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# Assessment of Right Ventricular Function in Children with Sickle Cell Anaemia Seen in Enugu, Nigeria.

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# Abstract

Background: Sickle cell anaemia (SCA) is characterized by attendant ischemia-reperfusion injury especially to the heart. Objectives: To compare the right ventricular function of children with SCA in steady state (subjects) with those with haemoglobin AA genotype (controls), using echocardiography.

Methods: The cross-sectional study utilized echocardiographic measurements to assess right ventricular function among children with SCA and their controls.

Results: The mean trans annular plane systolic excursion (TAPSE) in subjects, 28.24±5.23 (Z score: 0.258±1.10) was higher than that in control, 25.82±3.59 (Z score: - 0.263±0.80), and the difference in mean was statistically significant, (t=2.703, p=0.008). Significantly higher proportion of subjects with sickle cell anaemia had right ventricular dysfunction (Abnormal TAPSE), 25 (50.0% when compared with those in control, 11 (22.0%, ($\chi$ 2 =8.5, p=0.0035). A higher proportion of subjects with sickle cell anaemia (25.5%) had Pulmonary hypertension (RVP) when compared with control (2.0%) and the difference in proportions was found to be statistically significant, ($\chi$ 2 =11.668, p=0.001). The prevalence of right ventricular diastolic dysfunction in subjects was 9.8 % while control was 0%.

Conclusion Children with sickle cell anaemia present with right ventricular dysfunction. Prevalence of right ventricular systolic and diastolic dysfunction were higher in subjects. More children with genotype SS group, (25.5%) had pulmonary hypertension (RVP). Key words: Anaemia; children; Enugu; sickle cell anaemia; right ventricular function


# Background

Sickle cell anaemia is a hematologic and genetic disease characterized by recurrent episodes of ischemia-reperfusion injury to multiple vital organ systems. [1] Volume overload is not the only cause of cardiac abnormalities in SCA. Other potential issues are ischemia-reperfusion injury and iron overload toxicity in chronically transfused patients. [1, 2] It is important to note that the underlying haemolytic anaemia in children with sickle cell anaemia increases cell-free plasma haemoglobin which depletes nitric oxide and causes vasoconstriction, leading to pulmonary hypertension.1,2] Right ventricular (both systolic and diastolic) dysfunction and pulmonary hypertension have been reported to start from the age of 3 years. [2] They are due to progressive increase in pulmonary vascular resistance. This dysfunction continues till adulthood but through a different mechanism. [2]

For instance, the cause of right ventricular dysfunction in children stems mainly from progressive increase in pulmonary resistance alone, whereas in adults; it is usually from high steady-state serum lactate dehydrogenase (LDH) levels, largely reflecting intravascular haemolysis, renal insufficiency, cholestatic hepatic dysfunction and iron overload. [3]

Trans annular plane systolic excursion (TAPSE) has been noted as a validated marker for right ventricular systolic dysfunction and has been seen as an easily measurable parameter in evaluating right ventricular

systolic function. [4]

Elevated tricuspid regurgitation gradient (TRV), TAPSE and Tricuspid inflow (e/a) velocity which are surrogate markers for pulmonary hypertension(PHT) are very relevant indices of right ventricular dysfunction which occurs in children with sickle cell anaemia and is associated with low hemoglobin and elevated reticulocyte count. [5]

Accurate assessment of right ventricular function of children with sickle cell anaemia in steady state by echocardiography helps in early detection of cardiac diseases, enhances risk stratification, and allows timely initiation of appropriate therapy. [6]

An assessment of right ventricular function among children with sickle cell anaemia is known to have some predictive values for deteriorating clinical outcome. [7] For instance, increases in right ventricular diastolic and systolic dysfunction have been reported to correlate with frequency of acute chest syndromes. [7]

Assessment of ventricular function in children with sickle cell anaemia in steady state using echocardiography can assist in early detection of right ventricular dysfunction and pulmonary hypertension. [7] Treatments such as use of drugs that enhance right ventricular function could potentially reverse the disease process as well as prevent the increased morbidity and mortality associated with them. [7]

Assessment of right ventricular function in children with sickle cell anaemia are very uncommon in Nigeria as only three studies were undertaken on this. So more studies are needed to breach this knowledge gap.

