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ORIGINAL ARTICLE

Observed versus expected mortality in pediatric patients intubated in the field with Glasgow Coma Scale scores < 9

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Abstract

Purpose A Glasgow Coma Scale (GCS) score of 8 or less in patients suffering from severe traumatic brain injury (TBI) represents a decision-making marker in terms of intubation. This study evaluated the impact of prehospital intubation on the mortality of these TBI cases among different age groups.

Methods This study included the data from patients predominantly suffering from severe TBI [Abbreviated Injury Scale (AIS) of the head ≥ 3, GCS score < 9, Injury Severity Score (ISS) > 9] who were registered in TraumaRegister DGU® from 2002 to 2013. An age-related analysis of five subgroups was performed (1–6, 7–15, 16–55, 56–79, and ≥ 80 years old). The observed and expected mortality were matched according to the Revised Injury Severity Classification, version II.

Results A total of 21,242 patients were included. More often, the intubated patients were severely injured when compared to the non-intubated patients (median ISS 29, IQR 22–41 vs. 24, IQR 16–29, respectively), with an associated higher mortality (42.2% vs. 30.0%, respectively). When compared to the calculated expected mortality, the observed mortality was significantly higher among the intubated patients within the youngest subgroup (42.2% vs. 33.4%, respectively; $p = 0.03$).

Conclusions The observed mortality in the intubated children 1–6 years old suffering from severe TBI seemed to be higher than expected. Whether or not a GCS score of 8 or less is the only reliable criterion for intubation in this age group should be investigated in further trials.

Keywords Glasgow Coma Scale · Intubation · Pediatric · Prehospital · Traumatic brain injury

Introduction

Hypoxia is associated with increased mortality in patients suffering from severe traumatic brain injury (TBI), which underscores the impact of adequate airway management [1–3]. Although intubation is considered to be the standard procedure for managing patients suffering from severe TBI with Glasgow Coma Scale (GCS) scores < 9 in Germany [4, 5], there is a lack of evidence confirming this approach. The reasons for this controversy surrounding prehospital intubation include the potential benefits, such as maintaining the airway, preventing aspiration, and improving oxygenation, weighed against the risks, such as a prolonged scene time, multiple intubation attempts, improper tube placement, and hyperventilation resulting in hypocapnia [6, 7]. A publication by Hoffmann et al. showed better outcomes and lower mortality rates for those patients that were both intubated and sedated in the prehospital setting [8]. Other surveys

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have revealed a better functional outcome, but no impact on the mortality correlated with prehospital intubation [9, 10]. A recently published analysis of US National Trauma Data Bank patients with isolated severe blunt TBIs showed a higher mortality [6]. Gausche et al. focused on the pediatric cohort stating that neither a better outcome nor reduced mortality was seen in these cases undergoing prehospital intubation [11].

In the literature, there is less evidence on the roles of prehospital intubation and sedation and their impact on the outcomes and mortality rates among different age groups. Therefore, it seemed necessary to scrutinize whether a GCS score < 9 alone was an adequate and sufficient decision-making tool for choosing whether or not to intubate pediatric patients. Therefore, the aim of this study was to retrospectively analyze the impact of prehospital intubation on mortality in predominantly severe TBI cases (GCS score < 9) based on the age of the patients.

Methods

TraumaRegister DGU®

The TraumaRegister DGU® (TR-DGU) database of the German Trauma Society (Deutsche Gesellschaft für Unfallchirurgie; DGU) was founded in 1993. The aim of this multicenter database is the anonymous and standardized documentation of severely injured patients. The data are collected prospectively in four consecutive time phases from the site of the accident until discharge from the hospital: (A) prehospital phase, (B) emergency room and initial surgery, (C) intensive care unit (ICU), and (D) discharge. The documentation includes detailed information about the demographics, injury patterns, comorbidities, pre- and in-hospital management, ICU course, relevant laboratory findings (including the transfusion data), and outcomes of each individual. The inclusion criterion includes admission to the hospital via the emergency room with subsequent ICU/intermediate care (IMC) or arrival at the hospital with vital signs and death before admission to the ICU.

