ISSN 0973-2063 (online) 0973-8894 (print)

Bioinformation 22(10): 6772-6778 (2026)

©Biomedical Informatics (2026)

BIOINFORMATION
Discovery at the interface of physical and biological sciences

BIOMEDICAL INFORMATICS

www.bioinformation.net

Volume 22(10)

Research Article

Received October 1, 2026; Revised October 31, 2026; Accepted October 31, 2026, Published October 31, 2026

DOI: 10.6026/973206300226772

SJIF 2026 (Scientific Journal Impact Factor for 2026) = 8.478
2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

Declaration on Publication Ethics:
The author's state that they adhere with COPE guidelines on publishing ethics as described elsewhere at https://publicationethics.org/. The authors also undertake that they are not associated with any other third party (governmental or non-governmental agencies) linking with any form of unethical issues connecting to this publication. The authors also declare that they are not withholding any information that is misleading to the publisher in regard to this article.

Declaration on official E-mail:
The corresponding author declares that lifetime official e-mail from their institution is not available for all authors

License statement:
This is an Open Access article which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly credited. This is distributed under the terms of the Creative Commons Attribution License

Comments from readers:
Articles published in BIOINFORMATION are open for relevant post publication comments and criticisms, which will be published immediately linking to the original article without open access charges. Comments should be concise, coherent and critical in less than 1000 words.

Disclaimer:
Bioinformation provides a platform for scholarly communication of data and information to create knowledge in the Biological/ Biomedical domain after adequate peer/editorial reviews and editing entertaining revisions where required. The views and opinions expressed are those of the author(s) and do not reflect the views or opinions of Bioinformation and (or) its publisher Biomedical Informatics. Biomedical Informatics remains neutral and allows authors to specify their address and affiliation details including territory where required.

Edited by Vini Mehta
E-mail: vmehta@statsense.in
Citation: Khandelwal *et al*. Bioinformation 22(10): 6772-6778 (2026)

Study on clinico-epidemiological characteristics and outcome of patients having intravascular hemolysis from 1 month to 18 years

Adarsh Khandelwal, Krishna Kumar & Shailesh Chandra*

Department of Pediatrics, Rani Hospital, Ranchi, Jharkhand, India; *Corresponding author

Affiliation URL:
https://ranihospital.com/

Author contact:
Adarsh Khandelwal - Email: adarshkhandelwal8@gmail.com
Krishna Kumar - Email: drkrishnakr@rediffmail.com

ISSN 0973-2063 (online) 0973-8894 (print)
Bioinformation 22(10): 6772-6778 (2026)
©Biomedical Informatics (2026)

Shailesh Chandra - Email: chandrasailesh@gmail.com

Abstract:
Intravascular hemolysis is an important cause of acute anemia and hemoglobinuria in children and may result from diverse inherited and acquired disorders. This ambispective observational study evaluated 122 children aged 1 month 18 years admitted with intravascular hemolysis at a tertiary care center in Ranchi, including 21 prospectively enrolled and 101 retrospectively identified cases. The mean age was 90.9±50.6 months, 87.7% were boys and pallor (81.1%), fever (70.5%), weakness (69.6%) and jaundice (60.6%) were the most common manifestations. Glucose 6 phosphate dehydrogenase deficiency (65.6%) was the predominant etiology, while complications occurred in 30.3%, with acute kidney injury (22.9%) being most frequent and mortality 4.9%. Thus, data shows the regional etiological and clinical spectrum of pediatric intravascular hemolysis and emphasizing early identification of precipitating factors and renal complications to improve outcomes.

Keywords: Intravascular hemolysis, G6PD deficiency, hemoglobinuria, acute kidney injury, autoimmune hemolytic anemia, children

