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Original Article

Association between inflammatory diseases and connective tissue disorders with atrial fibrillation/flutter

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Abstract: Background: The role of inflammatory disease in the occurrence of atrial fibrillation/flutter (AF/AFL) is not well studied. Objective: The goal of this study was to evaluate any association between inflammatory and autoimmune disorders with the occurrences of AF/AFL using a large database. Methods: Using the Nationwide Inpatient Sample (NIS) database and ICD-10 codes for AF/AFL and several inflammatory diseases for the years 2016-2020, we evaluated the above association. Results: A total of 23,037,013 patients were identified with a diagnosis of AF/AFL. The following diseases were independently associated with the presence of AF/AFL despite adjustment for age, demographics, and traditional risk factors: rheumatoid arthritis: OR: 1.05, CI 1.04-1.06, P<0.001, systemic sclerosis OR: 1.31, CI 1.26-1.36, P<0.001, systemic connective tissue disorders: OR: 1.07, CI 1.05-1.08, P<0.001, antiphospholipid syndrome: OR: 1.36, CI: 1.31-1.42, P<001, systemic lupus erythematosus: OR: 1.15, CI: 1.13-1.17, P<0.001 and Raynaud's syndrome: OR: 1.1, CI: 1.07-1.13, P<0.001. Ankylosing spondylitis was not found to be associated with AF/AFL. Conclusion: Using a large inpatient database, we found that some common inflammatory diseases and connective tissue disorders are independently associated with the presence of AF/AFL. Our findings are hypothesis-generating, requiring confirmation in prospective controlled trials.

Keywords: Atrial fibrillation, atrial flutter, risk factors, arrhythmia, inflammation, autoimmune disorders, systemic, systemic connective tissue disorders, antiphospholipid syndrome, systemic lupus erythematosus

Introduction

There is a collection of heterogeneous diseases referred to as immune-mediated inflammatory diseases that share a common biological mechanism related to inflammatory pathways and cytokine dysregulation [1]. Some examples of these inflammatory diseases include rheumatoid arthritis, systemic sclerosis, systemic connective tissue disorders, antiphospholipid syndrome, and systemic lupus erythematosus. Immune-mediated inflammatory diseases such as these often co-occur, and these patients are more likely to have another immune-mediated inflammatory disease compared to those without any [2].

Many studies have shown a significant association between immune-mediated inflammatory diseases and rates of cardiovascular mortality for a variety of reasons such as the role of the immune system in the development of atherosclerosis [3]. A 2024 meta-analysis which included a total of 24,107,072 patients concluded that patients with systemic autoimmune diseases present with increased risk of cardiovascular morbidity and mortality [4]. Cardiovascular events that were reported among these patients included cardiovascular mortality, non-fatal myocardial infarction, non-fatal stroke, and coronary revascularization [4]. Additionally, a population-based study which identified individuals with autoimmune disease and matched individuals without autoimmune disease found that the incidence rate of cardiovascular disease was greater in those with autoimmune disease compared to those without (23.3 events per 1000 patient-years vs. 15.0 events per 1000 patient years) [5]. Many patients with autoimmune inflammatory disease also have co-existing cardiovascular disease risk factors such as arterial hypertension and dyslipidemia [6].

Treatment of inflammatory diseases can also affect the occurrence of cardiovascular events. Glucocorticoids and oral non-steroidal anti-inflammatories are frequently used in this patient population. Some adverse effects of glucocorticoids include dyslipidemia and hypertension which are known risk factors for cardiovascular disease [7]. Another therapeutic option for autoimmune diseases includes disease-modifying antirheumatic drugs (DMARDs), such as Methotrexate. Methotrexate has been shown to have protective effects against atherosclerosis with several studies showing that Methotrexate use in patients with autoimmune diseases such as rheumatoid arthritis was "associated with a significant reduction of cardiovascular and all-cause mortality [8]". Medications such as Methotrexate are efficacious in controlling autoimmune disease activity. Control of patients' disease may translate to meaningful reductions in cardiovascular mortality. However, this may not be true for other immunomodulatory and anti-inflammatory agents. For example, one study showed that JAK Inhibitors can increase the risk of developing thromboembolic events [9] which may pose increased risk in those with a history of cardiovascular disease. The cardiovascular benefits of these therapies appear to correlate with the degree of inflammatory disease control that is achieved.