The infrastructure for the documentation, data management, and data analysis is provided by the Academy for Trauma Surgery (Akademie der Unfallchirurgie GmbH; AUC), a company affiliated with the DGU. The scientific leadership is provided by the Committee on Emergency Medicine, Intensive Care and Trauma Management (Sektion Notfall-, Intensivmedizin und Schwerverletztenversorgung; Section NIS) of the DGU. The participating hospitals submit their data anonymously into a central database via a web-based application. Because the TR-DGU is a compulsory tool for quality assessment in certified trauma networks, no informed consent was required for the data collection. The scientific data analysis was approved according to a peer-review procedure established by Section NIS.

The participating hospitals are located primarily in Germany (90%), but a rising number of hospitals from other countries contribute to the data as well (i.e., hospitals from Austria, Belgium, Finland, Luxembourg, Slovenia, Switzerland, The Netherlands, China, and the United Arab Emirates). Currently, approximately 35,000 cases from more than 600 hospitals are entered into the database annually.

Participation in the TR-DGU is voluntary, except for hospitals associated with TraumaNetzwerk DGU®. Network hospitals can choose reduced documentation, with approximately 40 items per case, while the standard documentation consists of approximately 100 items. Some of the variables evaluated in this paper were not available in the reduced dataset; therefore, this research was restricted to those cases documented with the standard dataset.

Study design and participant selection

Only European patients treated between 2002 and 2013 with complete prehospital documentation of intubation and a GCS score recorded by an emergency physician at the scene prior to resuscitation were included in this study. The further inclusion criterion was the complete outcome documentation in terms of survival through hospital discharge or death. A patient qualified for this analysis if the Injury Severity Score (ISS) was ≥ 9, and the patient had been admitted directly from the scene to the participating hospital (i.e., patients transferred from another hospital were excluded because no prehospital data were available). In addition, those patients transferred out to another hospital within 48 h were excluded because their outcome statuses were unknown.

Expected mortality

Because the injury patterns and severity may differ in the subgroups, the observed outcomes were compared with a prognostic estimate derived from the Revised Injury Severity Classification, version II (RISC-II) score [12]. This score was developed and validated through the TR-DGU. It considers the age, worst and second worst injuries, head injury, GCS score, pupil reaction and size, sex, pre-injury American Society of Anesthesiologists physical status (ASA), mechanism (blunt, penetrating), base excess, coagulation (international normalized ratio; INR), hemoglobin, shock, and cardiac arrest for the prognosis. The RISC-II prognosis reflects the average expected hospital mortality rate in the TR-DGU based on data from 2010 to 2011.

Definitions

A severe TBI was defined as a head Abbreviated Injury Scale (AIS) score of 3 or more. Severe injuries were also defined as an AIS of 3 or above for any other body region. Mortality was defined as any patient not surviving through hospital discharge. The TBI and consciousness alterations were scored using the GCS with the following codes: motor, coded 1–6; verbal, coded 1–5; and eye, coded 1–4. Unconsciousness was defined as a GCS score ≤ 8.

The patients were subclassified into five subgroups according to age: Group 1, 1–6 years old; Group 2, 7–15 years old; Group 3, 16–55 years old; Group 4, 56–79 years old; and Group 5, ≥ 80 years old.

Analysis

The statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). The data are presented as median with interquartile range (IQR) for the continuous variables and as a percentage for the categorical variables. Because a large volume of data was presented, a formal p value calculation was avoided for some of the comparisons. Furthermore, the large number of cases from the registry allowed us to focus on the clinically relevant differences rather than on the formal significance. In selected comparisons, statistical tests were made, or alternatively, a 95% confidence interval (CI) was calculated; a p value < 0.05 was considered to be statistically significant.

