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Epidemiology of abdominal trauma: An age- and sex-adjusted incidence analysis with mortality patterns

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ABSTRACT

Purpose: Abdominal injuries may occur in up to one-third of all patients who suffer severe trauma, but little is known about epidemiological trends and characteristics in a Northern European setting. This study investigated injury demographics, and epidemiological trends in trauma patients admitted with abdominal injuries.

Methods: This was an observational cohort study of all consecutive patients admitted to Stavanger University Hospital (SUH) with a documented abdominal injury between January 2004 and December 2018. Injury demographics, age- and sex-adjusted incidence, and mortality patterns are analyzed across three time periods.

Results: Among 7202 admitted trauma patients, 449 (6.2%) suffered abdominal injuries. The median age was 31 years, and the age increased significantly over time (from a median of 25 years to a median of 38.5 years; $p = 0.020$). Patients with ASA 2 and 3 increased significantly over time. Men accounted for 70% (316/449). The injury mechanism was blunt in 91% (409/449). Transport-related accidents were the most frequent cause of injury in 57% (257/449). The median Injury Severity Score (ISS) was 21, and the median New Injury Severity Score (NISS) was 25. The annual adjusted incidence of all abdominal injuries was 7.2 per 100,000. Solid-organ injuries showed an annual adjusted incidence of 5.7 per 100,000. The most frequent organ injury was liver injury, found in 38% (169/449). Multiple abdominal injuries were recorded in 44% (197/449) and polytrauma in 51% (231/449) of the patients. Overall 30-day mortality was 12.5% (56/449) and 90-day mortality 13.6% (61/449).

Conclusion: The overall adjusted incidence rate of abdominal injuries remained stable. Age at presentation increased by over a decade, more often presenting with pre-existing comorbidities (ASA 2 and 3). The proportion of polytrauma patients was significantly reduced over time. Mortality rates were declining, although not statistically significant.

Introduction

Severe injuries are a leading cause of death and disability globally [1]. Abdominal injuries occur in <10% of all injured patients [2–6] but in up to one-third of those suffering from severe injuries [7], with the liver, spleen, and kidney as the most commonly injured organs [2,6,8,9].

Notably, the true incidence of abdominal injuries and epidemiological variation is scarcely described. Further, the trauma population is changing, with more elderly patients presenting with injuries [3,10]. Worldwide, the mortality rate of abdominal trauma is reported to be between 1 and 20% [2,3,11–14], likely reflecting the variation in the reported populations.

The epidemiology of injuries in northern Europe is less well described, particularly for the spectrum of severe abdominal injuries.

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However, updated knowledge of abdominal injuries' epidemiologic patterns is essential to improve trauma care and patient outcomes.

This study aimed to investigate the epidemiologic trends, including incidence, demographics, clinical patterns, and mortality of patients with abdominal injuries admitted at a Norwegian trauma center.

Material and methods

Ethics approval

The Regional Committee for Medical and Health Research Ethics (REK #2018/341) approved this study. Patients still alive by April 2019 received written information to enable an individual decision to participate. The Regional Ethics Committee's approval permitted the inclusion of deceased patients. The Stavanger University Hospital trauma registry holds approval from the personal data officer as a quality registry.

Study design and period

This observational cohort study is a retrospective analysis of the prospectively maintained institutional trauma registry database covering all trauma patients admitted to Stavanger University Hospital between January 1^{st,} 2004, and December 31st, 2018.

The STROBE guidelines were applied [15] when appropriate.

Setting

Stavanger University Hospital (SUH) is a trauma center located on the southwestern coast of Norway. The primary catchment area covers a population that increased from about 290.000 to 370.000 inhabitants during the study period [16]. A mixed rural and urban settlement characterizes the region. As the only hospital in this region, the current study allows for reliable epidemiological data assessment, as described previously [17–20].

In addition, the hospital serves as a trauma center for an extended catchment area of about 0.5 million inhabitants.

The trauma registry of SUH has been prospectively maintained since 2004, as described previously [21]. Prespecified criteria will prompt a trauma team activation and inclusion in the trauma registry [21]. Additionally, any patients admitted to the emergency department without a trauma team activation but with an Injury Severity Score (ISS) >9 on diagnostic screening or have a penetrating injury to the head/neck/torso proximal to the elbow or knee, head injury with Abbreviated Injury Scale (AIS) ≥3 or ≥2 proximal long bone fractures are registered in the trauma registry. All available information on eligible patients, including patient records, imaging studies, operation notes, and autopsy data are investigated by AIS code-certified registrars at the point of inclusion.

Participants and data description

Patients with documented abdominal injury of any severity according to the Abbreviated Injury Scale (AIS) 1990 revision, update 98(AIS 98) [22] and 2005 revision, update 08 (AIS 08) [23] were identified from the institutional trauma registry database and included in the study.

