Geriatric Trauma Outcome Score and Mortality in Elderly Trauma Patients: A Retrospective Cohort Study

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Abstract

Background: The aging population in Thailand is rapidly increasing, leading to a rise in elderly trauma cases. Understanding the epidemiology, causes, complications, and outcomes of geriatric trauma is crucial for improving care and developing preventive strategies.

Objective: To analyze the epidemiological patterns, causes, complications, and outcomes of elderly trauma patients, and to assess the relationship between the Geriatric Trauma Outcome Score (GTOS) and mortality.

Materials and Methods: This retrospective study included 466 patients aged 60 years and older who were diagnosed with trauma between 2011 and 2021 at Chiang Mai University Hospital. Medical records were retrospectively reviewed, and data were extracted between September 2022 and July 2023. Statistical analyses included descriptive statistics, Fisher's exact test, Student's t-test, and univariable and multiple risk regression analyses.

Results: The majority of patients were over 65 years old (77.68%) and male (51.93%). Falls (62.66%) and traffic accidents (24.68%) were the main causes of injury. The mortality rate was 3.43%. Pneumonia (RR 1.54, 95% CI 1.02 to 2.33, p=0.040) and failed or difficult intubation (RR 1.81, 95% CI 1.15 to 2.85, p=0.010) were significant predictors of mortality. GTOS showed good predictive ability for mortality (AUC 0.807, 95% CI 0.73 to 0.88). Factors associated with high GTOS included age >65 years, ISS >15, and blood transfusion.

Conclusion: Falls are the primary cause of injury in elderly patients, with a significant impact on mortality. GTOS is an effective tool for predicting mortality in this population. Prevention strategies need to focus on fall prevention, and care protocols should address the specific needs of elderly trauma patients.

Keywords: Geriatric trauma; Epidemiology; Falls; Geriatric Trauma Outcome Score; Mortality

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The global population is aging rapidly, with the World Health Organization (WHO) projecting that the proportion of the world's population over 60 years will nearly double from 12% to 22% between 2015 and 2050[1]. Thailand is no exception to this demographic shift, with projections indicating that by 2025, 28% of the Thai population will be aged 60 years or older[2]. This demographic transition presents new challenges for healthcare systems, particularly in the care and management of elderly trauma patients.

Trauma in the elderly population is a significant public health concern, associated with higher morbidity and mortality rates in comparison to younger populations. The physiological changes associated with aging, such as decreased bone density, reduced muscle

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What is already known about this topic?

The relationship between GTOS and mortality in elderly trauma patients is well-established. GTOS helps clinicians predict the mortality risk more effectively in older adults, considering both injury severity and age-related factors such as comorbidities and functional status. This tool has become an important addition to the trauma care guidelines, offering better risk stratification and guiding clinical decision-making. However, challenges remain in ensuring that elderly trauma patients receive timely and comprehensive care, and ongoing research continues to improve prediction models and trauma management strategies for this vulnerable population.

What does this study add?

This study likely adds to the existing knowledge by validating and possibly improving the GTOS in predicting mortality and long-term outcomes in elderly trauma patients. It may also introduce more refined and personalized approaches to elderly trauma care, while providing a basis for clinical practice changes and future research directions.

mass, and diminished sensory acuity, make older adults more susceptible to injuries and complications[3]. In addition, pre-existing medical conditions common in this age group can complicate treatment and recovery processes.

Epidemiological studies from various countries have consistently identified falls as the leading cause of trauma in the elderly, followed by traffic accidents[4-7]. In Thailand, data from the Bureau of Epidemiology, Department of Disease Control, corroborate these findings, highlighting falls and traffic accidents as the primary causes of injury in the elderly population[8]. The prevalence of these injuries not only impacts the quality of life of older adults but also places a substantial burden on healthcare resources.

The assessment and prediction of outcomes in elderly trauma patients present unique challenges. Traditional trauma scoring systems may not adequately account for the physiological reserves and comorbidities common in older adults. The Geriatric Trauma Outcome Score (GTOS) was developed specifically for elderly trauma patients, incorporating age, Injury Severity Score (ISS), and the need for blood transfusion within 24 hours[9]. This tool has shown promise in predicting mortality and guiding clinical decision-making in geriatric trauma care.

This study aims to analyze the epidemiological patterns, causes, complications, and outcomes of elderly trauma patients admitted to Chiang Mai University Hospital, a tertiary care center in Northern Thailand. Such an investigation is essential for the development of targeted prevention strategies, the improvement of clinical care protocols, and the optimization of resource allocation.