The use of TAPSE and Tricuspid inflow (e/a) velocity in assessing right ventricular function is not commonly used in this setting, this also creates a yearning gap in determining the actual ventricular function in children with SCA as the traditional use of tricuspid regurgitation has lots of flaws and false positives.

Apart from assessing right ventricular function (Systolic and diastolic), this study went further to ascertain the prevalence of right ventricular dysfunction (Systolic and diastolic) which is not usually documented in many studies among children in Nigeria.

The use of TAPSE and tricuspid inflow (e/a) velocity (TIV) have better predicting effects on right ventricular systolic and diastolic dysfunction respectively when compared with other methods such as M mode and myocardial contractility. [8] Published works on cardiac changes in SCA are also limited in Africa. [9] This work could also form a template for future studies.

Detecting those with right ventricular dysfunction and pulmonary hypertension would aid in early intervention. This intervention includes starting on drugs that modulate and enhance right ventricular systolic and diastolic function and as such, improve quality of life of these children.

### Research Questions

- How do right ventricular function and pulmonary function as determined by TAPSE and Tricuspid inflow (e/a) velocities of children with sickle cell anemia (SCA) compare with those with haemoglobin AA genotype in Enugu?
- Null Hypotheses (H0): There is no difference between the right ventricular function of children with sickle cell anaemia compared to those obtained in children with haemoglobin AA genotype.
- Null Hypotheses(H0): There are no differences in the right ventricular function and pulmonary hypertension in children with sickle cell anemia as determined by TAPSE and TIV as against tricuspid regurgitation velocity (TRV)
- Alternative hypothesis (H1): There is a difference in right ventricular function in children with sickle cell anaemia compared to observations in those with Haemoglobin AA genotype
- Alternative hypothesis (H1): There are differences in the right ventricular function and pulmonary hypertension in children with sickle cell anemia as determined by TAPSE and TIV as against tricuspid regurgitation velocity (TRV)

The aim of this work is to assess the right ventricular function in children with sickle cell anaemia and those with haemoglobin AA in Enugu using echocardiography while the objectives are:

1. To determine the mean Trans annular plane systolic excursion (TAPSE) in millimeter, in children with sickle cell anemia in steady state compared with age and sex matched controls with haemoglobin AA genotype in Enugu,
2. To determine the mean Tricuspid inflow(e/a) velocity in millimeter, in children with sickle cell anemia compared with that obtained in age and sex matched controls with haemoglobin AA genotype,
3. To determine the relationship between age, gender and mean Trans annular plane systolic excursion / mean Tricuspid inflow(e/a) velocity among children with sickle cell anaemia compared to observations in age and sex matched control with haemoglobin AA genotype,
4. To determine the proportion of subjects and controls that have right ventricular systolic dysfunction using TAPSE,
5. To determine the proportion of subjects and controls that have abnormal right ventricular diastolic function using TVE/A,
6. To determine the prevalence of pulmonary hypertension in children with sickle cell anaemia and compare it with the value obtained in age and gender matched controls with normal haemoglobin AA genotype,
7. To compare which methods, TAPSE and TVE/A versus TRV that best assess right ventricular function.

# Materials And Methods

### Study design

This was a cross-sectional study that assessed the right ventricular function among children with sickle cell anaemia in Enugu. Children with sickle cell anaemia who attended the sickle cell clinic and fulfilled the inclusion criteria were consecutively recruited into the study. For the control group, the same method was used to recruit apparently healthy children (with HbAA genotype confirmed by haemoglobin electrophoresis) coming for follow up at the children out patient department and the consultant's clinic.

