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CHINESE SECTION

Epidemiological characteristics of adult SCIWORA in Tianjin, China: a preliminary study

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Abstract
Introduction The epidemiology of spinal cord injury without radiographic abnormality (SCIWORA) is less frequently reported in adults as compared with children. The annual incidence of SCIWORA was approximately 5.74% per million in Tianjin from 2004 to 2008. Importantly, the epidemiological characteristics of adult SCIWORA may be different from that in children. The aim of this study was to evaluate the radiological-clinical data of patients with adult SCIWORA, and to relatively analyze the epidemiological features.
Materials and Methods Inpatients with cervical SCIWORA who were 16 and above in Tianjin were admitted in municipal hospitals in Tianjin from 2004 to 2008; all the patients received MRI scanning in sagittal and axial views. Epidemiological characteristics, such as injury origin, injury level or severity, neurological scale and MRI feature were acquired.
Results In total, 203 patients were enrolled. The average age among the adult groups was 55.9 years (men 55.8 years, women 53.6 years). SCIWORA occurred more commonly in adults in the 46–60 age group, and falls were the leading cause of injury (52.2%), followed by vehicular injury (28.6%). The most predominantly affected level was C4/5 (48.7%), followed by C5/6 (30.5%) and C3/4 (12.8%), respectively. The occurrence of central cord syndrome (50.2%) with posterior longitudinal ligament tear (43.8%) was relatively higher than other injury patterns.
Conclusion It is clear that adult cervical SCIWORA is different from that in the pediatric group. Our study highlights the epidemiological properties of adult SCIWORA in Tianjin, China. Differing from other reports, particularly epidemiology study, we represent the first report regarding adult SCIWORA from China. As the geriatric population increases, it is very important to set up an individualized evaluation system based on a nationally scaled epidemiological database. The results from our study will be useful in assisting in the creation of such a database.

Keywords Epidemiology · Spinal cord injury · Radiographic · Abnormalities · China

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Introduction

In 1974, SCIWORA was described for the first time, as a special type of pediatric cord injury [2]. The term "SCIWORA" was initially coined in 1982 by Pang and Wilberger [14], as "spinal cord injury without evidence of vertebral fracture or dislocation on plain radiographs and computed tomography". SCIWORA is thought to represent mainly a pediatric entity and its incidence in adults is

relatively underreported. However, SCIWORA in adults may have catastrophic consequences. It has been reported recently that adults have a different injury profile from children, due to different anatomical and physiological properties and exposure to variable risk factors [7]. Unlike the children's spines, the flexibility of adult spine is reduced with increasing age, and the likelihood of spinal injury becomes greater. Interestingly, SCIWORA is commonly seen among middle-aged and geriatric populations [8].

In adults, the epidemiological and pathological backgrounds of SCIWORA are possibly different from that in the pediatric group. Most of the adult patients with SCIWORA may reveal abnormalities on radiographic findings, including degenerative stenosis, ossification of the posterior longitudinal ligament (OPLL), modic changes, etc. [8]. Many factors, ranging from injury origin, injury level or severity, and MRI features allow for the assessment of the epidemiology of SCIWORA.

To date, there are few reports concerning the epidemiology of adult SCIWORA; unfortunately, the sample sizes were relatively small, and their results were almost inconclusive [18, 25]. China is one of the largest countries in the world, and has a large population with increasing cervical degeneration [16]. However, as far as we know, relative studies that probe epidemiological characteristics of SCIWORA in China are rare. The goal of this study was to demonstrate the epidemiological properties by analyzing the radiological-clinical data of adult SCIWORAs in Tianjin.

Methods

Study population

The present study included all inhabitants 15 years or older living in Tianjin from 1 January 2004 to 31 December 2008. The total population in this city was 10,236,700 in 2004 and 11,760,000 in 2008, including 77.23% urban and 22.77% rural population. The population aged 15 years or older had reached approximately 9,158,326 in 2006. The average incidence rates of SCIWORA for this population were calculated based upon the information acquired from the Tianjin Bureau of Statistics for 2006 (the middle time interval of this study). Children below 15 years of age in rural areas were excluded from this study.