Results

A total of 21,242 patients with a prehospital GCS scores < 9 and complete documentation were available for analysis (Fig. 1). Eighty-five point one percent of the cases were registered in Germany. Males were dominantly (72.5%) affected by TBI in this cohort. The mean age of the patients was 46.8 ± 22.7 years. Those patients between 16 and 79 years old (86%; 18,267 patients; Groups 3 and 4) represented the majority of the population. There were 961 patients (4.5%) in Groups 1 and 2 (patients ≤ 15 years old), and 2014

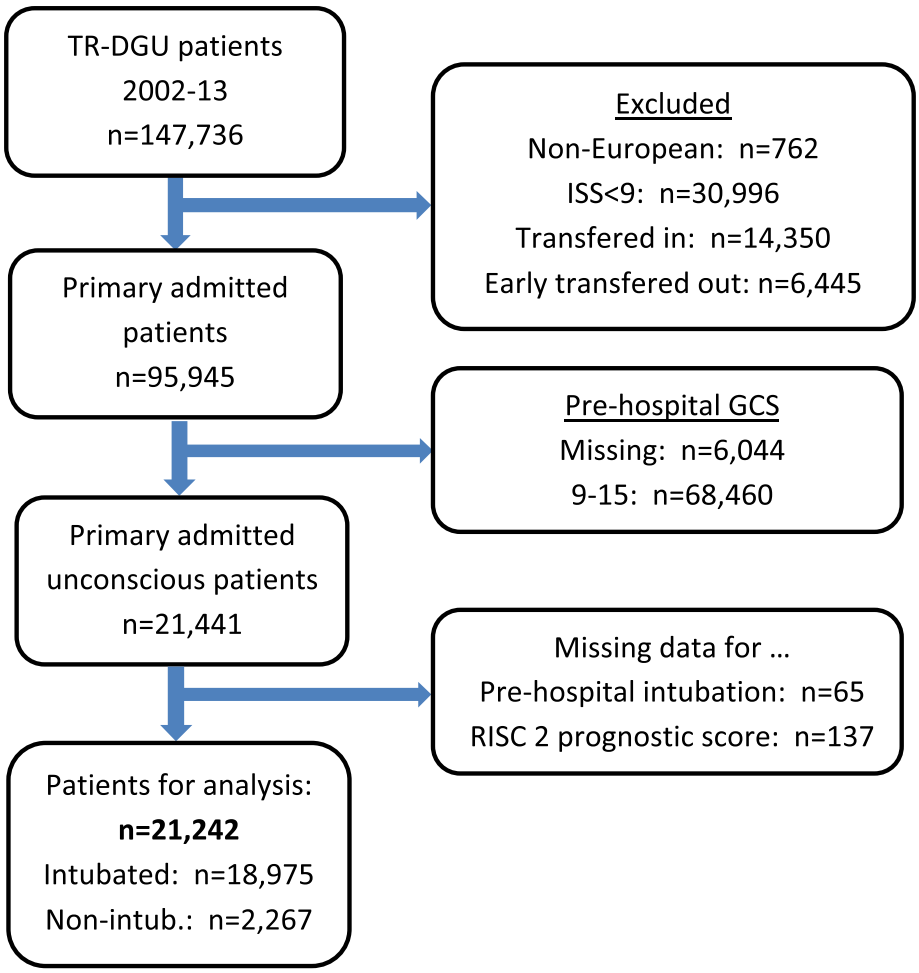

Fig. 1 Overall patient numbers and excluded cases

patients were 80 years old or older (9.5%; Group 5). The intubation rates were the lowest in Groups 1 and 5 (Fig. 2).

The time to hospital admission was significantly longer in the intubated patients when compared to the non-intubated patients (median intubated 65 min, IQR 52–85 min vs. median non-intubated 52 min, IQR 39–69 min, respectively, $p < 0.001$). However, the severe head injury prevalence did not differ between the intubated and non-intubated patients ($AIS_{head} \geq 3$; 81.9% vs. 79.0%, respectively). The intubated patients were most likely to be transferred into a Level 1 Trauma Center (79.6% vs. 69.5%, respectively). Whether prehospital intubation was conducted or not, the children between 1 and 6 years old (Group 1) with GCS scores < 9 were most commonly transferred into a Level 1 Trauma Center (79.1% and 89.2%, respectively). The patients' core injury characteristics are provided in Table 1.

The intubated patients demonstrated a higher median ISS of 29 (IQR 22–41) comparing to non-intubated patients (median ISS 24, IQR 16–29), with an associated higher observed mortality (41.3% vs. 28.6%, respectively) when compared to the non-intubated patients. Significantly different median ISSs were not detected between any of the subgroups (Table 2).

