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Prevalence and pattern of sensorineural hearing loss among children and adolescents with sickle cell disease in a tertiary health facility, Northwest Nigeria

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Abstract

Sickle Cell Disease (SCD) can result in painful vascular occlusion crises, anoxia, and ischemia, which can occasionally cause damage to tissues and organs, including the auditory system, particularly the blood-rich cochlea. Despite being underreported, Sensorineural Hearing Loss (SNHL) is a well-known consequence of SCD globally. The study's objective was to determine the prevalence and pattern of hearing loss in children and adolescents aged 5 to 16 years old with SCD who were in steady state and were seen at the hematology and pediatric outpatient clinics at Ahmadu Bello University Teaching Hospital (ABUTH), Zaria, Nigeria. A prospective hospital-based case-control study was conducted with 125 children with SCD in steady state, aged 5 to 16, who were enrolled in the hematology clinic at the Ahmadu Bello University Teaching Hospital in Zaria, Nigeria, and 125 'age- and sex-matched healthy controls, who were selected from the ABUTH's pediatric outpatient clinics. An organized questionnaire was used to collect fundamental data on the sociodemographic characteristics and medical history of the participants and controls. In a sound-treated booth, the participant's hearing was evaluated using tympanometry and pure tone audiometry. Overall, 68 (54.4%) and 57 (45.6%) out of the 125 assessed participants were male and female, respectively, with a male-to-female ratio of 1.2:1 and the mean age 10.17±3.55 years. Due to age-sex matching, the subject's age and sex distributions match those of the controls. Children with SCD experienced bilateral SNHL ≥25 dB in 32/125 (25.6%) cases (21 males;11 females). The control group, which had a HbAA phenotype that was normal, did not exhibit any hearing loss. 21/32 (65.6%) of the participants had mild (26-40 dB) hearing loss, and SNHL occurred more frequently in males (21/32 (65.6%) than in females (11/32 (34.4%). In comparison to 3(9.4%) HbSC and 1(3.1%) HbSS+F, SNHL was more common in individuals with 28(87.5%) HbSS phenotypes. While diverse frequencies were impacted in the affected participants, there was no consistency in the frequency pattern of hearing loss. The current study showed that SNHL is a frequent complication in children and adolescents with SCD. About 25% of children and adolescents with SCD experienced SNHL, which disproportionately affected males. Frequent audiometry should be carried out to check the children's hearing levels and identify any early hearing losses so that interventions can be made to perhaps prevent associated speech and language issues that might cause educational challenges.

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Introduction

One of the most common genetic blood disorders in the world is Sickle Cell Disease (SCD). It happens when either homozygous or heterozygous abnormal hemoglobin (HbS, HbC, Hb-thalassemia) is discovered. Anoxia, ischemia, and severe vascular occlusion crises brought on by SCD can occasionally result in tissue or organ damage. The effects of chronic hemolytic anemia and blood vessel obstruction, which are pathophysiologic features of sickle cell disease, can also affect the auditory system. Therefore, sensorineural/cochlear hearing loss develops as a result of repeated sickle cell crises, causing cochlear microvascular occlusion with resultant anoxia and subsequent ischaemic alterations/damage to the auditory system.[1-3]

Nigeria was one of the three nations that contributed 57% of the world's total number of newborns with SCD in 2010. It is anticipated that by 2050, Nigeria's share of the overall number of newborns with SCD will rise from 30% to 35% (more than 150,000 per year).[4]

In the past, SCD was so life-threatening that few persons reached adulthood, and the presence of a hearing loss with some other complications seen today was not of primary concern. People with SCD are now living longer, through the adolescent years, thanks to recent improvements in affiliated (specialist) management of the disease. With increasing lifespan among children and adolescents with SCD, a quality-of-life concern that needs to be addressed by pediatricians, adult physicians, and otorhinolaryngologists (ENT surgeons) is the prevalence of disease-associated consequences, including Sensorineural Hearing Loss (SNHL).[1,3]

