Nigerian Medical Journal
NIGERIA MEDICAL ASSOCIATION
Print ISSN 0300-1652, E-ISSN 2229-774X

Original Article

Blood Pressure Abnormalities Amongst Children with Sickle Cell Anaemia in Steady State and in Crises Attending a Tertiary Hospital in South East Nigeria.

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Abstract

Background: Sickle cell anaemia (SCA) is a hereditary haemoglobin disorder associated with significant cardiovascular complications. Blood pressure abnormalities, including both hypertension and hypotension, are increasingly recognized as important contributors to morbidity in affected children. This study aims to determine the prevalence of hypertension and hypotension among children with SCA in steady state and during vaso-occlusive crisis, and to compare these findings with age- and sex-matched controls with normal haemoglobin genotype (HbAA).

Methodology: This cross-sectional study included 135 children with SCA aged 2–17 years, evaluated during both steady state and crisis, alongside age- and sex-matched HbAA controls. Blood pressure was measured using a standard mercury sphygmomanometer (Accoson) with appropriately sized cuffs. Data were analysed using appropriate statistical methods, with significance set at $p<0.05$.

Results: In the steady state, 4.4% of children with SCA were hypertensive, and 11.1% were hypotensive. During the crisis, 6.7% were hypertensive and 6.7% hypotensive. Among controls, 4.4% were hypertensive and 2.2% hypotensive. Mean systolic and diastolic blood pressures were comparable across steady state, crisis, and control groups ($p=0.462$). In the crisis group, haemoglobin concentration showed a significant negative correlation with diastolic blood pressure ($r = -0.37$, $p = 0.011$). Age demonstrated strong positive correlations with both systolic and diastolic blood pressures in the steady state ($r = 0.78$ and 0.79, respectively; $p = 0.001$) and during crisis ($r = 0.66$ and 0.57, respectively; $p = 0.001$).

Conclusion: Blood pressure abnormalities, encompassing both hypertension and hypotension, occur in children with SCA irrespective of clinical status. Despite comparable mean blood pressure values, acute crises are associated with dynamic variations influenced by age and haemoglobin levels. Routine and vigilant blood pressure monitoring is essential for early detection and optimal management.

Keywords: sickle cell anaemia, steady state, crises, hypertension, hypotension, blood pressure

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How to Cite: Kawa A, Nwolisa C, Chinawa AT, Ossai EN, Chinawa JM. Blood Pressure Abnormalities Amongst Children with Sickle Cell Anaemia in Steady State and in Crises Attending a Tertiary Hospital in South East Nigeria. Niger Med J 2026; 67 (2): 3163-3176. https://doi.org/10.71480/nmj.v67i2.1344

Quick Response Code:

Introduction

Sickle cell anaemia (SCA) is an inherited haemoglobin disorder characterized by the presence of homozygous haemoglobin S, leading to the deformation of erythrocytes into rigid, sickle-shaped cells [1]. It remains a major public health challenge, particularly in sub-Saharan Africa, where it affects approximately 2% of all births and contributes substantially to childhood morbidity and mortality [2]. The global burden of SCA has continued to rise, underscoring the need to better understand its clinical complications [3]. Among these, cardiovascular abnormalities are a leading cause of morbidity and mortality in affected children.

Blood pressure is a critical clinical parameter and an important indicator of disease severity in children with SCA. Both elevated and reduced blood pressure have been described in this population. Elevated blood pressure is associated with an increased risk of renal dysfunction, pulmonary hypertension, and cerebrovascular events, while hypotension is also commonly reported and may reflect underlying haemodynamic alterations that contribute to adverse outcomes [5,10,13–16]. Although children with SCA are generally reported to have lower baseline blood pressure than their healthy counterparts, even modest increases may predispose them to severe complications.

