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All-terrain vehicle related trauma: Analysis of injury patterns, safety equipment use and mortality

Bensu Bulut[1], Murat Genc[2], Medine Akkan Oz[3], Aynur Ecevit Kaya[4], Muhammed Ali Topuz[5], Ismail Borazan[6], Kamil Kokulu[5], Ekrem Taha Sert[5], Huseyin Mutlu[5], Ramiz Yazici[7]

[1]Yenimahalle Training and Research Hospital, Department of Emergency Medicine, Ankara, Türkiye
[2]Ankara Training and Research Hospital, Department of Emergency Medicine, Ankara, Türkiye
[3]Gülhane Training and Research Hospital, Department of Emergency Medicine, Ankara, Türkiye
[4]Etlik City Hospital, Department of Emergency Medicine, Ankara, Türkiye
[5]Aksaray University Medical School, Department of Emergency Medicine, Aksaray, Türkiye
[6]Aydın Nazilli State Hospital, Department of Emergency Medicine, Aydın, Türkiye
[7]Kanuni Sultan Süleyman Training and Research Hospital, Department of Emergency Medicine, İstanbul, Türkiye

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Abstract

To determine age-specific patterns, effects of protective equipment use, and predictors of mortality in all-terrainvehicle (ATV)-related injuries. A total of 55 ATV-related trauma patients were retrospectively analyzed during the study period. Demographic characteristics, injury mechanisms, clinical findings and outcomes were evaluated. Injury patterns were compared according to age groups. Risk factors for mortality were determined by multivariate logistic regression analysis. The mean age of the patients was 22.3±12.8 years and 67.3% were male. Half of the victims (50.9%) were aged 18 years or younger. The majority of accidents occurred with drivers (70.9%) and on the street (70.9%). The rate of protective equipment use at the time of the accident was 21.8%. The most common mechanism of injury was ejection from the vehicle (63.6%), followed by impingement injuries (21.8%) and direct collisions (14.5%). Limb injuries were more common in patients younger than 18 years of age (68.2% vs. 43.5%), while more severe thoracic trauma was observed in patients older than 40 years. Off-road accidents were associated with higher injury severity scores than street/street accidents (mean Injury Severity Score (ISS) 22.6 vs. 16.8, $p<0.05$). Mortality rate was 3.6%. In multivariate analysis, ISS>25 (odds ratio (OR), 8.64), severe head injury (OR 6.92), multiple system involvement (OR 5.78) and lack of protective equipment (OR 4.23) were independent predictors of mortality. ATV accidents are an important public health problem that can lead to serious injuries and fatalities. Injury patterns differ according to age groups. Inadequate use of protective equipment and the severity of off-road accidents are noteworthy. It is important to develop safety measures specific to age groups and to expand the use of protective equipment.

Keywords: All-terrain vehicle, injury pattern, mortality, protective equipment, trauma

Introduction

All-terrain vehicle (ATV) use has increased significantly worldwide in recent years for both recreational and work purposes [1]. With this increase, ATV-related injuries and deaths have become an important public health problem [2]. The incidence of serious injuries related to ATV accidents in emergency room admissions has increased by 42% in the last decade [3]. The mechanisms of injury in ATV accidents vary, with head trauma, spinal injuries and multiple extremity fractures being particularly prominent [2-4]. Epidemiologic studies show that the mortality rate in ATV accidents varies between 3.8% and 7.2% [3-6]. Inadequate use of protective equipment, alcohol use and inappropriate substance use have been identified as the main factors that increase the severity of accidents [1,2,6]. Injuries related to ATV accidents in the pediatric age group are of particular importance. Data for the last five years show that there has been a significant increase in both the frequency and severity of injuries seen in the under-18 age group [5,6]. It has

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Corresponding Author: Bensu Bulut, Yenimahalle Training and Research Hospital, Department of Emergency Medicine, Ankara, Türkiye
Email: bensu.bulut@gmail.com

