Original Article

Dan Med J 2020;67(7):A10190581

Characteristics and outcomes of paediatric patients admitted to a Danish level-1 trauma centre

Ole M. Hansen[1], Ronni Mikkelsen[1, 2], Jennifer Rosenkjær Eskol[1] & Ole Brink[1]

1) Trauma Research Unit, Department of Orthopaedics, Aarhus University Hospital, 2) Department of Neuroradiology, Aarhus University Hospital, Denmark

Dan Med J 2020;67(7):A10190581

ABSTRACT

Introduction: This study sought to expand the very limited data on Scandinavian paediatric poly-trauma patients by charactering patients from this population admitted to a Danish level-1 trauma centre.

Methods: This retrospective cohort study included all patients 15 years or younger who were admitted to the trauma centre at Aarhus University Hospital, Denmark from January 2000 to May 2014. Injury severity was calculated using the Injury Severity Score (ISS). The Wilcoxon rank-sum test was used to determine significant differences between sexes.

Results: A total of 880 children (499 boys and 391 girls) were included. No significant sex-related differences were observed in the numbers admitted during the study period, age at admission or severity of injuries. Overall, 30% of the paediatric patients were admitted in the afternoon (3-6 p.m.). The crude death rate was 2.7% of all admissions. Traffic accidents accounted for 48% of all admissions and two-thirds of all deaths. All non-survivors received ISSs of 16 or higher, and 20% of deaths in this group and 42% of overall deaths occurred within the first 24 hours.
Conclusions: Our study suggests that in Denmark, children admitted to a trauma centre are most likely to have been injured in traffic accidents and/or in the afternoon. Deaths were few and limited to the severely injured children; many survived despite severe injuries.

Funding: none.

Trial registration: not relevant.

The paediatric trauma patient would be expected to differ from the adult patient because of differences in anatomy, physiology and daily activities. In addition, current knowledge about severe paediatric traumas was obtained primarily from studies conducted outside of Scandinavia. Here, cultural and infrastructural differences might be reflected by different trauma

mechanisms: for example, firearms-related traumas are exceedingly rare among children in Scandinavia compared with the United States [1, 2].

To our knowledge, only a single study has examined the Danish paediatric trauma population; in 2017, Ekström et al described 648 children aged 15 years or younger [2]. As this is the only study performed, it remains unknown whether their findings are representative of other Danish regions. Therefore, a study aiming to gather a larger sample of new comparable data from the population of paediatric trauma patients in Denmark is relevant. Accordingly, in the present study we analysed the characteristics of paediatric trauma patients admitted to a Danish level-1 trauma centre.

METHODS

In this retrospective cohort study, we enrolled all trauma patients aged 15 years and younger admitted alive to the regional trauma centre at Aarhus University Hospital, Denmark, from January 2000 to May 2014. This regional level-1 trauma centre is solely responsible for an area in which 225,000 children younger than 15 years reside, including the hospital-adjacent primary catchment wherein approximately 53,000 children live.

Patient data were extracted from the hospital trauma register where all trauma patients are continuously registered. Injury severity was continuously classified initially by a senior orthopaedic consultant, later by a senior registered nurse and lastly by the authors using the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS). The AIS was subsequently used to calculate the maximum AIS (MAIS) [3]. The mechanism of injury was categorised using the Nordic Medico-Statistical Committee (NOMESCO) classification system [4].

Statistical analyses were performed using Stata 15.1. Non-normally distributed variables are presented as medians and interquartile range (IQR). The Wilcoxon rank-sum test was used to determine whether age, MAIS and ISS differed significantly between the sexes. A one-way analyses of variance (ANOVA) and the two-sample t-test were used to analyse the length of stay (LOS).

Trial registration: not relevant.

RESULTS

A total of 880 children were admitted to the trauma centre during the study period, and the distributions of sex are presented in **Table 1**, with no significant differences between age or sex ($p = 0.41$).

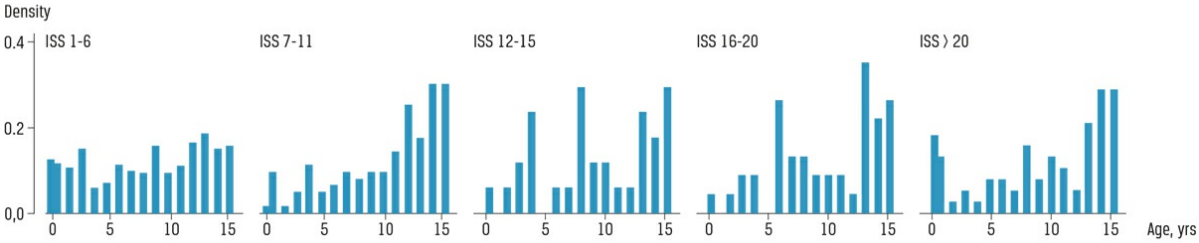
TABLE 1 / Classification according to Injury Severity Score subgroups.