In cases with missing data in the trauma registry and for determination of mortality, clinical data on patients were collected from the hospital's electronic patient records (EPR) when needed.

Patients suffering injuries resulting in prehospital deaths are not included in the trauma registry and therefore not investigated in this study. Patients who returned a written reservation from participation in this study were excluded ($n = 6$).

Time intervals

We defined three 5-year intervals, 2004–2008, 2009–2013, and 2014–2018, as incremental periods to assess temporal trends.

Definitions

Abdominal injuries were defined in line with the criteria of the AIS [22,23]. Hence diaphragmatic injuries were not defined as abdominal injuries and are excluded from the study.

Solid-organ abdominal injuries comprised the following organs; liver, spleen, kidney, pancreas, mesentery, omentum, or adrenal glands. Hollow viscus injury was an injury to the stomach, duodenum, small bowel, colon, rectum, biliary tract, bladder, or ureter. Damage to the abdominal vessels was defined as an injury to, or bleeding from, identified vascular structures in the abdominal cavity. Ano-genital injuries included male and female reproductive organs.

Polytrauma was defined as an injury with an AIS score ≥ 3 in two or more body regions.

Children were defined as patients ≤16 years of age, adult patients were between 17 and 64 years, and elderly patients were those ≥65 years of age.

Mortality was defined as death within 30 and 90 days after the trauma event. Patients deemed dead on arrival were based on descriptions from the trauma team leader in patients with no signs of life at admission and futile treatment efforts given during the primary survey (resuscitation/transfusion) and/or emergency surgery procedures (e.g., thoracic drains, emergency thoracotomy).

Statistics

The SPSS® version 25.0.0.0 for Mac (IBM, Armonk, New York, USA) and R version 3.6.2 were used for data analysis.

Continuous data were summarized by median and interquartile range, and categorical data were presented as numbers and percentages. Kruskal-Wallis test was used to test for differences between periods in continuous variables and the chi-square test for categorical variables.

Crude incidence rates were calculated as the number of abdominal injuries in the catchment area per 100,000 person-years. The annual population of the eighteen municipalities that constitute the SUH primary catchment area was provided by Statistics Norway [16]. Adjusted incidence rates were then calculated by age- and sex-adjusting the crude rates to what these rates correspond to in standard populations for Norway, EURO, USA 2010, WHO, and World. Five-year age bands were used in these calculations. Poisson regression was used to test for differences in the incidence over time and between sexes.

All tests are two-sided, and p-values of <0.050 were considered statistically significant.

Results

The frequency of abdominal injuries is displayed in Fig. 1. Baseline characteristics according to the three time periods are outlined in Table 1. The median age in adult patients increased significantly from the first period to the last period (from 27 years to 39 years, respectively; $p = 0.027$). A non-significant increase in age from 69 to 76 was observed in the elderly.

Among children with abdominal injuries, ISS>15 were found in 61% (46/75) and ISS>25 in 16% (12/75). Adult patients with abdominal injuries displayed ISS>15 in 69% (221/322) and ISS>25 in 46% (148/322). In elderly patients, 75% (39/52) had an ISS>15, and 50% (26/52) had an ISS>25. Neither children nor elderly pa-

