

## ORIGINAL ARTICLE

# Adrenal trauma *experience* at a major tertiary centre in Sweden: Clinical and radiological findings

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## Abstract

**Background and Objective:** Information on the incidence of adrenal trauma and its association with other injuries is limited. Our objective was to study the incidence of adrenal haemorrhage, its association with other injuries, clinical parameters, and long-term outcomes.

**Patients and Measurements:** All patients treated for severe abdominal trauma (Level 1) at Karolinska University Hospital, Solna, between January 1, 2013 and December 31, 2018 were included. Patients with a radiological picture of adrenal haematoma were selected. The injury severity score (ISS) was analysed in the entire cohort. Data were collected from the electronic medical files.

**Results:** In total, 1.7% ( $n = 29/1743$ ) was affected by adrenal trauma. Right adrenal trauma ( $n = 20/29; 69\%$ ) was more common than left ( $n = 6/29; 21\%$ ,  $p < 0.01$ ), and 10% were bilateral ( $n = 3/29$ ). There was no difference in volume in right versus left adrenal trauma [(median 13 (interquartile range (IQR) (7–15) versus 8 (5–13)) ml,  $p = 0.30$ ). ISS was 23.4 (17–43) in adrenal haematoma patients, higher compared with other trauma patients 16 (8–27) ( $n = 1714$ ) ( $p < 0.001$ ).

Rib fractures, pneumothorax, and liver lacerations were the three most common findings in association with adrenal trauma. The underlying cause in 48% of the cases was falling from height ( $\geq 3$  m). Biochemical data demonstrated normal sodium and potassium levels while the lowest haemoglobin level was 72 g/l. At follow-up, 4 (2–6) years after the trauma, except for three patients who died as in-patients, all other persons were still living. None seemed to have adrenal insufficiency.

**Conclusions:** Adrenal trauma is rare and does not seem to be associated with clinical features of adrenal insufficiency, even if the bleeding is bilateral.

## KEYWORDS

adrenal gland, adrenal insufficiency, blood pressure, long-term outcome, trauma

## 1 | INTRODUCTION

The adrenals are located in the retroperitoneum, above the kidneys. They are richly innervated and vascularized.<sup>1</sup> Via their production of two types of hormones, catecholamines, and steroids, they are important regulators of metabolic, immune, and cardiovascular processes.<sup>2</sup> Abdominal trauma is present in 7%–10% of all trauma victims and in cases of severe trauma it is often associated with other orthopaedic, thoracic, or central nervous system injuries.<sup>3</sup> There is a scarcity of data with only a few reports on adrenal trauma in association with other injuries and its causes in the literature. From reports from earlier studies, adrenal trauma is rare. These studies have shown an incidence of up to 2% of adrenal haemorrhage in abdominal traumas.<sup>4–6</sup> Adrenal trauma seems to be associated with more severe injuries and an increased mortality rate.<sup>4</sup> In postmortem studies, however, the reported incidence of adrenal haemorrhage or injury in trauma patients is higher; 7%–26%.<sup>7</sup>

The aim of the study was to investigate the incidence of adrenal trauma in a busy trauma centre, its association to other injuries, and associated clinical parameters as well as long-term outcome.

## 2 | MATERIAL AND METHODS

### 2.1 | Study design

This was a retrospective study of all patients treated for severe abdominal trauma (Level 1) at Karolinska University Hospital, Solna, registered at the Swedish Trauma register from January 1, 2013 to December 31, 2018. Karolinska University Hospital, Solna, is a major tertiary centre responsible for all major trauma in the Stockholm region with a population of about 2,344,000 inhabitants. All computed tomography (CT) scans were initially examined by two radiologists (an advanced trainee in radiology and a specialist radiologist) and then all CT scans were also discussed in multidisciplinary team (MDT) meetings with trauma surgeons and radiologists present. All this information was later (within 30 days of the trauma) recorded in the Swedish Trauma register (SweTrau) (<https://rcsyd.se/swetrau/>).