For more than 50 years, there has been ample evidence linking SCD to hearing loss. Several studies have revealed that individuals with SCD globally have a prevalence of 3.8-41% for varied degrees of SNHL, ranging from mild to profound, with a range of 3.6% to 12% in studies that included only paediatric patients.[5-23] Unfortunately, only a few studies[14,21-23] conducted in Nigeria during the past two decades have examined the frequency and pattern of sensorineural hearing loss in young people with sickle cell disease. The current study is necessary since there is currently no published data on the hearing status of children with SCD in the Northwest of Nigeria. The findings of this study will aid in the affiliated and comprehensive management of children and adolescents with SCD in this region and elsewhere. In light of these circumstances, the current study sought to ascertain the prevalence and pattern of hearing loss in children and adolescents aged 5 to 16 years with SCD who were enrolled in the hematology and pediatric outpatient clinics at Ahmadu Bello University Teaching Hospital (ABUTH), Zaria, Nigeria.

Materials and Methods

Study design

A case-control cross-sectional descriptive study was carried out at the Pediatrics Sickle Cell and Pediatrics Outpatients Clinics of the Paediatric Department, and the Ear, Nose, and Throat (ENT) Unit of the Department of Surgery in Ahmadu University Teaching Hospital (ABUTH), Zaria, Northwest, Nigeria. The pediatric sickle cell clinic and the ENT clinic both have once-weekly appointments (Wednesday and Tuesday, respectively). The Paediatrics Outpatient Clinic runs every day of the week.

Study setting

The 500-bed Ahmadu Bello University Teaching Hospital, Zaria, is a tertiary institution that is situated in the Shika-Giwa Local Government area of Kaduna State.

Sample size determination

To calculate n, the formula used was

$$n = \frac{z^2pq}{d^2}$$

where:

n = the desired minimum sample size,
z = the standard normal deviation, the value corresponding to a 95% confidence interval is 1.96
p = prevalence SNHL among children with SCD in a study carried out by Ogisi *et.al* was 8%[23]
q = 1– p
d = degree of accuracy set at 0.05 for this study
n (minimum acceptable sample size + 10% attrition) = 125, each for the subjects and controls

Selection of the study population

The study population was made up of 125 children and adolescents with SCD ((subjects)) in their steady state and 125 'age- and sex-matched healthy children and adolescents with HbAA (controls) aged 5 to 16 years. These individuals were chosen through simple random sampling from a table of random numbers created based on the total number of individuals who presented to the weekly sickle cell clinic and the daily paediatrics outpatient clinics of ABUTH, respectively.

Inclusions and exclusions criteria for the subjects

Children and adolescents between the ages of 5 and 16 having a confirmed diagnosis of SCD (SS, SC, SS+F, and any additional forms of SCD) in their clinic file were eligible for inclusion if their parents or legal guardians gave their agreement. Children above the age of seven also provided their assent for the study. The study excluded participants with acute SCD crises, any signs of recent infections within 4 weeks of recruitment, a family history of hearing loss, head injuries, strokes, measles, mumps, meningitis, acute or chronic otitis media, participants taking ototoxic medications, and participants receiving chronic blood transfusions. Subjects whose guardians refused to allow their children to participate in the study were also excluded.

Inclusions and exclusions criteria for the controls

The inclusion criteria comprised HbAA-phenotype children between the ages of 5 and 16 who appeared to be in good health and were visiting the pediatric outpatient clinic for minor illnesses or routine tests. Children with other chronic hemolytic anemias or malignancies, those with a family history of hearing loss, head injury history, acute or chronic otitis media, meningitis, mumps, or measles, as well as those whose parents or carers denied consent, were excluded from the study.

Every other week for a total of twelve (12) months, children and adolescents (subjects and controls) who met the inclusion criteria were included in the study. Every week, five participants and five controls were recruited. According to the overall number of clinic attendees, a table of random numbers was created. The selec-

tion order was determined by dividing the total number of clinic attendees by 5. Often, the first subject or control was chosen at random to begin with. On the recruitment day, Tympanometry and Pure Tone Audiometry (PTA) tests were conducted on the selected subjects and controls. On the second day, venous blood was drawn for a Complete Blood Count and Differential, as well as Hb-electrophoresis for the controls (on appointment).

