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RESEARCH

Patient Characteristics and Outcomes Following Operative Repair of Acute versus Chronic Traumatic Diaphragmatic Hernia

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Background: Diaphragmatic hernia is a complication of trauma that may lead to significant morbidity and mortality if unrecognized. The clinical sequelae following missed traumatic diaphragmatic hernia (TDH) diagnoses have not been well-defined.

Methods: The 2005–2015 ACS-NSQIP databases were accessed to identify patients ≥18 years old who underwent operative repair of acute and chronic TDH. Patient demographics, health characteristics, pertinent complications, and 30-day outcomes were collected. Categorical variables were analyzed using chi-square and Fisher's Exact Test. Logistic regression was used to perform multivariate analyses with odds ratios (OR) and 95% confidence intervals (CI) constructed about group differences.

Results: From 2005–2015, 1000 patients underwent operative repair for TDH, of which 285 (28.5%) were acute and 715 (71.5%) were chronic. Patients undergoing acute repairs had a greater percentage of emergency procedures (29.8% vs. 10.2%, $p < 0.0001$). Acute TDH patients were more likely to be male (46.7% vs 37.2%, $p = 0.01$) and have concomitant infection (14.0% vs 6.6%, $p = 0.0002$). Chronic TDH patients were more likely to be obese (55.2% vs 42.8%, $p = 0.0004$) and have an ASA > 2 (51.2% vs 43.2%, $p = 0.02$). Acute TDH patients were more likely to develop postoperative wound infection (1.40% vs 0.28%, $p = 0.05$), infectious process (11.2% versus 7.0%, $p = 0.03$), failure to wean from mechanical ventilation (8.1% vs 3.4%, $p = 0.0015$), and remain hospitalized at 30 days (4.3% vs 0.9%, $p = 0.0058$).

Conclusions: Patients with acute TDH repair are more likely to develop postoperative complications. Further study is necessary to determine the optimal timing of surgery for TDH discovered following initial resuscitation and evaluation.

Keywords: diaphragmatic hernia; trauma; diaphragm; hernia

Introduction

Diaphragmatic hernia is a rare but serious complication of trauma that may lead to significant morbidity and mortality if unrecognized. Conservative estimates suggest that the incidence of diaphragmatic injury is 0.8%–8% from blunt abdominal trauma and 10%–15% after penetrating trauma, with more extensive diaphragmatic injuries associated with blunt trauma [1–4]. The true incidence of traumatic diaphragmatic hernia (TDH) remains uncertain as the wide variety in clinical presentations leads to diagnostic challenges [1, 2, 5–8].

Despite the numerous radiologic and surgical approaches utilized, the diagnosis is frequently missed. The diagnostic challenge has been attributed to asymptomatic presentations, more distinct and urgent concomitant injuries, positive pressure in the chest due to intubation, and visceral "plugging" over the diaphragmatic defect [2, 5, 8]. The literature suggests that a high index of suspicion is most important to allow for early diagnosis of traumatic diaphragmatic hernia (TDH) [9, 10]. It is estimated that missed diaphragmatic hernias in conservatively managed patients occur 12% to 66% of the time [11]. Missed injuries with subsequent herniation requiring hospitalization later, or chronic TDH, may lead to cardiopulmonary dysfunction, impaired venous return, decreased pulmonary function, and obstruction, incarceration, or strangulation of abdominal contents, though the incidence of these clinical sequelae has not been well-defined [7]. The current knowledge about the incidence of post-operative complications of missed TDH is based largely upon single-center case series of minimal sample size.

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) Participant Use Data File (PUF) contains patient-level, aggregate data from hundreds of U.S. hospitals. The aim of this study was to use the NSQIP dataset to compare the characteristics and outcomes associated with patients undergoing operative repair for acute versus chronic traumatic diaphragmatic hernias.

