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ORIGINAL ARTICLE

Prehospital intubation for isolated severe blunt traumatic brain injury: worse outcomes and higher mortality

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Abstract

Purpose Prehospital endotracheal intubation (ETI) for traumatic brain injury (TBI) is a controversial issue. The aim of this study was to investigate the effect of prehospital ETI in patients with TBI.

Methods Cohort-matched study using the US National Trauma Data Bank (NTDB) 2008–2012. Patients with isolated severe blunt TBI (AIS head ≥3, AIS chest/abdomen <3) and a field GCS ≤8 were extracted from NTDB. A 1:1 matching of patients with and without prehospital ETI was performed. Matching criteria were sex, age, exact field GCS, exact AIS head, field hypotension, field cardiac arrest, and the brain injury type (according PREDOT-code). The matched cohorts were compared with univariable and multivariable regression analysis.

Results A total of 27,714 patients were included. Matching resulted in 8139 cases with and 8139 cases without prehospital ETI. Prehospital ETI was associated with significantly longer scene (median 9 vs. 8 min, $p < 0.001$) and transport times (median 26 vs. 19 min, $p < 0.001$), lower Emergency Department (ED) GCS scores (in patients without sedation; mean 3.7 vs. 3.9, $p = 0.026$), more ventilator days (mean 7.3 vs. 6.9, $p = 0.006$), longer ICU (median 6.0 vs. 5.0 days, $p < 0.001$) and total hospital length of stay (median 10.0 vs. 9.0 days, $p < 0.001$), and higher in-hospital mortality (31.4 vs. 27.5 %, $p < 0.001$). In regression analysis prehospital ETI was independently associated with lower ED GCS scores (RC −4.213, CI −4.562/−3.864, $p < 0.001$) and higher in-hospital mortality (OR 1.399, CI 1.205/1.624, $p < 0.001$).

Conclusion In this large cohort-matched analysis, prehospital ETI in patients with isolated severe blunt TBI was independently associated with lower ED GCS scores and higher mortality.

Keywords Traumatic brain injury · Prehospital endotracheal intubation · Prehospital care · Outcome · Matched-pair analysis

Introduction

The role of prehospital endotracheal intubation (ETI) in patients with traumatic brain injury (TBI) is a controversial issue. Several retrospective and prospective studies reported worse outcomes associated with prehospital ETI in patients with TBI, including desaturation [1], poor oxygenation at hospital admission [2], more infectious complications [2], poorer neurologic outcomes and functional impairment scores [3], and a higher mortality rate [2, 4–7]. A randomized trial reported that prehospital ETI in patients with severe TBI had no effect on the in-hospital mortality but was associated with a significantly higher rate of favourable neurological outcomes at 6 months [8]. Other studies reported a higher rate of unexpected survivors associated with prehospital ETI in patients with severe TBI [9], no effect [10], or decreased mortality [11] in patients with a field GCS score ≤8 undergoing prehospital ETI.

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Previous studies investigating the effect of prehospital ETI on outcomes included patients with severe TBI, defined as an abbreviated injury scale (AIS) head ≥3 or a Glasgow Coma Scale (GCS) ≤8, but most did not differentiate patients with and without associated extracranial traumatic injuries. This is a major limitation, because extracranial injuries may significantly impact the management and outcomes of patients with TBI. Furthermore, the majority of studies included patients with blunt and penetrating injuries. Penetrating TBI is associated with higher rates of certain complications, a different pathophysiology, and a much higher mortality rate when compared to blunt TBI [12–14].

The goal of prehospital ETI in patients with severe TBI is to maintain the airway and prevent hypoxia, thus potentially preventing aspiration and secondary brain injury [15–17]. However, prehospital ETI may be challenging [18], and potential benefits have to be outweighed with ETI-related complications, including multiple intubation attempts [6, 19, 20], improper tube placement [21–24], prolonged scene time [6, 19, 25], transient desaturation [1, 26], hyperventilation [26–29], hypotension [26, 30], hypertensive response to laryngoscopy and ETI [31] which may lead to increased intracranial pressure [32], and ETI/laryngoscopy-induced increased intracranial pressure [33, 34].

