Integrating Prehospital and Trauma Registry Data: A California EMS Data Linkage Initiative

Emergency Medical Services Authority

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Preventive Health and Health Services Block Grant (PHHSBG)

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ABSTRACT

Linking emergency medical services (EMS) data with hospital trauma records is essential for evaluating how effectively EMS teams identify and transport critically injured patients. This study aims to create a comprehensive, patient-level view of the continuum of trauma care, from the prehospital setting to definitive treatment in the hospital, by linking EMS electronic patient care reports (ePCRs) with hospital electronic health records (EHRs). Using a probabilistic matching method, the study integrates two large statewide databases: the California Emergency Medical Services Information System (CEMSIS), which captures data on EMS provider assessments, interventions, and transport decisions, and Patient Registry, which contains detailed information on hospital-based trauma care, including diagnoses, procedures, and patient outcomes. The linkage process enables a more complete analysis of how prehospital triage and transport decisions relate to injury severity and clinical outcomes. The study follows a structured three-step matching process:

1. Exact matching (records with identical key details),
2. Refined criteria-based matching (using additional patient and incident details), and
3. Fuzzy matching (allowing minor discrepancies, such as dates differing by up to one day).

Following extensive data cleaning and standardization, 22,745 CEMSIS records were included, and 10,281 (45.2%) were successfully matched and merged with Patient Registry records. Despite this, challenges in data linkage persisted due to differences in EMS and hospital documentation, missing patient details, and the inherent limitations of probabilistic matching techniques.

For the matched records, this study examines the association between EMS-documented trauma triage criteria (TTC) and hospital-reported injury severity scores (ISS) and evaluates whether TTCs effectively predict severe injury. The findings indicate that physiological criteria, particularly abnormal vital signs and neurological impairment (e.g., Glasgow Coma Score ≤ 13), were the strongest predictors of severe trauma. Although TTC count was statistically correlated with ISS, the association was weak, suggesting that additional predictive factors such as mechanism of injury, comorbidities, and prehospital interventions should be considered. Moreover, ICU admission and ventilator use rates increased with higher ISS categories, reinforcing the utility of ISS as a predictor of hospital resource utilization.

The results of this study provide crucial insights into EMS trauma triage practices, documentation accuracy, and data linkage feasibility. Additionally, they highlight both the benefits and limitations of probabilistic matching in integrating

EMS and hospital datasets. Based on these findings, the California EMS Authority (EMSA) will develop a formal quality improvement (QI) project proposal to address data standardization and linkage accuracy, which will be presented to the California Executive Data Advisory Group for review and recommendations in the future.

BACKGROUND

CEMSIS and Trauma Data Linkage Initiative Report is a deliverable for the Preventive Health and Health Services Block Grant (PHHSBG). Under the provisions of the PHHSB Grant, this study utilizes probabilistic matching to link patient records between two independent data sources: CEMSIS and Patient Registry.

CEMSIS

CEMSIS is a comprehensive statewide database that compiles EMS data from electronic patient care reports (ePCRs). CEMSIS adheres to the National Emergency Medical Services Information System (NEMSIS) which is a national database and data standard that ensures uniformity in the collection, exchange, and analysis of EMS data across states and agencies. CEMSIS encompasses prehospital patient demographics, clinical evaluations, treatment interventions, and transport details from the local EMS agencies (LEMSAs). There are 34 LEMSAs in California, covering all 58 counties. Some LEMSAs serve a single county (e.g., Los Angeles County EMS Agency) whereas others serve multiple counties in a regional model (e.g., Sierra-Sacramento Valley EMS Agency). See LEMSA map in Appendix A (pg. 41). LEMSAs operate under the authority of EMSA and implement EMS systems to meet their local needs while ensuring statewide consistency in EMS operations. They play a crucial role in California's prehospital care system by delivering efficient, high-quality, and locally adapted EMS services. Their work directly impacts patient outcomes, EMS system performance, and public safety.

For this study, CEMSIS trauma patients were identified using the California EMS System Core Quality Measures Project specifications for measure TRA-2: Transport of Trauma Patients to a Trauma Center. See Appendix B (pg. 42) for the complete TRA-2 report criteria. TRA-2 is defined as the percentage of patients originating from an emergency response who met trauma triage criteria for the red criteria (Injury Patterns and Mental Status and Vital Signs) or the yellow criteria (Mechanism of Injury) in the 2021 American College of Surgeons (ACS) National Guideline for the Field Triage of Injured Patients and were transported to a trauma center. The ACS National Field Triage Guidelines provides a standardized, evidence-based framework for EMS personnel to identify severely injured patients who would benefit from treatment at trauma centers. These guidelines employ a structured four-step algorithm: (1) Injury Patterns, which includes anatomic criteria addressing specific serious injuries such as penetrating trauma, multiple long-bone fractures, or significant chest injuries that mandate trauma center evaluation; (2) Mental Status and Vital Signs, which includes physiological criteria and prioritizes immediate transport based on compromised vital signs such as Glasgow Coma Scale (GCS) < 6, systolic blood pressure <90 mmHg, or abnormal respiratory rates; (3) Mechanism of Injury Criteria, which consider high-risk scenarios like falls, high-speed crashes, or pedestrian incidents; and (4) EMS Judgment, including patient-specific factors such as age, pregnancy, anticoagulant use, or EMS provider judgment. By systematically identifying patients likely to experience significant morbidity or mortality without specialized trauma care, these guidelines aim to reduce preventable deaths and improve patient outcomes following traumatic injury. See Appendix C (pg. 43) for the complete ACS criteria. TRA-2 aligns with the ACS criteria, excluding (4) EMS Judgment. It is a key performance indicator used by EMSA and LEMSAs to assess EMS providers' ability to identify, treat, and transport patients with suspected or confirmed traumatic injuries. The criteria align with the NEMSIS version 3.5.0 data standard, which was implemented statewide by EMSA and all participating LEMSAs in CEMSIS in 2024.

PATIENT REGISTRY

Patient Registry is a statewide database of hospital electronic health records (EHRs) containing trauma patient data from California designated trauma centers. Patient Registry is structured according to the American College of Surgeons (ACS) National Trauma Data Bank Standard, which serves as the largest aggregation of trauma registry data in the United States and is designed to improve trauma care through standardized data collection and benchmarking. This data includes abbreviated injury scale (AIS) coding and scoring, which is used to calculate injury severity score (ISS). ISS is described further in the next section.

The Patient Registry currently receives data from designated trauma centers across California. A designated trauma center is a hospital that has been officially designated by a LEMSA to provide specialized care for severely injured patients. These hospitals meet strict state and national standards for trauma care, ensuring rapid and coordinated treatment for patients with life-threatening injuries. Trauma centers are designated by the LEMSA based on compliance with California Code of Regulations, Title 22, Division 9, Chapter 6, Article 3 and ACS standards. Trauma hospitals have the option to pursue a more rigorous designation through the ACS program. In California, trauma centers are categorized into Levels I, II, III, IV, and based on their capabilities:

- Level I: Highest level; must have in-house trauma surgeons 24/7, comprehensive trauma research programs, and education initiatives.
- Level II: Provides definitive trauma care but may not have research or residency programs.
- Level III: Stabilizes and transfers severe cases but manages moderate trauma independently.
- Level IV: Provides initial stabilization and transfer to higher-level centers if needed.

Trauma centers have resources such as specialized trauma teams, 24/7 surgical and critical care services, trauma-trained personnel, and participate in quality improvement programs. As such, these facilities receive priority transport of critically injured patients from EMS providers based on trauma triage criteria. These centers play a critical role in reducing preventable deaths and improving patient outcomes through rapid and specialized trauma care.

INJURY SEVERITY SCORE

The injury severity score (ISS) is a standardized anatomical scoring system used to assess trauma severity and predict patient outcomes. It is calculated based on injuries sustained across six body regions:

- Head/Neck
- Face
- Chest
- Abdomen/Pelvis
- Extremities
- External/Soft Tissue

The ISS is derived from the AIS, which assigns a severity score (1 to 6) to each injury in a specific body region. The three most severe injuries across different regions are squared and summed to generate the final ISS value, ranging from 1 (minor injury) to 75 (un-survivable trauma). ISS is widely used in trauma research, clinical decision-making, and hospital triage systems due to its strong correlation with morbidity, mortality, and healthcare resource utilization. For this study, ISS severity classifications are defined as follows: Mild trauma (0-14), Moderate trauma (ISS 15-24), and Severe trauma (ISS ≥ 25). These classifications are based on widely accepted trauma scoring guidelines used in trauma research, clinical decision-making, and triage protocols, including those from the ACS, NTDB, CDC Field Triage Guidelines, and national trauma studies. Additionally, EMSA utilizes a different ISS categorization scheme for trauma system evaluation and data reporting. EMSA groups ISS into the following categories: 0-14, 15-24, 25-34, 35-44, 45-54, 55-64, 65-74, and 75+. This grouping provides a more granular breakdown of severe trauma cases and better aligns with state-level trauma data collection and analysis practices.

ISS Range	Severity Classification	Clinical Significance
0-14	**Mild Trauma**	Possible hospital admission, typically no ICU admission, low mortality, often discharged home.
15-24	**Moderate Trauma**	Considered "major trauma" in some systems, associated with higher hospitalization rates.
≥ 25	**Severe Trauma**	High ICU admission rates, ventilator dependence, and mortality risk.

OBJECTIVES

The primary objectives of this study are to enhance the percentage of successfully linked records between the CEMSIS and Patient Registry databases for a defined population and to evaluate the correlation between prehospital trauma triage criteria, as documented in EMS records, and the injury severity score recorded in hospital trauma data. The results and analysis of this study may inform improvements in EMS care and patient outcomes. It can also inform several key areas related to trauma care and EMS efficiency such as:

1. **EMS and Hospital Data Integration**

   a. Demonstrates the feasibility and reliability of probabilistic matching between EMS and hospital datasets.
   b. Highlights potential data quality issues, such as missing or inconsistent records, that could impact interoperability.
   c. Supports statewide efforts to create a more comprehensive patient care continuum by linking prehospital and hospital data.
2. **EMS Triage Accuracy and Effectiveness**

   a. Evaluates how well prehospital trauma triage criteria predict injury severity.
   b. May identify over-triage (patients sent to trauma centers with low ISS) and under-triage (severe trauma cases not identified in the field).
   c. Provides evidence for evaluating triage guidelines to improve patient outcomes and resource utilization.
3. **Trauma System Performance Metrics**

   a. May assess whether trauma centers receive appropriate patient populations based on prehospital assessment.
   b. Helps evaluate the timeliness and accuracy of EMS triage decisions, potentially influencing regional trauma system planning.
   c. Provides data regarding transport protocols.
4. **Predictive Analytics for Patient Outcomes**

   a. Identifies patterns in prehospital triage data that correlate with high ISS, potentially informing real-time EMS decision support or the development of predictive tools that could help EMS providers make more informed transport decisions.
5. **Policy and Funding Decisions**

   a. Provides data for policymakers to assess the effectiveness of current EMS triage protocols and documentation.
   b. Supports evidence-based decision-making for regulatory updates regarding trauma triage and patient transport.
   c. May justify funding for EMS training, data integration projects, or trauma system enhancements, including staff positions for highly skilled data specialists, clinical researchers, or epidemiologists.