	ISS 1-6	ISS 7-11	ISS 12-15	ISS 16-20	ISS > 20	Total
Children, n (%)						
Girls	259 (68.0)	56 (14.7)	10 (2.6)	21 (5.5)	35 (9.2)	381 (43.3)
Boys	348 (69.7)	66 (13.2)	23 (4.6)	23 (4.6)	39 (7.8)	499 (56.7)
Subtotal	607	122	33	44	74	880 (100)
Age, median (IQR), yrs	9 (3-13)	12 (7-14)	9 (6-13)	10.5 (6-13.5)	10 (5-14)	9 (4-13)
Traffic, n (%)						
Pedestrian, n (%)	55 (47.0)	23 (19.7)	5 (4.3)	14 (11.0)	20 (17.1)	117 (100)
Bicycle	64 (68.1)	16 (17.0)	3 (3.2)	3 (3.2)	8 (8.5)	94 (100)
Moped/motorcycle	33 (50.8)	13 (20.0)	4 (6.2)	4 (6.2)	11 (16.9)	65 (100)
Car	144 (77.8)	13 (7.0)	6 (3.2)	4 (2.2)	18 (9.7)	185 (100)
Other	3 (42.9)	3 (42.9)	1 (14.2)	0	0	7 (100)
Subtotal	299 (63.9)	68 (14.5)	19 (14.5)	25 (5.3)	57 (5.3)	468 (100)

IQR = interquartile range; ISS = Injury Severity Score.

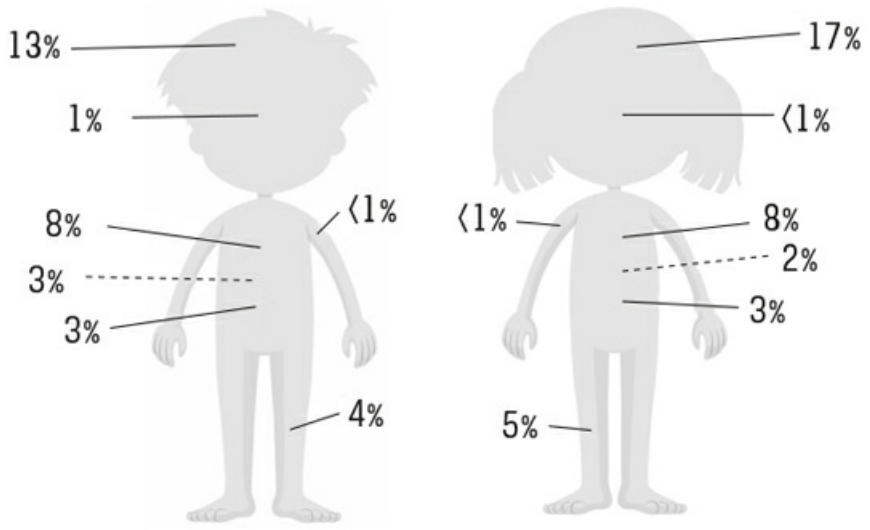
Regarding injury severity, the median ISS was 4 and the IQR 1-9. Injury severity did not differ with respect to sex. Distribution of age within subgroups are shown in **Figure 1**. By contrast, injury severity tended to increase with age, and children aged ten years or older had significantly higher ISS scores than younger children (Wilcoxon rank-sum test, p = 0.002).

FIGURE 1 / Age distribution within Injury Severity Score (ISS) subgroups.