In addition, this study evaluates the association between the GTOS and mortality in this population. GTOS is a tool specifically developed to predict mortality in elderly trauma patients and has been validated in several countries. However, to date, no study has validated GTOS within the Thai context, where differences in epidemiology, injury patterns, and healthcare systems may exist compared with the countries in which the tool was originally developed.

Therefore, this study focuses on assessing the relationship between GTOS and mortality while also providing comprehensive epidemiological data to better understand the local context and to support the interpretation of the study findings.

Objectives

1. The primary objective: To describe the epidemiology and clinical outcomes of elderly trauma patients.

2. Secondary objective: To assess the association between the GTOS and mortality

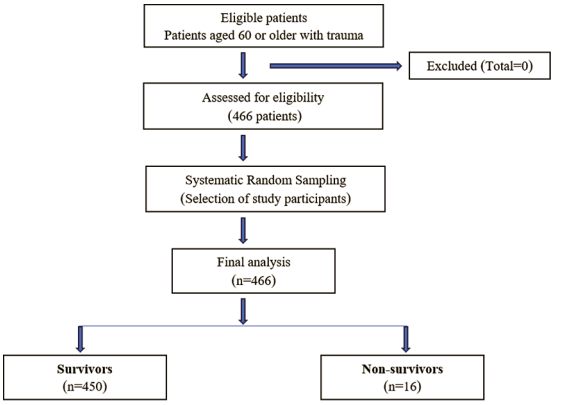

Figure 1. Flow diagram of patient selection for this study.

Materials and Methods

This study employed a retrospective descriptive design, analyzing data from Chiang Mai University Hospital, a tertiary care and level 1 trauma center in Northern Thailand. The study period spanned from January 1, 2011, to December 31, 2021.

The study included all patients aged 60 years and older who were admitted to the hospital with a primary diagnosis of trauma during the study period. Patients were identified using the electronic medical record system of the hospital. Patients with complete outcome data (i.e., mortality status) who met the study eligibility criteria were included in the analysis. Exclusion criteria included patients with missing outcome data (i.e., mortality status) who were excluded from the analysis.

Based on the hospital statistics, approximately 466 elderly trauma patients were admitted during the study period[10]. The sample size was calculated using the formula for estimation of a population proportion with specified absolute precision[11], and a sample size of 466 was determined. Systematic random sampling was employed to select the study participants. Figure 1 illustrates the process of participant selection, exclusion, and inclusion in the final analysis.

Data Collection

Data were extracted from electronic medical records using a standardized data collection form. The data collected were age, sex, mechanism of injury, ISS, Glasgow Coma Scale (GCS), Charlson Comorbidity Index (CCI), mortality, length of hospital stay, treatment costs, complications during hospitalization, and GTOS. In this study, only patients with complete

data for all variables of interest were included in the analysis. Therefore, no missing data were present in the final analytical dataset.

The GTOS was calculated using the formula:

GTOS = age + (2.5 × ISS) + 22 (if transfused with packed red blood cells within 24 hours after admission)[9].

Ethical Approval

The study protocol was approved by the Research Ethics Committee of the Faculty of Medicine, Chiang Mai University (approval number: 276/2022). Medical records were retrospectively reviewed, and data were extracted between September 2022 and July 2023. As this was a retrospective study using de-identified data, the requirement for individual patient consent was waived.

Statistical Analysis

Data analysis was performed using Stata Statistical Software, version 16 (StataCorp LLC, College Station, TX, USA). Descriptive statistics were used to summarize patient characteristics, injury patterns, and outcomes. Continuous variables were presented as mean, standard deviation, or median with interquartile range (IQR), depending on the distribution of data. Categorical variables were presented as frequencies and percentages. Comparisons between groups (survivors vs. non-survivors, low GTOS vs. high GTOS) were made using Student's t-test or Mann-Whitney U test for continuous variables and chi-square test or Fisher's exact test for categorical variables, as appropriate. The optimal cutoff value of 113.5 was derived from receiver operating characteristic (ROC) curve analysis, which identified the point that maximized both sensitivity and specificity for predicting mortality in this Thai elderly trauma population.

Clinical interpretation: A new paragraph has been added to explain that a GTOS score >113.5 is associated with a higher risk of mortality, whereas a GTOS score ≤113.5 indicates a lower risk of mortality. This cutoff can assist clinicians in initial risk stratification and in the allocation of resources for elderly trauma patients within the Thai healthcare system.

The association between various factors and mortality was assessed using univariable and multivariable risk regression analyses. Variables with a p-value less than 0.2 in the univariable analysis were included in the multivariable model. Results were presented as risk ratios (RR) with 95% confidence intervals (CI).