Atrial fibrillation (AF) is the most common cardiac arrhythmia, and the incidence of AF continues to increase [10]. AF has also been found to be an independent risk factor for all-cause mortality in patients with incident AF [11]. A literature review from 2021 discussed the relationship between inflammation and the development and propagation of AF [12]. This relationship was determined when observing that inflammatory cardiac conditions such as myocarditis and pericarditis are often associated with AF [12]. Recent literature discusses the role of autoimmune cardiac channelopathies in the development of arrhythmias such as AF. A 2025 review discussed a "multi-hit" theory, which proposes that anti-cardiac ion channel autoantibodies alone might not cause arrhythmias but play a role in their development [13].

While the relationship between autoimmune inflammatory disease and atherosclerosis is well established, the relationship between autoimmune inflammatory disease and AF is not as extensively studied. A recent systematic review and meta-analysis concluded that patients with inflammatory bowel disease (IBD) are at nearly 1.5 times the risk of developing AF compared to the non-IBD population [14]. It is suggested that the link between IBD and AF may be related to the role of systemic inflammation [14] and medications used to treat IBD [15]. Another systematic review concluded that patients with psoriasis are at higher risk for the development of AF [16]. The role of inflammatory cytokines in the development of arrhythmias has also been researched in experimental studies. In a 2023 review, several cytokines, including TNF, IL-1, IL-6, and IL-17 were discussed as enhancing arrhythmia susceptibility [17].

Our study aims to expand on this literature and evaluate any association between inflammatory and autoimmune diseases and connective tissue disorders with the presence of AF/AFL using a large national inpatient database.

Methods

Data source

Patient data for this study was obtained from the Nationwide Inpatient Sample (NIS) database. Data was evaluated from the years 2016 to 2020. The NIS is a component of the Healthcare Cost and Utilization Project (HCUP), which is sponsored by the Agency for Healthcare Research and Quality (AHRQ). The NIS database accounts for admissions across approximately 1,000 hospitals. Data from the NIS database is publicly available to researchers at www.hcup-us.ahrq.gov and is de-identified. Therefore, this study was exempt from Institutional Review Board (IRB) approval. The research reported in this paper adhered to Human research Helsinki Declaration as revised in 2013X guidelines. For multivariate analysis, we used commonly known cardiovascular risk factors.

Data origin: The primary source is administrative billing data from hospital discharge abstracts. It includes clinical data (diagnoses and procedures using ICD-10-CM/PCS codes) and resource use data (total charges, length of stay, and payer information). State Inpatient Databases (SID): Individual hospitals submit

their billing data to Statewide Data Organizations. These state organizations (HCUP Partners) then provide the data to AHRQ for inclusion in the HCUP project. The sampling frame currently includes 48 statewide data organizations, covering 3. National Sampling & Redesign (2012). The method for creating the final NIS research sample changed significantly in 2012 to improve national estimates.

Current design (Post-2012): It is a systematic 20% sample of discharge records drawn from all hospitals in the sampling frame. Prior Design (Pre-2012): It was a sample of 20% of hospitals, where all discharges from those specific hospitals were retained. Sampling is stratified by hospital characteristics such as ownership, bed size, teaching status, urban/rural location, and U.S. Census division. De-identification: To protect patient and hospital privacy, the data is non-identifiable and generally considered IRB exempt for researchers. Each record is assigned a "discharge weight" that researchers used to calculate national estimates from the 20% sample. Access: Researchers must purchase the data through the HCUP Central Distributor, complete an online Data Use Agreement (DUA) Training, and sign a legal agreement. These resources explain the National Inpatient Sample (NIS) database's collection process, sampling design, and its use in clinical research.

