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Original Research Article

CORRELATION ANALYSIS OF PERIPHERAL BLOOD SMEAR MORPHOLOGY WITH HAEMOLYSIS INDICES IN SICKLE CELL ANAEMIA: AN INSTITUTIONAL BASED STUDY

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ABSTRACT

Background: Sickle cell anaemia is a chronic haemolytic disorder characterised by recurrent vaso-occlusive events and persistent red cell destruction, leading to substantial morbidity. Peripheral blood smear evaluation remains an accessible diagnostic tool, yet its correlation with objective haemolysis indices in stable outpatient populations is not fully established. Identifying morphological markers that reflect haemolytic severity may enhance disease monitoring, especially in resource-constrained settings. **Aim:** To correlate peripheral blood smear morphology with haemolysis indices in sickle cell anaemia. **Materials and Methods:** Present study was conducted in Department of Pathology, GMERS Medical college, Rajpipla, Narmada, Gujarat (India) and included 52 clinically stable sickle cell anaemia (HbSS) patients. Peripheral blood smears were prepared and examined for key morphological abnormalities, including sickled cells, target cells, anisopoikilocytosis, polychromasia, Howell–Jolly bodies and nucleated red blood cells. Haemolysis indices—haemoglobin, haematocrit, reticulocyte count, lactate dehydrogenase (LDH), indirect bilirubin, haptoglobin and mean corpuscular volume—were analysed using standard laboratory procedures. **Results:** Sickled cells were universally present (100%), while target cells (88.46%), anisopoikilocytosis (86.54%) and polychromasia (73.08%) were also highly prevalent. Howell–Jolly bodies (42.31%) and nucleated RBCs (34.62%) indicated splenic dysfunction and marrow stress. Mean haemoglobin was low (7.82 ± 1.26 g/dL), and LDH (612.38 ± 148.22 U/L), indirect bilirubin (1.84 ± 0.66 mg/dL) and reticulocyte count (6.42 ± 1.58%) were elevated, confirming significant haemolysis. Strong correlations were found between sickled cell proportion and LDH ($r = 0.62$, $p = 0.0001$), polychromasia and reticulocyte count ($r = 0.58$, $p = 0.0002$) and NRBCs with LDH ($r = 0.44$, $p = 0.002$). Patients with Howell–Jolly bodies exhibited significantly lower haemoglobin and higher bilirubin, LDH and reticulocyte counts, indicating greater haemolytic burden. **Conclusion:** Peripheral smear morphology is closely associated with haemolysis severity in sickle cell anaemia and serves as a valuable, low-cost adjunct for disease monitoring in outpatient care. Morphological abnormalities can reliably reflect haemolytic activity and support early identification of patients at higher risk.

INTRODUCTION

Sickle cell anaemia is one of the most common severe monogenic disorders worldwide and remains a major cause of chronic morbidity and premature mortality despite advances in screening and supportive care. The disease is caused by a single point mutation in the β-globin gene, yet its clinical expression is remarkably heterogeneous, ranging from relatively mild disease to a severe multisystem vasculopathy with recurrent hospitalisations and reduced life expectancy.[1] Globally, sickle cell anaemia imposes a substantial health burden on low- and middle-income countries, particularly in sub-Saharan Africa, India, the Middle East and parts of the Mediterranean, where access to comprehensive care is often limited and many patients are managed in overburdened outpatient settings. Epidemiological

