ORIGINAL ARTICLE

Adrenal gland injury in trauma patients and its impact on clinical outcomes

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ABSTRACT

BACKGROUND: Adrenal gland injury (AGI) associated with trauma is an uncommon and often overlooked condition. This study aimed to evaluate the frequency of AGI in individuals with severe trauma injuries and investigate the outcomes of patients with AGI.

METHODS: All patients admitted to a tertiary trauma referral center under the trauma protocol who had a computed tomography (CT) scan between January 2012 and January 2023 were analyzed retrospectively. Patients who were dead on arrival and patients with incomplete data were excluded. They were classified into two main groups, adult and pediatric, and further subcategorized by the presence or absence of radiologically evident AGI. Demographic data, mechanism of injury, injury severity scores (ISS), presence of concurrent abdominal injury, and 30-day mortality rates were compared. A separate analysis was performed for factors affecting mortality rates.

RESULTS: A total of 1,253 patients were included: 950 adults and 303 pediatric patients. In the adult group, AGI was detected in 45 (4.7%) patients and was more commonly associated with the following mechanisms of injury: motor vehicle accidents (26.7% vs. 14.3%) and pedestrian accidents (37.8% vs. 15.5%). Injury to the right side was more common (55.6%). Patients with AGI had higher rates of concurrent liver (17.8% vs. 3.9%), spleen (11.1% vs. 3.6%), and kidney injuries (15.6% vs. 1.3%). In the pediatric population, AGI was detected in 30 patients (14.8%), a significantly higher rate compared to the adult group. Similar to the adult group, AGI was more commonly associated with concurrent abdominal injuries and had a right-sided dominance (60%), but the rate of concurrent abdominal injuries was higher in the pediatric group (80% vs. 46%). The 30-day mortality was significantly higher in both adult and pediatric AGI groups compared to patients without AGI (adult: 15.6% vs. 2.9%, pediatric: 10% vs. 1.8%). In patients with AGI, major head and neck injuries and chest injuries were associated with mortality.

CONCLUSION: Adrenal gland injuries due to trauma are not uncommon. They are usually associated with blunt trauma and other concurrent abdominal organ injuries. The major contributors to mortality in patients with AGI were major head and neck injuries and chest injuries.

Keywords: Adrenal trauma; adrenal gland injury; blunt adrenal injury; injury severity score.

INTRODUCTION

Adrenal gland injury (AGI) was considered a rare entity, occurring after high-energy trauma.[1-3] With the advent of imaging technologies and the use of whole-body computed tomography (CT) scans to evaluate patients with high-energy trauma, AGI is being observed more commonly by clinicians.[2] Although in the past decade, several studies from different re-

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gions, including large registries, have been published, the management of these patients remains a topic of debate for several reasons. In most studies, AGI is diagnosed retrospectively. Even when the diagnosis can initially be established, no solid data exist regarding the optimal management strategies for patients presenting with AGI. There are also conflicting statements regarding whether AGI is associated with increased morbidity and mortality in patients with trauma.[1,2,4]

The aims of the present study were to investigate the incidence of traumatic AGI over a ten-year period during which routine CT imaging was used in our trauma center, and to analyze the presentation characteristics of AGI and the short-term outcomes of adult and pediatric patients with AGI.

MATERIALS AND METHODS

Study Population and Evaluation of Trauma

The data of 1,372 patients who had been hospitalized at our tertiary trauma referral center due to blunt or penetrating thoracic/abdominal trauma or multiple injuries between January 2012 and January 2023 were reviewed. Patients who were dead on arrival were excluded. The evaluation of all hemodynamically stable patients presenting with blunt or penetrating thoracic or abdominal trauma or multiple injuries includes routine contrast-enhanced computed tomography at our center. Hemodynamically unstable patients are transferred directly to the operating room for exploratory surgery. Of the 1,372 patients, CT scan images were not available for 119, and these patients were excluded (Fig. 1). The study group included 1,253 patients for whom CT scan images were available on our hospital's picture archiving computer system (PACS). The images were reviewed by two experienced radiologists who were blinded to the clinical data of the patients, and the presence of AGI was decided by consensus of the two readers with the following criteria: expanding hematoma, irregular hemorrhage, uniform swelling, and active extravasation.