Data collection

The NIS database records patients' reasons for hospitalization using ICD-10 (International Classification of Diseases, 10th Revision) billing codes. In our search, we extracted relevant patient demographics by searching for specific ICD-10 billing codes. We began by identifying all patients who were admitted to NIS-affiliated hospitals from 2016 to 2020. From the total patients identified, we then identified patients with a diagnosis of atrial fibrillation/flutter (AF/AFL) and without AF/AFL. For inflammatory and connective tissue disorders, we used the following ICD-10 coding: For AF/AFL: I48, I48.0, I48.1, I48.11, I48.19, I48.2, I48.20, I48.21, I48.3, I48.4, I48.9, I48.91, I48.92. We also used ICD-10 codes to identify patients with specific autoimmune inflammatory diseases including rheumatoid arthritis (M05, M06), systemic sclerosis (M34), systemic connective tissue disorders (M35), gout (M10), arthropathic psoriasis (L40.50), polyarteritis nodosa (M30), Raynaud's syndrome (I73.0), Buerger's disease (I73.1), ankylosing spondylitis (M45), antiphospholipid syndrome (D68.61, D68.312), and systemic lupus erythematosus (M32.10, M32.11, M32.12, M32.14, M32.15, M32.19, M32.8, M32.9). The association was evaluated by assessing the presence of inflammatory disease diagnoses, identified through the above ICD billing codes, among patients with and without AF/AFL. Inclusion criteria consisted of adult patients (greater than or equal to 18 years old) reported in the NIS database during the study period of 2016-2020. Exclusion criteria included patients under the age of 18. A multivariate analysis was also conducted, adjusting for age, gender, race, alcohol use, and well-known cardiac risk factors including coronary artery disease (CAD), smoking, type 2 diabetes, hypertension, hyperlipidemia, chronic kidney disease (CKD), and chronic obstructive pulmonary disease (COPD).

Statistical analysis

Patient demographic, clinical, and hospital characteristics are reported as medians with interquartile ranges (IQRs) for continuous variables and proportions with 95% confidence intervals for categorical variables. Uni and multivariate logistic regression were performed, adjusting for baseline characteristics and comorbid conditions to study the independent association. All *p*-values were two-sided, and $P<0.05$ was considered statistically significant. Data were analyzed using STATA 17 (Stata Corporation, College Station, TX).

Results

A total of 148,767,786 individuals were identified in the NIS database from the years 2016 to 2020. 23,037,013 patients were identified as having a diagnosis of AF/AFL. 125,730,773 patients were included who did not have a diagnosis of AF/AFL. The mean age of patients in the study was 58.00±20.23 years old. The mean age of patients with AF/AFL in this study was 74.82±11.83 years old. There was a slight female predominance of patients included in this sample, with 57.32% female patients in the total sample. However, of the individuals who had AF/AFL, only 46.66% were female. The sample included primarily white individuals

Table 1. Demographic characteristics of population

Demographic information	Total	Atrial Fibrillation & Flutter	Other	*P*-value	Odds Ratio (95% C.I.)
Age				<0.001	
Mean ± SD	58.00±20.23	74.82±11.83	54.92±19.93		
Median (IQR)	61 (41-74)	77 (67-84)	57 (37-71)		
LOS				<0.001	
Mean ± SD	5±7	6±7	5±6		
Median (IQR)	3 (2-5)	4 (2-7)	3 (2-5)		
Total Charges $				<0.001	
Mean ± SD	5718±96852	73246±117348	54516±92311		
Median (IQR)	32666 (1740-63364)	40654 (21597.5-81032)	31389 (16813-60490)		
Gender					
Male	42.69%	53.34%	40.74%		
Female	57.31%	46.66%	59.26%	<0.001	0.60 (0.60-0.60)
Race					
White	67.00%	80.38%	64.53%		REF
Black	15.31%	9.48%	16.39%	<0.001	0.46 (0.46-0.47)
Hispanic	11.27%	5.76%	12.28%	<0.001	0.38 (0.37-0.38)
Asian/Pac Isl	2.77%	1.99%	2.92%	<0.001	0.55 (0.53-0.56)
Native American	0.66%	0.37%	0.71%	<0.001	0.42 (0.40-0.44)
Others	2.99%	2.02%	3.17%	<0.001	0.51 (0.50-0.52)
Comorbidities					
Coronary Artery Disease	20.65%	43.39%	16.49%	<0.001	3.88 (3.86-3.91)
Smoking	23.13%	30.37%	21.81%	<0.001	1.56 (1.55-1.57)
Obesity	8.57%	9.17%	8.46%	<0.001	1.09 (1.08-1.10)
Diabetes Type 2	25.84%	37.02%	23.79%	<0.001	1.88 (1.87-1.89)
Hypertension	56.07%	83.83%	50.99%	<0.001	4.98 (4.94-5.03)
Hyperlipidemia	33.46%	52.92%	29.90%	<0.001	2.64 (2.62-2.65)
Chronic Kidney Disease	17.75%	34.90%	14.61%	<0.001	3.13 (3.12-3.15)
Chronic Obstructive Pulmonary Disease	16.17%	28.66%	13.89%	<0.001	2.49 (2.48-2.51)
Alcohol	6.43%	4.02%	6.88%	<0.001	0.57 (0.46-0.57)
Inflammatory Diseases					
Rheumatoid Arthritis	1.87%	2.50%	1.76%	<0.001	1.43 (1.42-1.44)
Systemic Sclerosis	0.10%	0.13%	0.10%	<0.001	1.26 (1.22-1.30)
Systemic Connective Tissue Disorders	0.50%	0.81%	0.45%	<0.001	1.81 (1.79-1.84)