METHODOLOGY

Trauma Patient Identification and Data Compliance

To obtain the sample populations for this study, CEMSIS data was queried for all patient encounters in the first and second quarters of 2024 that met trauma triage criteria and resulted in transportation to a designated trauma center per TRA-2 numerator specifications. Concurrently, Patient Registry data was queried for trauma patients that arrived at a trauma center via EMS and were treated in quarter 1 or 2 of 2024. To maximize the record linkage rate between EMS and hospital trauma data, EMSA identified the most viable and accessible data elements across both sources. The following sections detail the methodology, additional criteria, and data elements used to query the sample populations. Probabilistic matching was performed to link records across the two datasets using a three-phase linkage process. Matching was conducted using powerful analytical tools, including SAS and Excel Power Query to maximize linkage efforts.

- **Initial Match**: Records were matched based on patient date of birth (DOB) and date of incident, establishing an initial set of linked cases.
- **Refined Match**: A secondary matching process was performed using patient age, gender, patient postal code, incident date, incident county, and destination facility to refine the record linkage and account for cases with no date of birth recorded and potential discrepancies in data entry.
- **Fuzzy Match**: The final match was executed to account for potential variations in reported incident dates. Records were matched based on the patient date of birth and incident date plus or minus one day. In cases where patient date of birth was blank, patient age, gender, patient postal code, incident county, destination facility and incident date plus or minus one day was used for linkage. The goal of this approach was to capture records where minor discrepancies in incident date/times or emergency department or hospital admission dates/times may have otherwise prevented linkage.

STEP 1: CEMSIS DATA

A single comprehensive transactional report was queried in CEMSIS that adheres to the TRA-2 measure numerator specifications, identifying trauma patients who met ACS Field Trauma Triage Criteria (Steps 1, 2, or 3 only) and were transported to a designated trauma center.

CEMSIS TRANSACTIONAL REPORT

1. Incident Dates: January 1, 2024, through June 30, 2024
2. Report Criteria: See TRA-2 Numerator criteria table in Appendix B (pg. 42)

STEP 2: PATIENT REGISTRY DATA

A single comprehensive transactional report was queried in Patient Registry.

PATIENT REGISTRY TRANSACTIONAL REPORT

1. Incident Dates: January 1, 2024, through June 30, 2024
2. Transport Mode Hospital Arrival: Ground Ambulance, Fixed-Wing Ambulance, or Helicopter Ambulance
3. ISS is not blank

STEP 3: DATA QUALITY

To ensure data accuracy and consistency, the following steps were taken for both CEMSIS and Patient Registry data:

1. **Data Validation and Error Detection**
    - Verified documented patient age by using the incident date and time and patient date of birth to manually calculate age.
    - Identified, corrected or removed implausible values (e.g., negative ages, illogical dates).
    - Cross-checked patient demographic fields for inconsistencies.
    - Validated geographic data.
    - Standardized date and time formats for consistency.
    - Incorporated additional matching fields where available (e.g., hospital ID).
    - Identified date transpositions, misspellings, insertions, omissions, and other data entry inconsistencies.
2. **Duplicate Record Handling**
    - Assigned unique IDs to each patient encounter to facilitate accurate tracking and duplicate record removal.
    - Merged or removed duplicate records while preserving key data points.
    - Retained duplicate records that could not be removed due to variations in documentation across EMS providers, discrepancies in patient demographic information, and instances where multiple LEMSAs provided care for the same patient.
3. **Data Standardization and Transformation**
    - Ensured uniform terminology across datasets for categorical fields (e.g., gender, race, facility, facility code, trauma region, etc.).
    - Removed duplicate entries of positive trauma triage criteria.
    - Organized trauma triage criteria in alphabetical order and grouped them for categorization.
    - Calculated the number of positive trauma triage criteria per patient, excluding criteria marked as "not applicable" or "not recorded in the total count of +TTC.

- **Note:** For all analyses, only affirmative trauma triage criteria (TTC) were treated as "positive." Data element entries coded as "Not Applicable," "Not Recorded," or left blank were excluded from TTC counts and individual TTC indicator variables used in correlation, regression, and categorical analyses. These values were included in descriptive frequency tables solely to highlight documentation patterns and were not interpreted as indicative of positive TTCs.

4. **Quality Assurance Checks**
    - Performed random audits of linked records to assess accuracy.
    - Compared the linked dataset against known benchmarks or previous studies to detect anomalies.

STEP 4: DATA LINKAGE

This study employed a three-phase record linkage process to match patient records between CEMSIS and Patient Registry. The linkage methodology was designed to prioritize high confidence matches, ensuring dataset reliability while minimizing false positives. The hierarchical structure of the matching process allowed for an incremental approach, where records with complete and highly reliable identifiers were linked first, followed by cases where broader matching criteria were applied when key identifiers were missing. This approach maximized both accuracy and completeness in the final dataset.

To facilitate data linkage, integration, and analysis, a combination of SAS and Excel Power Query was employed for data management, statistical analysis, and visualization. Excel was used for initial data cleaning, addressing missing values, standardizing variable names, and correcting formatting inconsistencies. SAS was utilized to execute the hierarchical probabilistic matching process, ensuring that linkage rules were applied systematically to maintain data integrity. Excel Power Query enabled efficient merging of matched and unmatched records, while also serving as an additional validation tool for reviewing data joins and verifying linkage accuracy.

For statistical analysis, SAS was used to conduct correlation analysis and categorical assessments of TTC and ISS. This included:

- Spearman's rank correlation to measure the association between TTC count and ISS, as well as TTC type and ISS.
- Kruskal-Wallis test to compare ISS distributions across TTC categories.
- Chi-square test to assess whether TTC count was significantly associated with ISS severity categories.
- Logistic regression modeling to evaluate the predictive power of TTC count for severe trauma (ISS $\geq$ 25).

SAS was used to generate statistical outputs, ensuring a comprehensive and reproducible statistical workflow. Excel charts and tables were then used to visualize key findings, allowing for clear interpretation and evidence-based decision-making. By integrating SAS for statistical analysis with Excel for efficient data handling, the study ensured a robust, systematic, and high-quality analytical framework.

The table on the next page outlines the structured linkage phases used in this study, detailing the specific matching criteria, descriptions, strengths, and limitations at each phase.

TABLE 1: DATA LINKAGE HIERARCHY TABLE

Linkage Phase	Matching Criteria	Description	Strengths	Limitations
Link 1	Incident Date (exact match) + Date of Birth (exact match)	Ensures the strongest, most reliable matches by requiring exact demographic alignment.	High specificity, eliminates false positives, strong temporal alignment.	Missed matches due to DOB entry errors or minor date discrepancies.
Link 2	Incident Date (exact match) + Patient Age & Age Units (exact match) + Gender (exact match) + Patient Postal Code (exact match) + Incident County (exact match) + Destination Facility (exact match)	Captures cases where DOB is missing but other demographic and location-based identifiers align perfectly.	Maintains high specificity, expands the linkage pool for records missing DOB.	False negatives due to age rounding errors, location discrepancies, gender misclassification or missed matches due to blank fields.
Link 3A	Date of Birth (exact match) + Incident Date (match within ±1 day)	Accounts for minor discrepancies in incident date recording while maintaining high specificity through DOB.	Adjusts for minor errors in incident date while preserving linkage accuracy.	Missed matches due to DOB entry errors or more significant date discrepancies.

Link 3B	Patient Age & Age Units (exact match) + Gender (exact match) + Patient Postal Code (exact match) + Incident County (exact match) + Destination Facility (exact match) + Incident Date (match within ±1 day)	Captures records where DOB is unavailable but other demographic and location-based identifiers align.	Adjusts for minor incident date errors and allows linkage when DOB is missing.	False negatives due to age rounding errors or location data or other inconsistencies exist.

RESULTS

Perspective from CEMSIS-Matched Records

The results section of this study presents analyses from matched records containing data from both CEMSIS and Patient Registry. However, the perspective of the analysis is based on the CEMSIS merged dataset, meaning that counts and percentages are reported in relation to CEMSIS records that were successfully linked, rather than from the perspective of Patient Registry. This approach ensures that the findings remain grounded in EMS data, reflecting prehospital triage decisions and transport patterns, while still incorporating hospital-reported patient outcomes (e.g., ISS) from Patient Registry for analytical purposes. For example, when reporting linkage rates, the percentage of CEMSIS records in its data set that were successfully matched to hospital data is provided, rather than the percentage of Patient Registry records that were linked to CEMSIS. This distinction maintains the study's focus on EMS documentation and triage performance, rather than the broader hospital trauma population.

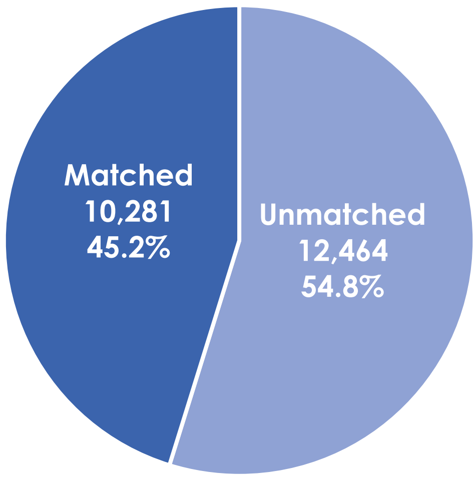
Additionally, data was presented with careful consideration of Protected Health Information (PHI) regulations and data governance policies. While the linked dataset includes patient demographics, hospital-reported injury severity metrics and outcome data, all analyses ensure that data is used only in aggregate and de-identified form, and that reporting remains consistent with data security and privacy requirements.

By structuring the results in this way, the analysis provides a clear assessment of how EMS-reported TTC correlate with hospital-reported ISS, without introducing potential biases from hospital-level reporting practices. This perspective also aligns with the study's goal of evaluating the effectiveness of EMS field triage and identifying areas for data quality improvement within CEMSIS records.

Future analyses may take a hospital-centered approach, examining Patient Registry cases that link back to CEMSIS to explore prehospital care patterns among trauma center admissions. However, for the current phase, the emphasis remains on CEMSIS as the primary dataset, ensuring that all findings are interpreted through the lens of EMS-reported data and prehospital decision-making. The following figures present the results of this study.

