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Pattern of Reported Infections Among Paediatric Patients with Sickle Cell Disease: A Single-Centre Cohort Study in Nigeria

Muhammad Aminu Idris [1,2,*], Lucia Ruggieri [3,*], Hafsat Rufai Ahmad [2,4], Abdulaziz Hassan [1,2], Ismaila Nda Ibrahim [1,2], Jamil Abdullahi Faruk [2,4], Niyi Mustapha Adebiyi [4], Sani Awwalu [1,2], Nasiru Usman [1,2], Rabiu Wada [5], Musa Muhammad [2,6], Saidu Abdulkadir [1,7], Fedele Bonifazi [3], Wale Atoyebi [8] and Baba Psalm Duniya Inusa [9,10]

1 Department of Haematology & Blood Transfusion, Ahmadu Bello University Teaching Hospital, P.M.B. 06, Zaria 810001, Nigeria
2 Faculty of Basic Clinical Sciences, College of Medicine, Ahmadu Bello University, P.M.B. 06, Zaria 810001, Nigeria
3 Fondazione per la Ricerca Farmacologica Gianni Benzi Onlus, 70124 Bari, Italy
4 Department of Paediatrics, Ahmadu Bello University Teaching Hospital, P.M.B. 06, Zaria 810001, Nigeria
5 College of Nursing, Ahmadu Bello University Teaching Hospital, P.M.B. 06, Zaria 810001, Nigeria
6 Antiretroviral Therapy Laboratory, Ahmadu Bello University Teaching Hospital, P.M.B. 06, Zaria 810001, Nigeria
7 Department of Medical Laboratory Science, Faculty of Allied Health Science, College of Medical Sciences, Ahmadu Bello University, P.M.B. 06, Zaria 810001, Nigeria
8 Department of Clinical Haematology, Oxford University Hospitals NHS Foundation Trust, Oxford OX3 7LE, UK
9 Faculty of Life Sciences and Medicine, King's College, London SE1 7EH, UK
10 Novo Nordisk plc, 2880 Bagsvaerd, Denmark
* Correspondence: aminumed@yahoo.com or p22699@abu.edu.ng (M.A.I.); lr@benzifoundation.org (L.R.)

Abstract

Background: Sickle cell disease (SCD) patients have increased susceptibility to infections, particularly encapsulated bacterial pathogens such as Streptococcus pneumoniae and Haemophilus influenzae type b. Hyposplenism as well as immune defects in SCD result in increased risks for infections; these are the most frequent complications in individuals with SCD. This study was performed within the African Research and Innovative initiative for Sickle cell Education (ARISE, EC GA No 824021) project to develop best practices in the clinical management of SCD. In this retrospective study we aimed to determine the most prevalent reported infections among SCD patients' records during clinic visits at Ahmadu Bello University Teaching Hospital, Zaria, Nigeria. **Methods**: The medical records of 1961 paediatric SCD patients from 1998 to 2023 were extracted and reviewed from a pilot electronic registry using a structural query. The data analysed patterns of infections reported during clinic visits at the ABUTH, Zaria, Nigeria. **Results**: 458 subjects (23.4%) manifesting at least one infection, of whom 392 (19.9%) subjects had a single infection (bacterial or parasitic) and 173 (8.8%) had more than one infection (bacterial and parasitic). **Conclusions:** Bacterial and parasitic infections are a significant complication of SCD patients attending a tertiary institution in northern Nigeria.

Keywords: infections; paediatrics; sickle cell disease; Nigeria

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1. Introduction

Sickle cell disease (SCD) patients have increased susceptibility to infections due to immune deficiencies, functional asplenia, tissue infarction and impaired adaptive immune

response and functional asplenia from an early age [1,2]. These infections, especially due to bacterial organisms, are the most frequent complications in individuals with SCD, leading to increased morbidity and mortality. Encapsulated bacterial pathogens such as *Streptococcus pneumoniae*, *Haemophilus influenzae type b* (Hib) is of special interest in SCD [3–5].