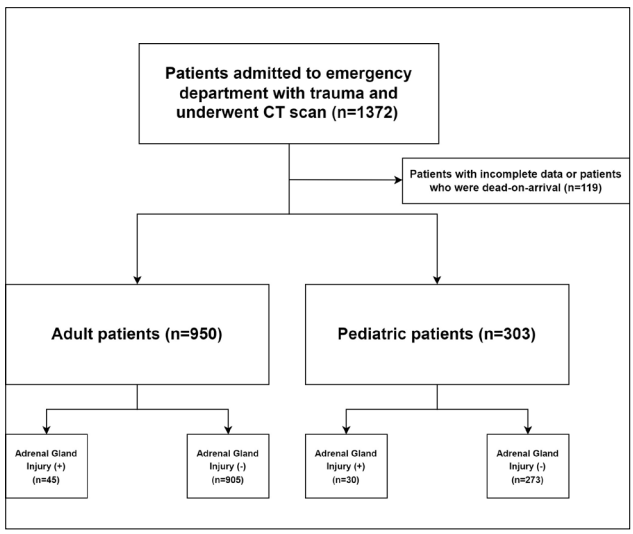

Figure 1. Study design.

Study Parameters

Demographic data, mechanisms of injury, injury severity score, the side of the adrenal injury, concurrent organ injuries, and the 30-day mortality rates were recorded for all patients. Injury severity scores (ISS) were calculated and categorized as minor (1-8), moderate (9-15), severe (16-25), and critical (≥25). Concurrent abdominal organ injuries were recorded and classified according to the abbreviated organ-specific injury scores (AIS).[6] The patients were divided into two groups according to age: adult (≥18 years) and pediatric (<18 years) patients. Adult and pediatric patients with AGI and without AGI were defined as A-AGI (+), P-AGI (+), A-AGI (-) and P-AGI (-) groups, respectively. Of the 1,253 patients included in the study, 950 were ≥18 years old, and 303 were <18 years old.

Demographics, mechanisms of injury, injury severity score, the side of adrenal injury, concurrent organ injuries with AIS≥3, and 30-day mortality rate were compared in patients with and without AGI in the whole group, and in adult and pediatric patients.

In order to determine factors that are strongly associated with mortality, a categorical comparison was performed for the whole group with the following categories: head and neck (AIS≥3), chest (AIS≥3), abdominal (AIS≥3) injuries, and AGI (+) with any of the previous categories. Moreover, for patients with AGI (+), a similar categorical comparison was performed for head and neck (AIS≥3), chest (AIS≥3), and abdominal (AIS≥3) injuries. Then, binary logistic regression analysis was performed to determine which of the previous categories are more significantly associated with mortality in patients with AGI.

Informed consent was obtained from all patients who underwent surgery before the surgery. This study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments, and under the approval of the institutional ethics review board (IU 30.01.2024-2391911).

Statistical Analysis

Statistical analyses were performed using IBM SPSS v28 (Armonk, NY, USA). Normally distributed data are presented as mean ± standard deviation (SD). Non-normally distributed data are presented within the median range. Categorical variables were compared using Fisher's exact test or the chi-square test. Continuous variables were compared using the independent t-test or the Mann-Whitney U test, considering normality. Binary logistic regression was used for regression analysis. Statistical significance was accepted when $p<0.05$.

RESULTS

The clinical features of the whole group were summarized in Table 1. The rate of AGI in the whole group was 6% (n=75/1,253). The mean age of the patients with AGI was significantly younger compared to that of the patients without

Table 1. Comparison of patients with and without adrenal gland injury: total population

Total (n=1253)	AGI (+) (n=75)	AGI (-) (n=1178)	p value
Age, mean ± SD years	24.5±17.3	34.3±22	<0.001
Sex (male/female)	54/21 (72%/28%)	923/255 (78.4%/21.6)	0.2
Mechanism of Injury, n (%)			
MVA	14 (18.7%)	154 (13.1%)	0.16
Motorcycle	2 (2.7%)	26 (2.2%)	0.35
Fall	25 (33.3%)	407 (34.6%)	0.8
Pedestrian	28 (37.3%)	189 (16%)	<0.001
Cyclist	0 (0%)	3 (0.3%)	0.6
Struck by	2 (2.7%)	39 (3.3%)	0.76
Stab	4 (5.3%)	275 (23.3%)	<0.001
GSW	0 (0%)	75 (6.4%)	0.02
Other	0 (0%)	10 (0.8%)	0.4
Adrenal Injury Side, n (%)			NA
Left	27 (36%)	0 (0%)	
Right	43 (57.3%)	0 (0%)	
Bilateral	5 (6.7%)	0 (0%)	
ISS, median (IQR)	25 (16-33)	25 (16-32)	0.49
ISS, n (%)			
Minor (1-8)	2 (2.7%)	19 (1.6%)	0.5
Moderate (9-15)	16 (21.3%)	142 (12.1%)	0.02
Severe (16-24)	19 (25.3%)	374 (31.7%)	0.24
Critical (≥25)	38 (50.7%)	643 (54.6%)	0.5
Abdominal Organ Injury, n (%)	45 (60%)	208 (17.7%)	<0.001
Spleen (AIS≥3)	10 (13.3%)	56 (4.8%)	0.001
Liver (AIS≥3)	19 (25.3%)	57 (4.8%)	<0.001
Kidneys (AIS≥3)	13 (17.3%)	15 (1.3%)	<0.001
Pancreas (AIS≥3)	2 (2.7%)	7 (0.6%)	0.04
Other (Hollow-viscus, major vascular injury, AIS≥3)	1 (1.3%)	103 (8.7%)	0.02
Solid organ injury (AIS≥3), n (%)	44 (58.7%)	135 (11.5%)	<0.001
30-day Mortality, n (%)	10 (13.3%)	31 (2.6%)	<0.001