modelling suggests that hundreds of thousands of infants are born each year with sickle haemoglobin, with the highest birth prevalence in regions where malaria has historically been endemic.[2,3] These projections highlight the scale of the problem and underscore the need for simple, robust tools that can be applied in routine clinical practice to risk-stratify patients and monitor disease activity over time. In many high-income countries, structured newborn screening and specialised sickle cell clinics have improved survival and reduced acute complications. However, in resource-constrained settings, patients frequently present late, follow-up is irregular, and disease monitoring often relies on basic haematological and biochemical tests, underlining the importance of maximising the diagnostic and prognostic value of routinely available investigations. The pathophysiology of sickle cell anaemia is driven by polymerisation of deoxygenated sickle haemoglobin (HbS), which leads to red blood cell deformation, membrane damage, and the characteristic rigid "sickle" shape. These sickled erythrocytes are prone to both haemolysis and vaso-occlusion. Intravascular and extravascular haemolysis contribute to chronic anaemia, increased bilirubin production, depletion of nitric oxide, and endothelial dysfunction, while adhesive interactions between sickled cells, leukocytes, platelets and the endothelium promote microvascular obstruction and ischaemia–reperfusion injury.[4] The cumulative consequence is a complex, multi-organ disease involving the central nervous, cardiopulmonary, renal, hepatobiliary and musculoskeletal systems, with recurrent vaso-occlusive crises superimposed on a background of chronic low-grade haemolysis and inflammation.[5] Peripheral blood smear examination remains one of the most accessible and informative investigations in the evaluation of sickle cell anaemia. Classical morphological features include sickled (drepanocytic) cells, target cells, polychromatophilic red cells, marked anisopoikilocytosis and, in many patients, nucleated red blood cells reflecting intense marrow stimulation. The presence of Howell–Jolly bodies is characteristic of functional hyposplenism or autosplenectomy, a well-recognised complication of sickle cell anaemia that develops in childhood and persists into adult life.[5] Although these morphological abnormalities are well described, they are often reported qualitatively in routine practice, and the potential value of semi-quantitative grading of smear changes as a surrogate marker of haemolytic burden has not been fully explored, particularly in stable outpatients. Laboratory markers of haemolysis provide complementary, objective evidence of ongoing red cell destruction. A typical haemolytic profile includes anaemia with an elevated reticulocyte count, increased lactate dehydrogenase (LDH) and indirect (unconjugated) bilirubin, and reduced or undetectable haptoglobin levels.[6] In sickle cell anaemia, these indices reflect the balance between red cell destruction and bone marrow compensation and can fluctuate with intercurrent infection, vaso-occlusive events, transfusion and other modifying factors.[4,6] Because they are routinely available in most tertiary laboratories, haemolysis indices are attractive candidates for incorporation into composite scores that capture disease activity in real-world outpatient cohorts. However, in many centres their interpretation remains largely descriptive, and the relationship between these biochemical markers and simple smear morphology has not been systematically characterised. There is growing recognition that the intensity of haemolysis is not merely a laboratory phenomenon but is closely linked to clinically important vascular complications. Studies in large sickle cell cohorts have shown that higher degrees of haemolysis, assessed using composite indices derived from LDH, bilirubin, reticulocyte count and related markers, are associated with pulmonary hypertension, hypoxaemia, leg ulcers and increased risk of death.[7]

MATERIALS AND METHODS

Present study was conducted in Department of Pathology, GMERS Medical college, Rajpipla, Narmada, Gujarat (India) and included 52 clinically stable sickle cell anaemia (HbSS) patients. The study aimed to correlate peripheral blood smear morphology with haemolysis indices to understand the extent of red cell destruction and morphological variation in routine clinical practice. The setting provided access to a diverse outpatient population and standardized laboratory facilities necessary for haemolysis marker evaluation and microscopic analyses. Patients were selected consecutively based on eligibility and willingness to participate. Inclusion criteria comprised individuals of any sex aged above one year with previously documented sickle cell disease, clinically stable at the time of sample collection. Exclusion criteria included patients receiving recent blood transfusion, those diagnosed with concurrent haemolytic disorders, active infections, renal insufficiency, or other comorbidities that could influence haemolysis markers. Written informed consent or assent with guardian consent was obtained prior to enrolment.