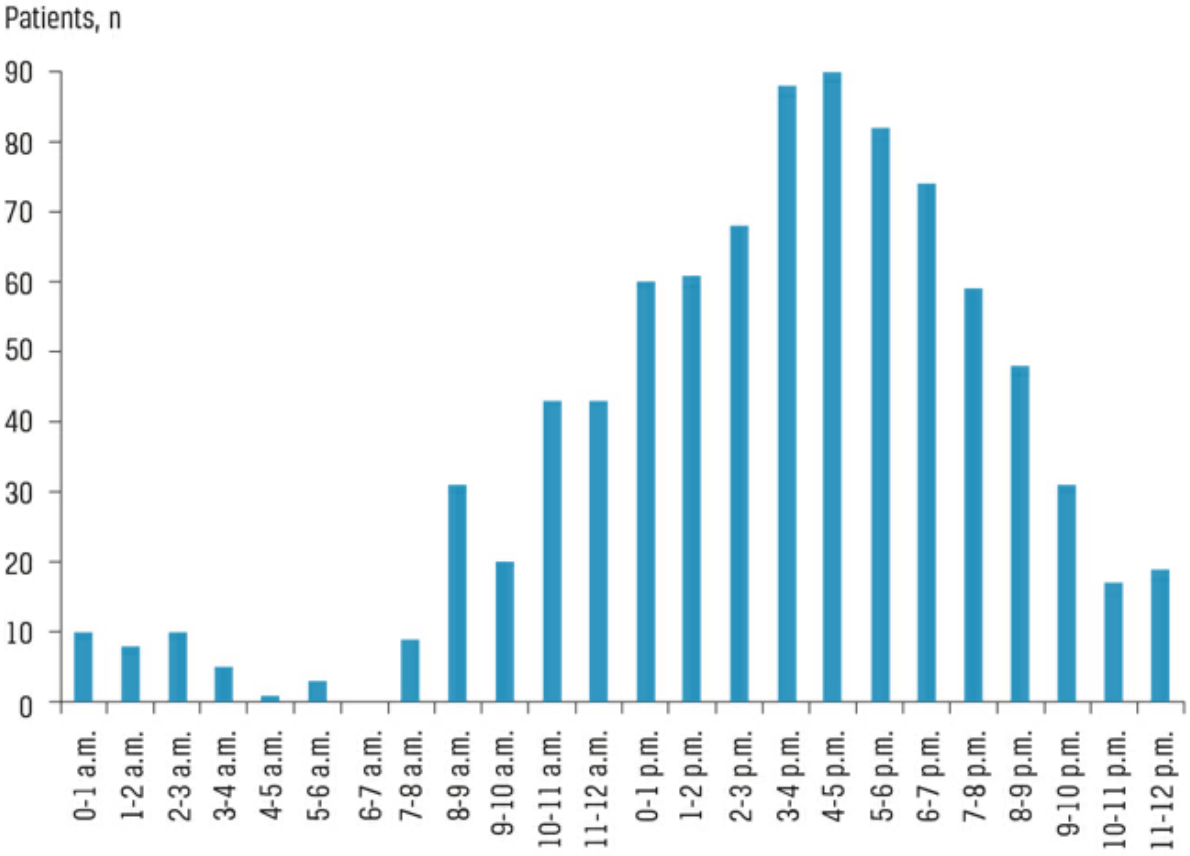
Regarding injury characteristics, injuries to the head region were most common and severe, with a median MAIS of 2, IQR 1-5. Children with injuries scored AIS of 3 (serious) and higher are presented in **Figure 2**. Additionally, 30% of all injured children were admitted to the trauma centre during the afternoon (3-6 p.m.) (**Figure 3**). Most trauma injuries were classified within the NOMESCO transportation subgroup: passenger in car, pedestrian and cyclist accounted for 21%, 13%, and 11% of all admissions, respectively (Table 1). Girls were only overrepresented in the sports subgroup (18.5% versus 8.6% male patients), and such injuries accounted for approximately 13% of all trauma admissions. Violence and self-inflicted injuries were recorded as the causes of injury in six cases (0.7%) and three cases (0.3%), respectively. The median LOS was one day, IQR 1-3, the longest was 99 days (excluding non-survivors) and LOS did not differ between sexes.

FIGURE 2 / Percentages of injuries scoring ≥ 3 in Abbreviated Injury Scale in boys and girls by anatomical regions.



Dotted lines = spine injuries.

FIGURE 3 / Admission time for trauma patients.



The crude death rate during the study period was 27.3/1,000 admissions. The median ISS of non-survivors was 44 and IQR 25-44 and all had an ISS 16. Of the 24 non-survivors, ten (42%) died within the first 24 hours and 19 (78%) within the first 48 hours, within a maximum interval of six days after admission. The numbers or time to death did not differ with regard to sex. Two-thirds of all fatalities were related to injuries from traffic accidents.

DISCUSSION

The results from our study describe the epidemiology and outcome from 880 severely injured children aged 15 years or younger admitted to a Danish trauma centre. The study represents the longest study period published from Denmark, and together with a similar and former study from Southern Denmark, our data make a more complete and valid picture of potentially severely injured children in Denmark [2].