Materials and Methods

Institutional review board exemption approval was obtained to access the 2005–2015 ACS-NSQIP participant use data files and identify patients >18 years of age with operative repair of traumatic diaphragmatic hernia. Current Procedural Terminology (CPT) codes for repair of traumatic, acute, non-neonatal diaphragmatic hernia (39540) and repair of traumatic, chronic, non-neonatal diaphragmatic hernia (39541) distinguished patients with acute and chronic hernia repairs, respectively. These codes describe patients with diaphragmatic hernias resulting from trauma that are surgically repaired by primary closure with or without prosthetic reinforcement [12]. Acute hernias are those that are recognized upon initial presentation following trauma, while chronic hernias are recognized days, months, or years following the initial post-trauma workup [13]. Patients were included in the analyses if they had the designated CPT codes as a primary, concurrent, or other procedure code. Primary postoperative diagnoses were collected using International Classification of Disease, Ninth Revision (ICD-9) codes.

Patient demographics, baseline health characteristics, relevant comorbidities, procedure description (emergency or elective), and American Society of Anesthesiology (ASA) classification were also obtained from the NSQIP database. Demographics included age, gender, race, ethnicity, and body mass index (BMI). Baseline health characteristics included recent weight loss and smoking within one year of the operation. Relevant comorbidities included diabetes mellitus, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), dyspnea, history of percutaneous intervention (PCI), hypertension, impaired sensorium, hemiplegia, prior transient ischemic attack (TIA) or cerebrovascular accident (CVA), renal failure, dialysis, chemotherapy, and pre-surgical sepsis. ASA scores were grouped as 2 or less (no or mild systemic disease) or greater than 2 (severe systemic disease, severe systemic disease that is a constant threat to life, or moribund patients).

Thirty-day outcomes and complications were also collected from the ACS-NSQIP data files. Outcomes included mortality, still in hospital at 30 days, discharge disposition, and readmission. Pertinent complications included wound and surgical site infections, pneumonia, re-intubation, pulmonary embolism, failure to wean off ventilator, renal insufficiency, CVA, neurological deficits, cardiac arrest requiring CPR, myocardial infarction, bleeding requiring a transfusion, return to the OR, urinary tract infection (UTI), and sepsis or septic shock.

All statistical analyses were performed on Statistical Analysis Software version 9.4 (SAS Institute, Carey, NC). Categorical variables were analyzed using chi-square and Fisher's Exact Test when appropriate. Logistic regression was used to perform multivariate analyses with odds ratios (OR) and 95% confidence intervals (CI) constructed about group differences. Type of TDH repair (chronic versus acute) was manually entered into all models and backwards selection with a p-value of 0.2 was used for patient demographics and comorbidities.

Results

Demographics

During this 11-year period, 1000 patients underwent operative repair for traumatic diaphragmatic hernia. Of these, 28.5% (n = 285) were treated for acute hernias and 71.5% (n = 715) were treated for chronic hernias. The most frequent postoperative diagnoses according to primary ICD-9 codes were diaphragmatic hernia without obstruction, diaphragmatic hernia with obstruction or gangrene (more commonly in the acute repair group), morbid and unspecified obesity (more commonly in the chronic repair group), and esophageal reflux (**Table 1**). Patients undergoing acute diaphragmatic hernia repairs had a greater percentage of emergency surgery cases (29.8% vs. 10.2%, $p < 0.0001$), while patients with chronic repairs had a greater percentage of elective surgery cases (51.2% vs. 29.5%, $p < 0.0001$). Acute repair patients were more likely to be male (46.7% vs. 37.2%, $p = 0.01$) have impaired sensorium (1.8% vs. 0.3%, $p = 0.02$) and have pre-surgical sepsis (14.04% vs. 6.57%, $p = 0.0002$). Patients undergoing repair for chronic diaphragmatic hernia were more likely to be obese (55.2% vs. 42.8%, $p = 0.0004$) and have an ASA score greater than 2 (51.2% vs. 43.2%, $p = 0.02$) (**Table 1**).

After multivariate analysis, emergency procedures were more likely seen in patients with diabetes (OR 2.12, CI 1.13–3.96) and pre-surgical sepsis (OR 14.94, CI 8.73–25.56) (**Figure 1**). Emergency cases were less likely in patients with chronic diaphragmatic hernia (OR 0.28, CI 0.19–0.42) and obesity (OR 0.25, CI 0.16–0.39). Pre-surgical sepsis was more likely seen in patients with emergency procedures (OR 15.49, CI 9.15–26.22) and current smokers (OR 1.98, CI 1.09–3.61) and less likely in patients with diabetes (OR 0.24, CI 0.07–0.82) (**Table 2**).

