

Isolated blunt severe traumatic brain injury in Bern, Switzerland, and the United States: A matched cohort study

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BACKGROUND:	The ideal prehospital management of patients with severe traumatic brain injury (TBI) including the impact of endotracheal intubation (ETI) and physicians on scene is unclear. Prehospital management differs substantially in Switzerland and the United States: in Switzerland, there is usually a physician on scene who may provide ETI and other advanced life support procedures, whereas in the United States, prehospital management (including ETI) is performed by paramedics.
METHODS:	This is a retrospective cohort-matched study of patients with isolated blunt severe TBI (head Abbreviated Injury Scale [AIS] score, 4–5) and no major extracranial injuries, using Bern University Hospital data from the Swiss PEBITA [Patient-relevant Endpoints after Brain Injury from Traumatic Accidents] (TBI-specific) database and the US National Trauma Data Bank from 2009 to 2010. A 1:4 cohort matching of Bern and US patients was performed. Matching criteria were sex, age (± 10 years), exact field Glasgow Coma Scale (GCS) score, exact head AIS score, and injury type (subdural hematoma, epidural hematoma, intraparenchymal hemorrhage, intraventricular hemorrhage, brain edema/swelling, brain stem injury). The matched cohorts were compared with univariable analysis (Fisher's exact test and Mann-Whitney U-test).
RESULTS:	Matching of the Bern ($n = 128$) and US ($n = 86,375$) cohort resulted in 355 matched cases (71 Bern and 284 US patients). Bern patients had significantly longer scene times (median, 23.0 minutes vs. 9.0 minutes, $p < 0.001$) and more frequent prehospital ETI (31.0% vs. 18.7%, $p = 0.034$) and air transportation (39.4% vs. 19.4%, $p < 0.001$). No significant difference in procedures (craniotomy/craniectomy, intracranial pressure monitoring, tracheotomy), intensive care unit and total hospital lengths of stay, ventilator days, and in-hospital mortality (14.1% vs. 15.8%, $p = 0.855$) was found between the two cohorts.
CONCLUSION:	When taking into account the limitation that patient- and injury-related factors, but not in-hospital treatment variables, were matched, the more frequent prehospital ETI and presence of a physician on scene in the Swiss cohort compared with the US cohort had no significant effect on outcomes, including intensive care unit and total hospital lengths of stay, ventilator days, and in-hospital mortality. (<i>J Trauma Acute Care Surg.</i> 2016;80: 296–301. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)
LEVEL OF EVIDENCE:	Therapeutic study, level IV.
KEY WORDS:	Traumatic brain injury; prehospital management; emergency physician; prehospital intubation; outcome.

The optimal prehospital care of patients with severe traumatic brain injury (TBI) including the impact of endotracheal intubation (ETI) and emergency physicians on scene is controversial. Although several studies showed no benefit of prehospital ETI,^{1–8} a randomized-controlled trial including 312 patients with severe TBI revealed better neurologic outcomes (extended Glasgow Outcome Scale [GOS]) at 6 months in patients undergoing field ETI by paramedics versus emergency department (ED) ETI by physicians.⁹ The role and impact of the prehospital care team, especially the presence of

an emergency physician, are reported differently in patients with TBI^{10,11} and in trauma overall.^{12–15}

The Swiss and American Emergency Medical Services (EMS) differ substantially. In the German-speaking countries in Europe, including Switzerland, the EMS team includes an anesthesiologist emergency physician (Notarzt), who may provide ETI and other advanced life support procedures on scene.¹⁶ In the United States, prehospital care is usually provided by trained paramedics. Even in helicopter-based patient transports, the EMS team includes an emergency physician in only 5%.^{16–19}

The aim of this study was to investigate the effect of prehospital ETI and a physician on scene in patients with severe TBI by comparing the prehospital management, operative procedures, and outcomes in patients from Bern, Switzerland, and in those from the United States.

PATIENTS AND METHODS

Approval for this study was obtained from the institutional review board (IRB) of the University of Southern California.

Patient Selection

This is a retrospective cohort-matched study using the Bern University Hospital data from the Swiss PEBITA

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[Patient-relevant Endpoints after Brain Injury from Traumatic Accidents] database²⁰ from 2009 to 2010 (Bern cohort) and the American College of Surgeons' National Trauma Data Bank (NTDB)²¹ from 2009 to 2010 (US cohort). PEBITA is a prospectively collected and deidentified TBI-specific database managed by the Swiss PEBITA research group. NTDB is a US trauma registry managed by the American College of Surgeons and contains Health Insurance Portability and Accountability Act (HIPAA) deidentified data of participating hospitals.