AGI: Adrenal Gland Injury; SD: Standard Deviation; IQR: Interquartile Range. MVA: Motor Vehicle Accident; GSW: Gunshot Wound; ISS: Injury Severity Score; AIS: Abbreviated Injury Scale; NA: Not Applicable.

AGI, with a predominance of male patients in both groups. When the patients with or without AGI were compared, the rates of pedestrian accidents, abdominal organ injury, solid organ injury, and of patients with moderate ISS were significantly higher in patients with AGI, while penetrating injuries and hollow viscus or major vascular injury were significantly more frequent in patients without AGI. The majority (57.3%) of the patients with AGI had right-sided adrenal injury, left-sided and bilateral AGI were detected in 36% and 6.7% of the patients, respectively. The overall rate of 30-day mortality was 3.3% (n=41/1,253). When 30-day mortality analysis was performed in categories defined in the methodology section, head and neck injury (AIS≥3) was significantly more common in patients with mortality (21 (51.2%) vs. 305 (25.2%); p<0.001) while chest injury (AIS≥3) and abdominal injury (AIS≥3) were not significantly different for patients with mortality (chest injury: 30 (73.2%) vs. 763 (63%); p=0.181, abdominal injury: 21 (51.2%) vs. 556 (45.9%); p=0.499). The mortality rate in patients with AGI was 13.3% (n=10/75) and it was 2.6% (n=31/1,178) in patients without AGI (p<0.001). A high mortality rate in the AGI group was significantly associated with concurrent AIS≥3 head and neck injury, chest, or abdominal injury (Supplementary Table 2). For the subgroup of AGI patients with and without mortality, mortality

Table 2. Comparison of adult patients with and without adrenal gland injury

Adult (n=950)	A-AGI (+) (n=45)	A-AGI (-) (n=905)	p value
Age, mean ± SD	41.6±18.5	35.7±14.4	0.09
Sex (male/female)	37/8 (82.2/17.8%)	720/185 (79.6/20.4%)	0.66
Mechanism of Injury, n (%)			
MVA	12 (26.7%)	129 (14.3%)	0.02
Motorcycle	1 (2.2%)	23 (2.5%)	0.89
Fall	10 (22.2%)	272 (30.1%)	0.26
Pedestrian	17 (37.8%)	140 (15.5%)	<0.001
Cyclist	0 (0%)	1 (0.1%)	0.8
Struck by	2 (4.4%)	28 (3.1%)	0.6
Stab	3 (6.7%)	234 (25.9%)	0.001
GSW	0 (0%)	71 (7.8%)	0.05
Other	0 (0%)	7 (0.8%)	0.5
Adrenal Injury Side, n (%)			NA
Left	17 (37.8%)	0 (0%)	
Right	25 (55.6%)	0 (0%)	
Bilateral	3 (6.7%)	0 (0%)	
ISS, median (IQR)	25 (16-41)	25 (16-34)	0.75
ISS, n (%)			
Minor (1-8)	0 (0%)	12 (1.3%)	0.4
Moderate (9-15)	7 (15.6%)	89 (9.8%)	0.2
Severe (16-24)	12 (26.7%)	275 (30.4%)	0.6
Critical (≥25)	26 (57.8%)	529 (58.5%)	0.9
Abdominal Organ Injured, n (%)	21 (46.7%)	176 (19.5%)	<0.001
Spleen (AIS≥3)	5 (11.1%)	33 (3.6%)	0.012
Liver (AIS≥3)	8 (17.8%)	35 (3.9%)	<0.001
Kidneys (AIS≥3)	7 (15.6%)	12 (1.3%)	<0.001
Pancreas (AIS≥3)	1 (2.2%)	6 (0.7%)	0.2
Other (Hollow-viscus, major vascular injury, AIS≥3)	0 (0%)	90 (9.9%)	0.03
Solid organ injury (AIS≥3), n (%)	21 (46.7%)	86 (9.5%)	<0.001
30-day Mortality, n (%)	7 (15.6%)	26 (2.9%)	<0.001

A-AGI: Adult Adrenal Gland Injury; SD: Standard Deviation; IQR: Interquartile Range; MVA: Motor Vehicle Accident; GSW: Gunshot Wound; ISS: Injury Severity Score; AIS: Abbreviated Injury Scale; NA: Not Applicable.

was significantly associated with concurrent head and neck injury (AIS≥3) and chest injury (AIS≥3) while abdominal injury (AIS≥3) rates were similar (head and neck: 70% vs. 18%; p<0.001, chest: 7 (70%) vs. 30 (46.2%); p<0.001, abdominal: 7 (70%) vs. 56 (86.1%); p=0.248) (Supplementary Table 3). When binary logistic regression analysis was performed in the AGI group, only concurrent head and neck injury (AIS≥3) was significantly associated with an increased likelihood of 30-day mortality compared to other categories (Estimate 3.1, p<0.001 vs. Chest estimate 1.4 p=0.13 vs. Abdominal -0.5, p=0.631).