Despite the clinical importance of blood pressure abnormalities in SCA, most existing studies have focused predominantly on patients in steady state, with limited data on blood pressure patterns during vaso-occlusive crises—a period characterized by significant physiological stress and haemodynamic instability. In addition, inconsistencies across populations suggest the influence of regional and environmental factors, yet data from Nigeria and other parts of sub-Saharan Africa remain limited. Furthermore, key determinants such as haemoglobin concentration, age, and anthropometric indices have not been adequately explored across different clinical states.

This study, therefore, aims to determine the prevalence of hypertension and hypotension among children with SCA during steady state and vaso-occlusive crisis, and to compare these findings with age- and sex-matched HbAA controls. It also seeks to identify factors associated with blood pressure abnormalities in this population, with the goal of informing improved clinical management strategies.

Research Questions

1. What are the blood pressure patterns among children with sickle cell anaemia compared with age- and sex-matched controls?
2. What is the prevalence of hypertension and hypotension among children with sickle cell anaemia compared with controls?

Hypotheses

For Blood Pressure Patterns:

- **Null Hypothesis (H_0):** There is no significant difference in blood pressure readings between children with sickle cell anaemia and controls.
- **Alternative Hypothesis (H_1):** There is a significant difference in blood pressure readings between children with sickle cell anaemia and controls.

For Prevalence of Hypertension and Hypotension:

- **Null Hypothesis (H_0):** There is no significant difference in the prevalence of hypertension and hypotension between children with sickle cell anaemia and controls.

- **Alternative Hypothesis (H_1):** There is a significant difference in the prevalence of hypertension and hypotension between children with sickle cell anaemia and controls.

Methods

Study Design and Setting

This was a hospital-based cross-sectional study conducted at the Children's Outpatient Clinic and Children's Emergency Unit of a tertiary healthcare institution that serves as a major referral centre for paediatric medical and haematological conditions. The study compared blood pressure patterns among children with sickle cell anaemia (SCA) in different clinical states and healthy controls.

Study Population and Eligibility Criteria

The study included children aged 2–17 years who were categorized into three groups: children with confirmed homozygous sickle cell anaemia (HbSS) in steady state, children with HbSS in crisis state, and age- and sex-matched controls with normal haemoglobin genotype (HbAA), confirmed by haemoglobin electrophoresis. Steady state was defined as the absence of acute illness, including no painful crisis requiring hospital treatment in the preceding 30 days and no blood transfusion within the previous four months. Crisis state was defined using standardized clinical criteria as the presence of vaso-occlusive crisis or other acute complications of SCA, including aplastic crisis, splenic sequestration, hyperhaemolytic crisis, hepatic crisis, dactylitis, or acute chest syndrome at presentation.

Controls were recruited from children attending the outpatient clinic for minor, non-systemic conditions and had no history of sickle cell disease or other haemoglobinopathies. Children in all groups were excluded if they had known or suspected congenital or acquired cardiovascular diseases that could affect blood pressure measurements. Written informed consent was obtained from parents or caregivers prior to enrolment. Participants were recruited consecutively until the required sample size was achieved.

Data Collection and Measurements

Data were collected using a structured questionnaire and clinical assessment. Information obtained included socio-demographic characteristics and relevant clinical history. Anthropometric measurements, including weight and height, were obtained using standard procedures, and body mass index was calculated accordingly.

Blood pressure was measured using an appropriately sized cuff and a calibrated sphygmomanometer, following standard paediatric guidelines. Measurements were taken with the child in a seated position after at least five minutes of rest, and the average of two readings taken at appropriate intervals was recorded. All measurements were performed by trained healthcare personnel to ensure consistency, and standard protocols were followed to minimize inter-observer variability.

Blood pressure classification was based on age-, sex-, and height-specific percentiles in accordance with established paediatric guidelines (e.g., the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents or updated American Academy of Pediatrics guidelines). Hypertension and hypotension were defined using these standardized thresholds.

Statistical Analysis

Data were entered and analysed using Statistical Package for the Social Sciences (SPSS) software (version XX). Continuous variables were summarized using means and standard deviations, while categorical variables were presented as frequencies and percentages. Comparisons between groups were performed using appropriate statistical tests, including the chi-square test for categorical variables and the independent t-test or analysis of variance for continuous variables. Multivariable analysis was conducted to identify factors independently associated with blood pressure abnormalities. Statistical significance was set at $p < 0.05$.