The prehospital treatment of trauma patients varies largely in the US [35–37], making it difficult to compare studies that investigated the effect of prehospital ETI in different US study populations. The aim of the current study was, therefore, to investigate the effect of prehospital ETI in patients with isolated severe blunt TBI by using the American College of Surgeons (ACS) National Trauma Data Bank (NTDB).

Patients and methods

Study design and setting

This is a retrospective cohort-matched study using NTDB 2008-2012. NTDB is a US trauma registry managed by the ACS and contains Health Insurance Portability and Accountability Act (HIPAA) de-identified data of participating hospitals [38].

Selection of participants

Patients with isolated severe blunt TBI and a GCS ≤8 were extracted from NTDB. Isolated TBI was defined as an AIS head score ≥3 and an AIS chest and abdomen score <3.

Included patients were divided into two groups: patients undergoing ETI before Emergency Department (ED) admission (prehospital ETI group) and patients not undergoing ETI before ED admission (no prehospital ETI group). Prehospital ETI was assessed using the initial ED GCS qualifier in NTDB.

Data collection

Data collection included patient characteristics (sex, age), injury severity [AIS head score, Injury Severity Score (ISS)], brain injury type (contusion, epidural hematoma, subdural hematoma, subarachnoid haemorrhage, intraparenchymal haemorrhage, intraventricular haemorrhage, diffuse axonal injury, brain swelling, brain laceration, pneumocephalus), prehospital variables (field systolic blood pressure, field GCS, Emergency Medical Service (EMS) prehospital times [total prehospital time (scene arrival to ED arrival), transport time (scene departure to ED arrival), scene time (scene arrival to scene departure)], ED GCS and vital signs (oxygen saturation, systolic blood pressure, heart rate), operative procedures [craniectomy, craniotomy, Intracranial pressure (ICP) monitoring, tracheostomy], and outcome variables [total hospital and intensive care unit (ICU) length of stay (LOS), ventilator days, in-hospital mortality]. Hypotension was defined as a systolic blood pressure <90 mmHg, cardiac arrest as a systolic blood pressure of 0 mmHg, and tachycardia as a heart rate >100 bpm.

Cohort matching

A 1:1 cohort matching of patients with and without prehospital ETI was performed. Matching criteria were age (±5 years), sex, exact field GCS score, exact AIS head score, field hypotension, field cardiac arrest, and the brain injury type (contusion, epidural hematoma, subdural hematoma, subarachnoid haemorrhage, intraparenchymal haemorrhage, intraventricular haemorrhage, diffuse axonal injury, brain swelling, brain laceration, pneumocephalus). The matching procedure was performed without replacement (Fig. 1).

Analysis

Prehospital times, ED variables, operative procedures, and outcome variables were compared in the matched cohorts of patients with and without prehospital ETI.

Normality of distribution was assessed using histograms, skewness, and the Shapiro–Wilk test.

Patient characteristics, injury severity, the brain injury type, prehospital variables, ED variables, operative procedures, and outcome variables were compared in univariable analysis. Categorical variables were analysed using Fisher's exact test, continuous variables were compared using the Mann–Whitney test. Results were reported as numbers and percentages or medians and interquartile ranges, as appropriate. p values <0.05 were considered statistically significant.