There was no statistically significant difference between the expected and observed mortality in the non-intubated 1- to 6-year-old patients, but there were significantly more deaths than expected in the intubated group [standardized mortality ratio (SMR) = 0.80 (95% CI 0.07–1.66) vs. 1.26 (95% CI 1.07–1.46); $p = 0.03$, respectively]. Regarding mortality, no significant differences were detected between Groups 2 and 3 whether they were intubated or not.

Discussion

Intubating a patient suffering from a severe TBI with a GCS score < 9 is considered a standard procedure in early trauma care. Since hypoxia and hypercapnia are potentially responsible for worse outcomes in these patients, the improvement and optimization of oxygenation are regarded as a main argument for prehospital or early intubation [4]. Based on this assumption, Hoffmann et al. showed better neurological outcomes and lower mortality in those cases being intubated and sedated [8], regardless of their age.

Underscoring the results of this study, a previous trial also based on data from the TR-DGU provided evidence for increased mortality, but improved early neurological outcomes for the survivors among patients younger than 7 years old suffering from TBIs when compared to older patients. However, no differences in the general therapeutic regimens were found that explained these results. Correlations between the age, intubation state, mortality, and/or the neurological outcome were not explicitly investigated [13].

The recent literature reports unfavorable results in adults after intubation regarding the functional outcomes and mortality [1, 14]. For example, Wang et al. described a higher mortality and less favorable functional outcomes in patients suffering from severe TBIs who underwent prehospital intubation. That study consisted of a large cohort throughout all age groups, but it did not have an age-specific subanalysis [15]. Additionally, a smaller series focusing on isolated TBI underscored these results [16]. One meta-analysis of the literature focusing on adult patients found no evidence for or against prehospital intubation [17]. Helm et al. postulated

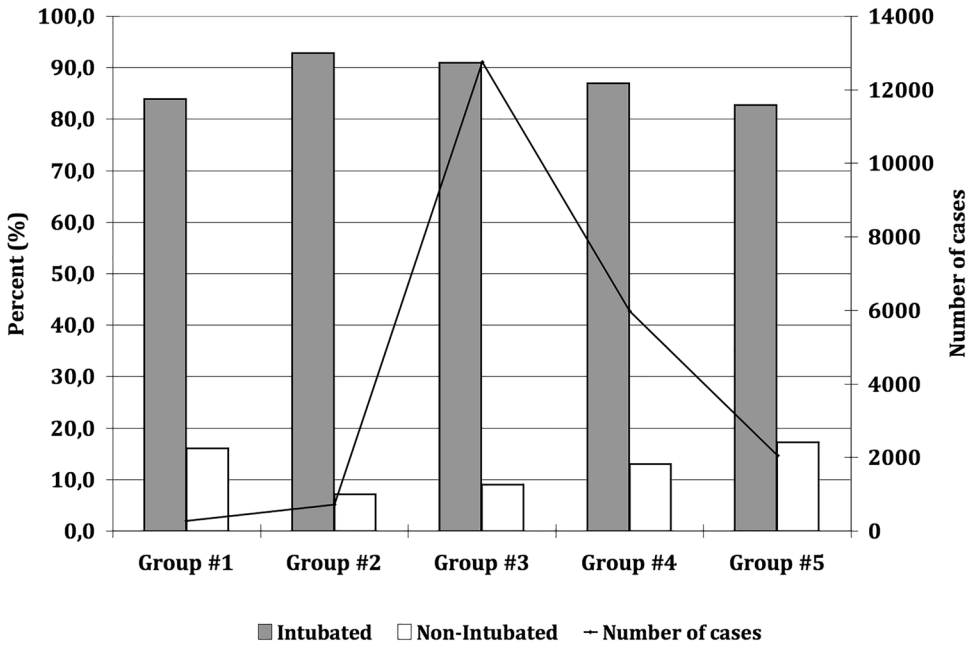

Fig. 2 Group-associated intubation rates. The bars represent the intubation rates, and the squares represent the number of cases. Group 1: 0–6 years old, Group 2: 7–15 years old, Group 3: 16–55 years old, Group 4: 56–79 years old, Group 5: ≥ 80 years old

