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Close to zero preventable in-hospital deaths in pediatric trauma patients – An observational study from a major Scandinavian trauma center

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ABSTRACT

Background: In line with international trends, initial treatment of trauma patients has changed substantially over the last two decades. Although trauma is the leading cause of death and disability in children globally, in-hospital pediatric trauma related mortality is expected to be low in a mature trauma system. To evaluate the performance of a major Scandinavian trauma center we assessed treatment strategies and outcomes in all pediatric trauma patients over a 16-year period.
Methods: A retrospective cohort study of all trauma patients under the age of 18 years admitted to a single institution from 1st of January 2003 to 31st of December 2018. Outcomes for two time periods were compared, 2003–2009 (Period 1; P1) and 2010–2018 (Period 2; P2). Deaths were further analyzed for preventability by the institutional trauma Mortality and Morbidity panel.
Results: The study cohort consisted of 3939 patients. A total of 57 patients died resulting in a crude mortality of 1.4%, nearly one quarter of the study cohort (22.6%) was severely injured (Injury Severity Score > 15) and mortality in this group decreased from 9.7% in P1 to 4.1% in P2 (p<0.001). The main cause of death was brain injury in both periods, and 55 of 57 deaths were deemed non-preventable. The rate of emergency surgical procedures performed in the emergency department (ED) decreased during the study period. None of the 11 ED thoracotomies in non-survivors were performed after 2013.
Conclusion: A dedicated multidisciplinary trauma service with ongoing quality improvement efforts secured a low in-hospital mortality among severely injured children and a decrease in futile care. Deaths were shown to be almost exclusively non-preventable, pointing to the necessity of prioritizing prevention strategies to further decrease pediatric trauma related mortality.

Background

Trauma is a leading cause of death and disability in children globally [1,2]. In the United States (US) a child dies every hour from injury or violence [3]. Experience with trauma in pediatric patients is crucial to optimize treatment, whether in specialized pediatric trauma centers or securing pediatric experience in adult trauma centers. A significant number of severe injuries in children happen in rural areas, underlining the importance of efficient transport to trauma centers to optimize trauma care and improve outcomes as shown in a Swedish study [4]. Although most children are healthy prior to the injury, their anatomical constitution provides less protection against traumatic insults compared to adults [5]. Furthermore, pediatric patients challenge most medical teams more than adults, both emotionally and technically [6]. Over the last decades, knowledge about pediatric trauma care has improved substantially, but outside the US there are few major studies de-

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scribing the characteristics of the pediatric trauma population [2,7–14].

In line with international trends, our initial treatment of trauma patients has changed substantially over the last two decades. Increased focus on Damage Control Resuscitation (DCR) protocols and interventional radiology have improved outcomes in adults overall and in subgroups of patients with specific injuries [15–20]. However, whether this holds true for the pediatric trauma population as a whole needs clarification. Evaluation of the care provided is necessary to optimize treatment and outcome. In-hospital mortality in pediatric trauma patients in a mature trauma system is expected to be low compared to adults [2,8,21] and in a recent study including 880 injured children referred to a Danish trauma center a crude mortality rate of 2.7% was reported [22]. Despite low mortality rates pediatric trauma is a major burden on the health care system and causes a wide range of morbidity in children [13,14]. Therefore, we assessed treatment strategies and outcomes including preventability of deaths in all pediatric trauma patients admitted to a major trauma center during a 16-year period.

Methods

Oslo University Hospital Ullevaal (OUHU) is the only high-volume trauma center in Norway with a catchment area of 3 million people covering approximately 60% of Norway's population. We performed a retrospective cohort study of all trauma patients under the age of 18 years admitted to OUHU during the period 1st of January 2003 to 31st of December 2018 and included in Oslo University Hospital Trauma Registry (OUH-TR)

The OUH-TR includes all trauma patients admitted through trauma team activation and patients with penetrating injuries proximal to elbow or knee, or patients with Injury Severity Score (ISS) [23] > 9 admitted to OUHU directly or via local hospitals within 24 h after injury. Approximately 15% of all trauma team activations are for the age group 1 – 17 years and nearly 40% of the total trauma population are severely injured with an ISS > 15 [24].

