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Research Article

# Prevalence of Sickle Cell Trait and Hematological Profile among Blood Donors at the National Transfusion Center in N'Djamena, Chad

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## Abstract

**Background:** Sickle cell trait (AS phenotype) is generally asymptomatic, which facilitates the inclusion of healthy carriers in the blood donor pool. However, the presence of hemoglobin S (HbS) can alter the quality of blood products and pose risks to some recipients.

**Objectives:** This study aimed to determine the prevalence of sickle cell trait and to evaluate the hematological profile of blood donors at the National Blood Transfusion Center (CNTS) in N'Djamena.

**Methods:** This was a prospective, cross-sectional, and analytical study conducted from June 2024 to May 2025. HbS screening was performed by hemoglobin electrophoresis at alkaline pH, supplemented by a complete blood count using the Yumizen H550 automated analyzer (Horiba Medical, HORIBA ABX SAS, Parc Euromédecine-Rue du caducée B.P. 7290, 34184 MONTPELLIER Cadex 4-France. Ref.: 1300032760. Int. Doc. Ref.: RAB312FR) for each included donor.

**Results:** Of the 433 donors recruited, the prevalence of sickle cell trait (SC) was 17.3% (n = 75). The population was predominantly male (sex ratio 3.3:1) with a mean age of 32.15 ± 9.2. The 18 - 30 age group was predominant (45.7%). It should be noted that 100% of donors were unaware of their electrophoretic status before the study. Hematologically, polycythemia was noted in 12% of donors and anemia in 4%. A statistically significant association was observed between hemoglobin status and hematological abnormalities ($p = 0.039$).

**Conclusion:** The high prevalence of sickle cell trait in blood donors unaware of their status underscores the need to integrate electrophoresis into the blood transfusion assessment.

**Keywords:** Sickle Cell Trait; Hemoglobin Electrophoresis; Blood Donation; Transfusion Safety; N'Djamena; Chad

## Abbreviations

AS: Heterozygous Sickle Cell; AA: Normal Subject; CNTS: National Blood Transfusion Center; CHU-ME: University Hospital Center for Mother and Child; Hb: Hemoglobin; HbS: Hemoglobin S; WHO: World Health Organization; MCV: Mean Corpuscular Volume; MCH: Mean Corpuscular Hemoglobin Concentration; MCHC: Mean Corpuscular Hemoglobin Concentration

## Introduction

Sickle cell disease, or sickle cell anemia, is a genetic hemoglobinopathy with autosomal recessive inheritance of major public health importance. At the molecular level, it results from a single point mutation (SNP) consisting of the substitution of adenine by thymine at the 17$^{th}$ nucleotide of the beta-globin gene (chromosome 11). This mutation induces the replacement of glutamic acid by valine at the 6th codon of the polypeptide chain. The presence of this variant hemoglobin, known as hemoglobin S (HbS), leads, under hypoxic conditions, to hemoglobin polymerization, causing the deformation of erythrocytes into rigid sickle-shaped cells (sickle cells) [1,2]. The World Health Organization (WHO) estimates that more than 50 million people are affected by this disease worldwide. Sub-Saharan Africa remains the most affected region, with over 300,000 births annually of children with major sickle cell syndromes [5]. The disease is responsible for significant infant mortality, reaching up to 16% in some regions of West Africa [5]. In Chad, although epidemiological data still need to be consolidated, estimates suggest that 2% of newborns are born with the severe homozygous form (SS), while a significant proportion of the pediatric population is affected by complications of the disease [6]. The clinical expression of sickle cell disease is polymorphic. The homozygous form (SS) manifests in the first six months of life with chronic hemolytic anemia and acute vaso-occlusive crises (VOCs), which can lead to severe organ complications (functional asplenia, osteonecrosis, cardiorespiratory involvement) [7,8]. Conversely, heterozygous individuals (AS), carriers of the sickle cell trait, are generally asymptomatic and have a normal hematological profile, which improves their eligibility for blood donation according to standard criteria [9,10]. Blood transfusion is the cornerstone of treatment for sickle cell patients in Chad. However, the presence of donors carrying the HbS trait within the transfusion pool raises critical clinical issues. Transfusing a unit of blood containing HbS to a recipient already diagnosed with sickle cell disease can paradoxically worsen blood viscosity, exacerbate microcirculatory occlusion, and compromise tissue oxygenation [7,12]. Furthermore, the rheological characteristics of AS red blood cells can impair the effectiveness of leukoreduction processes and reduce post-transfusion red blood cell survival [13,14]. Despite the scale of this problem, data on the hematological profile and prevalence of hemoglobin S in blood donors in Chad remain virtually nonexistent. The lack of systematic screening for hemoglobinopathies at the National Blood Transfusion Center (CNTS) in N'Djamena represents a significant gap in ensuring the safety of the transfusion chain. The absence of systematic screening for hemoglobinopathies at the National Blood Transfusion Center (CNTS) of N'Djamena represents a significant gap in ensuring the safety of the transfusion chain. It is in this context that the present study was carried out, with the general objective of determining the prevalence of sickle cell trait and evaluating its hematological profile in blood donors at the National Blood Transfusion Center (CNTS) of N'Djamena. The laboratory of the Mother-Child University Hospital Center (CHU-ME) allowed these analyses to be performed.