When we compare a similar population with age up to 15 years from this study, 65 potentially severely injured children were admitted annually to the trauma centre in Southern Denmark compared with 66 in ours, and the death rate was 2.9 per 100 admissions compared with our 2.7 per 100 admissions. The majority of children were boys in both studies (56% compared with our

57%). In this study, more than half (53%) of the children were injured in traffic, mostly as passengers in cars and secondly as pedestrians; roughly similar findings were seen in Southern Denmark, except that children injured with bicycles were the second most common activity in traffic among those admitted. In both studies, ISS increased with increasing age of the children, and head injuries were the most common and severe accidents [2].

The age distribution of the included population matches that of some European studies but differs from others, including a German study by Zwingmann et al that included fewer children at the age of 0-5, more children aged 6-12 years of age and an equivalent number of children older than 12 years of age [5, 6]. Furthermore, although previous European studies and two American studies reported a significant overrepresentation of boys, the age distribution and sex ratio among our population closely matched those of another Danish study by Ekström et al [1, 2, 7-9]. Although there is no clear reason for this difference, the overrepresentation of sports-related admissions among girls in our study might be a contributing factor.

Almost one-third of the children were admitted in the afternoon, and traffic accidents were the predominant cause of injury. Additionally, transportation-related traumas accounted for 48% of all injuries, which is similar to the 45.9% rate observed by Ekström et al when comparing relevant subgroups [2]. However, this rate is lower than the rates reported by studies from Germany, the Netherlands and Austria, where 68-81% of injuries were related to transportation activities [6, 8, 10]. We suspect that differences in infrastructure and traffic culture (e.g., school buses or use of bike helmets) may be a factor in these discrepancies. Regarding non-European studies, our data are similar to those of a Canadian study, which reported that 52% of cases involved traffic-related traumas [11]. However, several American studies reported lower rates of traffic-related traumas (31% and 34%, respectively) [1, 9]. These differences were most likely influenced by the factors listed for the above-mentioned European studies. Finally, the fraction of transportation-related traumas in our study was lower than the 70% reported for the adult Danish population, which may be attributed to differences in behaviours and related risks [12].

Boys were overrepresented in all age groups, but we found no differences in the injury severity in relation to sex. With increasing age, the injury severity tended to increase, which may possibly be explained by an increased level of autonomy from parents and by more independent traffic and sports-related activities.

The low overall death rate of 2.7% in our study might be explained by the large proportion of cases with only minor injuries. More than two thirds of the children had only minor injuries according to the ISS, thus indicating that over triage had occurred. Activation of our trauma team is based on protocols and prehospital assessment of physiological and anatomical factors and the trauma mechanism. When children are injured, factors not included in protocols might lower the threshold for activating the trauma team. In a systematic review by Drendel et al including more than 13,000 children received by trauma teams, the authors found that the criteria for trauma team activation were consistently inconsistent and not based on empirical evidence [13].

More than half of all our children had head injuries, and one in eight boys and one in six girls had head injuries categorised as serious or worse. With the exception of head injuries, the anatomical location of serious injuries was similar for boys and girls. Similar to our findings, Buschmann et al showed a dominance of head injuries [5]. The high incidence of head and thoracic injuries can be explained by child anatomy with a large head and trunk compared with the rest of the body. At birth, the head size accounts for a fourth of the total body length, and in adults only a seventh [14]. The large head, a higher centre of gravity, a thinner cranial bone to give protection and less myelinated neural structure altogether increase the risk of brain damage in children [15]. Children's neck ligaments and spine musculature are also weaker than those of adults; and together with the large head, this contributes to a high risk of serious cervical spine injuries [14].

Our observation that all non-survivors had an ISS score of at least 16 and a median score of 44 indicates that these children had extremely severe and life-threatening injuries. It should be noted that this population was alive when admitted and does not represent children who die before arrival; this is in line with the studies discussed below. Our findings of a 20% mortality rate among patients with an ISS 16 correlated very well with the German findings by Buschmann et al, who reported a mortality rate of approximately 19% for this group [5]. However, our findings somewhat contrasted with those of Zwingmann et al, who reported a mortality rate of 13% for the same group and a 57% rate of death within the first 24 hours of admission, compared with 42% in our study [6]. In the Netherlands, van der Sluis et al observed a mortality rate of 20% among patients with ISSs of 16, with 80% dying within one day of admission [10]. Although differences in sex ratio and injury mechanisms were observed among studies, these findings suggest that the studied populations differ little with respect to the most severely injured patients (i.e. ISS 16); additionally, as these populations tend to be small, a low number of fatalities can produce a significant difference in a comparison.