The study is presented according to STROBE-guidelines, checklist completed and uploaded as part of the submission [25]. From the OUH-TR we extracted age, gender, mechanism of injury (MOI), date of injury, Glasgow Coma Scale (GCS) score, admission systolic blood pressure (SBP), heart rate (HR), hemoglobin (Hb), base deficit (BD), lactate, platelets, fibrinogen, International Normalized Ratio (INR), ISS, anatomic injury classified according to the Abbreviated Injury Scale (AIS) 1990 revision-Update 98 [26], preinjury physical status according to the American Society of Anesthesiologists physical status classification system (PPS-ASA) [27], transfusions prior to admission in the intensive care unit (ICU), trauma team activation rate, hospital length of stay (LOS), LOS in ICU, probability of survival (Ps) calculated according to the Trauma and Injury Severity Score (TRISS) methodology with coefficients published from the National Trauma Data Bank in 2009 [28], 30-day mortality, and main cause of death. Survival status 30 days after injury was obtained from patient records and the Norwegian Population Registry. The study population was analyzed for differences between the periods 2003 and 2009 (Period 1; P1) and 2010–2018 (Period 2; P2). The cut-off point between time periods was chosen to visualize effects of institutional changes in trauma organization including improved DCR strategies with an updated massive hemorrhage protocol and the implementation of the regional trauma system further detailed with defined triage and transfer criteria [17]. Blood tests were not obtained routinely from all pediatric trauma patients leading to a high number of missing values, especially in Period 1. Furthermore, the study cohort was stratified into four age groups; <1, 1 – 4, 5 – 14 and 15 – 17 years of age and subjected to sub-group analyses.

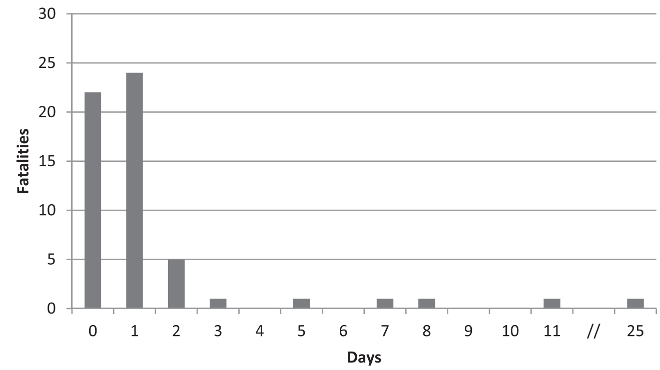

Fig. 1. Fatalities (n = 57) stratified by days after admission.

Continuous data are presented as medians with interquartile range (IQR). Comparisons between groups were performed using Mann-Whitney U test. Categorical data are reported as proportions and tested for significance using Pearson's chi- square test with Yates continuity correction and Fisher's exact test when appropriate. For all analyses, a p-value < 0.05 (derived from a two-tailed test or calculated as double the exact one-tailed probability) was considered to indicate statistical significance.

Mortality in the two time periods was compared and analyzed including W-statistics [29] (where differences in case mix are adjusted in line with ISS, physiology on arrival according to Revised Trauma Score, age, and injury mechanism). W-statistics (expressing excess survivors per 100 patients treated at OUH compared to TRISS model predictions) were calculated according to convention and used to compare outcomes for the two periods. Non-overlapping 95% confidence intervals were deemed as significant differences between groups. Deaths were further analyzed by retrieving information from patient charts. As part of the formal Mortality and Morbidity (M&M) conferences at OUHU, initiated by the Department of Traumatology in 2010, all trauma deaths are subjected to an assessment of preventability and whether futile operative care was performed. A primary reviewer assesses all trauma deaths and decides – based on defined criteria – whether they should be subject to a multidisciplinary discussion. The M&M panel consists of consultants and trauma coordinators from the Department of Traumatology, and consultants from all involved departments, i.e. anesthesiology, ICU, prehospital / helicopter emergency services, forensic medicine and all relevant surgical specialties. Deaths are categorized as non-preventable, possibly preventable, probably preventable or preventable in accordance with international standards [30]. All mortality assessments were performed according to the standards of care at the time of injury. The conclusion is based on panel consensus. All pediatric trauma deaths in the study period prior to 2010 were now assessed and relevant cases evaluated in a separate M&M conference in 2020. Cases already assessed were not reviewed again and the original conclusion was maintained.

