Electroencephalographic Findings from Routine EEG in Critically Ill Patients: Can They Predict Outcome?

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Abstract

Background: Impaired consciousness is a common condition in intensive care unit (ICU) patients. It is associated with high mortality and morbidity. Prolonged electroencephalography (EEG) is frequently used to detect nonconvulsive seizures, and to predict prognosis, whilst the benefit of periodic routine EEG remains unclear.

Objective: To evaluate clinical and EEG patterns from routine EEG among ICU patients who had alteration of consciousness.

Methods: A retrospective longitudinal cohort study was conducted. Adult ICU patients with Glasgow Coma Scale (GCS) score of less than 12 underwent routine EEG were enrolled. Patients with clinical seizures within 96 hours prior to EEG recording were excluded. Clinical characteristics, etiologies, EEG features, mortality, and functional outcomes, assessed by the modified Rankin Scale (mRS) had been reviewed for at least 6 months.

Results: A total of 59 patients were included, mean age of 61.7 years old, male of 38 (64.4%). Nonconvulsive seizures were not detected. The commonest etiologies were hypoxic–ischemic brain injury (HIBI) (25.5%) and metabolic encephalopathy (20.3%). HIBI patients had significantly lower initial GCS scores, worse outcomes than non-HIBI group. The absent of posterior dominant pattern, absence of anterior-posterior (AP)-gradient, and severe encephalopathic pattern were predictors for unfavorable outcomes.

Conclusions: Routine EEG recording can be used as a predictor for outcomes in ICU patients with impaired consciousness. Moreover, hypoxic ischemic brain injury was associated with more severe EEG patterns and had poorer outcomes.

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Introduction

Alteration of consciousness is a common condition among patients in intensive care unit (ICU), particularly in older adults, and is associated with high mortality and morbidity[1]. Disorders of consciousness in critically ill patients arise from heterogeneous etiologies, including hypoxic–ischemic brain injury (HIBI), cerebrovascular disease (stroke), metabolic/toxic encephalopathy, infection. To identify etiologies, manage and offer prognostication are particularly challenging[1,2]. Early identification of patients at risk for poor neurological outcomes is therefore essential to guide clinical decision-making, resource allocation, and communication with families.

In addition to clinical evaluation and neuroimaging, electroencephalography (EEG) is a noninvasive assessment tool for cerebral function and is widely used in the ICU setting, primarily for detecting nonconvulsive seizures[3,4]. Beyond seizure detection, EEG background characteristics such as continuity, reactivity, dominant background frequency, and voltage have been shown that they reflect the severity of cerebral function and carry important prognostic implications[3,5]. In particular, discontinuous or low or suppressed background activity and absent EEG reactivity have been consistently related to unfavorable neurological outcomes and increased mortality[5,6]. Moreover, sleep-related EEG elements, including K-complexes and spindles, are associated with favorable outcomes[7,8]. Subsequent reviews have further support the prognostic relevance of sleep spindles and other sleep-related EEG features, emphasizing their roles as biomarkers of preserved cerebral network function[8].

In patients with HIBI, EEG has been shown to be particularly useful for determining early prognostication. A narrative review by Hoedemaekers et al. highlighted EEG as a valuable tool for predicting outcomes in comatose ICU patients following hypoxic injury[9]. Furthermore, recent cohort studies have demonstrated that an unreactive EEG background is strongly associated with unfavorable outcomes across various etiologies of disorders of consciousness[6].

Although continuous EEG is superior for the detection of electrographic seizures, emerging evidence suggests that the prognostic accuracy of routine EEG may be comparable when background features are the primary focus[10]. Most available evidences have been derived from prolonged EEG recordings, which are resource-intensive and may not be universally available. However, continuous EEG is not available at resource-limited setting, while periodic routine EEG is practically feasible. The data for prognostic utility from short-duration routine EEG recordings in critically ill patients with impaired consciousness who had no prior motor seizures remains insufficient. We therefore hypothesized that periodic routine EEG recorded for 20–30 minutes could provide the meaningful prognostic information.

Methods

Our objectives were to identify 1) etiologies of altered mental status, 2) EEG pattern from 20-30-minute routine EEG recording, and 3) prognostic factors for determining both short-term and long-term outcome.