The performance of GTOS in predicting mortality was evaluated using ROC curve analysis. The area under the ROC curve (AUC) with 95% CI was calculated to assess the discriminative ability of GTOS.

A p-value less than 0.05 was considered statistically significant for all analyses.

Results

Patient Characteristics and Injury Patterns

A total of 466 geriatric trauma patients were included in the study. The mean age was 73.73±8.7 years (range 60-96 years), with 77.68% of patients being over 65 years old. Males accounted for 51.93% of the patients.

Falls were the leading cause of injury (62.66%), followed by traffic accidents (24.68%). Among falls, same-level falls were the most common (48.07%). The most frequent sites of injury were lower extremities (48.28%) and head or cervical spine (24.25%) (Table 1).

Injury Severity

The median ISS was 9 [IQR 4-16], with 79.61% of patients having an ISS ≤15. The majority of patients (89.48%) had a mild GCS score (13-15). The most common comorbidities were hypertension (57.51%) and diabetes mellitus (25.54%). The median CCI was 1 [IQR 0-2] (Table 1).

Length of Hospital Stay and Treatment Cost

The median length of hospital stay was 12 days [IQR 6-19]. The median treatment cost was 81,020 Thai Baht [IQR 37,570-163,012] (Table 1).

Complications

Complications were observed in a significant number of patients. The most frequent complications were pneumonia (9.44%) and urinary tract infections (8.80%) (Table 2).

Outcomes and Mortality

The overall mortality rate was 3.43% (16 deaths). The primary cause of death was traumatic brain injury (50% of deaths) (Table 1). Table 3 shows a comparison of clinical characteristics between survivors and non-survivors. Significant differences were observed in the proportion of patients with falls as the mechanism of injury, ISS, presence of severe injury (ISS >15), GCS (mild category), need for blood transfusion, and those with high GTOS (>113.5).

Geriatric Trauma Outcome Score and Mortality

GTOS was calculated for all patients. Low GTOS

Table 1. Demographic and clinical characteristics of geriatric trauma patients (n=466)

Parameters	Value
Age (years); mean±SD (min-max)	73.73±8.7 (60-96)
Age; n (%)	
60-65 years	104 (22.32)
>65 years	362 (77.68)
Sex; n (%)	
Male	242 (51.93)
Female	224 (48.07)
Mechanism of injury; n (%)	
Falls	292 (62.66)
Traffic accident	115 (24.68)
Burns	9 (1.93)
Assault	20 (4.29)
Machine	19 (4.28)
Others	11 (2.36)
Injury site; n (%)	
Head/cervical spine injury	113 (24.25)
Facial injuries/eye	5 (0.64)
Chest injury	20 (4.29)
Abdominal or pelvic content injury	19 (3.86)
Upper extremities	33 (6.88)
Lower extremities	233 (48.28)
External injury/laceration	10 (2.79)
Others	43 (9.01)
ISS score; median [IQR]	9 [4-16]
ISS; n (%)	
≤15	371 (79.61)
>15	95 (20.39)
GCS; n (%)	
Mild (13-15)	417 (89.48)
Moderate (9-12)	22 (4.72)
Severe (3-8)	27 (5.79)
Comorbidity; n (%)	
HT	268 (57.51)
DM	119 (25.54)
Renal failure	68 (14.59)
Others	11 (2.36)
CCI; median [IQR]	1 [0-2]
GTOS; n (%)	
Low GTOS (≤113.5)	256 (54.94)
High GTOS (>113.5)	210 (45.06)
Discharge status; n (%)	
Dead	16 (3.43)
Improved	450 (96.57)
Cause of death; n (%)	
Traumatic brain injury	8 (50.00)
Massive hemorrhage	6 (37.50)
Multi-organ failure	2 (12.50)
LOS (days); median [IQR]	12 [6-19]
Cost (Baht); median [IQR]	81,020 [37,570-163,012]

CCI=Charlson Comorbidity Index; ISS=Injury Severity Score; GCS=Glasgow Coma Scale; HT=hypertension; DM=diabetes mellitus; GTOS=Geriatric Trauma Outcome Score; LOS=length of stay; SD=standard deviation; IQR=interquartile range

Table 2. Prevalence of complications in geriatric trauma patients (n=466)

Complication	n (%)
Pneumonia	44 (9.44)
Urinary tract infection	41 (8.80)
Failed or difficult intubation	31 (6.65)
Acute respiratory failure	15 (3.22)
Septicemia	10 (2.15)
Others*	25 (5.36)