Methodology

Venous blood samples were collected under aseptic precautions into EDTA and plain vacutainers for haematological and biochemical analyses respectively. Peripheral blood smears were prepared immediately after sample collection using standard wedge-smear technique, air-dried, fixed, and stained with Leishman stain. Each smear was examined under light microscopy by trained personnel, focusing on red cell morphology including sickled cells, target cells, polychromasia, anisopoikilocytosis, Howell–Jolly bodies, and presence of nucleated red blood cells. Quantitative assessment was performed through semi-quantitative grading based on the proportion of abnormal cells

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observed per high-power field to ensure reproducibility.

Haemolysis indices were evaluated using automated haematology and biochemistry analysers that were subjected to routine internal and external quality control procedures. Parameters studied included haemoglobin concentration, haematocrit, reticulocyte count, lactate dehydrogenase (LDH), indirect bilirubin, haptoglobin (where applicable), and mean corpuscular volume (MCV). Reticulocyte count was performed using supravital staining, and LDH and bilirubin assays were measured using standardized enzymatic and colorimetric methods. All assays were conducted in accordance with manufacturer protocols to maintain analytical accuracy.

Statistical Analysis: All laboratory and clinical data were recorded in a structured case record form and subsequently entered into a secure digital database for analysis. Data were analysed using SPSS software version 26.0. Descriptive statistics were used to summarize demographic characteristics, morphological findings, and haemolysis indices. Correlation between peripheral smear morphology and haemolysis markers was assessed using Pearson or Spearman correlation coefficients depending on data normality. Continuous variables were expressed as mean ± standard deviation or median with interquartile range as appropriate. A p-value of <0.05 was considered statistically significant.

RESULTS

Table 1: Demographic Characteristics of the Study Population

The study included a total of 52 patients with confirmed sickle cell anaemia, with a slight predominance of adults over children. The majority of participants (38.46%) were older than 20 years, followed by 34.62% in the 10–20-year age group, and 26.92% below 10 years, indicating that a substantial proportion of the study population comprised adolescents and adults who continue to remain symptomatic and require outpatient follow-up. The sex distribution revealed a near-equal representation, with males constituting 53.85% and females comprising 46.15% of the cohort.

Table 2: Distribution of Peripheral Blood Smear Morphological Findings

Peripheral smear examination showed consistent abnormalities across the study group. Sickled cells were present in all 52 patients (100%), confirming their diagnostic hallmark in sickle cell disease. Target cells were observed in 88.46% of cases, which reflects membrane changes and chronic haemolytic status typical of the disease. Anisopoikilocytosis was noted in 86.54% of participants, demonstrating significant variability in red cell size and shape due to ongoing haemolysis and bone marrow compensatory response. Polychromasia was present in 73.08% of patients, indicating active erythropoiesis secondary to chronic haemolytic stress. Howell–Jolly bodies were identified in 42.31% of cases, suggesting functional hyposplenism or autosplenectomy, both known complications of sickle cell anaemia. Nucleated RBCs were found in 34.62% of patients, reflecting marked bone marrow drive and severe erythroid stress associated with sustained haemolysis.

Table 3: Haemolysis Indices Among Study Participants

The laboratory parameters further reinforced the presence of chronic haemolysis. The mean haemoglobin concentration was markedly reduced (7.82 ± 1.26 g/dL), and the mean haematocrit was also low at 23.60 ± 3.85%, consistent with chronic anaemia characteristic of sickle cell disease. Reticulocyte count was elevated (6.42 ± 1.58%), reflecting compensatory marrow hyperactivity in response to accelerated RBC destruction. LDH levels were significantly elevated (612.38 ± 148.22 U/L), supporting the presence of ongoing intravascular haemolysis. Indirect bilirubin was also elevated (1.84 ± 0.66 mg/dL), indicating active breakdown of haemoglobin. The mean haptoglobin level was markedly reduced (18.44 ± 6.22 mg/dL), as expected in chronic haemolytic conditions due to continuous haemoglobin binding. MCV values were within the low–normal range (83.16 ± 7.34 fL), aligning with normocytic or borderline microcytic red cell morphology commonly observed in haemolytic anaemias.