Outcomes

With univariate analyses, patients with acute diaphragmatic hernia repairs were more likely to develop a postoperative wound infection (1.4% vs. 0.3%, $p = 0.05$), failure to wean (ventilator for greater than 48 hours) (8.1% vs. 3.4%, $p = 0.0015$), and remain in the hospital at 30 days (4.3% vs. 0.9%, $p = 0.0058$). Differences in mortality, readmission, discharge disposition, and other complications were not statistically significant.

Table 1: Demographics of patients undergoing operative repair for acute and chronic traumatic diaphragmatic hernia.

Variable	Acute – N (%) 285 (28.5%)	Chronic – N (%) 715 (71.5%)	p-value
ICD-9 Code			
DH without obstruction	71 (24.9%)	200 (28.0%)	0.33
DH with obstruction or gangrene	69 (24.2%)	122 (17.1%)	0.01
Morbid obesity	45 (15.8%)	152 (21.3%)	0.05
Obesity, unspecified	3 (1.1%)	62 (8.7%)	<0.0001
Esophageal reflux	15 (5.3%)	32 (4.5%)	0.60
Emergency Surgery	85 (29.8%)	73 (10.2%)	<0.0001
Elective Surgery	84 (29.5%)	366 (51.2%)	<0.0001
Gender (males)	133 (46.7%)	266 (37.2%)	0.01
Age over 65	81 (28.4%)	192 (26.9%)	0.62
Race			
White Non-Hispanic	181 (63.5%)	440 (61.5%)	0.56
White Hispanic	18 (6.3%)	45 (6.3%)	0.99
Black Non-Hispanic	21 (7.4%)	69 (9.7%)	0.26
Black Hispanic	0 (0.0%)	1 (0.1%)	0.72
Asian	5 (1.8%)	6 (0.8%)	0.12
Unknown Non-Hispanic	4 (1.4%)	4 (0.6%)	0.12
Unknown Hispanic	0 (0.00%)	7 (1.0%)	0.09
ASA > 2	123 (43.2%)	366 (51.2%)	0.02
Obese	122 (42.8%)	395 (55.2%)	0.0004
History of Diabetes	24 (8.4%)	88 (12.3%)	0.08
Current Smoker	39 (13.7%)	108 (15.1%)	0.57
Functional Status			
Independent	261 (91.6%)	678 (94.8%)	0.05
Partially Dependent	16 (5.6%)	25 (3.5%)	0.13
Totally Dependent	8 (2.8%)	9 (1.3%)	0.05
COPD	18 (6.3%)	57 (8.0%)	0.37
CHF	4 (1.4%)	11 (1.5%)	0.87
History of PCI	4 (1.4%)	13 (1.8%)	0.20
Ascites	2 (0.7%)	3 (0.4%)	0.57
Hypertension	124 (43.5%)	345 (48.3%)	0.17
Impaired Sensorium	5 (1.8%)	2 (0.3%)	0.02
Hemiplegia	0 (0.0%)	2 (0.3%)	0.51
TIA	2 (0.7%)	7 (1.0%)	0.28
History of CVA	1 (0.4%)	3 (0.4%)	0.42
Renal Failure	5 (1.8%)	0 (0.0%)	0.0018
Dialysis	1 (0.4%)	0 (0.0%)	0.29
Dyspnea	50 (17.5%)	115 (16.1%)	0.57
Weight Loss >10% in last 6 months	4 (1.4%)	16 (2.2%)	0.40
Chemotherapy	2 (0.7%)	3 (0.4%)	0.30
Pre-surgical Sepsis	40 (14.0%)	47 (6.6%)	0.0002

DH: diaphragmatic hernia. ASA: American Society of Anesthesiologists physical status classification. COPD: chronic obstructive pulmonary disease. CHF: congestive heart failure. PCI: percutaneous coronary intervention. TIA: transient ischemic attack. CVA: cerebrovascular accident.