Pneumococcus infections account for 50–70% of bacterial infections in children under the age of 5, most of the remaining ones being accounted for by *Neisseria meningitidis*, *Haemophilus influenza*, and, to a lesser extent, *Escherichia coli* [6,7]. Salmonella infection does not have any specificity by age group, but a linear increase in incidence with increasing age is noted [6]. *Klebsiella* spp. and *Escherichia coli* mostly have incidence after 10 years and primarily after 20 years [6].

Malaria has a detrimental effect on homozygous SCD, resulting in higher morbidity and mortality when compared to persons without SCD [7–9]. Other parasitic infections are prevalent in patients with SCD, as confirmed in a Nigerian study conducted on 100 SCD patients; 27% of SCD patients had reported as having parasitic infections [10].

The routine immunisation schedule in Nigeria, based on the National Programme on Immunisation (NPI), starts at birth with BCG (Tuberculosis), Oral Polio Vaccine (OPV 0), and Hepatitis B, followed by key doses at 6, 10, and 14 weeks (Pentavalent, OPV, Pneumococcal/PCV, Rotavirus). Measles and Yellow Fever are given at 9 months [11].

In addition to the standard vaccination programme, SCD requires a series of additional vaccines, such as the annual flu shot, pneumococcal (PCV13 and PPSV23), meningococcal (ACWY and B) and *Haemophilus influenza type b* (Hib), to specifically counter their elevated infection risks due to functional asplenia and transfusion-related vulnerabilities [12]. A recent multicentre study confirmed pneumococcal vaccines are seldom offered routinely, and only 5.5% of SCD children in Port Harcourt had received pneumococcal vaccination, largely owing to cost, awareness, and availability barriers [13].

The main objective of this analysis is to report on the infection pattern of a subset of paediatric SCD patients in a clinical centre (Ahmadu Bello Teaching Hospital, ABUTH) at Zaria, North-Western Nigeria. The following aspects were described as well: infection rates and immunisation, association between infections' occurrence and age, and co-occurrence of infections.

2. Materials and Methods

This was a retrospective study using hospital records of clinic visits of patients with SCD from 1998 to 2023. Using a pilot Paediatric Electronic Registry (PER) developed using Microsoft Access (MS) in 2024 [14], about 65% of patients' last clinic visit hard copy records transferred to the PER were queried. The relevant information was extracted on the reported patterns of infections based on laboratory confirmation and clinical suspicion using MS structural query searching.

2.1. Study Site

The study was conducted in Ahmadu Bello University Teaching Hospital (ABUTH), Zaria, North-Western Nigeria. ABUTH is a federal government-owned tertiary-level hospital with a 750-bed capacity and 17 clinical departments with over 3000 paediatric patients with SCD. The consultant-led paediatric clinic runs weekly for SCD patients aged 0 months to 18 years.

Records of 1961 patients (65% out of the total patients) were retrieved during the pilot paediatric electronic registry already reported in a previous publication by the authors [14].

2.2. Study Period

The study was conducted over a 6-month period from 1 May 2024 to 30 October 2024 on the records generated over a period of 25 years.

2.3. Data Summary and Analysis

Information on infections was reported as included by the reference physician at the time of the visit and was part of the paper records. All the paper records were transferred to the pilot registry. In case of doubt interpretation, advice was requested from an expert from the paediatric SCD clinic. Records without information about bacterial or parasitic infection were excluded. The datasets were demographics, Hb electrophoretic patterns, records of immunisation and records of bacterial or parasitic infection.

A descriptive analysis was conducted to summarise the collected information. This included indicating relative and absolute frequencies for each of the complication using Jamovi statistical software, version 2.6.44.

2.4. Statistics

A Pearson chi-square test of association and post hoc test (standardised residuals) were performed to test the statistical significance.