Subjects and controls were recruited concomitantly bearing in mind the age and gender (by documentation in a chart) of each subject that had echocardiogram and getting exactly the same patient with the same age and gender, this was done consecutively until a sample size was achieved.

The questionnaire consists of demographic variables, echocardiographic measurements of cardiac structures and functions especially right ventricular function.

## Settings

This study was carried out in two tertiary hospitals, the University of Nigeria Teaching Hospital (UNTH), Ituku-Ozalla, Enugu, Nigeria. The University of Nigeria Teaching Hospital has a total bed space of 480 and provides specialized services in management of children with sickle cell anaemia and the hospital also serves as a referral centre for children with cardiac diseases.

University of Nigeria Teaching Hospital (UNTH) Ituku-Ozalla has the state of the art facility for management of all cases of cardiac diseases and performs open heart surgery in children. Enugu is in the south east geographic zone of Nigeria.

## Participants

These were children aged 3 years to 17 years,11 months who attended the sickle cell clinics of the study hospitals. The control population were children who were apparently healthy with haemoglobin genotype (HbAA) (matched for age and gender) and who came for follow up for common illnesses like malaria either in consultant clinic or children outpatient clinic.

The lower age limit of 3 years was chosen because the onset of right ventricular dysfunction in children with sickle cell anaemia starts from the age of 3 years and this stems from endothelial damage of pulmonary vascular walls and intimal proliferation which starts at this period as possible causes. [3]

## Consent

A written consent was obtained from each parent/ caregiver of the subjects and controls after explaining to them, in detail, the objectives of the study as well as the echo procedure.

## Child Assent

Assent was obtained from children older than seven years.

### Inclusion criteria for subjects

1. Children with sickle cell anaemia in steady state aged 3 years to 17 years, 11 months

### Exclusion criteria for subjects

1. Children with sickle cell anaemia who have congenital or acquired cardiac anomalies
2. Subjects who currently have sickle cell crisses
3. Subjects whose parents refused to give consent or children who refused assent to participating in the study.

### Inclusion criteria for controls

Controls aged 3 years to 17 years, 11 months with Genotype AA who came for follow up at the children out patient or consultant clinic matched for age and sex.

### Exclusion criteria for controls

1. Children with congenital or acquired cardiac anomalies.
2. Controls whose parents refused to give consent or children who refused assent to participating in the study.

The study had a quality control where another cardiologist got his findings at certain intervals so as to reduce bias.

**Study Duration:** The study was done over a three-month period (April 2019 to July 2019).

**Study tool:** The examinations were performed using the Hewlett-Packard (HP) model SONO 2000 Ultrasound Imaging System. The machine has a transducer with multi-frequency in the range 5.5-12MHz for children, and this was used for the study. For each examination, the child was laid supine or on the left lateral decubitus position. The younger subject who were not cooperative in the presence of their caregiver was pacified with toys or sedated with a mild short acting sedative (syrup Chlopheniramine 2.5mls for younger than I2 months and 5Mls between 1 and 4 years) as appropriate. For each patient, intra-cardiac anatomy was studied using the standard 2D echocardiographic views, right ventricular function was studied using TAPSE and tricuspid in flow velocities. All values obtained were converted to Z scores.

### Sample Size Estimation

The minimum sample size used in this study was calculated using the formula. [10]

$$n = \frac{(Z_{\alpha} + Z_{1-\beta})^2 (p_1 (1- p_1) + p_2 (1- p_2))}{(p_1- p_2)^2}$$

Minimum sample size = 37

To obtain an appropriate sample size for 400 children on regular follow-up at UNTH Paediatric Sickle Cell Clinic, the formula for determining sample size in finite population was used.

$n = n_0 / 1 + (n_0 -1) / N$, n = 35

A 20% attrition rate was incorporated into the study, but rounded off to 50. (For subjects and control)

### Data Analysis

Trans annular plane systolic excursion (TAPSE) and Tricuspid inflow (e/a) velocity was analyzed using Mean (SD) if normally distributed or Median (Interquartile Range) if skewed. Mean TAPSE was compared using Student T test. Mean Trans Tricuspid inflow (e/a) velocity was compared using Student T test.

