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Hematological and Biochemical Profile of Pediatric Sickle Cell Disease at the Regional Hospital Center of Kenitra (Morocco)

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ABSTRACT:

Background: Sickle cell disease (SCD) is a prevalent hemoglobinopathy in Morocco, with considerable clinical and biological variability, imposing a significant public health burden.

Methods: A cross-sectional study analyzed 232 pediatric SCD patients in steady state (156 SS, 37 AS). Hematological and biochemical parameters were assessed to establish reference profiles for clinical evaluation and therapeutic follow-up.

Results: The mean age was 8.4 years, with a male-to-female ratio of 1.4. Hemoglobin levels were significantly lower in SS compared to AS patients (6.45 vs. 9.3 g/dL; $p < 0.001$). Severe anemia affected 45.3% of patients, while normocytic, microcytic, and macrocytic anemia were observed in 33.2%, 18.5%, and 3.0%, respectively.

Conclusions: Moroccan children with SCD, particularly SS patients, present marked hematological abnormalities reflecting severe disease. These findings highlight the importance of early diagnosis, systematic monitoring, and strengthened public health strategies to reduce morbidity and improve long-term outcomes.

KEYWORDS : Sickle cell disease, hemoglobinopathy, pediatric, Morocco, hematological profile

INTRODUCTION

Sickle cell disease (SCD) represents a major public health concern due to the high prevalence of severe SS forms. In some regions worldwide, the prevalence of hemoglobinopathies may reach up to 25%. SCD is among the most common monogenic diseases globally [1].

It is estimated that approximately 312,000 infants with homozygous hemoglobin SS are born each year worldwide, with the majority (about 236,000) occurring in sub-Saharan Africa[2]. In Morocco, the World Health Organization estimates the carrier rate to be 6.5% [3], suggesting the existence of nearly 30,000 cases of major hemoglobinopathies, including sickle cell disease and thalassemia [4,5].

Several regional studies conducted across Morocco indicate that the north-western part of the country is a high-prevalence area for hemoglobinopathies. In particular, the Rabat–Salé–Kenitra region appears to be the most affected, with Kenitra—especially the Mnasra municipality—identified as a major endemic focus [6,7].

Given the lack of local data on biological parameters in patients with sickle cell disease during the steady state, this study was undertaken to address this gap. Establishing baseline hematological and biochemical profiles may provide a valuable reference for comparison during acute crises and contribute to the evaluation and optimization of patient management strategies from a public health perspective.

METHODS

Study design and setting

We conducted a cross-sectional descriptive study in the Pediatric Department of the Regional Hospital Center (RHC) of Kenitra, Morocco. The study period extended from 1 January 2011 to 31 December 2015.

Study population

The study population comprised 232 pediatric patients with sickle cell disease who were followed at the RHC of Kenitra. Patients included homozygous SS individuals, heterozygous AS individuals, and compound heterozygotes. Eligible patients were either newly diagnosed at the study site or had previously received pediatric follow-up in other healthcare facilities before referral.

Only patients in steady state were included. Steady state was defined as the absence of fever, vaso-occlusive crisis, or acute hemolytic episode at the time of blood sampling.

Eligibility criteria

Patients were included if the diagnosis of sickle cell disease was confirmed by complete blood count and hemoglobin electrophoresis, complemented by family investigation when available. Medical records constituted the primary source of information.

Patients with incomplete or missing medical records were excluded.

Data collection procedures

Sociodemographic, clinical, hematological, and biochemical data were collected retrospectively from patient medical records using a standardized data extraction form. Data collection was performed between June and November 2015.

LABORATORY MEASUREMENTS

Hematological parameters

Venous blood samples (5 mL) were collected in EDTA tubes from all patients. Complete blood counts were performed using a Coulter T-540 automated analyzer. Hemoglobin electrophoresis was carried out at alkaline pH. A sickling test was performed in patients with detected hemoglobin S. Baseline hemoglobin concentration and hematological phenotypes were recorded.

Biochemical parameters

An additional 5 mL venous blood sample was collected in a dry tube and centrifuged at 3,000 revolutions per minute for five minutes. Serum samples were separated and stored at −20 °C until analysis. Biochemical assays were performed by spectrophotometry using an automated analyzer (CPA-Coulter).

Ethical considerations

Permission to access patient medical records was obtained from the administration of the Provincial Hospital of Kenitra. All data were anonymized prior to analysis and handled in accordance with confidentiality requirements. Ethical approval for the study was granted on 15 May 2015 by the Department of Biology, University of Kenitra.

