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ORIGINAL ARTICLE

Volume and flow of trauma team activation patients throughout the 24-hour day over a 3-year period at an academic trauma center

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ABSTRACT

Background: Road traffic accidents are the eighth leading cause of mortality globally and the second in Saudi Arabia. Trauma patients need specialized care and access to health care facilities. Early intervention by a multidisciplinary team results in better outcomes in terms of mortality and morbidity. The aim of this study was to analyze the association between the different mechanisms of injury that resulted in trauma team activations (TTAs) and the time in the 24-hour day over a 3-year period in a tertiary trauma center.

Methods: A single center retrospective study with trauma patients triggering the TTA was conducted. The study was conducted over a 3-year period, and the sample size was 587.

Results: The highest volume of TTA's during the 3 years occurred from 20:00 and 23:00 and the busiest single hour was 21:00. Pedestrian trauma was more prevalent at the end of the day from 18:00 to 22:00. Our study showed the mechanism of injury for more than half of the sample was a motor vehicle accident, followed by pedestrian trauma. The highest proportion of the sample was admitted from the Emergency Department to an intensive care unit (46.6%) or operation room/angiography (37.5%). After 19:00, there were more severe injuries and unstable patients, who required an intensive care unit or operation room/angiography. The peak occurred after 17:00 for 1 hour. Age, systolic and diastolic blood pressure were not statically significant. The mortality rate was higher in TTA patients' groups with an initial mean heart rate of 118 per minute and a 91% oxygen pulse oximetry.

Conclusion: The outcome of trauma patients was affected by the time of the 24-hour day. Severe injuries and unstable patients were more prevalent during nighttime. A higher initial heart rate for TTA patients was linked with increased mortality.

Keywords: Trauma, Emergency Medicine, trauma activation, health administration, Saudi Arabia.

Introduction

Traumatic injuries are a significant concern of public health globally [1,2]. Annually, the number of deaths related to trauma is more than the number of deaths from human immunodeficiency virus/acquired immunodeficiency syndrome, malaria, and tuberculosis combined [3-5]. Road traffic accidents (RTAs) are the eighth leading cause of mortality which is a concern when considering the high fatality rate, economic loss, and the long-term impact on human life and society [3,6,7]. Trauma patients need specialized care and access to health care facilities. Early intervention by a multidisciplinary team results in better outcomes in terms of mortality and morbidity. All healthcare facilities receiving trauma patients should have a protocol for appropriate multidisciplinary team mobilization which

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ensures that all resources to facilitate the clinical needs are available at all times during the day. Globally, there is no unified criteria for trauma team activation (TTA). These criteria are established by a committee in each trauma center. The American College of Surgeons recommends criteria for the presence of a surgeon if major resuscitation for the trauma patient is required on arrival or within 15 minutes, if any of the following major criteria are present: confirmed hypotension (systolic blood pressure <90 mm Hg), gunshot wound to the neck, chest, abdomen or proximal extremities, intubated patients transferred from the scene, respiratory compromise requiring an emergency airway, penetrating gunshot wound to the neck, chest, abdomen, or pelvis, and Glasgow Coma Scale score <8 attributed to trauma [8].

Saudi Arabia (SA) is one of many developing countries with a high burden of traumatic injuries, resulting in morbidity and mortality [9,10]. According to the Global Burden of Disease report, traumatic injuries represent 22.6% of potential life lost in SA [5]. A systematic review of RTA's in SA indicated that RTA accounts for more than 80% of all trauma related admissions [11]. RTAs are ranked second in the main causes of death in SA [12,13]. In addition, traumatic injuries drain a substantial amount of resources and result in major economic loss. As estimated by King Abdullah International Medical Research Center, the average cost of accidents in SA every year is 21 billion Saudi Riyal [13]. Unfortunately, the evidence about TTAs patients in hospitals in developing countries, including SA, is limited. The aim of this study was to analyze the association between the different mechanisms of injury that resulted in TTAs and the time of the 24-hour day over a 3-year period in a tertiary trauma center in Riyadh, SA. In addition, this study described the outcome of the TTA patients and the need for an operating room and intensive care unit. Identifying the trend of TTAs, the need for an operating room and the intensive care unit, and the factors causing increasing mortality will add to the current knowledge about this topic and support recommendations that will facilitate an improved understanding of the TTA volume and flow in the area as well in the outcomes of traumatic patients.