GENERAL CHARACTERISTICS AND DEMOGRAPHICS

FIGURE 1: MATCHED AND UNMATCHED CEMSIS RECORDS



Of the 22,745 CEMSIS records for trauma patients who met ACS Trauma Triage Criteria Steps 1, 2, and 3 for Q1-Q2 2024, 10,281 records (45.2%) were successfully matched to corresponding records in the Patient Registry. Approximately 6% of the matched records may have duplication (same patient, same incident) and could not be removed from the dataset due to variations in documentation by providers. 10% of unmatched records did not have a date of birth recorded, possibly preventing linkage.

FIGURE 2: MATCHED RECORDS BY DATA LINKAGE HIERARCHY

Linkage Phase	Linkage Name	Patient Demographics			Patient Characteristics	Date	Location		Records Matched
		Date of Birth	Age and Age Units	Gender	Patient Postal Code	Incident Date	Scene Incident County	Facility Destination Code	
1	**Initial**	Exact				Exact			**8,038**
2	**Refined Criteria**	Drop	Exact	Exact	Exact	Exact	Exact	Exact	**2,243**
3A	**Fuzzy 1**	Exact				+/- 1 Day			**0**
3B	**Fuzzy 2**	Drop	Exact	Exact	Exact	+/- 1 Day	Exact	Exact	**0**
									Total: 10,281

FIGURE 3: AGE AND GENDER

Age	Gender				
	Male	Female	Unknown	Other	**Grand Total**
1-14 Years	261	160			**421**
15-24 Years	1,292	430	4	4	**1,730**
25-34 Years	1,357	402	3	6	**1,768**
35-44 Years	1,188	303	8	3	**1,502**
45-54 Years	926	263	1	1	**1,191**
55-64 Years	968	344	2		**1,314**
65-74 Years	645	303	2	1	**951**
75+ Years	708	690	2	4	**1,404**
Grand Total	**7,345**	**2,895**	**22**	**19**	**10,281**

FIGURE 4: AGE

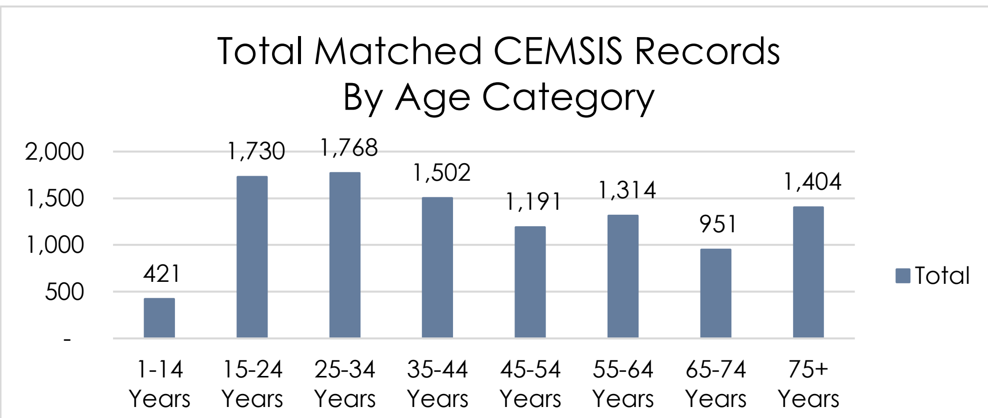


FIGURE 5: GENDER

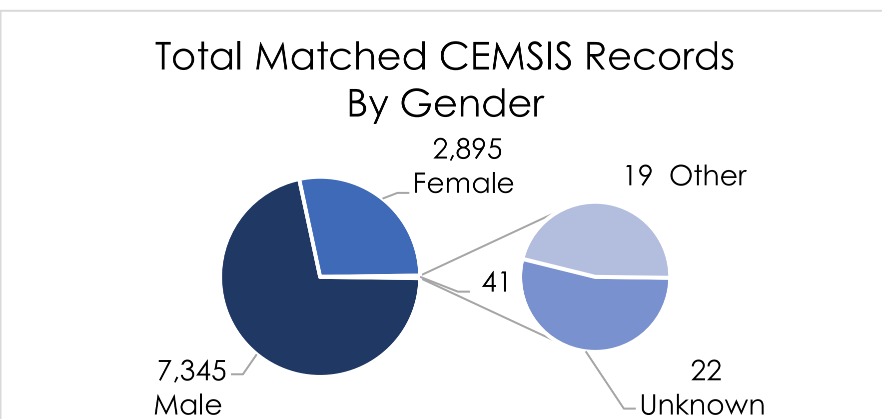


FIGURE 6: RACE

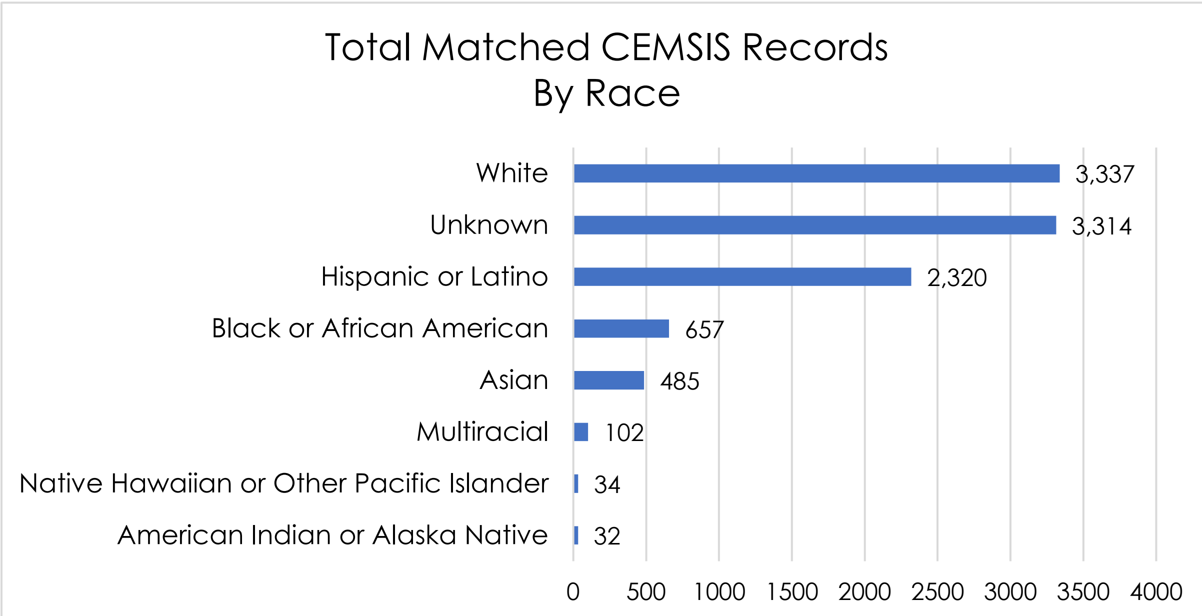
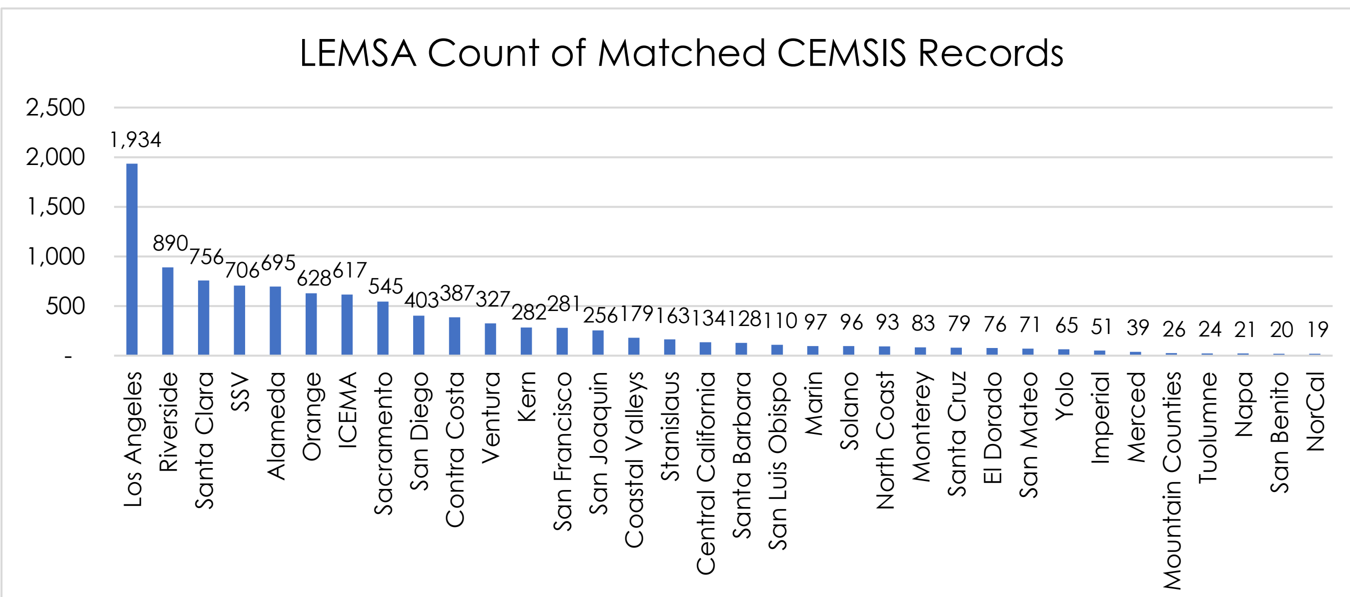


FIGURE 7: LEMSA COUNT



ISS CHARACTERISTICS

FIGURE 8: ISS SUMMARY A

ISS Category	Total Records	Average Age	Median Age	Average TTC Count	Average ISS	Median ISS	Most Common Gender	Most Common Race
0-14	7,904	45	42	1	6	5	Male	White
15-24	1,333	46	44	1	18	18	Male	White
25-34	757	47	45	2	28	27	Male	White
35-44	189	43	39	2	38	38	Male	White
45-54	60	40	37	3	48	50	Male	Hispanic or Latino
55-64	13	39	31	3	58	59	Male	Hispanic or Latino
65-74	3	48	55	3	66	66	Male	White
75+	22	47	47	2	75	75	Male	Hispanic or Latino

FIGURE 9: ISS SUMMARY B

ISS Category	Most Common TTC	ICU Admission Rate	Most Common ED Discharge Disposition	Most Common Facility Discharge Disposition	Ventilator Use Rate
0-14	Glasgow Coma Score <= 13 | Not Recorded	18%	Floor bed (general admission, non specialty unit bed)	Discharged to home or self-care (routine discharge)	6%
15-24	Glasgow Coma Score <= 13 | Not Recorded	59%	Intensive Care Unit	Discharged to home or self-care (routine discharge)	24%
25-34	Glasgow Coma Score <= 13 | Not Recorded	75%	Intensive Care Unit	Discharged to home or self-care (routine discharge)	54%
35-44	Glasgow Coma Score <= 13 | Not Recorded	85%	Intensive Care Unit	Deceased/Expired	73%
45-54	Pedestrian/bicycle rider thrown, run over, or with significant impact | Respiratory Rate <10 or >29 breaths per minute (<20 in infants aged <1 year) or need for ventilatory support	78%	Operating Room (Hybrid OR)	Deceased/Expired	85%