Patient inclusion and exclusion criteria

In order to perform an observational study reasonably and ethically, patient-including standards were formulated for the study: (1) adult patients who suffered from acute spinal trauma and needed hospitalization; (2) obvious occupying effects of hematomas identified by MRI scan; (3) without any bony abnormalities, including fracture and dislocation as shown by CT or X-ray film; (4) with bony malalignment and degeneration, including moderate or slight kyphosis, OPLL, and endplate modic changes as shown by CT or X-ray film; and (5) neurological deficit with Frankel Scale ASIA below E. Standards were carried out by senior spine surgeons independent of this study, and a document of permission for participation was signed by the inpatient's family. This investigation was also approved by the Ethics Boards of Tianjin Medical University. Moreover, this research was conducted through the Trauma Registry system at the General Hospital of Tianjin Medical University. The contents of the Trauma Registry met the diagnostic criteria, which were established by the Guidelines of the Management of Acute Cervical Spine and Spinal Cord Injuries (ASIA 2002). Neurologically injured patients with radiographic abnormalities who were hospitalized were excluded from this study.

Radiographic evaluation

Radiographic evaluation included CT and MRI. All the patients underwent routine CT and MRI in the sagittal or axial planes with T1 and T2. Cord signal was studied in T2-weighted midsagittal MRI images, according to Pang's description for edema characteristics. Radiographic records included bony abnormalities, cord damage (edema, cord transaction, minor and marked hemorrhage: hemorrhage involving a minor portion of the cord [within 1/3 portion] is considered a minor hemorrhage, while marked cord hemorrhaging means the majority of the cord's transverse diameter [at least 2/3 portion] is involved), soft tissue injuries, and ligamentous injuries on CT and MRI. Radiographic findings were assessed by two independent spine surgeons, and disagreement was resolved by consultation with a third independent orthopedic specialist.

Statistical analysis

Data recorded from the medical and radiographic records of all patients discharged from our medical center, included age, sex, origin of injury, level of injury, America Spinal Injury Association (ASIA) impairment scale, concomitant injury, etc. The causes of SCIWORA were divided into vehicle accident, accidental fall, sports-related injury and work accident. The neurological deficits were classified according to the ASIA classification. The average incidence rates of traumatic spinal cord injuries (TSCI) for this time period were calculated based on the population estimates from the Tianjin Bureau of Statistics for 2006 (the middle time point of the study). Children below 15 years of age were also excluded from this study. All the data were collected in a Microsoft Excel spreadsheet and statistical

analysis was performed by SPSS version 10.0 (SPSS Inc., Chicago, IL, USA). Continuous data are presented as mean ± SD (standard deviation); categorical data are presented as number (%). The goodness of fit test (χ^2 test) was used to test the distribution of SCIWORA regarding age, injury origin, injury level, and severity, etc.

Results

Incidence and age distribution pattern

On the basis of our previous database, for patients aged 15 and above, the numbers of adults with TSCI in each year between 2004 and 2008 were 139, 151, 178, 200 and 201, respectively. There were 869 cases of TSCI in total. According to the data in the present study, the annual numbers of adults with SCIWORA from 2004 to 2008 were 11, 23, 46, 55 and 68, respectively. There were 203 cases of SCIWORA among 869 cases of TCSI, and the estimated incidence was 5.74% per million population from 2004 to 2008.

In addition, sex and age distributions are shown in Table 1, 88.2% of the patients were male and 11.8% were female ($P < 0.001$). The male/female ratio was 7.13:1. The mean age of SCIWORA was 55.9 ± 12.7 years (men 55.8 ± 11.9 years, women 53.6 ± 12.7 years), with a range of 15–85 years. The age distribution had a peak in the 46–60-year age group, accounting for 47.3% of the total number of patients included ($P < 0.001$). Concerning the incidence by age groups, the highest incidence age group was in the 46–60-year age group, followed by the 61–75-year age group.

Cause of injury

Analysis of the acquired data showed that accidental fall was the leading cause of injury, indicating 52.2% of SCIWORA population ($P < 0.001$). In the accidental fall variant, the incidence rate of SCIWORA increased with age (11.9% for 16–30-year age group and 88.1% in the group aged 75 and above). In the vehicle accident variant, the incidence rate decreased with age (Fig. 1). Vehicle accident was the second cause of adult SCIWORA, occupying 28.6% of all SCIWORAs, and was dominant in the 16–30-year age group. Other origin factors included sports-related injuries (13.3%) and work accident (5.9%).