Gout	0.07%	0.13%	0.06%	<0.001	2.27 (2.21-2.34)
Arthropathic Psoriasis	0.15%	0.15%	0.14%	<0.001	1.05 (1.02-1.08)
Polyarteritis Nodosa	0.02%	0.02%	0.02%	<0.001	1.29 (1.21-1.39)
Raynaud's Syndrome	0.20%	0.22%	0.19%	<0.001	1.18 (1.15-1.21)
Buerger's Disease	0.01%	0.01%	0.01%	<0.001	0.67 (0.60-0.75)
Ankylosing Spondylitis	0.06%	0.07%	0.06%	<0.001	1.06 (1.02-1.11)
Antiphospholipid Syndrome	0.10%	0.08%	0.10%	<0.001	0.83 (0.80-0.86)
Systemic Lupus Erythematosus	0.59%	0.43%	0.62%	<0.001	0.69 (0.68-0.70)

Table 2. Univariate analysis showing higher association of some inflammatory disease and connective tissue disorder with presence of AF/AL except Systemic Lupus Erythematosus, Ankylosing Spondylitis and Buerger's disease

Diagnosis	Total	With AF/ Flutter	Without AF/Flutter	*P*-value	Odds Ratio (95% CI)
Rheumatoid Arthritis	1.87%	2.50%	1.76%	<0.001	1.43 (1.42-1.44)
Systemic Sclerosis	0.10%	0.13%	0.10%	<0.001	1.26 (1.22-1.30)
Systemic Connective Tissue Disorders	0.50%	0.81%	0.45%	<0.001	1.81 (1.79-1.84)
Polyarteritis Nodosa	0.02%	0.02%	0.02%	<0.001	1.29 (1.21-1.39)
Gout	0.07%	0.13%	0.06%	<0.001	2.27 (2.21-2.34)
Arthropathic Psoriasis	0.15%	0.15%	0.14%	<0.001	1.05 (1.02-1.08)
Raynaud's Syndrome	0.20%	0.22%	0.19%	<0.001	1.18 (1.15-1.21)
Ankylosing Spondylitis	0.06%	0.07%	0.06%	<0.001	1.06 (1.02-1.11)
Antiphospholipid Syndrome	0.10%	0.08%	0.10%	<0.001	0.83 (0.80-0.86)
Systemic Lupus Erythematosus	0.59%	0.43%	0.62%	<0.001	0.69 (0.68-0.70)
Buerger's Disease	0.01%	0.01%	0.01%	<0.001	0.67 (0.60-0.75)

(67.00% of the total), and of those who had AF/AFL, 80.38% were white. We also collected information regarding patients' comorbid conditions. The most common comorbidity of those who were included was hypertension, which affected 56.07% of the patients in the sample. Other comorbidities included hyperlipidemia (33.46%), type 2 diabetes (25.84%), smoking (23.13%), CAD (20.65%), CKD (17.75%), COPD (16.17%), obesity (8.57%), and alcohol use (6.43%). Demographic information is included in **Table 1**.

