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Evaluation of road traffic injuries in the post-pandemic era: a two-and-a-half-year review of clinical characteristics and outcomes at a major trauma center

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Abstract

Background Road traffic crash-related injuries (RTCs) pose a significant public health challenge. In Saudi Arabia, a notable decline in RTC-related injuries was observed from 2016 to 2020 during the pre-pandemic era. However, the status and outcomes of RTCs following the pandemic remain largely unexplored. This study aimed to review the first two and a half years of characteristics and outcomes of RTCs in the post-pandemic era in Riyadh, Saudi Arabia.

Method Data was obtained from the Saudi TraumA Registry– STAR during the pre-pandemic period from August 2017 to March 2020 and the post-pandemic period from July 2020 to December 2022. Data were collected on patient demographics, injury details, prehospital and in-hospital vital signs, and in-hospital outcomes. Logistic regression analysis was performed to examine the association between different variables and in-hospital mortality.

Results A total of 6,577 patients sustained a road injury during the study period, pre-pandemic phase $n=2,809$ (42.8%) and post-pandemic phase $n=3,768$ (57.2%). An increase in trauma cases by 14.4% was seen in the post-pandemic period (motor vehicle drivers 10.1%, motor vehicle passengers 1.9%, motorcycles 1.3%, and pedestrians 1.2%, $p<0.001$). In the post-pandemic period, there was an increase in head injuries by 3.3% ($p=0.013$), lower extremity injuries by 3.1% ($p=0.003$), and injuries to the upper extremity by 1.3% ($p=0.018$). There was a notable increase in the proportion of cases requiring intensive care unit admission by 5.6% ($p=0.001$) in the post-pandemic period. In-hospital mortality was 278 (4.2%), pre-pandemic 113 cases (1.7%), and post-pandemic 165 cases (2.5%), $p=0.478$.

Conclusion This study revealed a shift in the distribution of cases across age groups, mechanism of injury, injury severity, and outcomes, with notable changes in percentages and varying degrees of increases in cases after the pandemic. It is worth investing in increasing road traffic safety and reducing injuries to minimise the burden of RTC-related injuries in Saudi Arabia.

Keywords Road injury, Major trauma, Motor Vehicle crashes, After COVID-19, Post pandemic

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Introduction

Road traffic injuries stand as the primary source of unintentional injuries and are a significant contributor to mortality, disability, and hospital admissions across many countries [1, 2]. Currently, road traffic crashes (RTCs) hold the position of the eighth most common cause of death globally, disproportionately affecting children and young adults aged 5 to 29 years [3]. The World Health Organization (WHO) reports that RTCs are responsible for nearly 1.3 million preventable deaths and an estimated 50 million injuries each year [3]. Predominantly, these incidents occur in low- and middle-income countries, accounting for about 93% of global RTCs, with expectations that they will rise to become the seventh leading cause of death worldwide by 2030 [3, 4]. In Saudi Arabia, traffic-related injuries are a significant public health concern and the leading cause of death [4].

Coronavirus disease 2019 (COVID-19) was first reported in Wuhan, China in December 2019 and rapidly evolved into a global health crisis [5]. The WHO declared it a public health emergency on January 30, 2020, and a pandemic on March 11, 2020. In response, countries including Saudi Arabia imposed strict lockdowns. Saudi Arabia's first COVID-19 case emerged on March 2, 2020, leading to immediate measures such as closing schools, suspending public events, and halting international flights [6]. A stay-at-home order followed in Riyadh on April 6, 2020. By June 21, 2020, Saudi authorities relaxed these restrictions, allowing activities to resume under continued health precautions and social distancing [6].

During the pre-pandemic era, Saudi Arabia experienced a notable decline in road traffic-related incidents and fatalities. Specifically, from 2016 to 2020, there was a significant reduction in severe RTCs by 36% and in traffic-related deaths by 30% [7]. This positive trend aligns closely with the strategic objectives of Saudi Arabia's Vision 2030, where enhancing road safety is a crucial component of the National Transformation Program. This initiative reflects a broader commitment to improving public health and safety standards, promoting responsible driving behaviors, and implementing more stringent traffic regulations. During the pandemic, Saudi Arabia's enforcement of lockdown and home quarantine measures contributed to a notable decrease of 26.8% in road traffic crashes (RTCs), particularly those involving multiple vehicles [8]. Additionally, subsequent research indicated a 5.2% decrease in overall trauma cases, though there was a minor rise in in-hospital mortality of 0.6% in the year following the easing of these restrictions [9]. Despite these observations, there remains a significant gap in the literature regarding the effects and outcomes of RTCs post-pandemic. The timing of this study is critical for understanding how pandemic-related changes, such as reduced mobility during lockdowns and the rebound in activity post-pandemic, influenced RTC patterns. These shifts may have impacted traffic volumes, driver behaviors, enforcement practices, and healthcare access, resulting in changes in the frequency and severity of RTCs.