Background:
Hemolytic anemia comprises a group of disorders characterized by premature destruction of red blood cells (RBCs), resulting in reduced erythrocyte survival and compensatory bone marrow response. Hemolysis may occur either within the reticuloendothelial system (extravascular hemolysis) or directly within the circulation (intravascular hemolysis) **[1]**. Intravascular hemolysis is a particularly severe form in which red blood cells rupture within blood vessels, releasing free hemoglobin into the plasma. Excess plasma hemoglobin is filtered by the kidneys, producing hemoglobinuria, one of the hallmark features of intravascular hemolysis. The condition may present with acute or chronic manifestations and can lead to significant morbidity if not diagnosed and treated promptly **[2].** The etiological spectrum of intravascular hemolysis in children is broad and includes both inherited and acquired disorders. Inherited causes include glucose 6 phosphate dehydrogenase (G6PD) deficiency, sickle cell disease, hereditary red cell membrane defects and rare enzymatic disorders. Acquired causes include severe infections, autoimmune hemolytic anemia, paroxysmal nocturnal hemoglobinuria (PNH), disseminated intravascular coagulation, thrombotic microangiopathies and hemolytic transfusion reactions **[3].** The relative frequency of these disorders varies according to geographical region, ethnicity, genetic predisposition and healthcare accessibility. Recent studies have demonstrated that G6PD deficiency remains one of the most common enzymatic disorders worldwide, affecting nearly 400 million individuals globally. Oxidative stress induced by infections, drugs or fava bean ingestion may precipitate acute episodes of intravascular hemolysis in susceptible children **[4].** Similarly, hemoglobinopathies continue to contribute substantially to pediatric hemolytic disorders, particularly in regions where sickle cell disease and related disorders are prevalent **[5].** Infections constitute an important cause of intravascular hemolysis in developing countries. Malaria, bacterial sepsis and certain viral infections can induce extensive erythrocyte destruction through direct or immune-mediated mechanisms. Severe intravascular hemolysis in these settings is frequently associated with acute kidney injury, shock and increased mortality **[6].** Contemporary evidence has also highlighted the role of complement mediated disorders such as paroxysmal nocturnal hemoglobinuria, where deficiency of complement regulatory proteins leads to recurrent episodes of hemoglobinuria and chronic hemolysis **[7].** The clinical manifestations of intravascular hemolysis are often diverse and include pallor, jaundice, dark-colored urine, fatigue, abdominal pain, fever, hepatosplenomegaly and complications related to severe anemia. Laboratory evaluation typically reveals elevated reticulocyte count, indirect hyperbilirubinemia, increased lactate dehydrogenase levels, decreased haptoglobin concentrations, abnormal red cell morphology and evidence of hemoglobinuria. Early identification of the underlying etiology is crucial because management strategies differ substantially among various causes **[8].** Despite the clinical importance of intravascular hemolysis, data regarding its epidemiological profile, etiological distribution and outcomes among Indian children remain limited. Most available literature focuses on specific causes of hemolysis rather than the entire spectrum of pediatric intravascular hemolytic disorders **[8]**. Therefore, it is of interest to determine the etiological spectrum, assess the clinical profile and evaluate the outcomes of children admitted with intravascular hemolysis at a tertiary care pediatric center in Eastern India.

Materials and Methods:
Study design:
A hospital-based ambispective (retrospective and prospective) observational study was conducted to evaluate the clinico-epidemiological characteristics and outcomes of children diagnosed with intravascular hemolysis.

Study setting:
General setting:
The study was conducted in Ranchi, the capital city of Jharkhand, India. Ranchi district occupies an area of approximately 7,574 square kilometers and serves as a major healthcare referral center for surrounding districts including Khunti, Lohardaga, Ramgarh and neighboring areas of West Bengal. The district caters to a diverse population comprising both tribal and non-tribal communities.

Specific setting:
The study was carried out in the Department of Paediatrics, Rani Hospital, Ranchi. Rani Hospital is a 225-bedded tertiary care

pediatric hospital managed by the Dukhharan Memorial Charitable Trust and functions as a referral center for pediatric healthcare in Jharkhand and adjoining states. The hospital provides specialized services in General Paediatrics, Neonatology, Pediatric Nephrology, Neurology, Gastroenterology, Hematology, Oncology, Cardiology, Genetics, Metabolic Disorders, Nutrition and Pediatric Dentistry.

Study duration:
The study was conducted over a period of 15 months from November 2022 to January 2024. For the retrospective component, hospital records from January 2019 to January 2023 were reviewed. For the prospective component, all eligible children admitted from November 2022 until January 2024 were enrolled and followed up.

Study population:
The study population consisted of children aged 1 month to 18 years admitted with intravascular hemolysis in the Department of Paediatrics during the study period.

