Prehospital and Early Clinical Care of Infants, Children, and Teenagers Compared to an Adult Cohort

Analysis of 2,961 Children in Comparison to 21,435 Adult Patients from the Trauma Registry of DGU in a 15-Year Period

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Abstract

Background: Although the incidence of pediatric patients in emergency services is as low as 5–10%, trauma remains one of the leading causes of death during childhood. Only a few reports exist about the quality of the initial treatment of pediatric trauma patients. Therefore, we tested the hypothesis of whether prehospital treatment and emergency management in pediatric trauma patients is similar to the treatment that is provided for adult patients.

Materials and Methods: We performed a retrospective data analysis of the German Trauma Registry of the DGU from January 1993 to December 2007. Exclusion criteria were missing information about injury severity and/or age and patients older than 50 years. All pediatric patients were subdivided into five groups (infants 0–1 year, toddlers 2–5 years, children 6–9 years, pupils 10–13 years, teenagers 14–17 years) with regard to their age and were compared with the adult cohort (18–50 years). From 24,396 patients, 2,961 were below 18 years of age, thus, about 12% of the whole population of injured patients below the age of 50 years.

Results: 66.4% of infants sustained relevant head injuries (Abbreviated Injury Scale [AIS] $\geq$ 3), and this rate declined with increasing age. The mean Injury Severity Score (ISS) increased from 21.0 (±11.6) in the group of infants to 26.7 (±13.9) in the adult cohort. In all groups, the majority of patients were male. The injury pattern differed according to age, with predominant traumatic brain injury (TBI) in infants. During the preclinical treatment, infants were less often intubated and this was contrasted by a higher rate of cardiopulmonary resuscitation in this group (infants 16.2%, toddlers 6.8%, adults 3.1%). Diagnostic multislice computed tomography (CT) examination was less often performed in infants as compared to the other groups (infants 57.1%, toddlers 77.2%, adults 77.8%). Mortality and quality indicators such as timelines show no significant differences between children and adults.

Conclusion: We observed typical age-dependent differences regarding the injury pattern and severity and differences referring to the preclinical and initial treatment. With respect to the high rate of serious TBI in the infants and toddlers age groups, a more focused

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Received: June 13, 2010; accepted: June 15, 2010;
Published Online: July 30, 2010

education and training of emergency physicians and paramedics should be considered.

Key Words
Polytrauma management including prehospital and shockroom · Pediatric · Prehospital care · Multiple trauma · Pediatric trauma

Eur J Trauma Emerg Surg 2010;36:300–7
DOI 10.1007/s00068-010-1124-4

Background

The incidence of pediatric patients in emergency services is as low as 5–10% of all patients admitted to an emergency department [1, 2]. However, trauma remains one of the leading causes of disability and death during childhood up to an age of 15 years [2, 3] and, therefore, represents a great socioeconomic impact on families and society.

The preclinical assessment and treatment of injured patients has been substantially improved by the establishment of algorithms and guidelines for the care of adult patients. With regard to pediatric trauma patients, the experience of paramedics and emergency physicians to treat these patients is limited, and assessment and treatment algorithms are not well established. The comparability of outcome studies performed in different countries is limited since the organization of the emergency services differ profoundly [4, 5].

Only a few reports exist that assess the quality of pediatric trauma patient care in the preclinical and early clinical phase. Furthermore, there are conflicting reports regarding quality in the treatment of young patients as compared to adults [6–8].

Given the low incidence of pediatric trauma with the subsequent lack of treatment algorithms and the scarcity of properly trained personnel, we tested the hypothesis of whether prehospital treatment and emergency management in pediatric trauma patients is similar to the treatment that is provided for adult patients.

The Trauma Registry of DGU, a nationwide database that was established in 1993, collects data from trauma patients that are multiply injured. More than 40,000 patients could be included up to now and the registry serves as an important tool to analyze hypotheses to improve the care of multiply injured patients [9–12]. Data are collected at four different time points: (a) the scene of the accident, (b) emergency department, (c) intensive care unit (ICU), (d) hospital discharge. The database provides information about the mechanism of accident, initial findings and treatment on the scene, the further treatment in the emergency department (ED) and during the ICU stay, as well as the surgical treatment, diagnosis, and clinical outcome of the patients. Due to the high number of documented cases, the database is invaluably important to analyze entities that usually present with low case numbers, such as pediatric trauma patients.