This study aims to understand the evolving dynamics of road traffic injuries in the post-pandemic era. Strict lockdown measures during the pandemic significantly altered mobility and road use patterns, leading to an initial global decline in RTCs [10–13]. This reduction was also observed in Saudi Arabia [14]. However, the status of RTC characteristics and outcomes after the pandemic remains unclear. This study seeks to compare pre- and post-pandemic RTCs to understand changes in patient characteristics and outcomes following the pandemic. Insights from this comparison can inform the design of effective injury prevention strategies and support Saudi Arabia's Vision 2030 goals for reducing road fatalities. Specifically, the study aimed to review the characteristics and outcomes of RTCs during the first two and a half years of the post-pandemic era in Riyadh, Saudi Arabia.

Methods

Data for this study were obtained retrospectively from the Saudi TraumA Registry (STAR) at King Saud Medical City (KSMC) in Riyadh, Saudi Arabia. The STAR is an electronic system initiated in 2017 that records information exclusively from trauma patients treated at KSMC. The registry collects information on the trauma patient's journey from prehospital to discharge, encompassing 83 variables. It is managed under the trauma centre's directorate and includes a team of six data collectors, all certified by the Association for the Advancement of Automotive Medicine (AAAM). The registry includes patients who meet specific criteria, including a principal diagnosis of injury, death in the Emergency Department (ED) after injury, inpatient death following injury, or admission to the Intensive Care Unit (ICU) [15]. The registry's exclusion criteria are as follows: traumatic injury not being the reason for acute care, injuries distal to the wrist or ankle (except for amputations of the hand or foot at or proximal to the level of the metacarpals or metatarsals), a length of stay of less than three calendar days (apart from cases involving death or ICU admission), and injuries that occurred more than one week prior to admission to the first hospital [15].

The study included traumatic injury patients who presented to the ED or were admitted to the hospital during two periods: the pre-pandemic period from August 2017 to March 2020 and the post-pandemic period from July 2020 to December 2022. A three-month gap during the lockdown, between the pre-pandemic and post-pandemic periods, was excluded from the analysis to ensure a clear distinction between the two study phases.

This gap represents a transitional period where data were not included to avoid overlap or misclassification of RTC admissions. Data were collected on various variables, including patient demographics (e.g., age, gender), injury details (e.g., time and place of injury, mechanism and severity of injury), definitive care mode of arrival (e.g., ambulance, private vehicle), prehospital and in-hospital vital signs (e.g., systolic blood pressure, heart rate, respiratory rate, oxygen saturation), and ED and in-hospital outcomes (e.g., duration of hospitalization, ICU admission, mortality). To explore the characteristics and outcomes of RTC-related injuries, the analysis specifically concentrated on comparing the pre-pandemic and post-pandemic periods. Utilizing the STAR data, a detailed evaluation of injury patterns and outcomes was conducted for these distinct timeframes.

Statistical analyses

Categorical variables, for example, age groups, gender, injury time, and injury causes were analyzed using chi-square tests. Descriptive statistics and chi-square tests were employed to examine the relationships between the period of injury and various trauma-related variables. Descriptive statistics were used to summarize data on variables such as Glasgow Coma Scale (GCS) scores, Injury Severity Score (ISS) categories, ED discharge reasons, required operations, ICU admissions, hospitalization duration, and mortality rates.

Independent samples t-tests were conducted to compare means between different groups in the study. Specifically, t-tests were performed to examine the differences in vital signs, ICU stay duration, and hospitalization duration between the pre-pandemic and post-pandemic groups. Levene's test was used to assess the equality of variances, and based on the results, t-tests assuming equal variances were reported. Descriptive statistics were calculated for the variables of interest, including means and standard deviations. The level of statistical significance was set at $p < 0.05$ for all tests. The statistical software (SPSS 27) was utilized to perform the statistical analyses.

The variables, including injury year, Injury Severity Score (ISS), Glasgow Coma Scale (GCS) score, days in ICU, mode of arrival, injury type, requirement for operations, and injury year, served as independent variables, while in-hospital mortality was the dependent variable. Univariate analyses were conducted to identify predictors of in-hospital mortality in the pre- and post-periods. Factors that showed significant associations with the outcome variable in either period were then included in a multivariable logistic regression model.

Additionally, another logistic regression analysis was performed to examine the relationship between the mechanism of injury and outcomes, including ICU admission and in-hospital mortality. The variables included in this analysis were motor vehicle driver, motor vehicle passenger, motorcycle, and pedal cyclist, each representing different mechanisms of injury sustained by the participants. Adjusted Odds Ratios (AOR) and their 95% confidence intervals (CI) were calculated to quantify the strength and direction of the associations. Significance levels were determined using p-values, with a threshold of 0.05. This study was approved by the Institutional Review Board (IRB) Committee at KSMC (Ref: H1RI-20–June21-01). This study waived the need to obtain informed consent, according to the regulations approved by the IRB Committee at KSMC, Riyadh, Saudi Arabia, because this study used non-identifiable data from an existing data set. All methods were performed according to the relevant guidelines and regulations.

