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Association between prehospital time and injury severity in traffic crash patients

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ABSTRACT

This study aimed to examine the association between on-scene time and trauma severity, with particular attention to differences across age groups and anatomical injury regions among patients injured in traffic crashes. We conducted a retrospective cohort study by linking emergency medical services (EMS) prehospital records with hospital-based trauma registry data from a single Level 1 trauma centre in metropolitan Taipei between 2016 and 2022. Traffic crash patients transported by EMS were included. Prehospital time was disaggregated into response time, on-scene time, and transport time. Injury severity was assessed using the Injury Severity Score (ISS), with ISS $\geq$ 9 defined as severe injury. Multivariable logistic regression models were used to evaluate associations between prehospital time components and injury severity. Additional analyses were stratified by age group and anatomical injury region. Among 5,022 patients, 1,858 (37.0%) sustained severe injuries. Longer on-scene time was strongly associated with higher injury severity; each additional minute on scene was associated with a 10.1% increase in the odds of severe injury (adjusted odds ratio [AOR] = 1.101; 95% CI, 1.085–1.117). Older age, poor consciousness, pedestrian involvement, and late-night crashes were also associated with severe injury. Age- and region-stratified analyses demonstrated consistent associations between longer on-scene time and higher severity (AIS $\geq$ 3) for head, thoracic, abdominal, and extremity injuries, with more pronounced associations among older adults. Longer on-scene time is closely associated with trauma severity and likely reflects greater injury complexity and patient acuity rather than a direct causal effect. Given the observational nature of this study, the findings should be interpreted cautiously and may be influenced by reverse causation and confounding by indication. These results highlight the importance of early severity recognition, appropriate triage, and minimizing avoidable delays while ensuring essential life-saving interventions in prehospital trauma care.

1. Introduction

Crash-related injuries are a leading cause of death worldwide. According to the World Health Organization (WHO), approximately 4.4 million people die each year from such injuries, with one-third of these fatalities resulting from road traffic crashes. (World Health Organization, 2023) Traffic crashes not only cause considerable losses for individuals and families but also impose a global economic burden of

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billions of dollars annually, with the associated costs including health care costs, labour losses, and law enforcement expenses. (World Health Organization, 2023) In Taiwan, traffic crashes account for over 40% of injury deaths, contributing to approximately 7,000 fatalities annually. (Ministry of Health and Welfare 2024).

Prehospital emergency medical services (EMS) play a critical role in trauma care by providing early resuscitation and timely transport of injured patients to medical facilities (Boyd and Cowley 1983). Prehospital time is commonly conceptualised as a multidimensional construct comprising response time, on-scene time, and transport time, and has long been recognised as an important EMS parameter influencing trauma outcomes (Chen et al. 2020). Increasing evidence suggests that these time components represent distinct operational and clinical processes and may exert differential effects on injury severity and patient prognosis, underscoring the importance of disaggregating prehospital time rather than relying solely on total prehospital duration.

Several studies support an association between shorter prehospital time—particularly response and transport intervals—and improved outcomes. Using data from the U.S. Fatality Analysis Reporting System, Lee et al. decomposed EMS time into reporting time, response time, and transport-related intervals and applied a random-effects ordered probit model to evaluate injury severity (Lee et al. 2018). Their findings demonstrated that longer response time and longer combined on-scene/transport time were significantly associated with higher injury severity, whereas reporting time showed no significant effect, suggesting that delays occurring after dispatch may be more relevant to injury outcomes than crash reporting itself. Consistent with these findings, population-based studies from Quebec, Canada, reported that shorter total prehospital time was associated with lower mortality risk; specifically, total prehospital time exceeding 60 min was linked to significantly increased mortality, and subsequent analyses confirmed that this association persisted after adjustment for injury severity and patient age (Sampalis et al. 1993, Sampalis et al. 1999). More recent registry-based and cohort studies have further supported the importance of timely EMS response and transport, demonstrating that delayed response and prolonged transport are associated with worse survival or increased injury severity in selected trauma populations (Harmsen et al. 2015, Waalwijk et al. 2022, Siripakarn et al. 2023). In particular, contemporary analyses have shown that each one-minute increase in EMS response time is associated with a measurable increase in crash fatality risk, with recent estimates indicating a 2.6% increase in fatality odds per minute of delay (Huang et al. 2024).