Sample Size Determination
The sample size was calculated using the formula for comparison of two proportions [17]:

$$n = (Z\alpha + Z_{1-}\beta)^2 \{P_1(1 - P_1) + P_2(1 - P_2)\} / (P_1 - P_2)^2$$

Where P_1 represents the expected proportion of blood pressure abnormalities among children with sickle cell anaemia (SCA), and P_2 represents the expected proportion among children with a normal haemoglobin genotype (HbAA). The values for P_1 and P_2 were obtained from previously published studies [17] that reported a higher prevalence of abnormal blood pressure in children with SCA compared to controls. Specifically, P_1 was taken as the reported prevalence among children with SCA, while P_2 was derived from the corresponding prevalence among non-SCA controls in the same or similar population.

A confidence level of 95% ($Z\alpha = 1.96$) and a statistical power of 80% ($Z_{1-}\beta = 0.84$) were assumed for the calculation to ensure adequate ability to detect a statistically significant difference between groups.

The initial calculated sample size (n_0) was 70. Given that the total population of eligible SCA patients aged 2–17 years in the study centre was less than 10,000 (N = 100), a finite population correction was applied [18]:

$$Nf = n_0 / [1 + (n_0 / N)]$$

Substituting the values:
$Nf = 70 / [1 + (70/100)] = 41$

To improve statistical robustness and account for potential attrition or incomplete data, a 10% adjustment was added, resulting in a minimum sample size of approximately 45 participants per SCA subgroup.

A total of 135 participants were enrolled, comprising 90 children with SCA (45 in steady state and 45 in crisis) and 45 age- and sex-matched HbAA controls.

Ethical Approval and Consent to Participate
This was sought from the research and ethics committee of Federal Medical Centre, Owerri, Nigeria, with IRB number FMC/OW/HREC/VOL.II/052, obtained on 01/03/2022, while written informed consent was obtained from the mothers who brought their children to the health centers. Informed consent was obtained from a parent and/or legal guardian for study participation.

Anthropometric Measurements
Weight and height were measured using standardized calibrated equipment [18]. Body mass index (BMI) was calculated as weight (kg)/height (m^2) [18,19]. Nutritional status was assessed using WHO reference standards.

Blood Pressure Measurement
Blood pressure was measured using a mercury sphygmomanometer (Accoson, UK) with an appropriate cuff size [19,20]. Measurements followed standardized pediatric guidelines [12]. Three readings were taken at 1-minute intervals after 5 minutes of rest, and the average was recorded. Hypertension was defined as BP ≥95th percentile and hypotension as BP <5th percentile for age, sex, and height [21,22].

Laboratory Measurements
Haemoglobin concentration and genotype were determined using an automated haematology analyzer (Orphee Mythic 60, Switzerland). Samples were processed within 2 hours of collection.

Bias Reduction Measures

To minimize selection and measurement bias:

- Age- and sex-matched controls were used
- Standardized protocols were applied for all anthropometric and BP measurements
- Calibrated instruments were used
- Blood pressure was measured multiple times and averaged
- Known confounders, such as cardiovascular disease, were excluded

Statistical Analysis

Data were analysed using IBM SPSS version 26. Continuous variables were summarized using means and standard deviations, while categorical variables were presented as frequencies and percentages. **Chi-square test** was used for associations between categorical variables. **One-way ANOVA** was used to compare mean blood pressure across groups. **Pearson correlation** assessed relationships between haemoglobin, BMI, age, and blood pressure. **Fisher's exact test** was used where expected cell counts were small. A p-value <0.05 was considered statistically significant.