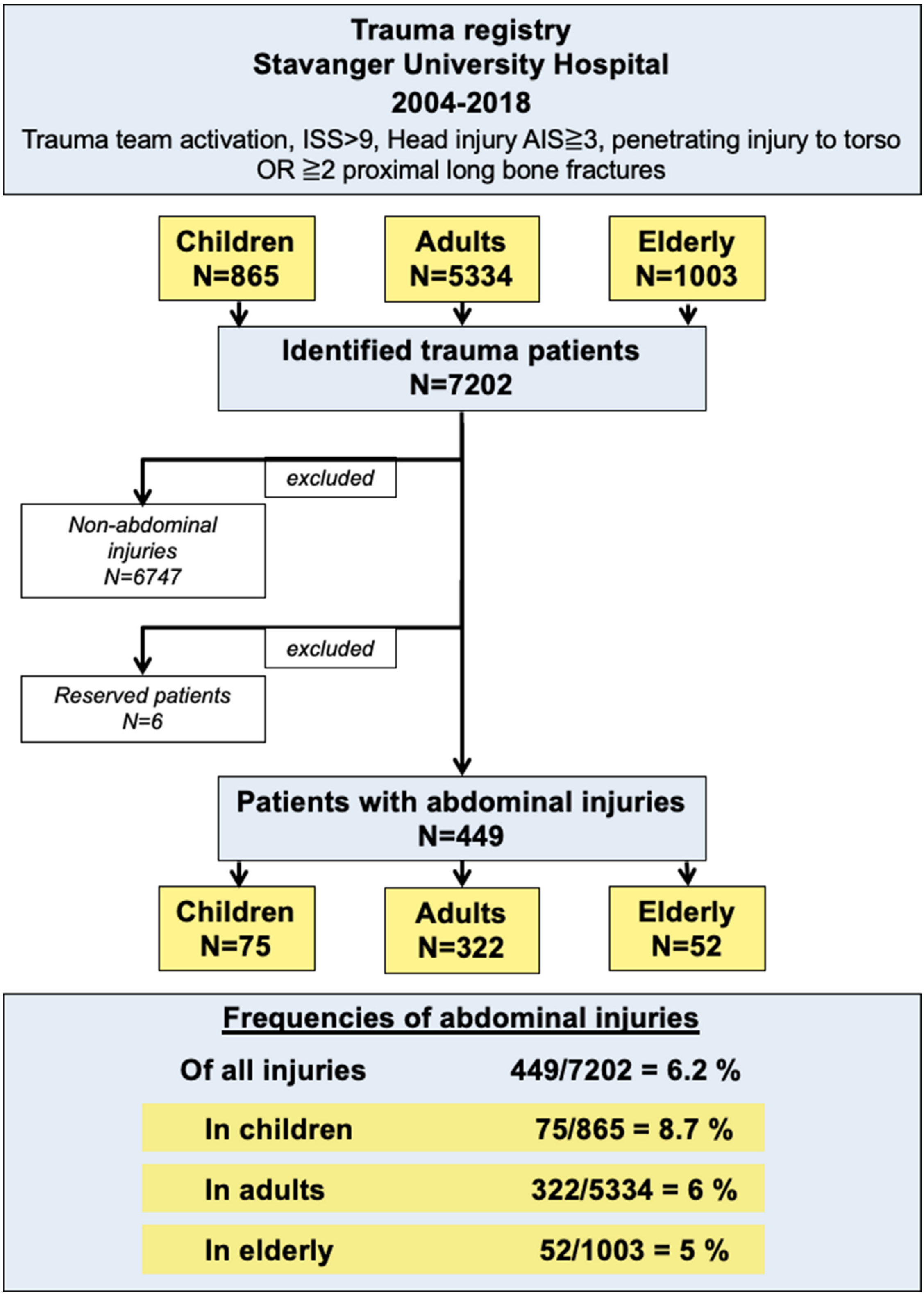

Fig. 1. Study flow chart. Showing patient selection and frequencies of abdominal injuries.

Table 1
Baseline characteristics of patients with abdominal injuries.

	Time periods				
	2004-2008	2009-2013	2014-2018	Total	p
Patients, n (%)	148 (33.0)	141 (31.4)	160 (35.6)	449 (100)	0.540
Age (years), *median (IQR)*	25 (18-45)	31 (20-55)	38.5 (20-55)	31 (19-51.5)	**0.020**
Age category					
Children, n (%)	32 (21.6)	16 (11.3)	27 (16.9)	75 (16.7)	0.064
Adult, n (%)	100 (67.5)	113 (80.1)	109 (68.1)	322 (71.7)	**0.027**
Elderly, n (%)	16 (10.8)	12 (8.5)	24 (15)	52 (11.6)	0.201
Male, n (%)	98 (66.2)	109 (77.3)	109 (68.1)	316 (70.4)	0.088
Type of injury					
Blunt, n (%)	133 (89.9)	128 (90.8)	148 (92.5)	409 (91.1)	0.711
Penetrating, n (%)	15 (10.1)	13 (9.2)	12 (7.5)	40 (8.9)	0.711
Transport time*	61 (41-81)	54 (38-81)	60 (40-100)	59 (40-90)	0.121
ASA, n (%)**					
1	120 (81.1)	88 (62.4)	90 (56.3)	298 (66.4)	**0.039**
2	17 (11.5)	29 (20.6)	40 (25.6)	87 (19.4)	**0.007**
3	11 (7.4)	22 (15.6)	27 (16.9)	60 (13.4)	**0.035**
4	0 (0)	2 (1.4)	1 (0.6)	3 (0.7)	0.564
SBP***	123 (103-140)	130 (110-140)	125 (110-140)	125 (110-140)	0.278
SBP<90 mmHg, n (%)	21 (14.2)	10 (7.1)	19 (11.9)	50 (11.1)	0.158
GCS	15 (13-15)	15 (14-15)	15 (14-15)	15 (14-15)	0.411
GCS<9, n (%)	26 (17.6)	22 (15.6)	20 (12.5)	68 (15.1)	0.456
ISS	24.5 (16-34)	21 (11.5-34)	17 (11-34)	21 (13-34)	0.066
ISS>15, n (%)	112 (75.7)	95 (67.4)	99 (69.9)	306 (68.2)	**0.033**
NISS	27 (17-47)	25 (13.5-39.5)101	22 (13-41)	25 (14-41)	0.078
NISS>15, n (%)	117 (79.1)	(71.6)	113 (70.6)	331 (73.7)	0.194
Polytrauma, n (%)	88 (59.5)	72 (51.1)	71 (44.4)	231 (51.4)	**0.030**
LOS, *median (IQR)*	6.5 (3-12)	6 (2-12)	5 (2-9)	6 (2-11)	0.183
30-day mortality					
Overall, n (%)	21 (14.2)	18 (12.8)	17 (10.6)	56 (12.5)	0.634
ISS >15, n (%)	21 (18.8)	18 (18.9)	17 (17.2)	56 (18.3)	0.634
ISS >25, n (%)	21 (30)	17 (29.3)	16 (27.6)	54 (29.0)	0.529
DOA, n (%)	8 (5.4)	7 (5.0)	8 (5.0)	23 (5.1)	0.884