Inclusion criteria:
Children fulfilling all of the following criteria were included:
[1] Age between 1 month and 18 years.
[2] Clinical and laboratory evidence suggestive of intravascular hemolysis.
[3] Presence of hemoglobinuria defined as positive urine dipstick test for blood with absence of red blood cells on urine microscopy.

Exclusion criteria:
Children were excluded if they:
[1] Had evidence of hemolysis without hemoglobinuria.
[2] Did not provide informed consent for the prospective component.
[3] Were lost to follow-up, preventing assessment of clinical outcome.

Sample size and sampling technique:
A complete enumeration method was adopted. All eligible children diagnosed with intravascular hemolysis during the study period and fulfilling the inclusion criteria were included in the study.

Diagnostic criteria:
Clinical criteria:
Clinical evidence of hemolytic anemia included one or more of the following:
[1] Pallor
[2] Icterus
[3] Gallstones
[4] History of neonatal jaundice
[5] Positive family history of anemia
[6] Previous cholecystectomy
[7] Hepatosplenomegaly

Laboratory criteria:
Diagnosis of intravascular hemolysis required hemoglobinuria along with one or more laboratory indicators of hemolysis:
[1] Elevated reticulocyte count
[2] Increased indirect bilirubin
[3] Elevated lactate dehydrogenase (LDH)
[4] Decreased serum haptoglobin
[5] Increased urinary urobilinogen
[6] Abnormal red blood cell morphology on peripheral smear

Study procedure:
Prospective component:
After obtaining approval from the Institutional Ethics Committee, eligible children were enrolled following informed written consent from parents or guardians. Detailed demographic information, clinical history, family history, drug exposure, transfusion history, dietary history and physical examination findings were recorded using a structured proforma. Blood and urine samples were collected for baseline investigations including complete blood count, reticulocyte count, liver function tests, LDH levels, serum haptoglobin, peripheral smear examination and urinalysis. Subsequent etiological investigations were performed based on clinical suspicion.

Retrospective component:
Medical records of children admitted between January 2019 and January 2023 with intravascular hemolysis were reviewed. Relevant demographic, clinical, laboratory, treatment and outcome data were extracted using a standardized data collection form.

Etiological evaluation:
Children were further investigated based on suspected causes:
[1] **G6PD deficiency:** G6PD assay performed in children with drug-induced or fava bean-related hemolysis.
[2] **Hemoglobinopathies:** Hemoglobin electrophoresis performed for suspected sickle cell disease.
[3] **Autoimmune hemolysis:** Direct Coombs test (DCT).
[4] **Paroxysmal nocturnal hemoglobinuria:** Flow cytometry for CD55/CD59 deficiency.
[5] **Infectious hemolysis:** Blood culture, peripheral smear and relevant microbiological investigations.
[6] **Microangiopathic hemolysis:** Peripheral smear examination for schistocytes.

Laboratory equipment:
[1] **FUS-1000 Urinalysis System** for urine examination.
[2] **Mindray BC-2600 Auto Hematology Analyzer** for complete blood count and reticulocyte count.
[3] **Vitros 4600 Analyzer** for haptoglobin estimation and Direct Coombs Test.
[4] **Ebra Chem 5X** for G6PD assay.
[5] Biochemistry analyzers for liver function tests and LDH estimation.

Study variables:
Independent variables:
[1] Age
[2] Gender
[3] Religion
[4] Ethnicity
[5] Presenting complaints
[6] Drug exposure
[7] Fava bean intake
[8] Blood transfusion history
[9] Vaso-occlusive crisis
[10] Neonatal jaundice
[11] Consanguinity
[12] Family history
[13] Clinical findings
[14] Laboratory parameters
[15] Treatment received
[16] Duration of hospital stay

Outcome variables:
[1] Etiological distribution of intravascular hemolysis
[2] Clinical profile of affected children
[3] Duration of hospitalization
[4] Recovery status
[5] Complications
[6] Mortality

Statistical analysis:
Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 22.0. Categorical variables were expressed as frequencies and percentages. Continuous variables were summarized using mean ± standard deviation or median with interquartile range according to distribution. Associations between categorical variables were assessed using Chi-square test or Fisher's exact test, while independent t-test was used for continuous variables. A p-value <0.05 was considered statistically significant.