Injury level

The injury levels and their distribution patterns among SCIWORAs are shown in Table 2. The C4/5 segment was the most common level, accounting for 48.7% of all SCIWORA ($P < 0.001$). C5/6 was the next and C3/4 was the third most common level, which accounted for 30.5 and 12.8%, respectively.

Table 1 Demographic data, injury origins of patients with adult SCIWORA in Tianjin, China from 2004 to 2008

	2004	2005	2006	2007	2008	Total	*F*	*P*
Number of cases	11	23	46	55	68	203		
Gender								
Male	7 (63.6)	20 (87.0)	41 (89.1)	50 (90.9)	61 (89.7)	179 (88.2)		
Female	4 (36.4)	3 (13.0)	5 (10.9)	5 (9.1)	7 (10.3)	24 (11.8)		
						$\chi^2 = 118.3$, $P < 0.001$		
Age (mean, SD)	58.6 ± 11.6	59.8 ± 12.5	55.1 ± 12.5	53.6 ± 13.1	56.5 ± 12.8	55.9 ± 12.7	1.198	0.313
15–30	0	1 (4.4)	2 (4.3)	3 (5.5)	1 (1.4)	7 (3.5)		
31–45	1 (9.1)	1 (4.4)	9 (19.6)	11 (20.0)	12 (17.6)	34 (16.7)		
46–60	6 (54.5)	11 (47.8)	21 (45.7)	26 (47.3)	32 (47.1)	96 (47.3)		
61–75	3 (27.3)	7 (30.4)	12 (26.1)	13 (23.6)	18 (26.5)	53 (26.1)		
>75	1 (9.1)	3 (13.0)	2 (4.3)	2 (3.6)	5 (7.4)	13 (6.4)		
						$\chi^2 = 127.025$, $P < 0.001$		
Hospitalization, days	12.4 ± 2.3	12.7 ± 2.1	12.7 ± 2.2	13.0 ± 2.0	12.5 ± 2.3	12.7 ± 2.1	0.405	0.805
Injury origins								
Vehicle accident	3 (27.3)	6 (26.1)	15 (32.6)	16 (29.1)	18 (26.4)	58 (28.6)		
Sports-related	1 (9.1)	3 (13.0)	7 (15.2)	6 (10.9)	10 (14.7)	27 (13.3)		
Accidental fall	6 (54.5)	13 (56.5)	21 (45.7)	31 (56.4)	35 (51.5)	106 (52.2)		
Work accident	1 (9.1)	1 (4.4)	3 (6.5)	2 (3.6)	5 (7.4)	12 (5.9)		
						$\chi^2 = 101.9$, $P < 0.001$		

Continuous data are presented as the median (range) or mean ± SD; categorical data are presented as number (%)

In the C4/5 segment variant, the percentage rate of level of involvement gradually increased with age (27.9% for 16–30-year age group and 48.8% for those older than 75 years; Fig. 2). The C3/4 segment was the dominant level of involvement in 16–30-year age group.

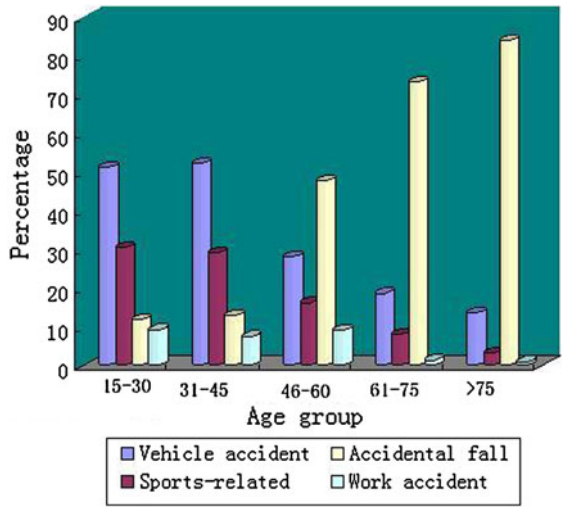

Fig. 1 Percentages of SCIWORA according to age groups by origin of injury in Tianjin, from 2004 to 2008 period