All statistical analyses were performed using the IBM SPSS Version 28.0.1.1 (IBM SPSS Statistics, Armonk, NY). Approval for the study was obtained from the Institutional Data Protection Officer at Oslo University Hospital (18/06,570, 23.04.2019).

Results

The study cohort consisted of 3939 patients; of whom 63% were male, and median age was 9 years (IQR 4;14). A total of 57 patients died for a crude mortality of 1.4%. The vast majority (80.7%) of the non-survivors died within 48 h as shown in Fig. 1. The MOI was blunt in 96.2% of the children. The injuries were secondary to falls in 33.6% and traffic related incidents in 32.5%, mainly represented

Table 1
Patient characteristics stratified by time periods.

	P 1 $n = 1152$	P 2 $n = 2787$	p
Age, years	11 (5;15)	9 (3;14)	<0.001
Male gender, n (%)	744 (64.6)	1749 (62.8)	0.279
SBP, mm Hg	120 (110;135)	118 (105;130)	0.001
HR, beats/min	100 (85;115)	103 (85;120)	<0.001
GCS score	15 (14;15)	15 (15;15)	<0.001
ISS	10 (4;17)	5 (1;10)	<0.001
ISS > 15, n (%)	360 (31.3)	531 (19.1)	<0.001
BD, mmol/L	1.6 (0.5;3.4)	2.1 (0.8;3.5)	0.001
Penetrating injury, n (%)	55 (4.8)	95 (3.4)	0.042
Transfused, n (%)	56 (4.9)	46 (1.7)	<0.001
ED surgery, n (%)	11 (1.0)	2 (0.1)	<0.001
Endovascular procedures	32 (2.8)	41 (1.8)	0.006
Intubated, n (%)	302 (26.2)	321 (11.5)	<0.001
Ps Mean (SD)	0.966 (0.125)	0.987 (0.067)	<0.001
TTA n (%)	974 (84.5)	2693 (96.6)	<0.001
Mortality, n (%)	35 (3.0)	22 (0.8)	<0.001
LOS in ICU, days	3 (2;8)	2 (2;6)	<0.001
LOS in hospital, days	2 (0;3)	1 (0;2)	<0.001

P1; Period 1, P2; Period 2, SBP; Systolic blood pressure, HR; heart rate, GCS; Glasgow Coma Scale, ISS; Injury Severity Score, BD; Base deficit, Transfused; patients transfused in the Emergency Department, ED surgery; Emergency Department surgery Intubated; patients intubated prehospital or in the Emergency Department, Ps; probability of survival, TTA; Trauma team activation, ICU; Intensive Care Unit, LOS; Length of stay, Values are median and interquartiles when not stated otherwise. Number of patients with missing values in P1: SBP; 185 HR; 113 ISS; 35, Patients transfused; 5, ED Surgery; 4, Ps; 35, LOS ICU; 1. P2: SBP; 385, HR; 137, GCS; 2, ISS; 140, Ps; 140.

by pedestrians, occupants in cars, or bicyclists. Nearly one quarter of the study cohort (22.6%) was severely injured and crude mortality in this subgroup was 6.2%.