The information system (RIS)/picture archiving and communication system (PACS) were used to review the imaging of the adrenals. One radiologist (with 5 years of radiology experience) reviewed all adrenal haematoma patients in the SweTrau between 2013 and 2018 and if uncertainty was encountered, a specialist radiologist with more extensive experience was consulted. Patients were stratified according to the radiological picture of the adrenal haematoma, its laterality, or if it was bilateral.

Information on the demographics, including age and sex as well as comorbidities, medications including anticoagulation, type of trauma including all organs that had been affected, injury severity score (ISS), neurological severity score (NSS) at admission, initial and discharge blood pressure, biochemical data, length of hospital and

intensive care unit (ICU) stay, mechanical ventilation, treatment, 30-day-mortality, in-hospital death, status at discharge from the hospital and follow-up data from the last recorded visit according to the electronic medical record were collected. An ISS of 1–8 is considered minor, 9–15 moderate, 16–24 severe, and 25 and higher very severe. ISS and NSS as well length of hospital stay and 30-day mortality was analysed in the entire trauma cohort. Signs and symptoms of adrenal insufficiency, including the use of glucocorticoids, adrenocorticotropic hormone (ACTH)-stimulation tests, and serum cortisol measurements, both in-patient and after discharge were searched for in the medical files. As the most common imaging manifestation of an adrenal haematoma is an oval-shaped haematoma,<sup>8</sup> the size of the adrenal haematoma was calculated according to length x width x height (in cm) x 0.50.<sup>9</sup> Radiological follow-up was performed in some of the patients. At the same time, the National Population Register was consulted to find out if the included patients were still alive, and the date of death was retrieved if applicable.<sup>10</sup>

The study was approved by the Swedish Ethical Review Authority (number 2019-05643) and due to its retrospective design, formal consent was waived.

### 2.2 | CT protocol

A 256-slice multidetector CT (Revolution CT, GE Healthcare) and 64-slice MDCT scanner (LightSpeed VCT, GE Healthcare) was used for multitrauma evaluation after intravenous injection of approximately 100 (70–120) ml iodinated contrast agent (Iohexol 350 mg/ml) with a flow rate of approximately 4.5–5 ml/s in studies including arterial phase, venous phase 2.5–3.5 ml/s.<sup>11</sup>

### 2.3 | Laboratory measurements

Plasma sodium (ref 135–145 mmol/L), potassium (ref 3.5–5.0 mmol/L), glucose (reference < 7.8 mmol/L, 2 h after eating), and blood haemoglobin (ref men 130–170 g/L, women 120–155 g/L) were measured at the admission and recorded in the study. Also, the lowest haemoglobin level was noted. All biochemical analyses were done with routine methods.

### 2.4 | Statistical analysis

Continuous data are presented as median (interquartile range [IQR]), while categorical data are presented as numbers and percentages. Comparisons between two groups were done with the Mann–Witney *U* test or Pearson's  $\chi^2$ -test for continuous and categorical data, respectively. Linear regression analysis was performed to compare adrenal volume haematoma to heart rate, acute systolic or diastolic blood pressure, and with the laboratory parameters: glucose, haemoglobin, sodium, and potassium levels. A  $p < 0.05$  was considered significant.