Data collection procedure

The subjects/controls and their parents/guardians were surveyed using a standardized interviewer-administered questionnaire specifically created for the study. The questionnaire asks about sociodemographic factors, nutritional status, anthropometric measurements, full blood counts and differentials, and Hb-electrophoresis results for the controls. For the subjects, it also asks for information on suspected risk factors for sensorineural hearing loss, such as age at diagnosis and onset of sickle cell crisis, the type, severity, and frequency of sickle cell crises in the previous 12 months or the most recent episode of crisis encountered, as well as clinic visits. Following a clinical examination, the weights, heights, and Body Mass Index (BMI) of all recruited subjects and controls were recorded.

Only those with clear external auditory canals and intact, shining tympanic membranes proceeded further in the study after all enrolled patients and controls had otoscopy. However, mild syringing of the ear was performed on participants or controls who had wax impaction, and additional audiological testing was postponed for at least two weeks. Each subject's and the control group's middle ear function was evaluated using tympanometry - a calibrated TYMP 87 Clinical Middle Ear Analyzer made by the Danish company GN Otometrics Copenhagen. Audiometry was only performed on participants and controls who had a Type A tympanogram and an auditory reflex.

A clinical audiologist used a properly calibrated audiometer (MADSEN ITERA made by GN Otometrics Copenhagen, Denmark) and well-fitting TDH 35 earphones to perform diagnostic audiometry on each subject and control in a double-walled, soundproof cabin. The audiometer was pre-calibrated at frequencies of 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, 6000 Hz, and 8000 Hz.[24-28] Air conduction measurements of pure tone thresholds were made for each ear at 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz.[29,30] After carefully explaining the procedure to the subjects, controls, and their parents or carers and receiving their informed consent, one milliliter (1 ml) of venous blood was drawn from each subject and control for the Full Blood Count (FBC) analysis as well as Hb electrophoresis for the controls.

Definitions and measurements

A >25 dB stimulus at one or more of the tested frequencies in one or both ears was considered to be hearing loss for this investigation.[29,31-33] Pure tone averages calculated for frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz were divided into the following categories: within normal limits (10-25dB HL), mild hearing loss (26-40dB HL), moderate hearing loss (41-70dB HL), severe hearing loss (71-90dB HL), and profound hearing loss (>91dB HL).[29,30]

In this investigation, controls were defined as children attending the pediatric outpatient clinic who appeared to be in good health and who had a known HbAA phenotype or a verified HbAA phenotype (as determined by Hb electrophoresis performed in this study). In this study, subjects were considered to be in a "steady state" if they had not experienced any symptoms (such as bone pain or fever) or signs (such as severe pallor, dehydration, or tenderness) suggestive of crisis for 4-6 weeks, as determined by a thorough history and physical examination.[33-35] Using the "Wong-Barker FACES Pain Rating Scale," the retrospective severity of the vaso-occlusive crises in the previous 12 months or more current crisis was assessed and divided into three levels: mild (score 0-2), moderate (scoring 4-6), and severe (score 8-10).

The approach suggested by Oyedeji et al.[36] was used to determine the socioeconomic class of the study population. Based on the parent's employment status and level of education, each child's social class was identified in this case. The social class of each kid chosen for the study was determined by averaging the four scores (two for each parent, representing occupational position and educational attainment) to the nearest whole number. The procedure states that when one parent is tardy, the child's social status is determined by the parent or guardian who is still alive. WFH/BMI was calculated using the WHO growth guidelines for children and adolescents to assess the subjects' nutritional health.[37]

Data processing and analysis

The collected information was cleaned, coded, and entered into the SPSS for Windows version 24 program (SPSS Inc., Chicago, IL, USA). For categorical data, descriptive analysis was carried out using frequency tables, figures, and proportions; for continuous variables, the mean was used. The connection between categorical variables was determined using the Pearson chi-square test. Using 95% confidence intervals and P-values under 0.05, statistical significance was calculated.

