutes. *J Pediatr Surg*. 2026;61(2):162664. doi:10.1016/j.jpedsurg.2025.162664

59. Tayes C, Schiro S, Smith B, Willner D, Winslow JE, Patel MD. Rural-urban differences in prehospital deaths due to injury in North Carolina. *Am J Emerg Med*. 2026;104:44-49. doi:10.1016/j.ajem.2026.02.039

60. Schaefer RM, Bank EA, Krohmer JR, et al. Removing the barriers to prehospital blood: A roadmap to success. *J Trauma Acute Care Surg*. 2024;97(2S Suppl 1):S138-S144. doi:10.1097/TA.0000000000004378

61. Hashmi ZG, Rokayak O, Boggs KM, et al. Teletrauma Use in US Emergency Departments. *JAMA Surg*. 2024;159(12):1383. doi:10.1001/jamasurg.2024.3758