### 3 | RESULTS

During the study period, 1743 patients with suspected or manifest trauma were treated at Karolinska University Hospital, Solna, of whom 29 had adrenal trauma (1.7%) (Figure 1). The median ISS and NSS in the entire group of adrenal trauma were median (IQR) 23.5 (17–43) and 30.5 (17–48), while in the nonadrenal trauma group 16 (8–27) and 17 (9–34) ( $p < 0.001$ , for both) (Table 1). The adrenal trauma group had a longer length of hospital stay ( $p < 0.01$ ) but no differences in 30-day mortality (Table 1). General patient data are summarized in Table 2. Of those suffering an adrenal trauma 79% were men ( $n = 23$ ) and 21% women ( $n = 6$ ), reflecting a higher male incidence in the total cohort ( $n = 1205/1743$ ; 70%,  $p = 0.29$ ) (Tables 1 and 2). The underlying cause in 48% of the traumas was falling from height ( $\geq 3$  m), in 38% traffic accidents, and in 14% other reasons. Right adrenal trauma ( $n = 20/29$ ; 69%, Figure 2A,B) was more common than left ( $n = 6/29$ ; 21%,  $p < 0.01$ ), and 10% ( $n = 3$ ) were bilateral. There was no significant difference in volume in right versus left adrenal trauma (13 (7–15) vs. 8 (5–13) ml,  $p = .030$ ) (Table 2). Rib fractures, pneumothorax, and liver lacerations were the three most common findings in association with adrenal trauma. Biochemical data demonstrated normal sodium and potassium levels while the lowest haemoglobin level was 72 g/L and median (IQR) 89 (82–112) g/L. The glucose level was slightly raised (9.8 (6.9–12.3) mmol/L). Initial systolic and diastolic blood pressure seemed quite normal (120 (107–130) and 75 (60–81) mmHg, respectively). Adrenal haemorrhage volume did not correlate with other

parameters (heart rate, systolic or diastolic blood pressure, glucose, haemoglobin, or sodium levels) except for potassium levels upon admission in which a negative correlation was present ( $r = -.58$ ,  $p = 0.003$ ,  $n = 25$ ). Of the patients, 62% were operated on immediately or during hospital stay and 66% were treated in an ICU (Table 2). No patient received hydrocortisone or other glucocorticoids.

Of the patients 62% ( $n = 16/26$ ) had a radiological CT follow-up (Table 2). In four of these (25%) some sort of rest findings were present, with a follow-up in these subjects at 1, 2, 7, and 9 months, respectively.

At clinical follow-up, 4 (2–6) years after the trauma, except from three patients (10%) who died as in-patients, all other persons were still living, also the three with bilateral adrenal trauma.

None seemed to have adrenal insufficiency and of the surviving in the majority the health seemed totally restored ( $n = 22/26$ , 84%), but a few were still in some way affected, handicapped by the trauma ( $n = 1/26$ , 4%) or severely handicapped ( $n = 3/26$ , 12%). However, no patient had a postinjury ACTH stimulation test or a cortisol level measured.

### 4 | DISCUSSION

In this study from a tertial level 1 trauma centre in patients with blunt or penetrating abdominal trauma, adrenal trauma was found to be present in 1.7% of the cases. It was more often right located and did