* Others: acute anemia=7, hypokalemia=6, hyponatremia=4, coagulation defect=2, heart failure=2, urticaria=2, hematuria=1, phlebitis=1

Table 3. Comparison of characteristics between survivors and non-survivors

Characteristic	Survivors (n=450)	Non-survivors (n=16)	p-value
Age >65 years; n (%)	349 (77.56)	13 (81.25)	1.000
Male; n (%)	230 (51.11)	12 (75.00)	0.075
Falls as injury mechanism; n (%)	281 (62.44)	11 (68.75)	0.042
ISS; median [IQR]	9 [4-16]	20 [9-25]	0.002
ISS >15; n (%)	114 (25.33)	11 (68.75)	<0.001
GCS (mild); n (%)	405 (90.00)	12 (75.00)	<0.001
Blood transfusion; n (%)	206 (46.09)	16 (100)	<0.001
High GTOS (>113.5); n (%)	196 (43.56)	14 (87.50)	0.001

ISS=Injury Severity Score; GCS=Glasgow Coma Scale; GTOS=Geriatric Trauma Outcome Score; IQR=interquartile range

(≤113.5) was observed in 54.94% of patients, while 45.06% had high GTOS (>113.5). High GTOS was significantly associated with mortality, with 87.50% of deaths occurring in the high GTOS group (p<0.001) (Table 1). The optimal cutoff value of 113.5 was derived from ROC curve analysis, which identified the point that maximized both sensitivity and specificity for predicting mortality in this Thai elderly trauma population.

Multivariable analysis revealed that independent predictors of GTOS included age >65 years (RR 1.55, 95% CI 1.04 to 2.29, p=0.029), ISS >15 (RR 2.56, 95% CI 1.74 to 3.77, p<0.001), and blood transfusion (RR 1.10, 95% CI 1.07 to 1.12, p<0.001) (Table 4).

Multivariable analysis revealed that independent

Table 4. Factors associated with GTOS in elderly trauma patients (adjusted risk ratio multivariable analysis)

Parameters	Total (n=466)	Adjusted RR (95% CI)	p-value
Age (years); n (%)			
≤ 65	101 (22.32)	1.00	
>65	365 (77.68)	1.55 (1.04 to 2.29)	0.029*
Sex; n (%)			
Male	242 (51.93)	1.00	
Female	224 (48.07)	0.96 (0.69 to 1.32)	0.792
Comorbidity; n (%)			
HT	268 (57.51)	1.00 (0.74 to 1.36)	0.993
DM	119 (25.54)	0.86 (0.58 to 1.27)	0.445
Hyperlipidemia	28 (6.02)	0.73 (0.29 to 1.85)	0.505
Gout	28 (6.02)	1.17 (0.69 to 1.98)	0.567
Renal failure	68 (14.59)	1.21 (0.82 to 1.81)	0.336
Dementia	11 (2.36)	1.25 (0.54 to 2.90)	0.607
Mechanism of injury; n (%)			
Falls	292 (62.66)	1.00	
Others (traffic accidents, burns)	174 (37.44)	0.91 (0.78 to 1.06)	0.241
GCS score; n (%)		1.02 (0.80 to 1.32)	0.854
Mild	31 (6.65)		
Moderate	18 (3.86)		
Severe	417 (89.48)		
ISS; n (%)			
≤15	341 (73.18)	1.00	
>15	125 (26.82)	2.56 (1.74 to 3.77)	<0.001***
Length of stay (days); mean±SD	16.12±14.66	1.00 (0.99 to 1.01)	0.940
Blood transfusion within 24 hours; mean±SD	10.55±11.00	1.10 (1.07 to 1.12)	<0.001***
Complication; n (%)			
Urinary tract infection	41 (8.80)	1.08 (0.68 to 1.71)	0.738
Pneumonia	45 (9.66)	0.98 (0.63 to 1.52)	0.921
Acute renal failure	10 (2.15)	0.98 (0.43 to 2.23)	0.966

RR=risk ratio; CI=confidence interval; HT=hypertension; DM=diabetes mellitus; ISS: Injury Severity Score; GCS: Glasgow Coma Scale; GTOS: Geriatric Trauma Outcome Score; SD=standard deviation

* p<0.05, ** p<0.01, *** p<0.001

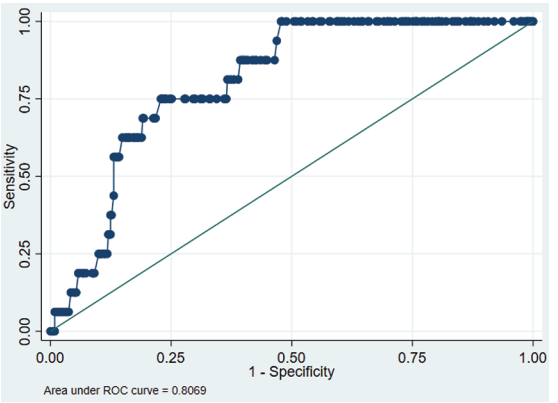

Figure 2. The ROC curve GTOS score vs mortality (n=466).

