SCIENTIFIC ARTICLE

Is there unique difference in the type of renal stones in Northern Sri Lanka? Analysis of chemical composition of renal stones in Jaffna by infrared spectroscopy

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Keywords: Renal stone; chemical composition; Staghorn & Non staghorn calculi

Abstract

Introduction

Renal stone disease is a common clinical problem in surgical practice. Renal stone is a common cause for obstructive uropathy and renal impairment. Because of differing "aetio-pathology", kidney stones are usually mixtures of two or three or more chemical components. Analysis of chemical composition and type of renal stone could aid in the prevention and management of stone formation and its recurrence. The comparison of the prevalence of renal stone types in Northern Sri Lanka with other geographical regions can help in the identification of possible environmental "geo-chemical" factors associated with nephrolithiasis.

Objective

The objective of this study was to analyse the chemical composition of renal stones in Jaffna by infrared spectroscopy. Age and gender of patients who had surgical intervention for renal stones and type and morphology of renal stones were considered for analysis.

Study design

This is an institutional based prospective "cross-sectional" analytic study. Following ethical approval, clinical profiles of patients were recorded. Chemical composition and type of the stones were analysed. Different stone types and stone morphologies were compared with available local and international data.

Results

A total of 104 patients were surgically treated for nephrolithiasis during the study period. Their "ages" ranged from 20-70 years with the mean age of 48.21 years [SD 14.43]. Among them 77 [74%] were males and 27[26%] were females. Calcium oxalate, carbonate apatite, uric acid, cystine, struvite and calcium carbonate types of renal stones were found in 79 [75.9%], 7[6.7%],14[13.5%], 1[1%] 2[1.9%] and 1[1%] patients respectively. 86[83%] patients had pure stones and 18 [17%] had mixed stones. Staghorn calculi were found in 23 [22.1%] patients and non-staghorn calculi were found in 81 [77.9%] patients. Among the staghorn calculi, 16 [69.6%] were calcium oxalate and among the non-staghorn calculi 64 [79%] were calcium oxalate. Among 14 patients who had uric acid stone 10 of them had type II diabetes.

Conclusion

Calcium oxalate is the commonest renal stone type in Jaffna. Prevalence of uric acid type renal stone has increased in Jaffna over three decades.

Introduction

The prevalence of urolithiasis is influenced by dietary pattern, environment, and social factors such as ethnicity and heredity. Those countries that have the stone prevalence between 10-15% lie in the "Stone Belt" extending across the world [1]. Sri Lanka, with its water, diet pattern and social conditions fits into the stone belt in Asia. Renal stone is a common cause for obstructive uropathy and renal impairment in Sri Lanka and it has a significant impact on health care system [2].

The chemical composition of renal stones varies in different countries. Although there is no convincing evidence yet, it is anecdotally considered that the prevalence of renal stones is high in certain parts of dry zones in Sri Lanka. The fluoride content of water in the wells of dry zone may contribute to increased renal stone formation [3].Comparison of chemical composition of kidney stones in Northern Sri Lanka with other geographical regions can identify environmental "geo chemical" factors associated with nephrolithiasis .

Treatment and prevention of stone formation and its recurrence could be based on the results of analysis of chemical composition of kidney stones [4].The aim of the study is to assess the different chemical compositions of renal stones in Jaffna by "Fourier transform" infrared spectroscopy and to compare the renal stone types with national and international data to find out any unique difference in type of renal stones in Northern Sri Lanka.

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Methodology

This is an institutional based "cross sectional" analytic study carried out on patients treated surgically for renal stones in urology and general surgical wards of Teaching Hospital, Jaffna from July 2016 to June 2018. Patients not residing in Jaffna for more than 10 years were excluded from the study. Approval for this study was obtained from the Ethical Review Committee of Faculty of Medicine, University of Jaffna. Informed written consent was obtained from participants. Analysis of composition of renal stones was performed using "Fourier transform" infrared spectroscopy [FT-IR].

A research grant was obtained from the University of Jaffna to meet the cost of stone analysis. Chi square test was used for statistical analysis and $p < 0.05$ was considered statistically significant.

Results

A total of 104 patients were surgically treated for renal stones during the approved period of study. The surgical treatment included open surgery and endoscopic stone treatment. Mean age of patients was 48.21 [SD 14.43], with the range of 20-75years. 77[74%] were males, 27[26%] were females and the male: female ratio was 2.85:1.