Adult Patients

Of the 950 adult patients, 45 (4.7%) had accompanying AGI. Demographic data, mechanisms of injury, injury severity score, the side of adrenal injury, concurrent organ injuries with AIS≥3, and the 30-day mortality rate in the adult group were summarized in Table 2. Demographic data showed no significant difference between the A-AGI (+) and A-AGI (-) patients.

The leading mechanisms of injury in A-AGI (+) patients consisted of pedestrian accidents in 17 (37.8%), motor vehicle accidents in 12 (26.7%), and falls from heights in 10 (22.2%)

Table 3. Comparison of pediatric patients with and without adrenal gland injury

Pediatric (n=303)	P-AGI (+) (n=30)	P-AGI (-) (n=273)	p value
Age, n ± SD	11.5±4.9	9.4±5.6	0.19
Male/female, n (%)	17/13 (56.7/43.3%)	203/70 (74.4/25.6%)	0.04
Mechanism of Injury, n (%)			0.21
MVA	2 (6.7%)	25 (9.2%)	0.6
Motorcycle	1 (3.3%)	3 (1.1%)	0.3
Fall	15 (50%)	135 (49.5%)	0.9
Pedestrian	11 (36.7%)	49 (18%)	0.015
Cyclist	0 (0%)	2 (0.7%)	0.6
Struck by	0 (0%)	11 (4%)	0.2
Stab	1 (3.3%)	41 (15%)	0.08
GSW	0 (0%)	4 (1.5%)	0.5
Other	0 (0%)	3 (1.1%)	0.5
Adrenal Injury Side, n (%)			NA
Left	10 (33.3%)	0 (0%)	
Right	18 (60%)	0 (0%)	
Bilateral	2 (6.7%)	0 (0%)	
ISS, median (IQR)	17 (16-26.7)	16 (16-32)	0.38
ISS, n (%)			
Minor (1-8)	2 (6.7%)	7 (2.6%)	0.6
Moderate (9-15)	9 (30.0%)	53 (19.4%)	0.17
Severe (16-24)	7 (23.3%)	99 (36.3%)	0.16
Critical (≥25)	12 (40%)	114 (41.8%)	0.8
Abdominal Organ Injured, n (%)	24 (80%)	62 (22.7%)	<0.001
Spleen (AIS≥3)	5 (16.7%)	23 (8.4%)	0.138
Liver (AIS≥3)	11 (36.7%)	22 (8.1%)	<0.001
Kidneys (AIS≥3)	6 (20%)	3 (1.1%)	<0.001
Pancreas (AIS≥3)	1 (3.3%)	1 (0.4%)	0.06
Other (Hollow-viscus, major vascular injury, AIS≥3)	1 (3.3%)	13 (4.7%)	0.7
Solid organ injury (AIS≥3), n (%)	23 (76.7%)	49 (17.9%)	<0.001
30-day Mortality, n (%)	3 (10%)	5 (1.8%)	0.035

A-AGI: Adult Adrenal Gland Injury; SD: Standard Deviation; IQR: Interquartile Range; MVA: Motor Vehicle Accident; GSW: Gunshot Wound; ISS: Injury Severity Score; AIS: Abbreviated Injury Scale; NA: Not Applicable.

patients. In A-AGI (-) patients, the most common types of injury were falls from heights in 272 (30.1%), stab injuries in 234 (25.9%), pedestrian accidents in 140 (15.5%), and motor vehicle accidents in 129 (14.3%) patients. When the mechanism of injury was compared, the rates of pedestrian accidents and motor vehicle accidents were significantly higher in A-AGI (+) patients, while stab injuries were significantly more common in A-AGI (-) patients (Table 2).

In the A-AGI group, the right-sided injury constituted 55.6% (n=25/45) of the involved adrenal glands, followed by the left-sided (37.8%) and the bilateral (6.7%) injury. According to the ISS, the majority of both the A-AGI (+) and the A-AGI (-) groups consisted of critical patients. There was no significant difference in terms of the ISS between the A-AGI (+) and A-AGI (-) groups (Table 2).