Comparison between periods

P1 included 1152 patients and P2 included 2787 patients. Mechanism of injury was blunt in
> 95% in both periods (Table 1). Median ISS, hospital LOS, and LOS in ICU were lower in P2. Trauma team activation rate increased to 96.6% in P2, whereas crude mortality rate fell to 0.8% (Table 1). The main cause of death was brain injury in both periods, 80.0% in P1 and 90.9% in P2 (p 0.272). The number of severely injured patients (ISS > 15) was 360 in P1 and 531 in P2 with an observed reduction in mortality from 9.7% to 4.1% ($p < 0.001$)

In the groups of patients with an ISS > 25 median ISS was 29 (26;36) in P1 and 30 (26;35) in P2. However, mortality fell from 18.5% (34/184) to 8.5% (19/223) (p=0.003).

Comparison between age groups

Patient characteristics stratified by age groups are presented in Table 2. Differences between adjacent age groups were modest, except when comparing the two oldest cohorts. Median ISS, hospital LOS, and LOS in ICU were higher in the oldest age group accompanied by a higher proportion of patients with penetrating injuries and patients undergoing acute interventions. Main cause of death was brain injury in all age groups.

Evaluation of mortality, preventability, and futile care

Patient characteristics in survivors and non-survivors are shown in Table 3. Not surprisingly, non-survivors were more physiologically compromised on admission, more severely injured (median ISS = 35) and with reduced Ps when compared to survivors (Tables 3 and 4). W-statistics showed 0.24 excess survivor per 100 patients in P1 (95% CI, −0.53; 1.00) and 0.50 excess survivor per 100 patients in P2 (95% CI, 0.14; 0.85). As previously described, brain injury was the main cause of death throughout the study period (Table 5) and in all age groups and most deaths (46/57) occurred within the two first days after injury (Fig. 1). Based on the assessment by the panel in the M&M conferences 55 out of 57 deaths were deemed non-preventable, one potentially preventable due to inadequate volume resuscitation, and one probably preventable due to delayed targeted treatment of a patient with head injury. The M&M panel found elements of futile care in 11 patients based on information of extensive surgery in patients in whom survival were unlikely, e.g., patients that underwent Emergency Department (ED) thoracotomy with additional operative procedures after severe blunt trauma. Most of these patients (8/11) were admitted in P1. The rate of emergency surgical procedures performed in the ED also decreased during the study period.

Discussion

This study describes the pediatric trauma population in a major Norwegian trauma center over a 16-year period. In a large cohort of 3939 patients, we registered an overall in-hospital mortality of 1.4%. The total number of patients more than doubled from P1 to P2 accompanied by a reduction in mortality from 3.0% to 0.8%. Although this reduction is probably related to differences in case mix, one of the known limitations of retrospective studies, the actual numbers of deaths declined from 35 in P1 to 22 in P2, and the mortality in the group of severely injured (ISS > 15) confirmed a decrease from 9.7% in P1 to 4.1% in P2. Moreover, in the group of patients with an ISS > 25, mortality fell from 18.5% to 8.5% from P1 to P2, despite a slightly increased median ISS in P2. Since in-hospital pediatric trauma related mortality is expected to be low in a mature trauma system [2,7], causality between improved survival and specific elements of quality development might be difficult to prove, but still worth mentioning and indicates that ongoing quality improvement work is fruitful.

Previous studies from our institution have shown similar tendencies in the adult trauma population and specific subgroups [15–20,31]. Groven et al. demonstrated that increased survival coincided in time with the formalisation of a dedicated trauma service [15]. Such an improvement in trauma outcomes is most likely multifactorial and includes increased focus on multidisciplinary approach, development of a clinical governance structure and performance improvement programs as the most important contributors.

Curtis et al. evaluated care provided to 490 severely injured children in New South Wales, Australia and found adverse events in 7.6% of the cases. However, none of the 18 fatalities were deemed absolutely preventable [32]. In our study 55 out of 57 fatalities were deemed non-preventable by the M&M panel, one potentially preventable and one probably preventable. It is important to underline that the mortality assessments were performed according to the standards of care at the time of injury, potentially contributing to the low rate of preventable deaths also during the early study period. This might appear as a weakness of the study in addition to the ones associated with its retrospective design. The study addresses two consecutive periods, and the number of patients has increased steadily over the study period which we attribute to the maturing trauma system leading to general improvement in care.