The aim of this study was to find out more about the treatment modalities, with special interest in prehospital and early hospital procedures of pediatric patients who suffered from severe trauma and to compare these results with the treatment of adult trauma patients.

Materials and Methods

We performed a retrospective analysis of the data of the Trauma Registry of DGU (http://www.traumaregister.de). All seriously injured (Injury Severity Score [ISS] ≥ 9) patients up to the age of 50 years were included in this study. All pediatric patients were subdivided into five groups regarding their age (infants 0–1 year, toddlers 2–5 years, children 6–9 years, pupils 10–13 years, teenagers 14–17 years) and were compared with the adult cohort (aged 18–50 years). Exclusion criteria were missing information about injury severity and/or age and patients older than 50 years due to the expected higher incidence of preexisting illnesses [13]. Data were analyzed towards physiological and clinical findings, mechanism of injury, performed diagnostic and therapeutic procedures during the preclinical and early clinical care, and the clinical outcome. The data were compared with special reference to differences in the quality of treatment between the various age groups. The overall injury severity was calculated using the ISS according to Baker et al. [14] and injury pattern was described using the Abbreviated Injury Scale (AIS) [15]. The initial consciousness was evaluated using the Glasgow Coma Scale (GCS) [16].

Statistical analysis was performed using SPSS (SPSS Inc., v15.0) and Microsoft Excel 2003. Total numbers, percentages, and means ± standard deviations (SDs) are given. Categorical variables were compared using the Chi-square test and means were compared using Student's *t*-test and analysis of variance (ANOVA). A two-tailed p-value of < 0.05 was considered to be statistically significant.

Results

Basic Data

From January 1993 to December 2007, a total of 24,396 patients met the inclusion criteria and were analyzed in this study. Overall, 119 (0.5%) infants, 311 (1.3%) toddlers, 395 (1.6%) children aged between 6 and 9 years, 508 (2.1%) pupils, and 1,628 (6.7%) teenagers were identified and compared with 21,435 (87.9%) adults. Interestingly, in all groups, the majority of patients were male and predominately blunt trauma lead to the need for emergency treatment. The basic data of our study population is shown in Table 1.

We observed significant differences with respect to the injury severity and the injury pattern between the age-dependent groups. 66.4% of infants sustained relevant (AIS ≥ 3) injuries of the head, which declined with higher age to a rate of 52.1% in teenagers and even further in the adult cohort to 45.7%. This trend was opposed by the age-dependent increase of severe chest, abdominal, and extremities injuries. The mean ISS increased from 21.0 (±11.6) in the group of infants to 26.7 (±13.9) in the adult cohort. Figure 1 illustrates the different injury patterns and injury severity.

Preclinical Data

The mean time for transportation from the scene of accident to the hospital took more than 60 min in all groups. There were no differences in the rate of helicopter-based transportation, irrespective of age. The rate of primary admissions was 68.1% for infants, which was significantly lower compared to other groups (toddlers 79.4%, children 82.3%, pupils 82.1%, teenagers 82.7%, adults 83.3%, χ^2: $p < 0.001$), indicating a higher referral rate of injured patients up to the age of 1 year.

There was a higher rate of performed cardiopulmonary resuscitation (CPR) in infants (16.2%) as compared to 3.1% in the cohort of adult patients (χ^2: $p < 0.001$). Further results referring to preclinical findings and treatment are shown in Table 2. 57.4% of adults were intubated, but this rate decreased to 41.9% of infants and 50.9% of toddlers, respectively. Similar to the higher rate of performed CPR in infants, catecholamine therapy was also initiated more frequently in this age group (Table 2). In case of adult patients, the application of catecholamines was necessary in 7.4%, in case of teenagers in 7.7%, respectively. Volume substitution therapy was performed in 60.2% of infants and this increased with age, so 74.9% in the group of toddlers and 89.2% in case of injured teenagers received fluid replacement (results for primary and secondary admissions). The emergency medical service (EMS) staff established chest tubes in 6.8% of adults and in 4.8% of teenagers; in the other groups, the same procedure was performed in only 2.5–2.7%.