ISS Category	Most Common TTC	ICU Admission Rate	Most Common ED Discharge Disposition	Most Common Facility Discharge Disposition	Ventilator Use Rate
55-64	Glasgow Coma Score <= 13 | Motorcycle Crash > 20 MPH | Pedestrian/bicycle rider thrown, run over, or with significant impact	77%	Intensive Care Unit	Long Term Care Hospital (LTCH)	77%
65-74	Auto Crash: Partial or complete ejection | Chest wall instability, deformity, or suspected flail chest | EMS Provider Judgment | Glasgow Coma Score <= 13 | Motorcycle Crash > 20 MPH | Respiratory Rate <10 or >29 breaths per minute (<20 in infants aged <1 year) or need for ventilatory support | Systolic Blood Pressure <90 mmHg	100%	Intensive Care Unit	Acute care hospital	100%
75+	Penetrating injuries to head, neck, torso, and proximal extremities	36%	Intensive Care Unit	Not Applicable	77%

The ISS characteristics tables A and B provide key insights into demographics, clinical severity, and hospital outcomes for trauma patients. Across all ISS categories, the majority of patients were male and White, with Glasgow Coma Score (GCS) ≤ 13 being the most frequently documented TTC. As expected, higher ISS categories were associated with increased injury severity and hospital resource utilization.

- Patients in the 0-14 ISS category had an average ISS of 6, with a low ICU admission rate (18%). In contrast, patients in the highest ISS categories (≥25) exhibited substantially higher ICU admission rates (average 77%) indicating the clinical significance of ISS in predicting critical outcomes. Notably, ventilator use increased significantly with ISS severity, with 85% of patients in the ISS 45-54 category requiring mechanical ventilation, compared to less than 6% in the mild trauma category (ISS 0-14).
- Emergency Department Discharge and Facility Discharge Dispositions also varied by severity. Lower ISS categories were predominantly discharged home, whereas higher ISS cases were admitted to intensive care units or required operative interventions.

These tables illustrate important trends in trauma outcomes, reinforcing the utility of ISS as a predictor of hospital resource needs and patient survival. The increasing trends in ICU admission, ventilator dependence, and discharge dispositions across ISS categories support ongoing evaluation of prehospital triage protocols to ensure timely and appropriate transport of high-risk trauma patients to definitive care facilities.

FIGURE 10: LEMSA SUMMARY

LEMSA	Total Records	Average TTC Count	Median TTC Count	Most Common TTC	TTC 2 or More %	Severe Case %
Alameda	695	2.22	2	Penetrating injuries to head, neck, torso, and proximal extremities	69%	10%
Central California	134	1.81	1.5	Not Recorded | Penetrating injuries to head, neck, torso, and proximal extremities	50%	12%
Coastal Valleys	179	1.97	2	EMS Provider Judgment | Penetrating injuries to head, neck, torso, and proximal extremities	65%	8%
Contra Costa	387	1.79	2	Penetrating injuries to head, neck, torso, and proximal extremities	52%	8%
El Dorado	76	1.93	2	Not Applicable | Penetrating injuries to head, neck, torso, and proximal extremities	53%	13%
Inland Counties	617	1.89	2	Motorcycle Crash > 20 MPH | Not Applicable	55%	11%
Imperial	51	1.71	2	EMS Provider Judgment | Motorcycle Crash > 20 MPH | Not Recorded	55%	8%
Kern	282	1.73	1	Not Recorded | Penetrating injuries to head, neck, torso, and proximal extremities	42%	12%
Los Angeles	1,934	1.27	1	Glasgow Coma Score <= 13 | Not Recorded	24%	7%
Marin	97	1.45	1	Motorcycle Crash > 20 MPH | Not Applicable	34%	10%
Merced	39	2.08	2	Auto Crash: Significant intrusion (including roof): >12 inches occupant site; >18 inches any site; need for extrication | EMS Provider Judgment	77%	10%
Monterey	83	2.19	2	EMS Provider Judgment | Penetrating injuries to head, neck, torso, and proximal extremities	76%	16%
Mountain Counties	26	2.46	2	Auto Crash: Vehicle telemetry data consistent with severe injury | Not Recorded	73%	19%

LEMSA	Total Records	Average TTC Count	Median TTC Count	Most Common TTC	TTC 2 or More %	Severe Case %
Napa	21	1.38	1	Auto Crash: Significant intrusion (including roof): >12 inches occupant site; >18 inches any site; need for extrication	19%	14%
North Coast	93	1.91	2	EMS Provider Judgment | Penetrating injuries to head, neck, torso, and proximal extremities	61%	11%
Northern California	19	3.05	2	Age 10-64 years: SBP < 90 mmHg | EMS Provider Judgment | Penetrating injuries to head, neck, torso, and proximal extremities | Respiratory distress or need for respiratory support | Room-air pulse oximetry < 90% | Systolic Blood Pressure <90 mmHg	90%	21%
Orange	628	1.46	1	Not Applicable | Rider separated from transport vehicle with significant impact (eg, motorcycle, ATV, horse, etc.)	36%	12%
Riverside	890	2.14	2	EMS Provider Judgment | Glasgow Coma Score <= 13	74%	12%
Sacramento	545	1.8	1	Not Applicable | Penetrating injuries to head, neck, torso, and proximal extremities	50%	12%
San Benito	20	1.75	2	Motorcycle Crash > 20 MPH | Suspected pelvic fracture	60%	5%
San Diego	403	1.95	2	Motorcycle Crash > 20 MPH | Not Applicable	69%	8%
San Francisco	281	2.23	2	EMS Provider Judgment | Pedestrian/bicycle rider thrown, run over, or with significant impact	71%	14%
San Joaquin	256	1.81	2	EMS Provider Judgment | Penetrating injuries to head, neck, torso, and proximal extremities	59%	17%
San Luis Obispo	110	1.35	1	Glasgow Coma Score <= 13 | Not Applicable	24%	26%

LEMSA	Total Records	Average TTC Count	Median TTC Count	Most Common TTC	TTC 2 or More %	Severe Case %
San Mateo	71	2.3	2	EMS Provider Judgment | Penetrating injuries to head, neck, torso, and proximal extremities	82%	17%
Santa Barbara	128	1.57	1	Glasgow Coma Score <= 13	40%	9%
Santa Clara	756	1.71	2	Auto Crash: Significant intrusion (including roof): >12 inches occupant site; >18 inches any site; need for extrication	52%	7%
Santa Cruz	79	2.09	2	Not Applicable | Pedestrian/bicycle rider thrown, run over, or with significant impact	70%	4%
Sierra-Sacramento Valley	706	1.82	2	Auto Crash: Significant intrusion (including roof): >12 inches occupant site; >18 inches any site; need for extrication | Not Applicable	54%	9%
Solano	96	1.46	1	Glasgow Coma Score <= 13 | Not Recorded	35%	15%
Stanislaus	163	2.09	2	Auto Crash: Significant intrusion (including roof): >12 inches occupant site; >18 inches any site; need for extrication	70%	7%
Tuolumne	24	3.04	3	Crash Intrusion, including roof: > 12 in. occupant site; > 18 in. any site | Glasgow Coma Score <= 13 | Respiratory Rate <10 or >29 breaths per minute (<20 in infants aged <1 year) or need for ventilatory support | SBP < 110 for age > 65 | Systolic Blood Pressure <90 mmHg	96%	21%
Ventura	327	1.37	1	Glasgow Coma Score <= 13 | Not Recorded	28%	10%
Yolo	65	2.08	2	Fall from height > 10 feet (all ages)	69%	17%

This table explores trauma triage trends at the LEMSA level, focusing on TTC documentation, the frequency of multiple TTC being met, and the proportion of severe trauma cases. The findings illustrate regional variations in prehospital triage documentation and injury severity across California's EMS jurisdictions:

- LEMSAs with the highest average TTC counts, such as Northern California (3.05), Tuolumne (3.04), and Mountain Counties (2.46), suggest a greater number of triage criteria being met per patient. This may reflect a higher proportion of complex trauma cases, stronger EMS documentation practices, or local trauma system protocols that emphasize comprehensive triage documentation. Conversely, LEMSAs such as Los Angeles(1.27), San Luis Obispo(1.35), and Ventura (1.37) reported lower average TTC counts, which could indicate fewer documented triage criteria per case, variations in EMS provider assessment approaches, or differences in local triage protocols.

- The percentage of cases meeting two or more TTC varied significantly by LEMSA, with Tuolumne reporting the highest proportion (96%), followed by Northern California (90%) and San Mateo (82%). This may suggest that patients in these regions are more likely to present with multiple indicators of severe trauma, potentially necessitating advanced prehospital interventions and priority transport to high-level trauma centers. In contrast, Napa (19%), San Luis Obispo (24%) and Los Angeles (24%) reported lower rates, which may indicate fewer cases with multiple triage criteria met, regional differences in EMS provider documentation, or variations in patient presentation.
- The proportion of severe trauma cases (ISS ≥ 25) also differed across LEMSAs, with San Luis Obispo (26%), Northern California (21%), and Tuolumne (21%) reporting the highest percentages. This suggests that certain EMS jurisdictions may encounter a higher volume of critical trauma cases, potentially necessitating expanded trauma resources, refined triage protocols, or increased access to specialized trauma care. In contrast, Santa Cruz (4%), San Benito (5%), and Santa Clara (7%) reported lower severe trauma rates, which could reflect differences in patient populations, trauma mechanisms, or patterns of interfacility transport and trauma center utilization.

Implications for Trauma System Optimization

These findings underscore the regional variations in trauma triage documentation and injury severity, emphasizing the need for ongoing evaluation of EMS triage protocols across LEMSAs. The variability in TTC documentation and severe trauma proportions suggests opportunities for enhanced EMS training, improved triage standardization, and more targeted trauma resource allocation. By better understanding these regional trends, policymakers and EMS administrators can refine prehospital triage strategies to optimize trauma system performance and patient outcomes.

FIGURE 11: TRAUMA HOSPITAL REGION SUMMARY

Trauma Hospital Region	Total Cases	Average ISS	Median ISS	Severe Case (ISS ≥ 25) Percentage	ICU Admission Rate	Ventilator Use Rate
Bay Area Region	2,628	10	8	10%	20%	10%
Central California Region	611	13	10	11%	23%	16%
Northern California Region	1,948	12	10	11%	37%	14%
South Eastern California Region	1,879	11	9	10%	34%	17%
Southern Region	3,215	9	8	9%	28%	12%

This table analyzes trauma patterns across California's trauma hospital regions (see map in Appendix D, pg. 44), highlighting differences in injury severity, ICU admission rates, and ventilator use. The findings reveal regional variations that may be influenced by trauma system infrastructure, prehospital triage efficiency, and hospital capabilities.