In contrast, the relationship between on-scene time and outcomes appears more complex and context dependent. From a system-efficiency perspective, limiting on-scene time is considered desirable for high-acuity trauma cases and may improve EMS resource availability (Vincent-Lambert and Mottershaw 2018). Several studies have suggested that prolonged on-scene time may be detrimental, reporting increased mortality or severe complications when scene times exceed 10 min, particularly in the absence of clear medical justification (Krost et al. 2006, Siripakarn et al. 2023). These findings support a rapid transport approach in selected patient populations.

However, other investigations have challenged the notion that shorter on-scene time is universally beneficial. Systematic reviews and multicentre analyses have shown that although shorter response and transport times are generally associated with improved survival, extended on-scene time may, in certain contexts, reflect appropriate stabilisation, extrication, or advanced prehospital interventions rather than avoidable delay (Harmsen et al. 2015). A large prospective cohort study involving 146 EMS agencies and 51 trauma centres in North America found no association between EMS time intervals and in-hospital mortality among trauma patients with physiological abnormalities, with consistent results across injury types, age groups, and transport modes (Newgard et al. 2010). Moreover, evidence suggests that relatively few trauma patients require immediate hospital transport or consistently benefit from faster transport speeds (Di Bartolomeo et al. 2007, Stiell et al. 2008, Newgard et al. 2010, Kleber et al. 2013). Supporting this concept, moderate on-scene times of approximately 9–16 min were associated with the highest survival rates among ICU-admitted trauma patients, consistent with an “optimal” rather than “minimal” on-scene time framework (Van et al. 2022). Analyses from Japan’s national trauma registry further illustrated this trade-off, showing that physician-staffed ambulances—while capable of advanced interventions—were associated with longer prehospital times and higher mortality, particularly among hypotensive trauma patients (Siripakarn et al. 2023).

The impact of prehospital time also varies by injury mechanism. In patients with penetrating trauma, both response time and on-scene time have been independently associated with in-hospital mortality, and some studies have suggested that a shorter pre-response interval combined with a “scoop and run” strategy may be beneficial (McCutcheon et al., 2025; Nasser et al., 2020). In urban settings, EMS transport has not consistently demonstrated a survival advantage over nonmedical transport, such as police vehicles, when shorter injury-to-hospital times outweigh the benefits of prehospital interventions (McCutcheon et al., 2025).

Overall, existing evidence indicates that the effects of prehospital time on injury severity and outcomes are heterogeneous and strongly influenced by trauma type and baseline severity. Trauma severity and prehospital time jointly determine patient outcomes, and sensitivity to prehospital time appears to vary across severity strata (Sampalis et al. 1993). Although modern trauma systems are designed to minimise prehospital time to optimise outcomes, current evidence remains inconclusive regarding the relationship between time to definitive treatment and mortality, highlighting the need for context-specific and component-based evaluation of prehospital time (Waalwijk et al. 2022).

In summary, research has obtained conflicting findings regarding the effect of shorter prehospital time on outcomes for various trauma severity levels. The effect of on-scene time on trauma severity has received limited scholarly attention. This study focuses on the relationship between on-scene time and trauma severity, with particular attention to how this association varies across different age groups and anatomical injury regions.

2. Methods

2.1. Data sources

Metropolitan Taipei has 41 administrative districts and 17 Level 1 trauma centres. In Taiwan, Level 1 trauma centres are government-designated tertiary hospitals that provide 24-hour comprehensive trauma care, including immediate availability of trauma surgeons, emergency physicians, anaesthesiologists, and advanced surgical and critical care services. Each centre receives trauma patients from its own district as well as neighbouring districts.

This study used two complementary data sources: an EMS prehospital database and a single hospital-based trauma registry dataset. The EMS prehospital database includes records of all trauma patients transported to hospitals by EMS personnel. The database captures comprehensive prehospital information, including injury mechanisms (such as traffic crashes, falls, stab wounds, and gunshot injuries), event cause and time, emergency medical technician (EMT) response time, on-scene time, transport time to hospital, and prehospital vital signs.

The hospital-based trauma registry is maintained by trained trauma registrars and contains standardised records for all patients treated at the trauma centre, including those managed in the emergency department. This hospital dataset systematically records patient demographic characteristics (e.g., sex and age), details of in-hospital treatment, length of hospital stay, final injury diagnoses, and corresponding trauma severity scores.

2.2. Data linkage

The EMS prehospital database and the hospital-based trauma registry were linked at the individual patient level using a unique patient identification number assigned within the trauma system. This identifier enabled direct linkage of prehospital EMS records with corresponding hospital trauma registry records, thereby constructing a unified dataset covering both the prehospital and in-hospital phases of trauma care.