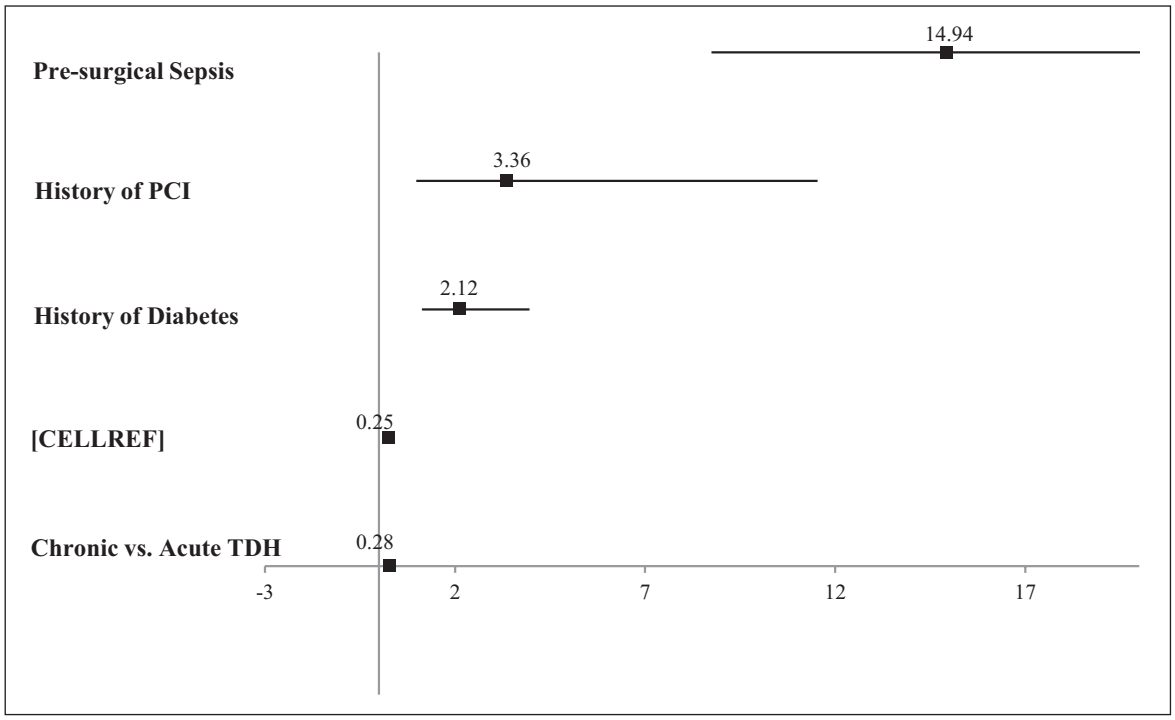

Figure 1: Odds ratios for traumatic diaphragmatic hernia surgery designated as emergency surgery.

Table 2: Logistic regression models for emergency surgery and pre-surgical sepsis.

Effect	Odds Ratio	95% CI Lower	95% CI Upper
Emergency Surgery			
Chronic vs. Acute TDH	0.28	0.19	0.42
Obesity	0.25	0.16	0.39
History of Diabetes	2.12	1.13	3.96
History of PCI	3.36	0.98	11.54
Pre-surgical Sepsis	14.94	8.73	25.56
Pre-Surgical Sepsis			
Chronic vs. Acute TDH	0.91	0.53	1.54
Emergency Surgery	15.49	9.15	26.22
Age over 65	1.47	0.87	2.51
History of Diabetes	0.24	0.07	0.82
Current Smoker	1.98	1.09	3.61
CHF	2.61	0.62	3.61

TDH: traumatic diaphragmatic hernia. PCI: percutaneous coronary intervention. CHF: congestive heart failure. Logistic regression was performed with potentially predictive variables in which the p-value was <0.05 in univariate analysis. Backwards selection was used with a p-value of 0.2 for inclusion into the final model.

Due to the small frequencies of all complications relative to the sample size, related outcomes were combined into broader categories. Grouped outcomes were designated as "death or cardiac arrest" (death or cardiac arrest requiring CPR), "wound complication" (superficial incisional surgical site infection, wound infection, organ space surgical site infection, or wound dehiscence), serious cardiovascular and pulmonary morbidity (myocardial infarction, pulmonary embolism, or DVT requiring therapy), and "infectious complication" (sepsis, septic shock, pneumonia, or UTI). With univariate analyses, patients were more likely to have an infectious process (11.23% vs. 6.99%, p = 0.03) (**Table 3**) following acute repair of traumatic diaphragmatic hernia. Chronicity of TDH repair was not a statistically significant predictor of mortality, failure to wean, death or cardiac arrest, wound complications, clotting complications, and infectious processes.