n = number of patients; Transport time as time from incident to arrival, given in minutes; ASA = American Society of Anesthesiologists (ASA) physical status classification system; SBP = Systolic Blood Pressure in mmHg, on admission; GCS = Glasgow Coma Scale on admission; ISS = Injury Severity Score; NISS = New Injury Severity Score; Polytrauma = AIS score ≥ 3 in two or more body regions; LOS = Length of hospital stay in days; DOA = Dead on arrival.

* 43 patients with missing data

** One patient with missing data

*** 31 patients with missing data on admission

tients with abdominal injuries had statistically significant different ISS compared to adult abdominal trauma patients.

The complete spectrum showing all the specific organ injuries arranged by frequency and the number of injuries with Abbreviated Injury Scale (AIS) ≥3 are outlined in Table 2. A solid-organ injury occurred in 83% (373/449) of the patients, with liver injury (38%, 169/449), splenic injury (33%, 146/449), and kidney injury (23%, 102/449) encountered most frequent. Hollow viscus injury was found in 20% (89/449) of the patients. The small intestine (8%, 35/449) and colon (6%, 25/449) were most often injured, and vascular injuries were encountered in 15% (67/449) of the patients.

Multiple abdominal injuries were recorded in 44% (197/449) of the patients. Two different abdominal injuries were found in 27% (120/449), while 12% (53/449), 3% (14/449), and 2% (10/449) had three, four, and five abdominal injuries, respectively. A combination of solid organ injury and hollow viscus injury was found in 11% (50/449). Combined liver and spleen injuries were most commonly observed (8%, 35/449), followed by combined liver and kidney injuries (7%, 30/449). A combined spleen and kidney injury was observed in 6% (25/449) of the patients.

In children, a solid-organ injury was seen in 93% (70/75), hollow viscus injury in 12% (9/75), and vascular injuries in 4% (3/75) of the patients. The spleen was most frequently injured (43%, 32/75), followed by the liver (35%, 26/75) and kidney (28%, 21/75). Multiple abdominal injuries were seen in 37% (28/75) of children. Liver injury combined with a kidney injury (8%, 6/75) was slightly more common than the combination of injuries to the spleen and kidney (5%, 4/75).

Associated injuries

Associated injuries in other body regions were found in 86% (386/449) of the patients with abdominal injuries. Most frequently encountered were thoracic injuries (66%, 295/449), followed by lower extremities (46%, 205/449), upper extremities (40%, 179/449), head (29%, 132/449), and associated injuries to the spine in 26.5% (119/449). Polytrauma was documented in 51% (231/449), showing a significant decrease over the three time periods.

Incidence

The overall adjusted incidence rates of SUH in regards to national, European, and global standard populations for both abdominal injuries and the subgroup of solid-organ injuries are presented in Table 3. The adjusted incidences for all abdominal injuries in the three incremental periods are shown in Fig. 2 A. The annual crude incidence rate for abdominal injuries during the study period was 7.1 per 100,000. Solid-organ injuries showed an equal crude and adjusted incidence rate of 5.7 per 100,000 per year for the entire study period.

The overall crude incidence of abdominal injuries was 4.3 per 100,000 per year in females and 9.9 per 100,000 per year in males. Annually adjusted incidence rates for all abdominal injuries during the study period for male and female patients are presented in Fig. 2 B. The difference in adjusted incidence rates between sexes was statistically significant in both abdominal injuries and the subgroup of solid-organ injuries.

Table 2
Specific organ injuries.

