



GDF -15 and Severity Scores in Sickle Cell Disease Patients Attending Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, Nigeria

Chide Okocha^{1*}, Patrick Manafa², Joy Anowi², Vera Manafa³ and Chilota Efobi¹

¹Department of Haematology, College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria.

²Department of Medical Laboratory Science, College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria.

³Department of Chemical Pathology, Nnamdi Azikiwe University Teaching Hospital, P.M.B. 5025, Nnewi, Anambra State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Authors PM and CO designed the study and wrote the protocol. Author JA performed the experiments and statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Authors VM and CE reviewed the manuscript for critical content. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMMR/2020/v32i130347

Editor(s):

(1) Dr. Antonio Vaz de Macedo, Head of the Haematology Clinic, Hospital da Policia Militar (Military Hospital), Belo Horizonte, Minas Gerais, Brazil.

Reviewers:

(1) N. I. Ugwu, Ebonyi State University, Nigeria.

(2) Muhammad Muizz Uddin, Dow University of Health Sciences, Pakistan.
Complete Peer review History: <http://www.sdiarticle4.com/review-history/54250>

Original Research Article

Received 24 November 2019

Accepted 28 January 2020

Published 07 February 2020

ABSTRACT

Aim: Granulocyte differentiation factor 15 (GDF15) is a growth factor and biomarker for many disorders where Ischaemia Reperfusion Injury (IRI) is pathophysiologically relevant. Hence the need to evaluate GDF-15 as a biomarker in Sickle Cell Disease (SCD).

Study Design: This is a cross sectional study.

Place and Duration of Study: Department of Haematology, Nnamdi University Teaching Hospital, Nnewi, Anambra state, Nigeria, between January and December 2018.

Methods: Ninety subjects were randomly recruited with haemoglobin (Hb) phenotypes SS (test), AS and AA (controls); numbering 30, 28 and 32 respectively. Disease severity was

determined by calculating an objective score. 5 mls of blood was collected and used to determine Full Blood Count (FBC), haemoglobin Phenotype and GDF-15 levels (by Enzyme Linked Immunosorbent assay). Data collected was analysed using Statistical Package for Social Sciences software version 20 (SPSS Inc., IL, Chicago, USA). $P < 0.05$ was considered as significant.

Results: GDF-15 level was found to be significantly different in the different HB phenotypes $p = 0.005$ and correlated negatively with sickle cell disease severity ($r = -0.307$, $p = 0.098$). The difference between median GDF-15 levels of HBSS subjects with mild and moderate disease was statistically significant at $p = 0.01$.

Conclusion: We hypothesize that GDF-15 may be a potential therapeutic target for intervention against ischaemia/reperfusion induced micro-vascular injury. Natural GDF-15 mimetics may be useful in taking advantage of this potential therapeutic target.

Keywords: GDF- 15; sickle cell disease; ischaemia reperfusion injury; GDF-15 mimetics.

1. INTRODUCTION

Haemoglobinopathies are the single most important genetic disorder in the world [1] In Nigeria alone 2-4% and 25-30% of the population suffer from Sickle Cell Disease (SCD), and carry the sickle cell gene respectively [2]. In sub-Saharan Africa, where there is a high burden of this disease, malaria, which maintains and drives this gene in the population due to balanced disequilibrium, is still endemic [3]. This seems to tip the equilibrium towards an increase in prevalence.

This disorder is caused by a mutation that causes glutamine to be replaced by valine in the 6th position of the beta haemoglobin chain, causing haemoglobin molecules to polymerize when they are deoxygenated. An extension of this pathophysiological process brings about the protean manifestations of SCD in every tissue and system of the body. Though SCD patients have exactly the same genetic mutation, they present with a wide range of phenotypes; the reason why this happens is not completely understood. Finding biomarkers that predict these phenotypes has become very important for individualized therapy [4,5,6] some of these biomarkers may also become useful as therapeutic tools.

Granulocyte differentiation factor 15 (GDF15) is a growth factor that is part of the bone Morphogenic protein (BMP) group of genes and is produced in the CNS and macrophages under physiological conditions and has been found to be an important biomarker for many disorders, including those where the pathophysiological process involves injury caused by ischaemia and reperfusion (IRI) [7,8] IRI is a very important event in the pathophysiology of SCD [9], hence it

becomes important to evaluate GDF15 as a biomarker in SCD patients.