Table 5. Factors associated with mortality in elderly trauma patients (adjusted risk ratio multivariable analysis)

Parameters	Total (n=466)	Adjusted RR (95% CI)	p-value
Age (years); n (%)			
≤65	101 (22.32)	1.00	
>65	365 (77.68)	0.99 (0.78 to 1.27)	0.964
Sex; n (%)			
Male	242 (51.93)	1.00	
Female	224 (48.07)	0.97 (0.79 to 1.19)	0.759
Mechanism of injury; n (%)			
Falls	292 (62.66)	1.07 (0.83 to 1.40)	0.591
Traffic	115 (24.68)	0.83 (0.39 to 1.79)	0.640
Burns	9 (1.93)	1.05 (0.76 to 1.44)	0.772
Others	50 (10.73)	1.00	
CCI; mean±SD	1.67±1.55	1.01 (0.94 to 1.07)	0.851
ISS; n (%)			
≤15	341 (73.18)	1.00	
>15	125 (26.82)	0.93 (0.68 to 1.29)	0.682
GCS score; n (%)			
Mild	31 (6.65)	1.00	
Moderate	18 (3.86)	1.03 (0.64 to 1.66)	0.904
Severe	417 (89.48)	0.92 (0.58 to 1.47)	0.732
Blood transfusion score; mean±SD	10.55±11.00	1.00 (0.98 to 1.01)	0.573
GTOS; n (%)			
Low	256 (54.94)	1.00	
High	210 (45.06)	1.05 (0.73 to 1.50)	0.802
Complication; n (%)			
Urinary tract infection	41 (8.80)	1.16 (0.74 to 1.81)	0.520
Pneumonia	45 (9.66)	1.54 (1.02 to 2.33)	0.040*
Failed or difficult intubation	31 (6.65)	1.81 (1.15 to 2.85)	0.010**
Acute renal failure unspecified	10 (2.15)	1.14 (0.54 to 2.39)	0.727

RR=risk ratio; CI=confidence interval; CCI=Charlson Comorbidity Index; ISS=Injury Severity Score; GCS=Glasgow Coma Scale; GTOS=Geriatric Trauma Outcome Score; SD=standard deviation

* p<0.05, ** p<0.01, *** p<0.001

predictors of mortality included failed intubation (RR 1.81, 95% CI 1.15 to 2.85, p<0.01) and pneumonia (RR 1.54, 95% CI 1.02 to 2.33, p<0.05) (Table 5).

The ROC curve analysis for GTOS in predicting mortality showed an AUC of 0.807 (95% CI 0.73 to 0.88), sensitivity 87.50%, specificity 56.44%. Optimal cutoff 113.5, indicating good predictive ability (Figure 2).

Discussion

This study aimed to analyze the epidemiology, causes, complications, and outcomes of care for elderly trauma patients, as well as assess the relationship between the GTOS and mortality at Chiang Mai University Hospital. The findings provide valuable insights into the care of elderly trauma patients in the

context of Thailand.

The study found that the average age of patients was 73.73 years, with the majority being male (51.93%). Falls were the main cause of injury (62.66%), followed by traffic accidents (24.68%). These findings are consistent with studies from other Asian countries, such as the study by Chua et al. in Singapore, which found falls to be the primary cause of injury in the elderly (67.2%), followed by traffic accidents (17.1%)[5]. Ranjan et al. reported comparable results in Northern India[6].

Moreover, these findings align with global trends, as demonstrated by Miyoshi et al. (2020) in Japan, who found that falls were the main cause of injury in the elderly, accounting for 56.7% in the 65-79 age group and 78.9% in those 80 years and older[4]. Benhamed et al. in Canada also reported falls as the primary cause of injury in the elderly (84.7% to 88.3%)[7].

This consistency emphasizes the critical need for the development of appropriate fall prevention strategies for the elderly population, especially considering that same-level falls were the most common[12]. This indicates that even seemingly minor accidents can lead to significant injuries in older adults.

The average ISS was 9 [IQR 4-16] in 79.61% of cases, indicating moderate severity (ISS ≤15). However, it is noteworthy that same-level falls resulted in severe and life-threatening injuries (ISS >15) in 60.00% of all fall cases, which is a point of interest that warrants further investigation.