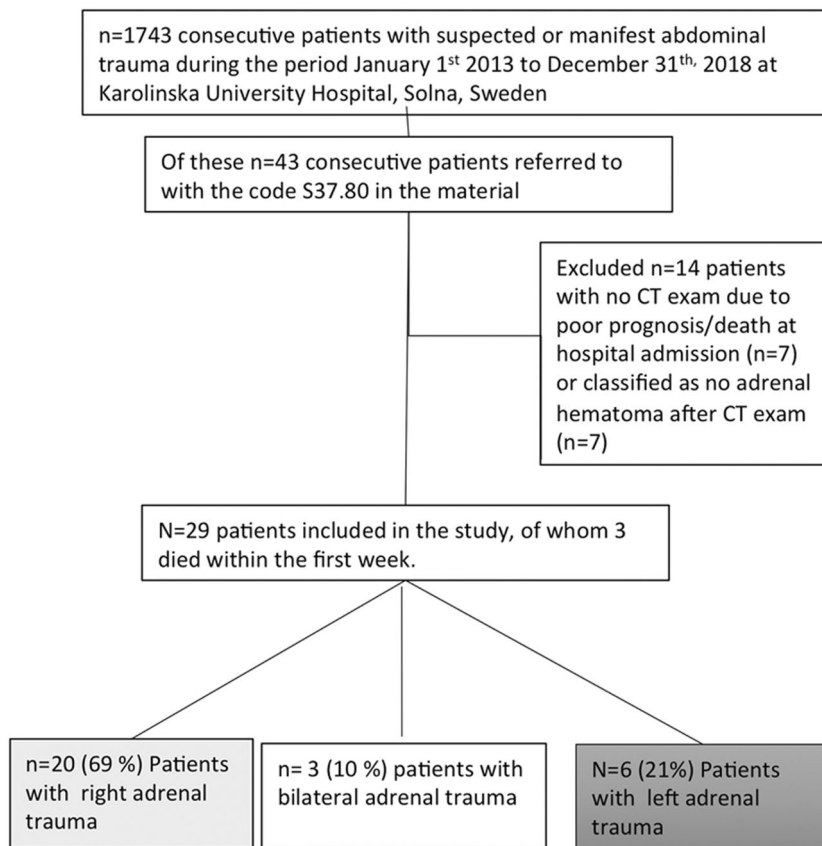


FIGURE 1 Flowchart of patient inclusion

**TABLE 1** ISS and NSS score in the adrenal haematoma versus all other trauma patients between 2013 and 2018

	Adrenal haematoma (n = 29)	Other trauma patients (n = 1714)	p value
Injury severity score			
Gender (male/female) n (%)	23/6 (79%/21%)	1205/509 (70%/30%)	0.29
ISS	23.5 (17–43)	16 (8–27)	<0.001
NSS	30.5 (17–48)	17 (9–34)	<0.001
Length of hospital stay (days)	8 (3–32)	5 (2–12)	<0.01
30-day mortality, n (%), n = 1735	2 (7%)	159 (9,3%)	0.66

Not: A *p*-value less than 0.05 was considered significant.

Abbreviations: ISS, injury severity score; n, numbers; NSS, neurological severity score.

**TABLE 2** Demographics, comorbidities, radiology, laboratory, and outcome data for hospitalized individuals with adrenal trauma between 2013 and 2018 at the Karolinska University Hospital

	All (n=29)	Right (n=20)	Left (n=6)	p values	Bilateral (n=3)
Demographics					
Gender (male/female), n (%)	23/6 (79%/21%)	15/5 (75%/25%)	4/2 (83%/17%)	0.59	3/0 (100%/0%)
Age (years)	52 (34–56)	43 (25–54)	58 (46–62)	0.06	60 (56–62)
Comorbidities					
Depression-on antidepressives, n	6 (21%)	4 (20%)	0 (0%)	0.07	2 (67%)
Earlier on-going addiction	5 (17%)	4 (20%)	0 (0%)	0.39	1 (33%)
Anticoagulation/Thromboembolic disease, n	1 (3%)	1 (5%)	0 (0%)	0.80	0 (0%)
Antihypertensives, n	4 (14%)	2 (10%)	0 (0%)	0.02	2 (67%)
Kidney disease, n	1 (3%)	0 (0%)	0 (0%)	1	1 (33%)
Diabetes, n	2 (7%)	1 (5%)	0 (0%)	0.15	1 (33%)
Clinical characteristics at admission					
Unconscious, n	7 (25%)	7 (37%)	0 (0%)	0.11	0 (0%)
GCS at admission	15 (14–15)	15 (13–15)	15 (15–15)	0.12	14 (13–15)
Type of violence					
Fall from high altitude, n	14 (48%)	9 (45%)	2 (33%)	0.15	3 (100%)
Traffic accident, n	11 (38%)	7 (35%)	4 (67%)	0.13	0 (0%)
Other reasons, n	4 (14%)	4 (20%)	0 (0%)	0.35	0 (0%)
Injury severity score					
ISS	23.5 (17–43)	21 (17–43)	22 (17–30)	0.74	34 (17–48)
NSS	30.5 (17–48)	27 (17–53)	32 (22–43)	0.88	34 (17–48)
Radiologic findings					
Adrenal volume haematoma (ml)	13 (7–14)	13 (7–15)	8 (5–13)	0.30	14 (9–23)
Liver laceration, n	15 (52%)	13 (65%)	2 (33%)	0.07	0 (0%)
Pneumothorax, n	16 (55%)	11 (55%)	3 (50%)	0.89	2 (67%)