1.1 Research in Context

The standard of care and available drugs to definitely treat sickle cell disease (SCD), does not include drugs that address ischaemia reperfusion injury (IRI), which is a very important part of the SCD pathophysiology.

Added value of this study: Our study demonstrates that GDF-15 may be a potential therapeutic target for intervention against IRI induced micro-vascular injury.

Implications of all the available evidence: It is potentially possible to use Polyphenols found in Cassava (*Manihot esculenta* Crantz) leaves which function similarly as therapy for SCD.

2. MATERIALS AND METHODS

A total of ninety subjects were randomly recruited from sickle cell disease clinics in Nnamdi Azikiwe university teaching hospital in Anambra State, Nigeria. Thirty were homozygous SCD (HbSS) patients in steady state. Steady state was defined as subjects who had been free from blood transfusion, crisis and fever for at least 3 months, one month and two weeks respectively [4]. Apparently normal individuals with haemoglobin phenotypes HbAS (28 subjects) and HbAA (32 subjects) made up the rest of the recruited subjects and served as controls. Phenotypic, anthropometric and demographic data such as age, sex, weight, height, occupation, average number of pain crisis per year and complications were obtained by questionnaire. Complications were such events like priapism, stroke, gall stones, ankle ulcers and nephropathy.

BMI was determined by anthropometric method as described by Odutola et al. [10] Height (m) was measured using a Stadiometer while body weight (kg) was taken using a body weight weighing scale with the subject wearing light clothing and without shoes. Body mass Index (BMI) was calculated as the ratio of weight (kg) to the square of height (m²).

2.1 Disease Severity in Hb SS Patients

Disease severity was determined by calculating an objective score based on scoring five parameters, pain crisis, anaemia, white cell count, SCD complications and blood transfusion. Scores of ≤ 3 , 3-7 and ≥ 7 were considered mild, moderate and severe disease respectively, as described by Okocha et al. [4]. Pain crisis was defined as pain that necessitated the administration of an oral or parenteral analgesic with or without visit to a chemist shop or medical facility.

2.2 Sample Collection and Laboratory Analysis

A total of 5 mls of blood was aseptically collected from each subject. 2 mls was dispensed into tubes containing Ethylene Diamine Tetraacetic Acid (EDTA) and used to determine Full Blood Count (FBC) and haemoglobin Phenotype. The rest of the sample was dispensed into plain tubes, allowed to clot, centrifuged for 5 minutes at 5000 rpm. Serum was collected and used to determine GDF-15 levels.

Haemoglobin phenotype was determined by Khon's method (1957) as described by Manafa et al. [11]. GDF-15 was determined by sandwich Enzyme Linked Immunosorbent assay (ELISA) using commercially available kits (Melsin Medical Co., Limited, Xiaonan Street, Kuancheng District, Changchun 130000, Jilin Province, China) while FBC was determined by the Sysmex method as described by Buttarello and Plebani (2008). Parameters determined included packed cell volume, haemoglobin concentration, white blood cell count and differentials.

2.3 Statistical Analysis

Data collected was analysed using Statistical Package for Social Sciences software version 20 (SPSS Inc., IL, Chicago, USA). Values obtained were subjected to statistical analysis using Analysis of variance (ANOVA), Kruskal-Wallis

and Student T-test. Person's correlation test was used to determine correlation between variables. $P < .05$ was considered as significant.

3. RESULTS

A total of 90 subjects, 48 males and 42 females, with haemoglobin (Hb) phenotypes SS (test), AS and AA (controls); numbering 30, 28 and 32 respectively were studied. Out of the 30 Hb SS individuals studied, disease severity was mild in 8 and moderate in 22. The mean ages in years of the different Hb phenotypes SS, AS and AA were 21.57, 22.53 and 23.77 respectively. These were not statistically different, $p = .44$. However, weight, height and body mass index (BMI) were statistically different across the different Hb phenotypes (Table 1).

Serum levels of GDF-15 was also significantly different across Hb phenotypes, although the difference between Hb phenotype AS and AA was not significant statistically, $p = .05$ and $.47$ respectively. Disease severity negatively correlated with GDF-15 with p value ($.098$) almost statistically significant (Table 3).

Figure 1 is a bar chart comparing the median serum levels of GDF-15 between Hb SS individuals who had mild and moderate disease severity. The difference was statistically significant at $p = .01$.

