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Assessment of Oxygen Saturation Using Pulse Oximetry in Patients with Steady State HbSS

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Abstract

Background: The exact consequence of hypoxemia SCA is unclear, however, many studies have shown haemoglobin desaturation is common in patient with SCA even at steady state, and may predispose to several complications including pulmonary hypertension, stroke and acute chest syndrome. Therefore, detection of hypoxemia is important in patients with SCA.

Objectives: We sought to compare SpO_2 of patients with HbSS in steady state and healthy individuals with HbAA genotype; and to determine the prevalence of hypoxemia amongst HbSS patients during steady state.

Materials and Methods: This is a prospective cross-sectional study involving ninety three adults with SCA in steady state and forty-eight healthy age and sex matched HbAA participants as controls. The oxygen saturation was recorded using a finger pulse oximeter (Suaoki, Model FS20A).

Results: The HbSS patients had a significantly lower mean SpO_2 of 95.5% (4.1) compared to 99.06% (1.14) for the healthy HbAA group (p=0.0001). Male and female HbSS patients had a comparable SpO_2 (95.8% vs 96.1%, p=0.610). Similarly, mean SpO_2 was similar in male and female HbAA group (p=0.258). The prevalence of hypoxemia among the HbSS patients was 30.25% compared to 2.7% amongst the HbAA. The lowest SpO_2 recorded among the HbSS patients was 88%.

Conclusion: The prevalence of hypoxemia in steady state HbSS patients was high. This finding underscores the importance of monitoring HbSS patients for prompt detection of hypoxemia, and to institute therapy where necessary to prevent complications including pulmonary hypertension and cerebrovascular disease.

Keywords: Hypoxemia; Pulse oximetry; Sickle cell anaemia

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Introduction

The lungs are a major site of involvement in patients with sickle cell disease (SCD), with both acute and chronic pulmonary complications commonly reported, and associated with increased mortality [1,2]. Sickle cell chronic lung disease presumably results from recurrent episodes of pulmonary infarction and infection. It is characterized by reduced lung luscency, abnormal pulmonary function, and in its severe form, pulmonary hypertension [1,3]. Moderate to severe pulmonary function impairment can results in hypoxemia, which may initiate or exacerbate vasculopathy [4]. There are reports of increased risk for central nervous system events with hypoxemia, whereas, higher oxygen saturations (SpO_2) was associated with less frequent acute chest syndrome [5,6]. Many studies showed haemoglobin desaturation to be common in patient with sickle cell anaemia (SCA) even at steady state [7-9], and high prevalence of hypoxemia has been documented in children with SCA [10,11]. With improved care, the median survival of patients with SCA has risen, and therefore the prevalence of chronic organ diseases encountered in the adult population has also increased. In this study, SpO_2 was assessed in adults with SCA using pulse oximetry, a widely utilized noninvasive technique. We sought to compare SpO_2 of patients with HbSS in steady state and healthy individuals with HbAA genotype; and to determine the prevalence of of hypoxemia amongst HbSS patients during steady state.

Research Methodology

Ninety three patients with steady state HBSS were evaluated during routine outpatient visits at the Haematology unit of the University of Maiduguri Teaching Hospital, from January through June 2017. Forty-eight healthy age and sex matched HbAA participants were used as controls. Oxygen saturation was recorded using a finger pulse oximeter (Suaoki, Model FS20A). This uses the principle of spectrophotometery and photoelectric plethysmography in determining oxygen saturation [12]. The appropriate sensor was placed on the right or left index finger and the values recorded after at least 2 minutes of stable SpO_2, determined as regular pulsatile photoplethysmography signal apparent on the visual display of the oximeter. All measurements were made while the patient was breathing room air. Low oxygen saturation was defined as SpO_2 less than 96%, which predicts a PaO_2 of less than 70 mm Hg based on a normal oxyhaemoglobin curve [10]. The data was analyzed using the statistical package for social sciences version 20.0 (SPSS Chicago III USA.). Normality of data was tested using Kolmogorov-Smirnov test, and continuous variables expressed using means (SD) or proportions and compared using Student's t-test. A p value of <0.05 was considered significant for all statistical analysis.

Results

The HbSS patients were made up of 36 (38.7%) males and 57 (67.3%) females, while HbAA controls comprised of 24 (50%) males and 24 (50%) females; with a mean age of 23.11 (6.03) years for the HbSS patients and 25.8 (6.19) years for the HbAA controls (p=0.07). The pulse rates and SpO_2 of HbSS patients and HbAA controls are illustrated in **Table 1**. The HbSS patients had a significantly lower mean SpO_2 of 95.5% (4.1) compared to 99.06% (1.14) for the healthy HbAA group (p=0.0001). Male and female HbSS patients had a comparable SpO_2 (95.8% vs. 96.1%, p=0.610). Similarly, mean SpO_2 was similar in male and female HbAA group (p=0.258) (**Table 2**). The prevalence of hypoxemia among the HbSS patients was 30.25% compared to 2.7% amongst the HbAA (**Table 3**). The lowest SpO_2 recorded among the HbSS patients was 88% **(Figure 1)** and 95% for the controls respectively (**Figure 2**).