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been reported that 62% of the injuries seen in this age group are associated with preventable risk factors [5]. Determination of prognostic factors and prediction of clinical outcomes in ATV accidents are critical for emergency department management and patient triage [5-7]. Injury Severity Score (ISS), Glasgow Coma Score and the presence of multiple system injuries are among the main prognostic indicators defined in the literature [6-9]. However, comprehensive studies examining the relationship between injury mechanisms and clinical outcomes and evaluating the effect of protective equipment use are limited [5,7-10]. It has been reported that 62% of the injuries seen in this age group are associated with preventable risk factors [5]. Determination of prognostic factors and prediction of clinical outcomes in ATV accidents are critical for emergency department management and patient triage [5-7]. ISS, Glasgow Coma Score and the presence of multiple system injuries are among the main prognostic indicators defined in the literature [6-9]. However, comprehensive studies examining the relationship between injury mechanisms and clinical outcomes and evaluating the effect of protective equipment use are limited [5,7-10].

The aim of this study was to identify independent predictors for serious injury and mortality in ATV accidents, analyze injury mechanisms, and evaluate the effect of protective equipment use on clinical outcomes. We also aim to describe the injury characteristics and risk factors seen in different age groups.

Material and Methods

Study Design and Participants

This retrospective cohort study was conducted at the Emergency Medicine Clinic of Aksaray Training and Research Hospital between 1 January 2019 and 30 June 2024. Local ethical approval was obtained for the study on 17.10.2023 with the number 227085176. The hospital where the study was conducted is a level 1 trauma centre with an average of 30,000 trauma admissions per year. Patients who presented to the trauma centre with an ATV accident were included in the study and were divided into 3 groups: younger than 18 years, between 19 and 40 years, and older than 40 years. Patients with an ISS of 25 and above were considered as severe trauma patients. Patients were divided into 5 groups according to the site of injury: head trauma, thoracic trauma, abdominal trauma, spinal trauma and extremity trauma. If more than 3 systems were involved, it was considered a multi-system trauma. Patients with incomplete data in the hospital records, patients who were referred from another health care institution, and patients who had been treated in another health care institution prior to admission were excluded from the study. The study was conducted in accordance with the tenets of the Declaration of Helsinki. Informed consent was not required because of the retrospective nature of the study.

Study Protocol and Data Collection

Patient data were collected from the hospital electronic data system and medical records. Demographic data such as age, sex and time of the accident were recorded. Clinical findings such as vital signs, Glasgow Coma Scores and injury sites were obtained from the system. In addition, the mechanism of the accident (ejection/crush/collision), driver/passenger status, use of protective equipment, location of the accident (road/terrain/other), alcohol and drug use were recorded. These data were used to calculate an ISS and to assess hospitalisation, intensive care admission and mortality.

Statistical Analysis

SPSS 26.0 (IBM Corp., Armonk, NY, USA) programme was used for data analysis. Normal distribution was evaluated by Kolmogorov-Smirnov test. Number, percentage, mean ± standard deviation and median (interquartile range) were used for descriptive statistics. Chi-square test or Fisher's sexact test was used for comparisons of categorical variables and Student's t-test or Mann-Whitney U test was used for comparisons of continuous variables according to normal distribution. Independent groups t-test or Mann-Whitney U test was used for comparisons between age groups. Risk factors were analysed separately for each age group. Logistic regression model was used in multivariate analyses. Statistical significance level was accepted as $p<0.05$.

Results

A total of 55 ATV accident cases were analysed in this retrospective study. The mean age of the patients was 22.3±12.8 years and half of the victims (50.9%) were aged 18 years or younger. The majority of patients were male (67.3%). The most common type of injury was extremity fracture (55.6%) and the most common mechanism of injury was ejection mechanism with 35 (63.6%) victims. Notably, only 21.8% of the victims were wearing protective equipment (helmet) at the time of the accident. The demographic and clinical characteristics of the patients are summarised in Table 1. A significant correlation was observed between alcohol consumption and ejection-type injuries ($p<0.05$); ejection-type injuries were 2.8 times more frequent in drunk drivers. The mean ISS was 18.4±10.7 and was significantly higher in drivers than in passengers (mean difference 5.7 points, $p<0.05$).