Following successful linkage, all personal identifiers were removed, and the analytic dataset was fully de-identified prior to analysis to ensure patient confidentiality. Records that could not be reliably linked between the EMS and hospital datasets were excluded from the final study cohort. This linkage approach allowed for accurate integration of prehospital time intervals with in-hospital injury severity measures while maintaining compliance with data protection and privacy requirements.

Traffic crash cases were identified from the hospital-based trauma registry using ICD-10 external cause-of-injury codes V01–V89, which define land transport crashes involving pedestrians, cyclists, motorcyclists, and motor vehicle occupants. After excluding injuries unrelated to traffic crashes and records with missing data, a total of 5,022 patients transported to hospitals by EMS personnel were included in the final analytic cohort.

This study was approved by the Institutional Review Board of Shin Kong Wu Ho-Su Memorial Hospital (Approval No. 20230727R) and the Taipei City Fire Department, and was conducted as a retrospective database analysis.

Fig. 1 Sample selection flowchart based on combined data from the Metropolitan Taipei Fire Department's EMT prehospital records and the trauma registry of a single Level 1 trauma centre for 2016 to 2022.

2.3. Definition of variables

Patient age was categorised into the following groups: child (0–17 years), young adult (18–40 years), middle adult (41–64 years), and older adult (65 years and above). Traffic crashes were categorised as occurring