Our study had several strengths, including a long observation period (14 years), a large sample, and a systematic and uniform data collection at a single trauma centre. Accordingly, a selection bias toward the severely injured is not relevant; as our trauma centre is the only level-1 centre in the region and the only hospital with the relevant paediatric subspecialties. Denmark has four level-1 trauma centres, and when we compare our data with those of the study from Southern Denmark, they together represent almost half of the catchment area and population in Denmark. The documented similarities in findings from the two studies indicate a high degree of external validity.

As the study only represents a Danish population, the findings are not necessarily representative of other countries, although we have presented similar findings from studies conducted abroad.

However, our study also had some limitations, including a retrospective design which increased the risk of recall bias and missing data. Furthermore, data regarding the use of safety precautions (e.g., bicycle helmets or seatbelts) were not obtained, and the effect of these factors could not be assessed.

CONCLUSIONS

We must realise that children are not miniature adults [14]. More than half of children admitted to the trauma centre had head injuries, were mostly admitted in the afternoon hours and had mostly been injured in traffic-related accidents. A valid focus may therefore be a reduction in head injuries. For bicycle riders, this would mean using a bicycle helmet; for car passengers, using seatbelts. However, this does not address head injuries among, e.g., pedestrians. Furthermore, many children survived despite severe injuries and high ISSs. Most fatalities occurred within 24 hours of admission.

Correspondence: *Ole M. Hansen*. E-mail: omhansen@gmail.com

Accepted: 20 April 2020

Conflicts of interest: none. Disclosure forms provided by the authors are available with the full text of this article at Ugeskriftet.dk/dmj

LITERATURE

1. Cassidy LD, Cook A, Ertl A et al. Is the trauma mortality prediction model (TMPM-ICD-9) a valid predictor of mortality in pediatric trauma patients? J Pediatr Surg 2014;49:189-92.
2. Ekström DS, Larsen RH, Lauritsen JM et al. Children and adolescents admitted to a university-level trauma centre in Denmark 2002-2011. Dan Med J 2017;64(4):A5356.
3. Association for the Advancement of Automotive Medicine. The Abbreviated Injury Scale 1990 revision - update 98. Barrington, USA, 1998.
4. Nordic Medico-Statistical Committee. NOMESCO classification of external causes of injuries. 4th ed. NOMESCO, 2007:139.
5. Buschmann C, Kühne CA, Lösch C et al. Major trauma with multiple injuries in German children: a retrospective review. J Pediatr Orthop 2008;28:1-5.
6. Zwingmann J, Schmal H, Mehlhorn A et al. Injury patterns in polytraumatized children and consequences for the emergency room management. Acta Chir Orthop Traumatol Cech 2010;77:365-70.
7. Sala D, Fernández E, Morant A et al. Epidemiologic aspects of pediatric multiple trauma in a Spanish urban population. J Pediatr Surg 2000;35:1478-81.
8. Schalamon J, Bismarck S V, Schober PH et al. Multiple trauma in pediatric patients. Pediatr Surg Int 2003;19:417-23.
9. Wan GJ, Neff-Smith MP. The impact of demographics, injury severity, and trauma type on the likelihood of survival in child and adolescent trauma patients. J Trauma Inj Infect Crit Care 1996;40:412-6.
10. Van Der Sluis CK, Kingma J, Eisma WH et al. Pediatric polytrauma: short-term and long-term outcomes. J Trauma 1997;43:501-6.
11. Condello AS, Hancock BJ, Hoppensack M et al. Pediatric trauma registries: The foundation of quality care. J Pediatr Surg 2001;36:685-9.
12. Houshian S, Larsen MS, Holm C. Missed injuries in a level i trauma center. J Trauma 2002;52:715-9.
13. Drendel AL, Gray MP, Lerner EB. A systematic review of hospital trauma team activation criteria for

children. Pediatr Emerg Care 2019;35:8-15.

14. Huelke DF. An overview of anatomical considerations of infants and children in the adult world of automobile safety design. Annu Proc Assoc Adv Automot Med 1998;42:93-113.

15. Sookplung P, Vavilala MS. What is new in pediatric traumatic brain injury? Curr Opin Anaesthesiol 2009;22:572-8.