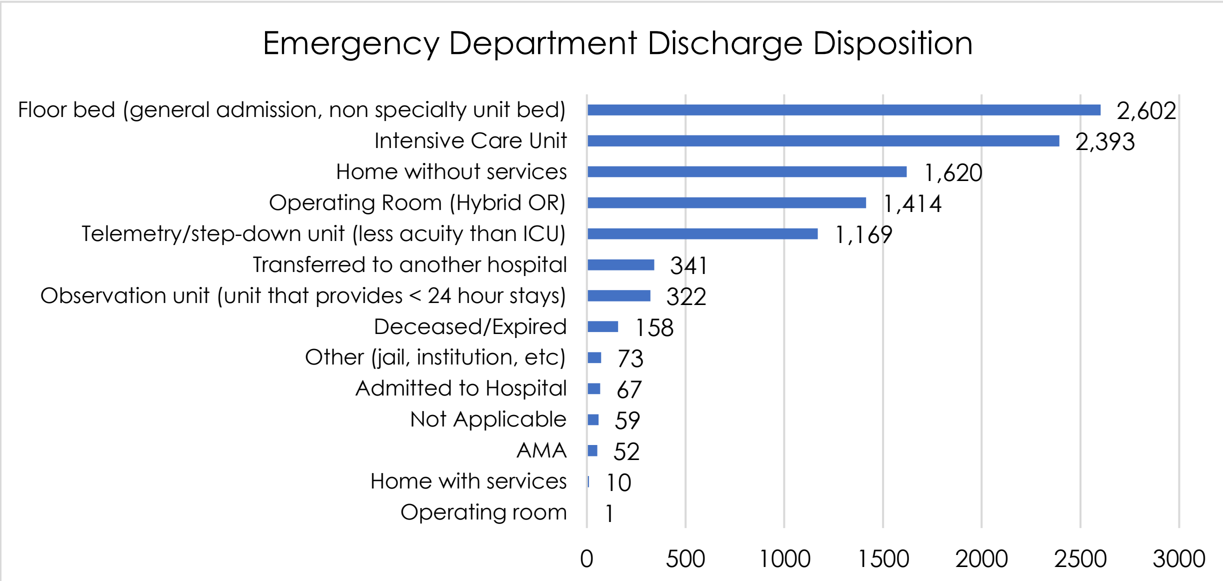
- The Southern Region (3,215 cases) and Bay Area Region (2,628 cases) reported the highest number of trauma cases, while Central California (611 cases) had the lowest. Despite handling the largest trauma volume, the Southern Region had the lowest average ISS (9), whereas Central California had the highest (13). The Northern California and Central California Regions had the highest proportion of severe trauma cases (11%), suggesting that certain areas experience a greater concentration of high-acuity injuries.
- ICU admission rates varied significantly across regions. The Northern California Region had the highest ICU admission rate (37%), followed by South Eastern California (34%), while the Bay Area (20%) and Southern Region (28%) reported the lowest. These disparities may reflect differences in trauma center capacity, hospital resource utilization, or variations in triage and patient management practices.
- Ventilator use rates also showed notable differences. The South Eastern California Region (17%) and Central California (16%) reported the highest rates of ventilator use, which may indicate a higher proportion of critically injured patients requiring respiratory support. The Bay Area Region (10%) and Southern Region (12%) had the lowest ventilator use rates, potentially reflecting differences in patient acuity or hospital treatment protocols.

These regional patterns provide insight into variations in trauma system performance, resource allocation, and patient outcomes. Future analyses may further explore the impact of geographic factors, transport times, ambulance patient off-load times and trauma center availability on critical care utilization.

Implications for Trauma System Planning

These findings illustrate regional differences in trauma severity and patient outcomes, emphasizing the need for continued evaluation of trauma system performance across the state. The higher severity of trauma cases and ICU admissions in Northern and South Eastern California may indicate a need for expanded trauma center resources, improved EMS triage protocols or documentation, or increased access to timely interventions. Additionally, the higher mortality rates in certain regions suggest potential disparities in prehospital care and hospital capacity, warranting further investigation into transport times, trauma activation criteria, and geographic accessibility of high-level trauma care. By understanding regional differences in trauma burden and patient outcomes, stakeholders can optimize resource allocation, strengthen prehospital triage accuracy, and enhance trauma system efficiency to improve survival rates and long-term recovery for trauma patients across California.

FIGURE 12: EMERGENCY DEPARTMENT DISCHARGE DISPOSITION

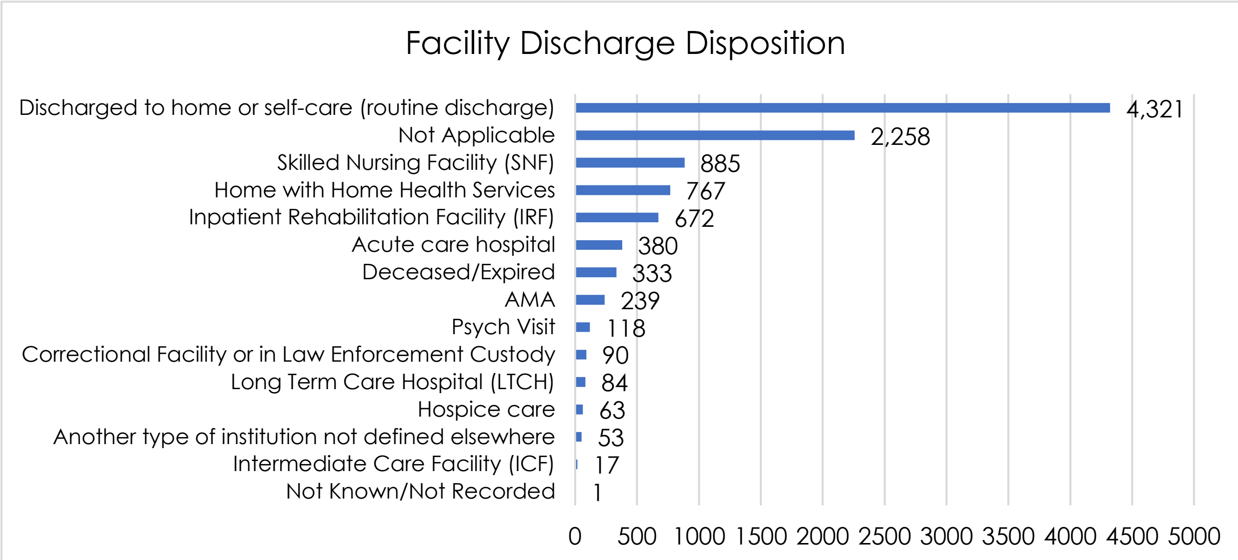


The Emergency Department (ED) discharge disposition bar chart highlights key patterns in how trauma patients are managed after initial hospital assessment. More than 50% of trauma patients required hospital admission, with 25% placed in a general hospital bed and 23% admitted to the ICU, reflecting the burden of high-acuity trauma cases that necessitate intensive monitoring, ventilatory support, or critical care interventions.

In contrast, 16% of patients were discharged home directly from the ED, suggesting that a significant subset of EMS-transported trauma cases were non-severe or had been stabilized effectively upon arrival. Meanwhile, 14% of trauma patients required immediate surgical intervention, emphasizing the importance of rapid trauma assessment and operating room (OR) activation for critical cases. Additionally, 11% of trauma patients were admitted to telemetry or step-down units, an intermediate level of care for patients who require continuous monitoring but do not need ICU-level intervention. This further supports that not all critical trauma cases require full ICU admission and that some can be effectively managed with intermediate care resources.

These findings provide critical insights into hospital resource allocation, trauma triage accuracy, and the downstream impact of EMS transport decisions on hospital patient flow. The high proportion of ICU and OR admissions highlight the importance of efficient prehospital triage, while the notable percentage of home discharges suggests opportunities for refining EMS field decision-making. Future analyses may further stratify these findings by ISS, trauma mechanism, or EMS transport mode to gain deeper insights into trauma system performance.

FIGURE 13: FACILITY DISCHARGE DISPOSITION



The Facility Discharge Disposition chart provides insights into post-hospital outcomes for trauma patients, illustrating patterns in recovery, long-term care needs, and rehabilitation utilization. The bar chart contains the distribution of discharge dispositions, showing that many trauma patients (42%) were discharged to home or self-care, indicating that a significant number of patients recovered sufficiently to leave the hospital without requiring additional medical support.

A notable 22% of cases were marked as "Not Applicable", which may include cases where patients left against medical advice but not documented accordingly, were transferred before a final disposition, or where documentation was incomplete. Beyond direct home discharges, 9% of patients were transferred to a skilled nursing facility (SNF), while 8% required home health services, suggesting that a portion of trauma patients needed continued medical support post-hospitalization. Additionally, 7% of patients were transferred to an inpatient rehabilitation facility (IRF), reflecting cases where patients required extended rehabilitation to regain functional independence following severe injuries.

These findings highlight the complexity of post-hospital care pathways for trauma patients, where some recover fully, while others require rehabilitation, skilled nursing, or home-based care. The relatively high proportion of SNF and IRF discharges underscores the need for comprehensive post-trauma care planning, particularly for patients with high ISS scores or long hospital stays. Further stratification by injury severity, trauma mechanism, or hospital length of stay could provide deeper insights into which patient populations are most likely to require long-term care or rehabilitation services.

DISCUSSION

MATCHED RECORDS

The relationship between trauma triage criteria (TTC) and injury severity score (ISS) was assessed using correlation analysis, non-parametric comparison, and categorical analysis tests in SAS to determine how well TTC predicts injury severity. ISS data are skewed, bounded, and sensitive to outliers. Most patients have low ISS scores, while fewer experience severe injuries, creating a right-skewed distribution. ISS is derived from predefined injury severity categories, causing gaps in the data rather than a continuous distribution. Due to these characteristics, standard statistical methods such as ANOVA and Pearson's correlation are inappropriate. Non-parametric tests, including the Spearman's rank correlation and Kruskal-Wallis test, were used because they are designed to handle skewed data.