Both concurrent abdominal organ and solid organ injury rates were significantly higher in the A-AGI (+) groups (46.7% vs. 19.5%; 46.7% vs. 9.5%, respectively). The most frequent concurrent solid organ injury in the A-AGI (+) group was liver injury, which was detected in 8 of 45 (17.8%) patients. Concurrent kidney and spleen injuries were found in 7 (15.6%) and 5 (11.1%) patients in the A-AGI (+) group, respectively. Other abdominal organ injuries including hollow viscus and major vascular injuries were significantly more frequent in

the A-AGI (-) group (p=0.03) (Table 2). However, the 30-day mortality rate was significantly higher in the A-AGI (+) group (15.6% vs. 2.9%; p <0.001)

Pediatric Patients

The incidence of AGI was 9.9% (n=30/303) in pediatric patients. Demographic data, mechanisms of injury, injury severity score, the side of adrenal injury, concurrent organ injuries with AIS≥3, and the 30-day mortality rate in the pediatric group were summarized in Table 3. The mean age for the P-AGI (+) and P-AGI (-) groups showed no significant difference (p=0.19). There was a significant male gender predominance in the P-AGI (-) group compared to the P-AGI (+) group (p=0.04).

The major mechanism of injury in both groups was falls from heights (P-AGI (+): 15 (50%) vs. P-AGI (-) 135 (49.5%)). Pedestrian accidents were observed significantly more frequently in the P-AGI (+) group (36.7% vs. 18%; p=0.015). Although the rate of stab injuries in the P-AGI (-) group (15%) was higher compared to that in the P-AGI (+) group (3.3%), the difference was not statistically significant (p=0.08).

The most common side of injury was the right side at 60% (n=18), followed by the left at 33.3% (n=10), and the bilateral adrenal glands at 6.7% (n=2). The majority of the patients in both the P-AGI (+) and P-AGI (-) groups had ISS>15, but there were no significant differences between the two groups (Table 3).

The rates of concurrent abdominal organ injury and solid organ injury were significantly higher in the P-AGI (+) group (80% vs. 22.7%; p<0.001 and 76.7% vs. 17.9%; p<0.001, respectively). The most frequent concurrent abdominal solid organ injury in the P-AGI (+) group was the liver, detected in 11 (36.7%) patients, followed by the kidney, detected in 6 (20%), and the spleen, detected in 5 (16.7%) patients in the P-AGI (+) group. Other abdominal organ injuries including hollow viscus and major vascular injuries showed no significant difference between the two groups (p=0.7) (Table 3). However, the 30-day mortality rate was significantly higher in the P-AGI (+) group (3 (10%) vs. 5 (1.8%); p=0.035) (Table 3).

Comparison of Adult and Pediatric Patients with AGI

The rates of AGI in adult and pediatric patients were 4.7% and 9.9%, respectively (p=0.001). The characteristics of adult and pediatric patients with AGI were summarized in Table 4. The percentage of male patients was higher in the A-AGI (+) group compared to the P-AGI (+) group (p=0.016). When the mechanism of injury was compared, motor vehicle accidents were significantly more frequent in the A-AGI (+) group, and the rate of falls from heights was significantly higher in the P-AGI (+) group, respectively. There were no significant differences between the sides of injury and ISS subcategories. The rate of concurrent liver injury in the P-AGI (+) group was two-fold higher than that in the A-AGI (+) group, but the difference did not achieve statistical significance. However, the overall rate of concurrent solid organ injury in the P-AGI (+) group was significantly higher compared to the A-AGI (+) group (76.6% vs. 47%; p=0.01). The rate of 30-day mortality showed no significant difference between the two groups (Supplementary Table 1).

DISCUSSION

In this study, we investigated the incidence of trauma-induced AGI in 1,253 patients who underwent CT scans at the time of initial admission after trauma. The clinical characteristics and 30-day mortality rate in adult or pediatric patients with or without AGI were analyzed. The incidence of AGI in the whole group was 6.3%, and AGI was significantly more frequent in pediatric patients compared to adult patients. The leading mechanisms of injury in adult patients with AGI consisted of pedestrian and motor vehicle accidents, while the major mechanism of injury in the pediatric group was falls from heights both in AGI (+) and AGI (-) patients. In the whole group, concurrent solid organ injury was significantly more frequent in patients with AGI compared to those without AGI. When adult and pediatric patients with AGI were compared with respect to concurrent solid organ injury, the rate was significantly higher in pediatric patients. In both the adult and pediatric group, the ISS scores showed no significant difference between the patients with or without AGI, but the 30-day mortality rate was significantly higher in patients with AGI in both adult and pediatric patients.

