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Electrical and Echocardiographic Abnormalities in Sickle Cell Disease Followed up at the National Sickle Cell Disease Reference Centre (CNRD)

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Abstract

Objective: To study the electrical and echocardiographic aspects in patients with major sickle cell syndrome. **Methods**: This was a prospective descriptive cross-sectional study carried out at the National Reference Center for Sickle Cell Disease and the cardiology department of the National Hospital of Niamey over a period of 6 months (from September 2021 to February 2022). **Results**: We included 100 patients, including 53 women and 47 men, with a sex ratio of 0.88. The average age was 32.6 ± 12 years, with extremes ranging from 16 to 65 years. The SS phenotype represented 87%, the SC phenotype 11% and only 2% of S beta-thalassemia. The mean baseline hemoglobin level was 8.89 ± 1.6 g/dL. Electrically, we found QT elongation, left ventricular hypertrophy, sinus tachycardia, negative T waves, first-degree atrioventricular block, right ventricular hypertrophy and left atrial hypertrophy in respectively 28%, 15%, 14%, 11%, 4% and 3% of cases. Echocardiographic abnormalities were dominated by valve involvement in 64% of cases with 53% valve leakage, 4% mitral insufficiency, 5% aortic insufficiency, 2% moderate to severe tricuspid insufficiency; followed by dilation of the left atrium and left ventricle in 30% and 13% of cases respectively. Dilation of the right ventricle and right atrium was present in 3% and 4% of cases, respectively. 4 cases of pulmonary arterial hy-

pertension and 4 cases of ventricular communication were observed. We also noted 1 case of systolic dysfunction, 1 case of hypokinetic dilated cardiomyopathy. The homozygous SS form was found to be the most severe. **Conclusion**: Sickle cell disease is a severe disease whose prognosis is worsened by cardiac involvement.

Keywords

Electrocardiogram, Echocardiography, Anomalies, Sickle Cell Diseases and CNRD

1. Introduction

Sickle cell disease is a genetic disease, with autosomal recessive transmission, characterized by the mutation of a gene in the beta chain of hemoglobin. This mutation induces the synthesis of an abnormal hemoglobin called hemoglobin S "HbS" [1]. The major sickle cell syndromes are represented by the homozygous form SS, the double heterozygotes SC, SD Punjab, S/βthalassemia, SO Arab and SE [2]. It is the most widespread genetic disease in the world, particularly affecting black populations [3]. Africa is the most affected region with a prevalence of sickle cell trait varying from 2% to 30% depending on the geographical area. In certain parts of sub-Saharan Africa, sickle cell disease affects up to 2% of newborns [4]. However the migration of the world's population has made this condition a pathology frequently found in industrialized countries [5]. Around 500,000 children with sickle cell disease are born each year in Africa, 60% to 80% of whom die before the age of 5 due to a lack of early screening and adequate treatment [6].

This, therefore, represents a considerable public health challenge for Africa. Niger is one of the countries where sickle cell disease constitutes a major public health problem due to its high prevalence estimated at [18% - 25%] [7]. Major sickle cell syndrome begins in childhood and is characterized by the association of acute vaso-occlusive crises with hemolytic anemia and progressive organ damage, which can sometimes be life-threatening for the patient [8] [9].

The progression of the disease is punctuated by numerous complications and those affecting the heart are among the least well documented. The high cost of treatment leads parents to consult most often during a complication. Explorations are then carried out for this purpose. Thus, cardiac complications, which are often late, are only discovered in symptomatic patients [10] [11]. However, asymptomatic cardiac abnormalities are very frequent due to chronic anemia [12]. In our environment, cardiac complications of sickle cell disease are often revealed by electrical and echocardiographic abnormalities [13]. Very few studies have been carried out on cardiac abnormalities in sickle cell patients in Niger. Thus, we undertook this work, with the aim of studying the electrical and echocardiographic aspects in major sickle cell patients (SS, SC, S/βthalassemia forms) aged over 15 years.