Methods

Study setting and design

This retrospective study was conducted at King Abdulaziz Medical City (KAMC), Department of Emergency Medicine, Riyadh, SA. KAMC is considered as an advanced trauma center, in which the Emergency Medicine Department offers trauma care 24 hours a day, including immediate access to specialized teams such as general, vascular, and orthopedic surgeons. Additionally, the Emergency Medicine Department of KAMC is ranked as the fourth Emergency Care Center outside the United States, to provide Pre-Hospital Trauma and Life Support programs. The bed capacity of KAMC includes 1,501 beds, of which 132 are in the Emergency Department (ED) [14].

TTA criteria

The trauma team is activated for trauma patients presenting with any of the following: 1. A trauma patient with hemodynamic instability (defined by systolic blood pressure <100 mm Hg for an adult. 2. All gunshot wounds to the head, torso, and extremities proximal to elbow or knee. 3. Positive focused abdominal sonography for trauma. 4. Multiple stab wounds to the neck, chest, abdomen or a single torso stab wound with hemodynamic instability. 5. Fracture of two or more long bones with evidence of hypotension, active bleeding or pulseless limb. 6. Open or unstable pelvic fracture. 7. Glasgow Coma Scale of 12 or less. 8. Trauma victims showing deterioration during initial assessment by an emergency physician (deterioration in Glasgow Coma Scale or blood pressure). 9. Clinical evidence of flail chest. 10. An initial chest tube output greater than 300 cc of blood or persistent significant output. 11. Pregnant trauma victims. 12. Clinical evidence or suspicion of a spinal cord injury and hemodynamic instability. 13. Amputation proximal to wrist or ankle. 14. Burns to airway or smoke inhalation (adults 15% or more of surface area). 15. Severe maxillofacial fracture with concern or evidence of airway compromise.

Data collection

The dataset used in this study was collected from the KAMC Trauma Registry and the patients' electronic files. The Trauma Registry has detailed information of all the hospital trauma-related admissions. All consecutive patients, 14 years and older, from all nationalities and who presented as a TTA from January 2018 to December 2020 were included in the analysis. The patients' electronic files were accessed to extract the required data. The patients who were announced dead upon arrival, transferred to another hospital, treated in the ED, and then discharged were not included in the study. The data included demographic variables, initial vital signs, trauma level, mode of arrival transportation, date and time of trauma code activation, mechanism of injury, Glasgow Coma Scale, treatment variables, and the final disposition.

Statistical analysis

Data were analyzed with the Statistical Package for the Social Sciences (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY). The demographic information and baseline characteristics were analyzed. The categorical variables are reported in frequency and proportion, and the numerical variables as mean and standard deviation (SD). The comparison between survival and mortality groups was done with a Chi-square test. The prevalence was calculated with a 95% confidence interval (CI). All tests were considered significant with a p-value less than 0.05.

Results

Patient characteristics, clinical data, and outcome

Over the study period from January 1, 2018, to December 31, 2020, more than 1,286 trauma patients were triaged to level I or II, and a trauma team was activated for 587 patients. The group who was included in the analysis after meeting the inclusion and exclusion criteria for the study was 539 patients. The excluded group was due to no time of arrival or triage data. Just more than half (54%, *n* = 247) of TTA patients were triaged to level I and 46% to level II. Most of the TTA patients were male (*n* = 495, 91.8%). The patients were relatively young with a mean age of 31.5 (SD ± 13) years. The mean initial heart rate was 104 (SD ± 26.2) with 129 mmHg as the mean systolic blood pressure. The mechanism of injury for more than half of the patients (*n* = 302, 56%) was a motor vehicle accident, followed by pedestrian trauma (*n* = 108, 20%). The initial Glasgow Coma Scale was less than 9 in 44% of the TTA patients (*n* = 237) with a Glasgow Coma Scale of 15 in 29.3%. A small proportion (6%, *n* = 32) arrested in the ED. More than two-thirds of TTA patients were intubated in the ED (*n* = 388, 72%) and more than one-third needed central line access (*n* = 218, 40.4%). The majority of patients were transferred from the ED to an intensive care unit (*n* = 251, 46.6%) or operation room/angiography (*n* = 202, 37.5%). The baseline characteristics, clinical data, and outcomes of the TTA patients are displayed in Table 1.