In Trauma Registry Database studies, the rate of AGI in adult trauma patients ranged between 0.15% and 5.68%.[1,3-7] Tanizaki et al. reported a high rate of 14.5% adrenal trauma in 262 patients with abdominal blunt trauma, which they associated with the increased use of CT in trauma evaluation, leading to the detection of minor, asymptomatic adrenal injuries.[8] Similarly, Rana et al. found that the detection rate of adrenal trauma increased from 0.8% to 1.9% with the routine use of diagnostic abdominal CT in trauma patients.[7] In pediatric patients with abdominal trauma, the rate of AGI ranged from 0.22% to 4.95%. In our study, all our patients underwent abdominal CT, and the overall rate of AGI was 6.3%. The rate of AGI was 9.9% in our pediatric patients, which was higher compared to the rates reported in previously published pediatric series. We also found a significantly higher rate of AGI in the pediatric population compared to the adult population.

Right adrenal glands were most commonly involved in patients with AGI caused by high-energy trauma.[2,5,9] Although the exact mechanism of injury leading to AGI is not known, there are two main propositions: a sudden rise in inferior vena cava pressure due to compression might lead to AGI, which might explain why right-sided injuries are more common since it has a short venous branch. Second, the gland can be compressed by the spine and surrounding organs, which can explain why adrenal injuries usually occur on the same side as the injured concurrent organs.[10] In our study, we also found that the right adrenal gland was involved in approxi-

mately 60% of both adult and pediatric patients with AGI.

Adrenal gland injury resulted mainly from blunt abdominal trauma rather than penetrating injury in the majority of cases, and motor vehicle accidents and falls from heights were the most common mechanisms of injury in patients with AGI (+). In our study, traffic accidents (motor vehicle or pedestrian) were the leading mechanism of injury in adult patients with AGI, whereas falls from heights were the most frequent type of injury in pediatric patients. Only 4% of our patients with AGI had penetrating trauma, while the rate of penetrating trauma was 23.3% in patients without AGI.

The hypothesis that AGI is associated with higher ISS and mortality is controversial. Earlier studies, including an analysis of a national trauma registry, concluded that AGI is associated with more severe injuries and leads to increased morbidity and mortality.[1,2,5,6,11] However, other studies stated that adrenal gland injury was not associated with severe injury or an increased risk of mortality.[3,4] One of the largest series, published by Stawicki et al., included 322 adult patients with AGI. The authors documented that when the AGI group was compared with the non-AGI group, the AGI group had a higher ISS and a higher mortality rate with higher concurrent abdominal organ injuries, which included liver, kidney, and spleen injury in 57.8%, 41.3%, and 32.9% of their patients with AGI.[1] Other studies also showed that the liver, spleen, and kidney were the most frequent concurrent solid organ injuries in patients with AGI. Another study published by Liao et al. reported an increased AIS associated with AGI without any major increase in mortality.[12] Similarly, Tanizaki et al. found that AGI was associated with an increased ISS and increased rate of concomitant head, chest, and pelvic injuries.[8] In most studies, the most frequent concurrent organ injury in patients with AGI involved the liver. The rate of liver injury concurrent with AGI ranged between 39% and 57% in several studies.[1,4,9] More than 50% of our patients had an ISS greater than 25, but our study group does not include patients with minor trauma who did not undergo a CT scan of their abdomen; thus, these results do not truly reflect the distribution patterns of the general trauma population. We found that AGI was significantly associated with an increased rate of concurrent abdominal solid organ injury and mortality in both adult and pediatric patients. In our study, the overall rate of concurrent liver injury in patients with AGI was 25%, and the liver was the most frequent organ involved in concurrent solid organ injury in both adult and pediatric patients with AGI. We found a significantly higher rate of concurrent solid organ injury in pediatric AGI (+) patients compared to adult AGI (+) patients. The aforementioned study was conducted between the late 1980s and the early 2000s, and the overall tendency to operate on major trauma cases has decreased since then.[13,14] In a recent study by Tanizaki et al. of 38 patients with AGI, 12 (31.6%) required interventions.[8] The authors reported that non-surgical management such as abdominal or pelvic transcatheter arterial embolization constituted 67% of all interventions while laparotomy constituted only 23%.

Despite the substantial body of literature supporting the aforementioned hypothesis, DiGiacomo et al. postulated that many studies include major design flaws that can potentially affect the results due to confounding variables. They conducted a case-matched study with six matching variables (age, sex, year of admission, ISS, Revised Trauma Score (RTS), and injured body region). The mortality rates were similar between the two groups (AGI (+): 5.6% vs. AGI (-): 5.9%; whole registry: 6.5%). The ISS after the match was similar to that expected between the two groups (18.7 vs. 17.1) but significantly higher than that of the whole registry (10.6). When adrenal injury was excluded from the analysis, the abdominal AIS was similar, suggesting that the presence of adrenal injury is not directly related to mortality and does not significantly contribute to ISS.[3] In our study, we found that the rate of patients with ISS≥25 constituted the majority of our patients, either with or without AGI. Although we showed no significant difference with respect to ISS in adult or pediatric patients with or without AGI, the 30-day mortality rate was significantly higher in patients with AGI.