Patients with isolated blunt severe TBI were extracted from both databases. Isolated severe TBI was defined as an Abbreviated Injury Scale (AIS) head score greater than 3 and an AIS chest, abdomen, extremities, and external score less than 3. Patients younger than 16 years and patients with field cardiac arrest, defined as a systolic blood pressure (SBP) of 0 mm Hg, were excluded.

Cohort Matching

A 1:4 matching of the Bern and US cohort was performed. Matching criteria were sex, age (± 10 years), exact field Glasgow Coma Scale (GCS) score, exact AIS head score, and the brain injury type (subdural hematoma [SDH], epidural hematoma [EDH], intraparenchymal hemorrhage [IPH], intraventricular hemorrhage [IVH], brain edema/swelling, and brain stem injury). In the Bern cohort, the brain injury type was recorded according to the head computed tomography reports. In the US cohort, the brain injury type was defined according to the AIS Predot code available in the NTDB. The matching procedure was performed without replacement.

Data Collection and Comparison

Prehospital, ED, operative procedure, and outcome variables were compared in the matched Bern and US cohorts.

Prehospital variables included prehospital ETI, air transportation, EMS scene time, and transport time. The EMS scene time and transport time were analyzed in all patients included and separately in the subgroups of ground- and air-transported patients. ED variables included the GCS score at ED admission in nonintubated patients as well as SBP, heart rate (HR), and oxygen saturation (SaO₂) at ED admission. Collected operative procedures were craniotomy and craniectomy, intracranial pressure (ICP) monitoring, and tracheostomy. Outcome variables included ventilator days, total hospital and intensive care unit (ICU) lengths of stay (LOS), and in-hospital mortality.

Statistical Analysis

Normality of distribution of continuous variables was assessed using histograms, skewness, and the Shapiro-Wilk test.

Prehospital, ED, operative procedure, and outcome variables of the Bern and US cohort were compared in a univariate analysis. Categorical variables were analyzed using Fisher's exact test, whereas continuous variables were compared using the Mann-Whitney U-test. Results were reported as numbers and percentages, medians and interquartile ranges (IQRs), or as indicated otherwise. *p* values < 0.05 were considered statistically significant.

Statistical analysis was performed using SPSS statistics (IBM Corporation, Armonk, NY).

RESULTS

Included Patients

A total of 128 patients with isolated blunt severe TBI were extracted from the Bern cohort. The US cohort contained a total of 86,375 patients with isolated blunt severe TBI. After patients younger than 16 years, patients with field cardiac

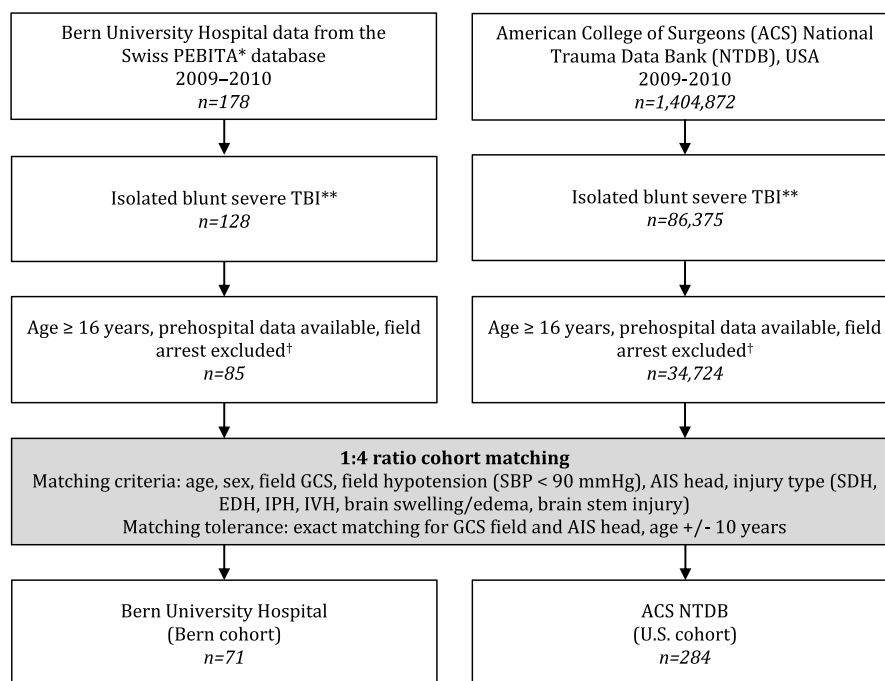


Figure 1. Case selection and matching. *PEBITA, Patient-relevant Endpoints after Brain Injury from Traumatic Accidents. **Isolated severe TBI: AIS head score greater than 3; AIS chest, abdomen, extremities, and external scores less than 3. †Field arrest: SBP of 0 mm Hg.

arrest, and patients with incomplete prehospital data were excluded, 85 patients from the Bern cohort and 34,724 patients from the US cohort were included in the 1:4 cohort matching. The matching revealed 71 patients from the Bern cohort and 284 patients from the US cohort, which formed the basis of the statistical analysis (Fig. 1).