Injuries	n	AIS ≥ 3 n (%)
Solid organ injuries		
Liver	169	95 (56.2)
Spleen	146	95 (65.1)
Kidney	102	44 (43.1)
Mesentery	45	7 (15.6)
Omentum	11	0 (0.0)
Pancreas	9	3 (33.3)
Adrenal gland	7	1 (14.3)
Hollow viscus injuries		
Small bowel	35	21 (60.0)
Colon	25	4 (16.0)
Stomach	16	11 (68.8)
Duodenum	9	3 (33.3)
Biliary tract	7	4 (57.1)
Bladder	7	4 (57.1)
Rectum	5	4 (80.0)
Ureter	3	3 (100.0)
Other injuries		
Abdominal wall	83	3 (3.6)
Abdominal vessels*	67	63 (94.0)
Ano-genital incl. urethra	12	3 (25.0)

n = number of specific injuries. AIS = Abbreviated Injury Scale. Percentage of serious to critical injury (AIS≥3) given for each specific organ injury.
* Named vessels not included in other organ injury description.

Mechanism

Injury mechanisms for the total study period and the three incremental periods are presented in Table 4. Patients suffering abdominal injuries after transport-related mechanisms were less often polytrauma patients, decreasing from 70% (66/94) in the first incremental period to 47% (38/81) in the last incremental period; $p = 0.006$. Abdominal injuries caused by motorbike accidents were predominately male patients (90% males versus 10% females; $p \leq 0.001$) Work-related abdominal injuries were observed more frequently in male patients, accounting for 97% of these injuries.

In children, transport-related injuries were the most common trauma mechanism, observed in 53% (40/75) of the patients. Falls were the cause of abdominal injury in 33% (25/75). Two children suffered abdominal injuries from interpersonal violence. No injuries were due to self-harm in this age group. Injuries during leisure activities accounted for 79% (59/75) of the children.

In elderly patients with abdominal trauma, injuries were transport-related in 52% (27/52) and due to falls in 38.5% (20/52). Only one elderly patient was registered as exposed to interpersonal violence. Two elderly patients had an abdominal injury due to self-harm caused by falls after suicidal attempts.

Blunt versus penetrating injuries

During the study period, 8.9% (40/449) of the patients were exposed to a penetrating injury, with a significant male predominance (77.5%, 31/40). Stab wounds constituted 87.5% (35/40) of the penetrating injuries. Only two patients suffered gunshot wounds. Of the penetrating injuries, 32.5% (13/40) were self-harm, one gunshot injury, and 12 stab injuries. Only two children and one elderly patient suffered penetrating injuries, all stab injuries as an act of violence.

Mortality

The overall 30-day mortality was 12.5% (56/449), with a 90-day overall mortality of 13.6% (61/449). Male patients had 13% (42/316) and 14% (44/316) 30-day and 90-day mortality, respectively. Female patients presented with 10.5% (14/133) 30-day mortality and 13% (17/133) 90-day mortality. The mortality difference in 30-/90-day mortality between sexes showed no statistical significance. In elderly patients, 30-day mortality was 19% (10/52), while 90-day mortality was 25% (13/52). Only 3% (2/75) of injured children died within 30-days. No further deaths occurred in children within 90-days. The median age in deceased patients was 45 (range 11–96), with a median ISS of 50 (range 9–75).

Patients suffering from solid organ injuries had 12.6% (47/373) and 12.9% (48/375) 30-/90-day mortality, respectively. Hollow viscus injuries as a group showed 9% (8/89) 30-day mortality and 12.4% (11/89) 90-day mortality. The group of patients suffering vascular injuries showed 31% (21/67) 30-day mortality and 36% (24/67) 90-day mortality. A single abdominal injury was seen in 36% (22/61) of deceased patients, with liver injury ($n = 8$) and vascular injury ($n = 8$) as the most frequent. Of those who died, 97% (59/61) had associated injuries in other body regions; thoracic injuries in 93% (57/61), lower extremity in 79% (48/61), head injury in 64% (39/61), upper extremity in 59% (36/61) and spinal injury in 41% (25/61). Polytrauma was present in 96% (54/56) of patients deceased within 30 days.

Within the subgroup of penetrating injuries, the 30-day mortality was 12.5% (5/40), with a 90-day mortality rate of 15% (6/40). Self-inflicted injuries showed 30-day mortality of 11% (3/27) and 90-day mortality of 15% (4/27).

Discussion

In the current study, the annual adjusted incidence of abdominal trauma was found to be 7.2 per 100,000. The adjusted incidence rate of solid organ injuries was 5.7 per 100,000 per year. The observed proportion of abdominal injuries in this study (6.2%) is lower than reported in other studies [2–6,24]. In both abdominal

Table 3
Adjusted incidences (i.e. numbers/100 000/year with 95% confidence intervals) of abdominal injuries.