Correlation Analysis

Spearman's rank correlation measures strength and direction of monotonic relationships between two variables. This means the test measures how closely two variables move together—whether they consistently increase or decrease together. It doesn't require the relationship to be linear or normally distributed. In this study, Spearman's rank correlation was initially used to evaluate the relationship between the total number of TTC met per patient and their ISS. The results showed a weak but statistically significant positive correlation ($\rho = 0.1902$, $p < 0.001$). The positive correlation coefficient (ρ) indicates the direction and strength of the relationship; in this case, the positive value shows that as patients meet more TTC, their ISS tends to increase. The p-value ($p < 0.001$) demonstrates that this observed relationship is statistically significant, meaning it's unlikely to be due to chance alone. However, the modest strength of the correlation ($\rho = 0.1902$) suggests that additional factors (e.g., mechanism of injury, comorbidities, pre-hospital interventions) may significantly contribute to variations in ISS.

The second Spearman's rank correlation analysis took a more detailed approach by splitting TTCs into individual variables per patient and analyzing each one separately against ISS for greater specificity. This allowed for a more precise measurement of each TTC's correlation with ISS. The coefficients (ρ values) indicate the strength of the relationship: values closer to 1 indicate stronger relationships, while values near 0 suggest weaker associations. Statistically significant p-values ($p < 0.001$) confirm these relationships are unlikely due to chance. The analysis identified physiological criteria as having the strongest relationships with ISS:

- Respiratory Rate <10 or >29 breaths per minute: $\rho = 0.141$ ($p < 0.001$)
- Glasgow Coma Score ≤ 13: $\rho = 0.127$ ($p < 0.001$)

- Respiratory distress or need for respiratory support: ρ = 0.121 ($p < 0.001$)
- Unable to follow commands (motor GCS < 6): ρ = 0.111 ($p < 0.001$)
- Room-air pulse oximetry < 90%: ρ = 0.095 ($p < 0.001$)
- Systolic Blood Pressure <90 mmHg: ρ = 0.082 ($p < 0.001$)

The findings from this test suggest that certain TTCs are associated with higher ISS values, but the strength of the correlation varies by TTC type. This does not mean the TTC causes higher ISS, only that patients who meet these criteria are more likely to have higher ISS scores. The refined Spearman analysis provides a more detailed understanding of how different TTC types contribute to identifying severe trauma cases. It suggests that prehospital triage systems should emphasize physiological criteria, as these are the strongest indicators of severe injury. Anatomic and mechanism-based criteria still hold value, but their predictive strength is lower compared to physiological indicators.

Non-Parametric Comparison

To further examine variations in ISS across TTC categories, a Kruskal-Wallis test was performed. The Kruskal-Wallis test is a nonparametric alternative to ANOVA used to evaluate differences among groups when data do not follow a normal distribution. In this study, it determines whether ISS scores significantly differ across groups defined by TTC. Specifically, the test assesses whether certain TTCs (such as GCS ≤ 13, respiratory distress, or abnormal respiratory rate) are associated with higher ISS. Instead of comparing average ISS scores, the test ranks all the ISS scores from lowest to highest and then looks at the average rank for each TTC group. If a group has a higher average rank, it generally means patients in that group had more severe injuries. This approach allows comparison between groups without assuming a normal distribution. A higher average rank means that, overall, patients in that TTC group tend to have higher ISS values, which translates to a higher median ISS (the middle value of the ranked scores). The Kruskal-Wallis test then determines whether these rank differences across TTC groups are statistically significant. The test statistic ($H = 2582.65$) measures how much the ranks differ between groups, with larger H values indicating greater variation in ISS across TTC categories. In this case, the high H value suggests substantial differences in injury severity among TTC groups. The small p-value ($p < 0.001$) confirms that these differences are highly unlikely to be due to chance. This finding reinforces the idea that patients meeting different TTC experience distinctly different levels of injury severity, emphasizing the clinical relevance of TTC categories in trauma triage.

Categorical Analysis

To further examine the relationship between TTC and ISS, a Chi-square test was conducted. This statistical test determines whether there is a significant association between two categorical variables by comparing observed data to what would be expected if no relationship existed. If no association were present, ISS severity (mild, moderate, severe) would be evenly distributed across different TTC counts, meaning patients with low, moderate, or high TTC counts would have similar proportions of injury severity. A significant result, however, suggests a meaningful connection rather than random variation. In this study, ISS severity was categorized into Mild (0–14), Moderate (15–24), and Severe (≥25). The Chi-square test assessed whether TTC count (the number of criteria met per patient) was associated with ISS severity. The analysis revealed a statistically significant association ($p < 0.001$), indicating that patients with higher TTC counts were more likely to have severe injuries than expected by chance. This finding reinforces the clinical importance of TTCs in trauma assessment, as a greater number of criteria met correlates with increased injury severity.

Given the statistically significant relationship between TTC count and injury severity identified through the Chi-square test, further analysis was conducted to quantify this association and assess its predictive value. Logistic regression was used to determine how strongly TTC count predicts the likelihood of severe trauma (ISS ≥ 25). Logistic regression predicts the likelihood that patients will fall into one of two outcome groups (e.g., severe vs. non-severe trauma) based on predictor variables. It provides an odds ratio (OR), which indicates how strongly a predictor variable is associated with the outcome. A univariate logistic regression model was utilized to evaluate whether the number of TTC met (TTC count) predicts severe trauma (ISS ≥ 25). Results indicated each additional TTC significantly increased the odds of severe trauma by 65% (OR = 1.65, $p < 0.001$). The odds ratio (OR = 1.65) means that each extra TTC a patient meets increases their likelihood of experiencing severe trauma by 65%, compared to patients meeting fewer criteria. The very small p-value ($p < 0.001$) confirms that this relationship between TTC count, and severe trauma is statistically significant and unlikely to be due to chance. This highlights TTC count as an effective tool in prehospital trauma triage for identifying patients at higher risk of severe injury.

Overall, the statistical analyses emphasize the clinical importance of physiological TTC in predicting severe injury, while underscoring that multiple factors contribute to injury severity. Future research should consider multivariable models incorporating additional patient and incident characteristics for more comprehensive trauma assessment.

UNMATCHED RECORDS

Handling Unmatched Records: Current Study Scope and Future Considerations
In this phase of the study, the analysis focused on matched records between CEMSIS and Patient Registry, without further evaluating unmatched cases. This decision was made to streamline the initial correlation and predictive analysis of TTC and ISS based on available linked data. However, it is acknowledged that the exclusion of unmatched records may introduce selection bias, as patients who could not be linked between datasets may differ systematically from those successfully matched. Certain subgroups, such as patients with incomplete documentation, interfacility transfers, or discrepancies in recorded identifiers, may be disproportionately omitted from the analysis. Additionally, without examining unmatched cases, it is difficult to estimate the false-negative rate, meaning there is no clear measure of how many records should have been linked but were not due to missing or inconsistent data fields. This could result in an underestimation of trauma incidence and severity, particularly if more severe cases were more likely to have incomplete or inaccurate identifiers.

Despite these limitations, focusing on matched records in this phase allows for a more controlled and methodologically sound approach, establishing a robust foundation for probabilistic matching before introducing the complexity of unlinked records. This approach also provides a clearer initial evaluation of TTC and ISS relationships, avoiding confounding effects from cases with uncertain linkages.

Future phases of this research may incorporate an analysis of unmatched records to assess their impact on data completeness and linkage accuracy. This could include a comparison of demographic and clinical characteristics between matched and unmatched cases to identify potential biases in the current dataset. Additionally, an assessment of false-negative rates may be conducted to determine how many records were excluded due to minor data inconsistencies. Based on these findings, refinements to record linkage methodologies could be developed and implemented to improve future match rates. Expanding the scope to include unmatched cases would support a more comprehensive evaluation of data, minimize the risk of selection bias and strengthen the overall validity of the study's conclusion.

LIMITATIONS

While this study provides valuable insights into probabilistic matching and trauma triage protocols, several limitations must be acknowledged:

1. **Data Quality and Completeness**
    - The CEMSIS database is a large convenience sample, consisting solely of data submitted by participating EMS providers. As it is not a population-based dataset, it is subject to various forms of bias, including selection bias, inconsistencies in clinical variable documentation, and inter-agency differences in treatment and transport practices.
    - CEMSIS also inherits deficiencies from its contributing agencies, including variability in data quality, inconsistent reporting, and missing data. While EMSA continually cleans and standardizes the data, errors persist due to limitations inherent in the original data sources.
    - Missing or incomplete patient identifiers (e.g., unique IDs, patient names, name variations, missing birthdates) may result in false positives (incorrect linkages) or false negatives (missed matches).
    - Variability in documentation practices across different LEMSAs and hospitals could introduce bias in data interpretation.
    - A lack of consistent documentation of patient demographics, gender, race, and other identifiers across EMS and hospital systems can result in linkage failures.
    - Partial system representation: not all EMS providers or designated trauma centers submit data to CEMSIS and Patient Registry respectively, which restricts data completeness and matching efforts.
    - Cases where ISS = 0. A subset of cases (n = 70) had an ISS of 0, despite all having documented TTC and recorded emergency department or facility discharge dispositions. Since ISS is derived from the abbreviated injury scale and is only calculated in the presence of injury, an ISS of 0 is typically not valid. These cases may be the result of data entry errors, minor injuries that were not scored, or missing ISS assessments despite trauma evaluation. While these cases were retained in the analysis, their inclusion may introduce some uncertainty in ISS-based comparisons. Future research should implement data validation processes to ensure accurate ISS recording and minimize inconsistencies in trauma severity assessment.

2. **Standardization and Variability in Trauma Triage Criteria**
    - Differences in how EMS providers document trauma triage criteria may impact the ability to accurately assess correlations with injury severity scores.
    - Poor documentation of key trauma-related variables, including:
        - eInjury.03 (Trauma Triage Criteria (High Risk for Serious Injury)
        - eInjury.04 (Trauma Triage Criteria (Moderate Risk for Serious Injury)
        - eDisposition.23 (Hospital Capability)

      These documentation gaps create barriers to identifying trauma patients transported to a trauma center.
    - The use of "not applicable" or "not recorded" values for TTC creates ambiguity, as it is unclear whether EMS providers are deliberately assessing and documenting these criteria or defaulting to them by omission. This uncertainty complicates the assessment of trauma triage performance and may result in the unintended exclusion or inclusion of relevant cases.
    - The transition of trauma triage criteria from the CDC to ACS guidelines implemented by LEMSAs in 2024 may also impact standardization, requiring EMS providers to adjust documentation practices accordingly.
    - Ongoing updates to the TRA-2 measure and NEMSIS data standard should improve data accuracy, consistency, and completeness.

3. **Matching Accuracy and Probabilistic Linkage Constraints**
    - Probabilistic matching assumes that key data elements (e.g., date of birth, incident date) are recorded correctly. However, errors such as transpositions, omissions, or inconsistent formatting can reduce linkage rates.
    - The fuzzy matching approach (±1 day) accounts for minor discrepancies in reported incident dates but may inadvertently introduce false linkages in cases where multiple trauma incidents occurred within a short timeframe or exclude valid records due to strict matching criteria (false negatives).
    - Minor discrepancies, such as misspellings in patient names (e.g., "Jon Doe" vs. "Jonathan Doe") or formatting variations in incident dates, can impact linkage accuracy.
    - Differences in documentation practices and ePCR coding across agencies and hospitals, multiple responding EMS agencies, and interfacility transfers can complicate data consistency, leading to duplicate or mismatched records.