The most common injury locations were lower extremities (48.28%) and head/cervical spine (24.25%). This is consistent with the study by Rocha et al., which found that injuries in the elderly commonly occur in the leg and head areas[13]. Similarly, Ranjan et al. reported that 55.56% of elderly patients suffered lower extremity injuries after falls[6].

The high rate of head injuries, despite most patients having mild GCS scores (89.48%), is concerning, especially considering that traumatic brain injury was the primary cause of death in our sample (50% of deaths).

The most common comorbidities were hypertension (57.51%) and diabetes (25.54%), which is consistent with the general profile of elderly patients. These conditions can complicate trauma care and recovery, necessitating a comprehensive management approach.

The most frequent complications were pneumonia (9.44%) and urinary tract infections (8.80%), findings which were in alignment with the findings of Bonne and Schuerer, who identified these as common complications in elderly trauma patients[3]. The elderly trauma patients are particularly vulnerable to complications such as pneumonia and urinary tract infections, which are associated with increased mortality and prolonged hospital stay. This heightened risk is largely attributable to age-related physiologic decline, reduced functional reserve, and the presence of comorbidities. These findings underscore the importance of early recognition, proactive respiratory care, infection prevention strategies, and comprehensive multidisciplinary management to improve outcomes in this population. These results emphasize the importance of early mobilization, respiratory care, and careful attention to catheter management in this population. Therefore, special attention should be given to the prevention and treatment of these complications, such as careful implementation of hospital-acquired infection prevention measures.

It is important to obtain information about chronic medical conditions and pre-injury functional status shortly after hospital admission to facilitate inpatient care and discharge planning. This information gathering and development of ongoing care plans can be accomplished through formal geriatric consultation or by adding geriatric expertise to the multidisciplinary trauma team[14].

The overall mortality rate was 3.43%, which is lower than some reports in the literature[15]. This may reflect differences in healthcare systems or injury patterns. However, the significant association between high ISS, need for blood transfusion, and mortality underscores the vulnerability of elderly trauma patients.

Falls were statistically significantly the main cause of death (68.75% of all deaths, $p<0.05$). The primary cause of death was traumatic brain injury (50% of deaths), a finding consistent with the study by Gardner et al., which found that the elderly are at high risk for brain injury and have higher mortality rates than other age groups, with falls being the main cause[16].

The identification of failed intubation and pneumonia as independent predictors of mortality (RR 1.81, 95% CI 1.15 to 2.85, $p<0.01$ and RR 1.54, 95% CI 1.02 to 2.33, $p<0.05$, respectively) highlights the critical importance of airway management and respiratory care in this population. These findings suggest that strategies to improve intubation success rates and prevent respiratory complications could significantly impact survival rates.

The GTOS demonstrated good discriminatory ability for predicting in-hospital mortality in our cohort, with AUC of 0.807 (95% CI 0.73 to 0.88). According

to widely accepted criteria, an AUC exceeding 0.80 indicates good discrimination[17], confirming that GTOS is a reliable prognostic tool in this Thai geriatric trauma population. The optimal cutoff was determined to be 113.5, identified by maximizing the Youden Index (J = sensitivity + specificity – 1)[18,19], yielding a sensitivity of 87.50% and a specificity of 56.44%. Patients with GTOS >113.5 accounted for 87.50% of all in-hospital deaths (p<0.001).

This cutoff is modestly lower than those reported in other Asian geriatric trauma cohorts, 123 (AUC 0.84) in a Chinese population[9] and 121.8 (AUC 0.80) in a Taiwanese population[10]. This discrepancy may be attributed to a lower baseline mortality rate (3.43%), a higher proportion of low-energy fall mechanisms (62.66%), and potentially reduced physiological reserve at equivalent ISS values in our Thai cohort. Collectively, these factors shift the optimal Youden index-derived operating point toward a lower GTOS threshold while preserving high sensitivity.

Despite its strong ROC performance, GTOS did not emerge as an independent predictor in multivariable logistic regression (RR 1.05, 95% CI 0.73 to 1.50, p=0.802) (Table 5). This apparent discrepancy is explained by structural collinearity: GTOS is a composite score derived from age, ISS, and transfusion status variables that were simultaneously included as independent covariates in the regression model. As a result, the predictive contribution of GTOS is largely captured by its individual components. Notably, failed or difficult intubation (RR 1.81, 95% CI 1.15 to 2.85, p=0.010) and hospital-acquired pneumonia (RR 1.54, 95% CI 1.02 to 2.33, p=0.040) remained significant independent predictors of mortality (Table 5). These findings highlight that ROC analysis and multivariable regression address complementary aspects of prognostication: GTOS is valuable for early bedside risk stratification and clinical triage, whereas regression analysis identifies the mechanistic drivers of mortality.