Results

Patient demographics

Out of the 13,346 trauma patients recorded in the STAR database from August 1, 2017, to December 31, 2022, a total of 6,577 sustained road injuries during the study period. Of the 6,577 patients, 2,809 (42.8%) patients were in the pre-pandemic phase (period 1), and 3,768 (57.2%) patients were in the post-pandemic phase (period 2). There was an increase in the total number of road injuries by 14.4% in the post-pandemic period. We observed changes in the distribution of injury cases across different age groups. The age group 0–14 accounted for 8.4% (550 cases) of the total cases, which increased from 3.5 to 4.9% after the pandemic. Age group 15–29, the most significant portion of total cases, 48.9% (3212 cases), saw an increase of 2.7% after the pandemic (pre = 1518, post = 1695 cases). Age groups 30–44 and 45–59 showed an increase of 7% and 2.4% in cases after the pandemic, respectively. Most cases were male, comprising 37.7% before the pandemic and increasing to 49.9% afterward, while females represented 5% before the pandemic and 7.4% afterward of the total cases. Table 1 presents patients' demographic and presentation characteristics, comparing pre-pandemic (period 1) and post-pandemic (period 2) data.

Injury time distribution revealed a 5.5% increase in daytime cases (6:00–18:59) and a 9.1% increase in nighttime cases (19:00–5:59) between the pre- and post-pandemic periods. Before the pandemic, daytime cases accounted for 15.1% (991 cases), while nighttime cases represented 27.6% (1818 cases). Additionally, ISS scores increased by 6.6% for ≤ 14, 7.6% for 15–40, and 0.4% for > 40, with a significant association between injury periods and ISS categories ($\chi^2 = 43.993$, df = 2, $p < 0.001$).

Table 1 Demographic and presentation characteristics of traumatic injury patients of pre- and after pandemic

Variables	Total	Pre- pandemic	Post- pandemic	% changes	*P* value
		30 months Period 1	30 months Period 2		
	N **= 6577**	***N*** **= 2809 (42.8)**	***N*** **= 3768 (57.2)**	**14.4**	
Mean age in years (SD)					
Age group, *n* (%)	**6575**	**2808**	**3767**		< 0.001
1–14	550 (8.4)	227 (3.5)	323 (4.9)	1.4	
15–29	3213 (48.9)	1518 (23.1)	1695 (25.8)	2.7	
30–44	1709 (26.0)	623 (9.5)	1086 (16.5)	7	
45–59	772 (11.7)	308 (4.7)	464 (7.1)	2.4	
≥ 60	331 (5.0)	132 (2.0)	199 (3.0)	1	
Gender *n* (%)	**6577**	**2809**	**3768**		0.145
Male	5764 (87.6)	2481 (37.7)	3283 (49.9)	12.2	
Female	813 (12.4)	328 (5.0)	485 (7.4)	2.4	
Injury time, *n* (%)	**6577**	**2809**	**3768**		0.553
Day (6:00–18:59)	2347 (35.7)	991 (15.1)	1356 (20.6)	5.5	
Night (19:00–5:59)	4230 (64.3)	1818 (27.6)	2412 (36.7)	9.1	
Mechanism of injury, *n* (%)	**6577**	**2809**	**3768**		< 0.001
Motor Vehicle– drivers	3442 (52.3)	1387 (21.1)	2055 (31.2)	10.1	
Motor Vehicle– passengers	1623 (24.7)	750 (11.4)	873 (13.3)	1.9	
Motorcycle	427 (6.5)	173 (2.6)	254 (3.9)	1.3	
Pedal cyclist	35 (0.5)	14 (0.2)	21 (0.3)	0.1	
Pedestrian	1050 (16.0)	485 (7.4)	565 (8.6)	1.2	
Injury type, *n* (%)	**13,065**	**5567**	**7498**		
Head	2033 (15.7)	822 (6.2)	1211 (9.5)	3.3	0.013
Face	1350 (10.4)	546 (4.2)	804 (6.2)	2	0.059
Neck	29 (0.2)	9 (0.04)	20 (0.1)	0.1	0.203
Thorax	1959 (15.1)	814 (6.2)	1145 (8.7)	2.5	0.216
Abdomen & pelvic	745 (5.7)	308 (2.3)	437 (3.4)	1.1	0.423
Spine	2382 (18.3)	1042 (8.0)	1340 (10.3)	2.3	0.201
Upper extremities	1632 (12.5)	738 (5.6)	894 (6.9)	1.3	0.018
Lower extremities	2935 (22.1)	1288 (9.5)	1647 (12.6)	3.1	0.003
Procedure at scene, *n* (%)	**6531**	**2774**	**3757**		< 0.001
Yes	1756 (26.9)	828 (12.7)	928 (14.2)	1.5	
No	4775 (73.1)	1946 (29.8)	2829 (43.3)	13.3	
Definitive Care Mode of Arrival, n (%)	**6169**	**2580**	**3589**		< 0.001
Red Crescent ambulance	2241 (36.3)	1149 (18.6)	1092 (17.7)	-0.9	
Helicopter	108 (1.8)	33 (0.5)	75 (1.2)	0.7	
Private/ govt ambulance	3083 (50.0)	1031 (16.7)	2052 (33.3)	16.6	
Private/police vehicle	737 (11.9)	367 (5.9)	370 (6.0)	0.1	
Trauma Team Activation, *n* (%)	**6548**	**2792**	**3756**		< 0.001
Yes	779 (11.9)	398 (6.1)	381 (5.8)	-0.3	
No	5769 (88.1)	2394 (36.6)	3375 (51.5)	14.9	
Blood transfusion in ED, *n* (%)	**6571**	**2809** 1	**3762**		0.060
Yes	368 (5.6)	40 (2.1)	228 (3.5)	1.4	
No	6203 (94.4)	2669 (40.6)	3534 (53.8)	13.2	
On arrival at the ED, mean (SD)					
First systolic BP	124.2 (21.6)	124.7 (22.1)	123.9 (21.2)	0.03	0.138
First heart rate	93.8 (19.1)	93.5(19.3)	94.10 (18.9)	− 0.02	0.266
First RR	19.8 (2.5)	19.8 (2.4)	19.8 (2.6)	− 0.01	0.655
First O_2 saturation	96.4 (6.5)	96.3 (7.56)	96.6 (2.64)	− 0.04	0.095
Respiratory assistance, *n* (%)	**6399**	**2672**	**3727**		< 0.001