Table 4: Correlation Between Peripheral Smear Morphology and Haemolysis Indices

A strong positive correlation was observed between the proportion of sickled cells and LDH levels ($r = 0.62$, $p = 0.0001$), indicating that higher degrees of sickling were associated with more intense haemolysis. Target cells showed a moderate positive correlation with indirect bilirubin ($r = 0.41$, $p = 0.003$), suggesting that increased membrane deformity may be associated with enhanced extravascular haemolytic activity. Polychromasia exhibited a strong positive correlation with reticulocyte count ($r = 0.58$, $p = 0.0002$), confirming that visible polychromatophils on smear reflect heightened marrow regenerative response. Howell–Jolly bodies demonstrated a significant negative correlation with haemoglobin levels ($r = -0.36$, $p = 0.009$), supporting the notion that functional hyposplenism contributes to more severe anaemia. Presence of nucleated RBCs correlated positively with LDH ($r = 0.44$, $p = 0.002$), indicating that patients displaying NRBCs on smear experienced more pronounced haemolysis and marrow stress.

Table 5: Comparison of Haemolysis Indices Between Patients with and without Howell–Jolly Bodies

Patients with Howell–Jolly bodies (n=22) exhibited significantly more severe haemolysis compared to those without (n=30). Haemoglobin levels were lower in the Howell–Jolly-positive group (7.46 ± 1.18 g/dL vs. 8.08 ± 1.23 g/dL; $p = 0.041$), suggesting greater anaemia in patients with functional

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hyposplenism. Reticulocyte counts were significantly higher in those with Howell–Jolly bodies (6.88 ± 1.72% vs. 6.08 ± 1.39%; p = 0.048), reflecting a stronger erythropoietic response to anaemia. LDH values were also higher in the Howell–Jolly-positive group (651.24 ± 158.12 U/L vs. 583.63 ± 139.45 U/L; p = 0.036), indicating increased haemolysis. Indirect bilirubin levels followed the same trend, being significantly elevated among those with Howell–Jolly bodies (2.06 ± 0.72 mg/dL vs. 1.67 ± 0.58 mg/dL; p = 0.022).

Table 1: Demographic Characteristics of the Study Population (N = 52)

Variable	Category	Frequency (n)	Percentage (%)
Age Group (years)	<10	14	26.92
	10–20	18	34.62
	>20	20	38.46
Sex Distribution	Male	28	53.85
	Female	24	46.15

Table 2: Distribution of Peripheral Blood Smear Morphological Findings (N = 52)

Morphological Feature	Present (n)	Percentage (%)
Sickled cells	52	100.00%
Target cells	46	88.46%
Anisopoikilocytosis	45	86.54%
Polychromasia	38	73.08%
Howell–Jolly bodies	22	42.31%
Nucleated RBCs	18	34.62%

Table 3: Haemolysis Indices Among Study Participants (Mean ± SD)

Parameter	Mean ± SD	Reference Interpretation
Haemoglobin (g/dL)	7.82 ± 1.26	Low
Haematocrit (%)	23.60 ± 3.85	Low
Reticulocyte count (%)	6.42 ± 1.58	Elevated
LDH (U/L)	612.38 ± 148.22	Elevated
Indirect bilirubin (mg/dL)	1.84 ± 0.66	Elevated
Haptoglobin (mg/dL)	18.44 ± 6.22	Reduced
MCV (fL)	83.16 ± 7.34	Normal–low

Table 4: Correlation Between Peripheral Smear Morphology and Haemolysis Indices

Morphological Feature	Haemolysis Marker	Correlation Coefficient (r)	p-value
Sickled cells (%)	LDH	r = 0.62	p = 0.0001
Target cells (%)	Indirect bilirubin	r = 0.41	p = 0.003
Polychromasia (grade)	Reticulocyte count	r = 0.58	p = 0.0002
Howell–Jolly bodies	Haemoglobin	r = −0.36	p = 0.009
NRBCs	LDH	r = 0.44	p = 0.002