Table 3: Outcomes of patients undergoing operative repair for acute and chronic traumatic diaphragmatic hernia.

Variable	Acute – N (%) 285 (28.5%)	Chronic – N(%) 715 (71.5%)	p-value
Death	6 (2.1%)	12 (1.7%)	0.65
Superficial surgical site infection	4 (1.4%)	22 (3.1%)	0.13
Wound Infection	4 (1.4%)	2 (0.3%)	0.05
Organ Space SSI	3 (1.1%)	13 (1.8%)	0.17
Dehiscence	5 (1.8%)	5 (0.7%)	0.31
Pneumonia	15 (5.3%)	21 (2.9%)	0.07
Unplanned Intubation	11 (3.9%)	20 (2.8%)	0.38
Pulmonary Embolism	2 (0.7%)	4 (0.6%)	0.79
Ventilator > 48 hr	23 (8.1%)	24 (3.4%)	0.0015
Acute Renal Failure	0 (0.0%)	3 (0.4%)	0.37
Progressive Renal Insufficiency	2 (0.7%)	5 (0.7%)	0.32
Stroke/CVA with neurological deficit	3 (1.1%)	2 (0.3%)	0.12
Deep Vein Thrombosis (DVT)	2 (0.7%)	6 (0.8%)	0.83
Cardiac arrest requiring CPR	2 (0.7%)	5 (0.7%)	0.17
Myocardial Infarction	3 (1.1%)	3 (0.4%)	0.24
Urinary Tract Infection (UTI)	4 (1.4%)	15 (2.1%)	0.47
Sepsis	15 (5.3%)	20 (2.8%)	0.06
Septic Shock	9 (3.2%)	12 (1.7%)	0.14
Return to OR	20 (7.0%)	31 (4.3%)	0.08
Still in Hosp > 30d	7 (4.3%)	4 (0.9%)	0.0058
Readmission	15 (11.0%)	26 (6.4%)	0.08
Discharge Home*	146 (92.4%)	427 (93.4%)	0.66
Death or Cardiac Arrest	7 (2.5%)	14 (2.0%)	0.62
Wound Complication[+]	15 (5.3%)	39 (5.5%)	0.90
Clotting Complication[∞]	6 (2.1%)	11 (1.5%)	0.17
Infectious Process[Φ]	32 (11.2%)	50 (7.0%)	0.03

SSI: surgical site infection. CVA: cerebrovascular accident.
* Discharge Home = Discharge to Home OR Facility which was Home, vs. Rehab OR Separate Acute Care OR Skilled Care, Not Home.
[+] Wound complication defined as superficial incisional SSI or wound infection or organ/space SSI or wound disruption.
[∞] Clotting complication defined as myocardial infarction or pulmonary embolism or DVT requiring therapy.
[Φ] Infectious process defined as sepsis or septic shock or pneumonia or UTI.

Discussion

In the current analysis of 1000 patients who underwent surgical repair for traumatic diaphragmatic hernia, we found that patients with acute TDH repairs had emergency procedures nearly three times as frequently as those with chronic repairs. Previous reports suggest that diaphragmatic injury without other associated harm may not be considered a true emergency [14, 15]. When identified, however, they should be repaired as such. Our finding underscores the point that traumatic diaphragmatic hernias are often recognized acutely because of their co-occurrence with more life threatening concomitant injuries that warrant surgical exploration and repair [16]. Perhaps these other clinical concerns may have diverted clinicians from evaluating patients for more occult injuries, leading to missed diagnosis of acute diaphragmatic hernias [7, 17].