2.5. Ethical Approval

Ethical approval to set up the PER was obtained from the ABUTH Health Research Ethics Committee (HREC) on 27 January 2023 (ABUTHZ/HREC/F43/2023), and a request for waiving consent on retrospective data collection was granted by the committee.

3. Results

Data of 1961 paediatric SCD patients, i.e., aged <20 years, was retrieved from the registry. Demographic characteristics are shown in Table 1a, with subjects aged <9 years old having the highest population. The most common haemoglobin phenotype among study subjects is HbSS (1476 subjects, 75,3%, Table 1b).

Table 1. (**a**) Study subjects age groups (*n* = 1961). (**b**) Study subjects Hb Electrophoretic patterns (*n* = 1961).

(**a**)			
Age group (years)	Male (%)	Female (%)	Total (*n* = 1961)
<5	387 (53.9)	331 (46.1)	718
5–9	433 (52.0)	339 (48.0)	832
10–14	85 (59.9)	57 (40.1)	142
15–19	37 (49.3)	38 (50.7)	75
* NA	112 (57.7)	82(42.3)	194
(**b**)			
Hb Electrophoretic patterns	Male (%)	Female (%)	Total (*n* = 1961)
SS	874 (51.6)	821 (48.4)	1695
SC	18 (64.3)	10 (35.7)	28
* NA	134 (56.3)	104 (43.7)	238

* NA; not available.

For both variables (age and Hb pattern), ≥10% of data were unavailable due to missing records in patients' case folders. The pilot electronic registry was implemented to identify inconsistencies in the paper-based system but faced challenges including limited access to some folders (due to referrals), illegible handwriting, missing data, and inconsistent data

entry between adult and paediatric haematologists; further details are provided in another publication by the same authors.

In our cohort there were 458 subjects (23.4%) manifesting at least one infection (bacterial or parasitic), of whom 392 (19.9%) subjects had a single infection over the study period and 173 (8.8%) had more than one infection.

The most prevalent infection among subjects with one or more infection patterns was malaria, followed by osteomyelitis, acute diarrhoeal disease, acute respiratory infection and urinary tract infection (Table 2).

Table 2. Frequency of infections (n = 458).

Infection Type	Cases No (%)
Malaria	196 (42.8)
Osteomyelitis	145 (31.6)
Acute diarrhoeal disease	58 (12.7)
Acute respiratory infection	34 (7.4)
Urinary trait infections	25 (5.5)

The pathogens responsible for osteomyelitis, acute diarrhoeal disease, acute respiratory infection and urinary tract infection were not recorded in the patient's case files, and only clinical diagnoses were documented.

The most common haemoglobin electrophoretic pattern among subjects with infection (n = 458) was HbSS (450 subjects, 98.3%), followed by HbSC (8 subjects, 1.7%).

Data on the occurrence of infections by age groups are reported in Table 3. The test of association indicates that the age groups 5–14 had a statistically higher infection rate compared to those >14 years (Table 4).

Table 3. Age group and infections (n = 458).

Age Group (Years)	No Infection	Single Infection	Multiple Infections	Total	Chi-Sqr (df)	*p*-Value
<5 years	605 (84.3)	101 (14.1)	12 (1.7)	718 (100)	18.058 (6)	0.006
5–9	668 (80.3)	142 (17.1)	22 (2.6)	832 (100)		
10–14	130 (91.5)	11 (7.7)	1 (0.7)	142 (100)		
15–19	64 (85.3)	7 (9.3)	4 (5.3)	75 (100)		
Total	1467 (83.0)	261 (14.8)	39 (2.2)	1767 (100)		
Pearson chi-square test of association and post hoc test (standardised residuals) 5–9 yrs and No infection = −2.887, 5–9 yrs and Single infection = 2.567, 10–14 yrs and No infection = 2.822, 10–14 yrs and Single infection = −2.460						

Table 4. Routine immunisation and infection (n = 1904).