## Materials and Methods

### Study setting, type, and period

### Study setting

This study was carried out at the National Blood Transfusion Center (CNTS) in N'Djamena, the main institution responsible for the collection, biological qualification, and distribution of blood products in Chad. The biological analyses were performed at the laboratory of the Mother-Child University Hospital Center (CHU-ME) in N'Djamena, a referral hospital equipped with multidisciplinary services and a technical platform suitable for biomedical investigations.

The selection of these two institutions was based on their technical and organizational capacities, which ensure the performance of reliable and standardized biological analyses. The laboratories are equipped with modern facilities enabling automated complete blood counts, hemoglobin electrophoresis, and other diagnostic tests required for the study.

### Study type and period

This was a prospective, cross-sectional, and analytical study. The data collection and biological sampling phase took place over

a 12-month period, from June 2024 to May 2025, thus covering potential seasonal variations in donor activity.

### Study population and sampling

**Eligibility criteria:** Recruitment targeted all donors presenting at both sites.

**Inclusion criteria:** Voluntary or surrogate (family) donors, aged 18 to 65 years, weighing 50 kg or less, and who reported no recent medical history contraindicating donation (fever, medication use) were included. Written or verbal informed consent was systematically obtained.

**Exclusion criteria:** Donors presenting clinical signs of severe anemia during the pre-donation interview, those refusing to participate in the study, and donors whose samples were hemolyzed or insufficient for analysis were excluded.

### Sampling and population size

In the absence of recent local data on the prevalence of sickle cell trait among donors in Chad, the Schwartz formula was used to estimate representativeness. However, to increase the statistical power of the study, exhaustive consecutive recruitment sampling was applied throughout the study period, allowing for the inclusion of all donors meeting the criteria.

### Sample collection and processing

#### Sampling procedure

The sample was collected by qualified personnel under strict aseptic conditions. After venipuncture at the antecubital fossa, 4 mL of venous blood was collected in a tube containing the anticoagulant EDTA (K2 or K3). The tubes were immediately identified with a unique code and homogenized by slow inversions (5 to 8 times) to prevent microcoagulation.

### Packaging and storage

The complete blood count (CBC) was performed within a maximum of 4 hours after collection. After the initial analysis, the tubes were centrifuged at 3000 rpm for 5 minutes to separate the formed elements from the plasma. The plasma and packed red blood cells were aliquoted into 1.5 mL microtubes and then stored at -80°C in a secure storage unit for further analysis (biochemistry or molecular biology if necessary).

### Laboratory analyses

#### Complete blood count (CBC)

Cytological analysis was performed on the YUMIZEN H550 analyzer (Horiba Medical), a high-precision hematology analyzer using flow cytometry and impedance analysis.

The parameters measured included:

- Hemoglobin (Hb) level and hematocrit (Hct).
- Redblood cell indices (MCV, MCHC, MCHC).
- White blood cell and platelet counts.

Internal quality control was performed daily to validate the reliability of the results.

### Diagnosis of sickle cell disease

Screening and confirmation of the sickle cell trait (Hb AS, SS, SC, etc.) were performed by hemoglobin electrophoresis at alkaline pH, supplemented if necessary by solubility tests (Emmel test).