From a clinical perspective, a GTOS >113.5 should prompt immediate escalation of care, including early multidisciplinary team activation, proactive airway management with video-laryngoscopy availability, and initiation of goals-of-care discussions. These findings are consistent with previous validation studies that have demonstrated the utility of GTOS as a rapid, easily calculated composite triage tool in elderly trauma patients[9,10,18].

The potential unmeasured confounders in this study, including time to definitive hemostasis, CT interval, pre-hospital intubation attempts, nutritional status, and polypharmacy, have been acknowledged for their possible influence on the observed associations between failed intubation, pneumonia, and mortality.

These findings are consistent with the study by Hashmi et al., which identified increasing age, high ISS, and comorbidities as important risk factors for mortality[15]. Elderly patients typically have reduced physiological reserve and functional capacity, impacting their health outcomes[20,21]. Higher ISS indicates more severe injuries, leading to increased systemic inflammatory response and possible organ failure[14,20]. The presence of additional health conditions may complicate treatment and recovery, further affecting health outcomes in elderly trauma patients[20]. Blood transfusion is commonly required in patients with severe injuries, for example, those involved in serious accidents may need blood transfusions to replace blood loss[20]. Cook et al. confirm that GTOS is a highly accurate tool for predicting mortality rates in elderly trauma patients[21]. GTOS demonstrated good discriminatory performance for mortality prediction in elderly trauma patients in our study, with ROC of 0.807 (95% CI 0.73 to 0.88). These findings are consistent with previous studies that have demonstrated the usefulness of GTOS in predicting mortality among elderly trauma patients[9]. The use of GTOS can assist in risk assessment, clinical decision-making, and effective communication with patients and families.

Clinical Implications for Practice and Policy in Thailand

Early GTOS calculation at initial assessment is recommended, with values >113.5 identifying high-risk patients requiring prompt escalation of care and early multidisciplinary team involvement. Institutions should strengthen airway management protocols with video-laryngoscopy and structured difficult airway algorithms, alongside proactive respiratory surveillance and infection prevention strategies. Early mobilization, strict catheter care, and fall-prevention measures should be implemented. In high-risk patients, early goals-of-care discussions are also recommended to support shared decision-making and appropriate care planning.

Limitation

Several limitations of this study should be acknowledged when interpreting the findings.

1. Retrospective single-center design. Data were obtained from a single tertiary referral center in Northern Thailand, which may limit the generalizability

of findings to community hospitals, rural settings, or other geographic regions with different patient demographics, injury mechanisms, and resource availability. Selection bias inherent to a referral center, where more severely injured patients may be over-represented, cannot be excluded.

2. Retrospective data collection. Reliance on medical records introduces the risk of incomplete documentation, particularly for pre-injury functional status, frailty assessment, and medication history (e.g., anticoagulant or antiplatelet use). Missing data may have led to the underestimation of important confounders.

3. No long-term follow-up. Outcomes were restricted to in-hospital events. Post-discharge mortality, functional decline, institutionalization rates, and quality of life were not captured, limiting the ability to assess the full burden of geriatric trauma beyond the acute episode.

4. GTOS validation scope. Although GTOS demonstrated good discrimination in this cohort, the score has not been prospectively validated in a Thai population. The cut-off of 113.5, derived by the Youden index from a relatively small number of deaths (n=32), may be subject to statistical instability and should be confirmed in a larger, prospective, multicenter study.

This study provides valuable population-specific data on geriatric trauma epidemiology and outcome prediction in the Thai context and represents a foundation for prospective multicenter validation of GTOS and development of institution-specific geriatric trauma care pathways.

Recommendation

Based on our findings, we propose the following evidence-informed recommendations for the clinical management of elderly trauma patients:

1. Based on the findings of this study, early calculation of the GTOS is recommended during the initial trauma assessment. A GTOS value greater than 113.5 may serve as a high-risk indicator, suggesting the need for prompt escalation of care. Future studies should further investigate the implementation of GTOS in clinical decision-making protocols and evaluate its impact on patient outcomes across different healthcare settings

2. Multidisciplinary team activation is recommended for patients identified as high-risk based on GTOS. Early involvement of trauma surgery, geriatric medicine, and critical care specialists within the first 24 hours of admission may facilitate timely and comprehensive management. Future research should evaluate the impact of structured multidisciplinary protocols guided by GTOS on patient outcomes, resource utilization, and mortality in geriatric trauma populations.