Standard populations	Abdominal injuries			Solid organ injuries		
	Total	Male	Female	Total	Male	Female
Norway	7.2 (6.4-8.0)	9.9 (8.8-11.3)	4.4 (3.6-5.3)	5.7 (5.1-6.4)	8.0 (7.0-9.2)	3.4 (2.7-4.2)
EURO	7.1 (6.4-8.0)	9.9 (8.7-11.4)	4.4 (3.6-5.3)	5.7 (5.0-6.4)	8.0 (6.9-9.3)	3.3 (2.6-4.2)
US 2010	7.2 (6.5-8.0)	10.2 (8.9-11.5)	4.4 (3.6-5.3)	5.8 (5.1-6.5)	8.2 (7.1-9.4)	3.4 (2.7-4.3)
WHO	7.2 (6.4-8.0)	10.1 (8.9-11.5)	4.2 (3.4-5.1)	5.8 (5.2-6.6)	8.2 (7.1-9.4)	3.4 (2.7-4.3)
World	7.0 (6.3-7.8)	9.8 (8.6-11.2)	4.2 (3.4-5.2)	5.8 (5.1-6.5)	8.1 (7.0-9.3)	3.5 (2.7-4.4)

Adjusted incidences of all abdominal injuries and the subgroup of solid organ injuries in SUH catchment area. Adjusted towards standard populations for Norway, EURO, USA 2010, WHO and World to enable comparison between geographical regions.

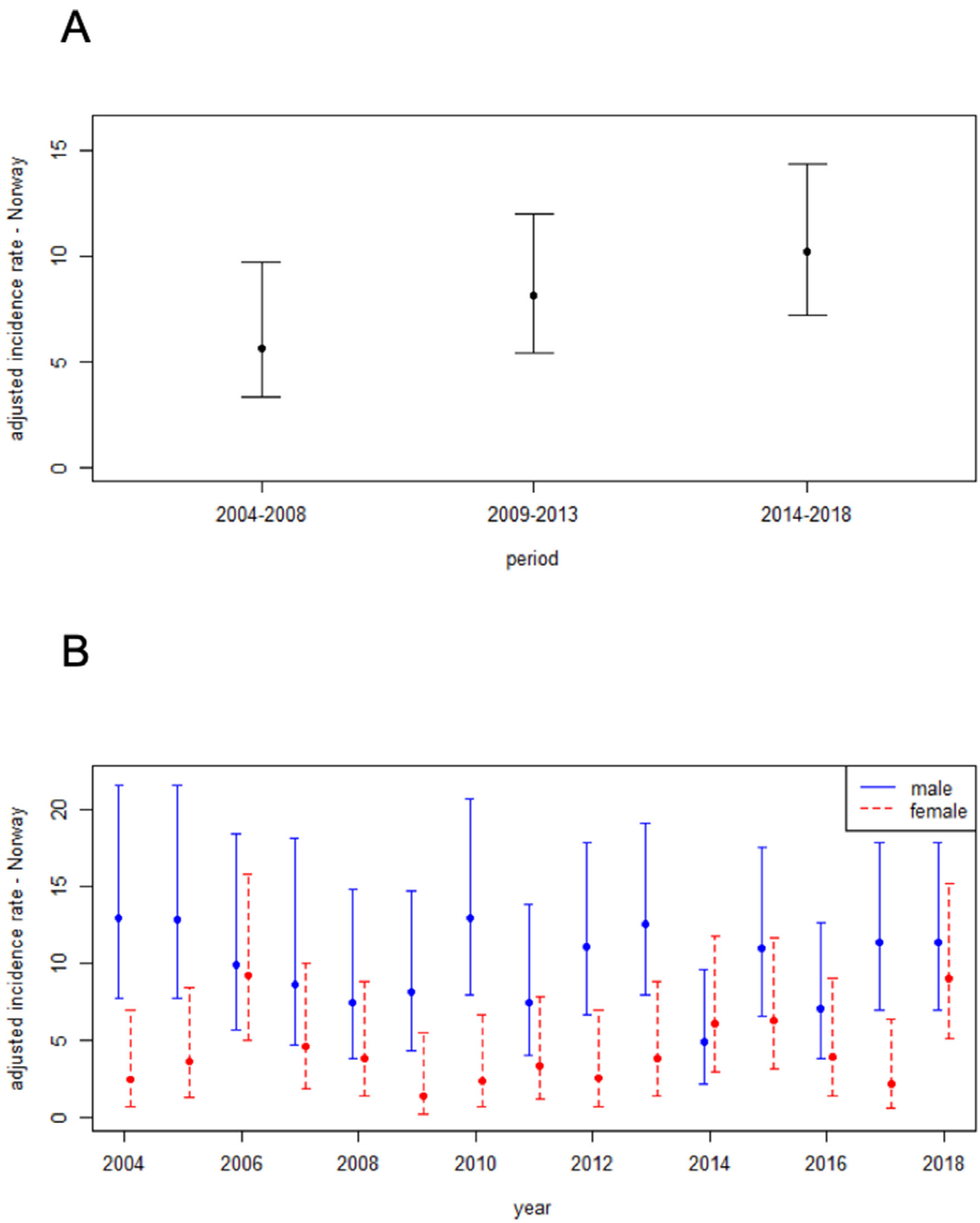

Fig. 2. Adjusted incidence of abdominal injuries. Panel A: Adjusted incidence of all abdominal injuries in SUH catchment area presented for the three incremental periods. Adjusted to standard population of Norway. Panel B: Annual adjusted incidence of all abdominal injuries in SUH catchment area presented for male and female patients. Adjusted to standard population of Norway.