Study Design and Setting

This study was a retrospective longitudinal cohort study conducted in the intensive care units of Phramongkutklao Hospital, Thailand. Medical records and electroencephalographic data were reviewed for patients admitted at ICU between January 1st, 2024, and June 30th, 2025.

Study Population

Inclusion criteria were 1) adult patients aged 18 years or older, 2) admitted to an ICU, 3) impaired consciousness, defined as a Glasgow Coma Scale (GCS) score of less than 12 at the time of EEG recording, and 4) available data of routine EEG recording for reassessment. Exclusion criteria was patients with clinical motor seizures within 96 hours prior to EEG recording.

Clinical Data Collection

Demographic data, etiology of impaired consciousness, preadmission functional status, assessed by the modified Rankin Scale [mRS], initial GCS score, antiseizure medications and anesthetic agents prescribed, and timing of EEG recording relative to ICU admission were collected. Etiologies, including hypoxic–ischemic brain injury (HIBI), traumatic brain injury (TBI), ischemic stroke, intracerebral hemorrhage (ICH), metabolic/toxic/septic encephalopathy, encephalitis, etc., were reviewed.

Electroencephalography

Routine EEG recordings were performed using a standard international 10–20 electrode placement system. Each EEG was recorded for approximately 20-30 minutes. EEGs for this cohort were independently reviewed by 2 interpreters, a neurologist (W-M) and an epileptologist (P-S). Further validation for the agreement of findings were obtained. EEG patterns, including background symmetry, posterior dominant rhythm, anteroposterior (AP) gradient, background frequency, continuity, voltage, EEG reactivity to external stimuli, the presence of sleep-related elements, including K-complexes, vertex sharp waves and spindles, ictal or interictal epileptiform discharges, periodic or ictal–interictal continuum (IIC) patterns, and degree of encephalopathy, classified as mild, moderate, or severe, were analyzed.

Outcome Measurement

Primary outcomes were in-hospital morbidity, 1-month and 6-months mortality rate. Functional outcomes were assessed using the modified Rankin Scale (mRS) at hospital discharge, 1-month, and 6-month after discharge from the hospital. Favorable functional outcome was defined as an mRS score of 0–2.

Statistical Analysis

Continuous variables were summarized as mean and standard deviation (SD). If data were non-parametric, median, and interquartile range (IQR) were reported. Categorical variables were presented as number and percent. Comparisons between groups were performed using Student's t-test or Mann–Whitney U test in case nonparametric data for continuous variables. Chi-square test or Fisher's exact test were applied for categorical variables. A p-value of less than 0.05 was considered as statistically significant. Statistical analysis was performed using standard statistical software, IBM SPSS statistics version 26.

Ethical Considerations

This study was approved by the institutional review board of royal Thai army (the IRBRTA study code - R151h/68_Exp). Given the retrospective in nature of the study and the use of unidentified data, the requirement for informed consent was waived.

Results

Patient Characteristics

A total of 117 ICU patients with impaired consciousness underwent EEG evaluation was identified. Of these, 58 patients were excluded. The 59 remaining patients met the inclusion criteria and were included in the final analysis, Figure 1.

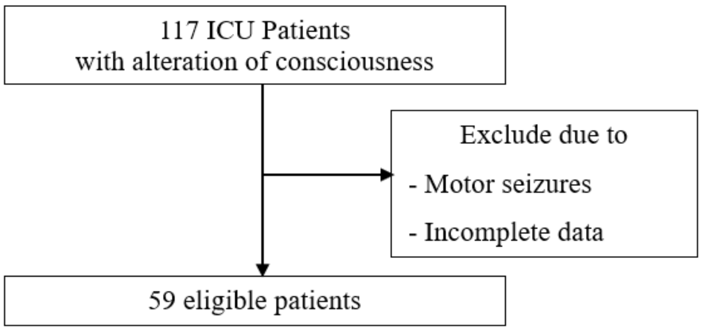

Figure 1. Study flow chart

The mean age was 61.7 ± 20.6 years, and 64.4% were male. Hypoxic–ischemic brain injury (HIBI) accounted for 15 cases (25.5%), while the remaining patients had non-HIBI etiologies which were metabolic/toxic or septic encephalopathy, ischemic stroke, intracerebral hemorrhage, encephalitis, traumatic brain injury, and other causes, Table 1. Patients in the HIBI group had significantly lower initial GCS scores compared with the non-HIBI group (median 3 vs. 7, p-value <0.001), Table 1.