Ethical clearance

The parents/caregivers of the participants gave their informed consent and, where appropriate, children older than 7 years old, gave their assent before recruitment into the study. Ethical approval (Reference number ABUTH/HREC/ K6/16) was obtained from the Ethics and Research Committee of ABUTH, Zaria.

Results

Two hundred and fifty children (250) between the ages of five and sixteen were included in the study. One hundred twenty-five (125) of these children had SCD (Hb SS, HbSS+F, or Hb SC) in steady state, while one hundred twenty-five (125), who were age- and sex-matched controls, appeared to be healthy children with hemoglobin AA.

Age and gender distribution of the participants

Among the 125 participants tested, 68 (54.4%) were males and 57 (45.6%) were females, resulting in a male-to-female ratio of 1.2:1 and a mean age of 10.17±3.35 years. Due to age and sex matching between the subject and control groups (Table 1) the age and sex distribution of the subjects is the same as that of the controls (χ^2=0.75; p=0.69).

Sociodemographic characteristics of the participants

As shown in Table 2, the subjects' and the controls' socioeconomic classes ranged from class I to class V. Compared to 39 (31.2%) of the controls, 71 (56.8%) of the 125 subjects assessed were from a lower socioeconomic level (IV or V). Statistics showed that the difference was significant (χ^2=17.28; p=0.002;

df=4). The highest Hb phenotype among the subjects tested was homozygous HbS 85 (68%), and the lowest was HbSC disease 6 (4.8%), indicating a significant difference in the distribution of Hb phenotypes (*Fisher's exact* = 15.896; p=0.001; df=3).

Prevalence of Sensorineural Hearing Loss in the study population

All subjects (SCD) and controls (HbAA) investigated had type A tympanogram and positive acoustic reflex. Of the study subjects, 25.6% (32 out of 125) had bilateral sensorineural hearing loss of more than 25 dB at two or more frequencies. In the control group, no one had hearing loss (Table 3). With a 1.9:1 male-to-female ratio among the 32 subjects (SCD) with sensorineural hearing loss, 21 (65.6%) of them were males, while 11 (34.4%) were females.

Prevalence of Sensorineural Hearing Loss across the age groups

As shown in Table 4, the modal age ranges for SNHL among subjects (SCD) were (>8-12 years) and (>12-16 years), respectively. The prevalence rate of SNHL was 17.8% in the age group (5-8 years), compared to 25.5% and 36.4% in the age groups (>8 to 12 years) and (>12 to 16 years), respectively. However, the difference was not statistically significant (χ^2=3.453; df=2; p=0.178; df=2).

Prevalence of Sensorineural Hearing Loss across hemoglobin phenotypes

According to hemoglobin phenotypes by hearing level, of the 85 homozygous SCD (HbSS) subjects, 28 (32.9%) had sensorineural hearing loss. HbSS+F 2.9% (1 out of 34) and HbSC disease 50% (3 out of 6) were the remaining hearing-impaired cases. Fisher's exact =15.896; p=0.001; df=2; indicating that the prevalence rate of SNHL was statistically significant throughout the range of hemoglobin phenotypes. The prevalence of SNHL according to hemoglobin phenotypes reveals that of the 32 (25.6%) participants with SNHL, 28 (87.5%) were HbSS (SCA), and the remaining subjects with SNHL were HbSC 3 (9.3%) and SS+F 1 (3.2%), respectively.

Sensorineural Hearing Loss and gender

Twenty-one (65.6%) subjects with SNHL were males, while females constituted 11 (34.4%). Furthermore, the prevalence of sensorineural hearing loss among male subjects was 30.9%, while among females, it was 19.3%, giving a male-to-female ratio of 1.9:1

Age of onset of Sensorineural Hearing Loss among subjects

The study's total SNHL of the subject (SCD) population had a mean age of 11.0±3.2 years. Nonetheless, SNHL was identified in

Table 1. Distribution of subjects and controls by age and gender.

| | SCD (n=125) | | Control (n=125) | | |
| | Female n (%) | Male n (%) | Female n (%) | Male n (%) | Total n (%) |
Age (years)					
5-8	22 (38.6)	23 (33.8)	22 (38.6)	23 (33.8)	90 (36.0)
>8-12	20 (35.1)	27 (39.7)	20 (35.1)	27 (39.7)	94 (37.6)
>12-16	15 (26.3)	18 (26.5)	15 (26.3)	18 (26.5)	66 (26.4)
Total	57 (45.6)	68 (54.4)	57 (45.6)	68 (54.4)	250 (100.0)

SCD, sickle cell disease; χ^2=0.75; p=0.69; mean age = 10.11±3.35; df=3.