injuries and the subgroup of solid-organ injuries, a non-significant increase in incidence was noted. While the literature is scarce regarding adjusted incidences of abdominal injuries, one report from Norway [25] and reports from other countries [2,3,9] indicate an increasing incidence in the past two decades. Whether this may be attributed to more precise diagnostics and improved trauma service for a better recording of these injuries, or if the observed increasing incidence is an actual increase in numbers, remains a question. Baseline information on the incidence and frequency of abdominal injuries is of significant interest when planning future trauma care and education. It may also aid the trauma teams and personnel working with follow-up after admittance regarding suspicion of injury. However, it is worth noting that some of the minor injuries might be of little clinical importance. At the same time, f.ex, a seatbelt sign in a patient with a negative CT scan might induce a higher workload during management and follow-up than a low grade organ injury in a stable patient.

The age at presentation increased by more than a decade. Elderly patients constituted about 15% of the abdominal trauma workload in the last incremental period, which is in line with other

Table 4
Mechanism of injury.

Mechanism, n (%)	2004-2008 n=148	2009-2013 n=141	2014-2018 n=160	Total n=449	p
Transport related	**94 (63.5)**	**82 (58.2)**	**81 (50.6)**	**257 (57.2)**	0.071
Motor vehicle accident	48 (32.4)	41 (29.1)	36 (22.5)	125 (27.8)	0.140
Motor bike accident	17 (11.5)	17 (12.1)	19 (11.9)	53 (11.8)	0.988
Bicycle accident	16 (10.8)	15 (10.6)	16 (10.0)	47 (10.5)	0.970
*Pedestrian**	10 (6.8)	5 (3.5)	5 (3.1)	20 (4.5)	0.249
Other	3 (2.0)	5 (3.5)	4 (2.5)	12 (2.7)	0.716
Fall	**21 (14.2)**	**28 (19.9)**	**57 (35.6)**	**106 (23.6)**	<0.001
<1m	2 (1.4)	6 (4.3)	20 (12.5)	28 (6.2)	0.059
1-5m	12 (8.1)	13 (9.2)	28 (17.5)	53 (11.8)	0.745
>5m	7 (4.7)	9 (6.4)	9 (5.6)	25 (5.6)	0.124
Violence	**10 (6.8)**	**9 (6.4)**	**6 (3.8)**	**25 (5.6)**	0.454
Other	**3 (2)**	**14 (9.9)**	**13 (8.1)**	**30 (6.7)**	0.018
Self-harm**	**9 (6.1)**	**5 (3.5)**	**13 (8.1)**	**27 (6)**	0.237
Situation, n (%)					
Work related injury	**19 (12.8)**	**24 (17)**	**24 (15)**	**67 (14.9)**	0.608
Leisure activities	**88 (59.5)**	**40 (28.4)**	**90 (56.3)**	**218 (48.6)**	<0.001
Other	**41 (27.7)**	**77 (54.6)**	**46 (28.8)**	**164 (36.5)**	<0.001

n = number of patients.
* Pedestrian hit by motorized vehicle.
** Includes transport related injuries, falls and stab injuries.

reports [26]. The increase among patients >65 years was not statistically significant and may only partly explain the rise in median age for patients with abdominal injuries overall. A relevant change was found in the adults, with an increase in the median age at presentation of 12 years during the study period. An increasing trend of more elderly patients suffering from other traumatic injuries [27,28] has also been shown for injuries to the abdomen [3]. Most likely, this reflects the elderly population being healthier and more active with an inherent risk of injury at a more advanced age. Together with an increase in pre-existing medical conditions, shown in our material as a significant rise of patients with ASA-score 2 and 3, serves as a challenge for future trauma team efforts.

The number of falls leading to abdominal injuries increased, mainly due to falls from heights <1 m. A higher median age was noted for patients sustaining low-energy falls (48 years versus 31 years of age), and 25% were elderly patients. The findings concur with those reported by others [3], including a recent publication from our center, showing a high degree of low-energy falls among elderly trauma patients [29]. This knowledge may aid us in further preventing injuries and correctly triaging this group.