Time of day

The time of day affects the volume and flow of patients to the ED. As a result, TTA's are also affected by the time of day. The highest volume of TTA was between 20:00 and 23:00 and the busiest single hour was 21:00. A lower volume of TTAs occurred between 8:00 to 13:00 and 4:00 was the quietest hour. The previous findings were almost similar to trauma from RTAs. There were two peaks during the 24-hour day for RTA patients who required a TTA; the first peak was from 5:00 to 7:00 and the second peak from 20:00 to 23:00. Pedestrian trauma was more prevalent at the end of the day from 18:00 to 22:00. There were more severe injuries and unstable patients, who required an intensive care unit or operation room/angiography, after 19:00 with a peak after 17:00 for 1 hour. The mortality rate in the ED due to trauma increased from 17:00 to 18:00 and from 21:00 to 22:00. Figures 1-4 illustrate the number, dispositions, and mortality of TTA patients.

Predictors of mortality among TTA patients

The bivariate analysis for mortality in TTA patients is detailed in Table 2. The mortality rate for the TTA patients was 3.3% (*n* = 18) in the ED and 14.4% during their hospital stay. Age, systolic and diastolic blood pressure were not statically significant. The mean initial heart rate for the group who was discharged alive was 102 (SD ± 25) and for the group who died was 118 (SD ± 30), (*p*-value = <0.0001). Mortality was higher in TTA patients with an abnormal initial oxygen pulse oximetry. The initial mean was 95% oxygen pulse oximetry for the survival group (SD ± 7) and 91% (SD ± 10) for the group who died in the hospital.

Discussion

Trauma is a leading cause of mortality globally, which is still increasing in developing countries. In SA, trauma is a significant challenge. Some reports indicate that trauma is ranked as the number two killer in SA [12,13]. RTAs is

Table 1. *Baseline characteristics, clinical data and outcome among TTA patients.*

Variable	Category	N/ mean	%/ SD
Gender	Male	495	91.8
	Female	44	8.2
Age (years)		31.5	13.0
Height (centimeter)		169.0	7.5
Weight (kilogram)		72.0	16.0
Initial vital signs	Heart rate	103.9	26.2
	Respiratory rate	23.8	7.0
	Oxygen pulse oximetry	95.6	7.7
	Systolic blood pressure	129.2	29.9
	Diastolic blood pressure	83.7	25.0
Comorbidities	Hypertension	20	3.7
	Diabetes	25	4.6
	Heart diseases	4	0.7
	Others	23	4.3
Trauma level	Level 1	247	54.2
	Level 2	209	45.8
Injury mechanism	Motor vehicle accident	302	56
	Motorcycle accident	36	6.7
	Pedestrian	108	20
	Stab wound	20	3.7
	Gunshot	23	4.3
	Fall	30	5.6
	Others	20	3.7
Mode of arrival	EMS	495	91.8
	Private car	44	8.2
Glasgow Coma scale	3	76	14.2
	4	16	3
	5	12	2.2
	6	34	6.4
	7	54	10.1
	8	45	8.4
	9	24	4.5
	10	28	5.2
	11	11	2.1
	12	15	2.8
	13	29	5.4
	14	34	6.4
	15	157	29.3
Arrest in ED		32	5.9
Expired in ED		15	2.8
Procedure	Intubation	388	72
	Chest tube	117	21.7
	Central line	218	40.4
	Thoracotomy	5	0.9
	Pericardiocentesis	1	0.2
Disposition from ED	Intensive care unit	251	46.6
	Operation room or angiography	202	37.5
	Ward	60	11.1
	Discharge home	8	1.5
	Death	18	3.3
Disposition from hospital	Discharge home	396	74.9
	Death in the hospital	76	14.4
	Transfer to other hospital	54	10.2
	Discharged against medical advice	3	0.6