Figure1 shows the distribution of renal stones based on gender and age groups of patients in this study. Different combinations of chemical compositions of renal stones were detected by "Fourier transform" infrared spectroscopy. The details of the chemical composition of renal stones in this study are illustrated in Table (1).

Type of renal stones was identified from the percentage of chemical composition described by Abdel-Halim et al. A renal stone will be classified as "uric acid stone" when it contains more than 20% uric acid as component composition. The stone that contains more than 40% oxalate will be classified as "oxalate stone". The renal stone that is made up of more than 10% phosphate and less than 40% oxalate and less than 20% uric acid will be labelled as "phosphate stone" [5]. A renal stone that has more than 3% magnesium will be classified as "struvite stone" [infection stone or magnesium ammonium phosphate hexa hydrate] [5]. The distribution of type of renal stones among surgically treated patients in Jaffna is illustrated in Figure 2.

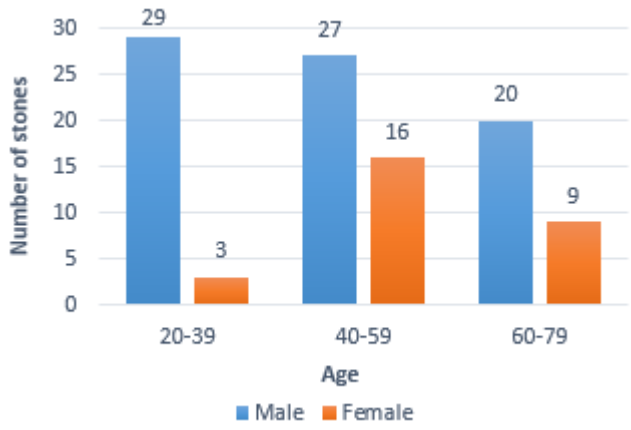

Figure 1. Distribution of renal stones based on gender and age groups

Table 1. Distribution of renal stones based on chemical composition

Compositions	Number
COM+COD	67
COM + COD + CA	10
COM + UA	3
COM + CA	1
COM + CA + MAP	2
AH + CHP + MHP	1
PCHP + AH	1
UA	13
CA	5
Cys	1
Total	**104**

COM - Calcium oxalate monohydrate
COD - Calcium oxalate dihydrate
CA - Carbonate apatite
UA - Uric acid
MAP - Magnesium ammonium phosphate hexahydrate
AH - Ammonium hydrogen urate
CHP - Calcium hydrogen phosphate
MHP - Magnesium hydrogen phosphate
PCHP- Penta calcium hydroxidphosphate
Cys - Cystine

The age and gender distribution of different types of renal stones were analysed (Figure 3 & Figure 4). The association between the type of stone with gender [p = 0.16] or with age group of patients [p = 0.897] were not statistically significant.

Morphology of renal stones was analysed. There were 23 staghorn calculi and 81non staghorn calculi. The association between the morphology of stone with gender or with age group of patients was not statistically significant (Figure 5 & Table 2).