Table 1. Baseline Characteristics of ICU Patients with Impaired Consciousness stratified by Etiology

Variables	Overall (n=59)	HIBI group (n=15)	Non-HIBI group (n=44)	*p*-value
Age (years) [mean ± SD]	61.7 ± 20.6	66.3 ± 11.9	60.1 ± 21.4	0.321
Male [number (%)]	38 (64.4)	10 (66.7)	28 (63.6)	0.832
GCS [median (IQR1-IQR3)]	6 (3-8)	3 (3-4)	7 (5-8)	<0.001*
Time from admission to EEG (day) [median (min-max)]	5.0 (0.1-79.8)	6.6 (4.4-11.9)	4.7 (0.1-79.8)	0.439
ASM used [number (%)]	33 (55.9)	9 (60)	24 (54.5)	0.713
Pre-admission mRS [median (IQR1-IQR3)]	1 (0-3)	1 (0-1)	1 (0-3)	NA
Anesthetic agents use [number (%)]	2 (3.4)	2 (13.3)	0 (0)	0.061
Etiologies [number (%)]				
- TBI	5 (8.5)	-	-	-
- HIBI	15 (25.5)	-	-	-
- ICH	7 (11.9)	-	-	-
- Ischemic stroke	7 (11.9)	-	-	-
- Metabolic or toxic or septic encephalopathy	12 (20.3)	-	-	-
- Encephalitis	7 (11.9)	-	-	-
- Other etiology	6 (10.2)	-	-	-

*,*p*-value<0.05;SD,standard deviation; GCS, Glasgow Coma Scale; IQR, interquartile range; EEG, electroencephalography; ASM, anti-seizure medication; mRS, modified Rankin Scale: TBI, traumatic brain injury; HIBI, hypoxic-ischemic brain injury; ICH, intracerebral hemorrhage; NA, not applicable

EEG Findings

Routine EEG was performed at a median time from ICU admission to EEG recording of 5 days. Most common EEG patterns were medium-to-high voltage (61.1%), symmetrical (78%), continuous (66.1%), delta waves (59.3%). The degrees of encephalopathy were mild (6.8%), moderate (33.9%) and severe (40.7%). There was no electrographic nor nonconvulsive seizures captured in this cohort. Compared HIBI with non-HIBI patients, it was significantly demonstrated the worse EEG background characteristics, in particular the reduced continuity, absent EEG reactivity, and suppressed or low-voltage patterns (p-value <0.001). Severe encephalopathy was more observed in the HIBI group than non-HIBI group (86.7% vs. 25%), Table 2. Sleep-related EEG elements were rarely observed.

Table 2. Electroencephalographic Characteristics of ICU Patients with Impaired Consciousness