Patients in the acute TDH repair cohort also had increased rates of pre-surgical sepsis. These higher-acuity patients are associated with a greater number of emergency procedures. Postoperatively, acute TDH patients were more likely to have an infectious complication, wound infections, remain on a ventilator for >48 hours, and still be in the hospital after 30 days. In multivariate models, the type of TDH was not independently associated with any patient outcomes. These findings follow those of previous studies in which mortality is not predicted by TDH independently, but rather by

the associated traumatic injuries [4, 18–21]. Kuo et al (2012), in a case series of 43 patients, found that time to diagnosis was not significantly associated with mortality. Nursal et al (2001), in a retrospective analysis of 26 patients, found that acute TDH patients had higher Injury Severity Scores (ISS), while late-presenting patients had longer lengths of stay and higher morbidity. Overall, very few studies have compared patients with early and late TDH diagnoses and the impact of delays in diagnosis and treatment remains controversial [20].

The identification of chronic TDH may occur through several mechanisms, including more severe signs of organ obstruction or strangulation, ambiguous or nonspecific respiratory symptoms, or as an incidental finding during another procedure [3, 21, 22, 23]. In the present study, patients with chronic TDH repairs were more complex at baseline with higher percentages of obesity and ASA scores greater than 2. Overall, there were fewer adverse outcomes and complications following repair of chronic TDH when compared to the group whose TDH repaired during the index trauma admission, which contradicts the widespread assumption that delayed identification of TDH is associated with increased complications and poorer patient outcomes [3, 11, 20]. Given these results, we suspect that a significant portion of our chronic TDH patients were identified and repaired through an incidental finding or as a complication following another procedure. These phenomena have been previously described by others [24–26]. Furthermore, prior literature has suggested that obesity itself may cause herniation via enlargement of the normal anatomical diaphragmatic esophageal hiatus or formation of acquired hernia defects [27].

In 1974, Grimes categorized the natural progression of diaphragmatic hernia in three phases. The initial, or acute, stage begins with the traumatic event and often involves asymptomatic patients with missed diagnoses. The latent, or delayed, stage involves the process of herniation with symptoms ranging from none to vague distress. The obstructive phase terminates the latent phase and describes the process where, without recognition and repair, herniated viscera become obstructed, strangulated, and necrotic [28–30]. While this clinical progression has been well described, the timing of these stages, particularly the latent stage, can be highly variable [31]. In the present acute and chronic TDH cohorts, fewer than half of patients had a primary postoperative diagnosis of a diaphragmatic hernia. Though we were unable to assess detailed concomitant injury information, given the postoperative diagnoses of our cohort, we believe that many chronic TDH patients in our sample were treated for a latent phase hernia that was identified incidentally.

In this study, we were limited to a retrospective analysis of the ACS-NSQIP database, which is compiled through manual data entry and therefore may contain abstraction errors. We were unable to access specific clinical factors including type of trauma, presenting symptoms, wound location, and diagnostic workup processes. A latent, non-obstructed TDH that is recognized incidentally in an asymptomatic patient may differ significantly from a chronic TDH that has become strangulated in the years following trauma and causes respiratory distress at presentation, and we recognize that our study populations may be more nuanced than what is suggested by CPT codes. Indeed, patients with acute and chronic traumatic diaphragmatic hernias may be considerably different cohorts clinically. Additionally, we were unable to assess outcomes after 30 days. Future analyses should incorporate these additional clinical factors in large, multi-institutional studies.

Despite the established concept that missed TDH diagnoses are associated with increased complications, few studies have evaluated the clinical outcomes of these patients. While we do not suggest modifying or delaying early management for TDH, we provide an assessment of the general characteristics and outcomes of acute and chronic traumatic diaphragmatic hernia cohorts in significant number using a large, national database.

Conclusions

Traumatic diaphragmatic hernia is a rare condition with a highly variable clinical presentation that creates diagnostic challenges. The theoretical association between missed TDH leading to chronic herniation and more severe and potentially life-threatening sequelae follows the natural progression of disease and has been well-described, but there has been little empiric evidence to support these claims. This study assesses the demographics and outcomes of surgical repair for acute versus chronic TDH using a large, multisite database. Patients with acute TDH repair are more likely develop postoperative complications including infections compared to patients with repair of chronic TDH. However, the timing of presentation is not independently associated with postsurgical outcomes. Patients with chronic TDH repair are more likely to have medical co-morbid conditions and undergo elective procedures. Contrary to assumptions in the literature, chronic TDH patients had relatively few complications and adverse 30-day outcomes. We suspect that this was due to many chronic hernias being identified incidentally in the latent stage of herniation.

Competing Interests

The authors have no competing interests to declare.

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