Table 2. Ethnicity, social class, and haemoglobin phenotypes of subjects and controls.

Variables	SCD (n=125) n (%)	Controls (n=125) n (%)	Total (n=250) n (%)	Statistics χ^2	p
Ethnic group				38.122	<0.001
Hausa	106 (84.4)	63 (50.4)	169 (67.6)		
Yoruba	9 (7.2)	17 (13.6)	26 (10.4)		
Igbo	1 (0.8)	20 (16.0)	21 (8.4)		
Other	9 (7.2)	25 (20.0)	34 (13.6)		
Social class				17.279	<0.002
Class I	6 (4.8)	11 (8.8)	17 (6.8)		
Class II	16 (12.8)	27 (20.6)	43 (17.2)		
Class III	32 (25.6)	48 (38.4)	80 (32.0)		
Class IV	52 (41.6)	31 (24.8)	83 (33.2)		
Class V	19 (15.2)	8 (6.4)	27 (10.8)		
Hb phenotypes					
Hb SS	85 (68.0)	-	85 (34.0)		
Hb SS + F	34 (27.2)	-	34 (13.6)	Fisher's exact	
Hb SC	6 (4.8)	-	6 (2.4)	15.896	0.001
Hb AA	-	125 (100)	125 (50.0)		

a subject (male) as young as 5 years old. In contrast to 11.6±3.8 years for female subjects, the mean age at which SNHL developed in male subjects was 10.1±2.9 years. Whilst the difference was not statistically significant (t=0.687; df=30; p=0.497), it was nonetheless present.

Severity/degree of Sensorineural Hearing Loss among subjects

Of the 32 subjects with SNHL assessed for hearing loss severity, it was found that 21 (65.6%) had mild SNHL, 10 (31.3%) had moderate SNHL, and only one (3.1%) had severe SNHL. None of the subjects experienced SNHL which was profound. Fourteen out of the twenty-one (66.7%) subjects with mild SNHL were male, while 33.3% (7 out of 21) were female. Similarly, male participants made up 60% (6 out of 10) of the 10 subjects with moderate SNHL, while female subjects made up 40% (4 out of 10). The only subject in the study with severe SNHL was a male.

Severity/degree of Sensorineural Hearing Loss with haemoglobin phenotypes

According to the haemoglobin phenotype distribution, among the 28 subjects with HbSS (sickle cell anemia) who acquired SNHL, 18 (64.3%) had mild hearing loss, while 9 (32.1%) and 1 (3.6%) had moderate and severe hearing loss, respectively. Likewise, 2 (66.7%) of the 3 HbSC phenotype subjects who expe-

rienced sensorineural hearing loss had mild hearing loss, while 1 (33.3%) had moderate hearing loss. Only one subject with the HbSS+F phenotype experienced moderate sensorineural hearing loss (Table 5). Fisher's exact= 17.586; df=4; p=0.002 indicated a statistically significant variation in the severity/degree of hearing loss between hemoglobin phenotypes.

Sensorineural Hearing Loss and hearing frequencies affected

Overall, high frequency (2000HZ-8000HZ) sensorineural hearing impairment predominated among the 32 subjects with SNHL in both the right 15 (46.9%) and left 14 (43.8%) ears. This was followed by hearing loss in both frequencies (low and high frequencies) in the right 9 (28.1%) and left 11 (34.4%) ears, while low-frequency hearing loss (125 Hz-1000 Hz) was least affected in the right 8 (25.0%) and left 7 (21.9%) ears, respectively. Similarly, in both the right 15 (43.8%) and left 12 (37.5%) ears of the male patients, high frequency (2000 Hz-8000 Hz) SNHL was the most prevalent kind of hearing loss, whereas low frequency (125 Hz-1000 Hz) SNHL predominated in the right and left ears of the female subjects, 5 (15.8%) respectively. The difference in frequency range hearing loss distributions by gender in the right (Fisher's exact = 9.995; df=2; p=0.006) and left (Fisher's exact = 6.427; df=2; p=0.035) ears were statistically significant using the Fisher's exact probability test (Table 6).