Baseline Characteristics

In the unmatched cohorts, Bern patients were more frequently male (76.5% vs. 65.9%, $p = 0.042$), had more frequent field hypotension (5.9% vs. 1.8%, $p = 0.018$), had lower field GCS scores (median, 12.0 vs. 14.0, $p < 0.001$), and had more frequent EDH (14.1% vs. 7.6%, $p = 0.037$) and IPH (25.9 vs. 8.8%, $p < 0.001$). Median age and median AIS head scores as well as SDH, IVH, brain swelling/edema, and brain stem injury were not significantly different between the two cohorts.

After the cohort matching, baseline characteristics of the Bern and US cohorts were not significantly different (Table 1).

Prehospital Variables

Prehospital ETI (31.0% vs. 18.7%, $p = 0.034$) and air transportation (39.4% vs. 19.4%, $p = 0.001$) were significantly more frequent in the Bern cohort compared with the US cohort.

In all patients included, Bern patients had significantly longer times from EMS arrival on scene to ED arrival (median, 50.0 minutes vs. 34.0 minutes; $p < 0.001$) and significantly longer scene times (median, 23.0 minutes vs. 9.0 minutes; $p < 0.001$) but not significantly different transport times from EMS scene departure to ED arrival (median, 21.0 minutes vs. 24.0 minutes; $p = 0.902$).

In the subgroup of patients transported by ground ambulance, Bern patients had significantly longer times from EMS arrival on scene to ED arrival (median, 55.0 minutes vs. 30.0 minutes; $p < 0.001$) and significantly longer scene times

TABLE 1. Baseline Characteristics of the Matched Cohorts

	Bern Cohort (n = 71)	US Cohort (n = 284)	<i>p</i> *
Sex (male/female)	59/12 (83.1/16.9)	236/48 (83.1/16.9)	1.000
Age, y**	59.8 (38.0)	56.0 (40.0)	0.894†
Field hypotension (SBP < 90 mm Hg)	1 (1.4)	4 (1.4)	1.000
GCS field score**	13.0 (7.0)	13.0 (7.0)	1.000†
AIS head score**	4.0 (1.0)	4.0 (1.0)	1.000†
AIS head score of 4	47 (66.2)	188 (66.2)	1.000
AIS head score of 5	24 (33.8)	96 (33.8)	
Injury Severity Score (ISS)**	22.0 (13.0)	21.0 (8.0)	0.130†
SDH	38 (53.5)	152 (53.5)	1.000
EDH	11 (15.5)	44 (15.5)	1.000
IPH	18 (25.4)	72 (25.4)	1.000
IVH	3 (4.2)	12 (4.2)	1.000
Brain stem injury	1 (1.4)	4 (1.4)	1.000
Brain swelling/edema	0 (0.0)	0 (0.0)	n.a.

*Fisher's exact test unless indicated otherwise.

**Values are median (IQR).

†Mann-Whitney U-test.

Values are n (%) unless indicated otherwise.

n.a., not applicable.

TABLE 2. Prehospital Variables

	Bern Cohort (n = 71)	US Cohort (n = 284)	<i>p</i> *
Prehospital intubation**	22 (31.0)	53 (18.7)	0.034 †
Air transportation**	28 (39.4)	55 (19.4)	0.001 †
Arrival on scene to ED, min			
Overall	50.0 (94.0)	34.0 (23.0)	<0.001
Ground transportation	55.0 (99.0)	30.0 (21.0)	<0.001
Air transportation	46.0 (53.0)	52.5 (14.0)	0.332
Departure from scene to ED, min			
Overall	21.0 (36.0)	24.0 (21.0)	0.902
Ground transportation	24.0 (90.0)	22.0 (18.0)	0.317
Air transportation	21.0 (12.0)	40.0 (21.0)	0.010
EMS scene time, min			
Overall	23.0 (16.0)	9.0 (9.0)	<0.001
Ground transportation	21.5 (15.0)	9.0 (8.0)	<0.001
Air transportation	26.0 (20.0)	13.0 (10.0)	0.008

*Mann-Whitney U-test unless indicated otherwise.