One of the major limitations of our study, similar to previously reported studies, was that we did not match patients with potential confounding variables. We also believe that the association between higher ISS and mortality rates in patients with AGI is most likely related to correlation rather than causation. Moreover, similar to almost all studies, none of the patients had a diagnostic work-up for adrenal insufficiency, because most of the studies were retrospective in nature. Therefore, whether patients with AGI developed adrenal insufficiency, which could have significantly affected patient outcomes, is still an unanswered question that would require prospective multicentric detailed analysis.

In our analysis of 30-day mortality with limited parameters, we found that total mortality was associated with severe head and neck and chest injuries but not abdominal injuries. AGI with any of the previous categories was also more commonly observed in patients with 30-day mortality. Subgroup analysis of patients with AGI and mortality indicated that head and neck and chest injuries were again more commonly associated with mortality. Regression analysis showed that the major determinant factor for 30-day mortality was head and neck injuries.

In this report, we aimed to present our own experience of dealing with trauma patients, provide an abstract analysis of short-term patient outcomes with AGI, and scientifically contribute to a nationally uncharted territory.

CONCLUSION

Adrenal gland injury is not uncommon after high-energy trauma. It is associated with an increased risk of concurrent organ injuries and a high rate of mortality in both adult and pediatric populations. The rate of concurrent solid organ injuries is

higher in pediatric patients with AGI than in adult patients. Although the association between adrenal gland injury and morbidity/mortality is more likely due to correlation rather than causation, clinicians should remain vigilant for patients with adrenal gland injury.

Ethics Committee Approval: This study was approved by the Istanbul University, Istanbul Faculty of Medicine Ethics Committee (Date: 12.01.2024, Decision No: 01).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Adrenal bez yaralanmalarının travmalı hastalarda klinik sonuçlara etkisi

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AMAÇ: Travma ilişkili adrenal yaralanmalar, gözden kaçabilen ve nadir olduğu düşünülen olgulardır. Bu çalışmada, travma ilişkili ciddi yaralanmalarda adrenal bez yaralanması görülme sıklığı, ve hastaların erken dönem sonuçlarına etkisini değerlendirme amaçlanmıştır.

GEREÇ VE YÖNTEM: Üçüncü basamak refere travma merkezine, Ocak 2012 ve Ocak 2023 arası travma protokolü ile başvuran, bilgisayarlı tomografi çekilen tüm hastalar retrospektif olarak incelendi. Gelişinde ölü kabul edilenler ve eksik verisi olanlar çalışmadan çıkartıldı. Hastalar yetişkin ve pediyatrik olarak iki gruba; radyolojik veya klinik olarak tanısı konulan adrenal yaralanması olup olmamasına göre de alt gruplara bölündü. Demografik veriler, yaralanma mekanizması, yaralanma ciddiyet skoru, eşlik eden diğer abdominal organ yaralanmaları, ve 30-günlük mortalite oranları karşılaştırıldı.

BULGULAR: Toplam 1253 hasta çalışmaya dahil edildi: 950 yetişkin ve 303 pediyatrik. Yetişkin grubunda adrenal yaralanma 45 (%4,7) hastada görüldü. Mekanizmalar incelendiğinde araç içi trafik kazası (%26,7 vs. %14,3) ve yaya kazasının (%37,8 vs %15,5) adrenal yaralanmalı hastalarda daha sık olduğu görüldü. Penetran travma adrenal yaralanmalı grupta daha azdı. Sağ tarafın yaralanma oranı daha fazlaydı (%55,6). Adrenal yaralanması olan hastaların yaralanma ciddiyet skorları daha yüksekti ve eşlik eden karaciğer (%17,8 vs. %3,9), dalak (%11,1 vs. %3,6) ve böbrek (%15,6 vs. %1,3) yaralanma oranları daha fazlaydı. Pediyatrik grupta adrenal yaralanma 30 hastada tespit edildi (%14,8). Yetişkin grubu gibi, adrenal yaralanma daha çok künt travma ilişkiliydi ve sağ taraf dominanttı (%60). Yetişkin grubuna kıyasla, yaralanma ciddiyeti skoru, yaralanma olan ve olmayan gruplar arası benzerdi. Eşlik eden organ yaralanması yetişkin grubu gibi adrenal yaralanma olan hastalarda daha fazlaydı. 30-günlük mortalite oranı, hem yetişkin hem pediyatrik grupta anlamlı olarak yüksekti (yetişkin: %15,6 vs. %2.9, pediyatrik: %10 vs. %1,8). Adrenal yaralanmalı hastalarda mortaliteye en çok etki eden faktörler majör baş&boyun ve toraks yaralanmalarıydı.