Ethical considerations:
Ethical approval was obtained from the Institutional Ethics Committee before commencement of the study. Written informed consent was obtained from parents or legal guardians for the prospective component. Waiver of consent was granted for retrospective record review. Confidentiality and privacy of participant information were maintained throughout the study.

Results:
A total of 122 children admitted with intravascular hemolysis were included in the study. Of these, 21 children were enrolled prospectively and 101 were included from retrospective hospital records. The mean age of the study population was 90.9 ± 50.6 months, while the median age was 86.5 months with an interquartile range of 48.0–131.75 months. The youngest child was 1 month old and the oldest was 204 months old. Majority of children belonged to the 61–120 months age group, comprising 50 cases (41.0%). Children older than 120 months formed the second largest group with 32 cases (26.2%), followed by 25–60 months with 29 cases (23.8%). Only 11 children (9.0%) were aged 24 months or less. There was a marked male predominance, with boys accounting for 107 cases (87.7%) and girls for 15 cases (12.3%), giving a boy-to-girl ratio of approximately 7.1:1. Non-tribal children constituted 92 cases (75.4%), while tribal children accounted for 30 cases (24.6%) **(Table 1).** Dark-colored urine was reported in all children, as hemoglobinuria was part of the diagnostic criteria. Pallor was the most frequent clinical feature, seen in 99 children (81.1%). Fever was present in 86 children (70.5%), weakness in 85 children (69.6%) and jaundice in 74 children (60.6%). Respiratory distress was observed in 45 children (36.9%), abdominal pain in 42 children (34.4%), vomiting in 41 children (33.6%) and back pain in only 2 children (1.6%). None of the children presented with neonatal jaundice or vaso-occlusive crisis. The clinical presentation was dominated by features of acute hemolysis. Pallor, fever, weakness, jaundice and dark urine were the major presenting manifestations. Drug exposure was reported in 12 children (9.8%), mainly following naphthalene and ayurvedic drug intake. History of blood transfusion was present in 20 children (16.4%). Family history was uncommon, with consanguinity reported in 6 children (4.9%) and affected siblings in 5 children (4.1%). Faba bean ingestion was documented in 33 children (27.0%), suggesting an important oxidative trigger in susceptible children **(Table 2).** The most common etiology of intravascular hemolysis was G6PD deficiency, diagnosed in 80 children (65.6%). Autoimmune hemolytic anemia was the second most common cause, seen in 20 children (16.4%). Acute viral hepatitis with underlying G6PD deficiency was identified in 8 children (6.6%). Other infections were noted in 6 children (4.9%), including scrub typhus, rickettsial infection, *Klebsiella* infection and fungal urinary tract infection. Malaria was diagnosed in 4 children (3.3%), naphthalene poisoning in 3 children (2.4%) and blood transfusion reaction in 1 child (0.8%). G6PD deficiency was the predominant etiology, accounting for nearly two-thirds of cases. AIHA contributed to 16.4% of cases. Infective causes, including malaria and other bacterial, rickettsial, scrub typhus and fungal infections, formed an important acquired group. Complications occurred in 37 children (30.3%). Acute kidney injury was the most common complication, affecting 28 children (22.9%), followed by respiratory complications in 10 children (8.2%), sepsis and shock in 8 children (6.6%) and CNS involvement in 6 children (4.9%). Other complications included myositis, subacute infarct, hepatorenal syndrome and Addisonian crisis **(Table 3).** The mean duration of hospital stay was 5.5 ± 2.9 days, while the median duration was 5 days with an interquartile range of 3.25–7.0 days. The minimum stay was 1 day and maximum stay was 14 days. Mortality was observed in 6 children (4.9%). The remaining 116 children (95.1%) were discharged, referred, or left against medical advice. Among these, final outcome could not be confirmed in 16 children who were either referred or discharged against medical advice. There was no statistically significant association between age and mortality, as the mean age among discharged/referred children was 91.0 ± 50.4 months compared with 87.8 ± 60.1 months among children who died (p=0.880).