Table 1 (continued)

Variables	Total	Pre- pandemic	Post- pandemic	% changes	*P* value
		30 months Period 1	30 months Period 2		
	N **= 6577**	***N*** **= 2809 (42.8)**	***N*** **= 3768 (57.2)**	**14.4**	
Assisted respiration	1524 (23.8)	776 (12.1)	748 (11.7)	-0.4	
Unassisted respiration	4875 (76.2)	1896 (29.6)	2979 (46.5)	16.9	

Interquartile Range = IQR; Blood Pressure = BP; Respiratory Rate = RR; Standard Deviation = SD; Emergency Department = ED. ^{M} = Median

Mechanism of injury

Injury cases were attributed to various causes across both the pre-pandemic and post-pandemic periods. Among the categories analyzed, the highest percentage of cases was observed in motor vehicle drivers (pre 21.1% vs. post 31.2%), followed by motor vehicle passengers (pre 11.4% vs. post 13.3%), motorcycles (pre 2.6% vs. post 3.9%), pedal cyclists (pre 0.2% vs. post 0.3%), and pedestrians (pre 7.4% vs. post 8.6%). The comparison between the pre-pandemic and post-pandemic periods revealed significant changes in the distribution of trauma cases by injury cause (χ^2 = 22.468, df = 4, $p < 0.001$). Specifically, there was a substantial increase of 10.1% in injury cases related to motor vehicle drivers and a 1.9% increase in cases related to motor vehicle passengers. Moreover, cases related to motorcycles and pedestrians increased 1.3% and 1.2%, respectively.

Clinical characteristics

In the pre-pandemic period, 6.2% ($n = 822$) of cases involved head injuries, increasing to 9.5% ($n = 1211$) post-pandemic (χ^2 = 6.233, df = 1, $p = 0.013$). Face injuries showed a marginally significant 2.0% increase (χ^2 = 3.562, df = 1, $p = 0.059$). Upper extremity injuries rose by 1.3% (χ^2 = 5.594, df = 1, $p = 0.018$), and lower extremity injuries increased by 3.1% (χ^2 = 8.993, df = 1, $p = 0.003$), both showing significant associations with the pandemic period. Further, the hospital mode of arrival distribution changed between the pre-pandemic and post-pandemic periods. The pre-pandemic period showed Red Crescent ambulance (18.6%) as the first most common mode of arrival. In comparison, the post-pandemic period saw a decrease of approximately − 1% in cases arriving by Red Crescent ambulance. On the other hand, there was a substantial increase of about 16.6% in cases arriving by Private/Government ambulance, which became the most common mode of arrival during the post-pandemic period (pre 16.7% vs. post 33.3%) (χ^2 = 196.136, df = 3, $p < 0.001$).

The analysis revealed that trauma team activation was less frequent in both periods, with 36.6% in the pre-pandemic period and 51.5% in the post-pandemic period, showing a significant association (χ^2 = 25.826, df = 1, $p < 0.001$). An independent t-test comparing vital signs (blood pressure, pulse rate, respiration rate, and oxygen saturation) showed no significant differences between the periods ($p > 0.05$). However, cases with unassisted respiration increased by 16.9% post-pandemic, with a significant association between injury periods and respiration assistance (χ^2 = 69.047, df = 1, $p < 0.001$).

Patients outcome

Table 2 shows patient outcomes following injury events. In the pre-pandemic period, the majority of cases were discharged to the Ward (32.8%), followed by ICU (8.0%) and operation theatre (1.7%). However, in the post-pandemic period, there was a notable increase in the proportion of cases in each category: Ward (42.1%), ICU (12.6%), and operation theatre (2.6%) (χ^2 = 13.746, df = 3, $p = 0.003$). There was a 10.5% increase in the proportion of cases requiring operations and a 4.1% increase in the proportion of cases not requiring operations from the pre-pandemic to the post-pandemic period (χ^2 = 2.382, df = 1, $p = 0.123$). Further, in the post-pandemic period, the proportions increased by 5.6% for ICU admission cases (χ^2 = 11.656, df = 1, $p = 0.001$).