Infection	Immunisation Status			Chi-Sqr (df)	*p*-Value
	No (%)	Yes (%)	Total		
No	511 (37.6)	849 (62.4)	1360 (100)	5.992 (1)	0.014
Yes	172 (31.6)	372 (68.4)	544 (100)		
Total	683 (35.9)	1221 (64.1)	1904 (100)		
Pearson chi-square test of association					

Only 1221 children (64.1%) had received routine immunisation (Table 4). Among children who were not immunised, a higher proportion had no infection (37.6%) compared with those who had an infection (31.6%). Conversely, among immunised children, the

proportion with infection (68.4%) was higher than the proportion without infection (62.4%). This finding should be interpreted with caution, as malaria—the most common infection identified in this study—is not currently preventable through routine immunisation in Nigeria.

4. Discussion

This study reported the pattern of infection among paediatric SCD patients attending the ABUTH clinic retrospectively from a pilot paediatric electronic registry (PER) which was designed and implemented by transferring about 65% of hard-copy medical records documented at clinic visits using structural query searching of MS Access. The search revealed that only 64.1% of the SCD patients had received routine immunisation according to the Nigerian National Programme on Immunisation (NPI) routine schedule. The level of vaccination is low, as it often targets 80 to 90% of the population. It was found that malaria was the most prevalent infection, with 42.8%, perhaps because malaria is endemic in this part of the world even among non-SCD patients. This is corroborated by a study conducted in Nigeria that reported that 66% of SCD children presenting with severe anaemia had malarial infection, and the overall mortality was 8.7% [15]. Malaria has been described as the most common precipitating cause of crisis in endemic countries [16,17].

Osteomyelitis was 31.6% among the patients. Osteomyelitis was reported to occur between 0.5 and 16% in children and adults with SCD [18–21]. A total of 42–57% of acute osteomyelitis in North America is caused by *Salmonella* species and *S. aureus* [22,23]. The most common pathogens in West Africa and Saudi Arabia are said to be *Salmonella* species [22,24]. *Salmonella typhi* (the only encapsulated Salmonella species), *Salmonella non-typhi* species, *Gram-negative* enteric bacteria, and *S. aureus* can all cause osteomyelitis [25].

Twelve-point seven percent of the patients had acute diarrhoeal disease. Diarrhoea is a common gastrointestinal symptom in individuals with SCD [26]. The exact cause of diarrhoea in sickle cell patients can vary, but it may be related to factors like medications, infections, or the disease itself [25,27].

Acute respiratory infections affected 7.4% of individuals. Respiratory infections are a risk factor for triggering acute chest syndrome (ACS) in sickle cell anaemia patients and often lead to several complications [28]. Influenza-associated hospitalisation and complications in paediatric SCD patients were reported to be 56-times higher than in non-SCD patients [28].

Urinary tract infection (UTI) was reported in 5.5% of patients in this study, and this is in line with other findings, especially in studies conducted in the West African region. UTI prevalence in SCD patients ranges from 6 to 26% and is more common in children with SCD than healthy children [29]. A UTI is a risk factor for renal impairment, especially in SCD patients. Vaso-occlusion within the vasa rectae of the inner medulla causes ischaemia, renal infarction, papillary necrosis, and scarring of the renal medulla, which promotes UTIs [30]. Many episodes of *Gram-negative* septicaemia in SCD are secondary to UTI [30,31]. It was not documented in the registry whether pneumonia is one of the causes of the ACS; the most common cause of pneumonia in younger children is *S. pneumoniae*, *Chlamydia pneumoniae*, *Mycoplasma pneumoniae*, *Mycoplasma hominis*, and *S. aureus* (and, to a lesser extent, *Legionella* species) in older children and adults [3,30,31]. Pulmonary infection is one of the leading causes of ACS, and it is usually difficult to differentiate patients with ACS from those with pneumonia or those who have both. Of 670 ACS episodes analysed during a 4-year period, 45.7% had an unknown cause, 29.4% were attributed to infection, 16.1% to infarction, and 8.8% to fat embolism [32]. In an analysis of 292 ACS episodes in which a cause could be determined, infection was responsible for one-half of the cases, and of these,

25% were caused by a *Chlamydia* species, 22% were caused by Mycoplasma species, and 22% were caused by viruses [32].