Results

Table 1: Characteristics of the respondents

Variable	Stable HbSS (n=45)	HbSS Crisis (n=45)	HbAA (n=45)	F	p-value
Age of respondents in years					
Mean±SD	8.1±4.4	8.1±4.7	8.1±4.7	0.000	1.0
Age of respondents in groups					
<5 years	13 (28.9%)	15 (33.3%)	15 (33.3%)	0.685*	0.953
5-9 years	15 (33.3%)	12 (26.7%)	12 (26.7%)		
≥10 years	17 (37.8%)	18 (40.0%)	18 (40.0%)		
Gender					
Male	23 (51.1%)	29 (64.4%)	29 (64.4%)	2.222*	0.329
Female	22 (48.9%)	16 (35.5%)	16 (25.6%)		
Weight (Kg)					
Mean±SD	27.6±12.5	28.0±13.4	31.4±16.5	0.937	0.394
Height (cm)					

Mean±SD	125.8±24.7	125.2±25.3	130.8±26.3	0.642	0.528

*Chi-square test

A total of 135 children were enrolled, comprising 45 in steady state HbSS, 45 in HbSS crisis, and 45 HbAA controls.

Baseline Characteristics (Table 1)

The mean age of participants was comparable across the three groups (8.1 ± 4.4 years in steady state, 8.1 ± 4.7 years in crisis, and 8.1 ± 4.7 years in controls; p = 1.000). Age distribution and sex proportions did not differ significantly between groups (p = 0.953 and p = 0.329, respectively). Similarly, there were no statistically significant differences in mean weight (p = 0.394) or height (p = 0.528) across the groups.

Table 2: Distribution of BP in Study Groups

	Steady State		Crisis		Control	
Statistics	**Systolic BP**	**Diastolic BP**	**Systolic BP**	**Diastolic BP**	**Systolic BP**	**Diastolic BP**
Mean	96.1	58.3	97.8	59.5	98.2	58.8
Std. Deviation	11.0	10.4	12.5	10.7	9.9	8.4
Minimum	80.0	40.0	80.0	40.0	80.0	40.0
Maximum	130.0	90.0	130.0	84.0	120.0	80.0
5th Percentile	78.0	41.0	77.0	42.0	82.0	45.0
25th Percentile	89.0	50.0	90.0	50.0	90.0	51.0
75th Percentile	100.0	60.0	107.0	61.0	105.0	60.0
95th Percentile	117.0	80.0	126.7	80.7	119.4	77.6

Blood Pressure Distribution (Table 2)

Mean systolic and diastolic blood pressures were similar across the study groups. There were no statistically significant differences in systolic blood pressure (p = 0.462) or diastolic blood pressure (p = 0.830) among children in steady state, crisis, and controls.

Hypertension was observed in 3/45 (6.7%) of children in crisis, 2/45 (4.4%) in steady state, and 2/45 (4.4%) among controls. Hypotension occurred in 5/45 (11.1%) of children in steady state, compared with lower proportions in the other groups.

Table 3: Correlation of Hb with blood pressure in study groups

Hb vs	Steady State r, (p-value)	Crisis r, (p-value)	Control r, (p-value)
Systolic BP	-0.02 (0.848)	-0.26(0.084)	0.36(0.014)*
Diastolic BP	0.07 (0.639)	-0.37(0.011)*	0.41(0.005)*

*r: Pearson's correlation coefficient, *statistically significant (p<0.05)*

Correlation Between Haemoglobin and Blood Pressure (Table 3)

In the crisis group (n = 45), haemoglobin concentration showed a significant negative correlation with diastolic blood pressure ($r = -0.37$, $p = 0.011$), but not with systolic blood pressure ($p = 0.084$). In the control group (n = 45), haemoglobin concentration was positively correlated with both systolic blood pressure ($r = 0.36$, $p = 0.014$) and diastolic blood pressure ($r = 0.41$, $p = 0.005$). No statistically significant correlations were observed in the steady state group.