3. Airway management in geriatric trauma patients should be optimized, as failed intubation is a major predictor of mortality. The use of video-laryngoscopy and a structured difficult airway algorithm is recommended, and further studies should evaluate their impact on intubation success and outcomes.

4. Early mobilization and infection prevention should be prioritized in geriatric trauma patients, including physiotherapy-led mobilization, incentive spirometry, and aseptic catheter care. Further research should assess their impact on reducing pneumonia and urinary tract infection.

5. Respiratory surveillance should be prioritized in high-risk geriatric trauma patients. Daily monitoring, including auscultation, chest radiographs, and temperature trends, is recommended, with further research needed to evaluate its impact on pneumonia prevention and outcomes.

Conclusion

This retrospective cohort study analyzed 466 elderly trauma patients (mean age 73.73 years) admitted to Chiang Mai University Hospital and demonstrated that falls are the predominant mechanism of injury (62.66%), with same level falls capable of producing severe injuries (ISS >15) in 60% of cases. The most frequently injured anatomical regions were the lower extremities (48.28%) and the head/cervical spine (24.25%). Traumatic brain injury accounted for 50% of all in-hospital deaths, and the overall mortality rate was 3.43%.

In addressing the primary objective—to characterize the epidemiology, injury mechanisms, complications, and treatment outcomes of elderly trauma patients, our findings confirm that hypertension (57.51%) and diabetes mellitus (25.54%) are the most prevalent hospital complications. Falls were the leading cause of death (68.75% of fatalities, $p<0.05$). Multivariable analysis identified failed intubation (RR 1.81, 95% CI 1.15 to 2.85, $p=0.010$) and hospital-acquired pneumonia (RR 1.54, 95% CI 1.02 to 2.33, $p=0.040$) as independent predictors of mortality.

With respect to the secondary objective of evaluating the relationship between GTOS and mortality, GTOS demonstrated good discriminatory performance (AUC 0.807, 95% CI 0.73 to 0.88). The optimal cut-off for the Thai geriatric trauma population

was determined to be 113.5 (Youden index), at which sensitivity was 87.50% and specificity 56.44%. Patients with GTOS >113.5 accounted for 87.50% of all deaths ($p<0.001$). Although GTOS did not emerge as an independent predictor in multivariable regression—an expected consequence of collinearity with its component variables (age, ISS, and transfusion requirement)—it retains strong clinical value as a rapid, easily calculated composite triage tool that consolidates the three principal mortality-related variables into a single bedside score.

In conclusion, age, injury severity, and blood transfusion requirement synergistically elevate the risk of in-hospital death in elderly trauma patients. Airway management competency and proactive respiratory care represent the highest-leverage clinical targets for mortality reduction in this population. Routine application of GTOS at the time of admission can support early risk stratification, guide multidisciplinary team escalation, and facilitate timely goals-of-care discussions, ultimately contributing to improved outcomes for this vulnerable and growing patient group.

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Authors Contributions

KC: Conceptualization, methodology, investigation, data curation, and writing-original draft. NC: Conceptualization, methodology, supervision, and writing-review & editing. PK: Methodology, data curation, investigation, project administration, writing-original draft, and review & editing. SR: Data curation, investigation, and writing-original draft. WC: Methodology, formal analysis, writing-original draft, and review & editing. WK: Writing-review & editing and project administration (including manuscript preparation and submission coordination).

Clinical Trial Registration

Not applicable, as this study was a retrospective observational study and did not involve a registered clinical trial.

Conflicts of Interest

The authors declare no conflict of interest.

Data Available Statement

The datasets generated and/or analyzed during the current study are not publicly available due to patient privacy and institutional restrictions, but are available from the corresponding author on reasonable request and with permission from the Faculty of Medicine, Chiang Mai University.

Ethics Approval and Consent to Participate

This study was approved by the Research Ethics Committee of the Faculty of Medicine, Chiang Mai University (approval number: 276/2022). As this was a retrospective study using de-identified data, the requirement for informed consent was waived.

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Use of Artificial Intelligence

Artificial intelligence (AI) tools were used to assist in translating selected paragraphs of the Discussion, Clinical Implications for practice and policy in Thailand, and Research Recommendations section from Thai into English and to improve clarity and readability. Specifically, Claude Pro (version 4.6) was utilized for this purpose. No AI tools were used for data analysis, interpretation, or generation of scientific content. All content was critically reviewed, revised, and approved by the authors, who take full responsibility for the accuracy and integrity of the manuscript.

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