SONUÇ: Yüksek enerjili travmalara bağlı adrenal yaralanmalar nadir değildir. Genellikle künt travma ve eşlik eden diğer abdominal organ yaralanmaları ile beraber görülürler. Otuz-günlük mortalite oranları, yaralanma olan hastalarda daha yüksektir.

Anahtar sözcükler: Adrenal travma; adrenal bez yaralanması; künt adrenal yaralanma; yaralanma şiddeti skoru.

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Supplementary Table 1. Comparison of patients with adrenal gland injury: adult vs. pediatric population

AGI (+) (n=75)	A-AGI (+) (n=45)	P-AGI (+) (n=30)	p value
Age, mean ± SD	41.6±18.5	11.5±4.9	<0.001
Sex (male/female)	37/8 (82.2/17.8%)	17/13 (56.7/43.3%)	0.016
Mechanism of Injury, n (%)			
MVA	12 (26.7%)	2 (6.7%)	0.03
Motorcycle	1 (2.2%)	1 (3.3%)	0.8
Fall	10 (22.2%)	15 (50%)	0.01
Pedestrian	17 (37.8%)	11 (36.7)	0.9
Cyclist	0 (0%)	0 (0%)	NA
Struck by	2 (4.4%)	0 (0%)	0.2
Stab	3 (6.7%)	1 (3.3%)	0.5
GSW	0 (0%)	0 (0%)	NA
Other	0 (0%)	0 (0%)	NA
Adrenal Injury Side, n (%)			0.9
Left	17 (37.8%)	10 (33.3%)	
Right	25 (55.6%)	18 (60%)	
Bilateral	3 (6.7%)	2 (6.7%)	
ISS, n (%)			
Minor (1-8)	0 (0%)	2 (6.7%)	0.07
Moderate (9-15)	7 (15.6%)	9 (30%)	0.1
Severe (16-24)	12 (26.7%)	7 (23.3%)	0.7
Critical (≥25)	26 (57.8%)	12 (40%)	0.1
Abdominal Organ Injured, n (%)	21 (46.7%)	24 (80%)	0.004
Spleen (AIS≥3)	5 (11.1%)	5 (16.7%)	0.5
Liver (AIS≥3)	8 (17.8%)	11 (36.7%)	0.06
Kidneys (AIS≥3)	7 (15.6%)	6 (20%)	0.6
Pancreas (AIS≥3)	1 (2.2%)	1 (3%)	0.8
Other (Hollow-viscus, major vascular injury, AIS≥3)	0 (0%)	1 (3%)	0.2
Solid organ injury	21 (46.7%)	23 (76.6%)	0.01
30-day Mortality, n (%)	7 (15.6%)	3 (10%)	0.5

A-AGI: Adult Adrenal Gland Injury; P-AGI: Pediatric Adrenal Gland Injury; SD: Standard Deviation; MVA: Motor Vehicle Accident; GSW: Gunshot Wound; ISS: Injury Severity Score; AIS: Abbreviated Injury Scale; NA: Not Applicable.

Supplementary Table 2. 30-day mortality analysis for total population (n=1253)

	Mortality (+) (n=41)	Mortality (-) (n=1212)	p value
Head and Neck Injury (AIS≥3), n (%)	21 (51.2%)	305 (25.2%)	<0.001
Chest Injury (AIS≥3), n (%)	30 (73.2%)	763 (63%)	0.181
Abdominal Injury (AIS≥3), n (%)	21 (51.2%)	556 (45.9%)	0.499
Patients with AGI with any of the above conditions, n (%)	10 (24.4%)	63 (5.2%)	<0.001

AIS: Abbreviated Injury Scale; AGI: Adrenal Gland Injury.

Supplementary Table 3. 30-day mortality analysis for patients with AGI (n=75)

	Mortality (+) (n=10)	Mortality (-) (n=65)	p value
Head and Neck Injury (AIS≥3), n (%)	7 (70%)	7 (10.8%)	<0.001
Chest Injury (AIS≥3), n (%)	7 (70%)	30 (46.2%)	<0.001
Abdominal Injury (AIS≥3), n (%)	7 (70%)	56 (86.1%)	0.248

AGI: Adrenal Gland Injury; AIS: Abbreviated Injury Scale.

Supplementary Table 4. Binary logistic regression mortality analysis for patients with AGI

				Wald Test		
	Estimate	Standard Error	z	Wald Statistic	df	p
(Intercept)	-3.459	1.184	-2.921	8.531	1	0.003
Head and Neck Injury (AIS≥3)	3.108	0.863	3.600	12.959	1	<0.001
Chest Injury (AIS≥3)	1.352	0.892	1.515	2.295	1	0.130
Abdominal Injury (AIS≥3)	-0.454	0.944	-0.481	0.231	1	0.631

AGI: Adrenal Gland Injury; AIS: Abbreviated Injury Scale.