Table 5: Comparison of Haemolysis Indices Between Patients With vs. Without Howell–Jolly Bodies

Parameter	Present (n=22) Mean ± SD	Absent (n=30) Mean ± SD	p-value
Haemoglobin (g/dL)	7.46 ± 1.18	8.08 ± 1.23	p = 0.041
Reticulocyte count (%)	6.88 ± 1.72	6.08 ± 1.39	p = 0.048
LDH (U/L)	651.24 ± 158.12	583.63 ± 139.45	p = 0.036
Indirect bilirubin (mg/dL)	2.06 ± 0.72	1.67 ± 0.58	p = 0.022

DISCUSSION

The present study evaluated 52 outpatients with sickle cell anaemia and showed that adolescents and adults constituted the majority, with 73.08% of patients aged ≥10 years and a slight male predominance (53.85%). This age–sex pattern reflects the chronic nature of sickle cell disease (SCD), in which many patients continue to require outpatient follow-up beyond childhood. A Ghanaian cohort of 75 SCD patients reported an age range of 4–59 years, with 36.0% aged 1–15 years, 32.0% aged 16–30 years and a marked female predominance (50 females, 25 males), illustrating that adult survivors form a substantial proportion of clinic-based populations, although sex distributions may vary by region (our 53.85% males vs. 33.3% males in that series). Antwi-Boasiako et al. (2018)[8] also highlighted that such mixed paediatric–adult cohorts are typical of routine SCD care settings, consistent with the demographic profile seen in the current study.

Peripheral blood smear analysis in our cohort demonstrated universal presence of sickled cells (100.00%), very high frequencies of target cells (88.46%), anisopoikilocytosis (86.54%) and polychromasia (73.08%), confirming that morphologic abnormalities are pervasive even in clinically stable outpatients. These findings align closely with the descriptions by Mangla et al. (2023), who note that sickle cell anaemia characteristically

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shows sickled (drepanocytic) red cells along with target cells, polychromatic cells and occasional nucleated red blood cells on peripheral smear, reflecting chronic haemolysis and marrow response.[9]

More specifically, Howell–Jolly bodies were seen in 42.31% and nucleated red blood cells (NRBCs) in 34.62% of our patients, pointing to functional hyposplenism/autosplenectomy and pronounced erythroid stress. Lynch, in the classic Clinical Methods chapter on the peripheral blood smear, emphasised that Howell–Jolly bodies are nuclear DNA remnants normally removed by the spleen and are therefore characteristic of asplenia or hyposplenism, while NRBCs and polychromatophilic cells indicate intense marrow stimulation in haemolytic states.[10]

Haemoglobin and haematocrit values in this study (mean haemoglobin 7.82 ± 1.26 g/dL; haematocrit 23.60 ± 3.85%) indicate moderate normocytic anaemia, which is typical for steady-state HbSS disease. In a steady-state Congolese cohort, Nanitelamio et al. (2021) reported mean haemoglobin of 7.24 ± 1.62 g/dL and haematocrit 21.15 ± 4.60% in sickle cell patients, significantly lower than control subjects (14.16 ± 1.68 g/dL and 38.49 ± 5.31%, respectively).[11]

The mean reticulocyte count in the present study (6.42 ± 1.58%) together with polychromasia in 73.08% of cases reflects an active but not maximal erythropoietic response to chronic haemolysis. Meier et al. (2013) analysed 59 infants with sickle cell anaemia and showed that those who were subsequently hospitalised within the first three years of life had significantly higher absolute reticulocyte counts in early infancy (204 ± 94 K/µL) than those who were not hospitalised (140 ± 63 K/µL), despite similar haemoglobin levels (8.8 ± 1.4 vs. 9.0 ± 1.1 g/dL).[12]