2. Methodology

Type and Period of Study

This was a prospective, descriptive, cross-sectional study conducted from September 1, 2021, to February 1, 2022 (6 months).

Study Population

Our sample consisted of 100 patients with major sickle cell syndrome aged over 15 years who consulted at the CNRD during the study period.

Inclusion Criteria

The study included patients with major sickle cell syndrome (SS, SC, S/β-Thalassemia), regardless of gender, followed at the CNRD, aged over 15 years, and who had given their consent to participate in the study.

Data Collection

Volunteer recruitment took place at the CNRD during follow-up appointments. Data were collected from individual survey forms containing epidemiological, clinical, laboratory, electrical, and echocardiographic data. After laboratory tests were performed at the CNRD, patients were referred to the Niamey National Hospital for ECG and cardiac Doppler ultrasound examinations free of charge.

Data Entry and Analysis: Microsoft Word 2016, Excel 2016, and Epi info version 7.2.4.0 were used for data entry and analysis.

Ethical Aspects:

Inclusion candidates were informed of the existence of our study and its objectives, and were given the choice to participate or not.

We informed each patient and/or their parent about the purpose and significance of our research prior to recruitment. Prior approval from the heads of the various departments was obtained, and the examinations (ECG and cardiac ultrasound) performed were free of charge for the patients.

Limitations of the study

The patients did not receive frontal chest X-rays or LDH level measurements.

3. Results

We identified 100 cases of major sickle cell disease out of a total of 2160 patients seen during the study period, representing a frequency of 21.6%.

Females were the most common sex in 53% of cases, with a F/M sex ratio of 0.88. The mean age was 32.6 ± 12 years, with a range of 16 to 65 years. The 21 - 30 age group was the most common in 53% of cases (**Figure 1**).

The most common ethnic group was the Zarma-Sonrhaï ethnic group, representing 45% of cases (n = 45). Forty-four percent (44% (n = 44)) of our patients had a higher education level. The majority of our patients resided in the city of Niamey in 97% of cases (n = 97). The patients had an average socioeconomic level in 51% of cases (n = 51).

Only two (2) of our patients were older than 50 years and female; all male patients were younger than 45. Only one patient was hypertensive.

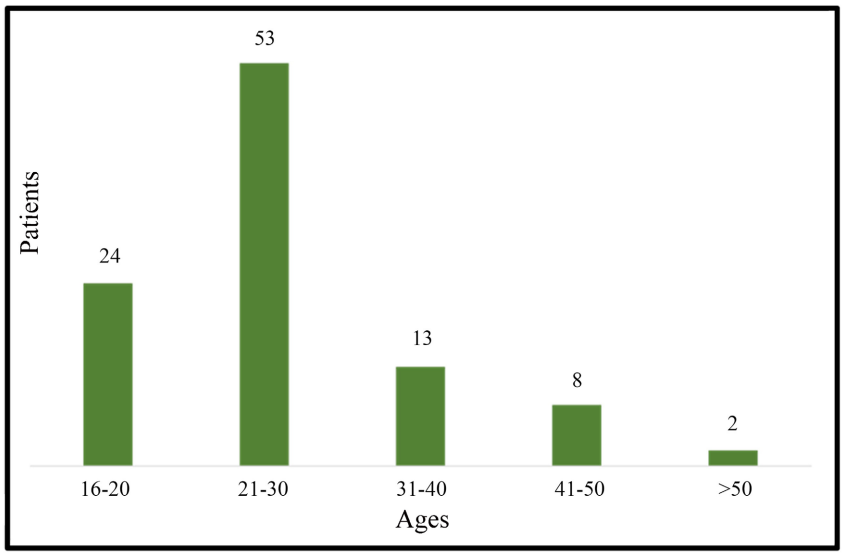

Figure 1. Distribution of patients according to age groups.