(Continues)

TABLE 2 (Continued)

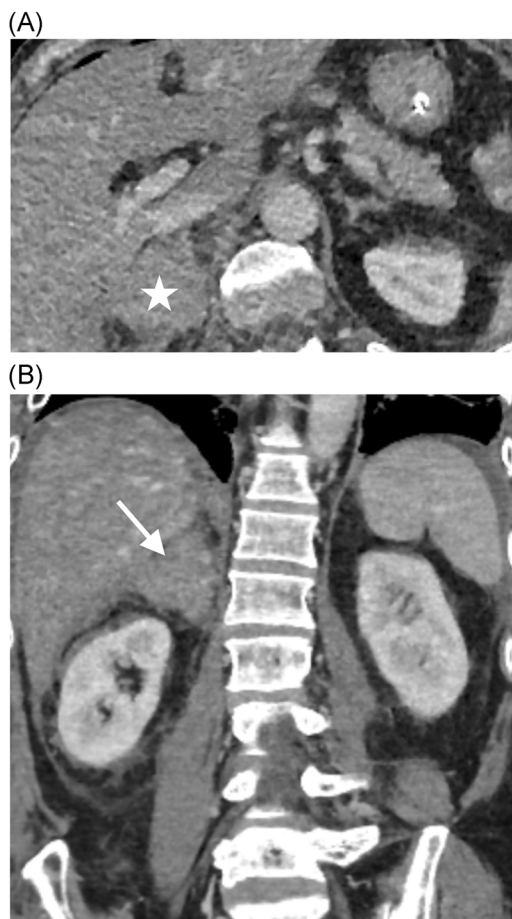
	All (n=29)	Right (n=20)	Left (n=6)	p values	Bilateral (n=3)
Rib fractures, n	21 (72%)	14 (70%)	5 (83%)	0.79	2 (67%)
Thoracic spine, n	6 (21%)	2 (10%)	3 (50%)	0.09	1 (50%)
Lumbar spine, n	9 (31%)	5 (25%)	2 (33%)	0.34	2 (67%)
Pelvic fracture, n	6 (21%)	4 (20%)	1 (17%)	0.84	1 (33%)
Spleen laceration, n	5 (17%)	2 (10%)	2 (33%)	0.31	1 (33%)
Kidney laceration, n	6 (21%)	4 (20%)	1 (17%)	0.84	1 (33%)
Subarachnoidal/subdural haemorrhage, n	8 (28%)	5 (25%)	1 (17%)	0.26	2 (67%)
Other fracture, n (%)	14 (46%)	12 (67%)	1 (17%)	0.17	1 (33%)
Clinical data	All	Right	Left	p value	bilateral
<b>At Admission</b>					
Heart rate (beats/min)	80 (72–105)	90 (72–110)	78 (73–83)	0.41	80 (72–86)
Systolic blood pressure (mmHg)	120 (107–130)	115 (105–130)	130 (110–130)	0.29	140 (120–140)
Diastolic blood pressure (mmHg)	75 (60–81)	70 (60–80)	75 (60–81)	0.69	85 (80–90)
P-Sodium (mmol/L)	138 (136–140)	138 (137–140)	141 (139–143)	0.19	136 (124–138)
P-Potassium (mmol/L)	4 (3.5–4.3)	4 (3.5–4.2)	4.1 (3.7–4.3)	0.72	3.6 (3.3–5)
P-Glucose (mmol/L)	9.8 (6.9–12.3)	10.6 (8–14.4)	6.8 (6.7–7.8)	0.13	14.5 (10.6–18.3)
B-Haemoglobin (initial, g/L)	125 (99–144)	127 (105–144)	130 (98–155)	0.83	113 (91–140)
<b>During hospital stay</b>					
Signs of adrenal cortex failure, n (%)	0 (0%)	0 (0%)	0 (0%)	-	0 (0%)
B-Haemoglobin (lowest, g/L)	89 (82–112)	87 (81–110)	101 (86–120)	0.16	83 (73–140)
Specific treatment for adrenal dysfunction, n	0	0	0	-	0
ICU, n	19 (66%)	14 (70%)	3 (50%)	0.66	2 (67%)
Length of ICU stay (days)	3 (0–7)	4 (0–7)	0.5 (0–50)	0.73	3 (0–8)
Operation during stay including laparotomi, n	18 (62%)	12 (60%)	3 (50%)	0.33	3 (100%)
Length of hospital stay (days)	8 (3–32)	7 (3–16)	19 (7–43)	0.19	34 (3–35)
<b>At discharge</b>					
Status at discharge, submission to rehab or psychiatric clinic for care, n	13(47%)	8 (47%)	2 (40%)	0.18	3 (100%)
Treatment discharged with opioids, n	22 (85%)	16 (89%)	4 (80%)	0.58	2 (67%)
Systolic blood pressure (mmHg)	112 (108–120)	114 (108–120)	110 (97–130)	0.58	120 (110–160)
Diastolic blood pressure (mmHg)	47 (65–83)	70 (65–83)	68 (65–70)	0.63	90 (80–100)
<b>Outcome data</b>					
30-day mortality, n	2 (7%)	2 (10%)	0 (0%)	0.66	0 (0%)
In-hospital death, n	3 (10%)	2 (10%)	1 (17%)	0.78	0 (0%)
<b>Radiological outcome CT (n = 26)</b>					
Follow-up scan	16 (62%)	12 (60%)	2 (33%)	0.53	2 (67%)
Follow-up (months)	9 (2–30)	9 (3–26)	2 (2–2)	0.17	19 (7–30)
Rest adrenal findings, n	4 (25%)	2 (17%)	1 (50%)	0.41	1 (50%)