Biochemical markers further confirmed chronic haemolysis in our patients, with elevated LDH (612.38 ± 148.22 U/L) and indirect bilirubin (1.84 ± 0.66 mg/dL). Kato et al. (2006) demonstrated that in adults with sickle cell disease, higher LDH levels, reflecting increased intravascular haemolysis, were strongly associated with lower haemoglobin, higher bilirubin and reticulocyte counts, and with clinical complications such as pulmonary hypertension, leg ulceration and increased mortality, defining a "hemolysis-associated" subphenotype.[13]

The mean haptoglobin level in this study (18.44 ± 6.22 mg/dL) was markedly reduced compared to typical reference ranges, consistent with chronic intravascular haemolysis and ongoing haemoglobin scavenging. Santiago et al. (2018) evaluated paediatric SCD patients and found that serum haptoglobin and hemopexin levels were profoundly depleted compared with controls, often approaching or falling below the lower limit of detection, supporting the concept that sustained haemolysis exhausts these scavenger proteins and contributes to oxidative and vascular injury.[14]

Correlation analyses in the present study demonstrated a strong positive relationship between the proportion of sickled cells and LDH ($r = 0.62$, $p = 0.0001$), a strong correlation between polychromasia grade and reticulocyte count ($r = 0.58$, $p = 0.0002$), and a positive association of NRBCs with LDH ($r = 0.44$, $p = 0.002$), indicating that morphological severity on the peripheral smear closely parallels biochemical haemolysis indices. Stankovic Stojanovic and Lionnet (2016) reviewed the role of LDH in SCD and concluded that LDH strongly correlates with other markers of haemolysis (bilirubin, reticulocyte count) and with severe clinical phenotypes such as pulmonary hypertension and leg ulceration, emphasising LDH as a central surrogate of haemolytic burden.[15]

Finally, patients with Howell–Jolly bodies in our cohort had significantly lower haemoglobin (7.46 ± 1.18 vs. 8.08 ± 1.23 g/dL; $p = 0.041$) and higher reticulocyte counts (6.88 ± 1.72 vs. 6.08 ± 1.39%; $p = 0.048$), LDH (651.24 ± 158.12 vs. 583.63 ± 139.45 U/L; $p = 0.036$) and indirect bilirubin (2.06 ± 0.72 vs. 1.67 ± 0.58 mg/dL; $p = 0.022$) than those without Howell–Jolly bodies, indicating more pronounced anaemia and haemolysis in the functionally hyposplenic subgroup. Harrod et al. (2007) quantitatively analysed Howell–Jolly bodies in children with SCD and showed that Howell–Jolly body counts increased markedly with age and were strongly influenced by splenic status and hydroxyurea therapy, supporting their use as a surrogate for splenic dysfunction and disease severity.[16]

CONCLUSION

The present study demonstrates that peripheral blood smear morphology correlates strongly with haemolysis indices in sickle cell anaemia outpatients, highlighting its value as a simple and reliable indicator of disease activity. Morphological abnormalities such as sickled cells, polychromasia, Howell–Jolly bodies, and NRBCs were significantly associated with more severe biochemical haemolysis. These findings emphasize that detailed smear evaluation can complement standard laboratory markers, particularly in resource-limited settings. Incorporating routine morphological assessment into outpatient follow-up may enhance early identification of patients with higher haemolytic burden and guide timely clinical interventions.