Descriptive statistics were calculated for the association between injury periods and the duration of hospitalization, categorized as more than one day. In the pre-pandemic period, there were 1,215 cases (18.5% of the total) in this category, while in the post-pandemic period, there were 1,675 cases (25.5% of the total) (χ^2 = 8.219, df = 1, $p = 0.004$). A t-test was conducted to compare the mean duration of days spent in the ICU between the pre-pandemic and post-pandemic groups. Levene's test indicated unequal variances (F = 47.808, $p < 0.001$); therefore, the t-test assuming equal variances was reported. The t-test revealed a significant difference in means (t = -3.417, df = 6570, $p = 0.001$), indicating that the post-pandemic group (M = 0.27, SD = 0.445) had a more extended ICU stay compared to the pre-pandemic group (M = 0.23, SD = 0.424). Cohen's d was calculated as 0.436, suggesting a moderate effect size.

A t-test was conducted to compare the mean duration of hospital stays between the pre-pandemic and post-pandemic groups. Levene's test indicated unequal variances (F = 20.593, $p < 0.001$), and the t-test assuming equal variances was reported. The t-test revealed a marginally significant difference in means (t = -2.266, df = 6570, $p = 0.023$), suggesting that the post-pandemic

Table 2 Level of consciousness, injury severity, and patient outcome following injury events

Variables and outcomes	Total	Pre-Pandemic	Post-Pandemic	% changes	*P* value
		Period 1 30 months	Period 2 30 months		
	N **= 6574**	***N*** **= 2808**	***N*** **= 3757**		
GCS score, *n* (%)	**3107**	**1130**	**1977**		0.600
13 – 15	2582 (83.1)	929 (29.9)	1653 (53.2)	23.3	
9 – 12	114 (3.7)	43 (1.4)	71 (2.3)	0.9	
3 – 8	411 (13.2)	158 (5.1)	253 (8.1)	3.0	
ISS, *n* (%)	**6572**	**2809**	**3763**		< 0.001
≤ 14	4639 (70.6)	2104 (32.0)	2535 (38.6)	6.6	
15–40	1853 (28.2)	676 (10.3)	1177 (17.9)	7.6	
> 40	80 (1.2)	29 (0.4)	51 (0.8)	0.4	
Disposition from ED, *n* (%)	**6535**	**2787**	**3748**		0.003
Ward	4903 (74.9)	2148 (32.8)	2755 (42.1)	9.3	
ICU	1350 (20.6)	525 (8.0)	825 (12.5)	4.5	
Operating theatre	282 (4.3)	114 (1.7)	168 (2.6)	0.9	
Requires Operation, n (%)	**6565**	**2805**	**3760**		0.123
Yes	4312 (65.7)	1813 (27.6)	2499 (38.1)	10.5	.
No	2253 (34.4)	992 (15.1)	1261 (19.2)	4.1	
ICU admission, *n* (%)	**6572**	**2809**	**3763**		< 0.001
Yes	1684 (25.6)	660 (10.0)	1024 (15.6)	5.6	
No	4888 (74.4)	2149 (32.7)	2739 (41.7)	10	
Days in ICU (in days)[$]					
Median (IQR)	0 (1)	0 (1)	0 (2)	− 0.085	< 0.001
Days in hospital (in days)					
Median (IQR)	10 (14)	9 (13)	9 (12)	− 0.057	0.023
In-hospital mortality, *n* (%)	278 (4.2%)	113 (1.7)	165 (2.5)	0.8	0.478

Glasgow Coma Scale = GCS; Injury Severity Score = ISS; Emergency Department = ED; Intensive Care Unit = ICU; Interquartile Range = IQR

group (M = 1.00, SD = 0.040) had a slightly shorter hospital stay compared to the pre-pandemic group (M = 1.00, SD = 0.068). Cohen's d was calculated as 0.054, indicating a small effect size. In-hospital mortality was 1.7% (113 cases) in the pre-pandemic group and 2.5% (165 cases) in the post-pandemic group, with a chi-square value of 0.504 and $p = 0.478$.

Risk factors for ICU admission and mortality

The univariate results for predictors of in-hospital mortality following injury events are presented in the supplementary file, Appendix 1. Table 3 presents the results of the multivariable logistic regression model that was used to predict in-hospital mortality. The logistic regression results indicate that individuals aged 60 and above demonstrated a significantly increased risk of mortality in the pre-pandemic phase (AOR = 3.48) and the post-pandemic phase (AOR = 3.22). In the pre-pandemic phase, patients with injuries to the head and abdomen had a significantly higher risk of mortality (AOR = 2.17, 95% C.I. [1.26, 3.73], $p = 0.005$) and (AOR = 1.83, 95% C.I. [1.09, 3.07], $p = 0.022$), respectively. In the post-pandemic phase, similar patterns were observed for patients with head injuries (AOR = 1.52, 95% C.I. [1.00, 2.32], $p = 0.048$). However, injuries to the abdomen were found to be statistically insignificant.