Mortality was 4.7% among boys and 6.7% among girls, but this difference was not statistically significant (p=0.738). No deaths occurred among children with AIHA, while 6 deaths occurred among those without AIHA; however, the association was not statistically significant (p=0.266). Among children with G6PD deficiency, 5 deaths were recorded, giving a mortality of 6.3%, compared with 2.4% among children without G6PD deficiency; this difference was also not statistically significant (p=0.347). Infectious etiology was associated with 5.6% mortality compared with 4.8% among non-infectious etiologies, with no significant difference (p=0.892) **(Table 4).** Overall, the study showed that intravascular hemolysis in children was most commonly seen in school-age children, predominantly affected boys and was most often due to G6PD deficiency. Clinical presentation was characterized by dark urine, pallor, fever, weakness and jaundice. Acute kidney injury was the most frequent complication, emphasizing the need for early renal monitoring. Although mortality was relatively low at 4.9%, complications were observed in nearly one-third of children, highlighting the potentially serious nature of pediatric intravascular hemolysis.

Table 1: Demographic profile of study participants (n=122)

Variable	Category	Frequency (n)	Percentage (%)
Age group	≤24 months	11	9.0
	25–60 months	29	23.8
	61–120 months	50	41.0
	>120 months	32	26.2
Gender	Boys	107	87.7
	Girls	15	12.3
Ethnicity	Tribal	30	24.6
	Non-tribal	92	75.4

Table 2: Clinical profile and relevant history of study participants (n=122)

Variable	Frequency (n)	Percentage (%)
Dark-colored urine	122	100.0
Pallor	99	81.1
Fever	86	70.5
Weakness	85	69.6
Jaundice	74	60.6
Respiratory distress	45	36.9
Abdominal pain	42	34.4
Vomiting	41	33.6
Back pain	2	1.6
History of drug use	12	9.8
History of blood transfusion	20	16.4
Consanguinity	6	4.9
Siblings affected	5	4.1
History of faba bean intake	33	27.0

Table 3: Etiological distribution and complications among children with intravascular hemolysis (n=122)

Variable	Category	Frequency (n)	Percentage (%)
Etiology	G6PD deficiency	80	65.6
	Autoimmune hemolytic anemia	20	16.4
	Acute viral hepatitis with G6PD deficiency	8	6.6
	Other infections	6	4.9
	Malaria	4	3.3
	Naphthalene poisoning	3	2.4
	Blood transfusion reaction	1	0.8
Complications	Any complication	37	30.3
	Acute kidney injury	28	22.9
	Respiratory complications	10	8.2
	Sepsis and shock	8	6.6
	CNS complications	6	4.9
	Others	6	4.9

Table 4: Association of selected variables with outcome among study participants (n=122)

Variable	Category	Discharged/Referred n (%)	Death n (%)	p value
Age in months	Mean ± SD	91.0 ± 50.4	87.8 ± 60.1	0.880
Gender	Boys	102 (95.3)	5 (4.7)	0.738
	Girls	14 (93.3)	1 (6.7)	
AIHA	Yes	20 (100.0)	0 (0.0)	0.266
	No	96 (94.1)	6 (5.9)	
G6PD deficiency	Yes	75 (93.7)	5 (6.3)	0.347
	No	41 (97.6)	1 (2.4)	
Infectious etiology	Yes	17 (94.4)	1 (5.6)	0.892
	No	99 (95.2)	5 (4.8)	

Discussion:

The present ambispective observational study evaluated the clinico-epidemiological profile, etiological spectrum, complications and outcomes of 122 children admitted with intravascular hemolysis at a tertiary pediatric centre in Ranchi. The findings showed that pediatric intravascular hemolysis is a clinically heterogeneous condition, with G6PD deficiency being the predominant etiology, followed by autoimmune hemolytic anemia and infection-associated hemolysis. The condition was frequently associated with systemic complications, particularly acute kidney injury, although overall mortality remained relatively low. The mean age of the study participants was 90.9 ± 50.6 months, with the highest proportion of children belonging to the 61–120 months age group. This suggests that intravascular hemolysis was more commonly recognized among school-age children. This age group is more likely to be exposed to oxidative triggers such as infections, drugs, chemicals and dietary factors. Acute hemolytic episodes in G6PD-deficient children are commonly precipitated by infections, fava beans, certain drugs and chemical agents, who may explain the higher representation of older children in the present study **[3].** A marked male predominance was observed, with boys accounting for 87.7% of cases and a boy-to-girl ratio of 7.1:1. This finding is consistent with the X-linked inheritance pattern of G6PD deficiency, where hemizygous males are more frequently affected clinically. Although females may also manifest disease due to homozygosity or lyonization, severe symptomatic hemolysis is more commonly observed among males **[2].** The strong male preponderance in the present study therefore supports the predominance of G6PD deficiency as the leading cause of intravascular hemolysis. Dark-colored urine was present in all children, as hemoglobinuria was used as an essential diagnostic criterion. Pallor was the most common clinical feature, present in 81.1% of children, followed by fever, weakness and jaundice. These manifestations represent the classical clinical profile of acute hemolysis, where rapid destruction of red cells leads to anemia, unconjugated hyperbilirubinemia and systemic symptoms. Hemolytic markers such as raised lactate dehydrogenase, indirect hyperbilirubinemia, reticulocytosis, low haptoglobin and hemoglobinuria are useful in identifying intravascular hemolysis