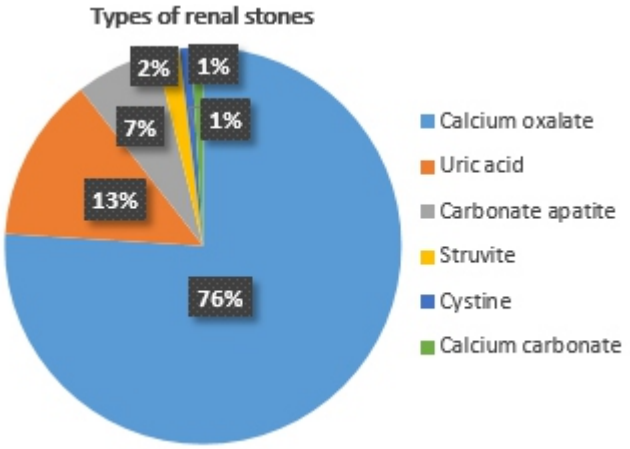

Figure 2. Distribution of renal stone types among surgically treated patients

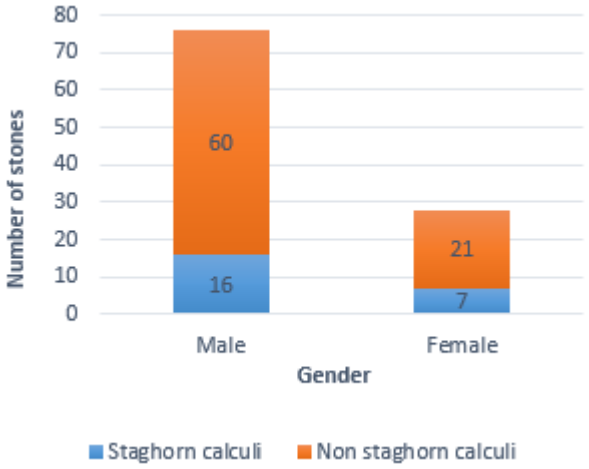

Figure 5. Gender distribution of patients among the staghorn and non-staghorn calculi

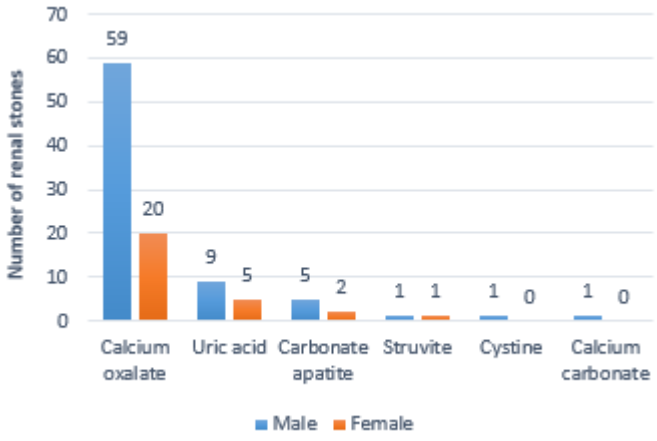

Figure 3. Gender distribution of patients among renal stone types

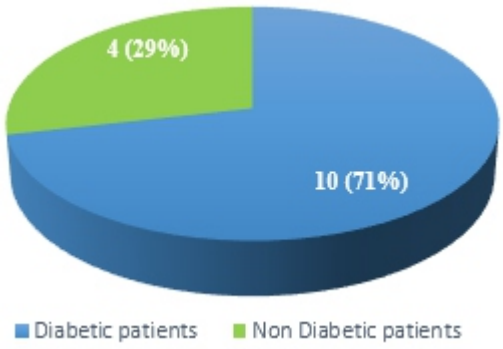

Figure 6. Distribution of uric acid stones among diabetic and non diabetic patients in Jaffna