### Ethical considerations and statistical analysis

#### Ethics and confidentiality

The study received approval from the local health authorities. Anonymity was maintained by assigning an alphanumeric code to each participant. Results were provided to donors during post-donation consultations, ensuring the direct benefit of the study for the patient.

### Data analysis

Data were analyzed using SPSS software. The survey form was prepared using Sphinx Plus2 - Lexica-V5 Edition software. Statistical association tests were performed using the chi-square test. Significant differences were defined as $P < 0.05$.

## Results

### Sociodemographic characteristics of the population

The study, conducted over a 12-month period at the National Blood Transfusion Center (CNTS), included a sample of 433 blood donors. The population was predominantly male (77.14%), corresponding to a male-to-female ratio of 3.3. The mean age of the donors was 32.15 ± 9.2 years, with a predominance of the 18 - 30 age group (45.72%). Family donors constituted the most represented group, accounting for 53.3% of inclusions (Table 1).

| Variable | | Effective (N) | Percentage (%) |
|---|---|---|---|
| Gender | Male | 334 | 77.14 |
| | Female | 99 | 22.86 |
| | Total | 433 | 100 |
| Age (years) | 18-30 | 198 | 45.72 |
| | 31-40 | 166 | 38.33 |
| | 41-50 | 60 | 13.85 |
| | 51-60 | 11 | 2.54 |
| | Total | 433 | 100 |

**Table 1:** Sociodemographic characteristics of blood donors.

## Knowledge and attitudes towards sickle cell disease

The survey revealed a significant lack of pre-analytical information: 100% of donors were unaware of their electrophoretic status before the study. While 72.7% reported being familiar with sickle cell disease, an overwhelming majority (89.4%) stated they had received no information about the transfusion risks associated with the sickle cell trait. Furthermore, 36.3% of participants reported the presence of the disease within their family. Regarding transfusion experience, 34.6% had already donated blood to a patient with sickle cell disease. Finally, only 35.6% of donors reported having received specific education or awareness training about this condition (Table 2).

| Variables | Terms and conditions | Effective (N) | Percentage (%) |
|---|---|---|---|
| Type of donors | Regular | 167 | 38.6 |
| | Irregular | 35 | 8.1 |
| | Family | 231 | 53.3 |
| | Total | 433 | 100 |
| Electrophoresis Examination | Yes | 0 | 0 |
| | No | 433 | 100 |
| | Total | 433 | 100 |
| Knowledge about sickle cell disease | Yes | 315 | 72.7 |
| | No | 118 | 27.3 |
| | Total | 433 | 100 |
| Sickle cell risk | Yes | 45 | 10.4 |
| | No | 388 | 89.6 |
| | Total | 433 | 100 |
| A family member suffers from sickle cell disease. | Yes | 157 | 36.3 |
| | No | 276 | 63.7 |
| | Total | 433 | 100 |
| Blood transfusion in sickle cell patients | Yes | 150 | 34.6 |
| | No | 283 | 65.4 |
| | Total | 433 | 100 |
| Premarital counseling | Yes | 0 | 0 |
| | No | 433 | 100 |
| | Total | 433 | 100 |
| Sickle cell disease education campaign | Yes | 154 | 35.6 |
| | No | 279 | 64.4 |
| | Total | 433 | 100 |

**Table 2:** Overall profile of knowledge about sickle cell disease among the subjects surveyed.

## Prevalence of the AS sickle cell trait

The overall prevalence of the heterozygous sickle cell trait (Hb AS) in the study population was 17.3% (75/433) (Table 3).

| | Modality | Frequency | Percentage (%) |
|---|---|---|---|
| Seroprevalence of the sickle cell genotype | AS | 75 | 17.3 |
| | AA | 388 | 82.7 |
| | Total | 433 | 100 |