A search for other medical history revealed that 53 patients had received at least one blood transfusion and 81 had suffered a vaso-occlusive crisis in the 2 years preceding our interview. There was also a history of priapism, retinopathy, gallstone disease, ureteral stenosis, cesarean section, tonsillectomy, and cholecystectomy.

On clinical examination, the main signs found were exertional dyspnea, palpitations, and chest pain in 68%, 29%, and 20%, respectively (**Figure 2**).

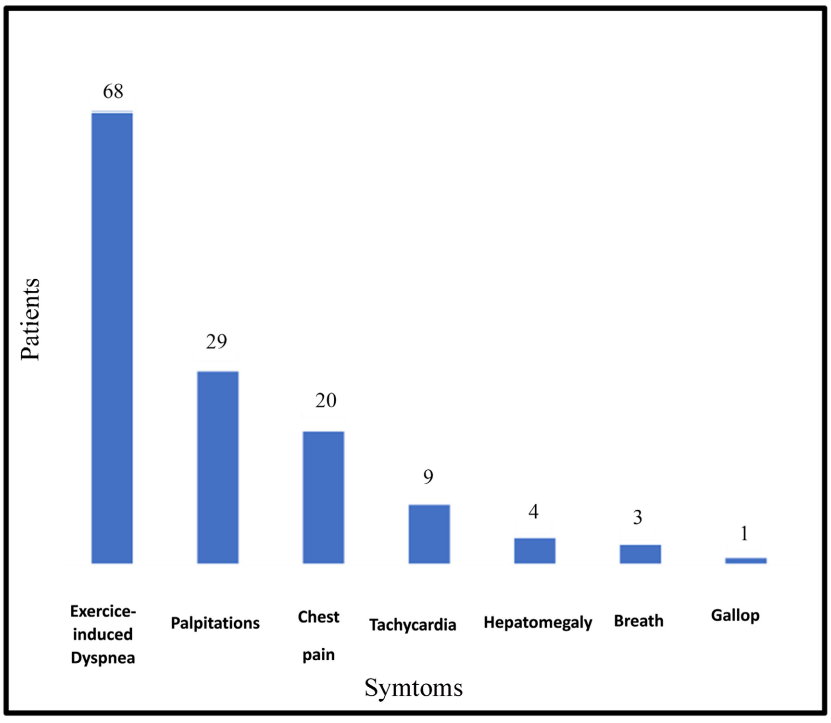

Figure 2. Distribution of patients based on clinical signs.

On laboratory tests, the predominant phenotype was SS in 87% (n = 87) of cases. The remainder consisted of SC phenotype and S/β thalassemias.

The mean hemoglobin level of our patients was 8.89 (±1.6) g/dL, with a range of 5.5 to 12 g/dL. More than half of our patients, or 58% (n = 58), had a hemoglobin level between 8.1 and 11 g/dL.

According to the sickle cell phenotype, 60.92% (n = 53) of homozygous SS patients and 45.45% (n = 5) of SC patients had a hemoglobin level ranging from 0.8 to 11 g/dl. The two S/β thalassemia patients had a hemoglobin level greater than 11 g/dl.

On the blood count, the mean leukocyte, platelet, and reticulocyte counts were 12.91 (±6.61) × 10^9/l, 511.1 (±293.7) × 10^9/l, and 201.9 (±45.98) × 10^9/l, respectively. Mean leukocyte and platelet counts were higher in SS sickle cell patients, but these differences were not significant (p = 0.39 and p = 0.24) (Table 1).

Table 1. Distribution of patients based on hemogram data and sickle cell phenotype.