The relationship between age and with mean Trans annular plane systolic excursion and mean Tricuspid inflow (e/a) velocity was ascertained using Pearson correlation variable. Proportion of children with abnormal right ventricular function was compared using Chi-square test and the proportion of subjects and controls who presented with pulmonary hypertension was ascertained using prevalence rate. Normal value of TAPSE was taken as 0.9-30mm while normal value for TVE/A was taken as 0.8-2.1. Level of significance was taken as $p < 0.05$

# Results

### Demographic characteristics of subjects and controls

The mean age of respondents in Genotype SS group was 9.73±4.09 while for controls, it was 8.88±4.00 (t=1.05, p=0.3). The mean age was 9.75±3.98 years for males and 9.83±4.60 for females (t= -0.62, p= 0.95) in the subjects. Among the controls the mean ages for males and females were 8.81±3.91 and 8.96±4.18 years respectively (t= -0.13, p=0.89). The Male: Female ratio was 1:1 (Table 1).

### Mean TAPSE, right ventricular pressure and tricuspid in flow velocities of subjects and controls

The mean TAPSE in subjects, 28.24±5.23 (Zscore: 0.258±1.10) was higher than that in control, 25.82±3.59 (Zscore: - 0.263±0.80), and the difference in mean was statistically significant, (t=2.703, p=0.008). The mean right ventricular pressure (RVP, an index of Pulmonary pressure) in subjects, 21.61±9.49 (Zscore: 0.49±1.2) was higher than that in control, 13.89±2.10 (Zscore: -0.49±0.3) and the difference in mean was statistically significant, (Student t=5.613, <0.001).

The mean tricuspid inflow velocities (TVE/A) of subjects, 1.88±1.43 (Zscore: 1.87±1.4) was higher than that in control, 1.70±0.21 (1.69±0.2) but the difference in mean was not found to be statistically significant, (Student t=0.904, p=0.34), Table 2.

### Prevalence of right ventricular dysfunction using TAPSE

Significantly higher proportion of respondents in subjects had abnormal TAPSE, 25 (50.0% when compared with those in control, 11 (22.0%), ($\chi^2$=8.5, p=0.0035). Among the subjects, 25 (50%) had values within the normal range, 3 (6%) had values above +2SD and 7 (14%) had values above +1SD, 28% had values -1SD and 2%, -2SD below the mean (Table 3).

### Correlation between TAPSE, TVE/A and TRV in subjects and controls

There was a positive correlation between TAPSE and TVE/A, increases in TVE/A were correlated with increases in TAPSE but this was not found to be statistically significant in both groups, (n=50, r=0.14, p=0.33) and (n=50, r=0.17, p=0.23) respectively. There was a significant positive correlation between TAPSE versus TRV in subjects (n=50, r=0.34, p=0.02). In controls, the correlation was positive although not statistically significant (n=50, t= 0.12, p= 0.91).

### Prevalence of pulmonary hypertension

A significantly higher proportion of subjects (25.5%) had Pulmonary hypertension (RVP) when compared with control (2.0%) and the difference in proportions was found to be statistically significant, ($\chi^2$=11.668, p=0.001). The prevalence of right ventricular diastolic dysfunction in subjects was 9.8 % while control was 0%.

### Indices of RV function in subjects based on gender

With respect to gender, 14.3% of male subjects had pulmonary hypertension (RVP), compared to 4.3% females ($\chi^2$=1.410, p=0.235).