TABLE 2 (Continued)

Clinical data	All	Right	Left	p value	bilateral
Long-term outcome (n = 26)					
Follow-up (years)	4 (2–6)	4 (1.5–6.5)	3 (0–7)	0.73	4 (4–6)
Restored health, n	22 (84%)	16 (89%)	3 (60%)		3 (100%)
Handicapped, n	1 (4%)	0 (0%)	1 (20%)	0.25	0 (0%)
Severely handicapped, n	3 (12%)	2 (11%)	1 (20%)		0 (0%)

Note: Values represent median (interquartile range) or numbers and percentage.

Abbreviations: GSC, Glasgow coma scale; ISS, injury severity score; n, numbers; NSS, neurological severity score.



**FIGURE 2** (A,B) Man in his 50 s, pedestrian hit by a car. Contrast-enhanced computed tomography, venous phase. (A) Axial view. Large adrenal haemorrhage (white star) at the right side with an ~ volume of 50 ml. (B) Coronal view in which the adrenal haematoma is also visualized (white arrow). Additional findings of rib fractures (not shown in the figure) and free fluid surrounding the spleen, under the diaphragm

not seem to be associated with abnormal sodium or potassium levels in the acute setting. Furthermore, it did not appear to be, even if bilateral, associated with acute or long-term adrenal insufficiency. There was no significant difference in volume between right and left

adrenal trauma. Compared with other studies, we did not rely only on registry data but reviewed all reported adrenal injuries using PACS. Also, the new CT scanners had the potential for increased sensitivity to detect adrenal injuries. Moreover, we had a longer follow-up.

The mortality rate in our material of adrenal trauma patients was 10%, thus only slightly higher compared with a reference abdominal trauma material which found around 9% and 8% in penetrating and nonpenetrating trauma, respectively,<sup>12</sup> however, slightly lower than the 14.6% in a recent study from Qatar.<sup>13</sup> It should be noted that apart from the three who died as in-patients in our study, all individuals were still living after median of 4 years of follow-up. In a study from the United States from the 2000s, adrenal trauma was only present in 0.15% of all their trauma patients but it was associated with a high mortality rate (32%).<sup>14</sup> This was a five-times higher mortality rate compared with nonadrenal trauma patients. Our mortality rates in adrenal trauma might reflect that our trauma care, in general, has improved for severely injured patients.