Injury severity

The extent of injuries was detected by dividing the neurological status and pattern into complete cord impairment (CCI), anterior cord syndrome (ACS), posterior cord syndrome (PCS), central cord syndrome (CCS), and Brown-Sequard syndrome (BSS). One hundred and two patients presented with CCS, indicating 50.2% of SCIWORAs

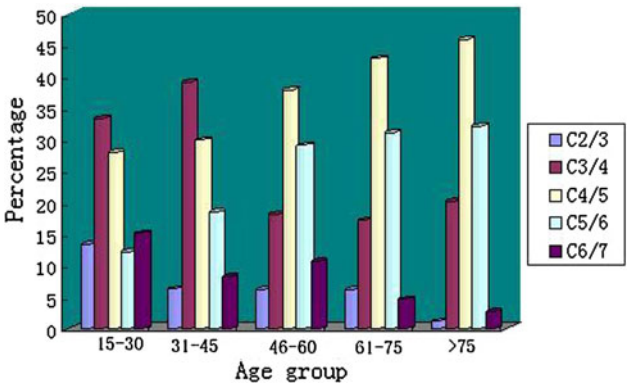

Fig. 2 Percentages of SCIWORA according to age groups by injury level in Tianjin, from 2004 to 2008 period

Table 2 Injury level and severity of patients with adult SCIWORA in Tianjin, China from 2004 to 2008

	2004	2005	2006	2007	2008	Total
Number of cases	11	23	46	55	68	203
Injury level						
C2/3	0	1 (4.4)	2 (4.3)	3 (5.5)	2 (3.0)	8 (4.0)
C3/4	2 (18.2)	3 (13.0)	5 (10.9)	6 (10.9)	10 (14.7)	26 (12.8)
C4/5	5 (45.4)	12 (52.1)	21 (45.7)	28 (50.9)	33 (48.5)	99 (48.7)
C5/6	3 (27.3)	6 (26.1)	15 (32.6)	18 (32.7)	20 (29.4)	62 (30.5)
C6/7	1 (9.1)	1 (4.4)	3 (6.5)	0	3 (4.4)	8 (4.0)
						$\chi^2 = 152.9$, $P < 0.001$
Severity						
CCI	3 (27.3)	6 (26.1)	13 (28.3)	20 (36.3)	24 (35.3)	66 (32.5)
ACS	1 (9.1)	1 (4.4)	3 (6.5)	4 (7.3)	3 (4.4)	12 (5.9)
PCS	0	1 (4.4)	2 (4.3)	3 (5.5)	2 (3.0)	8 (4.0)
CCS	6 (54.5)	12 (52.1)	23 (50.0)	28 (50.9)	33 (48.5)	102 (50.2)
BSS	1 (9.1)	3 (13.0)	5 (10.9)	0	6 (8.8)	15 (7.4)
						$\chi^2 = 171.2$, $P < 0.001$
ASIA scale						
A	3 (27.3)	6 (26.1)	13 (28.3)	20 (36.3)	24 (35.3)	66 (32.5)
B	5 (45.4)	9 (39.1)	16 (34.7)	19 (34.6)	28 (41.2)	77 (38.0)
C	1 (9.1)	3 (13.0)	5 (10.9)	12 (21.8)	15 (22.1)	36 (17.7)
D	2 (18.2)	5 (21.8)	12 (26.1)	4 (7.3)	1 (1.4)	24 (11.8)
						$\chi^2 = 36.5$, $P < 0.001$

CCI complete cord impairment, *ACS* anterior cord syndrome, *PCS* posterior cord syndrome, *CCS* central cord syndrome, *BSS* Brown-Sequard syndrome, *ASIA* American Spinal Injury Association

Continuous data are presented as the median (range) or mean ± SD; categorical data are presented as number (%)

($P < 0.001$), followed by CCI (32.5%), BSS (7.4%), ACS (5.9%), and PCS (4.0%).

The assessment of the ASIA scale is reflected in Table 2. Seventy-seven patients presented with ASIA grade B (38%), followed by grade A (32.5%), grade C (17.7%), and D (11.8%).