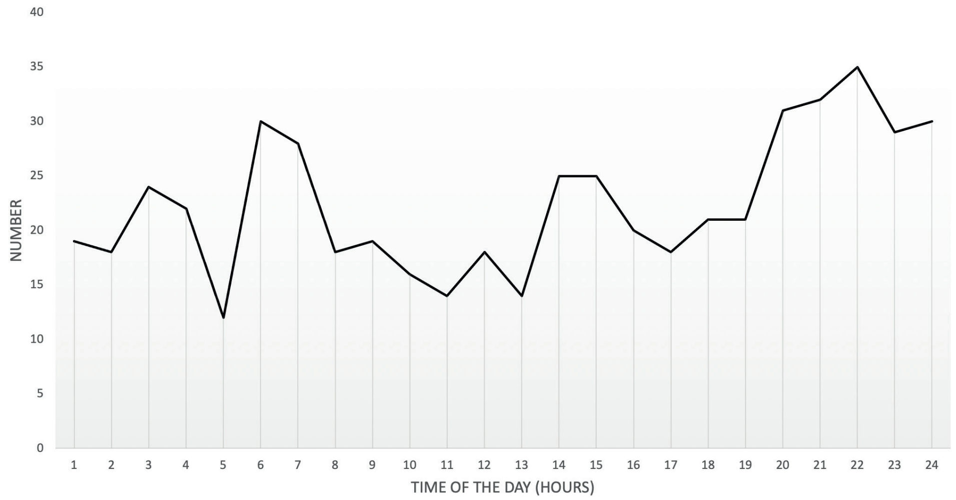

Figure 1. *Number of TTAs by time of day.*

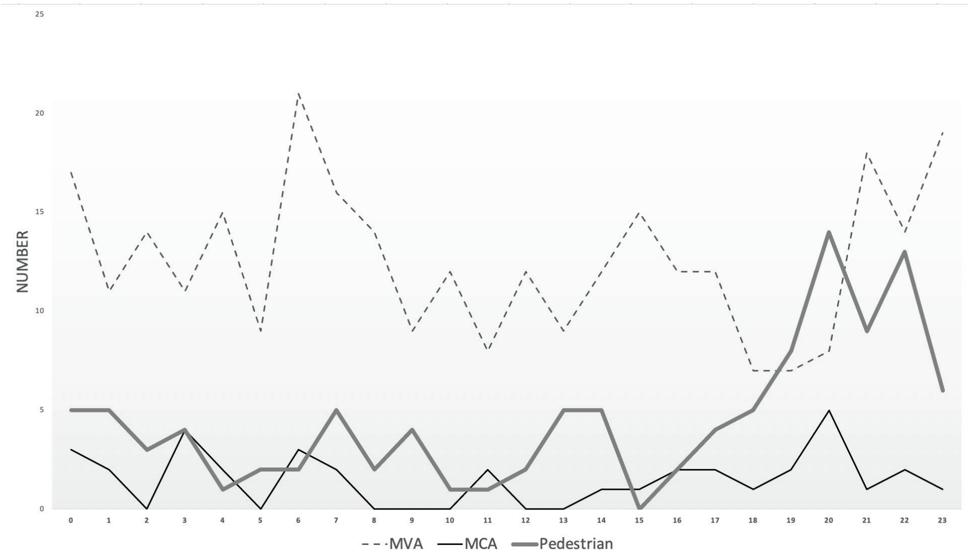

Figure 2. *RTAs related TTAs by time of day.*

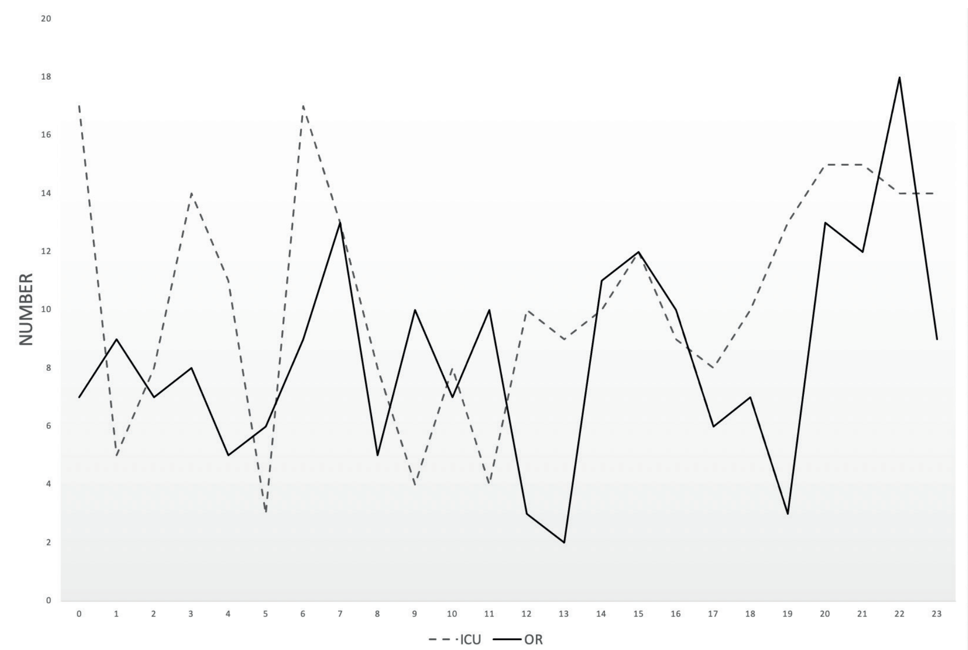

Figure 3. *Disposition to ICU and OR after TTA by time of day.*

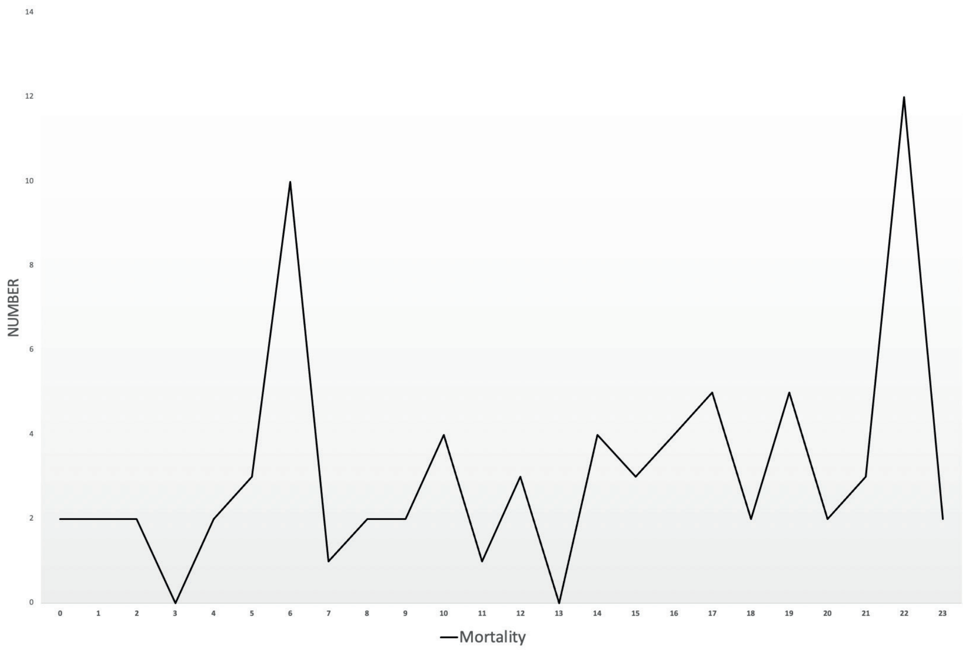

Figure 4. *Mortality of TTA patients after TTA by time of day.*

Table 2. *Bivariate analysis for predictors of mortality among TTA patients.*

Variable	Mortality				p value
	Alive		Death		
	Mean	SD	Mean	SD	
Age	31	13	33	15	0.238
Weight	71.3	16.3	76.8	13.3	0.003
Heart rate	102	25	118	30	<0.0001
Respiratory rate	23	7	26	7	0.001
Oxygen pulse oximetry	96	7	91	10	<0.0001
Systolic blood pressure	130	30	127	31	0.444
Diastolic blood pressure	83	24	86	28	0.461
Hours in ED	7:09	4:48	5:02	4:03	<0.0001

the cause of 80% to 85% of the trauma. It is important to know the trend and the results of the trauma. The purpose of this study was to delineate the association between the different mechanisms of injury resulting in TTAs and the time of the 24-hour day, to explore the need for operating room and intensive care units for TTA patients during the 24-hour day, and to identify the factors affecting the mortality of the TTA patients.