In our study more males than females were affected by adrenal trauma (79% vs. 21%) which reflects the ratio within the abdominal trauma group. Several studies of abdominal trauma, in general, have found a similar relationship between men and women.<sup>15</sup>

Several studies have investigated adrenal injury following trauma. In Australia, a study of 3900 trauma patients found a similar incidence of adrenal haemorrhage as ours, 2.4%, and the haemorrhage was located on the right side in 73% of the cases and was bilateral in 4%.<sup>16</sup> In another study from the United States in 1992 an equivalent number was found (2%).<sup>4</sup> Rana et al. found a 1.9% (51 out of 2692 patients) incidence in their cohort of trauma patients who underwent CT.<sup>3</sup> Patients with left adrenal gland injury had higher rates of mortality and morbidity, as well as the length of hospital stay,<sup>16</sup> which we could not find in our study. ISS is a measurement to account for the cumulative effect of injury in different body regions. Our median ISS of 23.4 with IQR of 17–43, compared with 16 in all other trauma patients, indicate that our patient group was severely affected by their traumas with no differences in ISS score between right and left adrenal trauma.

The hypothalamic–pituitary–adrenal axis is a major determinant of the individual's response to stress. Primary adrenal insufficiency (PAI) can either develop acutely, with nausea, vomiting, and hypotension or progress slowly, with nonspecific symptoms that may go



undiagnosed for long periods.<sup>17</sup> The most common clinical features of PAI include weakness, fatigue, anorexia, and weight loss.<sup>18</sup> Hyponatraemia, hyperkalemia, and hypotension are frequently present.<sup>19</sup> PAI has also been associated with direct adrenal parenchyma destruction secondary to for examples tuberculosis, malignancy, and sarcoidosis.<sup>20</sup> Acute adrenal crisis may develop with bilateral adrenal haemorrhage following sepsis, trauma, surgery, or burns. It has also been suggested to be present at least transiently in as much as 50% of cases with severe traumatic brain injury.<sup>21</sup>

We investigated electrolytes, blood pressure, symptoms, and use of glucocorticoids and did not find any patient with PAI. We found a negative association between adrenal haemorrhage volume and potassium levels. Frequent hypokalaemia has been noted after trauma. Hypokalaemia following trauma was associated with lower GCS, higher serum glucose levels, and longer hospital stays.<sup>22</sup> Furthermore, hypokalaemia immediately after trauma has been associated with higher epinephrine levels.<sup>23</sup> One might speculate that our association might reflect that the potassium levels tend to be lower and the adrenal haemorrhage larger in the more severely injured patients. In addition, these patients, with adrenal trauma, seem thus to be able to respond to the trauma.

This is the first study to examine long-term out-come after adrenal trauma and we found no clinical features of adrenal insufficiency, though no ACTH stimulation test was performed and no morning cortisol level was measured in any of the patients living after median 4 years follow-up. Most patients seemed to have recovered entirely from the trauma. However, 4% were handicapped and 12% severely handicapped.

This study has limitations like most retrospective studies. Despite the high quality of documentation and diagnosis coding in Sweden, we may have missed some patients with adrenal trauma. An ACTH stimulation test was not performed in any of the patients and a mild adrenal insufficiency can not be excluded in the living patients. Moreover, we cannot totally exclude that the three deaths were due to adrenal insufficiency even though it seems unlikely.

In conclusion, adrenal trauma is rare with only 1.7% of all severe abdominal trauma patients affected. It occurs more often on the right side. Adrenal haemorrhage, even if bilateral, was not associated with clinical features of adrenal insufficiency, although this observation could not be verified due to the absence of any biochemical testing of adrenocortical function. There was an 10% mortality rate, all happening during hospital admission. Long-term outcomes seem reasonable.

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## CONFLICTS OF INTEREST

The authors declare no conflicts of interests.

## DATA AVAILABILITY STATEMENT

Data are available on reasonable request from the authors.

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