Biology \ Phenotype	SS	SC	S/β thalassémie	Total population
	Average			
Leukocytes (10^9/L)	13.3 (±6.92)	10.5 (±3.16)	8.99 (±1.21)	12.91 (±6.61)
Hb (g/dl)	8.62 (±1.46)	10.51 (±1.06)	11.9 (±0.14)	8.89 (±1.6)
VGM (fl)	78.41 (±10.05)	70.27 (±8.47)	65 (±5.65)	77.25 (±10.25)
Patelet (10^9/L)	541.5 (±296.1)	317.9 (±189.8)	250 (±111.7)	511.1 (±293.7)
Reticulocytes (10^9/L)	203.3 (±46.5)	193.1 (±46.6)	188.6 (±18.7)	201.9 (±45.98)

The most common electrical abnormalities were QT prolongation in 28% of cases (n = 28), left ventricular hypertrophy in 15% (n = 15) of our patients, sinus tachycardia in 14% of cases (n = 14), and negative T waves involving different territories in 11% of cases (n = 11) (Table 2).

Table 2. Distribution of patients according to characteristics and electrical anomalies.

ECG abnormalities	Effective	Percentage (%)
QT prologation	28	28
HVG	15	15
Sinusal Tachycardia	14	14
Négative T wave	11	11
BAV first degree	4	4
HVD	3	3
HAG	3	3

Echocardiographically, we observed that the mean values of left ventricular diameter and left atrial surface area in our patients were elevated, indicating dilation of the cavities.

Echocardiographic abnormalities were dominated by moderate valve damage

in 64% of cases (53% leaks, 5% IAo, 4% MI, and 2% IT), followed by left atrial dilatation in 30% (n = 30) of cases (including 28 in SS patients and 2 in SC patients), and left ventricular dilatation in 13% (n = 13) of cases in SS patients. Pulmonary arterial hypertension (PAH) was found in 4 SS patients. We found 4 cases of congenital heart disease of the IVC type, 2 of which were small (Roger's disease), and 2 perimembranous IVCs measuring 4 and 5.2 mm (**Table 3**).

Overall, anomalies were more common in SS homozygous sickle cell patients.

Table 3. Averages of echocardiographic parameters.

Echocardiographic Variables	Average	Extreme
DVD (mm)	25.08 (±4.07)	19 - 55
DTDVG (mm)	51.45 (±5.52)	44.5 - 75.5
DTSVG (mm)	32.06 (±4.85)	19.6 - 52.7
OG (cm^2)	19.62 (±4.56)	11.4 - 34
OD (cm^2)	15.32 (±3.30)	9.38 - 33.64
SIV (mm)	7.90 (±1.14)	6 - 11.1
PP (mm)	8.43 (±1.29)	6 - 13
FEVG Simpson (%)	67.87 (±6.58)	39 - 82
VCI (mm)	14.1 (±2.41)	8 - 23.6

4. Discussion

It is commonly accepted that patients with major sickle cell disease are at increased cardiovascular risk, with nearly 25% of deaths related to cardiovascular causes [15]. This study allowed us to describe the various cardiac disorders in sickle cell patients. The age of 15 was discussed with pediatricians, and this constitutes the upper limit for pediatric ages. An age above 15 years is considered an adult.

We collected 100 cases of major sickle cell disease out of 2160 patients seen in consultation, representing a hospital frequency of 21.6%. Our result is higher than that of Bouwe M. in Niger in 2022 [16], who found a frequency of 15.12%, this study focused on the prevalence of sickle cell trait in Niger. This superiority is found in our study populations, as we worked on patients who came for consultation, unlike their study, which focused on hemoglobin electrophoresis. Females were the most common sex in 53% of cases, representing a sex ratio of 0.88. This result is consistent with those of Ondze-Kafata L I *et al*. in Guadeloupe in 2014 and of Ndongo Amougou *et al*. in Cameroon in 2018 [17] who found respectively 72 and 58.3% in favor of the female sex. However, Koko J *et al*. in Gabon in 2005 [18] in a retrospective study on 123 cases of children with sickle cell disease aged ≥ 3 years carried out at the Owendo Pediatric Hospital (Gabon) found a predominance of the male sex with a sex ratio of 1.5. This difference in results could be explained by a simple recruitment bias.