Extensive emergency surgical procedures decreased significantly over the study period; in fact, there were no ED thoracotomies in non-survivors after 2013. This is in accordance with international contemporary standards, trying to avoid desperate procedures in dying children, which in retrospect were deemed to be futile as summarized in a review article by Moskowitz et al. in 2017 [33]. They reported no survivors after ED thoracotomy in blunt trauma patients under the age of 15 in cardiac arrest and advised cautiousness in applying adult guidelines in such patients.

Table 2
Patient characteristics stratified by age groups.

	A1(<1 year) $n = 126$	A2(1 – 4 years) $n = 983$	p	A3(5 – 14 years) $n = 1901$	p	A4(15 – 17 years) $n = 929$	p
Male, n (%)	76 (60.3)	606 (61.6)	0.773	1204 (63.3)	0.374	607 (65.3)	0.297
SBP, mm Hg	104 (90;120)	110 (95;120)	0.077	119 (109;130)	<0.001	125 (115;140)	<0.001
HR, beats/min	155 (135;170)	128 (110;150)	<0.001	97 (85;110)	<0.001	90(77;101)	<0.001
GCS score	15 (15;15)	15 (15;15)	0.759	15 (15;15)	<0.001	15 (14;15)	<0.001
Mean (SD)	14.50 (1.765)	14.43 (2.018)		14.09 (2.503)		13.58 (3.160)	
ISS	2 (1;16)	2 (1;9)	0.068	5 (2;14)	<0.001	10 (4;19)	<0.001
ISS > 15, n (%)	28 (22.2)	116 (11.8)	0.001	422 (22.2)	<0.001	325 (35.0)	<0.001
BD, mmol/L	5.7 (4.3;10.5)	3.6 (2.4;5.2)	0.005	2 (0.8;3.3)	<0.001	1.6 (0.3;3)	<0.001
Penetrating injury, n (%)	0 (0.0)	29 (3.0)	0.058	62 (3.3)	0.650	59 (6.4)	<0.001
Transfused, n (%)	6 (4.8)	17 (1.7)	0.076	43 (2.3)	0.337	36 (3.9)	0.014
ED surgery, n (%)	0 (0.0)	2 (0.2)	1	3 (0.2)	1	8 (0.9)	0.016
Intubated, n (%)	9 (7.1)	115 (11.7)	0.127	281 (14.8)	0.023	218 (23.5)	<0.001
Ps Mean (SD)	0.994 (0.028)	0.990 (0.071)	0.050	0.985 (0.081)	<0.001	0.960 (0.117)	<0.001
TTA, n (%)	109 (86.5)	918 (93.4)	0.009	1770 (93.1)	0.778	870 (93.6)	0.590
Mortality, n (%)	2 (1.6)	7 (0.7)	0.544	25 (1.3)	0.143	23 (2.5)	0.025
LOS in ICU, days	1 (0;2)	1 (0;2)	0.195	1 (0;2)	<0.001	2 (1;3)	<0.001
Mean (SD)	2.30 (4.156)	1.66 (3.520)		2.04 (4.039)		3.50 (5.892)	
LOS in hospital, days	2 (2;6)	3 (2;13)	0.014	2 (2;6)	<0.001	3 (2;7)	<0.001

SBP; Systolic blood pressure, HR; heart rate, GCS; Glasgow Coma Scale, ISS; Injury severity score, BD; Base deficit, Transfused; patients transfused in the Emergency Department, ED surgery; Emergency Department surgery, Intubated; patients intubated prehospital or in the Emergency Department, Ps; probability of survival, TTA; Trauma team activation, ICU; Intensive Care Unit, LOS; Length of stay. Values are median and interquartiles when not stated otherwise. p-values; A1 vs A2, A2 vs A3, A3 vs A4. Number of patients with missing values in A1; SBP; 66 HR; 27, ISS; 16, Ps; 16, in A2; SBP; 354 HR; 110, ISS; 40, Ps; 40, in A3; SBP; 129, HR; 89, CGS; 2, ISS; 87, Patients transfused; 5, PS; 87, in A4; SBP; 21, HR; 24, ISS; 32, Ps; 32.