Table 1 Clinical parameters of HbSS patients and HbAA controls.

Parameters	HbSS (N=93)	HbAA (N=48)	P value
Age	23.11 ± 6.03	25.8 ± 6.19	0.07*
Pulse rate	88.9 ± 12.2	82.1 ± 8.89	0.001*
SpO_2	95.5 ± 4.1	99.06 ± 1.14	0.0001*
*Significant result using Student T test			

Table 2 Comparison of Mean SpO_2 in HbSS and HbAA groups based on gender.

Subjects	Mean SpO_2	Mean SpO_2	P value *
	Males	Females	
HbSS	95.80%	96.10%	0.61
HbAA	98.90%	99.20%	0.258
*Significant result using Student T test			

Table 3 Distribution of SpO_2 in HbSS patients and HbAA control group.

	Subjects (HbSS)			Controls (HbAA)	
SpO_2	Number of participants (93)	Cumulative %	SpO_2	Number of participants (48)	Cumulative %
< 90%	6	6.5	< 90%	0	0
90-95%	22	30.1	90-95%	1	2.7
96-100%	65	100	96-100%	48	99.3

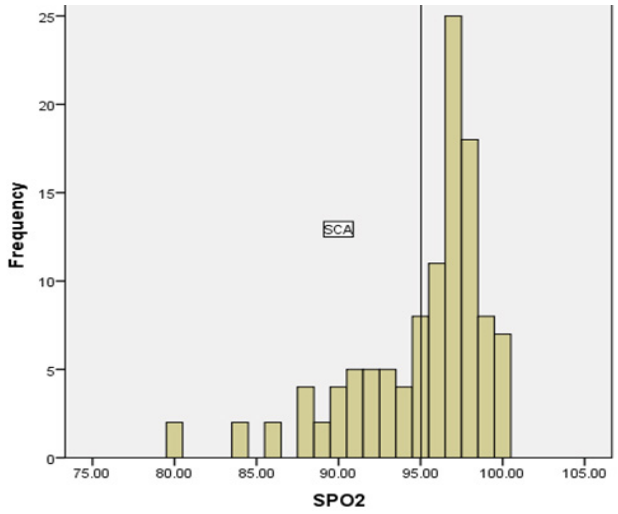

Figure 1 The mean oxygen saturation (vertical line) and its distribution amongst the subjects and control. The lowest SpO_2 recorded among the HbSS patients was 88%.

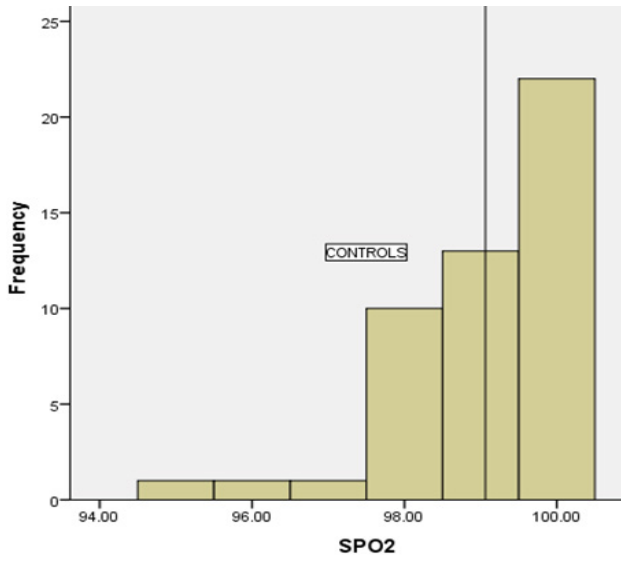

Figure 2 The mean oxygen saturation (vertical line) and its distribution amongst the subjects and control. The lowest SpO_2 recorded among the controls was 95%.

Discussion

We found a prevalence of 30.5% for hypoxemia in steady state SCA patients using pulse oximetry, a finding similar to earlier