The mean age of our series was 32.6 ± 12 years with extremes varying between 16 and 65 years. The 21 - 30 age group was the most represented in 53% of cases. This result is higher than those of Ndongo Amougou *et al*. in Cameroon in 2018 [19] who found an average age of 28.1 (±10.7) with extremes of 15 and 61 years and Leugeun P G in Senegal in 2012 [20] who found an average age of 24 years with extremes of 15 - 53 years. These results show that the life expectancy of sickle cell patients continues to increase. The Zarma-Sonrhaï ethnic group was the most represented in 45% of cases. This result is comparable to those of R. Omar in Niger in 2019 [21] who found 42.58% of Zarma-Sonrhaï and of Ramatoulaye H in 2020 in Niger [22] who found 42.35% of Zarma. This could be explained by the fact that our study was carried out in Niamey, a city of Zarma origin and surrounded by mainly Zarma towns such as Dosso and Tillabery. Our result differs from that of Abdoul Aziz H. [23] who found 30.53% of Zarma.

We found that 44% (n = 44) of our patients had a higher education level and 3% (n = 3) a primary education level and 97% resided in the city of Niamey. Patients with an average socioeconomic status accounted for 51% of cases, and those with a high socioeconomic status accounted for 24% of cases. This economic situation allows them to have regular follow-ups because regular care is relatively expensive.

We did not find any cardiovascular risk factors in our population, however only one patient was hypertensive. As for the history, 81% of our patients had suffered from at least one vaso-occlusive crisis during the last two years preceding the interview and 53% had benefited from at least one blood transfusion. Our results are similar to those of Tolo Diebkilé A *et al*. in Ivory Coast in 2010 [24] who found a history of transfusion in 28 patients and of CVO in 48 patients out of a total of 48, *i.e.* 58.3% and 100%, but lower than those of Malam Abdou B *et al*. [25] in Niger in 2015 who found 83.36% for transfusion and 44.28% for CVO. This difference could be related to the fact that our patients were in the inter-critical phase while those of Malam Abdou B *et al* are hospitalized patients.

The main clinical signs found were exertional dyspnea, palpitations and chest pain with respective percentages of 68%, 29% and 20%. These results were lower than those of Ndongo Amougou *et al*. [17] in Cameroon in 2018 who found 63.9%, 66.7% and 27.8% respectively for dyspnea, palpitations and chest pain. This difference could be linked to the number of their patients which was 36 against 100 patients in our study and in addition all their patients had at least one cardiac complication which is not the case in our patients.

The SS phenotype was predominant in 87% of cases followed by 11% of SC and 2% of S/βthalassemia. Our results are consistent with those of Malam Abdou B *et al*. in Niger in 2015 [25] who found 80.33% for the SS phenotype, 19.11% for the SC phenotype and only 1 case of S/βthalassemia. These results confirm the rarity of the association of sickle cell disease and βthalassemia. The mean hemoglobin level in our series was 8.89 (±1.6) g/dl with extremes of 5.5 and 12 g/dl. Our result is similar to those of Gnago Nina P in Morocco in 2008 [26] and Tolo-Diebkilé A

al. in Ivory Coast in 2010 [24] who found respectively a mean hemoglobin level of 9.1 and 9.5 g/dl. The mean hemoglobin level was lower in SS subjects 8.62 ± 1.46 compared to those of SC and S/βthalassemia subjects which were respectively 10.51 ± 1.06 and 11.9 ± 0.14 g/dl. This observation could be linked to the more hemolytic character of the SS phenotype.

QT prolongation was found in 28% of cases. This result is lower than those of Ellenga-Mbolla B F *et al.* [27] in Congo in 2013 and Ndongo Amougou *et al.* in Cameroon in 2018 [17] who found QT prolongation in 40.62 and 48.4% respectively.

Left ventricular hypertrophy was present in 15% of our patients, our result is higher than those of the same authors who found 7.8 and 8.3% respectively in favor of left ventricular hypertrophy. Sinus tachycardia was found in 14% of our patients unlike Koko J *et al* in Gabon in 2005 [29] who found 4 cases of sinus tachycardia in a total of 15 homozygous sickle cell children. We found 11% of negative T waves in different territories. This result is different from that of Ndongo Amougou *et al* in Cameroon in 2018 [17] who found 51.6% of T wave abnormalities.