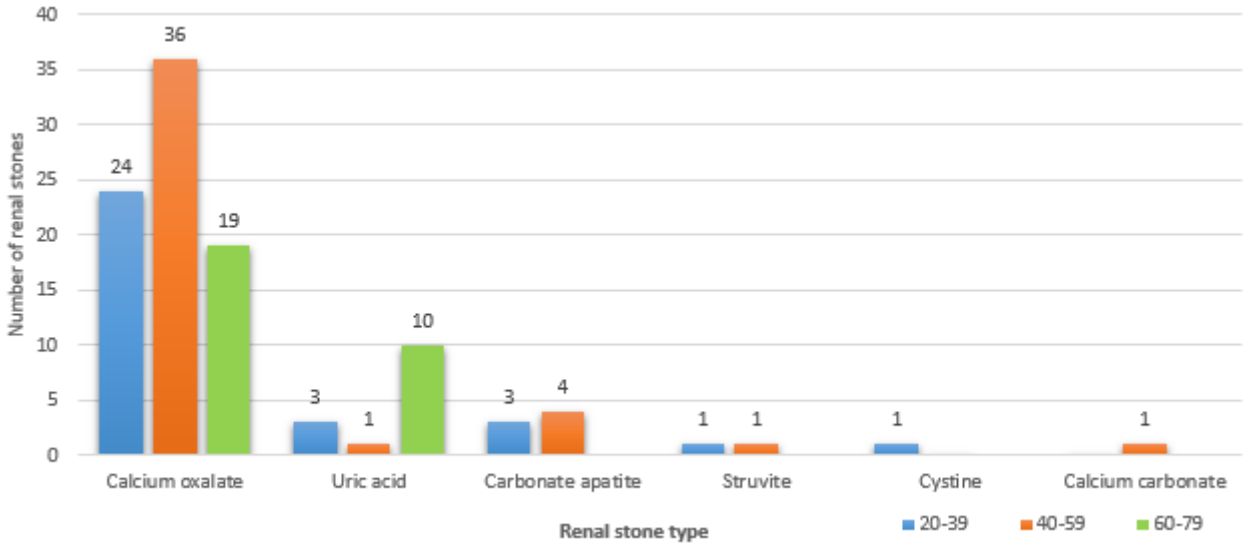

Figure 4. Distribution of renal stone types among age groups of patients

Table 2. Distribution of staghorn and "Non-staghorn" calculi in different age group of patients

Age group	Staghorn calculi	Non staghorn calculi
20-39	4	28
40-59	12	31
60-79	7	22
Total	23	81

Table 3. Distribution of renal stone types among staghorn and non-staghorn calculi

Renal stone type	Staghorn calculi (n=23)		Non staghorn calculi (n=81)	
Calcium oxalate	16	(69.6%)	63	(77.8%)
Uric acid	3	(13.0%)	11	(13.6%)
Struvite			2	(2.5%)
Cystine			1	(1.2%)
Carbonate apatite	3	(13.0%)	4	(4.9%)
Calcium carbonate	1	(4.4%)		

Table 4. metabolic evaluation of patients with uric acid stones

Metabolic parameter	Mean	Reference Range
Uric acid - serum	4.8375	2.6-6.0 mg / dL
Urine volume	1493.75	1100-2050ml
Uric acid – 24hr urine	396.8388	250.0-750.0 mg

Distribution of types of renal stone among staghorn and non-staghorn calculi was analysed. Calcium oxalate was the predominant type of renal stone among both morphological forms. The different renal stone types identified among the two morphological forms are shown in Table (3).

The prevalence of uric acid type of renal stones was found to be relatively high in Jaffna. Thus a metabolic evaluation of patients who had uric acid stones was performed. The results of the metabolic evaluation are given in Table (4). Many patients who had uric acid stones in Jaffna were type II diabetics. Figure 6 shows the distribution of uric acid stones among diabetic and "non diabetic" patients.

Discussion

Epidemiology of renal stone disease

The prevalence of kidney stone disease in developed countries is 4-20% [6]. The prevalence of this condition in adults in Saudi Arabia, North America, Europe, and Asia are 20%, 13%, 5-9% and 1-5% respectively. The incidence of kidney stone disease in males is 2.2 -3.4 times higher than in females. The incidence in females is increasing because of change in food habit, obesity and reduction in fluid intake [7]. 77 men underwent surgical removal of renal stone and the male: female ratio was 2.85:1. More patients in the age group of 40-59 years in this study had surgical intervention for renal stones. In a study done at national level in Colombo in a cohort of 50 patients surgically treated for renal stones, more patients were in the 40-60 years age group and male: female ratio was 2.6:1[8]. So this study in Jaffna has epidemiological resemblance to the study performed at national level.

Chemical composition of renal stones in the management of urolithiasis

Crystallization of chemical components and subsequent kidney stone formation occur in the presence of certain risk factors. Identification of chemical composition of kidney stone would be a "biochemical biopsy" of urinary environment during the event of crystal deposition. So this will allow identification of risk factors. Knowing the risk factors and thus the possible aetiology of renal stone type can aid in the preventive measures for their recurrence [9].

Analysis of chemical composition of renal stones

Wet chemical analysis is a simple lab technique for qualitative or quantitative assessment of renal stone. There are other sophisticated techniques available for renal stone analysis. Their cost will differ. Infrared spectroscopy, X-ray diffraction crystallography, thermogravimetry and polarized microscopy are some of them [9]

Fourier transform infrared spectroscopy [FT-IR] is considered to be the standard technique for chemical analysis of kidney stones. This technique is not only specific, but provides reliable quantitative analysis and thus characterizes any stone sample [7]. FT-IR was used to analyse chemical composition of renal stones in Jaffna in this study.