Table 4: Association of Gender and Blood Pressure in Study Groups

Gender	Hypertensive n,(%)	Normal n,(%)	Total n,(%)	p-value
Steady State				
Female	1(4.5)	21(95.5)	22(100.0)	0.974
Male	1(4.3)	22(95.7)	23(100.0)	
Crisis State				
Female	1(6.3)	15(93.8)	16(100.0)	0.933
Male	2(6.9)	27(93.1)	29(100.0)	
Normal				
Female	1(6.3)	15(93.8)	16(100.0)	0.6624
Male	1(3.4)	28(96.6)	29(100.0)	

Association Between Gender and Blood Pressure (Table 4)

There was no statistically significant association between gender and blood pressure category in any of the study groups: steady state ($p = 0.974$), crisis ($p = 0.933$), and controls ($p = 0.662$).

Table 5: Correlation of Age with blood pressure in study groups

Age vs	Steady State r, (p-value)	Crisis r, (p-value)	Control r, (p-value)
Systolic BP	0.78 (0.001)*	0.66 (0.001)*	0.83(0.001)*
Diastolic BP	0.79 (0.001)*	0.57 (0.001)*	0.68 (0.001)*

*r: Pearson's correlation coefficient, *statistically significant (p<0.05)*

Correlation Between Age and Blood Pressure (Table 5)

Age demonstrated a significant positive correlation with both systolic and diastolic blood pressure across all groups. In the steady state group (n = 45), systolic (r = 0.78, p < 0.001) and diastolic (r = 0.79, p < 0.001) blood pressures increased with age. Similar significant correlations were observed in the crisis group (systolic: r = 0.66, p < 0.001; diastolic: r = 0.57, p < 0.001) and in controls (systolic: r = 0.83, p < 0.001; diastolic: r = 0.68, p < 0.001)

Table 6: Association of Age Distribution and Blood Pressure Category in Study Group

Age Groups (years)	Hypertensive n,(%)	Normal n,(%)	Total n,(%)	p-value
Steady State				
2 – 5	0(0.0)	16(100.0)	**16(100.0)**	
6 – 9	0(0.0)	12(100.0)	**12(100.0)**	0.0007*
10 – 13	0(0.0)	12(100.0)	**12(100.0)**	
14 – 17	2(40.0)	3(60.0)	**5(100.0)**	
Crisis State				
2 – 5	0(0.0)	17(100.0)	**17(100.0)**	
6 – 9	0(0.0)	10(100.0)	**10(100.0)**	0.1773
10 – 13	2(18.2)	9(81.8)	**11(100.0)**	
14 – 17	1(14.3)	6(85.7)	**7(100.0)**	
Normal				
2 – 5	0(0.0)	17(100.0)	**17(100.0)**	
6 – 9	0(0.0)	10(100.0)	**10(100.0)**	0.0099*
10 – 13	0(0.0)	11(100.0)	**11(100.0)**	
14 – 17	2(28.6)	5(71.4)	**7(100.0)**	

**Statistically significant (<0.05)*

Association Between Age Group and Blood Pressure Category (Table 6)

A statistically significant association between age group and blood pressure category was observed in the steady state group ($p = 0.0007$) and among controls ($p = 0.0099$), but not in the crisis group ($p = 0.1773$).

Correlation of Anthropometric Measures with Blood Pressure

Height showed a significant positive correlation with both systolic and diastolic blood pressure across all groups ($p \leq 0.001$). Similarly, weight was positively correlated with systolic and diastolic blood pressure in all groups, with all correlations reaching statistical significance ($p \leq 0.001$).

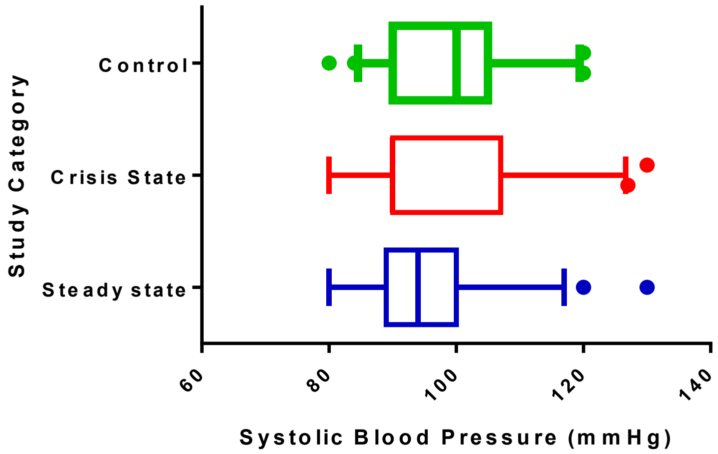

Figure 1: Box and Whisker Plot showing 25th and 95th Percentiles of Systolic Blood Pressure