**Values are n (%).

†Fisher's exact test.

Values are median (IQR) unless indicated otherwise.

Boldface indicates statistical significance ($p < 0.05$).

(median, 21.5 minutes vs. 9.0 minutes; $p < 0.001$) but not significantly different transport times from EMS scene departure to ED arrival (median, 24.0 minutes vs. 22.0 minutes; $p = 0.317$).

In the subgroup of air-transported patients, the time from EMS arrival on scene to ED arrival was not significantly different between the Bern and US cohort (median, 46.0 minutes vs. 52.5 minutes; $p = 0.332$). The scene time was significantly longer (median, 26.0 minutes vs. 13.0 minutes; $p = 0.008$), but the transport time from EMS scene departure to ED arrival was significantly shorter (median, 21.0 minutes vs. 40.0 minutes; $p = 0.010$) in the Bern cohort (Table 2).

ED Variables

At ED admission, the median GCS score in nonintubated patients and frequency of hypotension (SBP < 90 mm Hg), tachycardia (HR > 100 bpm), and hypoxia (SaO₂ < 90%) were not significantly different between the two cohorts (Table 3).

Outcome Variables

Operative procedures (craniotomy/craniectomy, ICP monitoring, tracheostomy) and outcome variables including ICU and total hospital LOS, ventilator days, and in-hospital mortality

TABLE 3. ED Variables

	Bern Cohort (n = 71)	US Cohort (n = 284)	<i>p</i> *
GCS score in ED nonintubated**	14.0 (5.0)	14.0 (3.0)	0.073†
Hypotension (SBP < 90 mm Hg)	3 (4.2)	5 (1.8)	0.204
Tachycardia (HR > 100 bpm)	9 (12.7)	62 (22.3)	0.097
Hypoxia (SaO ₂ < 90%)	3 (4.2)	5 (1.8)	0.201

*Fisher's exact test.

**Values are median (IQR).

†Mann-Whitney U-test.

Values are n (%) unless indicated otherwise.

TABLE 4. Operative Procedures and Outcome Variables

	Bern Cohort (n = 71)	US Cohort (n = 284)	p*
Craniotomy/craniectomy**	16 (22.5)	40 (14.1)	0.100†
ICP monitoring**	5 (7.0)	13 (4.6)	0.374†
Tracheostomy**	3 (4.2)	8 (2.8)	0.465†
In-hospital mortality**	10 (14.1)	45 (15.8)	0.855†
ICU LOS, d	3.0 (5.0)	3.0 (5.0)	0.361
Ventilator days	3.0 (3.0)	3.0 (8.0)	0.312
Total hospital LOS, d	5.0 (6.0)	5.0 (7.0)	0.650

*Mann-Whitney U-test unless indicated otherwise.
 **Values are n (%).
 †Fisher's exact test.
 Values are median (IQR) unless indicated otherwise.

were not significantly different between the Bern and US cohort (Table 4).

DISCUSSION

This study analyzed the effect of more aggressive prehospital intubation and an emergency physician or anesthesiologist on scene on outcomes in patients with isolated blunt severe TBI by comparing patients from two different EMS systems, namely, patients from Bern, Switzerland, and those from the United States. Patients in the Bern cohort had significantly longer scene times and more frequent prehospital ETI when compared with the US cohort. Outcomes including ICU and total hospital LOS, ventilator days, and in-hospital mortality were not significantly different between the two cohorts.

Potential benefits of prehospital ETI in patients with severe TBI, such as airway protection against aspiration and the avoidance of secondary brain injury caused by hypoxia and hypoventilation,^{22,23} have to be balanced with ETI-related complications, including multiple intubation attempts;³ improper endotracheal tube placement;²⁴ prolonged scene time;³ transient desaturation;^{7,25} hyperventilation;^{25–27} hypotension;^{25,28} hypertensive response to laryngoscopy, which may worsen the intracranial pressure;²⁹ and ETI/laryngoscopy-induced increased intracranial pressure.³⁰ The considerably more frequent prehospital intubation in the Bern cohort may be explained by the more frequent presence of an anesthesiologist or emergency physician on scene as well as by the different approach of the prehospital care, that is, the attempt to provide advanced life support on scene. The effect of the prehospital intubation on outcomes in patients with severe TBI is difficult to interpret in the current study because in the Bern cohort, the procedure was most likely performed by an anesthesiologist or emergency physician in the majority of cases, whereas in the US cohort, it was predominantly performed by paramedics. The worse outcomes reported with prehospital intubation in US studies^{1,2,4,6–8} may have been outweighed by the training and experience in ETI of anesthesiologist and emergency physicians in the Bern cohort.^{3,22}