More than half (57%) of the abdominal injuries were transport-related. Worldwide, motor vehicle accidents are the leading cause of abdominal injuries, accounting for over half of the injuries [2,4,5,11,13]. This material showed a decreasing trend in transportation-related injuries, with a decline in motor vehicle accidents contributing the most to this tendency. This finding is in line with a series from central Europe [30]. Our patients suffering abdominal injuries after transport-related mechanisms suffered less frequently from polytrauma over time. The global status report on road safety, launched by WHO in 2018, indicates a reduction in the number of road traffic deaths in the middle- and high-income countries [31]. The high-income profile of our catchment area suggests a predominance of modern vehicles with up-to-date safety equipment. This, together with zero-tolerance policies for alcohol use in drivers of motor vehicles, strict regulations of speed limits, and appropriate safety measures such as seatbelt use, may explain the decreasing trend.

Several studies have reported an increased incidence of penetrating abdominal injuries [2,32]. We did not find the same pattern. In contrast, although not statistically significant, a slight decrease was observed. Overall, 8.9% of the abdominal injuries were caused by penetrating injuries. This is lower than the 14% penetrating abdominal injuries recently reported from another Norwegian center [25], but higher than the 6% penetrating abdominal injuries from a low trauma-volume hospital in northern Sweden [11]. Other Scandinavian reports range from 9–12% penetrating mechanism in all severely injured trauma patients [33]. In a broader European setting, these proportions range from 3.7% in national data from England and Wales [34], to 8.5% in a single-center series from Switzerland [26], and up to 21% in a single-center series from the UK [35]. Additionally, one-third of the penetrating abdominal injuries in our material were due to self-harm. As a mixed urban/rural region characterized by a high socio-economic status with a low burden of inter-personal violence, this is also reflected in the demonstrated epidemiology with a low ratio of penetrating mechanisms in abdominal injuries.

A slight reduction in overall mortality from 14.2 to 10.6% was observed during the study period. The decrease was not statistically significant, but any reduction in mortality over time may be clinically relevant. This declining trend in mortality is in line with another recent Norwegian study that reported an overall 30-day mortality of 13.4% and 10.3% in their two incremental periods, respectively, although with a slightly higher median ISS in their patient cohort [25]. The report from northern Sweden had only one fatality among 110 patients with abdominal injuries, but a median NISS of 9 suggests a few severely injured patients in this patient cohort [11]. In a broader European setting, data from the UK covering adult blunt abdominal trauma patients from three major trauma centers showed overall mortality of 6.2% [36]. In a recent report presenting STAG (Scottish Trauma Audit Group) data for Scottish abdominal trauma patients between 2011 and 2015, 9.5% of the patients were classified as non-survivors [24]. On a global scale, two series from Australia reported mortality of 7–9% [2,3]. Of note, these reports define mortality as survival until hospital discharge, not specifying whether this is 30-day mortality, making comparison difficult. In smaller series, worldwide mortality ranges from 6% to 19%, but few reports on the 30-day mortality, and to our knowledge, none have reported on 90-day mortality [4,12,13,37,38]. It is worth noting that our material includes abdominal injured patients deemed dead on arrival during the trauma team management, and the fraction of such patients remained stable throughout the study period. This, together with reporting actual 30- and 90-day mortality, may contribute to our mortality ranging higher than studies with more conservative means of reporting. The maturing trauma system and the potential effect of treatment and mortality on subgroups of abdominal trauma patients will be the focus of further research from our group.

Limitations

Some limitations are worth mentioning. The population under investigation are the patients with abdominal injuries captured by our institution's trauma registry. Patients with isolated minor abdominal injuries may not be fully accounted for and thereby excluded from our calculation of incidence rates [39]. Also, prehospital deaths are not included in the study, which potentially could lead to an even more accurate estimate of incidence.

The trauma system has matured and developed during the study period [29,40,41]. Hence, this study's retrospective nature may serve as a limiting factor when comparing different incremental periods.

Conclusion

This study presents stable incidences of patients with abdominal injuries over time in a mixed rural/urban settlement. The patients are getting older and more often presenting with pre-existing comorbidities (ASA 2 and 3). Abdominal injuries following transport accidents are decreasing but more frequently observed after low-energy falls. The proportion of polytrauma patients was significantly reduced over time. Mortality rates were declining, although not statistically significant.

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None

Ethics approval

This study was approved by the appropriate ethics committee and has therefore been performed according to the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Declaration of Competing Interest

The authors report they have no conflicts of interest.

CRediT authorship contribution statement

Johannes Wiik Larsen: Conceptualization, Visualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Kjetil Søreide:** Conceptualization, Visualization, Data curation, Writing – review & editing. **Jon Arne Søreide:** Conceptualization, Visualization, Data curation, Writing – review & editing. **Kjell Tjosevik:** Conceptualization, Visualization, Data curation, Writing – review & editing. **Jan Terje Kvaløy:** Conceptualization, Visualization, Formal analysis, Data curation, Writing – review & editing. **Kenneth Thorsen:** Conceptualization, Visualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2022.06.020.

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