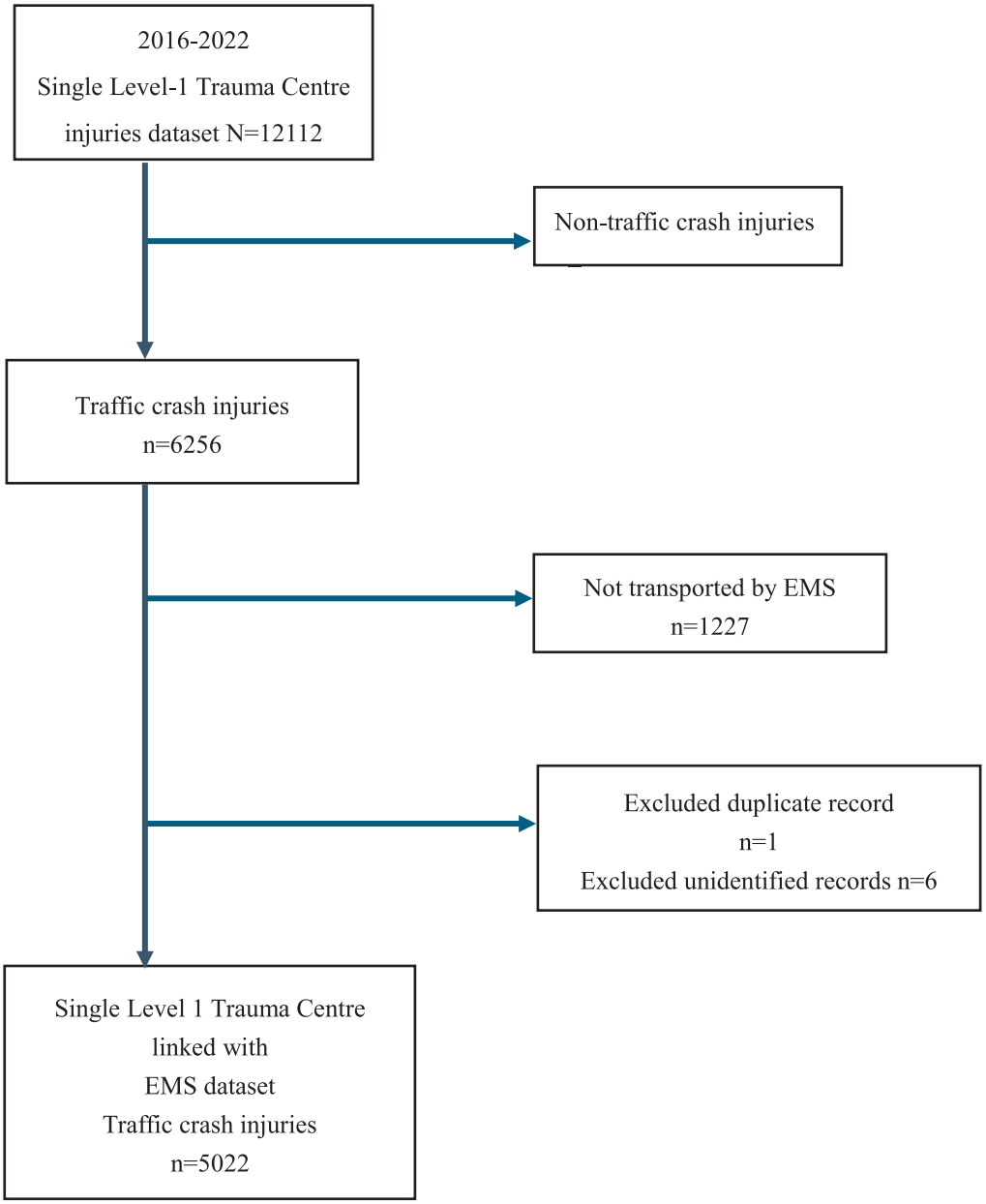

Fig. 1. Sample selection flowchart.

during rush hours (morning peak of 06:00-08:59 and evening peak of 17:00-19:59), nonrush hours (09:00-16:59), evening (20:00-23:59), or late night (0:00–05:59). Prehospital time was divided into response time (duration from the EMT dispatch notification to arrival at the scene), on-scene time (duration from EMT arrival at the scene to departure), and transport time (duration from departure from the scene to arrival at the hospital). The distribution of response time showed a mean of 5.14 min, a mode of 4 min, and a median of 5 min. The on-scene time had a mean of 8.82 min, a mode of 7 min, and a median of 8 min, while transport time demonstrated a mean of 6.9 min, a mode of 4 min, and a median of 6 min. Based on these distributions, the modal values of each time interval were used as the cut-off points for grouping in Table 1. Given the right-skewed distributions, modal values were used as cut-off points because they best represent the most frequently observed prehospital time intervals and are less influenced by extreme values.

Injury severity was assessed based on the Injury Severity Score (ISS), which was derived from the Abbreviated Injury Scale (AIS). The AIS is a globally recognised injury severity scoring system grounded in anatomical assessment that classifies an individual's injuries on the basis of the affected body region (Baker et al., 1974; Association for the Advancement of Automotive Medicine, 2016). Practitioners use the AIS system to categorise injuries anatomically and rank them on a scale from 1 (minor) to 6 (unsurvivable); injuries with a score of 3 or greater are considered serious. The classification accounts for structural damage, physiological derangements, and life-threatening factors. The highest AIS score for each body region is squared to form the basis of the ISS, which is calculated by summing the squared AIS scores from the 3 most severely injured body regions. A higher ISS indicates more severe injuries. In this study, we defined ISS $\geq$ 9 as indicative of severe injury. Poor level of consciousness was defined as a Glasgow Coma Scale (GCS) score $<$ 12 at initial assessment. This study adopted ISS $\geq$ 9 as the definition of severe trauma, primarily because in prehospital research, patients with ISS scores of 9–15 already represent clinically significant injuries and frequently require EMS intervention and trauma-related resources. Compared with the conventional threshold of ISS $\geq$ 16, the use of ISS $\geq$ 9 better reflects real-world EMS practice and avoids issues related to small sample size and limited statistical power.

The ISS and AIS were already recorded in the hospital trauma registry as part of the patients' medical records. Patients with ISS $\geq$ 9 accounted for 37% of the study population. Regarding AIS $\geq$ 3 injuries, the distribution by body region was 12.8% for the head, 7.8% for the chest, 2.4% for the abdomen, and 20.7% for the extremities.

2.4. Statistical analysis

We described the distribution of injury severity in traffic crashes according to a set of independent variables (Table 1). Chi-square tests were performed to examine the relationships between the independent variables and injury severity. Variables that showed statistically significant associations with severe injury were then entered into a stepwise logistic regression model to construct the multivariable model presented in Table 2. Adjusted models included covariates such as age, sex,

Table 1
Distribution of severity of traffic crash injuries and independent variables.

