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# Geospatial Analysis of Prehospital Triage and Early Potential Preventable Traumatic Deaths

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## Abstract

Severely injured patients often depend on prompt prehospital triage for survival. This study aimed to examine the under-triage of preventable or potentially preventable traumatic deaths. A retrospective review of Harris County, TX, revealed 1848 deaths within 24 hours of injury, with 186 being preventable or potentially preventable (P/PP). The analysis evaluated the geospatial relationship between each death and the receiving hospital. Out of the 186 P/PP deaths, these were more commonly male, minority, and penetrating mechanisms when compared with NP deaths. Of the 186 PP/P, 97 patients were transported to hospital care, 35 (36%) were transported to Level III, IV, or non-designated hospitals. Geospatial analysis revealed an association between the location of initial injury and proximity to receiving Level III, IV, and non-designated centers. Geospatial analysis supports proximity to the nearest hospital as one of the primary reasons for under-triage.

## Keywords

preventable mortality, trauma deaths, geospatial analysis

Trauma outcomes begin with efficient prehospital care and accurate triage. Identifying areas with potential improvement is necessary to improve prehospital interventions and mortality. Previous research has explored the systematic approach to identifying preventable and potentially preventable (P/PP) deaths.[1] Utilizing these criteria, analysis of deaths that occur in the prehospital and very early hospital settings can identify areas for improvement.

A sizable percentage of prehospital preventable deaths from uncontrolled hemorrhage due to inadequate care provided at an initial care facility.[2] The decision of where to transport a patient requires critical thinking by prehospital personnel to anticipate the future needs of an injured patient. Prehospital trauma triage protocols exist in an attempt to aid in efficient triage. Compliance with these protocols is inconsistent, ranging from 21 to 93%.[3] Distance to trauma centers has been found to cause nonadherence to set protocols.[4] Prehospital time is linked to increased mortality for patients with hypotension, a Glasgow Coma Score (GCS) of 8 or less, and non-extremity penetrating trauma.

This is a secondary analysis of a retrospective trauma deaths database from Harris County, Texas, in 2014; it included deaths within 24 hours of injury. Data measures included the preventability of death, demographics

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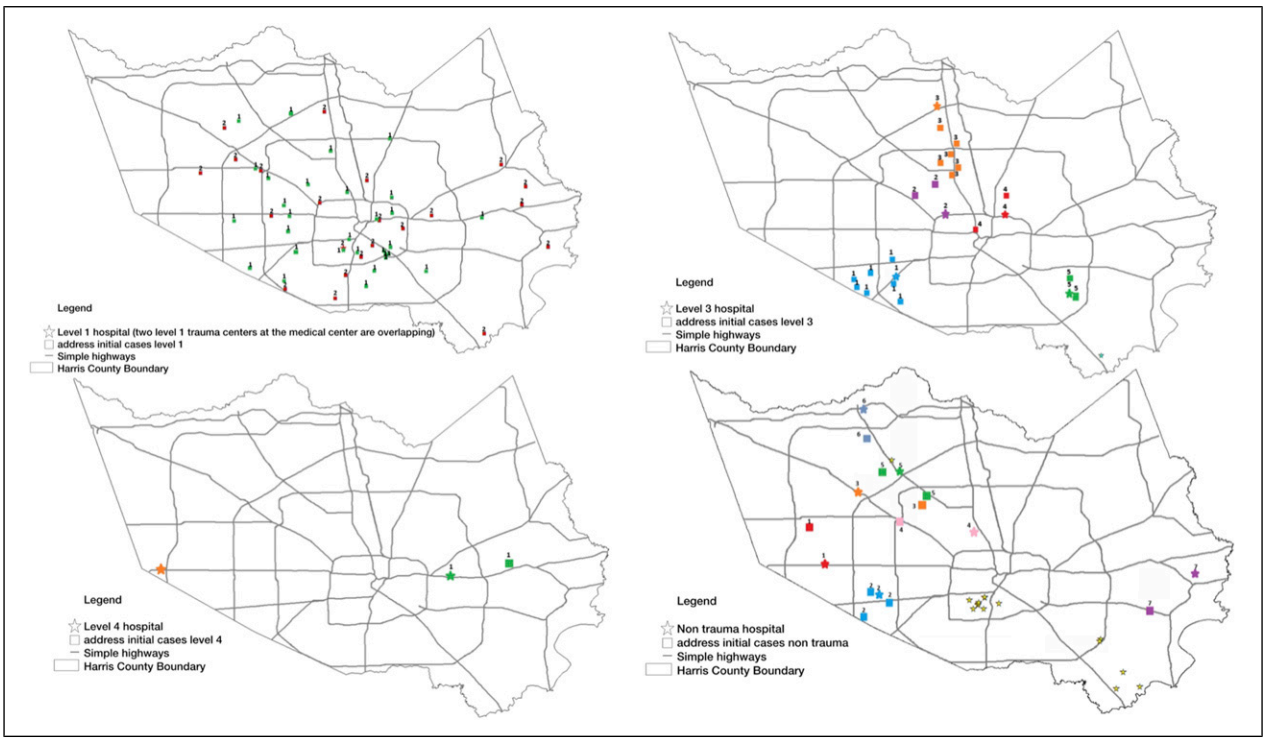


**Figure 1.** Trauma scene location and corresponding receiving hospital.

including patients' age, sex, race, mechanism of injury (blunt, penetrating, or other), Anatomic Injury Score (AIS), Injury Severity Score (ISS), location of death organized by trauma accreditation designation level (prehospital, Level I-IV trauma center or non-designated center), interventions for transported initial acute care settings, system and quality concerns for transported cases, and initial care decisions.