In the pre-pandemic phase, patients transported by Red Crescent ambulance and private/police vehicles had a higher risk of mortality compared to the reference group (AOR = 0.31, 95% C.I. [0.12, 0.80], $p = 0.016$) and (AOR = 0.17, 95% C.I. [0.03, 0.77], $p = 0.021$), respectively. However, these associations were not observed in the post-pandemic phase. Further, other mortality risk factors were respiratory assistance (AOR = 2.51, 95% C.I. [1.42, 4.42], $p = 0.001$), ICU admission (AOR = 6.27, 95% C.I. [3.09, 12.73], $p = 0.001$), and an increase in the number of days spent in the ICU (AOR = 1.05, 95% C.I. [1.02, 1.07], p = < 0.001) in the pre-pandemic phase. In the post-pandemic phase, requirement for operations showed a significant association with an increased risk of mortality (AOR = 0. 59, 95% C.I. [0.40, 0.86], $p = 0.007$), respiratory assistance (AOR = 3.63, 95% C.I. [2.23, 5.90], $p = 0.001$), ICU admission (AOR = 5.68, 95% C.I. [2.94, 10.97], $p = 0.001$), and an increase in the number of days spent in the ICU (AOR = 1.11, 95% C.I. [1.08, 1.15], $p = 0.001$).

Table 4 presents the adjusted predictors for ICU admission and in-hospital mortality based on the mechanism of injury. Among the significant predictors of the mechanism of injury, in the post-pandemic period,

Table 3 Multivariable logistic regression model predicting in-hospital mortality

Independent variable	Pre-pandemic Period 1	Post-pandemic Period 2
	Mortality	Mortality
	AOR (95% CI) *p* value	AOR (95% CI) *p* value
Age		
15–29	1.04 (0.65, 1.64) 0.867	0.69 (0.47, 1.02) 0.063
≥ 60	3.48 (1.61, 7.48) 0.001	3.22 (1.74, 5.93) 0.001
Gender		
Male	1.85 (0.87, 3.91) 0.106	1.91 (0.96, 3.80) 0.064
Female	Ref	Ref
Type of injury		
Head injury	2.17 (1.26, 3.73) 0.005	1.52 (1.00, 2.32) 0.048
Thorax injury	1.03 (0.65, 1.63) 0.888	1.00 (0.68, 1.46) 0.992
Abdomen and pelvic injury	1.83 (1.09, 3.07) 0.022	0.92 (0.56, 1.51) 0.760
Lower extremities injury	1.02 (0.62, 1.66) 0.933	0.98 (0.64, 1.52) 0.957
Mode of arrival		
By Red Crescent ambulance	0.31 (0.12, 0.80) 0.016	1.51 (0.18, 12.35) 0.696
By Helicopter	0.26 (0.04, 1.60) 0.147	4.03 (0.43, 37.35) 0.219
Private/ govt ambulance	0.44 (0.17, 1.11) 0.085	3.36 (0.43, 25.87) 0.243
By Private/police vehicle	0.17 (0.03, 0.77) 0.021	1.01 (0.08, 11.96) 0.992
Respiratory Assistance (yes)	2.51 (1.42, 4.42) 0.001	3.63 (2.23, 5.90) 0.001
ICU admission (yes)	6.27 (3.09, 12.73) 0.001	5.68 (2.94, 10.97) 0.001
Require operation (yes)	0.73 (0.45, 1.17) 0.192	0.59 (0.40, 0.86) 0.007
Length of stay in ICU	1.05, (1.02, 1.07) 0.001	1.11 (1.08, 1.15) 0.001
Length of hospital stay	0.966 (0.94, 0.98) 0.001	0.91 (0.88, 0.93) 0.001

Adjusted Odds Ratio = AOR; Glasgow Coma Scale = GCS; Injury Severity Score = ISS; Intensive Care Unit = ICU

Table 4 Adjusted predictors for ICU admission and in-hospital mortality by mechanism of injury

Mechanism of injury	Pre-Pandemic		Post-Pandemic	
	ICU admission	Mortality	ICU admission	Mortality
	AOR (95% CI) *P* value	AOR (95% CI) *P* value	AOR (95% CI) *P* value	AOR (95% CI) *P* value
Motor Vehicle drivers	0.95 (0.75, 1.2) 0.710	0.88 (0.56, 1.40) 0.611	1.13 (0.91, 1.39) 0.248	1.19 (0.76, 1.87) 0.426
Motor Vehicle passenger	0.88 (0.67, 1.15) 0.357	0.34 (0.18, 0.65) 0.001	1.08 (0.85, 1.37) 0.517	0.74 (0.43, 1.28) 0.284
Motorcycle	0.42 (0.26, 0.70) 0.001	0.19 (0.04, 0.84) 0.028	0.66 (0.46, 0.96) 0.030	0.17 (0.04, 0.72) 0.017
Pedal cyclist	0.49 (0.10, 2.22) 0.355	0.00 (0.00, 0.00) 0.999	2.14 (0.88, 5.20) 0.090	1.08 (0.13, 8.37) 0.941

pedal cyclists showed a marginal association with ICU admission (AOR = 2.147, $p = 0.090$). There was an association between motorcycle and mortality in both the pre-pandemic (AOR = 0.198, $p = 0.028$) and post-pandemic (AOR = 0.171, $p = 0.017$) periods. However, caution should be exercised as the variable pedal cyclist in the pre-pandemic period showed an extreme coefficient (B = -18.372) with an uninterpretable p-value ($p = 0.999$). In the post-pandemic period, pedal cyclists did not significantly affect mortality (AOR = 1.080, $p = 0.941$).