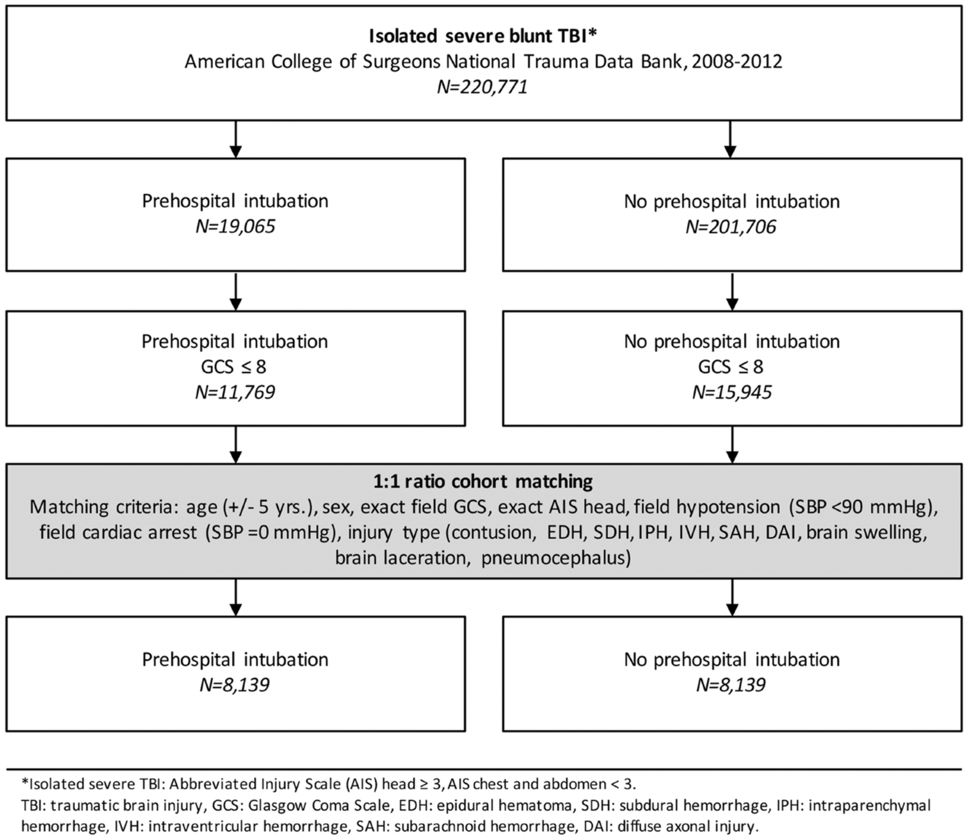

Fig. 1 Case selection and cohort matching

The effect of prehospital ETI on the ED GCS score (in non-sedated patients) and in-hospital mortality was adjusted for patient and injury related factors in multivariate linear and logistic regression analysis. The association of clinically important predictor variables [sex, age, field hypotension, field GCS score, transport time (EMS scene departure to ED arrival), ISS] with the ED GCS score and in-hospital mortality was assessed using Fisher's exact test, Spearman's rank order correlation, and logistic regression analysis, as appropriate, and entered in the regression model if the p values was ≤ 0.1. Regression analysis was performed using the enter method. Interactions of prehospital ETI with other predictor variables were assessed using separate regression analyses. Significant interactions ($p < 0.05$) were entered in the regression model as interaction terms. Continuous variables with interactions were dichotomized at the median for ease of interpretation. Multicollinearity was assessed using the variance inflation factor (VIF). A VIF <5 was assumed to exclude significant collinearity. Results were reported as odds ratio (OR) or regression coefficient (RC) with 95 % confidence intervals (CI). The regression model performance was assessed using χ^2 goodness of fit statistics, Cox & Snell R^2, and Nagelkerke R^2 for logistic regression, and analysis of variance (ANOVA), R^2, and adjusted R^2 for linear regression.

All statistical analyses were performed using SPSS Statistics (IBM Corporation, Armonk, NY).

Results

Included patients

A total of 220,771 patients with isolated severe blunt TBI were extracted from NTDB. Of these, 19,065 (8.6 %) underwent prehospital ETI and 201,706 (91.4 %) had no prehospital ETI. After the exclusion of patients with a field GCS score >8, the prehospital ETI group was comprised of 11,769 patients and the no prehospital ETI group of 15,945 patients. The 1:1 ratio cohort matching revealed 8139 patients in both groups (Fig. 1).

Baseline characteristics

After the cohort matching, baseline characteristics of the prehospital ETI group and no prehospital ETI group were equal (Table 1).

Prehospital times

Prehospital times were significantly longer in the prehospital ETI group, including the total prehospital time