		Trauma Severity		
Variable	**N (%)**	**Slight**	**Severe**	***p***
		n (%)	**n (%)**	
Total	**5022**	**3164 (63%)**	**1858 (37%)**	
Sex				0.077
Male	2876(57.3%)	1782(62.0%)	1094(38.0%)	
Female	2146(42.7%)	1382(64.4%)	764(35.6%)	
Age (years)				<0.05
≦17	192(3.8%)	137(71.4%)	55(28.6%)	
18–40	2350(46.8%)	1739(74.0%)	611(26.0%)	
41–64	1591(31.7%)	899(56.5%)	692(43.5%)	
≧65	889(17.7%)	389(43.8%)	500(56.2%)	
GCS				<0.05
<12	291(5.8%)	26(8.9%)	265(91.1%)	
≧12	4731(94.2%)	3138(66.3%)	1593(33.7%)	
Vehicles				<0.05
Motorcycles	4058(80.8%)	2669(65.8%)	1389(34.2%)	
Pedestrians	452(9.0%)	205(45.4%)	247(54.6%)	
Bicycles	372(7.4%)	210(56.5%)	162(43.5%)	
Cars	140(2.8%)	80(57.1%)	60(42.9%)	
EMS Time(minute)				
Response time				<0.05
≦4	2398(47.7%)	1564(65.2%)	834(34.8%)	
>4	2624(52.3%)	1600(61.0%)	1024(39.0%)	
On-scene time				<0.05
≦7	2169(43.2%)	1619(74.6%)	550(25.4%)	
>7	2853(56.8%)	1545(54.2%)	1308(45.8%)	
Transport time				<0.05
≦4	1594(31.8%)	1093(68.6%)	501(31.4%)	
>4	3428(68.2%)	2071(60.4%)	1357(39.6%)	
Prehospital time				<0.05
0–10	161(3.2%)	143(88.8%)	18(11.2%)	
11–20	2536(50.5%)	1827(72.0%)	709(28.0%)	
21–30	1841(36.7%)	957(52.0%)	884(48.0%)	
>30	484(9.6%)	237(49.0%)	247(51.0%)	
Crash Time				<0.05
Late-night (0:00–05:59)	405(8.1%)	217(53.6%)	188(46.4%)	
Rush (06:00–08:59,17:00–19:59)	1668(33.2%)	1031(61.8%)	760(38.2%)	
Nonrush (09:00–16:59)	2200(43.8%)	1419(64.5%)	658(35.5%)	
Evening (20:00–23:59)	749(14.9%)	497(66.4%)	252(33.6%)	

Severe injury: ISS ≧ 9.
GCS: Glasgow Coma Scale.

Table 2
Multivariable logistic regression analysis.

Variable	N (%)	AOR	95% CI	*p*
Sex				
Male	2876 (57.3%)	1.102	0.967–1.256	0.146
Female	2146 (42.7%)	Ref		
Age (years)				
≦17	192 (3.8%)	Ref		
18–40	2350 (46.8%)	0.999	0.698–1.431	0.997
41–64	1591 (31.7%)	2.333	1.628–3.343	<0.05
≧65	889 (17.7%)	3.584	2.470–5.202	<0.05
GCS				
<12	291 (5.8%)	20.465	13.467–31.099	<0.05
≧12	4731 (94.2%)	Ref		
Vehicles				
Motorcycles	4058 (80.8%)	Ref		
Pedestrians	452 (9.0%)	1.611	1.283–2.023	<0.05
Bicycles	372 (7.4%)	1.001	0.786–1.274	0.993
Cars	140 (2.8%)	0.773	0.519–1.151	0.204
EMS Time(minute)				
Response time	5022 (100%)	1.039	1.016–1.062	<0.05
On-scene time	5022 (100%)	1.101	1.085–1.117	<0.05
Transport time	5022 (100%)	1.050	1.034–1.067	<0.05
Crash Time				
Late-night (0:00–05:59)	405 (8.1%)	1.637	1.237–2.165	<0.05
Rush (06:00–08:59,17:00–19:59)	1668 (33.2%)	1.068	0.870–1.310	0.531
Nonrush (09:00–16:59)	2200 (43.8%)	0.995	0.815–1.213	0.957
Evening (20:00–23:59)	749 (14.9%)	Ref		

consciousness level (GCS), road user type, crash time of day, and other prehospital time components (response time and transport time), as shown in the tables. In this model, the adjusted covariates allowed us to estimate the independent effects of prehospital time components on the risk of severe injury.

An alpha value of 0.05 was applied, yielding a confidence level of 95%. Subgroup analyses were performed for injuries in specific anatomical regions according to different age groups, such as the head, chest, abdomen, and extremities, focusing on the effect of the on-scene time on injury severity. For the subgroup analyses by anatomical region and age group (Table 3), we fitted separate multivariable logistic regression models for each region–age stratum, adjusting for sex, GCS, road user type, crash time of day, response time, and transport time.