Table 1 Basic study characteristics

Parameter	Group 1		Group 2		Group 3		Group 4		Group 5		Total	
	Intub	Non-intub	Intub	Non-intub	Intub	Non-intub	Intub	Non-intub	Intub	Non-intub	Intub	Non-intub
Number of cases	223	37	652	49	11,335	1101	5100	731	1665	349	18,975	2267
Age (median, IQR)	4 (2–5)	3 (2–5)	13 (10–14)	12 (9–14)	33 (22–45)	35 (24–47)	68 (62–73)	68 (62–73)	84 (82–87)	85 (82–88)	45 (25–65)	53 (31–71)
Males (*n*, %)	140 (63.1)	19 (51.4)	418 (64.5)	26 (53.1)	8616 (76.4)	877 (79.9)	3497 (68.9)	498 (68.2)	809 (48.9)	144 (41.5)	13,480 (71.4)	1564 (69.2)
$AIS_{head} \geq 3$	194 (87.0)	26 (70.3)	557 (85.4)	38 (77.6)	9071 (80.0)	809 (73.5)	4234 (83.0)	610 (83.4)	1485 (89.2)	307 (88.0)	15,541 (81.9)	1790 (79.0)
ISS (median, IQR)	26 (16–41)	19 (16–25)	26 (19–38)	17 (11–26)	29 (22–41)	21 (14–29)	26 (21–38)	25 (16–29)	25 (22–35)	25 (17–26)	29 (22–41)	24 (16–29)
GCS (median, IQR)	3 (3–6)	7 (6–8)	4 (3–6)	7 (5–8)	3 (3–6)	6 (3–8)	3 (3–5)	6 (3–7)	3 (3–6)	4 (4–8)	3 (3–6)	6 (3–8)
Time to physician arrival (median, IQR)	15 (10–21)	11 (9–15)	15 (10–20)	12 (5–25)	15 (10–23)	15 (1–21)	15 (10–25)	15 (10–25)	15 (10–28)	17 (11–30)	15 (10–24)	15 (10–23)
Time to hospital admission (median, IQR)	65 (50–85)	50 (35–72)	63 (50–80)	48 (35–65)	65 (50–85)	50 (36–67)	65 (50–85)	51 (40–69)	64 (50–85)	55 (40–72)	65 (52–85)	52 (39–69)
Level of trauma care												
Level 1 (*n*, %)	189 (79.1)	33 (89.2)	528 (81.4)	33 (67.3)	9167 (81.3)	789 (71.9)	3978 (78.4)	507 (69.4)	1181 (71.4)	209 (60,2)	15,043 (79.6)	1571 (69.5)
Level 2 (*n*, %)	33 (13.8)	4 (10.8)	118 (18.2)	15 (30.6)	2043 (18.1)	275 (25.3)	1031 (20.3)	189 (25.9)	456 (27.6)	121 (34.9)	3681 (19.5)	604 (26.7)
Level 3 (*n*, %)	1 (0.4)	0 (0)	6 (0.9)	1 (2.0)	125 (1.1)	37 (3.4)	91 (1.8)	35 (4.8)	28 (1.7)	19 (5.5)	251 (1.3)	92 (4.1)

AIS Abbreviated Injury Scale, *ISS* Injury Severity Score

Table 2 Expected and observed mortality distribution for intubated vs. non-intubated patients in subgroups

Groups	Modus	*n*	Observed mortality (%)	Expected mortality* (%)	SMR
Group 1	Intubated	223	42.2	33.4	1.26 (1.07–1.46)
	Non-intubated	37	8.1	10.2	0.80 (0.07–1.66)
Group 2	Intubated	652	27.9	30.7	0.91 (0.80–1.02)
	Non-intubated	49	8.2	10.1	0.81 (0.05–1.57)
Group 3	Intubated	11,335	34.0	33.6	1.01 (0.99–1.04)
	Non-intubated	1101	14.6	14.0	1.05 (0.90–1.19)
Group 4	Intubated	5100	51.1	49.9	1.02 (0.99–1.05)
	Non-intubated	731	36.7	31.6	1.16 (1.05–1.27)
Group 5	Intubated	1665	76.6	73.9	1.04 (1.01–1.07)
	Non-intubated	349	69.9	60.0	1.17 (1.09–1.25)

SMR standardized mortality ratio

*The prognosis is based on the Revised Injury Severity Classification, version II (RISC-II)

that endotracheal intubation in the field does "not guarantee 'optimal' oxygenation and 'adequate' ventilation in patients with severe head injury" [18]. The retrospective data on rapid sequence intubation in the field from Norway confirmed this observation [19].