Figure 1 shows the percentile distribution of systolic pressure in the steady state, crisis, and control groups.

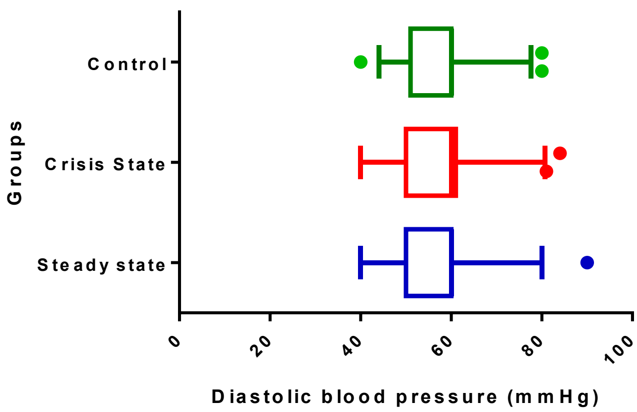

Figure 2:Box and Whisker Plot showing 25th and 95th Percentiles of Diastolic Blood Pressure

Figure 2 shows the percentile distribution of Diastolic pressure in the steady state, crisis, and control groups.

Percentile Distribution of Blood Pressure (Figures 1 and 2)

Figures 1 and 2 illustrate the percentile distributions of systolic and diastolic blood pressure across the three study groups.

Discussion

This study evaluated the prevalence and pattern of blood pressure abnormalities among children with sickle cell anaemia (SCA) in both steady state and vaso-occlusive crisis, compared with children with normal haemoglobin genotype (HbAA).

Principal findings

The prevalence of hypertension among children with SCA was low in both steady state (4.4%) and during crises (6.7%), although a modest increase was observed during vaso-occlusive episodes. In contrast, hypotension was more common among children with SCA than in controls, occurring in 11.1% of those in steady state and 6.7% during crises, compared with 2.2% among HbAA children. No statistically significant gender differences in blood pressure were observed across the study groups. Blood pressure values increased with age, and height demonstrated a positive association with both systolic and diastolic blood pressure. In addition, haemoglobin concentration showed a negative correlation with diastolic blood pressure among children with SCA in crisis, while a positive correlation with systolic blood pressure was observed in the control group.

Interpretation of findings

The slightly higher prevalence of hypertension during vaso-occlusive crises suggests that acute clinical states in SCA may influence blood pressure regulation. However, the overall low prevalence indicates that hypertension is not a dominant cardiovascular feature in this population.

The higher occurrence of hypotension among children with SCA supports the concept that lower blood pressure may be a characteristic haemodynamic pattern in these patients. This may reflect chronic anaemia and altered vascular tone, which together contribute to reduced systemic blood pressure. The absence of gender differences in blood pressure suggests that sex may not be a major determinant of blood pressure variation in this cohort. The observed increase in blood pressure with age is consistent with expected physiological trends during growth and development. Similarly, the positive association between height and blood pressure likely reflects normal haemodynamic relationships related to body size and vascular structure. The inverse relationship between haemoglobin concentration and diastolic blood pressure during crisis may indicate compensatory cardiovascular responses to anaemia, whereas the positive association observed in controls suggests a different physiological pattern in children without SCA.