For subjects, the mean TAPSE for males was 28.12±5.84 (Zscore: TPSE; 0.23±1.26) and this was lower than that for females, 28.37±4.51 (Zscore: 0.29±0.97) but the difference in mean was not found to be statistically significant, (t= -0.170, p=0.866). The mean TVR for males, 17.87±8.32 (Zscore: -0.21±0.92) was higher than that for females, 16.79±2.98 (Zscore: -0.27±0.74) but the difference in mean was found not to be statistically significant, (t=0.27, p=0.79). The mean TVE/A for males, 2.06±1.93 (Zscore: 0.26±1.89) was higher than that for females, 1.67±0.22 (Zscore: -0.11±0.22) but the difference in mean was found not to be statistically significant, (t=0.94, p=0.35). **Table 4.**

### Indices of RV function in controls based on gender

For Control, the mean TAPSE for males, 25.99±3.71 (Zscore: -0.23±0.80) was higher than that of females, 25.64±3.52 (Zscore: -0.30±0.76) but the difference in mean was not found to be statistically significant,

(t=0.34, p=0.74). The mean TVR for males, 14.54±1.83 (Zscore: 0.29±1.11) was comparable to that of females, 13.77±1.25 (Zscore: 0.18±1.10), (t=0.38, p=0.71). The mean TVE/A for males, 1.66±0.25 (Zscore: -0.12±0.24) was lower than that of females, 1.73±0.16 (-0.05±0.16) but the difference in mean was not found to be statistically significant, (t = -1.11, p=0.26). **Table 5**

### Correlation of age with Indices of RV function of TAPSE and TVE/A in Subjects and controls

There was a strong positive correlation between age in years and TAPSE in both subjects and controls, increases in age were correlated with increases in TAPSE and this was found to be statistically significant (n=50, r=0.52, p<0.001) and (n=50, r= 0.62, p<0.001) respectively. There was no correlation between age in years and TVE/A in subjects and controls (n=50, r=0.05, p= 0.75) and (n=50, r= 0.06, p=0.66) respectively.

# Discussion

We noted a significant difference in Right ventricular systolic function among children with sickle cell anaemia when compared with their counterpart with haemoglobin AA genotype, although all values remain within normal reference range. On further analysis, 50% of subjects have right ventricular systolic dysfunction (Using TAPSE) compared to 22% noted in control. These results are similar to other reports which also demonstrated right ventricular systolic dysfunction in spite of cardiac dilatation among children with Haemoglobin SS [4–9]. The high prevalence of right ventricular systolic dysfunction seen in this study was lower than that obtained by Simbo et al who had a prevalence of 39% [10]. The reason for the lower prevalence was that the authors used a very large sample size; again their study was a retrospective review of previous echocardiogram done among children with sickle cell anaemia.

It is important to note from this study, that though the tricuspid regurgitation gradient which is a surrogate of RV systolic function and pulmonary hypertension were higher in children with sickle cell anaemia compared to those with haemoglobin AA genotype, yet all values fell within normal reference range. These findings may show that children with sickle cell anaemia have a greater tendency of having pulmonary hypertension. When the subjects were analysed in isolation, we noted that the prevalence of pulmonary hypertension(PHT) using Tricuspid regurgitation (TR) velocity gradient of more than 2.5 m/s and Right ventricular pressure (RVP) of more than 25 mmHg, among children with sickle cell anaemia and their counterpart with haemoglobin AA genotype was 25.5 and 2% respectively. The 25.5% prevalence obtained in our study is similar to 22.3% obtained by Sokumbi et al [11]. Our findings however are similar to that obtained in a study in Northern Nigeria, where a prevalence of 25% was obtained. [12]

There is paucity of studies on the prevalence of PHT among children with sickle cell anaemia especially in developing countries and thus its significance in this age group is not well established. [9] Whereas there are studies on children from western countries which revealed prevalence ranging from 20 to 33% [13, 14] extrapolating these findings to the paediatric population in African countries may be misleading.