Radiographic characteristics

The radiographic findings revealed that cord minor hemorrhage was the most common feature on MRI, indicating 42.9% of all patients ($P < 0.001$). Other findings included 29.1% of marked hemorrhage, 24.1% of edema, and 3.9% of cord transaction. In addition, posterior longitudinal ligament tear (PLLT) was the most common pattern, accounting for 43.8% of soft tissue injuries ($P < 0.001$). Anterior longitudinal ligament tear (ALLT) was the second common pattern of injury, which indicated 25.1% of all cases (Table 3).

Discussion

Currently, most of the epidemiological investigations on SCIWORAs are performed in children. Pang [14] reported that the incidence of pediatric SCIWORA was about 13.7–18.9%. The cervical spine is the most frequently affected, followed by the thoracic region and lumbar spine [3, 10]. SCIWORAs are thought to represent a predominantly pediatric entity. However, the incidence of SCIWORAs in the adult population is relatively underreported. To date and to our knowledge, no local epidemiological research on adult SCIWORAs has been extensively carried out.

Cervical degeneration may play a critical role in the development of adult SCIWORAs [8, 9]. Most adult SCIWORAs present with degenerative manifestations, including cervical OPLL, cervical stenosis, and other degenerative factors. China, the largest developing country, and accounting for an estimated 25% of the world's population, has a high incidence of cervical degeneration, possibly because of the growth of aging in recent years [21, 23].

The range of incidence is directly related to population, patient age, and secondary degeneration. Gupta noted 15 adult SCIWORAs among 151 SCIs patients [20]. In addition, according to Ning's report [13], the total number of adult SCIs in Tianjin was 869 from 2004 to 2008. In our series, compared with other studies [22], the incidence rate of SCIs was about 5.74% per million population from 2004 to 2008. An increasing incidence of adult SCIWORAs in Tianjin was evident during the last 5 years. Therefore, with such a large population and rapid aging, the number of adult SCIWORAs in China could potentially increase.

Children up to 8 years of age and the elderly above the age of 60 years are more prone to develop SCIWORAs [6]. The mean age of patients in the present study was 55.9 ± 12.7 years, greater than that of other adult groups [20]. As far as the incidence age group was concerned, the age group with highest incidence was 46–60, followed by the 61–75-year age group. In Gupta's report [5], the age ranged from 20 to 60 years; it is important to note that Gupta's report was conducted in India. The slight difference might be explained by rapid aging of the whole population of China.

Table 3 Radiographic characteristics on MRI findings of patients with adult SCIWORA in Tianjin, China from 2004 to 2008

	2004	2005	2006	2007	2008	Total
Number of cases	11	23	46	55	68	203
Cord lesion types						
Edema	2 (18.2)	6 (26.1)	11 (24.0)	10 (18.2)	20 (29.4)	49 (24.1)
Minor hemorrhage	5 (45.4)	11 (47.8)	22 (47.8)	25 (45.5)	24 (35.3)	87 (42.9)
Marked hemorrhage	3 (27.3)	4 (17.4)	10 (21.7)	20 (36.3)	22 (32.3)	59 (29.1)
Transection	1 (9.1)	2 (8.7)	3 (6.5)	0	2 (3.0)	8 (3.9)
						$\chi^2 = 63.3$, $P < 0.001$
Soft tissue injuries						
ALLT	2 (18.2)	6 (26.1)	10 (21.7)	15 (27.2)	18 (26.4)	51 (25.1)
PLLT	6 (54.5)	11 (47.8)	18 (39.1)	23 (41.8)	31 (45.6)	89 (43.8)
IDR	1 (9.1)	4 (17.4)	9 (19.6)	11 (20.0)	13 (19.1)	38 (18.7)
ASB	1 (9.1)	0	5 (10.9)	3 (5.5)	4 (5.9)	13 (6.4)
WSTT	1 (9.1)	2 (8.7)	4 (8.7)	3 (5.5)	2 (3.0)	12 (6.0)
						$\chi^2 = 99.4$, $P < 0.001$

ALLT anterior longitudinal ligament tear, *PLLT* posterior longitudinal ligament tear, *IDR* intervertebral disc rupture, *ASB* anterior spaces bruise, *WSTT* without soft tissue injuries

Continuous data are presented as the median (range) or mean ± SD; categorical data are presented as number (%)

Pediatric SCIWORA is more often related to high-energy injuries [15]. In Launary's meta-analysis [10], the most common cause of injury was motor vehicle accident, followed by fall from height. However, in our series, accidental falls were the predominant cause of SCIWORAs, different from that of the pediatric group. The origins of trauma in the present study were related to low-energy injuries, and accidental fall was the leading cause of injury among adult groups.