Variables	Overall (n=59)	HIBI group (n=15)	Non-HIBI group (n=44)	*p*-value
Symmetrical background [number (%)]	46 (78)	14 (93.3)	32 (72.7)	0.211
Asymmetrical background [number (%)]	13 (22)	3 (6.7)	12 (27.3)	
- Mild asymmetry	6 (10.2)	0	6 (13.6)	-
- Markedly asymmetry	7 (11.9)	1 (6.7)	6 (13.6)	-
Presence of PDR [number (%)]	4 (6.7)	1 (6.7)	3 (6.8)	0.735
Presence of AP gradient [number (%)]	6 (10.2)	1 (6.7)	5 (11.4)	0.518
EEG "<u>best</u>" frequency [number (%)]				0.156
- Beta	7 (11.9)	3 (20)	4 (9.1)	-
- Alpha	1 (1.7)	0	1 (2.3)	-
- Theta	16 (27.1)	1(6.7)	15 (34.1)	-
- Delta	35 (59.3)	11 (73.3)	24 (54.5)	-
EEG continuity [number (%)]				<0.001*
- Continuous	39 (66.1)	4 (26.7)	35 (79.5)	-
- Nearly continuous	7 (11.9)	0	7 (15.9)	-
- Discontinuous	3 (5.1)	2 (13.3)	1 (2.3)	-
- Burst suppression	2 (3.4)	2 (13.3)	0	-
- Suppression	8 (13.6)	7 (46.7)	1 (2.3)	-
EEG reactivity [number (%)]				<0.001*
- Reactivity	14 (40.7)	4 (26.7)	35 (79.5)	-
- Non-reactivity	7 (11.9)	0	7 (15.9)	-
- SIRPIDS	0	0	0	-
- Unclear	11 (18.6)	0	11 (25)	-
Presence of (Sleep) stage change (K, V, SS) [number (%)]	2 (3.4)	0	2 (4.5)	0.553
EEG voltage [number (%)]				<0.001*
- Normal (medium-to-high voltage)	36 (61.1)	2(13.3)	34 (77.3)	-
- Low voltage	13 (22)	5 (33)	8 (18.2)	-
- Suppression	10 (16.9)	8 (53.3)	2 (4.5)	-
Presence of breach rhythm [number (%)]	4 (6.8)	0	4 (9.1)	0.298
Presence of periodic pattern [number (%)]	6 (10.2)	0	6 (13.6)	0.157
Presence of IIC [number (%)]	5 (8.5)	0	5 (11.7)	0.217
Presence of interictal EDs [number (%)]	3 (5.1)	0	3 (6.8)	0.407
Presence of EEG seizure [number (%)] (Prevalence of nonconvulsive seizures)	0	0	0	NA
Encephalopathic pattern [number (%)]				0.407
- No evidence of encephalopathy	11 (18.6)	0	11 (25)	-
- Mild encephalopathy	4 (6.8)	1 (6.7)	3 (6.8)	-
- Moderate encephalopathy	20 (33.9)	1 (6.7)	19 (43.2)	-
- Severe encephalopathy	24 (40.7)	13 (86.7)	11 (25)	-

*,*p*-value <0.05; EEG, electroencephalography: PDR. posterior dominant rhythm; AP gradient, anteroposterior gradient; SIRPIDs, stimulus-induced rhythmic, periodic, or ictal discharges; K, K-complex; V, vertex sharp waves; SS, sleep spindles; IIC, ictal-interictal continuum; EDs, epileptiform discharges; NA, not applicable

Mortality Outcomes

Overall, mortality rates were 49.2%, 49.2% and 50.8% for in-hospital, 1-month, and 6-month, respectively. Patients with HIBI had significantly higher mortality at all points of time than patients with non-HIBI, Table 3.

Table 3. Mortality and Functional Outcomes of ICU Patients with Impaired Consciousness

Variables	Overall (n=59)	HIBI group (n=15)	Non-HIBI group (n=44)	*p*-value
Death [number (%)]				
- In hospital	29 (49.2)	12 (80)	17 (38.6)	0.006*
- At 1-month	29 (49.2)	12 (80)	17 (38.6)	0.019*
- At 6-month	30 (50.8)	12 (80)	18 (40.9)	0.033*
mRS evaluation [median (IQR1 - IQR3)]				
- Pre-admission	1 (0-3)	1 (0-1)	2 (0-3)	0.413
- At 1-month	5 (4-6)	5 (4-6)	5 (4-6)	0.020
- At 6-month	5 (4-6)	5 (4-6)	5 (4-6)	0.075

*, p-value<0.05, mRS, modified Rankin Scale; IQR, interquartile range; HIBI, hypoxic-ischemic brain injury.

Functional Outcomes

Functional outcomes, determined by mRS score, were generally poor, with a median of 5 and 5 at 1-month and 6-month follow-up period, respectively, representing high morbidity and dependency among the studied population. HIBI group tended to have poorer function outcomes than non-HIBI group, Table 3.

Poor outcome: Death and/or dependency (mRS of 3-6)

At hospital discharges, mortality rate was assessed. There were 29 patients deceased. It was significantly associated with 1) low GCS (p-value 0.004), 2) HIBI etiology (p-value 0.006), 3) unfavorable EEG features; 3.1) absent posterior dominant pattern (PDR) (p-value 0.041); 3.2) absent of AP gradient (p-value 0.013); 3.3) loss of EEG continuity (p-value 0.005); 3.4) absent of reactivity (p-value 0.0.022); 3.5) low-to-suppressive background (p-value 0.001); 3.6) severe encephalopathic pattern (p-value 0.021), Table 4.