Prevalence of type of renal stones in Jaffna

Among the 104 patients, 79 patients [75.9%] had calcium oxalate and 14 patients [13.5%] had uric acid type of renal stones. Carbonate apatite, cystine, struvite and calcium carbonate types of renal stones were found in 7[6.7%], 1[1%]

Table 5. Prevalence of renal stone types in different regions

Renal stone type & the analytic method	Jaffna [FT-IR]	Colombo [Chemical method]	India [XRD]	China [FT-IR]	Iraq [XRD]	USA [FT-IR]
Calcium oxalate	77.9%	86%	93%	62.5%	46.1%	26%
Uric acid	15.4%	0	0.93%	12.5%	15.4%	5%
Cystine	1%	0				2%
Struvite	1.9%	2%	1.4%	12.5%	38.4%	22%

Table 6. Comparison of prevalence of chemical composition of renal stone in Jaffna over three decades

Chemical Composition of renal stone	T.Saravanapavananthan [1988] Number of patients	Current study [2018] Number of patients
COM + COD		67
COM + COD + CA		10
COM + UA		3
COM + CA	1	1
COM + CA + MAP	2	2
AH + CHP + MHP		1
PCHP + AH		1
UA		13
CA	2	5
Cys		1
COM	11	
COM + MAP + UA	2	
CC	1	
COM + CA + MAP + UA	1	
Total	**20**	**104**

2[1.9%] and 1[1%] patients respectively. 86[83%] patients had pure stones and 18 [17%] had mixed stones.

When the renal stone composition is identified the possible risk factors could be searched for the aetiology. Low urine volume is a common risk factor for urolithiasis as it increases super saturation and enhances stasis [10]. Patients who have calcium oxalate stones or a combination of calcium oxalate/phosphate stones could be investigated for risk factors such as hypercalciuria, hyperoxaluria, hyperuricosuria and hypocitraturia. Dietary modifications and medical intervention for specific risk factors could then be tailored to individual patients to prevent recurrent stone formation [11]. A low urine pH [< 6], hyperuricosuria /hyperuricaemia and metabolic syndrome are recognized risk factors for uric acid type renal stone formation [11]. Among 14 patients who had uric acid type renal stones in this study, 10 of them had type II diabetes indicating possible role of metabolic syndrome in the aetiopathology of uric acid stones.

Apart from patient related risk factors, collection of epidemiological data about environmental risk factors for renal stones may be useful for the assessment of existing prevalence of renal stone composition in Sri Lanka [3].

Renal stone types -National, regional and international comparison

Table (5) compares the prevalence of renal stone types in different regions. Although different analytical methods were used in the above studies, the calcium oxalate type renal stones were the commonest renal stones in Asian countries [8, 12, 7, 13, 14]. The urinary stones having mixed composition [mixed stones] were not compared in Table (5). A prospective study carried out on 50 stone samples obtained from a cohort of Sri Lankan patients during 2012-13, revealed 86% of renal stones consisted of calcium oxalate [8].

In another study among Sri Lankan population on mineralogical, compositional and isotope characterization of kidney stones, the majority had calcium oxalate type renal stones. This study revealed that the oxalate stones are well crystallized compared to other stones by analysing with scanning electron microscope [SEM] and X-ray diffraction crystallography [XRD]. Depleted values for the carbon isotope in renal stones were observed in Sri Lanka when compared with western world. This could be due to the dietary pattern where rice is a major component of the daily diet [15].

The most common type of renal stone varied between provinces in Iraq. These geographical differences were attributed to the variations in lithogenic and the climatological factors [12]. The composition of renal stones did not vary in different climate zones of Sri Lanka [8].

Morphology of renal stones – Staghorn Vs non- staghorn

A staghorn calculus is a stone that occupies the renal pelvis and extends into at least two major calyceal systems [16]. Staghorn calculi are associated with difficulties in operative removal and post-operative sepsis [8].

In this study, there were 23 staghorn [22.1%] and 81[77.9%] non staghorn type renal stones. The morphology of the renal stone [staghorn and non-staghorn] did not show statistically significant association with gender or with the age group of patients. In a study done at national level in Colombo, there were 21 [42%] staghorn and 29 [52%] non staghorn renal stones [8].