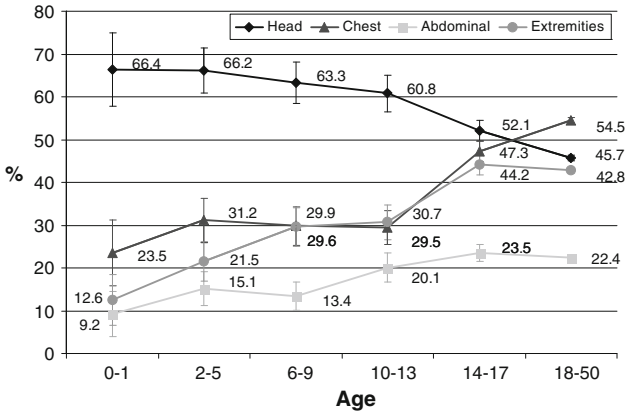

Figure 1. Percentage distribution of injury pattens (Abbreviated Injury Scale [AIS] ≥ 3).

Initial Clinical Treatment

In contrast to a higher incidence of CPR in the preclinical treatment period in infants, this parameter showed no age-dependent differences during the ED treatment. Also, there was no difference regarding endotracheal intubations in the ED (infants 17.0%,

Table 1. Basic data.

	Infants 0–1	Toddlers 2–5	Children 6–9	Pupils 10–13	Teenager 14–17	Adults 18–50	p-value
n	119	311	394	508	1,625	21,376	–
Mean ISS (points)	21	23.4	22.2	22.5	26.7	26.7	< 0.001
Mean NISS (points)	27.1	29.1	27	28.3	32.2	32.3	< 0.001
Male (%)	66.4	67.5	64.2	65	66.3	77.4	< 0.001
Primary admissions (%)	68.1	79.4	82.3	82.1	82.7	83.3	< 0.001
Blunt trauma (%)	96.6	97.4	98.2	97.4	95.9	94.6	< 0.001
Length of hospital stay (days)	14.03	12.59	15.92	17.92	23.71	27.55	< 0.001

Table 2. Initial physiological findings and treatment..

	Infants 0–1	Toddlers 2–5	Children 6–9	Pupils 10–13	Teenager 14–17	Adults 18–50	p-value
Mean Initial GCS (points)	10.2	9.8	10.1	10.5	10.2	11	< 0.001
Mean SBP (mmHg)	98	99	104	110	112	115	< 0.001
Mean HR/min	107	111	101	99	96	95	< 0.001
Mean SpO_2 (%)	94	95	93	95	94	93	0.13
Helicopter transported (%)	41.3	45.2	46.6	43.8	42.5	41.0	0.20
Mean time to admission (min)	68.6	65.3	66.8	61.9	69.6	71.7	< 0.05
Endotracheal Intubation (%)	41.9	50.9	56.3	54.1	61.9	57.4	< 0.001
Resuscitation (%)	16.2	6.8	6.9	2.4	4.8	3.1	< 0.001
Need for catecholamines (%)	13.5	9.4	6.9	5.8	7.7	7.4	0.21
Chest tube (%)	2.7	2.6	2.5	2.7	4.8	6.8	< 0.001
Analgosedation (%)	59.5	65.4	74.7	73.3	81.9	82.2	< 0.001

toddlers 22.5%, children 16.7%, pupils 19.6%, teenagers 19.0%, adults 20.5%). However, infants were less frequently intubated during the preclinical and the early clinical phase (39.6% as compared to 22.2% in adults), as shown in Figure 2. The application of catecholamines was necessary in 8.9% of children, 14.2% of infants, toddlers 13.4%, pupils 10.1%, and 19.8% of teenagers compared to 21.5% in the adult cohort. The establishment of chest tubes increased from 3.8% in the group of infants to 15.3% in case of teenagers compared to 21.6% in case of adult patients; this paralleled the increase of injury severity for thoracic injuries with increasing age. Although the rate of volume substitution therapy in the ED increased in comparison to the preclinical treatment in all groups, only 86.8% of infants received volume replacement compared to 97.9% of teenagers and 98.0% of adults, respectively.