4. **Limitations in Linking EMS and Hospital Trauma Records**
    - The retrospective study design limits outcome measures and available covariates since the data was not originally collected for this specific study.
    - The absence of common unique identifiers (e.g., patient names, social security numbers, electronic health record numbers) between CEMSIS and Patient Registry prevents the ability to perform deterministic matching.
    - Missing, inaccurate, or inconsistent data in CEMSIS and Patient Registry:
        - Date of birth inconsistencies impact linkage accuracy.
        - Variations in incident location, destination facility names, and injury descriptors further complicate the matching process.
    - ISS not included in NTDB data standard:
        - The injury severity score (ISS) is calculated using abbreviated injury scale (AIS) codes, which are included in the National Trauma Data Bank (NTDB). However, ISS is not a core data element in the NTDB, meaning variations in how trauma centers code and report ISS may impact its availability and comparability in this study.

5. **Temporal and Geographic Limitations**
    - The study includes data only from the first and second quarters of 2024, which may not capture seasonal variations in trauma incidence, patient volumes, or injury mechanisms.
    - Regional differences in EMS response times, trauma center accessibility, and injury patterns are not explicitly accounted for in the analysis, which may impact the interpretation of results.
    - In this analysis, ISS was stratified by LEMSA rather than by the level of receiving trauma center. This may affect interpretation, as lower-level trauma centers (e.g., Level III or IV) often receive less severely injured patients due to field triage protocols whereas more critical cases transport to higher-level centers (e.g., Level I or II), often in neighboring jurisdictions. As a result, counties served primarily by lower-level trauma centers may show lower average ISS, reflecting regional triage patterns rather than true injury severity differences. Future analyses will incorporate trauma center level to improve accuracy and contextual understanding.

6. **Scope and Relevance of Findings**
    - This study is limited to hospital data from Patient Registry, which only includes patients transported to designated trauma centers. As a

result, injured patients who were not taken to a trauma center are excluded. Additionally, the findings may not be generalizable to other states or EMS systems with different triage and transport protocols.

  - Findings may not be generalizable to individuals who experience delayed EMS activation due to regional or system-related factors.
  - Patients who arrived at a trauma center by methods other than ambulance (e.g., walk-ins, personal vehicle transport, law enforcement transport) were excluded, further limiting generalizability.

7. **Lack of Outcome Data Beyond Hospital Admission**
   - The dataset does not include long-term patient outcomes beyond the initial emergency department (ED), hospital admission and discharge disposition, limiting the ability to assess the full impact of EMS triage decisions on recovery and mortality.

RECOMMENDATIONS

Establishing a Quality Improvement (QI) Project

To enhance data linkage accuracy, trauma triage documentation, and EMS system performance, EMSA recommends the establishment of a QI project focused on improving data standardization, probabilistic matching methodologies, and overall data integration between EMS and hospital trauma databases. This QI project will aim to implement structured interventions to address the challenges identified in this study. EMSA recommends that the Executive Data Advisory Group (EDAG) be engaged in developing QI projects to address:

- Enhancing Data Standardization and Quality Control
- Improving Probabilistic Matching Techniques
- Increasing Data Completeness and Unique Identifiers
- Refining Trauma Triage Criteria Documentation

By implementing comprehensive recommendations through a structured QI project, EMS agencies, trauma centers, and data specialists can improve data quality, linkage success rates, and the effectiveness of trauma triage systems. These improvements will contribute to better patient care, more reliable research, and high-quality trauma system performance across California.

CONCLUSION

This study aimed to evaluate the effectiveness of probabilistic matching in linking EMS and hospital trauma records, assess the correlation between EMS-documented TTC and hospital-reported ISS, and determine how prehospital triage influences patient outcomes and transport decisions. By integrating data from CEMSIS and Patient Registry, this research provides valuable insights into the accuracy of EMS triage and its role in identifying patients with severe injuries.

A total of 22,745 CEMSIS records were included after data cleaning and validation, of which 10,281 records (45.2%) were successfully matched to hospital trauma records. This match rate highlights both the feasibility of probabilistic linkage, and the challenges associated with data integration due to documentation inconsistencies and missing data.

Key Findings

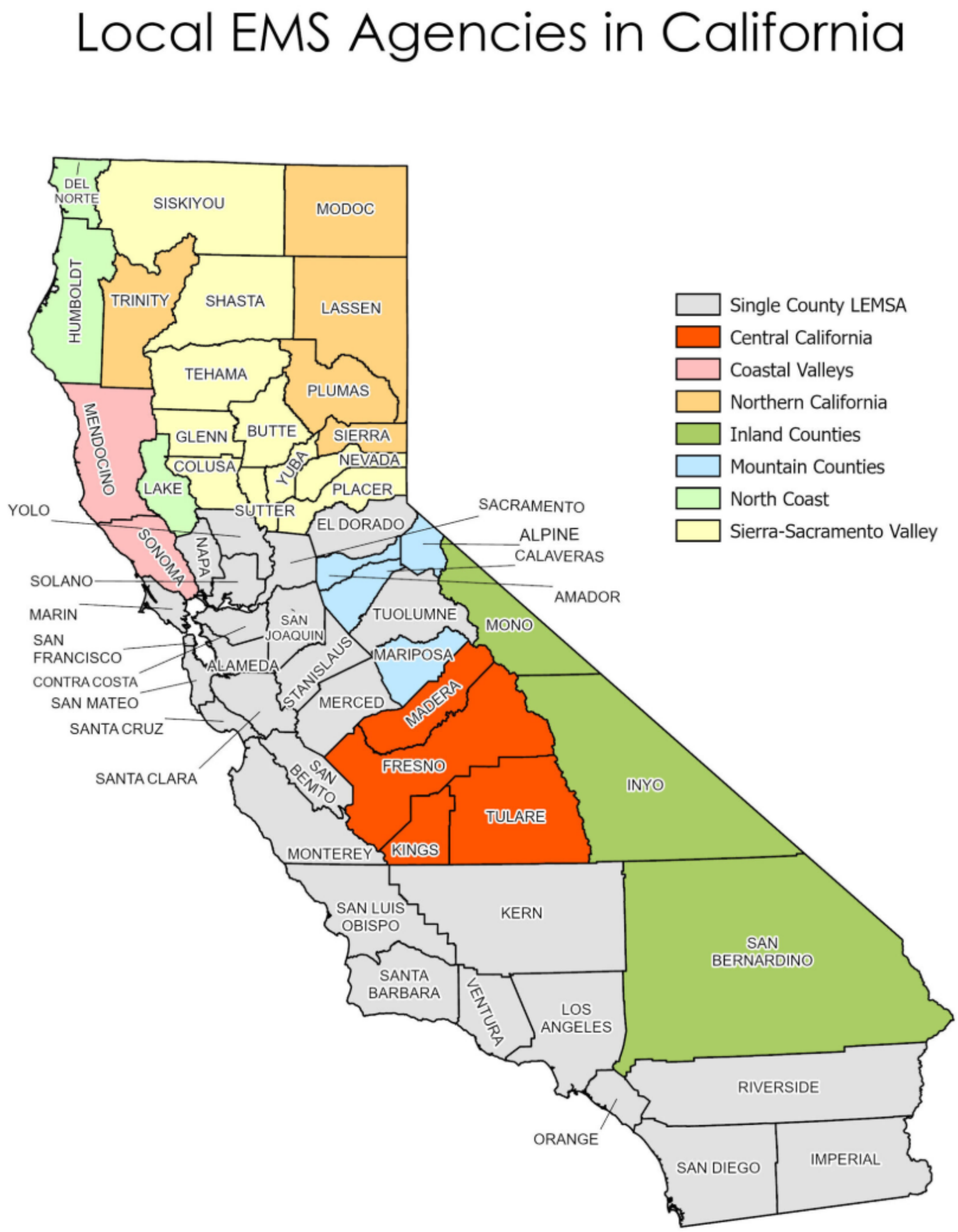
- The results demonstrate the utility of probabilistic matching in trauma data integration, allowing for a more comprehensive understanding of trauma patient outcomes. The study identified several trends:
    - Physiological criteria, particularly abnormal vital signs and neurological impairment (e.g., Glasgow Coma Score ≤ 13), were the strongest predictors of severe trauma.
    - While TTC count was statistically correlated with ISS, the association was relatively weak, suggesting that TTC alone does not fully capture injury severity.
    - Higher TTC counts were associated with increased ISS, but variability remained, indicating the need for additional predictive factors such as mechanism of injury, comorbidities, and prehospital interventions.
    - ICU admission and ventilator use rates increased with higher ISS categories, reinforcing the reliability of ISS as a marker for hospital resource utilization.
    - Regional and LEMSA-level variations in TTC documentation and patient outcomes suggest differences in triage application, EMS transport practices, and documentation across jurisdictions.

Despite methodological advancements, challenges such as documentation inconsistencies, missing data, and variations in data entry impacted the overall match rate. These limitations highlight the need for ongoing refinement of data linkage strategies, including enhanced standardization across EMS and hospital data systems. Future efforts should focus on improving data quality and exploring additional matching algorithms to increase linkage accuracy and expand research applications.

The insights gained from this study support continuous improvement in EMS and trauma care by reinforcing data-driven decision-making. Strengthening the integration between prehospital and hospital datasets enhances patient care coordination, facilitates outcome tracking, and ultimately improves trauma system performance leading to improved patient outcomes. Further research should expand upon these findings to explore broader applications of data linkage in emergency medical services and public health, ensuring that prehospital care is continuously refined to improve patient care and healthcare resource allocation.