Univariate analysis

In the initial univariate analysis, several autoimmune inflammatory conditions and connective tissue disorders were associated with an increased likelihood of developing AF/AFL as indicated by the odds ratios and 95% confidence interval. AF/AFL was more prevalent in patients with rheumatoid arthritis (OR: 1.43 CI: 1.42-1.44), systemic sclerosis (OR: 1.26, CI: 1.22-1.30), systemic connective tissue disorders (OR: 1.81 CI: 1.79-1.84), polyarteritis nodosa (OR: 1.29, CI: 1.21-1.39), gout (OR: 2.27, CI: 2.21-2.34), arthropathic psoriasis (OR: 1.05, CI: 1,02-1,08), Raynaud's syndrome (OR: 1.18, CI: 1.15-1.21), and ankylosing spondylitis (OR: 1.06, CI: 1.02-1.11). Patients with antiphospholipid syndrome (OR: 0.83, CI: 0.80-0.86), systemic lupus erythematosus (OR: 0.69, CI: 0.68-0.70), and Buerger's disease (OR: 0.67, CI: 0.60-0.75) had a lower association with the presence of AF/AFL. The results of the univariate analysis are reflected in **Table 2**.

Multivariate analysis

Next, a multivariate analysis was conducted adjusting for alcohol use, age, gender, race, and well-known cardiovascular risk factors, including CAD, smoking, type 2 diabetes, hypertension, hyperlipidemia, CKD, and COPD. The multivariate analysis showed the following odds ratios and confidence intervals: rheumatoid arthritis (OR: 1.05, CI 1.04-1.06), systemic sclerosis (OR: 1.31, CI 1.26-1.36), systemic connective tissue disorders (OR: 1.07, CI 1.05-1.08), Raynaud's syndrome (OR: 1.10, CI 1.07-1.13), antiphospholipid syndrome (OR: 1.36, CI 1.31-1.42), and systemic lupus erythematosus (OR: 1.15, CI 1.13-1.17). Ankylosing spondylitis was not associated with AF/AFL. The results of the multivariate analysis are reflected in **Table 3**.

Discussion

The relationship between autoimmune inflammatory diseases and atherosclerosis is well studied [3], however, the association between autoimmune inflammatory diseases and AF/AFL has not been well established in the literature. Atrial fibrillation is a common arrhythmia that is associated with increased morbidity and mortality [18]. Therefore, it is crucial to better understand who is at increased risk for developing AF/AFL. Several studies discuss the

Table 3. Multivariate analysis showing independent association between following inflammatory diseases and connective tissue disorder with AF/AFL after adjusting for known risk factors, age, and baseline characteristics

Inflammatory Disease	Odds Ratio	95% C.I. for OR	*P*-value
Rheumatoid Arthritis	1.05	1.04-1.06	<0.001
Systemic Sclerosis	1.31	1.26-1.36	<0.001
Systemic Connective Tissue Disorders	1.07	1.05-1.08	<0.001
Raynaud's Syndrome	1.1	1.07-1.13	<0.001
Antiphospholipid Syndrome	1.36	1.31-1.42	<0.001
Systemic Lupus Erythematosus	1.15	1.13-1.17	<0.001

pathogenesis of AF and the role of inflammation in its pathogenesis [12, 19]. Other studies have also shown that the presence of increased inflammatory markers is associated with greater AF risk [20], further supporting the role of inflammation in the pathogenesis of AF. One proposed explanation for the role of inflammation in the pathogenesis of AF includes the fibrotic changes to the myocardium that result from inflammation, causing the arrhythmia [12]. Given the understanding of the role of inflammation in the pathogenesis of AF, it would be reasonable to suspect an association between autoimmune inflammatory diseases and AF. Our goal in this study was to show this association using a large inpatient database.