Discussion

This study explored the characteristics and outcomes of road traffic injury patients treated at a major trauma center during the first two and a half years post-pandemic in Saudi Arabia. This study aligns with road traffic safety initiatives by identifying shifts in RTC trends, injury patterns, and outcomes. The data reveals a shift in the distribution of cases across age groups, with notable changes in percentages and varying degrees of increases in cases after the pandemic. The analysis of age distribution showing that the 30–44 age group experienced the highest increase in RTCs at 7%, followed by a 2.7% increase in the 15–29 age group. The study result is highly inconsistent with those studies stating that drivers of extreme ages are extensively involved in a higher incidence of vehicular mishaps, where older drivers often face crashes due to driver's error [16, 17], and younger drivers are influenced more by human factors such as executive function capacities and negative behaviors on the road [18, 19]. In contrast, the age group 30–44, which includes individuals in their peak working years, shows an increased involvement in RTCs, likely due to frequent commuting for work and a higher propensity for engaging in multitasking behaviors such as using mobile phones while driving, thus contributing to their

increased risk of accidents. Additionally, the mental and emotional impacts of the pandemic, including increased stress and anxiety [20, 21], might have influenced driver behavior, especially in the early months of the post-pandemic period. This could potentially lead to higher risk-taking or decreased attention while driving.

The data shows a percentage increase of 12.2% in male cases of RTCs from the pre-pandemic to the post-pandemic period, while the increase in female cases over the same period is 2.4%. This observation aligns with prior research on a similar theme, indicating a higher involvement of males in RTCs than females [22, 23]. This gender disparity could be attributed to males' higher prevalence and participation in driving activities. A study conducted in Saudi Arabia demonstrated that males predominated the case numbers throughout the study period. However, a significant increase in female cases was observed one year after the lifting of COVID-19 pandemic restrictions, based on prehospital data [24], this trend aligns with our study findings. Other studies have reported similar findings, where males constitute the majority of injured individuals [25, 26]. The slight increase in the percentage of females involved in RTCs may be attributed to the lifting of the driving ban on women in Saudi Arabia in June 2018. This change marked a significant shift from previous restrictions, granting women the freedom to drive. Over the study period, more women began driving and actively participating in navigating roadways. However, other factors, such as changes in the female population and admission patterns, may also contribute to the rise in female RTC involvement.

Regarding the data on injury time distribution, the study showed an increase in percentage for both daytime, 5.5%, and nighttime injury, 9.1%, in the post-phase. Similarly, studies suggest that most collisions, approximately 67%, happen in the early part of the night, between 18:00 and 22:00 [27]. Furthermore, other studies showed that 36.2% of cases are recorded between 18:00 and midnight [28], 44.2% occur from 6:00 to 12:00 [29], and the peak time for collisions is identified as between 16:00 and 17:00 [30]. As to the mechanism of injury, the majority of cases during the pre-and post-pandemic period were from different etiologies. In this study, the highest increment at 10.1% in injury cases is related to motor vehicle drivers. This points towards a significant impact of vehicular activities on the overall prevalence of RTCs. Following closely, there is a noteworthy 1.9% increase in cases related to motor vehicle passengers, emphasizing the vulnerability of passengers within the vehicle. Moreover, cases of motorcycles and pedestrians increased by 1.3% and 1.2%, respectively. Our study has findings similar to previous research that vehicle driver-related factors cause most RTC injuries [25].

Studies have shown that the head, extremities, and face are the most affected body parts during a collision. Parallel to our study, head injuries (3.3%), followed by lower extremity (3.1) injuries, had increasing trends. Related studies showed varied results regarding the most affected site of injury, which highly depends on the number of cases encountered during the study period. For example, one study showed that among 357 cases reviewed, 141 (39.5%) of them sustained multiple injuries, followed by lower limb injuries,108 (30.3%) in which closed wounds accounted for 219 (61.3%) [31].

The COVID-19 pandemic challenged access to health care even after the post-restriction period. The means of transportation is one of the social determinants of health that affect health outcomes. In our study, the definitive care mode of arrival variable distinguishes between types of ambulance services; Red Crescent ambulances provide prehospital emergency care, while private and government ambulances are generally utilized for interfacility transfers involving Ministry of Health (MOH) and private hospitals. In relation to our study, the mode of arrival to the hospital shifted from using Red Crescent Ambulance to private/government ambulances, thus becoming the most common mode of transport during the post-pandemic period. This analysis provides valuable insights into the evolving role of trauma care systems [32, 33], highlighting opportunities to enhance both prehospital and in-hospital responses. These findings are instrumental for refining strategies that address the dual challenge of increasing RTCs and improving care outcomes.