Statistical analysis using a test of association (Table 3) indicates that the age groups 5–14 had a statistically higher infection rate compared to those >14 years ($p < 0.001$), while paradoxically, the analysis between immunisation status and infection (Table 4) shows a significant ($p < 0.014$) association between routine immunisation and infection. However, it should be noted that the major infection reported was malaria, which is not an immunisation-preventable disease in Nigeria at the moment.

Study Limitations

One of the principal limitations of this study pertains to missing data and the limited availability of detailed pathogen information, attributable to the nature of the original dataset and consistent with its pilot design. Nevertheless, the findings provide valuable insight into the frequency of infections among children with SCD in a Nigerian setting, where such data have not previously been available.

5. Conclusions

Infection is one of the major causes of morbidity and mortality among children with SCD, especially in developing countries where access to quality care is lower than in the developed countries. Further research is needed to determine the mechanism behind the susceptibility to infection among SCD patients, especially in Africa, where the prevalence of infectious disease is high. Preventive measures such as vaccination, good hygiene and prophylaxis need to be put in place. It is our recommendation that the implementation of early diagnosis with penicillin V prophylaxis and prompt treatment of infections like salmonella and malaria be of paramount importance.

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Institutional Review Board Statement: The PER was developed in accordance with the Declaration of Helsinki and approved by the ABUTH Ethics Committee on 27 January 2023 (ABUTHZ/HREC/F43/2023).

Informed Consent Statement: A request for waiving individual consent on retrospective data collection was granted by the committee.

Data Availability Statement: Raw data from the registry were not shared and will not be shared. Only aggregated data will be disseminated and presented as results of the study. Primary (raw) data will be available only to the study principal investigator and authorised study team members, bound by professional secrecy. Only aggregated data (e.g., cumulative data and statistics) may be made available to third parties, if requested, for specific and verified purposes (e.g., a summary of research activities, abstracts/presentations or other scientific articles).

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Conflicts of Interest: Author B.P.D.I. has been involved as a consultant in Company Novo Nordisk plc. All the other authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ABUTH	Ahmadu Bello University Teaching Hospital
ACS	Acute Chest Syndrome
MS	Microsoft Access
NPI	National Programme on Immunisation
PER	Paediatric Electronic Registry
SCD	Sickle Cell Disease
UTI	Urinary Tract Infection