3. Results

Table 1 presents the distribution of severe injury according to each independent variable. Among the 5,022 patients who sustained traffic crash–related injuries and were included in this study, 1,858 (37.0%) had severe injuries, whereas 3,164 (63.0%) did not (Table 1). More than three-quarters of patients (3,941; 78.4%) were aged 18–64 years, while 17.7% were older adults; older adults had the highest proportion of severe injury (56.2%). Approximately 33% of crashes occurred during rush hours (06:00–08:59 or 17:00–19:59; 1,668; 33.2%). Nearly half of

Table 3
Multivariable logistic regression: Association between on-scene time and severe injury (AIS ≥ 3) by age group and anatomical region.

Variable	N	AOR	95% CI	*p*
Limbs	4109			
Age (years)				
0–17	138	1.057	0.974–1.148	0.185
18–40	2012	1.169	1.141–1.199	<0.05
41–64	1304	1.077	1.050–1.105	<0.05
≧65	655	1.102	1.061–1.144	<0.05
Head & Neck				
Age (years)				
0–17	40	1.030	0.894–1.186	0.687
18–40	321	1.084	1.023–1.149	<0.05
41–64	312	1.070	1.001–1.143	<0.05
≧65	292	1.093	1.005–1.188	<0.05
Thorax				
Age (years)				
0–17	13	0.457	0.150–1.388	0.167
18–40	195	1.145	1.066–1.231	<0.05
41–64	275	1.115	1.038–1.197	<0.05
≧65	170	1.222	1.090–1.371	<0.05
Abdomen				
Age (years)				
0–17	15	1.070	0.810–1.414	0.633
18–40	213	1.176	1.094–1.266	<0.05
41–64	97	1.106	1.002–1.221	<0.05
≧65	71	1.129	1.006–1.266	<0.05

patients involved in late-night crashes (46.4%) sustained severe injuries. About half of all patients (50.4%) had a total prehospital time of 11–20 min. On-scene time was > 7 min in 56.8% of cases, and for 68.2% of patients, transport time was > 4 minutes.

Patients with poor consciousness (GCS < 12) were substantially more likely to sustain severe injury than those with GCS ≥ 12 (91.1% vs. 33.7%). The proportion of severe injury was higher when on-scene time exceeded 7 min (45.8%) compared with < 7 min (25.4%). Among road user types, pedestrians had the highest proportion of severe injury (54.6%) compared with other vehicle types. Regarding crash time, the proportion of severe injury differed significantly across periods and was highest for late-night crashes (00:00–05:59) (46.4%) compared with crashes occurring at other times.

Table 2 presents the estimates from the logistic regression model. On-scene time was significantly associated with injury severity (AOR = 1.101 per additional minute; 95% CI 1.085–1.117), corresponding to a 10.1% higher odds of severe injury (ISS ≥ 9). Other factors significantly associated with severe injury included poor consciousness (GCS < 12) (AOR = 20.465; 95% CI = 13.467–31.099), older age (AOR = 3.584; 95% CI = 2.470–5.202), pedestrian involvement (AOR = 1.611; 95% CI = 1.283–2.023), and late-night crashes (0:00–05:59) (AOR = 1.637; 95% CI = 1.237–2.165).

Table 3 presents the AORs for injury severity by anatomical region for different age groups according to on-scene time. For extremity injuries, each additional minute of on-scene time was associated with 16.9%, 7.7%, and 10.2% higher odds of severe injury (AIS ≥ 3) across adult age groups, i.e., individuals aged 18 to 40, 41 to 64, and over 65 years old. Similar results were obtained for injuries of the head, thorax, and abdomen. In adult patients, each additional minute of on-scene time was associated with 8.4%–9.3% higher odds of severe head injury (AIS ≥ 3), 11.5%–22.2% higher odds of severe thoracic injury, and 10.6%–17.6% higher odds of severe abdominal injury.

A sensitivity analysis using ISS ≥ 16 as the threshold for severe injury was conducted to assess the robustness of the main findings (n = 736 cases, 14.7%). The analysis showed that longer on-scene time remained significantly associated with higher odds of severe injury (AOR = 1.064; 95% CI = 1.044–1.084 per minute), corresponding to a 6.4% increase in odds for each additional minute on scene. The direction and statistical significance of the association persisted, although the magnitude of the effect was attenuated compared to the ISS ≥ 9 threshold. Complete

results are presented in Supplementary Table S1.