The study further examined the relationship between injury period and respiration assistance during the pre-pandemic and post-pandemic periods. The significant increase of 16.9% in unassisted respiration at the ED observed during the post-pandemic period, compared to the pre-pandemic period, could potentially be attributed to advancements in emergency medical services. These advancements, such as faster response times or improved prehospital care protocols, may have led to more effective stabilization and management of patients with traumatic injuries before they arrive at the ED. As a result, the severity of injuries upon arrival at the ED may have been reduced, leading to a lower need for assisted respiration and potentially improving the survival rate for patients arriving by ambulance.

The study also analyzed the patient outcome, revealing an association between hospital duration and injury periods; indicating that the post-pandemic group had more extended ICU stay than the pre-pandemic group. The study also investigated into the associated risk factors for ICU admission and in hospital mortality. The results indicate that individuals aged 60 and above demonstrated a significantly increased mortality risk in both phases. Similarly, as mentioned in the literature, older age has

been recognized as an essential risk factor of mortality in COVID-19 among the studied population [34, 35]. Furthermore, the study found that patients require operation on arrival had a higher risk of mortality compared to the reference group in the post-pandemic phase. In addition, among the significant predictors of the mechanism of injury, motorcycle and pedal cyclists showed a marginal association with ICU admission in the post-pandemic period. This finding emphasizes the importance of recognizing and addressing the unique risks and medical needs of cyclists who have experienced traumatic injuries. However, in contrast to ICU admission, the study did not find a statistically significant association between cyclist injuries and mortality during the post-pandemic period.

This comprehensive study conducted at a major trauma center in Saudi Arabia reveals several critical insights into the evolving dynamics of RTC-related injuries in the post-pandemic period. Notably, the increase in RTCs, particularly among males, underscores the ongoing public health challenge and highlights the necessity for targeted interventions at both clinical and policy-making levels. Clinically, there is a pressing need to enhance trauma care readiness and post-care support to accommodate shifting injury patterns and increased caseloads. From a policy perspective, this surge in RTCs demands a revisitation and potential revision of traffic regulations and safety campaigns, emphasizing the need for stricter law enforcement and infrastructure improvements to enhance road safety. Overall, this study not only provides a clearer picture of the impact of the pandemic on road injuries but also serves as a call to action for healthcare providers, policymakers, and public health professionals to collaborate in devising comprehensive strategies that address both the direct and indirect effects of the increase in RTC-related injuries.

This study has several limitations that should be considered. First, one limitation of this study is the absence of absence of detailed data on the mechanism of RTCs, type of impact, and safety measures among road users. This gap restricts our ability to thoroughly assess how specific crash scenarios and user behaviors contribute to injury severity and types, potentially impacting the precision of our findings and the interpretation of the relationship between traffic incidents and trauma outcomes. Secondly, the study's data is drawn exclusively from a single trauma registry, potentially limiting the generalizability of the findings to other regions or populations not represented in the database. Future research could benefit from a multicenter study to provide more comprehensive and generalizable insights. Additionally, the retrospective nature of the data collection may introduce biases related to the accuracy and completeness of the records, which could influence the reliability of the analysis. Finally, another limitation of this study is that, despite the general lifting of lockdown in Saudi during the study period, some specific restrictions, particularly on sports gatherings, remained for several months. This could have continued to influence road traffic injury trends and thereby affect the study's findings.

Conclusion

In summary, this study revealed significant shifts in the distribution of RTC-related cases across various parameters, indicating a worsening trend in injury severity post-pandemic. This includes a higher proportion of critical injuries, increased ICU admissions, prolonged hospital stays, and elevated mortality rates in Saudi Arabia. It is imperative for preventive measures to address human, road, vehicle, and environmental factors to promote safer traffic conditions. Furthermore, sustained government and non-government investment and efforts are essential in enhancing road traffic safety and minimizing the burden of RTC-related injuries in the country.

Supplementary Information

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Supplementary Material 1

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Author contributions

All authors developed this study. RJA, AA2, EM, AA1, AA3, and SC contributed substantially to the study's conception or design. RJA planned, cleaned, analysed, and interpreted the data. RJA and EM prepared the first draft of this paper and revised critical comments and feedback from all authors. All authors approved the final version of the manuscript.

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Data availability

The datasets used during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval

This study was approved by the Institutional Review Board Committee at King Saud Medical City, Riyadh, Saudi Arabia (IRB Reference number H1RI-20–June21-01). This study waived the need to obtain informed consent, according to the regulations approved by the Institutional Review Board Committee at King Saud Medical City, Riyadh, Saudi Arabia, because this study used non-identifiable data from an existing data set. All methods were performed according to the relevant guidelines and regulations.

Competing interests

The authors declare no competing interests.

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