Additionally, prehospital and initial acute care interventions were abstracted and summarized. A panel of multidisciplinary trauma experts determined the preventability of death. This included emergency physicians, trauma/orthopedic/neurosurgeons, EMS medical directors, forensic pathologists, and forensic specialists. Data were included from prehospital records, death investigations, and autopsy reports. The categories of preventability included preventable (P), potentially preventable (PP), or non-preventable (NP). Preventable: anatomic injuries were considered survivable if appropriate care had been provided (including cases where the divergence from the standard of care caused the patient's death). Potentially preventable: severe anatomic injuries but deemed survivable under optimal conditions. Non-preventable: deaths resulting from anatomic injuries or comorbid conditions determined to be the primary cause of death in patients with major injuries.

Data analysis consisted of Pearson Chi-Square test to assess significant differences in the demographics (age, sex, race) between preventable and non-preventable deaths. Statistical significance was recognized at $P < .05$. Geospatial analysis was performed to plot the preventable injury address and the location of receiving facilities. The transported cases were matched with the type of trauma facility (Level I-IV trauma centers and non-designated centers). To analyze the distance from the scene, we used geospatial software to map and plot the preventable trauma injury locations and trauma facilities using Environmental Systems Research Institute's ArcMap 10.4.1.

Data were further analyzed to examine under-triage as determined using regional guidelines. The Southeast Texas Regional Advisory Council (SETRAC) provides these guidelines and is consistent with the American College of Surgeons (ACS) recommendations. The ACS defines under-triage as P/PP deaths taken to a non-trauma center, with a target rate of 1% or less.

There were 1848 traumatic deaths within 24 hours. Of those, 1662 (89.9%) were deemed non-preventable (NP) deaths. The remaining 186 P/PP early deaths include 89 (47.8%) prehospital and 97 (52.2%) who were transported to an initial acute care setting (Level I-IV and non-designated center) and later died within 24 hours of arrival. Of those transported, 62 (63.9%) arrived at a Level I Trauma Center, 21 (21.6%) at a Level III Trauma Center, 3 (2.1%) at a Level IV Trauma Center, and 11 (11.3%) at a non-designated center. ISS IQR ranged from 15 to 34,

with a median score of 25, and 74.7% had an ISS greater than or equal to 16.

Males were more likely to be deemed P/PP death when compared with NP death ($P = .028$). Minorities were also more likely to be deemed P/PP death when compared with NP death ($P < .001$). Penetrating mechanisms were more likely to be P/PP death when compared with NP death ($P < .001$).

Based on ACS guidelines, the P/PP under-triage rate was 11.3% (11/97). Furthermore, 79 of 97 transported cases had an ISS ≥16, with 6 (7.6%) being transported to a non-trauma center and 15 (19.0%) transported to Level III and IV trauma centers.

The four Level I Trauma Centers in Harris County are in the Texas medical center area, two are adult designated, and two have pediatric designations. There was no clustering based on the injury location for cases sent to a Level I Trauma Center with an average distance from the scene of 20.2 miles. Patients presenting to a Level II-IV, or non-designated centers were associated with a clustering pattern near the hospital (Level III-5.7 miles, Level IV-17.7 miles, Non-Designated Center-7.8 miles) (Figure 1).

Regional protocols dictate appropriate transport to a Level I Trauma Center, up to 45 minutes via the fastest means and up to 20 minutes for patients in traumatic arrest. Geospatial analysis demonstrates a deviation from the regional trauma transport guidelines. This stems from multiple factors, including geographical trauma center disparities. At the time of this study, only four Level I Trauma centers were in Harris County, of which all are directly adjacent to each other in the Texas Medical Center. This creates a barrier to timely access to such facilities, especially considering the wide geospatial area.

We assessed EMS regional triage by identifying all P/PP prehospital deaths within a region. Previous research has evaluated P/PP causes of traumatic death and the geographical influence on prehospital triage; however, there is a lack of studies that examine the relationship between the two. ZIP codes from discharged trauma patients were used in one study to identify geographical disparities.[5] This served as a rough approximation of location and did not include patients that did not survive to discharge. Another prospective national cohort study proved the feasibility of geospatial analysis for prehospital trauma patients but did not examine P/PP deaths.[6] This study used the precise origin of traumatic injury location for patients with P/PP deaths, allowing us to examine geographical variables associated with the under-triage of these patients.

Several limitations were encountered in this study. Incomplete documentation of initial assessment, such as vital signs and GCS, made it difficult to fully evaluate the appropriate receiving trauma center. Another limitation is that the study only evaluated deaths within 24 hours. This causes the denominator of the under-triage analysis to only account for deaths within the first 24 hours. The ACS guidelines do not have a time requirement, meaning the study would have missed P/PP deaths transported to a non-trauma center that lived over 24 hours.

This study shows that P/PP deaths under-triaged were likely to be closer to the receiving hospital. It also showed a higher proportion of P/PP deaths being male, minorities, and penetrating mechanisms. The under-triage rate was 11.7%.

## Declaration of Conflicting Interests

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