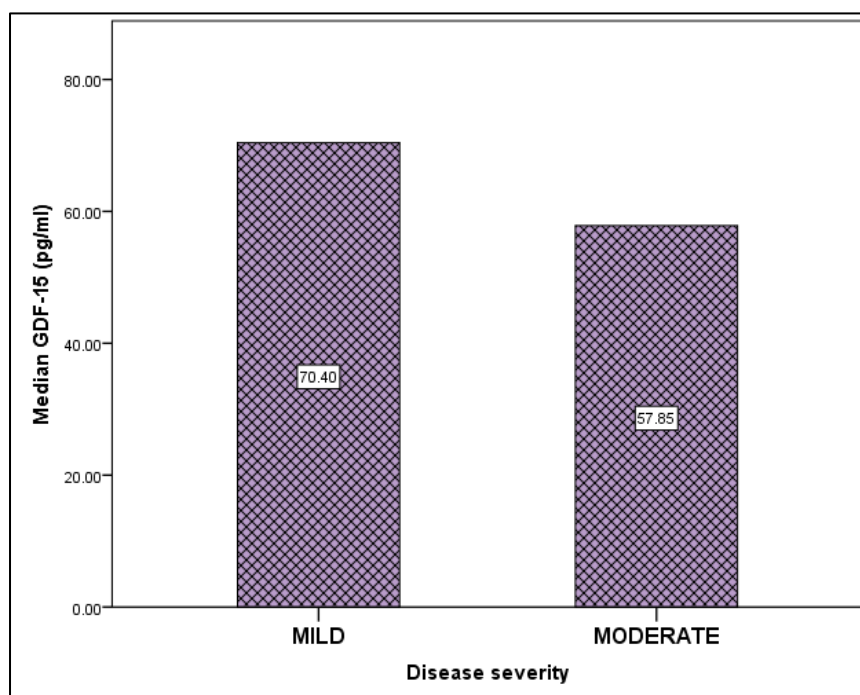
4. DISCUSSION

Sickle cell disease (SCD) is an inflammatory disease manifested by elevated leukocyte counts and increased levels of pro-inflammatory cytokines. Inflammatory response has been implicated as a key contributing factor to tissue injury in SCD. Growth differentiation Factor 15 (GDF-15) is an anti-inflammatory cytokine expressed in response to oxidative stress, inflammation and tissue injury. The authors evaluated the levels of GDF-15 in patients with homozygous sickle cell anaemia in steady state and found a significant difference in the median serum level of GDF-15 in the different haemoglobin (Hb) phenotype groups ($P < 0.05$). There was a significant increase in the median serum level of GDF-15 in patients with homozygous sickle cell disease (HbSS) compared with the control groups (HbAS & HbAA) ($P < 0.05$).

Table 1. Anthropometric data of different haemoglobin phenotype groups

Groups	Age (years)	Weight (kg)	Height (m)
SS phenotype (A)	21.57±10.90	44.53±17.30	1.54±0.21
AS phenotype (B)	22.53±1.98	65.80±9.58	1.70±0.09
AA phenotype (C)	23.77±2.70	68.33±8.94	1.74±0.09
f-value	0.841	32.624	15.495
p-value	.435	.001	.001
A vs B	.571	.001	.001
A vs C	.199	.001	.001
B vs C	.470	.436	.245

Key: vs= versus

**Fig. 1. Serum levels of GDF-15 in moderate and mild disease severity in patients with homozygous sickle cell disease (HbSS) in steady state. p=.010**

The increase in the levels of GDF-15 in patients with homozygous sickle cell disease in the steady state may be attributed to Ischaemia reperfusion (I/R) injury due to vasoocclusive events in homozygous sickle cell disease that triggers an inflammatory response leading to leukocyte mediated microvascular injury not only in the tissue exposed to the initial ischaemic insult, but in other tissues in remote organs. This phenomenon is called the multiorgan dysfunction syndrome (MODS) and is probable part of the reason why there is multiorgan failure in SCD [12,13]. Patients with homozygous sickle cell disease (HbSS) usually exhibit clinical symptoms and complications due to vasoocclusion² and this may represent a potential stimulus for the release of GDF-15 in

order to prevent the progression of inflammation; thus resolving the inflammatory response, promoting the return to homeostasis and inhibiting further tissue damage. The resolution process of the inflammation includes the limitation of neutrophil tissue infiltration, the counter-regulation of cytokines and chemokines, the induction of apoptosis in spent neutrophils and their efferocytosis by macrophages [14].