Data analysis

Qualitative variables (gender, pathologies, mortality) were expressed as counts and percentages; quantitative variables (age, length of hospital stay) as mean ± SD. Associations between categorical variables were assessed using Chi-square tests, while ANOVA was used to compare means across pathologies.

Odds ratios (ORs) were calculated to quantify the association between exposures (e.g., gender, admission period) and outcomes (presence/absence of pathologies). An OR > 1 indicates increased risk, while an OR < 1 indicates decreased risk [8,9]. Statistical analyses were performed using SPSS version 25.0.

RESULTS

Hematological findings

A total of 232 pediatric patients were included in the study at the Pediatric Department of the Regional Hospital Center of Kenitra. The mean age was 8.4 ± 4 years, ranging from 1 to 15 years. Among the patients, 136 (59%) were male and 96 (41%) were female, with a male-to-female ratio of 1.4.

Distribution of patients by phenotype

The SS and SBeta phenotypes were predominant among patients aged 11–15 years, representing 36% and 44%, respectively. The AS and SC phenotypes were more frequent in the 6–10-year age group, accounting for 57% and 50%, respectively. The AC phenotype was most common in the 0–5-year age group, with 67%. No statistically significant difference was observed across age groups ($F = 1.884$; $p > 0.05$).

Regarding sex distribution, the SS, SBeta, and AC phenotypes were predominant among male patients, with 59%, 57%, and 67%, respectively. The AS and SC phenotypes were more frequent among female patients, accounting for 54% and 75%, respectively. These differences were not statistically significant ($F = 1.456$; $p > 0.05$) (Table 1).

Table 1. Distribution of Sickle Cell Phenotypes by Age Group and Sex (N = 232)

	Phénotype SS N=156	Phénotype Sbeta N=32	Phénotype AS N=37	Phénotype SC N=4	Phénotype AC N=3
Sexe Masculin	92 (58,97%)	24 (75,00%)	17 45,95%)	1 (25,00%)	2 (66,67%)
Sexe Féminin	64 (41,03%)	8 (25,00%)	20 54,05%)	3 (75,00%)	1 (33,33%)

Tranche d'âge 0-5 ans	47 (30,13%)	8 (25,00%)	7 (18,92%)	1 (25,00%)	2 (66,67%)
Tranche d'âge 6-10 ans	53 (33,97%)	10 (31,25%)	21 (56,76%)	2 (50,00%)	0 (0,00%)
Tranche d'âge 11-15 ans	53 (35,90%)	14 (43,75%)	9 (24,32%)	1 (25,00%)	1 (33,33%)

- Female patients with hemoglobin levels between 6 and 10 g/dL were more frequent, representing 71.88% of cases.
- The SS and SBeta thalassemia phenotypes were more common among male patients, accounting for 68% and 18%, respectively, compared with 67% and 8% among female patients. The AS phenotype was more frequent in female patients (21%) than in male patients (12%). No statistically significant difference was observed ($\chi^2 = 7.942$; $p > 0.05$), indicating a similar distribution of phenotypes between male and female patients.

 The SS and SBeta thalassemia phenotypes were more prevalent in the 11–15-year age group, with 36% and 44% of cases, respectively. The AS phenotype was more common in the 6–10-year age group, representing 57% of cases, while the SS phenotype was frequent in the 0–5-year age group, accounting for 30%. No statistically significant differences were observed across age groups ($F = 0.387$; $p > 0.05$).

Distribution of patients by hemoglobin level

Female patients with hemoglobin levels between 6 and 10 g/dL were more frequent, representing 71.88% of cases. Hemoglobin levels of 6–10 g/dL were also most common among patients aged 6–10 years, accounting for 66.67% of cases (Table 2).

Table 2. Distribution of Patients by Hemoglobin Level, Sex, and Age Group (N = 232)

Paramètre		Taux d'd'hémoglobine		
		<6 g/dl 66 28,45%)	6-10 g/dl 152 (65,52%)	> 10 g/dl 14 (6,03%)
Sexe	Masculin	45 (33,09%)	83 (61,03%)	8 (5,88%)
	Féminin	21 (21,88%)	(71,88%)	(6,25%)
Age	0-5 ans	20 (30,77%)	22 (27,16%)	24 (27,91%)
	6-10 ans	42 (64,62%)	54 (66,67%)	56 (65,12%)
	11-15 ans	3 (4,62%)	5 (6,17%)	6 (6,98%)

- Hemoglobin levels during the steady (intercritical) phase ranged from 4.3 to 11.7 g/dL, with a mean of 7.6 ± 1.48 g/dL.
- In homozygous SS patients, hemoglobin levels ranged from 5.39 to 7.51 g/dL, with a mean of 6.45 g/dL. In double heterozygous SC patients, levels ranged from 6.6 to 11.66 g/dL, with a mean of 10.7 g/dL ($p < 0.001$).