**Table 3:** Seroprevalence of the sickle cell trait AS in the studied cohort.

## Hematological parameters in carriers of the AS trait

Biological analysis of the 75 subjects carrying the AS genotype revealed the following profiles: the erythrocyte lineage, specifically the erythrocyte count, was normal in 84% of cases. Polycythemia was observed in 12% of subjects and anemia in 4%. A statistically significant association was then demonstrated between the red blood cell count and the AS genotype (P = 0.039) (Table 4). Similarly, the hemoglobin level was normal in 65.3% of AS subjects, while 32% presented with polycythemia and 2.7% with anemia. No significant association was found between the hemoglobin level and the AS genotype (P = 0.248) (Table 5). However, the red blood cell indices (MCV and MCH) that characterized the profile were predominantly normocytic (68%) and normochromic (73%). Cases of microcytosis (24%) and hypochromia (25.3%) showed no significant association with AS status, with respective P-values of 0.441 and 0.258 (Table 6 and 7). Similarly, the platelet count showed a prevalence of thrombocytopenia of 17.3%. Analysis revealed no significant association between platelet count and AS trait (P = 0.258) (Table 8). Furthermore, the leukocyte count was normal in 74.7% of AS donors. Leukopenia was observed in 24% of subjects. Statistical analysis shows that there is a significant association between the leukocyte profile and the AS genotype (P = 0.045) (Table 9).

| Normal | | Erythrocyte value | | | Total | P-Value |
|---|---|---|---|---|---|---|
| | | Lower | Superior | | | |
| Variables | AS | 63 | 3 | 9 | 75 | 0.039 |
| | | 84.0% | 4.0% | 12.0% | 100.0% | |
| | AA | 300 | 13 | 45 | 358 | |
| | | 83.8% | 3.6% | 12.6% | 100.0% | |
| Total | | 363 | 16 | 54 | 433 | |
| 83.8% | | 3.7% | 12.5% | 100.0% | | |

**Table 4:** Association of erythrocyte profile with sickle cell genotype.

| Normal | | The value of the Hemoglobin level | | | Total | P-Value |
|---|---|---|---|---|---|---|
| | | Lower | Superior | | | |
| Variables | AS | 49 | 2 | 24 | 75 | 0.248 |
| | | 65.3% | 2.7% | 32.0% | 100.0% | |
| | AA | 264 | 12 | 82 | 358 | |
| | | 73.7% | 3.4% | 22.9% | 100.0% | |
| Total | | 313 | 14 | 106 | 433 | |
| 72.3% | | 3.2% | 24.5% | 100.0% | | |

**Table 5:** Statistical association of hemoglobin and sickle cell genotype.

| Normal | | The value of VGM | | | Total | P value |
|---|---|---|---|---|---|---|
| | | Lower | Superior | | | |
| Your result | AS | 51 | 18 | 6 | 75 | 0.441 |
| | | 68.0% | 24.0% | 8.0% | 100.0% | |
| | AA | 249 | 93 | 16 | 358 | |
| | | 69.6% | 26.0% | 4.5% | 100.0% | |
| Total | | 300 | 111 | 22 | 433 | |
| 69.3% | | 25.6% | 5.1% | 100.0% | | |

**Table 6:** Statistical association of MCV and sickle cell genotype.

| Normal | | The value of TCMH | | | Total | P Value |
|---|---|---|---|---|---|---|
| | | Lower | Superior | | | |
| Variables | AS | 55 | 19 | 1 | 75 | 0.258 |
| | | 73.3% | 25.3% | 1.3% | 100.0% | |
| | AA | 275 | 68 | 15 | 358 | |
| | | 76.8% | 19.0% | 4.2% | 100.0% | |
| Total | | 330 | 87 | 16 | 433 | |
| 76.2% | | 20.1% | 3.7% | 100.0% | | |

**Table 7:** Statistical association between TCMH profile and sickle cell status.

| Normal | | Platelet Value | | | Total | P Value |
|---|---|---|---|---|---|---|
| | | Lower | Superior | | | |
| Variables | AS | 61 | 13 | 1 | 75 | 0.674 |
| | | 81.3% | 17.3% | 1.3% | 100.0% | |
| | AA | 295 | 53 | 10 | 358 | |
| | | 82.4% | 14.8% | 2.8% | 100.0% | |
| Total | | 356 | 66 | 11 | 433 | |
| 82.2% | | 15.2% | 2.5% | 100.0% | | |