- First-degree BAV conduction abnormalities were present in 4% of our patients, Ndongo Amougou *et al.* [17] found 8.3%.

Right ventricular hypertrophy was present in 3% of cases, in Congo Ellenga-Mbolla B F *et al.* [27] had found 35.9% and Ndongo Amougou *et al.* [21] in Cameroon had found 2.8% of right ventricular hypertrophy.

As for left atrial hypertrophy we found a percentage of 3%; this result is close to that of Koko J *et al.* [18] in Gabon in 2005 who had found 2 cases.

On the echocardiographic level, left atrial dilation was noted in 30 patients (30%) including 28 homozygous SS and 2 heterozygous SC; This result is similar to that of Ondze-Kafata L I *et al.* in Guadeloupe in 2014 [19] in a population of 82 patients with an average age of 40 ± 12 years who found left atrial dilation in 36 patients (43.9%). The left ventricle was dilated in 13% of our homozygous SS patients.

This result is lower than that of Honga Vanina in Cameroon in 2006 [28] who found left ventricular dilation in 20 children with SS sickle cell disease out of a total of 34 children, or 58.8% of cases. Right ventricular dilation was found in 3 patients and right atrial dilation in 4 patients, all homozygous SS. Our result is lower than that of Ondze-Kafata L I *et al.* in Guadeloupe in 2014 [19] who found right ventricular dilation in 14 patients (17.1%) and right atrial dilation in 11 patients (13.4%).

The ejection fraction was on average 67.87% (±6.58) with extremes of 39 to 82% by the Simpson method. We found one (1) case of LV systolic dysfunction, this result is superimposable with that of Caldas C *et al.* [29] in Brazil in 2008 who reported LV dysfunction in 2 patients. Valve leaks represented 53% of our sample, this result lower than that of Ndongo Amougou *et al.* [17] in Cameroon in 2018 who found 91.4%.

Among these leaks we had counted 4 cases of mitral regurgitation (2 moderate, 2 severe), 5 cases of aortic regurgitation (2 grade I and 3 grade II), 2 cases of grade 2 tricuspid regurgitation. In Cameroon, in 2006, Honga Vanina [28] had found 47% of mitral valvulopathies, she had not however found any cases of tricuspid or aortic valvulopathies. Pulmonary arterial hypertension was found in 4% of patients, this result is lower than those of Ondze-Kafata L I *et al.* [19] in Guadeloupe in 2014 who found pulmonary arterial hypertension in 52.4% of 80 patients aged 16 to 70 years and of Gladwin *et al.* [30] in 2004 who observed pulmonary arterial hypertension in 32% of cases in a total population of 195 patients. Our results are higher than those of Kane A *et al.* in Senegal in 2001 [11] in their series of 80 subjects with an average age of 8.5 years who found pulmonary arterial hypertension in a single patient and that of Ndongo Amougou *et al.* [17] in Cameroon in 2018 who found no cases of pulmonary arterial hypertension in a series of 36 middle-aged patients. 28.1 ± 10.7 years. We observed 1 case of hypokinetic dilated cardiomyopathy in a homozygous SS patient.

5. Conclusion

This study of electrical and echocardiographic features allowed us to achieve our objectives, which were to highlight electrical abnormalities dominated by QT prolongation, left ventricular hypertrophy, sinus tachycardia, and negative T waves. Echocardiographically, the most common abnormalities were left ventricular dilation and valvular involvement. These results allow us to consider that patients with sickle cell disease are exposed to cardiac dysfunction at some point in their lives; hence, it is important to perform a routine ECG and cardiac ultrasound periodically, whether or not there are warning signs. This will help detect potentially serious abnormalities and facilitate early management.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Renaudier, P. (2014) Physiopathologie de la drépanocytose. *Transfusion Clinique et Biologique*, **21**, 178-181. https://doi.org/10.1016/j.tracli.2014.08.139

[2] Essono, E.M. and Nkoa, T. (2004) Diagnostic et anomalies biologiques chez un drépanocytaire. *Medicine Clinics in Mother and Child Health*, **1**, 12-20.