Previous literature has discussed the relationship between certain inflammatory autoimmune diseases and AF. Multiple studies have concluded that individuals with inflammatory bowel disease (IBD) are at increased risk of developing AF compared to non-IBD patients [14]. While we did not specifically include IBD in our study, we also showed that individuals with various autoimmune diseases are at increased risk of developing AF. A 2022 study showed that men had a larger AF risk associated with ulcerative colitis [21]. In this same study, women with rheumatic fever without heart involvement, multiple sclerosis, Crohn's disease, seropositive rheumatoid arthritis, psoriatic arthritis, enteropathy arthropathies, systemic sclerosis, and ankylosing spondylitis were found to have a larger AF risk [21]. Our study looked at some of the same conditions as this study with similar findings. We also found that patients with rheumatoid arthritis and systemic sclerosis had a higher risk of AF. Like this study, we also included psoriatic arthritis and ankylosing spondylitis, however, after the multivariate analysis, we did not find an association between AF and these two conditions. Another 2019 study investigated whether ankylosing spondylitis increases the risk of AF using a nationwide population database. This study found that patients with ankylosing spondylitis developed AF more frequently than non-AS subjects [22]. Our results differed from these two studies that looked at the association between AF and ankylosing spondylitis. This could be related to the fact that almost all patients with ankylosing spondylitis have cardiovascular risk factors which we adjusted for. After adjustment for cardiovascular risk factors, we could not find a direct association. Additionally, we had a much larger data set in comparison. Future prospective studies could further evaluate the association between ankylosing spondylitis and AF/AFL. Various studies have shown an increased risk of new-onset AF due to psoriasis, suggesting that the proinflammatory state in psoriasis plays a role in this development [16]. The association between thyroid abnormalities and AF has also been studied, with one study suggesting that, though unclear, thyroid hormones activate various inflammatory pathways that may play a role "in the development of arrhythmogenic substrate promoting the occurrence and recurrence AF [23]". While we did not specifically study psoriasis or thyroid disease in our study, showing that multiple other inflammatory diseases also increase the risk of developing AF strengthens the claim regarding a proinflammatory state playing a role in AF development. Additionally, a 2021 systematic review and meta-analysis of cohort studies also concluded that patients with inflammatory arthritis have an increased risk of AF [24]. The paper attributes this increased risk to chronic inflammation, reaching the same conclusions as the aforementioned studies [24]. A 2023 database study found that gout increases atrial arrhythmias [25]. However, they included all types of arrhythmias and not only AF/AFL, which could explain differences in their results compared to our findings. Our findings showed an association between AF and rheumatoid arthritis,

which was a finding that aligned with a 2024 literature review, which concluded that "Rheumatoid arthritis groups of patients are at increased risk of having atrial fibrillation and acute coronary syndrome [26]".

The result of our study adds to this growing literature showing an association between certain autoimmune inflammatory diseases and AF/AFL. Our study specifically shows an increased prevalence of AF/AFL in patients with rheumatoid arthritis, systemic sclerosis, systemic connective tissue disorders, Raynaud's syndrome, and systemic lupus erythematosus. There was no association found in this study between ankylosing spondylitis and AF/AFL in our study. There are many known traditional risk factors for AF/AFL, such as hypertension, smoking, obesity, type 2 diabetes, CAD, CKD, COPD, and alcohol use, that we controlled for by conducting a multivariate analysis. We also controlled for certain patient demographic information, including age, gender, and race, within the multivariate analysis. However, due to retrospective nature of our study, our results need to be confirmed in future studies.

Limitations

This study uses a large inpatient database, which allows for review of a large and diverse population. However, using this database is limited by the fact that all the data comes from inpatient records and may not be reflective of the outpatient population. Additionally, with using ICD-10 codes to access our data, there is a possibility for the occurrence of inaccuracies within coding. By relying on ICD-10 codes, we gathered patients who already had a diagnosis of an autoimmune disease. Not all the patients from the NIS sample were screened for autoimmune disease. Therefore, some patients may have had an autoimmune disease that was not known to us, making this another limitation to using ICD-10 codes to access our data. Another limitation of this study is that in patients with inflammatory and autoimmune diseases, differences in inflammatory status or whether their autoimmune diseases were inactive or active, were not accounted for. This data, such as inflammatory markers like CRP/ESR was unable to be extracted from our database. Additionally, information about pharmacotherapy was not accessible from our database, so we could not distinguish whether this impacted the results.

Conclusion

Using a large inpatient database, we found that some common inflammatory diseases and connective tissue disorders are independently associated with the presence of AF/AFL. Our findings are hypothesis-generating requiring confirmation in prospective controlled trials.

Disclosure of conflict of interest

None.

Abbreviations

AF, atrial fibrillation; AFL, atrial flutter; CAD, coronary artery disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; IBD, inflammatory bowel disease; IQR, interquartile range; ICD-10, International Classification of Diseases, 10th Revision; NIS, Nationwide Inpatient Sample.

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