References

1. Scourfield, L.E.A.; Nardo-Marino, A.; Williams, T.N.; Rees, D.C. Infections in sickle cell disease. *Haematologica* **2025**, *110*, 546–561. [CrossRef] [PubMed] [PubMed Central]
2. King, H.; Shumacker, H.B. Splenic studies: I. Susceptibility to infection after splenectomy performed in infancy. *Ann. Surg.* **1952**, *136*, 239–242. [CrossRef]
3. Booth, C.; Inusa, B.; Obaro, S.K. Infection in sickle cell disease: A review. *Int. J. Infect. Dis.* **2010**, *14*, e2–e12. [CrossRef]
4. Brown, B.; Dada-Adegbola, H.; Trippe, C.; Olopade, O. Prevalence and etiology of bacteremia in febrile children with sickle cell disease at a Nigeria tertiary hospital. *Mediterr. J. Hematol. Infect. Dis.* **2017**, *9*, e2017039. [CrossRef]
5. Di Nuzzo, D.V.; Fonseca, S.F. Anemia falciforme e infecções [Sickle cell disease and infection]. *J. Pediatr. (Rio J.)* **2004**, *80*, 347–354.
6. Magnus, S.A.; Hambleton, I.R.; Moosdeen, F.; Serjeant, G.R. Recurrent infections in homozygous sickle cell disease. *Arch. Dis. Child.* **1999**, *80*, 537–541. [CrossRef]
7. Aluoch, J.R. Higher resistance to Plasmodium falciparum infection in patients with homozygous sickle cell disease in western Kenya. *Trop. Med. Int. Health* **1997**, *2*, 568–571. [CrossRef]
8. Makani, J.; Komba, A.N.; Cox, S.E.; Oruo, J.; Mwamtemi, K.; Kitundu, J.; Magesa, P.; Rwezaula, S.; Meda, E.; Mgaya, J.; et al. Malaria in patients with sickle cell anemia: Burden, risk factors, and outcome at the outpatient clinic and during hospitalization. *Blood* **2010**, *115*, 215–220. [CrossRef]
9. Uyoga, S.; Macharia, A.W.; Ndila, C.M.; Nyutu, G.; Shebe, M.; Awuondo, K.O.; Mturi, N.; Peshu, N.; Tsofa, B.; Scott, J.A.G.; et al. The indirect health effects of malaria estimated from health advantages of the sickle cell trait. *Nat. Commun.* **2019**, *10*, 856. [CrossRef]
10. Ahmed, S.G.; Uraka, J. Impact of intestinal parasites on haematological parameters of sickle-cell anaemia patients in Nigeria. *East. Mediterr. Health J.* **2011**, *17*, 710–713. [CrossRef]
11. PAN Advisory Committee on Immunisation. Pediatric Association of Nigeria (PAN) recommended routine immunization schedule for Nigerian children. *Niger. J. Pediatr.* **2024**, *39*, 152–158. Available online: https://www.njpaediatrics.com/index.php/njp/article/view/1117 (accessed on 23 February 2026).
12. Adamkiewicz, T.V.; Sarnaik, S.; Buchanan, G.R. Invasive pneumococcal infections in children with Sickle Cell Disease in the era of penicillin prophylaxis, antibiotic resistance, and 23-valent pneumococcal polysaccharide vaccination. *J. Pediatr.* **2023**, *143*, 438–444. [CrossRef]
13. Goerge, I.O.; Onyearugha, C.N. Pneumococcal vaccination status of children with sickle cell disease in Port Harcourt, Nigeria. *Int. J. Pediatr. Res.* **2017**, *2*, 1–3.
14. Idris, M.A.; Ruggieri, L.; Ahmad, H.R.; Hassan, A.; Ibrahim, I.N.; Adullahi, F.J.; Awwalu, S.; Nasiru, U.; Bonifazi, F.; Inusa, B.P.D. Design and Implementation of a Sickle Cell Disease Electronic Registry in Resource Limited Setting in Nigeria—A Pilot Study. *Hemato* **2024**, *5*, 340–349. [CrossRef]
15. Ambe, J.P.; Fatunde, J.O.; Sodeinde, O.O. Associated Morbidities in Children with Sickle-Cell Anaemia Presenting with Severe Anaemia in a Malarious Area. *Tropical Doctor* **2001**, *31*, 26–27. [CrossRef]
16. Cannas, G.; Merazga, S.; Virot, E. Sickle cell disease and infections in high- and low-income countries. *Mediterr. J. Hematol. Infect. Dis.* **2019**, *11*, e2019042. [CrossRef]
17. Ahmed, S.G.; Ibrahim, U.A. A compendium of pathophysiologic basis of etiologic risk factors for painful vaso-occlusive crisis in sickle cell disease. *Niger. J. Basic Clin. Sci.* **2017**, *14*, 57–77. [CrossRef]
18. Bahebeck, J.; Atangana, R.; Techa, A.; Monny-Lobe, M.; Sosso, M.; Hoffmeyer, P. Relative rates and features of musculoskeletal complications in adult sicklers. *Acta Orthop. Belg.* **2004**, *70*, 107–111.