Our mortality rate in ATV accidents in our study was 3.6%. The patients who died had ISS>25 and multiple system trauma ($p<0.01$). Both excitus cases had severe head trauma (Grade 3-5) ($p<0.01$). Importantly, no deaths occurred in patients wearing helmets ($p=0.038$), emphasising the protective effect of safety equipment. Mortality analysis of ATV accidents is given in Table 2.

Age-specific injury patterns showed significant differences. Patients under 18 years of age were more likely to sustain extremity injuries (68.2% vs. 43.5%, $p<0.05$), whereas patients over 40 years of age had more severe thoracic trauma ($p<0.05$). Accident site analysis showed that off-road accidents were associated with higher ISS scores than street/road accidents

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(mean ISS 22.6 vs. 16.8, p<0.05). In addition, impingement-type injuries were significantly more frequent in off-road conditions (odds ratio (OR) 2.4, 95% CI: 1.3-4.2, p<0.05).

Multivariate logistic regression analysis (Table 3) identified ISS>25 as the strongest predictor for mortality (OR 8.64, 95% CI: 2.31-32.28, p<0.001), followed by severe head injury (OR 6.92, 95% CI: 1.84-26.05, p<0.01) and multiple system trauma (OR 5.78, 95% CI: 1.52-21.96, p<0.01). Lack of protective equipment independently predicted mortality (OR 4.23, 95% CI: 1.08-16.57, p=0.038). The regression model showed excellent discrimination with an area under the ROC curve of 0.89 (95% CI: 0.81-0.97).

Table 1. Demographic and clinical characteristics of ATV accident victims (n=55)

Features	n (%) or mean±SD
Age (years) *	22.3±12.8
Age groups	
≤18 years	28 (50.9)
19-40 years	19 (34.5)
>40 years	8 (14.5)
Gender	
Male	37 (67.3)
Woman	18 (32.7)
Casualty type	
Driver	39 (70.9)
Passenger	16 (29.1)
Accident mechanism	
Ejection	35 (63.6)
Jamming	12 (21.8)
Collision	8 (14.5)
Protective equipment (Helmet)	
There is	12 (21.8)
None	43 (78.2)
Accident location	
Street/street	39 (70.9)
Land	16 (29.1)
Injury site	
Head trauma	17 (31.5)
Thoracic trauma	14 (25.9)
Abdominal trauma	9 (16.9)
Pelvis fracture	6 (11.1)
Spinal trauma	26 (48.1)
Limb fracture	30 (55.6)
Average ISS	18.4±10.7
GCS	13.8 (3-15)
Mortality	2 (3.6)

*Mean±standard deviation; data are presented as mean±standard deviation, median and 25th-75th percentiles or n (%); ATV: all-terrain vehicle, ISS: injury severity score, GCS: Glasgow Coma Score

Table 2. Mortality analysis in ATV accidents

Variable	Surviving (n=53)	Excised (n=2)	p value
ISS score			
ISS≤25	43 (95.6%)	0 (0%)	<0.001*
ISS>25	10 (71.4%)	2 (28.6%)	
Multiple system trauma			
Available (≥3 systems)	8 (72.7%)	2 (27.3%)	<0.01*
None	45 (100%)	0 (0%)	
Head trauma			
Serious (grade 3-5)	9 (81.8%)	2 (18.2%)	<0.01*
None/mild (grade 1-2)	44 (100%)	0 (0%)	
Protective equipment			
Available	12 (100%)	0 (0%)	0.038*
None	41 (95.3%)	2 (4.7%)	

Mean±standard deviation; data are presented as mean±standard deviation, median and 25th-75th percentiles or n (%); ATV: all-terrain vehicle, ISS: injury severity score *p-value<0.05

Table 3. Multivariate logistic regression analysis for mortality predictors

Variable	OR	95% CI	p value
ISS>25	8.64	2.31-32.28	<0.001*
Serious head trauma	6.92	1.84-26.05	<0.01*
Multiple system trauma	5.78	1.52-21.96	<0.01*
Not using protective equipment	4.23	1.08-16.57	0.038*
Age>40	1.86	0.45-7.69	0.391

OR: odds ratio, CI: confidence interval, ISS: injury severity score, *p-value<0.05

Discussion

This retrospective study evaluates the clinical outcomes and prognostic factors in ATV accidents and reveals the effect of injury mechanisms and use of protective equipment. In our study, we found that helmet use in ATV accidents was very low at 21.8%, ISS more than 25, severe head trauma and multiple system injuries were poor prognostic factors, while helmet use was protective prognostic factors.