Table 3. Prevalence of sensorineural hearing loss in subjects and controls.

Variables	SCD (n=125) n (%)	Control (n=125) n (%)	Total n=250 n (%)
Hearing loss	32 (25.6)	-	32 (12.8)
No hearing loss	93 (74.4)	125 (100)	218 (87.2)
Total	125 (100)	125 (100)	250 (100)

SCD, sickle cell disease; HbAA, normal hemoglobin.

Table 4. Prevalence of sensorineural hearing loss among subjects with sickle cell disease across the age groups.

Variables	Sickle cell disease - Age groups (years)			
	5-8 yrs (n=45) n (%)	>8-12 yrs (n=47) n (%)	>12-16 yrs (n=38) n (%)	Total (n=125) n (%)
Hearing loss	8 (17.8)	12 (25.5)	12 (36.4)	32 (25.6)
No hearing loss	37 (82.2)	35 (74.5)	21 (63.6)	93 (74.4)
Total	45 (100)	47 (100)	33 (100)	125 (100)

SCD, sickle cell disease.

Table 5. Severity/degree of sensorineural hearing loss among hemoglobin phenotypes.

	Haemoglobin phenotypes			Total (n=32)	Statistics	
	HbSS (n=28) n (%)	HbSC (n=3) n (%)	HbSS+F (n=1) n (%)	n (%)	Fisher's	p
SNHL						
Mild (26-40 dB)	18 (64.3)	2 (66.7)	1 (100)	21 (65.6)		
Moderate (41-70 dB)	9 (32.1)	1 (33.3)	–	10 (31.3)	17.896	<0.002
Severe (71-90 dB)	1 (3.6)	–	–	1 (3.1)		
Total	28 (100)	3 (100)	1 (100)	32 (100)		

SNHL, sensorineural hearing loss; SCD, sickle cell disease; HbSS, sickle cell anemia; HbSS+F, sickle cell anemia with persistent fetal haemoglobin; HbSC, SC disease.

Discussion

In the present study, 25.6% of the children and adolescents with SCD exhibited sensorineural hearing loss of >25 dB in both ears. None of the children in the control group had hearing loss. All subjects with SNHL had type A tympanogram and acoustic reflex which indicates normal middle ear function. This study has once more supported the notion that those with SCD are more likely to experience hearing loss. The proportion of SCD children in the current study who have bilateral hearing loss (25.6%) is higher than the rates reported previously from Nigeria by Odetoyinbo et al.[22] (South-West, Nigeria), Alabi et al.[14] (North-Central, Nigeria), Ogisi et al.[23] (South-South, Nigeria), Mgbor and Emodi[21] (South-East, Nigeria), as well as in the United States by Heather et al.[6] and Brazil by de Castro Silva et al.[38] However, the present study prevalence is less than the percentages reported by Astina et al.[15] (Ghana), Taipale et al.[39] (Angola), and Tsibulevskaya et al.[24,40] (Kenya), respectively, of 29%, 36%, and 36.5%. Why there are variations in SNHL prevalence rates across research around the world is not entirely clear. It's possible that the sample size and methods used for identifying and diagnosing hearing loss, as well as various β-S haplotypes that are prominent in various races, age diversity in the study participants, all played a role. In contrast to other earlier series from Nigeria, the current study (North-West, Nigeria) found a high prevalence rate of SNHL. This could be because a higher percentage of the SCD children in this series came from low socioeconomic families and lived in rural areas far from healthcare facilities. When compared to their counterparts from higher socioeconomic backgrounds, subjects from lower socioeconomic backgrounds may be less likely to adhere to clinic follow-up, take prescribed medications, and maintain affiliated care due to poverty and ignorance, which results in a higher proportion of sickle cell disease morbidity.