In our data set we found the range of serum GDF15 in apparently normal individuals to be 16 - 691 pg/ml; the level rises dramatically when disease develops. This quick up regulation of GDF-15 is aimed at preventing cells from further damage [15]. GDF-15 probably does this by inhibiting the inflammatory response that

predominantly involves neutrophil infiltration and trans-endothelial migration via blocking the activation of $\beta 2$ integrin affinity and clustering thereby preventing neutrophil adhesion to ICAM-1 [16]. This is a protective effect against warm I/R injury [17].

GDF-15 seems to be an adaptational response to periods of ischaemia in tissues which if blunted in the steady state, may lead to increased severity in disease; hence in our data set, SCD patients who had a reduced median serum level of GDF-15 had disease of moderate severity compared to those who had higher median serum levels and presented with mild disease $p = 0.01$ (Fig. 1). This blunting may be because of increased ischaemic damage in SCD which may impair organ functions, leading to decreased expression of anti-inflammatory cytokines. We hypothesize that GDF-15 may be a potential therapeutic target for intervention against ischaemia/reperfusion induced microvascular injury; since it modulates generation of reactive oxygen species (ROS) thus maintaining cellular homeostasis.

Polyphenols in fruits and vegetables that function similarly are gaining growing interest as therapy in ROS related diseases. Tsumbu et al, evaluated Cassava [*Manihot esculenta* Crantz (MEC)] leaves - consumed by more than 200 million inhabitants in sub-Saharan Africa as food and folk medicine- in this regard and concluded that the role of this plant in the prevention of oxidative stress in ROS related diseases is worthy of further consideration. They found that the aqueous extract of MEC leaves had significant antiradical and antioxidant activities which were not impaired by low heat treatment [18,19] Baheka and Khale also found that MEC leave extracts significantly increased the serum levels of antioxidant enzymes such as superoxide dismutase, reduced glutathione and catalase [20]. Some of these enzymes have been found to be low in SCD [5].

Table 2. Levels of GDF-15 in different haemoglobin phenotype groups

Groups	GDF-15 (pg/ml)
SS phenotype (A)	60.40
AS phenotype (B)	50.40
AA phenotype (C)	45.15
p-value	0.005
A vs B (p-value)	.038
A vs C (p-value)	.041
B vs C (p-value)	.469

Key: vs=versus

Table 3. Correlation studies of variables with disease severity in subjects with homozygous sickle cell disease (HbSS)

Parameters	N	R	p-value
Disease severity vs age	30	-0.164	.385
Disease severity vs BMI	30	-0.071	.710
Disease severity vs GDF-15	30	-0.307	.098
GDF-15 vs Age	30	-0.099	.602

Key: vs = versus

The finding of this present study supports the observation of Papassotiriou et al. [21] who found that GDF-15 levels were elevated in patients with HbS/ β -thal compared with the control group ($p < 0.001$) and that it was negatively correlated with Hcpidin-25/Ferritin molar ratio. They also found GDF-15 elevated in SCD patients who had been on hydroxyurea therapy. Tantawy et al. [22] also concluded that GDF-15 levels were increased in sickle cell disease patients whether sickle cell anaemia or sickle- β thalassaemia compared with controls ($p < 0.001$). They however did not find GDF-15 significantly related to some indices of SCD severity such as frequency of sickling crisis and pulmonary hypertension [22]. We note here that the tool with which we scored for SCD severity was objective and robust, since it was a composite of multiple indices. This may have accounted for the difference between our work and that of Tantawy et al. where the authors correlated GDF-15 levels with single indices of SCD severity. This work is limited by the fact that it was done in a single centre. The results should therefore be confirmed by a multicentre study with a higher number of subjects.

5. CONCLUSION

In conclusion, the authors have found serum levels of GDF-15, which is an anti-inflammatory cytokine, to be increased in SCD compared to controls and to correlate negatively with disease severity. It may be a potential therapeutic target for intervention against ischaemia/reperfusion induced microvascular injury. Natural GDF-15 mimetic substances such as polyphenols found in Cassava (*Manihot esculenta* Crantz) leaves can potentially be explored as therapy for SCD.

CONSENT AND ETHICAL APPROVAL

Ethical committee approval and patient's written consent were obtained from the ethics committee

of Nnamdi Azikiwe University Teaching Hospital (NAUTH) and the patient respectively.

ACKNOWLEDGEMENT

We acknowledge the contributions of our sickle cell disease patients, who, under very difficult conditions, have not given up.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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