Table 3
Patient characteristics stratified by survivors and non-survivors.

	Survivors $n = 3882$	Non-survivors $n = 57$	p
Male, n (%)	2463 (63.4)	30 (52.6)	0.093
SBP, mm Hg	120 (107;130)	75 (49;120)	<0.001
HR, beats/min	100 (85;120)	100 (60;130)	0.173
GCS score	15 (15;15)	3 (3;5)	<0.001
ISS	5 (1;13)	35 (26;47)	<0.001
Penetrating injury, n (%)	145 (3.7)	5 (8.8)	0.128
Transfused n (%)	73 (1.9)	29 (51)	<0.001
ED surgery n (%)	1 (0.0)	12 (21.1)	<0.001
Intubated, n (%)	569 (14.7)	54 (94.7)	<0.001
Ps Mean (SD)	0.988 (0.053)	0.490 (0.301)	<0.001
TTA, n (%)	3611 (93)	56 (98.2)	0.174
LOS in ICU	1 (0;2)	1 (0;2)	0.274
LOS in hospital	3 (2;7)	2 (1;2)	<0.001

SBP; Systolic blood pressure, HR; heart rate, GCS; Glasgow Coma Scale, ISS; Injury severity score, Transfused; patients transfused in the Emergency Department, ED surgery; Emergency Department surgery, Intubated; patients intubated prehospital or in the Emergency Department, Ps; probability of survival, TTA; Trauma team activation, LOS; Length of stay, ICU; Intensive Care Unit, Values are median and interquartiles when not stated otherwise. Number of patients with missing values in survivors; SBP; 566, HR; 244, GCS; 2, Patients transfused; 5, ISS; 175 Ps; 175, LOS in ICU; 1, in Non-survivors; SBP; 4, HR; 6.

Table 4
Body temperature and conventional coagulation tests on arrival in survivors and non-survivors in Period 2.

	Survivors $n = 2765$	Non-survivors $n = 22$	p
BT, °C	36.5 (36.1;36.9)	34.3(32.1;35.9)	<0.001
Lactate, mmol/L	1.5 (1;0;2.2)	7.3 (3.5;11)	<0.001
Platelets, x 10^9/L	273 (231;320)	157 (112;213)	<0.001
Hemoglobin, g/dL	12.7 (11.9;13.7)	11.5 (8.8;13.5)	<0.001
INR	1.1 (1.1;1.2)	1.3 (1.2;1.5)	<0.001
Fibrinogen, g/L	2.5 (2.2;2.)	1.2 (0.6;1.9)	<0.001

Values are median and interquartiles. BT; Body temperature, INR; International normalized ratio. Number of patients with missing values in survivors; Temperature; 1139, Lactate; 1692, Platelets; 1148, INR; 1252, Hb; 1023, Fibrinogen; 1263, in Non-survivors; Temperature; 6, Lactate; 4, Platelets; 5, INR; 4, Hemoglobin; 3, Fibrinogen; 3.

Table 5
Main causes of death in Period 1 (P1) and Period 2 (P2).

	P1	P2
Brain injury	28	20
Bleeding	6	2
Unknown	1	0
Total	35	22

However, they recommended that guidelines for adults can be followed in children with cardiac arrest after penetrating trauma.