**Table 8:** Statistical association between platelet count and sickle cell status.

| Normal | | White Blood Cell Value | | | Total | P Value |
|---|---|---|---|---|---|---|
| | | Lower | Superior | | | |
| Your result | AS | 56 | 18 | 1 | 75 | 0.045 |
| | | 74.7% | 24.0% | 1.3% | 100.0% | |
| | AA | 289 | 52 | 17 | 358 | |
| | | 80.7% | 14.5% | 4.7% | 100.0% | |
| Total | | 345 | 70 | 18 | 433 | |
| 79.7% | | 16.2% | 4.2% | 100.0% | | |

**Table 9:** Association of white blood cells and sickle cell genotype.

## Discussion

Initially, we analyzed the sociodemographic characteristics of blood donors, revealing a marked male predominance with 77.14% men versus 22.86% women, resulting in a male-to-female ratio of 3.3. This finding is similar to those reported by [15] in Madagascar (male-to-female ratio of 3.4) and Nigeria (male-to-female ratio of 4) [14], reflecting a regional trend in sub-Saharan Africa where men often represent more than 70% of donors (WHO, 2022). However, our data were lower than those reported in Ghana (male-to-female ratio of 12) [16]. This predominance can be explained by several factors specific to women, including physiological contraindications to blood donation such as pregnancy, childbirth, breastfeeding, and menstruation [17], which reduce plasma volume and increase the risk of bleeding. Furthermore, studies indicate that men are motivated by social pressure and family obligations, while women act more out of pure altruism [18]. In our cohort, where nearly 64% of participants were married, these marital and parental responsibilities could encourage men to volunteer at blood transfusion centers (BTCs). In Chad, where cultural norms value the male provider role, as in many patriarchal societies in West Africa, these dynamics reinforce this disparity, thus highlighting the need for targeted campaigns to recruit more female donors and balance blood supplies. The age distribution reveals a majority in the 18 - 30 age group (45.72%), followed by the 31 - 40 age group (38.33%), with a mean age of 32.15 ± 9.2 years (minimum 18 years, maximum 60 years) [19] and [17]. These results indicate an overrepresentation of young donors, consistent with the Chadian demographic structure where more than 60% of the population is under 25 years old (UN data, 2023), thus promoting an optimal window for recruitment. The boldness of young people, as well as the context of family donation prevalent in Chad, where families often designate younger individuals to address an urgent need, also explains this trend, along with the better physiological tolerance to bleeding in younger subjects (higher hemoglobin, rapid recovery). Our findings are similar to those of the Malian studies (mean age 31.21 ± 8.7 years) and (mean age 31.15 years). However, they are higher than those of [20] in Sierra Leone (27 years) and [21] in the DRC (26 years), differences attributable to our larger sample size, extended study period, and low participation of older adults (Table 1). These latter findings reflect the logistical challenges of accessing blood transfusion centers for seniors in Chad, including reduced mobility and the increasing cardiovascular comorbidities associated with age. Family donors predominated at 53.3%, reflecting a shortage of voluntary or regular donors in Chad, whose prevalence remains below 20% according to the WHO (2022). This is explained by insufficient public awareness and the absence of structured follow-up programs for regular donors by health facilities, leading to an increased risk of infectious transmission due to less systematic testing. National campaigns promoting altruistic and voluntary blood donation are therefore essential to diversify recruitment and ensure transfusion safety, as demonstrated by South African models that reduced family donations by 40% in 5 years. Our results are lower than those of [22] in the DRC (62.27%) and [19] in Mali (90%), and well below those of Cameroon (98.7%) [23]. This relative decrease is explained, however, by institutional voluntary donation campaigns conducted during our study at the CNTS (National Blood Transfusion Center), which increased the availability of blood bags and reduced pressure on family donors, illustrating the positive impact of targeted interventions on recruitment dynamics. All participants were unaware of their sickle cell status (100%), having never undergone testing for hemoglobin S, the detection of which by electrophoresis is nevertheless recommended by the WHO for endemic areas. This lack of knowledge stems from a lack of awareness, education and communication on hemoglobin electrophoresis, particularly in a Chadian context where genetic tests are rare outside urban areas, thus promoting transfusions with hemolytic risk. Our results corroborate those of [14] in Madagascar and [24] in Italy (Table 2). Regarding the prevalence of the AS sickle cell trait, it was 17.3% (75/433), a rate exceeding that of [25] in Ghana (12.5%), but approaching that of [11] in Ghana (19.5%) and Nigeria (19.68%) [26], consistent with the estimated HbS allele frequency of 0.08-0.12 in Central Africa (global HBB database, 2023) [13]. However, it is lower than [27] in Nigeria (26.1%) and well below [78.8%]. Other studies report prevalences of 20-40% in Ghana [28], and [29], [26] or 29.4% among donors, variations explained by the type of study, sample size, sociodemographic profiles, time period and location, as well as by the fact that some donors were aware of (and perhaps avoided) their AS status, potentially avoiding erythrocyte deformation under hypoxic stress. Among AS carriers, whose erythrocyte lineage was normal in 84% of cases, we observed 4% anemia and 12% polycythemia, linked to compensatory increased erythropoiesis. Hemoglobin was normal (65.3%), followed by polycythemia (32%) and anemia (2.7%; p = 0.248, not significant).