[3] Idriss, L. (2021) Journée Mondiale de l'enfance: Combattre la drépanocytose chez les enfants. https://www.journalducameroun.com

[4] Grosse, S.D., Odame, I., Atrash, H.K., Amendah, D.D., Piel, F.B. and Williams, T.N. (2011) Sickle Cell Disease in Africa. *American Journal of Preventive Medicine*, **41**, S398-S405. https://doi.org/10.1016/j.amepre.2011.09.013

[5] Lena-Russo, D., Nord, M.L. and Girot, R. (1992) Epidemiology of Genetic Hemoglobin Diseases in Metropolitan France. *La Revue du Praticien*, **45**, 1867-1872.

[6] Sambo, G. (2011) Drépanocytose en Afrique: 500.000 naissances annuelles Organisation mondiale de la santé (OMS/Afro). Brazzaville.

[7] Ministère de la santé publique du Niger (2009) Guide de prise en charge de la drépanocytose au Niger.

[8] Hau, I. and Coic, L. (2008) L'enfant drépanocytaire aux urgences. *Médecine thérapeutique/Pédiatrie*, **11**, 35-42.

[9] Thuilliez, V., Ditsambou, V., Mba, J.R., Mba Meyo, S. and Kitengue, J. (1996) Aspects actuels de la drépanocytose chez l'enfant au Gabon. *Archives de Pédiatrie*, **3**, 668-674. https://doi.org/10.1016/0929-693x(96)87087-4

[10] Bertrand, E. (2005) Is the Sickle-Cell Trait a Risk Factor? *Medecine Tropicale*, **65**, 379-381.

[11] Kane, A., Mbengue-Dièye, A., Dièye, O., Sylla, A., Sall, G., Diouf, S.M., *et al*. (2001) Aspects échocardiographiques au cours de la drépanocytose en milieu pédiatrique. *Archives de Pédiatrie*, **8**, 707-712. https://doi.org/10.1016/s0929-693x(00)00302-x

[12] Batra, A.S., Acherman, R.J., Wong, W., Wood, J.C., Chan, L.S., Ramicone, E., *et al*. (2002) Cardiac Abnormalities in Children with Sickle Cell Anemia. *American Journal of Hematology*, **70**, 306-312. https://doi.org/10.1002/ajh.10154

[13] Akinlade, O.M., Akintunde, A.A., Olabode, O.P., Olatunji, L.A., Akinpelu, O.O., Soladoye, A.O., *et al*. (2019) Evaluation of Tp-e Interval and Tp-e/QTc Ratio among Patients with Steady State Sickle Cell Disease. *World Journal of Cardiovascular Diseases*, **9**, 425-436. https://doi.org/10.4236/wjcd.2019.96038

[14] Lee, M.T., Rosenzweig, E.B. and Cairo, M.S. (2007) Pulmonary Hypertension in Sickle Cell Disease. *Clinical Advances in Hematology & Oncology*, **5**, 645-653.

[15] Gladwin, M.T., Sachdev, V., Jison, M.L., Shizukuda, Y., Plehn, J.F., Minter, K., *et al*. (2004) Pulmonary Hypertension as a Risk Factor for Death in Patients with Sickle Cell Disease. *New England Journal of Medicine*, **350**, 886-895. https://doi.org/10.1056/nejmoa035477

[16] Bouwe, M. (2022) Trait drépanocytaire et paludisme: Étude prospective comparative et descriptive chez les sujets AA et AS. Ph.D. Thesis, Niamey Université Abdou Moumouni de Niamey.