A trimodal distribution of time to death after fatal injuries used to be referenced. This pattern is under debate and whether this can be found in the pediatric trauma population has been questioned [7,34,35]. McLaughlin et al. studied time to death in children (0 – 14 years) and compared this with adults (15 – 64 years) [36]. They found a time of death distribution in pediatric patients similar to the pattern in adults, with a small, but significantly higher proportion of early deaths and a lower proportion of late fatalities. Our data shows that most pediatric deaths after hospital admission (46/57) occurred within the first two days (Fig. 1), and data from the Norwegian Institute of Public Health confirms that most deaths occur on scene [37,38]. This supports a bimodal fatality curve. Multi-organ failure was a rare cause of death in our pediatric trauma population where most fatalities are caused by the primary insult. This is in accordance with the findings of Lichte et al. in a retrospective study of 1110 pediatric trauma patients compared to an adult cohort [39]. They found an increased rate of multi-organ failure and sepsis in adults compared to children, but a higher mortality after severe brain injury in children. Brain injury was the main cause of death in the vast majority of cases in our cohort (Table 5). Our findings are in accordance with the result presented in a Finnish study from 2011 in which head traumas constituted 67% of injury-related deaths in children [14]

Hypothermia and coagulopathy are shown to be important predictors of mortality in pediatric trauma patients. This corresponds well to the data presented in our study where non-survivors were hypothermic and coagulopathic on admission (Table 4). Based on analysis of more than 400 000 patients from the US National Data Bank, McCarty et al. found that hypothermia is an independent risk factor for mortality in pediatric trauma [40]. When evaluating close to 1000 children and adolescents from their institutional trauma registry in a retrospective study from a single trauma center, Liras et al. found that 57% of patients meeting the highest level of trauma activation presented in a state of coagulopathy with a 4-fold increased risk of death [41]. This association was even stronger in those with severe head injuries.

The reduction in in-hospital mortality in Period 2 coincides with a reduction in pediatric trauma-related fatalities in our Health Region which decreased from 47 fatalities in 2003 to 16 in 2018 [37]. In our material the vast majority of deaths were deemed non-preventable. On that background one might speculate that the annual number of children sustaining life-threatening injuries in our region is declining. This is in accordance with the findings in an in-depth evaluation of real-world car collisions from south eastern Norway, where Skjerven-Martinsen et al. documented that fatal and severe injuries in children were predominantly caused by restraint errors and unstrapped cargo [42]. The same group later showed that during the period 2009 – 2013 there were no fatalities among child occupants in south eastern Norway, compared to 18 in the time period 1999 to 2002 and attributed the reduction in mortality to improvements in child occupant safety and in automobile design [43]. As clearly pointed out in a Swedish study published 15 years ago, pediatric injury related deaths were reduced more than 50% from the first period (1966 – 1981) to the second period (1982 – 2001) on a national basis through implementation of prevention strategies such as improved car safety, the expansion of public child day-care centers including more organized leisure activities, mandatory program for swim training among school children and local child-safety programs [44]. In a retrospective study of 386 childhood traffic accidents admitted to a Finnish university hospital Nurmi et al. found that the majority were mild and required only minor treatment. However, the risk of traffic accidents and resulting injuries increased dramatically when the child reached the legal age of acquiring a driving license for a moped underlining the need for targeted prevention programs [12]. Moreover, the American Center for Disease Control and Prevention has stated that child injuries are predictable and preventable and that many effective strategies to reduce child injuries and mortality are available [45]. On this background, a continuous focus on prevention strategies seems to be the most important factor for further reduction of pediatric trauma related mortality.

In conclusion

A dedicated multidisciplinary trauma service with ongoing quality improvement efforts secured a low in-hospital mortality among severely injured children and a decrease in futile care. Deaths were shown to be almost exclusively non-preventable, pointing to the necessity of prioritizing prevention strategies to further decrease pediatric trauma related mortality.

Contributors

AHR, CG and PAN designed the study and conducted the literature search. AHR, NOS, TW, KBA, CG and PAN analyzed the data. All authors interpreted the data, and participated in writing, revising, and editing the article.

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Patient consent

Not required.

Ethics approval

Approval for the study was obtained from the Institutional Data Protection Officer at Oslo University Hospital.

Declaration of Competing Interest

None declared.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2022.07.043.

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