Few studies reported the effect of the prehospital care team on outcomes in patients with severe TBI. Lee et al.,¹⁰ in a retrospective review of 2010 severe blunt trauma patients with and without severe head injury, found no significant association

between the prehospital level of care and risk in mortality in patients who survived long enough to be admitted to the ICU. Another retrospective study by Garner et al.,¹¹ including 250 patients with severe blunt head injury, reported improved functional outcomes when prehospital care was provided by critical care teams. In the current study, the more frequent presence of an anesthesiologist or emergency physician on scene in the Bern cohort did not affect outcomes. It is important to note, however, that this finding has to be interpreted with caution, because a comparison of the actual EMS team members was not feasible in this study. Furthermore, a possible positive effect of a physician on scene on outcomes may have been counterbalanced by the longer scene time in the Swiss cohort.

To outline the differences of American EMS and European (Franco-German) EMS systems, the prehospital care strategies are often described as “scoop and run” and “stay and play,” respectively.^{19,23} However, in Switzerland, this concept is currently challenged. Efforts have been made particularly in helicopter EMS operations to provide advanced life support during the transport rather than on scene.³¹ In the present study, the longer EMS scene time in the Bern cohort is most likely related to the more frequent prehospital ETI and the more complex prehospital care provided by anesthesiologists and emergency physicians in the Bern cohort.

Air transportation was more than twice as frequent in the Bern cohort than in the US cohort. This difference may be explained by the mountainous topography in approximately one third of the Bern University Hospital trauma catchment area. The mountainous terrain complicates rescue operations and necessitates helicopter EMS transports.^{32,33} In the air-transported patients of the Bern cohort, scene time was significantly longer, but the transport time from scene departure to ED arrival was significantly shorter when compared with the US cohort. Thus, as the longer scene time in the Bern cohort was counterbalanced by the shorter transport time to the ED, the overall time of prehospital care in air-transported patients was not significantly different between the two cohorts. Switzerland is a country much smaller than the United States (15,940 sq mi vs. 3,805,927 sq mi), and the Swiss population density is much higher than the US population density (500.0 vs. 87.4 people per square mile).^{34,35} In the United States, approximately 16% of trauma patients have no access to a Level I or II trauma center within 60 minutes, most of them living in rural areas.³⁶ Therefore, transport distances for air rescue operations, which are usually needed in rural areas, are shorter in Switzerland.

Indications for tracheostomy in patients with TBI include a persistent decreased level of consciousness and poor airway protective reflexes.^{37–39} The frequency of tracheostomy in patients with TBI has been reported as 14.2%⁴⁰ and 24% in patients requiring decompressive craniectomy.⁴¹ In the current study, the incidence of tracheostomy was lower in both cohorts and not significantly different between Bern and US patients.

Finally, the current study has several limitations. First, there is a large discrepancy of the number of patients included in each cohort. In contrast, the much higher number of patients included in the US cohort allowed an exact matching of the field GCS score, AIS head score, and injury type. Second, the Bern University Hospital trauma catchment area may serve as a

good approximation of the Swiss topography in general, but the Bern cohort does not represent the Swiss EMS system overall. Third, because this is a retrospective cohort study, a more detailed analysis of prehospital variables (EMS team members, volume resuscitation, death on scene or during the transport) was not feasible, and although a cohort matching, taking into account patient-related, prehospital, and injury-related criteria was performed, a selection bias of included patients cannot be excluded. Fourth, although no significant difference in surgical procedures and ventilator days was found, it is possible that differences in the in-hospital care confounded the analysis. To address these limitations, further prospective studies investigating the optimal prehospital management of patients with severe TBI are warranted.

In conclusion, in this retrospective cohort-matched study of patients from Bern, Switzerland, and the United States, the more frequent prehospital ETI and presence of a physician on scene in the Swiss cohort had no significant effect on outcomes, including ICU and total hospital LOS, ventilator days, and in-hospital mortality.

AUTHORSHIP

T.H., B.S., and D.D. designed this study. T.H. conducted the literature search. T.H., M.B.M., M.K. contributed to data collection. T.H., E.B., and D.D. performed data analysis. T.H., B.S., E.B., S.S., K.I., and D.D. contributed to data interpretation. T.H. wrote the manuscript, with all authors critically revised.

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DISCLOSURE

The authors declare no conflicts of interest.

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