In contrast to other studies,[9,10,14,25] where SNHL was absent in subjects under seven years old, our study found sensorineural hearing loss in subjects as young as five years old, which is similar to the findings by Odetoyinbo et al.[22] (South-West, Nigeria), Mgbor and Emodi[21] (South-East, Nigeria), and Ajulo et al.[12] (United Kingdom), who also found hearing loss in preschool children. The presence of SNHL in the younger age group in the present study may be a more accurate indicator of the severity of sickle cell disease phenotypic variant in our environment, the younger age at which sickle cell crisis begins (mean age of 6±3.5 months) and the frequent and painful crisis that results from exposure to recurrent infections, such as malaria. In addition, the current investigation discovered a correlation between the incidence of hearing loss and advancing age among participants with sensorineural hearing loss, just like the earlier series.[13,21,41] However, this result differs from

that of other authors,[12,14,17,42] who did not discover an increased incidence of hearing loss with advancing age. Our findings may indicate that recurrent episodes of vaso-occlusive crises with ischemic damage to the cochlea and its appendages cause progressive hearing loss over time and, as a result, a rise in the incidence of SNHL in the older age group.

According to our research, males were more likely than females to experience hearing loss (30.9% versus 19.3%), and males were also more likely to have hearing loss that was worsening. This result supports the conclusion by Aderibigbe et al.[13] (Nigeria) that hearing sensitivity drops more than twice as quickly in males as in females at most ages and frequencies. While Al-Okbi et al.[43] in Oman observed a female majority among their SCD participants with SNHL; other authors[20,21,40,41] showed equal sex prevalence of SNHL, which is in contrast to our findings. It is unclear why hearing loss is more common and getting worse in males. We propose that the complexity of factors that determine care and quality, access to the best care, and potential genetic influence, which may have been diverse and challenging to appropriately analyze in all these researches, may be the cause of these conflicting findings.

In the past, children with homozygous SCD have been reported to suffer both bilateral sensorineural hearing deficit.[15-17,22,44] All of the SNHL subjects in our study showed bilateral ear involvement, albeit to varying degrees and frequencies. This result was consistent with earlier series,[14,21-23] although it was at variance with the finding of Alison et al.[11] who reported that 100% of SNHL cases in their study population were unilateral. Bilateral hearing loss is typically seen in people with sickle cell disease as a result of systemic affectation, despite the possibility of unilateral hearing loss of varied degrees and frequencies.

There have been numerous reports indicating that children and adolescents with SCD have a wide range of hearing loss severity. Past studies have indicated that the severity of hearing loss can range from mild to profound.[42,45-47] In our study, children with SCD were predominately affected by mild sensorineural hearing loss (65.6%). Only one of the subjects had severe hearing loss, but none were diagnosed with profound hearing loss. In line with earlier research[14,21,40,48,49] our analysis indicates that while children and adolescents with SCD in underdeveloped countries are at significant risk for hearing impairment, severe and profound hearing loss among them is not typical. However, hearing loss of any severity can delay speech-language maturation and have long-term effects on schooling, including grade failure, the need for educational aid, and perceptions of behavioural problems in day-to-day activities.

Some authors,[15,22,23,26] have found significant hearing loss at both lower and higher frequencies. In their series, Mgbor and

Table 6. Frequency of hearing level impairment by gender among subjects with sensorineural hearing loss.

| | Sickle cell disease subjects with SNHL (n=32) | | | | | |
| | Right ear (n=32) | | | Left ear (n=32) | | |
	Male n (%)	Female n (%)	Total n (%)	Male n (%)	Female n (%)	Total n (%)
Frequency type hearing level						
Low frequency (125HZ-1000Hz)	3 (14.3)	5 (45.5)	8 (25.0)	2 (9.5)	5 (45.5)	7 (21.9)
High frequency (2000HZ-8000Hz)	14 (66.7)	1 (9.1)	15 (46.9)	12 (57.1)	2 (18.2)	14 (43.8)
Both frequencies (low and high)	4 (19.0)	5 (45.5)	9 (28.1)	7 (33.3)	4 (36.4)	11 (34.3)
Total	21 (65.6)	11 (34.4)	32 (100)	21 (65.6)	11 (34.4)	32 (100)

Right Ear: Fisher's exact = 9.995; df=2; p=0.006; Left Ear: Fisher's exact = 6.427; df=2; p=0.035; SNHL, Sensorineural hearing loss.