Sports-related injury is another common cause of pediatric SCIWORAs. In older children, especially adolescents, SCIWORA is most commonly related to athletic competition [1]. Compared with developed countries, many kinds of sports are not popular in Chinese communities, such as diving, baseball, and cycle racing. Most of the major sports in China are not rigorous, such as taiji, yoga, and badminton. Thus, the incidence rates due to sports-related injury were comparatively lower, possibly owing to the unpopularity of risky sports in China.

The injury level of SCIWORAs depends not only upon the patient age, but also the characteristics of the spine. In the pediatric group, the proportionally bigger head and the underdeveloped neck musculature predispose young children to external forces beyond physiological endurance without bony disruption. The laxity of the ligament, horizontal articulation of the facet joints, and anterior wedging of the vertebral body also contributes to the susceptibility [11]. For younger children (average age 6.9 years), the most affected level of spinal injuries is generally C2, followed by T10 [17]. However, in this study, the most affected level was C4/5, followed by C5/6 and C3/4. The characteristics of injury level distribution among the adult groups were similar to that of cervical myelopathy. For the adult population, especially in Asian countries, the most prevalent predominant level of cervical myelopathy or spondylosis is C4/5, followed by C5/6 and C3/4 [12, 19]. The characteristics of injury level distribution due to the age group indirectly reveal that, secondary degeneration may participate in the onset of adult SCIWORA.

MRI remains the most efficient tool for evaluating the development of SCIWORAs [4]. Differing from other reports, soft tissue injuries in our series, especially PLLT, were commonly seen on MRI. Consistent with MRI characteristics, CCS was the major pattern among adult groups, and most of the CCSs were accompanied with the PLLT. Therefore, of injury severity and radiographic features indicated in the present study, hyperextension injury was the dominant mechanism of cervical SCIWORAs.

Sometimes, conventional MRI examination can fail to detect potential cord lesions, including invisible hematomas, contusions, and hemorrhages. On the other hand, some adult patients that were categorized as SCIWORA prior to the MRI examination were found to have specific lesions in the spinal cord. Under these conditions, conventional MRI images could not differentiate secondary lesions from primary ones. In Yucesoy's opinion [24], the real SCIWORAs should be termed as "spinal cord injury without neuroimaging abnormality". Those cases with negative MRI results should be evaluated carefully. Diffusion-weighted MRI may play a major role in detecting suspected real SCIWORA cases.

There are some limitations of the present study, which should be highlighted. Unfortunately, negative MRI results had not been accepted in our inclusion criteria, and this became one of the shortcomings. It is difficult to perform statistical analyses for those spinal injuries with negative MRI images. Although conventional MRI plays a critical role in diagnosing adult SCIWORAs, the question remains, should it be replaced with diffusion-weighted MRI as a routine? Secondly, it is difficult to confirm the exact interrelationship between cord damage type and soft tissue injury pattern, due to the complexity of the injury mechanism.

Overall, this study demonstrated that the epidemiological properties of adult SCIWORA were different from that of the pediatric group. This study helped us to deepen the understanding of the essence of adult SCIWORAs. However, some issues are still unexplained, such as what are the differences of radiographic feature between adult and pediatric groups? In addition, the epidemiological differences of adult SCIWORA between Western and far East countries are still unclear. The ongoing investigation of these topics is of critical importance in probing the pathogenesis of adult SCIWORAs.

Conclusions

In summary, this study highlights the epidemiological properties of adult SCIWORA in Tianjin, China. Differing from other reports on adult SCIWORA, particularly for epidemiological studies, this is the first report from a developing country. For the analysis of radiological-clinical features of every SCIWORA case, it is very important to set up an individualized evaluation system. As the aging of the general population continues, a registry system for adult SCIWORA, particularly including the management guidelines should be individually established.

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Conflict of interest The authors declare that they have no conflict of interest.

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