The severity of anemia varied considerably: it was severe in homozygous SS and S/β-thalassemia patients, and mild in AS trait carriers and in composite SC and AC forms. Biologically, anemia was severe in 45.26% of patients, normocytic in 33.19%, microcytic in 18.53%, and macrocytic in 3.02% (Table 3).

Table 3. Severity of Anemia in Patients (N = 232)

	Taux d'Hbg g/dl	Hgb A1	Hgb A2	Hgb F	Hgb S	Hgb C
SS 156	6,45 ± 1,06	-	2,88 ± 0,75	8,19 ± 2,46	88,92 ± 2,38	-
S/B-thalassémie 32	6,46 ± 0,80	20,5 ± 7,61	4 ± 1	8,46 ± 1,55	67,04 ± 8,51	-
AS 37	9,30 ± 1,23	47,10 ± 11,27	3,52 ± 1,13	2,59 ± 1,56	47,00 ± 10,20	-
AC 4	6,70 ± 0,48	67,9 ± 5,37	2,85 ± 0,70	0,9 ± 0,42	-	28,35 ± 4,87
SC 3	10,7 ± 0,96	-	2,6 ± 1,75	2,35 ± 1,35	-	47,63 ± 21,87

HEMOGLOBIN LEVELS DETERMINED BY ELECTROPHORESIS

- **Hemoglobin S:** In our series, levels ranged from 57.2 to 97.7 g/dL, with a mean of 88.3 g/dL.
- **Hemoglobin A2:** The mean level was 1 g/dL, ranging from 2.2 to 3 g/dL.
- **Hemoglobin F:** The mean level was 7 g/dL, with values ranging from 0.3 to 19.5 g/dL.
- **Hemoglobin A1:** The mean level was 33.2 g/dL, ranging from 7.4 to 78.9 g/dL.
- **Hemoglobin C:** The mean level was 41.2 g/dL, with a range of 22.8 to 87.1 g/dL.

Biochemical Findings

According to the management protocol for patients with sickle cell disease, patients received standard treatments and complementary laboratory tests according to their age, which varied depending on the clinical condition of each patient (Table 4).

Table 4. Standard Biochemical Tests and Treatments by Age Group

Paramètre			Effectif	Pourcentage
Age	Tranche d'âge 0-5 ans	Consultation	65	28,02%
		Prise en charge	97	41,81%
	Tranche d'âge 6-10 ans	Consultation	86	37,07%
		Prise en charge	92	39,66%
	Tranche d'âge 11-15 ans	Consultation	81	34,91%
		Prise en charge	43	18,53%
Le nombre de transfusion	<1		63	26,84%
	1-2		117	50,65%
	> 2		52	22,51%
La ferritinémie	Fait		52	22%
	Non fait		180	78%

The age at initiation of care was most common among patients aged 0–5 years, with 97 cases (41.81%), and among those aged 6–10 years, with 92 cases (39.66%).

The number of transfusions received in the Pediatric Department ranged from 0 (63 cases) to 5 (5 cases). A total of 52 patients (22.51%) received more than two transfusions per year.

Serum ferritin levels were measured in only 52 cases, representing 22% of the patients.

DISCUSSION

The aim of our study was to identify biological parameters that can serve as a baseline for evaluating patients during vaso-occlusive crises and to assess the effectiveness of sickle cell disease management.

As this study was hospital-based, selection bias is possible. Nonetheless, the sample size appears relatively large compared to that reported by Ouédraogo-Yugbaré et al. in Togo, who recorded 132 major sickle cell patients over one year of outpatient follow-up [10]. This highlights the ongoing need for structured sickle cell care in Morocco.

The mean age of our study population was 8.4 ± 4 years, ranging from 1 to 15 years. Hemoglobin levels during the steady (intercritical) phase ranged from 4.3 to 11.7 g/dL, with a mean of 7.6 ± 1.48 g/dL. The mean hemoglobin level was 6.45 g/dL in SS patients and 7.7 g/dL in SC patients. These results are consistent with previous studies reporting mean hemoglobin values of 6.5 g/dL (range 2.1–12 g/dL) [11,12], and a mean of 6.22–8.43 g/dL in SS and SC patients, respectively [13].