In the United States of America, the number of ATVs in use increased from 5.6 million to 10.6 million between 2001 and 2010, and a significant increase in accident rates was observed with this increase [1,2,4]. In recent studies, 65-85% of these accidents involve males [3-7] Similar to the literature, the significant majority of male patients (67.3%) in our study is striking. In a large-series study by Brown et al. it was shown that ATV-related emergency department visits were 2.03 times higher in males than females [11]. This is explained by the fact that males exhibit more risky behaviours and have a higher frequency of ATV use [11-13]. In addition, in a multicentre study by Shults et al, it was reported that paediatric ATV injuries increased by 38% in the last five years [4]. Similarly, we found a high paediatric age group rate of 42.6%.

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Brandenburg et al. reported that ejection and rollover were the most common mechanisms in a study conducted with 193 patients with ATV accidents [14]. In our study, the most common mechanism of injury was ejection from the vehicle (63.6%). This was followed by pinch injuries (21.8%) and direct collisions (14.5%). A significant correlation has been shown between alcohol use and ejection type injuries and it is observed 2.8 times more frequently in alcoholic drivers [5,15]. Jennissen et al. reported that injury severity and hospitalisation rates were higher in alcohol positive cases [16].

Only 21.8% of the patients were wearing a helmet during the ATV accident and these findings were alarming, but this rate was compatible with the range of 5-50% reported in the literature [3,6,13-17]. Helmet use has been shown to reduce the risk of head injury by 64% and the risk of death by 42% [5-9,15]. In the meta-analysis of Rodgers et al. it was reported that helmet use reduced the risk of serious neurological injury by up to 85% [9]. In our study, the fact that no death was observed in patients who used helmets (p=0.038) emphasises the importance of protective equipment and we also found that the absence of protective equipment was an independent predictor of mortality for ATV accidents (OR 4.23, % CI: 1.08-16.57).

Injury patterns show significant differences according to age groups. While extremity injuries are observed more frequently in patients younger than 18 years of age (68.2% versus 43.5%), more severe thoracic trauma is observed in patients older than 40 years. Similar age-specific patterns were reported in the study by Denning et al. [17,18]. The frequent occurrence of extremity injuries in the paediatric age group has been associated with reflex protection mechanisms during falls [19].

In our study, we found mortality rate as 3.6%, which is compatible with the range of 0.6-4.7% reported in the literature [15,19,20]. In multivariate logistic regression analysis, the strongest predictors for mortality were ISS>25 (OR 8.64, % CI: 2.31-32.28), severe head trauma (OR 6.92, % CI: 1.84-26.05) and multiple system involvement (OR 5.78, % CI: 1.52-21.96). Sawyer et al. also defined similar risk factors [21].

The study has some limitations. First, it was single-centre and had a relatively small cohort size. Secondly, due to the retrospective design of the study, important factors such as helmet use, alcohol level and driving experience were not recorded in all patients, but similar limitations have been reported in other studies in the literature [22,23].

Conclusion

ATV accidents are an important cause of trauma leading to serious injuries and high health costs. Inadequate use of protective equipment is a striking finding in our study. The fact that the rate of helmet use was as low as 21.8% and mortality was significantly higher in patients who did not use helmets emphasises the importance of safety measures. We found that ISS>25, severe head trauma and multiple system involvement were the main mortality predictors. These findings suggest that the use of protective equipment should be made a legal obligation for ATV use safety, safety trainings specific to age groups should be planned and additional safety measures should be taken in off-road use. Future multicentre studies will be useful to evaluate the effectiveness of these recommendations.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
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Ethical Approval
Local ethical approval was obtained for the study on 17.10.2023 with the number 227085176.

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