In children with sickle cell anaemia, estimated pulmonary systolic pressure correlates well with measurements obtained by cardiac catheterization. [9] A value of 2.5 m /s or more corresponds to an estimated pulmonary artery systolic pressure of 35 mm Hg. [9] While some authors have defined PHT as TRV of 3.0 m/s or more, values of at least 2.5 m /s have been associated with an increased risk of death among children with sickle cell anaemia. [9] The prevalence of pulmonary hypertension seen in this study is higher than that obtained by Adedoyin et al [9] who obtained a prevalence rate of 3.6% among children with sickle cell anaemia compared to none in controls. The lower prevalence obtained by Adedoyin could be because the sample frame was from younger ages and the cases were a selection of patients who were assumed to be better motivated for regular treatment in a tertiary hospital and in a commercial centre of the country.

Qurechi et al [3], in his study among children, using TR gradients > 2.5 m/sec, consistent with pulmonary hypertension, noted a prevalence rate of 16% among children with sickle cell anaemia. Qureshi's finding is different from ours in that they studied children older than 9 years whereas our study involved children in the age bracket 3–17 years. [3]

It is important to note that this increase of Tricuspid velocity (a surrogate of pulmonary hypertension) and TAPSE could be caused by increased TRV with severe haemolysis, elevated right ventricular filling pressure, renal dysfunction, and high circulating erythropoietin concentrations especially among children with sickle cell anaemia.[15] It is also suggested that children with sickle cell anaemia have greater tendency of having RV dysfunction because they have higher circulating erythropoietin concentrations. [16]. This could also be a marker of the potential contributions of increased erythropoiesis to increased pulmonary artery pressure. [17]

In summary, therefore, the prevalence of pulmonary hypertension varies between studies and the frequency rises with age; however, the peak age of occurrence of PHT varies from one socioeconomic region to another. The variation in prevalence could also be a reflection of the different phenotypic expression of haemoglobin SS which presents with various degrees of organ damage and survival.

Pulmonary hypertension is a life-threatening complication among children with sickle cell anaemia and may be clinically silent until late in the course of the disease. [18] It has been linked to accelerated mortality as mortality may be as high as 40% [19] or 10-fold higher compared with those with normal TRV (Surrogate of pulmonary hypertension). [19] This study showed that TAPSE is a better predictor of right ventricular systolic dysfunction when compared with TRV where results showed proportion of right ventricular dysfunction as 50% and 25.5% respectively. [19]

Right ventricular diastolic dysfunction is a mechanical abnormality that is caused by breakdown in the passive compliance and active myocardial relaxation; an intrinsic properties of the ventricle during diastole. [20] Diastolic dysfunction in children with sickle cell anaemia could be due to a pathological state that adversely affect the passive compliance during diastole, such as increases in myocardial wall thickness observed in concentric hypertrophy cardiomyopathy as a result of longstanding ischemia or hypoxaemia. [21]

From our study, we noted no difference in right ventricular diastolic function between subjects and controls. Though children with sickle cell anaemia had higher values when compared to those with haemoglobin AA genotype, all values obtained were within normal range. These higher values of RV E/A in children with sickle cell anaemia may perhaps denote that these children have a higher tendency of presenting with abnormal right ventricular diastolic function when compared with their normal counterparts.

Children with sickle cell anaemia, as a result of hypoxaemia and ischaemia or acute chest syndrome always have their right ventricles susceptible to impaired relaxation and even contraction especially in diastole. [21]

These findings in this study are in tandem with those of Barboasa and colleague [21] who noted in their study that though diastolic function (as evidenced by the fact that E and A waves, as well as E/e' ratio,) were higher in patients with SCA than controls, the values were nonetheless within normal ranges. [21]

When we looked at the overall prevalence rate of right diastolic dysfunction for both subjects and controls, we noted that children with sickle cell anaemia had a prevalence rate of 9.8% compared with their normal counterparts who had 0% prevalence. One study has also implicated a high prevalence of diastolic dysfunction of 45% among subjects with SCA. [22]

Regrettably, the author used Pulse wave diameter (PWD) and tissue Doppler index (TDI) to assess RV dysfunction. This indeed explains the differences between outcome of our study and theirs. RVE/A is superior to TDI indices because it is reproducible, easy to read and not prone to bias.