At 6-month, poor outcome was assessed. There were 43 patients who had poor outcome (mRS 3-6). It was significantly associated with 1) older age (p-value 0.021), low GCS (p-value 0.015), 3) unfavorable EEG features; 3.1) absent of PDR (p-value 0.002); 3.2), absent of AP gradient (p-value <0.001); severe encephalopathy patterns (p-value <0.001). Table 5.

Table 4. Comparison of Clinical and Electroencephalographic Characteristics Between Death and Survival Groups at hospital discharge

Variables	Death group (n=29)	Survived group (n=30)	*p*-value
Age (years) [mean ± SD]	61.7±22.7	61.7±18.8	0.098
Male [number (%)]	21 (72.4)	17 (56.7)	0.207
GCS [median (IQR1 - IQR3)]	4 (3-7)	7 (5-8)	0.004*
Time from admission to EEG (day) [mean ± SD]	11.5±16.1	9.2 ±15.3	0.574
ASM used [number (%)]	17 (58.6)	16 (53.3)	0.683
Pre-admission mRS [median (IQR1 - IOR3))	1 (0-2)	1 (0-3)	0.449
Anesthetic agents use [number (%)]	1 (3.4)	1 (3.3)	0.746
Etiology [number (%)]			0.096
- TBI	1 (3.4)	4 (13.3)	-
- HIBI	12 (41.4)	3 (10)	-
- ICH	3 (10.3)	4 (13.3)	-
- Ischemic stroke	2 (6.9)	5 (16.7)	-
- Metabolic/toxic/septic encephalopathy	4 (13.8)	8 (26.7)	-
- Encephalitis	3 (10.3)	4 (13.3)	-
- Other etiology	4 (13.8)	2 (6.7)	-
Subgroup to HIBI vs. non HIBI group	12 (41.4) vs. 17 (58.6)	3 (10) vs. 27 (90)	0.006*
EEG pattern [number (%)]			
- Symmetrical background	24 (82.8)	22 (73.7)	0.237
- Presence of PDR	0	4 (13.3)	0.041*
- Presence of AP gradient	0	6 (20)	0.013*
- EEG continuity	13 (14.8)	26 (86.7)	0.005*
- Presence of EEG reactivity	8 (27.6)	15 (533.3)	0.022*
- Presence of (Sleep) stage change	0	2 (6.7)	0.254
- Normal voltage	12 (41.4)	24 (80)	0.001*
- Presence of breach rhythm	2 (6.9)	2 (6.7)	0.681
- Presence of periodic pattern	1 (3.4)	5 (16.7)	0.105
- Presence of IIC	1 (3.4)	4 (13.3)	0.87
- Presence of interictal EDs	0	3 (10)	0.080
- Presence of EEG seizure	0	0	NA
- Encephalopathic pattern			0.021*
o Mild encephalopathy	0	4 (13.3)	-
o Moderate encephalopathy	8 (27.6)	12 (40)	-
o Severe encephalopathy	17 (58.6)	7 (23.7)	-

*,p-value<0.05; SD,standard deviation; GCS, Glasgow Coma Scale; IQR, interquartile range; EEG, electroencephalography; ASM, anti-seizure medication; mRS, modified Rankin Scale; TBI, traumatic brain injury; HIBI, hypoxic-ischemic brain injury; ICH, intracerebral hemorrhage; PDR, posterior dominant rhythm; AP gradient, anteroposterior gradient; IIC, ictal-interictal continuum; EDs, epileptiform discharges; NA, nor applicable

Table 5. Clinical and Electroencephalographic Characteristics According to 6-Month Prognosis in ICU Patients with Impaired Consciousness