Comparison with existing literature

The prevalence of hypertension observed in this study is lower than the 19% reported by Benneh-Akwasi et al. [25]. This discrepancy may be related to differences in study design, population characteristics, or environmental factors. The predominance of lower blood pressure among children with SCA is consistent with previous studies that describe relative hypotension as a common finding in this population [23–25]. In contrast to the findings of Kupferman et al. [25], who reported higher blood pressure values in males, this study did not observe significant gender differences. Variations in sample size, age distribution, and population characteristics may explain these differences. The positive association between anthropometric measures and blood pressure aligns with established evidence demonstrating that growth-related factors influence blood pressure in children [23–25].

Contextual considerations

Environmental and socio-demographic factors may have influenced the observed findings. The study setting in Southeast Nigeria is characterized by diverse socioeconomic conditions, dietary patterns, and varying access to healthcare, all of which may affect cardiovascular health. While genetic and environmental influences may contribute to blood pressure variation, these factors were not directly measured in this study and should therefore be interpreted cautiously.

Clinical Implications

These findings highlight the variability of blood pressure patterns in children with SCA and underscore the importance of routine monitoring in both steady state and during crises. However, given the cross-sectional design of this study, causal relationships cannot be established. Additionally, the findings are specific to the study population and may not be generalizable to other settings.

Limitations

This study has several limitations that should be acknowledged. First, the cross-sectional design limits the ability to infer causal relationships between sickle cell disease status and observed blood pressure abnormalities. Second, the hospital-based sampling approach introduces a potential selection bias, as participants may not fully represent the broader population of children with sickle cell anaemia in the community.

In addition, the study relied on single-point clinic blood pressure measurements rather than 24-hour ambulatory blood pressure monitoring. This may have reduced the sensitivity for detecting transient or masked hypertension and hypotension, thereby limiting the precision of blood pressure classification. There is also the possibility of observer-related measurement bias, which may have influenced blood pressure readings despite efforts to standardize procedures.

Furthermore, the relatively small sample size and the single-centre design may restrict the generalizability of the findings to other settings. Longitudinal cohort studies with larger, more diverse populations and the inclusion of ambulatory blood pressure monitoring would provide more robust evidence on blood pressure patterns and trends over time in this population.

Conclusion

This study highlights that blood pressure abnormalities, including both hypertension and hypotension, are common among children with sickle cell anaemia. Although mean blood pressure values may appear normal, clinically significant fluctuations were observed, particularly during vaso-occlusive crises, and were associated with factors such as age and severity of anaemia. These findings emphasize the need for routine and careful blood pressure monitoring in children with sickle cell anaemia to support early identification and timely management of cardiovascular complications.

Recommendations

1. **Routine Blood Pressure Monitoring:**
   Regular measurement of blood pressure should be incorporated into the routine clinical assessment of children with sickle cell anaemia in both steady state and during crises to enable early detection of hypertension and hypotension.
2. **Comprehensive Clinical Evaluation:**
   Clinicians should consider both elevated and low blood pressure as clinically significant in children with SCA, with appropriate evaluation for underlying causes such as anaemia severity and renal dysfunction.
3. **Individualized Patient Management:**
   Management protocols for children with SCA should include strategies tailored to blood pressure

abnormalities, particularly during vaso-occlusive crises, where haemodynamic changes may be more pronounced.

4. **Health Education:**
   Caregivers and patients should be educated on the importance of regular follow-up and monitoring, as well as recognizing symptoms suggestive of blood pressure abnormalities.
5. **Further Research:**
   Larger longitudinal studies are recommended to better understand the temporal relationship between haemoglobin levels, age, and blood pressure changes in children with SCA, as well as to explore regional variations within Nigeria and other African settings.
6. **Policy and Practice Integration:**
   Guidelines for the management of sickle cell anaemia should incorporate routine blood pressure assessment and standardize thresholds for intervention in paediatric populations.

Declaration

Ethical Approval and Consent to Participate

This was sought from the research and ethics committee of Federal Medical Centre, Owerri, Nigeria, with IRB number FMC/OW/HREC/VOL.II/052, obtained on 01/03/2022, while written informed consent was obtained from the mothers who brought their children to the health centers. Informed consent was obtained from a parent and/or legal guardian for study participation.

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