It is noteworthy to point out that diastolic dysfunction and pulmonary hypertension contribute independently to mortality in children with sickle cell anaemia. Children with both risk factors have extremely poor prognosis. These data support the implementation of echocardiographic screening of children with sickle cell anaemia in the attempts to identify high-risk individuals for further evaluation. [4–16]

We noted significant increases in TAPSE and TVE/A with increasing age in both subjects and controls showing that both functions worsens as age progresses. It is important to note that in children with sickle cell anaemia, aging is associated with increased levels of haemolysis, increased intimal proliferation, narrowing of pulmonary vessels and eventual increase of wedge pressure with attendant increase in pulmonary vascular resistance. These could then lead to alterations in right ventricular pressure.

However, we noted no significant association between age and pulmonary hypertension. Shokubi et al [11] also noted no association of age/gender and indices of right ventricular dysfunction in their study. These findings were also in keeping with outcome of other studies conducted in the United States of America. [11]

# Conclusions

The mean TAPSE of children with sickle cell anaemia was significantly higher than that obtained in children with haemoglobin AA genotype. The mean tricuspid inflow velocities (TVE/A) of children with sickle cell anaemia was higher than that gotten in children with haemoglobin AA genotype. The prevalence of right ventricular dysfunction among children with sickle cell anaemia is 50% compared with 22% obtained in control. These increase in right ventricular systolic and diastolic functions in children with sickle cell anaemia showed that these children have more tendency of right ventricular systolic and diastolic dysfunction. The prevalence of pulmonary hypertension is higher in children with sickle cell anaemia compared to children with haemoglobin AA genotype. Increase in indices of right ventricular function was influenced by age but independent of gender. TAPSE is a better predictor of right ventricular dysfunction than tricuspid regurgitation velocity.

### Recommendations

Children with sickle cell anemia in steady state have high tendency of developing right ventricular dysfunction when compared with their counterparts with hemoglobin AA genotype. It is therefore recommended that: Indices of right ventricular function should be assessed routinely among children with sickle cell anaemia. Indices of right ventricular function among children with normal haemoglobin genotype may be used as normative values especially in this locale.

### Strength Of The Study

The study is a cross sectional comparative study and prospective in nature. Again this is the first time this type of work is done in Enugu city. It may therefore provide baseline values that could be useful in subsequent studies. The instrument (echocardiography) used was validated.

### Limitations

This is hospital based study and thus generalization to the community may be difficult.

## List Of Abbreviations

TAPSE: Trans annular plane systolic excursion

RVP: Right Ventricular Pressure

TVE/A: Tricuspid valve inflow velocities

ACS: Acute chest syndrome

TRV: Tricuspid Velocity

RV: Right Ventricle

TDE: Tissue Doppler echocardiography

HBAA: Haemoglobin AA genotype

ESUTH: Enugu State University Teaching Hospital

MHZ: Megahertz

PHT: Pulmonary Hypertension

PWD: Pulse Wave diameter

TDI: Tissue Doppler Imaging

# Declarations

**Ethics approval and consent to participate:** This complies with national guidelines. [23] All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standard. Fortis hospital gave permission to use the data. Ethical approval was obtained from the ethic and research committee of the University of Nigeria Teaching hospital Enugu with IRB number of 00002323.

Informed written consent was also granted by the parents/caregivers of subjects, before they were operated upon.

**Consent for publication:**

Not applicable

**Availability of data and materials:** The data will not be shared in order to protect the participants' anonymity.

**Competing Interest:** The authors declare that they have no competing interests.

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**Author contributions:**
JMC conceived and designed this study while ANI, EOO helped in critical revision of the article. JMC, BFC and ENO also did the Data analysis/interpretation. AAE, ATC, read the article. All authors have read and approved the manuscript.

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## Tables

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