4. Discussion

In our sample, on-scene time was associated with higher odds of severe injury (ISS ≥ 9), with each additional minute linked to 10.1% higher odds (AOR = 1.101). Stratified analyses of anatomical regions indicated that a long on-scene time was correlated with an increase in the odds of a patient having severe injuries (AIS score ≥ 3). This result was significant across all adult age groups. Among adults aged 18–40 and ≥ 65 years with extremity injuries, each additional minute of on-scene time was associated with 16.9% and 10.2% higher odds of severe injury (AIS ≥ 3), respectively. Similar patterns were observed for other regions: each additional minute was associated with 8.4%–9.3% higher odds of severe head injury, 11.5%–22.2% higher odds of severe thoracic injury, and 10.6%–17.6% higher odds of severe abdominal injury. Similarly, a previous study noted that a long prehospital time was associated with increased mortality in severely injured patients; for example, in patients with penetrating trauma, each additional minute spent on the scene resulted in a 1% increase in mortality. (Nasser et al. 2020) The observed association between longer on-scene time and higher injury severity should be interpreted with caution. This relationship may partly reflect reverse causation or confounding by indication, whereby more severely injured patients require prolonged on-scene stabilisation, advanced airway management, hemorrhage control, or technical extrication (e.g., rescue from a crashed vehicle), rather than on-scene delay causing increased injury severity. Prior studies have reported similar findings, noting that extended on-scene time often reflects injury complexity and patient acuity, particularly in high-severity or entrapment-related trauma cases (Newgard et al. 2010, Harmsen et al. 2015, Siripakarn et al. 2023). Nevertheless, other investigations have shown that excessively prolonged on-scene time without clear medical justification remains associated with worse outcomes, even after adjustment for injury severity and physiological status (Krost et al. 2006, Nasser et al. 2020). Collectively, these findings suggest that on-scene time may function both as a marker of injury severity and, in certain contexts, a modifiable system factor, underscoring the importance of distinguishing necessary life-saving interventions from potentially avoidable delays in prehospital trauma care. Our sensitivity analysis using ISS ≥ 16 confirmed the robustness of our main findings, with on-scene time remaining significantly associated with injury severity (AOR = 1.064 per minute; 95% CI = 1.044–1.084). The observed attenuation in effect size compared to ISS ≥ 9 (AOR = 1.101) further supports our interpretation that on-scene time functions primarily as a marker of injury complexity rather than a causal factor. At the highest severity levels (ISS ≥ 16), anatomical injury is determined at crash impact, and prolonged on-scene time reflects the technical complexity of essential stabilisation procedures—such as advanced airway management, hemorrhage control, or vehicle extrication—rather than delays that worsen anatomical severity.

The choice of severity threshold has important implications for EMS research. While ISS ≥ 16 is commonly used to define major trauma, our primary analysis employed ISS ≥ 9 to better reflect the spectrum of injuries requiring EMS intervention in real-world prehospital care. Patients with ISS 9–15 account for a substantial proportion of trauma centre admissions requiring specialised care, even without ICU (Intensive Care Unit) admission. The consistent findings across both thresholds demonstrate that our conclusions are robust to threshold selection and reflect genuine patterns in prehospital time-injury complexity relationships.

Our study demonstrated a clear association between on-scene time and injury severity for various anatomical regions. To facilitate timely identification of severe injuries (AIS score ≥ 3), EMTs should assess vital signs and anatomical regions on the scene. Signs of shock, such as systolic blood pressure under 90 mmHg, particularly in patients with abdominal or pelvic trauma, may indicate severe injury. Similarly, respiratory distress or airway obstruction caused by thoracic, facial, or laryngeal trauma suggests severe injury. A lower-than-normal level of consciousness (e.g., Glasgow Coma Scale score < 12) and evidence of spinal cord injury (e.g., paralysis) are also strong indicators of severe injury. Additionally, depressed skull fracture, severe facial fracture, and unstable pelvic or open long bone fracture may be classified as severe injuries (Association for the Advancement of Automotive Medicine, 2015). Studies have indicated that even a 1-min reduction in prehospital time can improve survival by approximately 2%. Consequently, when EMTs suspect a severe injury (AIS score ≥ 3) in any anatomical region, minimising the on-scene time and ensuring rapid transport to a trauma centre with definitive care capabilities is essential for ensuring favourable patient outcomes. Although our findings suggest that prolonged on-scene times are associated with higher injury severity, our data do not allow direct assessment of EMTs' clinical evaluations or triage decisions in the field. Therefore, these results should not be interpreted as evidence that EMTs failed to recognise signs of severe injury. Rather, prior literature has shown that prehospital identification of severe trauma remains challenging, with undertriage frequently reported even in mature trauma systems (MacKenzie et al. 2006, Newgard et al. 2010, Staudenmayer et al. 2016). These challenges are particularly pronounced among patients with atypical presentations or occult injuries. Our findings should thus be viewed in the context of system-level limitations in prehospital trauma recognition, underscoring the importance of ongoing training, standardised triage criteria, and decision-support tools to assist EMTs in identifying patients at risk of severe injury.