In contrast to adults, Gausche et al. showed no benefit in prehospital intubation for children [11]. Although they presented data derived from a battle zone, Sokol et al. showed that prehospital intubation could even have a seemingly negative effect on survival and neurological outcome [20].

Prehospital airway management in general has often been the subject of surveys and trials in the past [2, 14, 20–23], and there have not been many considerations of the age-specific aspects. The discrepancy between the expected and observed mortality in the youngest age group correlated with early intubation, as shown in the present study, has not been described before. This finding is even more remarkable, because children are initially admitted more often to a Level I Trauma Center than adults. The data provided by the TR-DGU may not directly allow any explanations for or conclusions from this finding, but assuming comparable treatment conditions in the specialized trauma centers (at least in Germany, which amounts for more than 85% of the cases in this population), the question arises whether differences in prehospital processes may explain this correlation. The composition of the primary responding prehospital team (emergency physician vs. paramedic, etc.), its level of experience, and the impact of these factors on the outcomes of the patients has been the subject of previous trials [23, 24].

In general, prehospital emergency intubation correlates with inferior outcomes when compared to in-hospital standard intubation, likely due to insufficient ventilation. However, the ventilation method itself (endotracheal intubation vs. mask ventilation) seemingly affects neither the mortality rates nor the rate of procedural complications, although the decision about which method to choose depends on the level of experience of the physician treating the patient initially [25]. As far as endotracheal intubation is concerned, former studies have postulated similar success rates in emergency cases, in both adults and children, when intubation is performed by paramedics [26]. An actual matched pair analysis of the data derived from the TR-DGU seems to verify this assumption [9]. Children younger than 1 year of age were also excluded in this study. Although some trials have provided similar prehospital intubation success rates when performed by paramedics and physicians, other publications have postulated higher mortality rates in cases, where the intubation was performed by a non-physician [3, 10, 24]. These investigations dealing with the influence of intubation on the outcomes and mortality place an emphasis on expertise and experience playing key roles in decreasing mortality and improving clinical neurological outcomes. According to these observations, investigations of pediatric drownings have shown that the initial presence of physicians at the scene as well as admission to a highly specialized center have positive influences on the clinical course [10].

Along the same lines, it must be asked whether prehospital intubation itself may be responsible for the higher mortality and worse outcomes observed, or possibly a lack of experience in the management of pediatric patients from the youngest age group by the initial treatment teams. These could also be explained by the prolonged prehospital management time and postponing admission to the hospital, which may be more important in pediatric patients than in adults.

Limitations

Survival is certainly influenced by different determining factors; therefore, a definitive correlation between preclinical intubation and the outcome is hard to define. Nevertheless, using the RISC-II, the other determining factors can be

compensated for mathematically. In addition, the TR-DGU does not differentiate between adult and pediatric GCS scores, which may also have influenced the data interpretation, especially concerning the pediatric population. Moreover, excluding the patients who passed away before reaching the hospital may have biased the study results, and the TR-DGU does not provide this information. Accordingly, no statements can be made about the possible specifications of this subgroup. Finally, the main limitation of this study was the lack of data concerning the qualifications and experience of the initial treatment team or the specific and influencing factors, which may explain the unexpected results of this study.

Conclusion

The observed mortality in the 1- to 6-year-old-intubated children suffering from severe TBI seemed to be higher than expected. Regarding intubation, decision-making based only on a GCS score ≤ 8 in children might provoke inferior outcomes. Therefore, further investigations are needed to scrutinize these observations and to identify further decision-making criteria.

Compliance with ethical standards

Conflict of interest Rolf Lefering's Institute (IFOM) has a service agreement with the AUC GmbH who is the owner of the TraumaRegister DGU. This includes support in data analysis for scientific publications. All other authors declare that they have no conflict of interest.

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