External stabilization of fractures was performed in only 2.9% of infants and 3.6% of toddlers. On the contrary, in the group of children aged between 6 and 9 years, the rate was 8.5, 7.6% in the group of pupils, and 7.3% in case of teenagers when compared to 8.2% in the adult cohort; this paralleled the increase of fractures with increasing age.

While the rate of traumatic brain injury (TBI) was higher in the infant group, fewer infants underwent multislice computed tomography (MSCT) as compared to other older patients, as shown in Figure 3. We could not observe any relevant differences referring to the time intervals necessary for diagnostic adjuncts as abdominal ultrasound, chest or pelvic X-rays, or CT.

Clinical Course and Outcome

After the completion of initial treatment in the ED, over 50% of patients up to the age of 9 years were directly transferred to the ICU. However, the need for primary ICU admission without further surgical intervention decreased with advancing age, being lowest in the adult group (Table 3). 46.6% of elderly patients

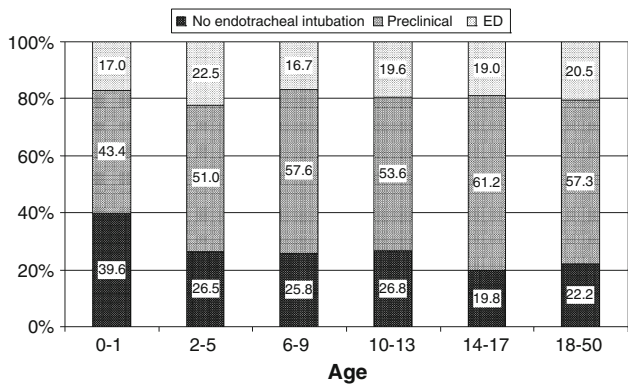

Figure 2. Age- and time-dependent distribution of performed endotracheal intubations.

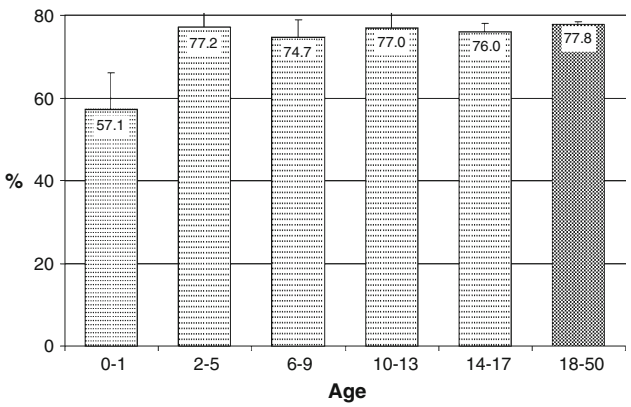

Figure 3. Rate of patients who received full-body multislice computed tomography (MSCT).

Table 3. Subsequent procedures after emergency department (ED) treatment.

	Infants 0–1	Toddlers 2–5	Children 6–9	Pupils 10–13	Teenager 14–17	Adults 18–50
Emergency surgical intervention (%)	4.1	13.3	5.0	7.5	9.0	9.0
Early surgical intervention (%)	30.6	30.1	38.5	42.9	45.9	46.6
Primary ICU admission (%)	53.1	51.0	52.0	43.4	39.6	38.8
Other Procedures (%)	12.2	5.6	4.5	6.1	5.5	5.6

(teenagers and adults) underwent early surgical interventions. The need for subsequent procedures is given in Table 3. During the adjacent hospital stay, we found a higher rate of patients who suffered from sepsis in the adult cohort (9.7%) as compared to the other groups (infants 3.1%, toddlers 6.5%, children/pupils each 4.5%, teenagers 7.8%). Furthermore, the rate of organ failure was higher in the adult cohort (36.0%) as compared to the younger patients (infants 23.7%, toddlers 33.1%, children 28.7%, pupils 27.7%, teenagers 34.3%), which is also reflected in the extended length of hospital stay of adult patients (Table 1). The length of the hospital stay increased from 14 days in the group of infants to 27.5 days in the adult cohort; this was paralleled by an increase in the ICU stay duration in these groups (infants 5 days, adults 10.4 days).