APPENDIX

A. LEMSA MAP



B. TRA-2: TRANSPORT OF TRAUMA PATIENTS TO A TRAUMA CENTER 2024

Data Element	Operator	Value
eResponse.05 Response Type of Service Requested	Is in AND	2205001 Emergency Response (Primary Response Area) 2205003 Emergency Response (Intercept) 2205009 Emergency Response (Mutual Aid)
eDisposition.30 Transport Disposition	Is in AND	4230001 Transport by This EMS Unit (This Crew Only) 4230003 Transport by This EMS Unit, with a Member of Another Crew 4230005 Transport by Another EMS Unit 4230007 Transport by Another EMS Unit, with a Member of This Crew
eResponse.07 Unit Transport and Equipment Capability	Is in AND	2207011 Air Transport-Helicopter 2207013 Air Transport-Fixed Wing 2207015 Ground Transport (ALS Equipped) 2207017 Ground Transport (BLS Equipped) 2207019 Ground Transport (Critical Care Equipped)
eInjury.03 Trauma Triage Criteria (High Risk for Serious Injury)	Has one or more which is in OR	2903001 Amputation proximal to wrist or ankle 2903003 Crushed, degloved, mangled, or pulseless extremity 2903005 Chest wall instability, deformity, or suspected flail chest 2903007 Glasgow Coma Score <= 13 (DEPRECATED) 2903009 Skull deformity, suspected skull fracture 2903011 Paralysis (DEPRECATED) 2903013 Suspected pelvic fracture 2903015 Penetrating injuries to head, neck, torso, and proximal extremities 2903017 Respiratory Rate <10 or >29 breaths per minute (<20 in infants aged <1 year) or need for ventilatory support (DEPRECATED) 2903019 Systolic Blood Pressure <90 mmHg (DEPRECATED) 2903021 Suspected fracture of two or more proximal long bones 2903023 Active bleeding requiring a tourniquet or wound packing with continuous pressure 2903025 Age >= 10 years: HR > SBP 2903027 Age >= 65 years: SBP < 110 mmHg 2903029 Age 0-9 years: SBP < 70mm Hg + (2 x age in years) 2903031 Age 10-64 years: SBP < 90 mmHg 2903033 Respiratory distress or need for respiratory support 2903035 Room-air pulse oximetry < 90% 2903037 RR < 10 or > 29 breaths/min 2903039 Suspected spinal injury with new motor or sensory loss 2903041 Unable to follow commands (motor GCS < 6)
eInjury.04 Trauma Triage Criteria (Moderate Risk for Serious Injury)	Has one or more which is in AND	2904001 Pedestrian/bicycle rider thrown, run over, or with significant impact 2904003 Fall Adults: > 20 ft. (one story is equal to 10 ft.) (DEPRECATED) 2904005 Fall Children: > 10 ft. or 2-3 times the height of the child (DEPRECATED) 2904007 Auto Crash: Death in passenger compartment 2904009 Auto Crash: Partial or complete ejection 2904011 Auto Crash: Significant intrusion (including roof): >12 inches occupant site; >18 inches any site; need for extrication 2904013 Auto Crash: Vehicle telemetry data consistent with severe injury 2904015 Motorcycle Crash > 20 MPH (DEPRECATED) 2904029 Auto Crash: Child (age 0-9 years) unrestrained or in unsecured child safety seat 2904031 Fall from height > 10 feet (all ages) 2904035 Rider separated from transport vehicle with significant impact (e.g., motorcycle, ATV, horse, etc.)
eDisposition.23 Hospitability Capability	Is in OR	9908021 Trauma Center Level 1 9908023 Trauma Center Level 2 9908025 Trauma Center Level 3 9908027 Trauma Center Level 4
eDisposition.02 Destination/Transferred To, Code	Is in	Refer to the California designated trauma center code list in appendix A

C. ACS NATIONAL GUIDELINES FOR THE FIELD TRIAGE OF INJURED PATIENTS

National Guideline for the Field Triage of Injured Patients

RED CRITERIA

High Risk for Serious Injury

Injury Patterns

- Penetrating injuries to head, neck, torso, and proximal extremities
- Skull deformity, suspected skull fracture
- Suspected spinal injury with new motor or sensory loss
- Chest wall instability, deformity, or suspected flail chest
- Suspected pelvic fracture
- Suspected fracture of two or more proximal long bones
- Crushed, degloved, mangled, or pulseless extremity
- Amputation proximal to wrist or ankle
- Active bleeding requiring a tourniquet or wound packing with continuous pressure

Mental Status & Vital Signs

All Patients

- Unable to follow commands (motor GCS < 6)
- RR < 10 or > 29 breaths/min
- Respiratory distress or need for respiratory support
- Room-air pulse oximetry < 90%

Age 0-9 years

- SBP < 70mm Hg + (2 x age in years)

Age 10-64 years

- SBP < 90 mmHg or
- HR > SBP

Age ≥ 65 years

- SBP < 110 mmHg or
- HR > SBP

Patients meeting any one of the above RED criteria should be transported to the highest-level trauma center available within the geographic constraints of the regional trauma system

YELLOW CRITERIA

Moderate Risk for Serious Injury

Mechanism of Injury

- High-Risk Auto Crash
  - Partial or complete ejection
  - Significant intrusion (including roof)
    - >12 inches occupant site OR
    - >18 inches any site OR
    - Need for extrication for entrapped patient
  - Death in passenger compartment
  - Child (age 0-9 years) unrestrained or in unsecured child safety seat
  - Vehicle telemetry data consistent with severe injury
- Rider separated from transport vehicle with significant impact (eg, motorcycle, ATV, horse, etc.)
- Pedestrian/bicycle rider thrown, run over, or with significant impact
- Fall from height > 10 feet (all ages)

EMS Judgment

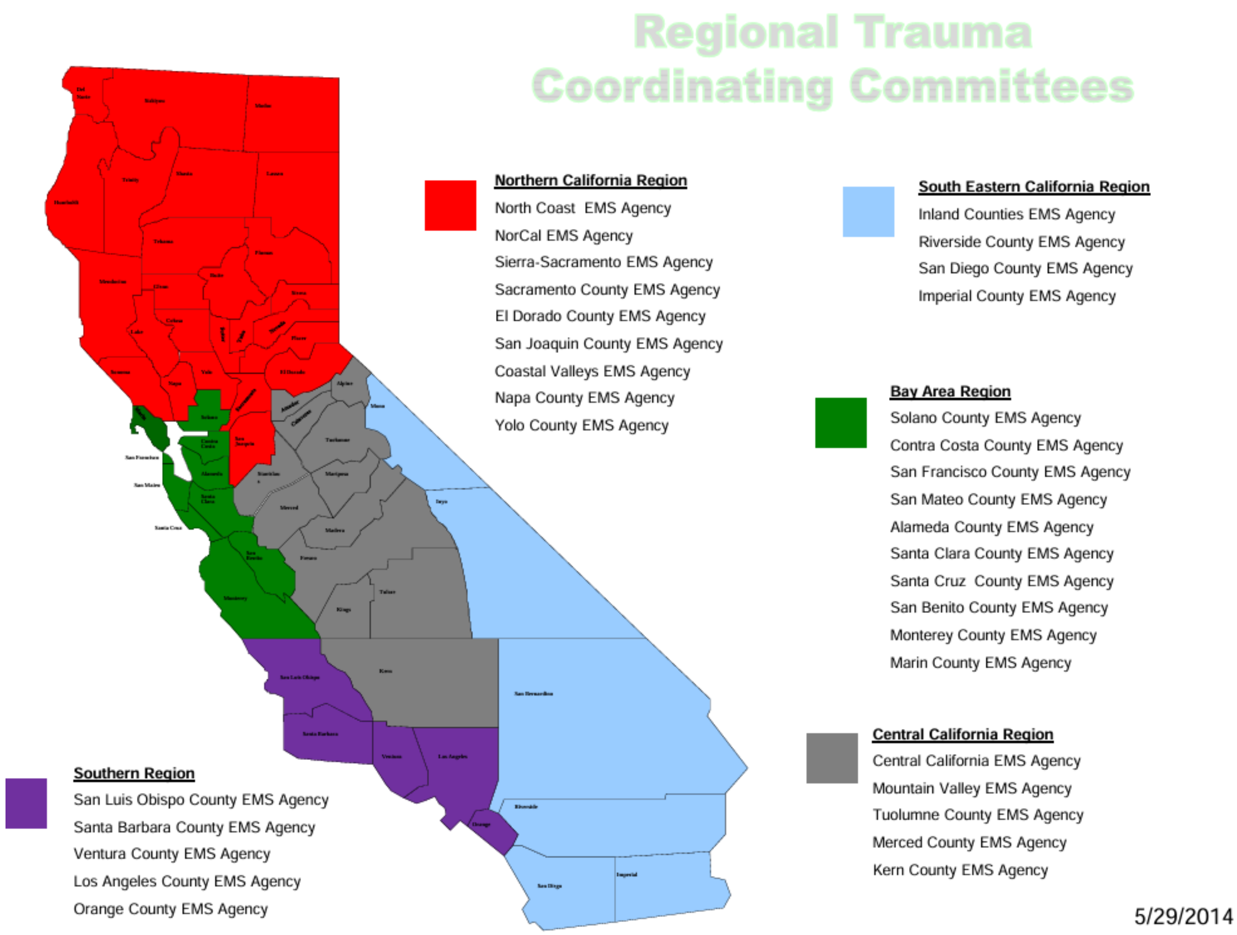
Consider risk factors, including:

- Low-level falls in young children (age ≤ 5 years) or older adults (age ≥ 65 years) with significant head impact
- Anticoagulant use
- Suspicion of child abuse
- Special, high-resource healthcare needs
- Pregnancy > 20 weeks
- Burns in conjunction with trauma
- Children should be triaged preferentially to pediatric capable centers

If concerned, take to a trauma center

Patients meeting any one of the YELLOW CRITERIA WHO DO NOT MEET RED CRITERIA should be preferentially transported to a trauma center, as available within the geographic constraints of the regional trauma system (need not be the highest-level trauma center)

D. REGIONAL TRAUMA COORDINATING COMMITTEE MAP



E. DATA LINKAGE INITIATIVE REPORTS

Other published data linkage reports by EMSA are accessible here (descending order):

- May 2024 – California Emergency Medical Services Information System and Trauma Data Linkage Initiative (Published May 2024) (pdf)
- June 2023 – California Emergency Medical Services Information System and Trauma Data Linkage Initiative (Published June 2023) (pdf)
- June 2022 – California Emergency Medical Services Information System and Trauma Data Linkage Initiative (Published June 2022) (pdf)
- October 2020 – California Emergency Medical Services Information System and Trauma Data Linkage Initiative (Published October 2020) (pdf)

F. REFERENCE

- **California Emergency Medical Services Information System (CEMSIS) – EMSA**
  Provides comprehensive data collection from EMS providers in California.

- **Quality Improvement – EMSA**
  Focuses on enhancing the quality of EMS services through continuous improvement initiatives, including the Core Quality Measures Project.

- **California Trauma System – EMS**
  The EMS Authority provides statewide coordination and leadership for the planning, development, and implementation of a State Trauma Plan.

- **National EMS Information System (NEMSIS)**
  A national repository for EMS data to improve patient care and EMS systems.

- **National EMS Quality Alliance (NEMSQA)**
  Dedicated to developing and promoting EMS performance measures.

- **American College of Surgeons National Trauma Data Bank (ACS NTDB)**
  The largest aggregation of U.S. trauma registry data, aiming to improve trauma care.

- **American College of Surgeons Trauma Centers**
  Information on ACS verified trauma centers committed to providing optimal care.

- **American College of Surgeons National Guidelines for the Field Triage of Injured Patients**
  The 2021 National Guidelines for the Field Triage of Injured Patients.