REFERENCES

1. Rees DC, Williams TN, Gladwin MT. Sickle-cell disease. Lancet. 2010;376(9757):2018–31. Available from:https://pubmed.ncbi.nlm.nih.gov/21131035/
2. Piel FB, Patil AP, Howes RE, Nyangiri OA, Gething PW, Dewi M, et al. Global epidemiology of sickle haemoglobin in neonates: a contemporary geostatistical model-based map and population estimates. Lancet. 2013;381(9861):142–51. Available from: https://pubmed.ncbi.nlm.nih.gov/23103089/

ISSN (O): 2687-5365; ISSN (P): 2753-6556

3. Kavanagh PL, Fasipe T, Wun T. Sickle cell disease: a review. JAMA. 2022;328(1):57–68. Available from: https://jamanetwork.com/journals/jama/fullarticle/2793821
4. Sundd P, Gladwin MT, Novelli EM. Pathophysiology of sickle cell disease. Annu Rev Pathol. 2019;14:263–92. Available from: https://pubmed.ncbi.nlm.nih.gov/30332562/
5. Lazarchick J. Sickle cell disease – RBC morphology. ASH Image Bank. 2009. Available from: https://imagebank.hematology.org/image/3958/sickle-cell-disease-ndash-rbc-morphology--1
6. Barcellini W, Fattizzo B. Clinical applications of hemolytic markers in the differential diagnosis and management of hemolytic anemia. Dis Markers. 2015;2015:635670. Available from: https://pubmed.ncbi.nlm.nih.gov/26819490/
7. Nouraie M, Lee JS, Zhang Y, Kanias T, Zhao X, Xiong Z, et al. The relationship between the severity of hemolysis, clinical manifestations and risk of death in 415 patients with sickle cell anemia in the US and Europe. Haematologica. 2013;98(3):464–72. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC3659937/
8. Antwi-Boasiako C, Dankwah GB, Dzudzor B, Asmah RH, Annani-Akollor ME, Owiredu W, et al. Hematological parameters in Ghanaian sickle cell disease patients. J Blood Med. 2018;9:203–209. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC6217132/
9. Mangla A, Agarwal N, Maruvada S. Sickle Cell Anemia. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 [updated 2023 Sep 4]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK482164/
10. Lynch EC. Peripheral Blood Smear. In: Walker HK, Hall WD, Hurst JW, editors. Clinical Methods: The History, Physical, and Laboratory Examinations. 3rd ed. Boston: Butterworths; 1990. Available from: https://www.ncbi.nlm.nih.gov/books/NBK263/
11. Nanitelamio EPL, Mokono SO, Mbani CJ, Atipo-Tsiba OG, Niama FR, Mokondjimobe E, et al. Hematological and biochemical profile of sickle cell patients in critical and inter-critical periods in Brazzaville, Republic of Congo. Open J Blood Dis. 2021;11(2):57–65. Available from: https://www.scirp.org/pdf/ojbd_2021062215193063.pdf
12. Meier ER, Byrnes C, Lee YT, Wright EC, Schechter AN, Luban NLC, et al. Increased reticulocytosis during infancy is associated with increased hospitalizations in sickle cell anemia patients during the first three years of life. PLoS One. 2013;8(8):e70794. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0070794
13. Kato GJ, McGowan V, Machado RF, Little JA, Taylor J, Morris CR, et al. Lactate dehydrogenase as a biomarker of hemolysis-associated nitric oxide resistance, priapism, leg ulceration, pulmonary hypertension, and death in patients with sickle cell disease. Blood. 2006;107(6):2279–2285. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC1895723/
14. Santiago RP, da Guarda CC, Figueiredo CVB, Fiuza LM, et al. Serum haptoglobin and hemopexin levels are depleted in pediatric sickle cell disease patients. Blood Cells Mol Dis. 2018;72:34–38. Available from: https://doi.org/10.1016/j.bcmd.2018.07.002
15. Stankovic Stojanovic K, Lionnet F. Lactate dehydrogenase in sickle cell disease. Clin Chim Acta. 2016;458:99–102. Available from: https://pubmed.ncbi.nlm.nih.gov/27138446/
16. Harrod VL, Howard TA, Zimmerman SA, Dertinger SD, Ware RE. Quantitative analysis of Howell–Jolly bodies in children with sickle cell disease. Exp Hematol. 2007;35(2):179–183. Available from: https://pubmed.ncbi.nlm.nih.gov/17258071/

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