Variables	Good prognosis group [survived + mRS 0-2] (n=7)	Poor prognosis group [death + mRS 3-5] (n=43)	*p*-value
Age (years) [mean ± SD]	47 ± 13.3	64.6 ± 21.2	0.021*
Male [number (%)]	4 (57.1)	28 (65.1)	0.495
GCS [median (IQR1 - IQR3)]	9 (6-11)	6 (3-7)	0.015*
Time from admission to EEG (day) [mean ± SD]	5.2 ± 6.9	11.0 ± 16.7	0.174
ASM used [number (%)]	4 (57.1)	26 (60.5)	0.470
Pre-admission mRS [median (IQR1 - IOR3)]	0 (0-0)	1 (0-3)	0.750
Anesthetic agents use [number (%)]	0	2 (4.7)	0.687
Etiology [number (%)]			0.357
- HIBI	1 (14.3)	30 (69.8)	-
- Non HIBI	6 (85.7)	13 (30.2)	-
EEG pattern [number (%)]			
- Symmetrical background	7 (100)	32 (74.4)	0.317
- Presence of PDR	3 (12.9)	0	0.002*
- Presence of AP gradient	5 (71.4)	0	<0.001*
- EEG continuity	7 (100)	24 (55.8)	0.288
- Presence of EEG reactivity	5 (71.1)	14 (32.6)	0.129
- Presence of (Sleep) stage change	1 (14.3)	0	0.140
- Normal voltage	7 (100)	22 (51.2)	0.052
- Presence of breach rhythm	0	3 (7)	0.630
- Presence of periodic pattern	1 (14.3)	4 (9.3)	0.546
- Presence of IIC	1 (14.3)	3 (7)	0.464
- Presence of interictal EDs	0	2 (4.7)	0.737
- Presence of EEG seizure	0	0	NA
- Encephalopathic pattern			<0.001*
o Mild encephalopathy	3 (50)	0	-
o Moderate encephalopathy	2 (33.7)	14 (40)	-
o Severe encephalopathy	1 (16.7)	29 (60)	-

*,p-value<0.05; SD, standard deviation; GCS, Glasgow Coma Scale; IQR, interquartile range; EEG, electroencephalography; ASM, anti-seizure medication; mRS, modified Rankin Scale; TBI, traumatic brain injury; HIBI, hypoxic-ischemic brain injury; ICH, intracerebral hemorrhage; PDR, posterior dominant rhythim; AP gradient, anteroposterior gradient; IIC, ictal-interictal continuum; EDs, epileptiform discharges; NA, nor applicable

Discussion

Our findings are consistent with prior literatures emphasizing the prognostic value of prolonged or continuous EEG background characteristics and sleep-related elements in critically ill patients. Sutter et al. demonstrated a four-year cohort study showing that the presence of electroencephalographic sleep elements was significantly associated with favorable neurological outcomes in patients with acute encephalopathy[7]. Similarly, Grigg-Damberger et al. highlighted that sleep spindles and K-complexes were favorable prognostic biomarkers in critically ill patients, suggesting that these EEG features reflect preserved thalamocortical network function[8]. In addition, Hoedemaekers et al. reported in a narrative review focusing on hypoxic–ischemic brain injury that EEG is a valuable tool for early outcome prognostication in comatose ICU patients following hypoxic injury[9]. In our cohort using routine EEG, although sleep-related EEG elements were infrequently observed, they were associated with favorable outcomes, supporting their roles as biomarkers for preserving cerebral function even when detected in short-duration recordings.

Benghanem et al. reported that an unreactive EEG background was strongly associated with unfavorable outcomes in patients with disorders of consciousness of various etiologies, with an odds ratio of 10.9.[6] Conversely, unfavorable EEG background characteristics have been consistently associated with poor outcomes. This finding aligns closely with our results, in which absent EEG reactivity, discontinuous or suppressed background activity, and severe encephalopathic patterns predict poor outcomes (death and dependency).

Regarding EEG monitoring strategies, Fenter et al. demonstrated that although continuous EEG is superior to routine EEG for the detection of electrographic seizures, the prognostic accuracy of routine EEG[10]. This observation is particularly relevant to our study, as no nonconvulsive seizures were detected in the cohort, which would be one of the limitations on the usage of periodic routine EEG. Other limitations of our study are its retrospective design, single-center, and small sample size. Nonetheless, our findings suggest that routine EEG provides meaningful prognostic information in ICU patients with impaired consciousness. The strength of our cohort is to investigate the outcome from routine EEG finding in which it is widely available in general hospital setting and it is feasible and not expensive for resources-limited countries.

Conclusion

Routine EEG recording in ICU patients with impaired consciousness without motor seizures provides prognostic information. Hypoxic ischemic brain injury is the commonest etiology the studied patients which correlates with severe EEG patterns and is consistently associated with poorer outcomes.

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