reports [9,13]. Contrary to reports of lower SpO_2 levels in male patients with steady state SCA [11,13], our male and female patients had comparable levels of SpO_2. Hemoglobin desaturation in patients with steady state SCA has been attributed to several factors. Recurrent episodes of ACS could result in a sequalae of irreversible chronic lung disease, giving rise to defective oxygenation of blood even when in steady state [14]. In addition, the sickle cell hemoglobin S has an inherent property of causing a rightward shift of the oxy-hemoglobin dissociation curve in a bid to enhance oxygen delivery at the tissue level, a trait it shares with raised levels of 2,3-diphosphoglycerate characteristic of SCA [10,15]. In keeping with this, the oxygen dissociation curve of 32 clinically well HbSS patient, 12 HbSC patient and 10 normal control was compared at 70 mmHg, 80 mmHg and 90 mmHg of PO_2. Despite having similar mean level of 2,3 DPG content, the oxygen dissociation curve of HbSS patient was more right shifted and significantly different when compared with those of the HbSC group (p=0.001). The authors inferred that HbS must have an effect on haemoglobin- oxygen affinity that is different from the effect of 2,3 DPG only. The HbSS patients had significantly lower mean resting oxygen saturation, than did patients with HbSC or the controls [5]. An earlier study had shown that oxygen affinity of HbSS blood is related to the intra cellular content of HbS and not 2,3 DPG [14]. All the subjects used for the index study were HbSS and may explain the low level of SpO_2 even during steady state. However, hypoxemia is not a universal finding in patients with SCA and this raises some pertinent questions on the significance of hypoxemia in patients with steady state SCA and the best way to manage them, since treatment of apparent hypoxemia based on pulse oximetry in asymptomatic patients carries the deleterious consequences of suppressing erythropoiesis [16].

Pulse oximeter is often use as a surrogate for arterial measurement of oxygen saturation. In patients with normal oxygen dissociation curve, this reading is fairly accurate based on the assumption of a normal P50 of 26.5 mmHg [17]. There have been conflicting reports on the reliability of pulse oximeter in detecting hypoxemia in patients with SCA [8,14,18]. Pulse oximeter measures oxy-hemoglobin as percentage of functional hemoglobin (oxy-hemoglobin and deoxy-hemoglobin), whereas blood gas analysis for oxygen saturation measures it as a percentage of total hemoglobin including carboxy-hemoglobin and met-hemoglobin [14]. In patients with SCA patient undergoing hemolysis, the blood gas measurement may therefore underestimate oxy-hemoglobin. Ratkoff et al. showed a wide variability in the oxygen dissociation curve of individuals with SCA and as a result, the SpO_2 may be normal for a given partial pressure of oxygen [10]. In addition, the correlation between SpO_2 measured by pulse oximetry and value obtained by calculation from blood gas co-oximetry has been shown to be excellent from these studies [10,14]. In low and middle income countries where the burden of SCA is very high, arterial blood gas testing is very scarce, hence, pulse oximetry is often relied upon to monitor oxygen saturation [11,19,20].

Conclusion

Chronic hypoxemia increases the risk of vasculopathy, pulmonary hypertension and cor pulmonale, a life-threatening complication in young adults with SCA [3,4,16]. Hemolysis has also been implicated in the pathogenesis of PH [16]. The levels of hemoglobin and reticulocytes, both potent markers of hemolysis, had been shown to be associated with hypoxemia in patients with HbSS [13,20]. Hypoxemia is associated with increased risk of central nervous system (CNS) events in patients with SCA [21,22]. This finding formed the premise on which screening and appropriate management of nocturnal hypoxemia was suggested as a safe and effective alternative to prophylactic blood transfusion for primary prevention of CNS events in patients with SCA [5]. Similarly, another study revealed that the odds of having stroke was 1.32 for each 1% decrease in SpO_2, with a further drop in the SpO_2 value during an impending stroke [8]. However, even with a normal daytime SpO_2, hypoxemia remains a concern in patients with SCA, as it does not exclude nocturnal hypoxia which has been associated with neurological complications [7]. This makes the detection of hypoxemia an important aspect of the management of patients with SCA.

Future Considerations

The prevalence of hypoxemia in steady state HbSS patients is high. This finding underscores the importance of monitoring HbSS patients for prompt detection of hypoxemia, and to institute therapy where necessary. However, despite the association of low oxygen saturation with CNS event and other serious complications, there is still no agreed treatment modality. Previous reports have shown a strong positive correlation between high HbF and increased SpO_2 [23,24]. Pashankar et al. reported on the improvement of oxygen saturation following treatment with hydroxyurea (HU). Hydroxyurea increases HbF level (which has a higher affinity for oxygen than HbS or HbA), and shifts the oxygen dissociation curve to the left which is associated with a high oxygen saturation. There results showed that after a 6 month of treatment, HU significantly increased oxygen saturation from a baseline of 95.15% to 98.4%, with the response sustained at 12 months post-treatment. This finding could pave way for the use of HU in SCA patients with hypoxemia; however, larger academic studies are needed to replicate this report.

Recommendations

In our study, HbSS patients had a suboptimal mean steady state SpO_2 of 95.7%, with the lowest SpO_2 of 88% despite having no evidence of respiratory distress. This underscores the importance of measuring SpO_2 during routine evaluation of SCA, as this will provide baseline data against which comparison can be made during acute illnesses, especially when acute chest syndrome is suspected. Baseline SpO_2 data may also be useful in prognostication, as well as inform the basis for further evaluation of asymptomatic pulmonary dysfunction e.g. pulmonary hypertension.

Conflict of Interest

None.

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