However, we observed a higher overall mortality and 24-h mortality for infants and toddlers compared to adult patients, as shown in Figure 4, but this was not significant.

Discussion

The results presented in our study describe a collective of over 24,000 trauma patients consecutively admitted over a 15-year period to one of the hospitals participating in the Trauma Registry of DGU. Younger patients demonstrated a different pattern of injury, a trend towards an elevated 24-h mortality, a decreased organ failure rate, and a shortened hospital stay. Regarding preclinical treatment, we observed some age-dependent differences, especially in infants with a higher rate of performed CPR and the need for catecholamines. However, in the preclinical phase, there was a decreased rate of invasive procedures, such as endotracheal intubations or the establishment of chest tubes, in the youngest group.

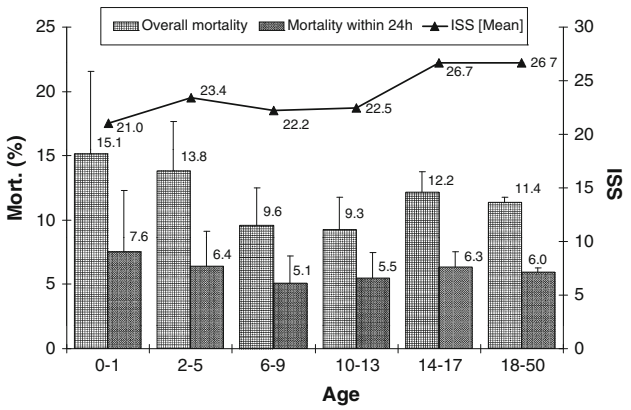

Figure 4. Overall and 24-h mortality rate and mean Injury Severity Score (ISS).

Given the high number of documented cases, the data demonstrates again the relatively low incidence of trauma in pediatric patients (12.1%) when compared to all trauma patients, and this is especially true for infants (0.5%), as seen in other studies (0.4–3.9%) [3, 6, 17, 18]. However, although the study was not primarily designed to analyze incidences, we still believe it to reflect accurately the current reality of age-dependent differences in pediatric preclinical and early trauma care in Germany. The relatively low number of injured infants is consistent with the results of Agran et al. on injuries in childhood up to the age of 3 years. In their manuscript, children aged 15–17 months had the highest overall injury rate, 94% higher than that of children aged 3–5 months, who had the lowest rate [18]. This coincides with developmental achievements such as independent mobility, exploratory behavior, and hand-to-mouth activity [18]. Interestingly, the group of infants and toddlers were mainly male, like it is commonly known for adult trauma cohorts. This surprising result differs to that of Soreide et al. [19], who found a near-equal distribution in children aged $\leq$ 14 years. The overwhelming number of adult trauma patients being male, such as occupational hazards or more dangerous leisure activities, may not be the only reason for the distribution observed in this study. It is tempting to speculate that this sex-specific distribution is due to a more risky behavior from early childhood onwards.

Furthermore, the data presented here shows typical differences with respect to an age-dependent injury

pattern. The majority of all injured children, and especially more than two-thirds in the groups of infants and toddlers, suffered from serious injuries of the head (AIS ≥ 3). The disproportionately large head and weak neck musculature in children (especially in those less than 3 years of age) puts them at a high risk for contrecoup brain injuries, even at low velocities [20]. This is in conjunction with a higher mortality in the younger groups, especially in the early clinical course up to 24 h in our study. These results further substantiate the need for an increased awareness of the emergency team for early referral to a level 1 trauma center and to initiate an early CT scan [7, 8]. A high awareness for the potential urgent need for interventions is reflected by the comparable rate of helicopter transport, an observation that, at least partially, contradicts the results from other groups [1, 4]. The younger the patients, the more often a secondary referral is performed with a cutoff at the age of 6 years – elderly children are approximately 10–20% more frequently admitted to the institution that definitively treated them, whereas infants and toddlers were more frequently referred to another hospital. The higher rate of secondary admitted young patients might be due to a smaller number of specialized hospitals for pediatric trauma care. After the initial treatment by the closest hospital, patients are secondary transported to a level I trauma center – this diagnosis and treatment sequence is not the gold standard, since, especially for the youngest patients, valuable time is lost. Therefore, the results of our study mandate the further development of regional trauma networks with clear guidelines for the treatment of children [21].