and differentiating it from other causes of anemia **[5].** Fever was present in 70.5% of children, indicating that infection may have acted either as a direct cause of hemolysis or as a trigger for oxidative hemolysis in predisposed children. G6PD deficiency was the most common etiology, accounting for 65.6% of cases. This finding is clinically important because G6PD deficiency is one of the most common inherited red cell enzymopathies worldwide. The global burden of G6PD deficiency is substantial and its prevalence is higher in malaria-endemic regions, where genetic selection may have contributed to persistence of the disorder **[7]**. In G6PD deficiency, red cells are unable to generate adequate reduced nicotinamide adenine dinucleotide phosphate through the pentose phosphate pathway, resulting in impaired protection against oxidative injury. Consequently, exposure to infections, fava beans, naphthalene, or oxidant drugs can precipitate acute intravascular hemolysis **[4].** Autoimmune hemolytic anemia was the second most common cause, observed in 16.4% of children. Pediatric AIHA is relatively uncommon but can present with severe anemia and hemolytic crisis. Although AIHA usually produces extravascular hemolysis, complement activation can result in intravascular red cell destruction and hemoglobinuria. Previous literature has emphasized that pediatric AIHA may have variable severity and requires timely recognition because treatment response and outcome depend on rapid diagnosis, immunosuppressive therapy and supportive care **[9, 10].** In the present study, no mortality was observed among children with AIHA, suggesting that early diagnosis and appropriate management may have contributed to favorable outcomes. In the present study, history of faba bean ingestion was documented in 27.0% of children, while drug or chemical exposure was reported in 9.8%, mainly following naphthalene and ayurvedic medication intake. Favism is a well-recognized precipitant of acute hemolysis in G6PD-deficient individuals **[3].** Naphthalene-induced hemolysis is also an important pediatric concern because mothballs may be accidentally ingested by young children, resulting in oxidative hemolysis, methemoglobinemia and acute kidney injury **[8].** These findings emphasize the importance of health education regarding avoidance of known oxidative triggers among families of children with G6PD deficiency. Infectious causes were also important contributors to intravascular hemolysis. Malaria accounted for 3.3% of cases, while other infections including scrub typhus, rickettsial infection, *Klebsiella* infection and fungal urinary tract infection accounted for 4.9%. Acute viral hepatitis with underlying G6PD deficiency was seen in 6.6% of children. Infection-associated hemolysis may occur through direct erythrocyte destruction, immune-mediated mechanisms, oxidative stress, inflammatory endothelial injury, or microangiopathic processes. Malaria is especially relevant because anemia results from destruction of parasitized as well as non-parasitized erythrocytes, splenic sequestration, dyserythropoiesis and inflammatory mechanisms **[11].** Severe malaria has also been associated with acute kidney injury in children, particularly when hemolysis, dehydration, shock and systemic inflammation coexist **[12].** Complications were present in 30.3% of children, indicating that intravascular hemolysis in pediatric patients can lead to significant morbidity. Acute kidney injury was the most common complication, occurring in 22.9% of cases. This is pathophysiologically plausible because free plasma hemoglobin released during intravascular hemolysis can cause renal vasoconstriction, tubular obstruction, oxidative tubular injury and pigment nephropathy. Occult kidney injury has been described in children with G6PD deficiency-related hemolysis, supporting the need for early renal monitoring even when initial symptoms appear mild **[13].** Naphthalene-induced hemolysis and severe malaria may further increase the risk of renal injury **[12, 14].** Respiratory complications were observed in 8.2% of children, while sepsis and shock were reported in 6.6%. CNS complications, including seizures and encephalopathy, were noted in 4.9%. These complications reflect the systemic consequences of severe hemolysis, anemia, hypoxia, infection, metabolic derangements and organ dysfunction. Multi-organ involvement may also occur in thrombotic microangiopathy, where hemolysis is associated with thrombocytopenia, renal injury and neurological manifestations **[15].** Intravascular hemolysis may worsen systemic inflammation and endothelial dysfunction and has been linked with adverse outcomes in sepsis. The overall mortality in the present study was 4.9%. Mortality did not show a statistically significant association with age, gender, G6PD deficiency, AIHA, or infectious etiology. However, five of the six deaths occurred among children with G6PD deficiency. The lack of statistical significance may be due to the small number of deaths rather than true absence of risk. Clinically, children with G6PD deficiency who develop severe anemia, acute kidney injury, shock, respiratory compromise, or sepsis remain vulnerable and require early intensive care support. Although paroxysmal nocturnal hemoglobinuria was considered in the diagnostic framework of the study, it was not a major contributor in the present cohort. PNH remains an important, rare cause of intravascular hemolysis and recurrent hemoglobinuria, especially when hemolysis is associated with marrow failure or thrombosis**.** The present study has several strengths. It included both retrospective and prospective cases over a broad study period and assessed clinical features, etiologies, complications and outcomes using predefined diagnostic criteria. However, it also has limitations. As a hospital-based study, it may not reflect the true community burden of intravascular hemolysis. Retrospective records may have incomplete documentation and final outcome could not be confirmed among children who were referred or left against medical advice. Despite these limitations, the study provides useful regional data and highlights G6PD deficiency, oxidative triggers, infections and acute kidney injury as major areas requiring early recognition and preventive strategies.