The present study revealed that the highest TTAs occur in the early evening at 20:00 with a continuous increase in the flow of patients who need TTAs until midnight, with a single busiest hour from 21:00 to 22:00. This trend of the TTAs is later than what was reported in a study conducted in California reporting the highest volume of TTAs from 16:00 and 22:00, with the busiest single hour for TTAs beginning at 19:00 [15]. In Germany, the trend of severe trauma admissions started from 08:00 with an double increase in the flow of patients at 16:00, which then reduced until the morning [16].

In the present study, TTAs from motor vehicle accidents increased early morning and in the evening, specifically 05:00 for 2 hours and after 20:00 until midnight. This was inconsistent with other studies indicating different patterns for the TTAs over the 24-hour period. Schellenberg et al. [15] found that TTAs due to motor vehicle accidents patients were constant over the 24-hour period, with the only spike from 02:00 to 04:00, contrasting our study. In comparison with a study conducted by Pape-Köhler et al. [16] both studies reported a spike in the TTAs due to motor vehicle accidents patients at 05:00. However, they had another spike at 15:00, which only reduced after 20:00. The current study only started the evening spike at 20:00.

Although there were consistent results regarding TTAs for pedestrian trauma during the day in Germany and the United States with two spikes at 07:00 and at 19:00, with a sharp decrease after 21:00, our results showed a significant increase in pedestrian patients triggering TTAs after 19:00 and until midnight [15,16]. In the Middle East, no literature is available regarding the trend of TTAs over a 24-hour period.

In comparison to a study indicating an increase in admissions for severe injuries during the evening time with a peak at 17:00, the present study had similar results of severe injuries and unstable patients during the 24-hour day who required an intensive care unit or operation room/angiography increasing after 19:00 with a 1-hour peak after 17:00. The patients' mortality in the ED due to trauma increased from 17:00 to 18:00 and from 21:00 to 22:00, which is consistent with the result in Germany with the highest mortality rate in the evening time 18:00 to 00:00 [16].

The current study is the first study in Riyadh to provide an overview of the patients triggering TTAs and to highlight the time of the TTAs throughout the 24-hour day, as well as the need for operating room and intensive care unit admission. However, this study has some limitations. One is the retrospective nature of the study which might lead to misclassification bias. Another is that this study was from a single tertiary center which reflects the situation in the center and not all hospitals in the city, country, or even the region. In addition, patients who were announced dead upon arrival were excluded from the study, as they were not in the data registry, which affects the patterns of trauma throughout the day. Some patients were unknown, and no comorbidities were mentioned in the registry. Our finding extends beyond trauma patient management. The availability of all services at all times of the day for immediate high-quality intervention is a challenge for the healthcare system. Knowing the surge hours for severe trauma for every hospital and city will support decision-makers to develop strategies that will affect the outcomes of the patients and save resources. Further multi-center studies across the city and the country may give a clearer picture and understanding of time of the 24-hour day and the TTA patients and their pattern of injuries and the need for operating rooms and intensive care units.

Conclusion

The mechanism of post-traumatic injury varies depending on the time of the 24-hour day in both volume and pattern. The nighttime shows a clear peak in trauma accidents that required TTA. The outcome of trauma patients was affected by the time of the 24-hour day. Severe injuries and unstable patients were more prevalent during the nighttime. A higher initial heart rate for the TTA patient was linked with increased mortality. A clear understanding of the association between the mechanism of injury, TTA volumes, and time of the 24-hour day demonstrated by this study, may facilitate care for the trauma patients through the allocation of appropriate hospital resources.

List of Abbreviations

CI	Confidence interval
ED	Emergency Department
KAMC	King Abdulaziz Medical City
RTA	Road traffic accident
SA	Saudi Arabia
SD	Standard deviation
TTA	Trauma team activation

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this article.

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Ethical approval

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