19. Vaishya, R.; Agarwal, A.K.; Edomwonyi, E.O.; Vijay, V. Musculoskeletal manifestations of sickle cell disease: A review. *Cureus* **2015**, *7*, e358. [CrossRef]
20. Onwubalili, J.K. Sickle cell disease and infection. *J. Infect.* **1983**, *7*, 2–20. [CrossRef]
21. Alhajri, M.M.; Alwazzeh, M.J.; Almulhim, G.; Alsahlawi, A.; Alharbi, M.A.; Alotaibi, F.; Alanazi, B.S.; Alzahrani, A.S.; Aljabbari, F. Challenges and Management Outcomes of Osteoarticular Infections in Adult Sickle Cell Disease Patients. *J. Clin. Med.* **2025**, *14*, 8542. [CrossRef]
22. Mallouh, A.; Talab, Y. Bone and joint infection in patients with sickle cell disease. *J. Pediatr. Orthop.* **1985**, *5*, 158–162. [CrossRef]
23. Anand, A.J.; Glatt, A.E. Salmonella osteomyelitis and arthritis in sickle cell disease. *Semin. Arthritis Rheum.* **1994**, *24*, 211–221. [CrossRef]
24. Faris, K.S.; Alrehaili, A.F.; Alsobhi, O.R.; Alenzi, A.A.; Almuhammadi, M.M.; Alerwi, F.S.; Alsuhaimi, O.O.; Almuzaini, M.M.; Faid, H.A.; Kabli, M.F. Genetic blood disorders in Saudi Arabia. *Multi-Knowl. Electron. Compr. J. Educ. Sci. Publ. (MECSJ)* **2022**, *58*, 1–26.
25. Lim, S.H.; Methé, B.A.; Knoll, B.M.; Morris, A.; Obaro, S.K. Invasive non-typhoidal Salmonella in sickle cell disease in Africa: Is increased gut permeability the missing link? *J. Transl. Med.* **2018**, *16*, 239. [CrossRef]
26. Obeagu, E.I.; Obeagu, G.U. Managing gastrointestinal challenges: Diarrhea in sickle cell anemia. *Medicine* **2024**, *103*, e38075. [CrossRef]
27. Grosse, S.D.; Odame, I.; Atrash, H.K.; Amendah, D.D.; Piel, F.B.; Williams, T.N. Sickle cell disease in Africa: A neglected cause of early childhood mortality. *Am. J. Prev. Med.* **2011**, *41*, S398–S405. [CrossRef]
28. Bundy, D.G.; Strouse, J.J.; Casella, J.F.; Miller, M.R. Burden of influenza-related hospitalizations among children with sickle cell disease. *Pediatrics* **2010**, *125*, 234–243. [CrossRef]
29. Tarry, W.F.; Duckett, J.W., Jr.; Snyder, H.M., 3rd. Urological complications of sickle cell disease in a pediatric population. *J. Urol.* **1987**, *138*, 592–594. [CrossRef]
30. Barrett-Connor, E. Bacterial infection and sickle cell anemia. An analysis of 250 infections in 166 patients and a review of the literature. *Medicine* **1971**, *50*, 97–112. [CrossRef]
31. Alima Yanda, A.N.; Nansseu, J.R.N.; Mbassi Awa, H.D.; Tatah, S.A.; Seungue, J.; Eposse, C.; Koki, P.O.N. Burden and spectrum of bacterial infections among sickle cell disease children living in Cameroon. *BMC Infect. Dis.* **2017**, *17*, 211. [CrossRef]
32. Vichinsky, E.P.; Neumayr, L.D.; Earles, A.N.; Williams, R.; Lennette, E.T.; Dean, D.; Nickerson, B.; Orringer, E.; McKie, V.; Bellevue, R.; et al. Causes and outcomes of the acute chest syndrome in sickle cell disease. *N. Engl. J. Med.* **2000**, *342*, 1855–1865. [CrossRef]