Notably, older individuals and those involved in late-night traffic crashes exhibited a higher likelihood of sustaining severe injuries, consistent with prior research. Previous studies have shown that adults aged ≥ 65 years have a substantially elevated risk of death following traffic crashes compared with younger individuals, a pattern often attributed to age-related physiological vulnerability and frailty, including reduced reaction time and impaired vision (Azami-Aghdash et al. 2018). Nighttime crashes have likewise been associated with increased injury severity and fatality risk, with one study reporting a 1.3-fold higher risk of death at night than during daytime, particularly among vulnerable road users such as motorcyclists and pedestrians (Ackaah et al. 2020, Rod et al. 2021). Proposed explanations include poor lighting and reduced visibility, driver fatigue, and higher operating speeds during late-night hours (Ackaah et al. 2020).

Extending these observations, several studies from our research team using Taiwanese population-based traffic crash data have demonstrated that older age is independently associated with a higher risk of fatal or severe injury, especially under adverse lighting conditions or reduced visibility (Chen and Pai 2019, Wiratama et al. 2020). Evidence related to lighting conditions, including glare and diminished illumination, suggests that impaired visibility may disproportionately affect older drivers and pedestrians, contributing not only to crash occurrence but also to increased injury severity through its influence on collision dynamics and impact energy (Elvik et al. 2019, Ma et al. 2019). Conceptually, adverse environmental conditions elevate crash risk prior to impact, while age-related limitations in perception and reaction, combined with higher nighttime travel speeds, may result in greater kinetic energy transfer at the moment of collision, thereby exacerbating injury severity (Evans 2004, Elvik et al. 2019). Collectively, these findings indicate that the heightened severity observed in nighttime crashes involving older adults likely reflects a multifactorial interplay between physiological vulnerability and environmental conditions, rather than a single direct causal mechanism.

5. Conclusions

Our study revealed that traffic crashes involving older adults or occurring late at night are associated with a higher likelihood of severe injury, and these factors are thus critical for EMTs to consider when making on-scene decisions. Furthermore, EMTs should be capable of

identifying the injured anatomical regions and evaluating injury severity. The primary objectives of prehospital emergency care are rapid assessment of vital signs, hemorrhage control, and airway management, which should be completed promptly at the scene. When initial anatomical or physiological findings suggest severe injury (AIS score $\geq$ 3), subsequent interventions—such as intravenous access, medication administration, and communication with the receiving hospital—should be prioritised during ambulance transport rather than prolonged at the crash scene. This approach may help limit on-scene time while maintaining essential prehospital care for patients with suspected severe injuries (Heffernan et al. 2010, Adams and Holcomb 2015).

6. Limitations

Several limitations should be acknowledged. First, certain potential confounders—such as environmental conditions and roadway characteristics—could not be evaluated because the data sources used in this study did not include detailed information from police crash scene reports. As a result, these factors were not incorporated into the analytical models. Second, data from general hospitals within the study region were not included; therefore, the study population may not fully represent the entire spectrum of trauma cases within the metropolitan area.

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8. Role of the funder/sponsor

The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

9. Additional contributions

We thank all those who participated in this study.

10. Additional information

All data analysed in this study were provided by the Metropolitan Taipei Fire Department's EMS prehospital records and the trauma registry of the Level 1 trauma centre.

CRediT authorship contribution statement

Li-Min Hsu: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Chun-Man Kuo:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Ching-Lin Chen:** Conceptualization. **Cheng-Wei Chan:** Conceptualization, Methodology, Investigation, Formal analysis. **Shih-Yu Ko:** Conceptualization. **Hon-Ping Ma:** Conceptualization. **Oscar Oviedo-Trespalacios:** Conceptualization. **Chenyi Chen:** Conceptualization. **Chih-Wei Pai:** Writing – review & editing, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aap.2026.108446.

Data availability

The data that support the findings of this study are not publicly available due to privacy restrictions but are available from the corresponding author on reasonable request.

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