Emodi[21] reported a hearing loss that mostly affected low frequencies, while Tsibulevskaya et al.[40] (Kenya) reported high frequency hearing loss in their study. Although high-frequency hearing loss predominates in the current investigation, the affected patients consistently showed worse hearing thresholds across all frequencies examined. Research has shown that the basal turn of the cochlear is first impacted by hearing loss complicating SCD, then the apical turn, and lastly, the entire cochlear duct. The low ability for anaerobic metabolism and the high oxygen consumption rate of the *stria vascularis* in this region account for the basal turn of the cochlea's sensitivity to anoxia. With venous blockage, it may be expected that high frequencies would be initially affected, followed by low frequencies, and then worsening at all frequencies. This is because the cochlea's basal turn records high frequencies, and the apical turn low frequencies. This is the typical pattern of hearing loss in SCD, and, probably, the cochlea is also affected by a low-grade continuous venous thrombotic process that doesn't include any clinically apparent episodes.[50-53]

Prior research has shown a strong correlation between the distribution of hemoglobin haplotypes and their possible immunity or susceptibility to auditory issues caused by sickle disease.[15-17,20,22,39,40,54] Others identified high rates and deteriorating SNHL across HbSC disease groups, contrary to certain authors' reports of worsening and greater prevalence rates of hearing loss among homozygous sickle haemoglobin (HbSS) subjects. Despite being challenged by some,[55,56] previous datasets have similarly found decreased hearing rates in populations of children and adolescents with persistent foetal haemoglobin (HbSS+F/HbSS+F).[57-59] Overall, the results of this study showed that the HbSS (sickle cell anaemia) group made up the bulk (87.5%) of the participants with hearing loss, while the HbSC and HbSS+F disease groups contributed 9.4% and 3.1%, respectively, to the pool. In our investigation, only one participant who had severe SNHL belonged to the HbSS phenotypic group. Contrarily, our investigation further revealed that 50% (3 out of 6) of the HbSC subgroup had SNHL based on sample frame distributions of the hemoglobin phenotypes, while 32.9% and 2.9% of the HbSS subgroup (28 out of 85) and HbSS+F disease (1 out of 34) displayed hearing loss, respectively. According to literature, individuals with homozygous SCD (HbSS), which is thought to be the most fatal and prevalent form of SCD seen in the majority of populations and regions of the world, have a greater and worsening incidence of complications, including auditory damage than those without it. Also, it is widely acknowledged that hemoglobin F (HbF) levels that are consistently high have a preventive impact against the severity of the disease and serious complications. While this might be the case for organs like the spleen, Ashoor and Al-Awamy[16] have demonstrated that it might not apply to the cochlea. The rate of auditory complications (SNHL) of 23.8% that they discovered was comparable to 21.7%, 21.4%, and 29% prevalence rates, reported in earlier studies by Todd et al.[41] (Jamaica), in later investigations by Odetoyinbo and Adekile (Nigeria), and Atsina and Ankra-Badu[15] (Ghana) respectively where the HbF levels are substantially lower. To this end, due to uneven sample frame distributions and a lack of foetal haemoglobin level estimation for those with persistent foetal haemoglobin, it will be challenging to draw conclusions from the previous series and this current study regarding which of the haemoglobin haplotypes/phenotypes (HbSS, HbSC, or HbSS+F) had a greater impact on the auditory system of these groups of children.

Conclusions

The study found that 28.8% of children and adolescents with sickle cell disease had sensorineural hearing loss. Hearing loss in children with SCD is typically bilateral and progressive. Early detection and treatment of hearing loss is important for children with sickle cell disease. Children with SCD should have their hearing tested at a young age and as they get older.

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