But even in the group of primary advised patients, we observed that the ''golden hour of shock'' as described by Cowley [22] elapses during the preclinical phase in all groups.

Regarding the preclinical and performed procedures during early clinical treatment, we observed some interesting differences. The rate of endotracheal intubations was only 41.9% in the group of infants, in contrast to 61.9% in case of teenagers and 57.4% in the adult cohort. This is notable with respect to a comparable initial mean GCS value in all groups with respect to the similar indications for early intubation and ventilation in patients that sustained a head trauma. This observation further supports the recommendation to secure the airway in a timely fashion and assure sufficient peripheral oxygenation for patients with head injuries with respect to the ''avoidable factors contributing to death of children with head injury'' described by Sharples et al. [8]. In another series, intubation was missing in 36.4% of patients [23]. Nevertheless, prompt assessment of the vital signs and rapid intervention to secure the airway and to maintain breathing and circulation are of particular importance, since hypoxia and hypoperfusion occur more rapidly than in adults. The pediatric airway is distinct from that of adults, which makes airway management potentially more difficult, even in experienced hands [24].

Furthermore, we observed a higher rate of performed CPR and the need for catecholamines, especially in the group of infants; there may be two possible reasons for these differences between the groups. On the one hand, the high rate of life-threatening TBI in the young groups might be a reason for the consecutive need for CPR. Another reason for the more frequent need for circulatory support may be age-dependent physiological differences in the heart rate and blood pressure in children. The physiological heart rate of an infant is much higher (up to 160 bpm) than it is in adults and, also, the normal systolic blood pressure (SBP) is lower, e.g., 60 mmHg in case of newborn babies compared to adults. Such initial physical findings may trigger the wrong diagnosis of hemodynamic shock or cardiac arrest if the EMS staff does not recognize the age-dependent differences in physiology, especially of infants. From our viewpoint, this result reflects the need for more education and regular training of EMS staff and emergency physicians regarding the distinct physiological findings and procedures such as endotracheal intubation in children. This is underlined by the results of Meyer et al., who found that emergency intubation can be performed safely in the field, provided it is carried out by trained physicians and adequate drugs are used [24, 25].

Up to now, there are no guidelines for termination trauma resuscitation in pediatric patients. The decision to withhold or terminate resuscitation attempts in the field is a difficult one. This is even more daunting in the case of a child, where the emotions of all the providers are heightened [26]. Due to these difficulties, paramedics and emergency physicians might withhold CPR until reaching the ED in case of children. With respect to the inclusion criteria of the Trauma Registry of DGU, which excludes every patient who does not reach the hospital alive, the rate of performed CPR might be higher in case of infants and toddlers in comparison to the adult cohort.

During the further treatment in the ED, we observed a rate of 57.1% of MSCT being performed in the group of infants. This rate was significantly less than the results in the other age-dependent groups (74.7–77.8%). However, CT imaging has become

essential in the imaging evaluation of trauma patients and is being used with progressively increasing frequency [27, 28], caused by the well documented benefit for the outcome of trauma patients [9, 29, 30]. Nevertheless, a byproduct of the increased use of CT has been the more frequent exposure of injured children to potentially harmful ionizing radiation [27]. Therefore, the lower rate of performed MSCT only in case of infants might be due to the possibility of performing a cranial ultrasound, if the ossification of the fonticulus is not completed. However, MSCT is the gold standard of imaging in multiply injured patients in adults as well as children and should be performed when in doubt.

Conclusions

In this manuscript, we observed several differences regarding the preclinical treatment of infants and toddlers in comparison to the adult cohort. In particular, traumatic brain injury (TBI) and the need for resuscitation is more common in younger children as compared to adolescents and adults. With increasing age, the incidence of relevant trauma to the extremities and, somewhat later, the torso, increases, most likely due to sports and leisure activities and participation in street traffic. Further education and training of paramedics and emergency physicians, with special respect to the anatomical and physiological specificities of infants and toddlers, should be considered.

Conflict of interest statement

The authors declare that there is no actual or potential conflict of interest in relation to this article.

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