Table 1 Baseline characteristics of the matched cohort

	Prehospital ETI ($n = 8139$)	No prehospital ETI ($n = 8139$)	p value†
Sex (male/female)	6133/2006 (75.4/24.6)	6133/2006 (75.4/24.6)	1.000
Age (years)*	42.0 (35.0)	42.0 (35.0)	0.291‡
Field hypotension (SBP <90 mmHg)	296 (3.6)	296 (3.6)	1.000
Field cardiac arrest (SBP = 0 mmHg)	0	0	n/a
GCS field*	3.0 (5.0)	3.0 (5.0)	1.000‡
AIS head*	4.0 (1)	4.0 (1.0)	1.000‡
AIS head 3	1491 (18.3)	1491 (18.3)	1.000
AIS head 4	3534 (43.4)	3534 (43.4)	
AIS head 5	3108 (38.2)	3108 (38.2)	
AIS head 6	6 (0.1)	6 (0.1)	
Injury type‡			
Contusion	697 (8.6)	697 (8.6)	1.000
DAI	792 (9.7)	792 (9.7)	1.000
Subdural hematoma	3021 (37.1)	3021 (37.1)	1.000
Epidural hematoma	433 (5.3)	433 (5.3)	1.000
Subarachnoid hemorrhage	775 (9.5)	775 (9.5)	1.000
Laceration	40 (0.5)	40 (0.5)	1.000
Intraparenchymal hemorrhage	518 (6.4)	518 (6.4)	1.000
Intraventricular hemorrhage	178 (2.2)	178 (2.2)	1.000
Brain swelling/edema	69 (0.8)	69 (0.8)	1.000
Infarction	0 (0.0)	0 (0.0)	n/a
Ischemic damage	1 (0.0)	1 (0.0)	1.000
Pneumocephalus	32 (0.4)	32 (0.4)	1.000

Values are numbers (percentages) unless indicated otherwise

ETI endotracheal intubation, *SBP* systolic blood pressure, *GCS* Glasgow Coma Scale, *AIS* Abbreviated Injury Scale, *DAI* Diffuse axonal injury

* Values are medians (interquartile range). † Fisher's exact test unless indicated otherwise. ‡Unspecified injuries not shown.

‡ Mann–Whitney *U* test

(37 vs. 28 min, $p < 0.001$), transport time (26 vs. 19 min, $p < 0.001$), and scene time (9 vs. 8 min, $p < 0.001$) (Table 2).

Emergency Department variables

The ED GCS score was significantly lower in the prehospital ETI group, both in all patients (median 3.0 vs. 5.0, $p < 0.001$) and the subgroup of patients without prehospital sedation (mean 3.7 vs. 3.9, $p = 0.026$). Patients undergoing prehospital ETI had more frequent ED hypotension (7.2 % vs. 4.6 %, $p < 0.001$), but less frequent ED desaturation <90 mmHg (4.6 % vs. 5.8 %, $p < 0.001$). The percentage of patients with ED tachycardia was not significantly different between the two groups (37.7 % vs. 36.5 %, $p = 0.103$) (Table 2).

Procedures

ICP monitoring and tracheostomy were significantly more frequently performed in the prehospital ETI group (14.5 % vs. 12.2 %, $p < 0.001$ and 19.6 % vs. 14.3 %, $p < 0.001$). The frequency of neurosurgical procedures (craniectomy and craniotomy) performed was not significantly different between the two groups (Table 2).

Outcome variables

In univariable analysis, patients undergoing prehospital ETI had a longer total hospital LOS (median 10 vs. 9 days, $p < 0.001$) and ICU LOS (median 6 vs. 5 days, $p < 0.001$), increased ventilator days (mean 7.3 vs. 6.9 days, $p = 0.006$), and a higher in-hospital mortality (31.4 % vs. 27.5 %, $p < 0.001$) (Table 2).

Effect of prehospital ETI on the ED GCS score and in-hospital mortality

In the logistic regression model for in-hospital mortality, a significant interaction of prehospital ETI and the ISS was

Table 2 Univariate analysis of prehospital times, Emergency Department variables, operative procedures, and outcome variables