In western countries about 60-75% staghorn calculi are struvite stones ["infective stones"] [17]. In our study 69% of staghorn calculi had calcium oxalate and none of the staghorn calculi had struvite. In the study done at national level in Colombo, 5% staghorn calculi contained struvite and 76% had calcium oxalate [8]. In India 4.02% of staghorn calculi were composed of struvite stone [12]. Since there is a striking difference in the predominant type of renal stones with staghorn morphology in loco-regional and the western world, the aetiology of staghorn calculi must be different in these regions. This has an impact on the management of patients with renal stones. The extent of renal tissue injury by longstanding oxalate stones is minimal when compared to that occurring with struvite stone [8]

In this study [in Jaffna], 64 non-staghorn renal stones [79%] were calcium oxalate type of stones whereas in the study done at national level [in Colombo], 27 non-staghorn renal stones [93%] were calcium oxalate type stones [8].

Renal stone composition in Jaffna – has it changed over three decades [1988 to 2018]

Prevalence of type of renal stones differs between different countries and can change in the same country over time. The prevalence of calcium oxalate stones has increased from 26% to 82% while the prevalence of struvite stones has decreased from 20% to 5% in India over three decades [4].

The first study on chemical composition on renal stones in Sri Lanka was carried out in Northern Sri Lanka during 1983-86 and was published in 1988 [18]. It was carried out in a small sample using a different method to analyse the stones. Twenty renal stones were analysed for chemical composition using wet chemical analysis. In that study the percentage of each component composition in each of the renal stone was not clearly mentioned. Therefore it is difficult to derive the type of renal stone using the guide described by Abdel-Halim et al [5].

The results of that study and the results of chemical composition of renal stones in the current study are given in Table (6) for comparison.

In the study on urinary calculi in Jaffna by T.Saravanapavananthan et al. during 1983-86 [published in 1988], calcium oxalate, calcium phosphate and calcium carbonate were found in 55%, 10% and 5 % of renal stones respectively. Two renal stones were found to be mixed uric acid stones. The current study on chemical composition of renal stones in Jaffna in 2018, demonstrated the presence of calcium oxalate in 77.9% of renal stones and uric acid in 15.4% of renal stones. Among the uric acid stones there were 13 pure uric acid stones and 3 mixed uric acid stones [Uric acid + Calcium Oxalate Mono hydrate].

While the prevalence of calcium oxalate stones remained the predominant renal stone in Jaffna, the prevalence of uric acid stones has shown a steep increase in Jaffna over thirty years. The sensitivity of analysis method, used to detect uric acid stone 30 years ago, might also be responsible for this difference.

Unique difference in composition of renal stone in Northern Sri Lanka

Hareendra et al mention about the hardly observable presence of uric acid stones in the study on chemical composition of kidney stones obtained from a cohort of Sri Lankan patients [8]. Furthermore Chandrajith et al demonstrated 5% uric acid stones in the study on mineralogical, compositional and isotope characterization of human kidney stones in a Sri Lankan population [15]. In this study (in Jaffna) 15.4% of renal stones were uric acid type stones. Since there is relatively higher prevalence of uric acid stones in Jaffna, it is important to perform metabolic evaluation of patients with uric acid stones.

Low urine volume and low pH of urine play major role in the pathogenesis of uric acid stones [11, 19]. Risk of formation of uric acid stone increases when there is underlying metabolic disorders such as metabolic syndrome and diabetes mellitus. Insulin resistance impairs glutamine metabolism and reduces the ammonium excretion by renal tubular cells. So the hydrogen ions in the glomerular filtrate will not be buffered adequately. The resulting low urine pH enhances uric acid nephrolithiasis [20].

Conclusions

Calcium oxalate is the predominant renal stone type in Jaffna and it is the common type of renal stone in both staghorn and non-staghorn morphological forms. Calcium oxalate remained the most prevalent type of renal stone in Jaffna over 30 years. Prevalence of many renal stone types in Jaffna was found to be comparable to the prevalence found in other regions of Sri Lanka.

The uric acid type renal stones have shown increase in prevalence in Jaffna over three decades. The prevalence of uric acid stone in Jaffna is relatively higher than in other regions in Sri Lanka based on the available publications on renal stone disease.

Recommendation

Nationwide large population study is warranted to identify the prevalence of renal stone types in Sri Lanka and the regional variations.

Acknowledgement

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