[17] Ndongo, A.S., Tchoungui, R.F., Dieudonné, D., Hamadou, B., Kuate, M.L., Jingi, M.A., *et al*. (2018) Anomalies cardiaques chez les patients drépanocytaires adultes au Cameroun. *Health Sciences and Diseases*, **19**, 45-48.

[18] Koko, J., Mengue, C., Mouba, J.F., Gahouma, D., Minko, M. and Onewin, A.G. (2015) Complications cardiaques de la drépanocytose Service de Pédiatrie Générale, Hôpital Pédiatrique d'Owendo Libreville (Gabon). 3*ème Congrès SAFHEMA*.

[19] Ondze-Kafata, L.I., Sanouiller, A., Hedreville, M., Hedreville, S. and Larifla, L. (2014) Aspects écho-cardiographiques au cours de la drépanocytose en Guadeloupe. *Pan African Medical Journal*, **18**, Article 45. https://doi.org/10.11604/pamj.2014.18.45.3820

[20] Leugueun, P.G. (2012) Evaluation de la rigidité artérielle par la mesure de la vitesse de l'onde de pouls chez les sujets atteints de syndromes drépanocytaires majeurs: Étude comparative cas/témoins. Ph.D Thesis, Université Cheick Anta Diop de Dakar.

[21] Omar, R. (2019) Les aspects épidémiologiques et thérapeutiques des SDM (à propos de 735 cas colligés au CNRD). Ph.D Thesis, Université Abdou Moumouni de Niamey.

[22] Ramatoulaye, H. (2020) Aspects épidémiologiques, diagnostiques et thérapeutiques des drépanocytaires SS suivis au CNRD de Niamey. Ph.D Thesis, Université Abdou Moumouni de Niamey.

[23] Abdoul, A.H. (2020) La drépanocytose chez les enfants de moins de 5 ans: Aspects épidémiologique, clinique et thérapeutique au CNRD à propos de 380 cas. Ph.D The-

sis, Université Abdou Moumouni de Niamey.

[24] Tolo-Diebkilé, A., Koffi, K.G., Nanho, D.C., Sawadogo, D., Kouakou, B., Siransy-Bogui, L., *et al*. (2010) Drépanocytose homozygote chez l'adulte ivoirien de plus de 21 ans. *Cahiers de Santé*, **20**, 63-67. https://doi.org/10.1684/san.2010.0184

[25] Malam-Abdou, B., Brah, S., Salissou, L., Daou, M., Andia, A., Mahamadou, S., *et al*. (2015) Complications des syndromes drépanocytaires majeurs à l'Hôpital National de Niamey (Niger). *Journal de la Recherche Scientifique de l' Université de Lomé*, **17**, 289-296.

[26] Gnago Nina, P. (2008) La drépanocytose dans un service de Médecine interne. Etude de 33 cas chez l'adulte. Ph.D Thesis, Université Mohammed V-Souissi.

[27] Ellenga-Mbolla, B.F., Okoko, A.R., Ekouya-Bowassa, G., Kocko, I., Oko, A., Moyen, E., *et al*. (2013) Anomalies électrocardiographiques de l'enfant drépanocytaire homozygote à Brazzaville (Congo). *Cardiologie Tropicale*, **137**, 18-22.

[28] Honga, V. (2006) Manifestations cardio- vasculaires de la drépanocytose chez l'enfant de 0 à 18 ans. Ph.D Thesis, Université de Bamako.

[29] Caldas, M.C., Meira, Z.A. and Barbosa, M.M. (2008) Evaluation of 107 Patients with Sickle Cell Anemia through Tissue Doppler and Myocardial Performance Index. *Journal of the American Society of Echocardiography*, **21**, 1163-1167. https://doi.org/10.1016/j.echo.2007.06.001

[30] Raman, S.V., Simonetti, O.P., Cataland, S.R. and Kraut, H.E. (2006) Myocardial Ischemia and Right Ventricular Dysfunction in Adult Patients with Sickle Cell Disease. *Haematologica*, **91**, 1329-1335.