	Prehospital ETI ($n = 8139$)	No Prehospital ETI ($n = 8139$)	p value[†]
Prehospital times			
Total prehospital time (min)*	37.0 (21.0)	28.0 (16.0)	<0.001[‡]
Transport time (min)*	26.0 (19.0)	19.0 (12.0)	<0.001[‡]
Scene time (min)*	9.0 (11.0)	8.0 (8.0)	<0.001[‡]
ED variables			
ED GCS score overall*	3.0 (0.0)	5.0 (6.0)	<0.001[‡]
ED GCS score, patients without sedation*	3.0 (0.0)[a]	3.0 (0.0)[a]	0.026[‡]
ED desaturation <90 %	257 (4.6)	314 (5.8)	<0.001
ED hypotension (SBP <90 mmHg)	581 (7.2)	374 (4.6)	<0.001
ED tachycardia (HR >100 bpm)	3047 (37.7)	2949 (36.5)	0.103
Procedures			
Neurosurgery	1117 (13.7)	1100 (13.5)	0.715
Craniectomy	375 (4.6)	391 (4.8)	0.579
Craniotomy	834 (10.2)	792 (9.7)	0.284
ICP monitoring	1179 (14.5)	992 (12.2)	<0.001
Tracheostomy	1592 (19.6)	1160 (14.3)	<0.001
Outcome variables			
Total hospital LOS (days)*	10.0 (17.0)	9.0 (18.0)	<0.001[‡]
ICU LOS (days)*	6.0 (11.0)	5.0 (11.0)	<0.001[‡]
Ventilator days*	4.0 (8.0)[b]	4.0 (9.0)[b]	0.006[‡]
Mortality	2553 (31.4)	2235 (27.5)	<0.001

Values are numbers (percentages) unless indicated otherwise

ETI endotracheal intubation, *EMS* emergency medical service, *ED* Emergency Department, *GCS* Glasgow Coma Scale, *ICP* Intracranial pressure, *SBP* systolic blood pressure, *HR* heart rate, *LOS* length of stay, *ICU* intensive care unit

* Values are medians (interquartile range)

[†] Fisher's exact test unless indicated otherwise. [‡] Mann–Whitney *U* test

[a] Mean (standard deviation) 3.7 (1.8) vs. 3.9 (2.2)

[b] Mean (standard deviation) 7.3 (8.4) vs. 6.9 (8.3)

identified ($p < 0.001$). In the linear regression model for the ED GCS score, significant interactions of prehospital ETI and field hypotension ($p = 0.035$), the field GCS score ($p < 0.001$), and the ISS ($p < 0.001$) were found.

No significant collinearity was detected between the predictor variables of the regression models (VIF <4).

In multivariate regression analysis, adjusting for patient characteristics, injury related factors and the transport time, prehospital ETI was independently associated with increased in-hospital mortality and lower ED GCS scores (Table 3).

Discussion

It is currently unclear whether patients with severe TBI and a field GCS ≤8 benefit from prehospital ETI, as the effect of prehospital ETI on outcomes is reported differently in the literature [1–9, 11]. Furthermore, due to the great variability of EMS systems in the US [35, 36, 39], the comparison of different prehospital treatment algorithms for patients with severe TBI is difficult.

The aim of this matched cohort study was to investigate the effect of prehospital ETI on outcomes in patients with isolated severe blunt TBI using NTDB, which is a large national database.

In the current study, only patients with a field GCS score ≤8 were included in the analysis. Several current guidelines report a GCS score ≤8, along with other criteria such as airway obstruction, persistent hypoxia despite supplemental oxygen, hypoventilation, severe haemorrhagic shock, and cardiac arrest, as an indication for ETI in patients with severe TBI [40–43]. Thus, all patients included in the current study had the traditional indications for ETI.

Previous studies reported a prolonged scene time [6, 19, 20, 44] and total prehospital time [45] associated with

Table 3 Adjusted effect of prehospital intubation on mortality and Emergency Department GCS score

	Adjusted OR[c]	Adjusted 95 % CI[c] (lower/upper)	$p=$	GoF			CS R^2	Nag R^2
				χ^2	*df*	$p=$		
Mortality								
Prehospital ETI, Ref. group*	1.399	1.205/1.624	<0.001	4032.501	7	<0.001	0.227	0.323
Prehospital ETI, ISS ≥ 25	1.107>	1.008/1.216	0.033					
	Adjusted RC[d]	Adjusted 95 % CI[c]	$p=$	ANOVA			R^2	Adj. R^2
				F	*df*	$p=$		
ED GCS score[b]								
Prehospital ETI, Ref. group[a]	−4.213	−4.562/−3.864	<0.001	207.913	9	<0.001	0.241	0.240
Prehospital ETI, field hypotension	−3.765	−4.766/−2.763	<0.001					
Prehospital ETI, field GCS = 3	−3.437	−3.782/−3.092	<0.001					
Prehospital ETI, ISS ≥25	−2.157	−2.507/−1.808	<0.001					