Conclusion:

Glucose-6-phosphate dehydrogenase deficiency was the leading cause of pediatric intravascular hemolysis, followed by autoimmune hemolytic anemia and infection-related hemolysis. Acute kidney injury was the predominant complication, with complications occurring in nearly one-third of children and overall mortality of 4.9%. Early etiological diagnosis, avoidance

of oxidative triggers, prompt infection management, careful transfusion and timely treatment of organ dysfunction are essential to improve outcomes.

References:

[1] Loriamini M *et al. Int J Mol Sci.* 2024 **25**:4296. [PMID: 38673882]
[2] Israel A *et al. Front Immunol*. 2023 **14**:1232560. [PMID: 37753082]
[3] Cappellini M & Fiorelli G. *The Lancet* 2008 **371**:64. [PMID: 18177777]
[4] Barcellini W & Fattizzo B. *Dis Markers*. 2015 **2015**:635670. [PMID: 26819490]
[5] Nkhoma ET *et al. Blood Cells, Molecules & Diseases.* 2009 **42**:267. [PMID: 19233695]
[6] Thangatorai R. *Cureus.* 2022 **14**:e23496. [PMID: 35494903]
[7] Voulgaridou A & Kalfa TA. *J Clin Med*. 2021 **10**:216. [PMID: 33435309]
[8] Michalak SS *et al. Immun Ageing*. 2020 **17**:38. [PMID: 33292368]
[9] White NJ. *Malar J*. 2018 **17**:371. [PMID: 30340592]
[10] Bond C *et al. Res Sq [Preprint].* 2025 **23**:rs.3.rs [PMID: 41333437]
[11] Abdel Hakeem GL *et al. Mediterr J Hematol Infect Dis*. 2016 **8**:e2016038.[PMID: 27648201]
[12] Dela Cruz M *et al. Case Rep Pediatr*. 2019 **2019**:1092575. [PMID: 31321110]
[13] Aranzazu Ceballos AD *et al. Glob Pediatr Health*. 2024 **11**:2333794X241307535. [PMID: 39691204]
[14] Brodsky RA. *Blood.* 2009 **113**:6522. [PMID: 19372253]
[15] Chen Y *et al. Front Neurol.* 2022 **13**:838746. [PMID: 35711261]

Caveat Emptor is applicable among the literate community where required and possible. The publisher, its journal, editors and the internal/external reviewers take adequate steps to check, evaluate, correct, edit, revise and improve content where possible and required.