Our findings support previous reports indicating that hemoglobin levels in SC heterozygotes, in the absence of complications, are close to normal [14]. Koffi et al. observed a mean hemoglobin of 9 g/dL in SC patients at the Yopougon University Hospital, concluding that acute anemia was more frequent in patients with HbS >50% or those with complications [15].

In our series, 90 cases had HbA2 levels below 4 g/dL, which is a key differential diagnostic criterion from thalassemia. Elevated HbA2 (11.22%) and HbF (38.32%, 41 cases) were considered consistent with sickle cell disease. The percentage of HbS ranged from 57.2 to 97.7 g/dL, with a mean of 88.3 g/dL; HbA2 ranged from 2.2 to 3 g/dL (mean 2.2 g/dL); and HbF from 0.3 to 19.5 g/dL (mean 7 g/dL). According to Galactéros and Beuzard, high HbF levels (>10 g/dL) partially inhibit sickling and modulate the clinical expression of the disease [16].

Regarding sickle trait, previous studies reported HbA2 <3.2 g/dL in 12 cases [17] and <3.5 g/dL in 60 cases [18]. Other studies with smaller datasets reported limitations in separating HbS and HbA2 using starch-block electrophoresis, highlighting methodological constraints [19].

In our cohort, 21 patients showed HbS (33.72 ± 8.5 g/dL) lower than HbA (60.22 ± 9.22 g/dL), compatible with sickle trait. Their HbF levels (3.23 ± 0.73 g/dL) were comparable to those observed in Congolese sickle cell carriers living in Belgium [20]. HbA2 levels were also similar (2.65 ± 0.43 g/dL). Physiologically, the absence of functional HbA stimulates compensatory synthesis of HbF and HbA2, depending on the type of deficit and patient age. Limitations of separation methods, minimal charge differences, and difficulties in quantification, particularly with gel electrophoresis, affect measurement accuracy. Advances in automated capillary electrophoresis and chromatography have improved care [21].

In our study, 75% of patients experienced acute anemia, compared to 66% in Bouzaid's series [22] and 40% in Harrak's study [23]. Literature reports a consistent anemia in the steady state, averaging 8 g/dL (range 6–10 g/dL), normocytic in homozygous SS, and milder with slight microcytosis in SC forms (10–12 g/dL) [24]. This reflects chronic hemolysis in SS patients with insufficient compensatory reticulocytosis and a shortened erythrocyte lifespan of 10–12 days, versus 29–33 days in SC patients [24].

Preventive care initiated in hospitalization included early management; 42% of patients began care before age 5. Early intervention improves prognosis, as suggested by Cabannes et al. [25], and allows most patients to reach adulthood without major disability [26,27].

Regarding vaccination, 95% of hospitalized patients were up to date, while 5% had incomplete vaccination, mainly for disease-specific vaccines. In a Congolese cohort, 65.5% of homozygous sickle cell children had received no specific vaccines [28]. Vaccination substantially reduces sickle cell–related morbidity.

In terms of therapeutic follow-up, 83.3% of patients received maintenance therapy, explaining the relatively low number of annual vaso-occlusive crises and the fact that 27% of patients required no transfusions. By comparison, Gendrel in Gabon reported an 85% transfusion rate in pediatric sickle cell patients [29].

Finally, awareness of hemoglobin type is critical in at-risk populations. Identifying heterozygous couples allows genetic counseling and prenatal diagnosis. Based on our findings, such counseling is strongly recommended in Morocco, where sickle cell disease remains a significant public health concern.

CONCLUSION

Homozygous SS sickle cell disease is distinguished from the SC form by the severity of its clinical presentation during the steady state, as confirmed by the biological parameters studied. The main difference lies in hemoglobin levels; therefore, in the presence of marked anemia in an SC patient, a vaso-occlusive crisis or complication should be investigated and treated. It is therefore important that children with sickle cell disease receive regular and careful follow-up to prevent the occurrence of complications, which often threaten the life or function of the affected organ.

However, the high cost of vaccines, medications, and laboratory tests for our patients, combined with limited laboratory infrastructure and the unavailability of specific treatments, makes the management of major sickle cell syndromes challenging in our country. This underscores the need for a national sickle cell care program.

Moreover, attention should be given to genetic counseling and prenatal diagnosis for parents carrying genetic abnormalities or couples who have already had a child affected by sickle cell disease.

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Conflict of interest statement,

The authors declare no conflicts of interest.

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DATA AVAILABILITY STATEMENT

The data underpinning the results of this study are not available to the public for reasons of confidentiality, for example, but are available on request from the corresponding author.

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