Multivariable logistic and linear regression analysis

OR odds ratio, *CI* confidence interval, *GOF* Goodness of Fit, *DF* degrees of freedom, *CS* Cox and Snell, *NAG* Nagelkerke, *RC* regression coefficient, *ANOVA* analysis of variance, *ETI* endotracheal intubation, *GCS* Glasgow Coma Scale, *ISS* Injury Severity Score

[a] Reference group: no field hypotension, field GCS > 3, and ISS < 25

[b] ED GCS score in non-sedated patients

[c] Adjusted for sex, age, field hypotension, field GCS score, and ISS

[d] Adjusted for age, field hypotension, field GCS score, transport time (Emergency Medical Service scene departure to Emergency Department arrival), and ISS

prehospital ETI. In the current study, the scene time, total prehospital time, and transport time were significantly longer in the prehospital ETI group. The longer scene time is most likely related to the more time-consuming prehospital care when ETI is performed, whereas the longer transport time in the prehospital ETI group also may reflect longer transport distances as an indication for ETI [44].

The admission GCS score has been identified as a significant predictor for the need for tracheostomy in patients with TBI undergoing craniotomy [46]. In the current study, the more frequent use of ICP monitoring and the higher number of tracheostomies performed in the prehospital ETI group may also be attributed to the lower ED GCS score in this group, although the scene GCS was similar in both groups.

Prehospital ETI was associated with significantly worse outcomes and more operative procedures performed (Table 2). Even after adjusting for patient and injury related factors, as well as the transport time, patients undergoing prehospital ETI had lower ED GCS scores and higher in-hospital mortality (Table 3). Taking into consideration the results of the current study, likely reasons for the worse outcomes of patients in the prehospital ETI group are the prolonged scene time and more frequent hypotension [26, 30] at ED arrival in this group. Other potential reasons for the worse outcomes of patients undergoing prehospital ETI are technical problems with the procedure, such as esophageal [21–24] or right mainstem bronchus intubation [22–24, 47], aspiration of gastric contents [48], hyperventilation, and the limited experience of paramedics for ETI. According to the American Heart Association guidelines for advanced cardiovascular life support, ETI should only be attempted by healthcare providers experienced in performing the procedure. Providers that perform less than 6–12 prehospital ETI per year should use alternative, non-invasive techniques for airway management according to the guidelines [49]. However, in the literature, the reported number of prehospital ETI performed by paramedics per year is much lower [50–53]. The worse outcomes associated with prehospital ETI therefore may also be related to the insufficient skills for the procedure.

Previous studies report a higher prehospital ETI success rate when the procedure was performed by physicians compared to non-physicians [54, 55] and anesthesiologists compared to non-anesthesiologists [56] It is possible that prehospital ETI performed by an experienced emergency physician may be associated with different outcomes in the current study population. Further randomized studies are needed to resolve this important issue.

Based on the results of the current study, routine prehospital ETI may not be justified in patients with isolated severe blunt TBI and a field GCS score ≤8. The effect of prehospital ETI on outcomes should be evaluated based on the resources and organization of an EMS service, taking into account the training of the providers [57, 58], presence of an emergency physician on scene [44], and transport times [59].

Besides the usual limitations of a retrospective analysis, the current study may be confounded by a selection bias. Despite the accurate matching on multiple patient and injury related factors, it cannot be excluded that patients with worse clinical conditions on scene were more likely to undergo prehospital ETI. Thus, the potentially worse prehospital clinical conditions of patients in the prehospital ETI group may have contributed to the worse outcomes found in these patients. Therefore, a prospective, randomized study, which includes only patients with isolated blunt TBI and takes into account the skills of the health care provider who performs the ETI is imperative.

Conclusion

In this large matched cohort study including patients with isolated severe blunt TBI, prehospital ETI was independently associated with lower ED GCS scores and higher in-hospital mortality.

Compliance with ethical standards

Conflict of interest Tobias Haltmeier, Elizabeth Benjamin, Stefano Siboni, Evren Dilektasli, Kenji Inaba, and Demetrios Demetriades have no conflicts of interest or financial ties to disclose.

Ethical approval Ethical approval for the current study was obtained from the Institutional Review Board (IRB) of the University of Southern California.

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