MCV indicated normocytosis (68%), microcytosis (24%) and macrocytosis (8%; p = 0.441, not significant), while MCH was normal (73%), hypochromic (25.3%) or elevated (1.3%). Overall, anemias (4%; microcytic 8%, hypochromic 25.3%) were infrequent, similar to those observed in asymptomatic AS populations where partial HbS polymerization does not significantly impair hematopoiesis (Nature Reviews Hematology, 2021). Our results partially align with those found in Lubumbashi (anemia 31.6%; microcytic 28.4%, hypochromic 36.4%) [30], but are lower than [31] in Mali (anemia 14%; microcytosis 25%, hypochromia 46.4%) and [26] (anemia 28%; hypochromic/microcytic 55.6%), differences reflecting improved iron nutrition or prior screening of our donors. The platelet count was normal in 81.3% of cases, with thrombocytosis (1.3%) and hypoplateletosis (17.3%) [26], consistent with (normal 83.6%; thrombocytosis 6.8%; hypoplateletosis 9.6%) as well as (thrombocytopenia 3.14%; thrombocytosis 6.29%), potentially due to subclinical platelet activation by minor vaso-occlusion. White blood cell counts were normal (74.7%), with leukopenia (24%) and leukocytosis (1.3%), a significant association with the AS genotype (p = 0.045) suggesting a subtle impact on innate immunity via subclinical chronic inflammation and compensatory neutrophilosis. This warrants prospective investigation to assess transfusion risks, including post-transfusion immunomodulation. These hematological profiles, which together highlight the importance of systematic screening for the AS trait at the CNTS, aim to optimize blood quality and minimize post-transfusion complications such as alloimmune reactions.

## Conclusion

This study, conducted at the National Blood Transfusion Center (CNTS) in N'Djamena, revealed that a significant proportion of donors (17.3%) carry the sickle cell trait AS, and almost all (100%) are unaware of their genetic status and the risks associated with their donations for certain vulnerable recipients, particularly homozygous SS patients. Indeed, transfusion of blood containing hemoglobin S can worsen vaso-occlusive crises, promote delayed post-transfusion hemolysis, anti-erythrocyte alloimmunization, and even multi-organ failure in these patients, due to increased polymerization under hypoxia and frequent antigenic incompatibility. In the Chadian context, where the prevalence of sickle cell trait fluctuates between 25 and 40% in the "sickle cell belt" and where neonatal screening remains in its infancy, the implementation of systematic screening for the AS trait by hemoglobin electrophoresis or rapid strips such as HemoType SC® before donation or on blood bags appears to be a relevant, cost-effective, and timely measure. Such a strategy, aligned with WHO recommendations for endemic areas, would not only drastically reduce the transfusion risk for sickle cell patients (avoiding a loss of >30% of post-transfusion HbA1c), but also optimize the overall quality of blood products, raise donor awareness, and promote early intervention, thus limiting morbidity and mortality related to sickle cell disease in Chad. These recommendations call for intersectoral collaboration (CNTS, Ministry of Health, associations like Elan de l'Espoir) for rapid implementation, thereby strengthening transfusion safety in a country where the need for safe blood is critical.

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## Conflict of Interest

The authors declare that there are no financial, personal, or institutional conflicts of interest that could have influenced the conduct of this study, the data analysis, or the interpretation of the results. This research was carried out within a strictly academic and scientific framework, without external funding that could introduce bias.

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