Positive and negative acute phase reactants in sickle cell diseases

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Received: January 2021; Accepted: February 2022; Published: March 1, 2022.
Citation: Mehmet Rami Helvaci et al. Positive and negative acute phase reactants in sickle cell diseases. World Family Medicine. 2022; 20(3): 36-42. DOI:10.5742/MEWFM.2022.952509

Abstract

Background: We tried to understand some positive and negative acute phase reactants (APR) in sickle cell diseases (SCD).

Methods: Consecutive patients with the SCD and controls were studied.

Results: The study included 193 patients (98 females) and 132 controls (67 females). Although the body weight and body mass index (BMI) were retarded in the SCD (58.9 versus 71.1 kg and 21.5 versus 26.8 kg/m2, respectively, p<0.000 for both), the body heights were similar in both groups (164.8 versus 162.8 cm, p>0.05). Parallel to the retarded body weight and BMI, fasting plasma glucose (FPG) (93.4 versus 102.4 mg/dL, p=0.025), low density lipoproteins (LDL) (70.4 versus 98.1 mg/dL, p<0.000), high density lipoproteins (HDL) (24.2 versus 35.8 mg/dL, p<0.000), and systolic (117.6 versus 127.9 mmHg, p=0.001) and diastolic blood pressures (BP) (77.3 versus 86.0 mmHg, p<0.000) were all retarded in the SCD. On the other hand, total bilirubin (TB) and lactate dehydrogenase (LDH) were both increased (4.0 versus 0.7 mg/dL and 638.9 versus 268.4 U/L, respectively, p<0.000 for both) in the SCD. Similarly, white blood cell (WBC) and platelet (PLT) counts (16.338 versus 7.407 /µL and 421.424 versus 268.612 /µL, respectively) and mean corpuscular volume (MCV) (90.3 versus 78.3 fL) were all increased whereas the hematocrit (Hct) level was decreased (23.2 versus 36.6%) in the SCD (p<0.000 for all).

Conclusion: Body weight, BMI, FPG, LDL, HDL, systolic and diastolic BP, and Hct may be some negative whereas TB, LDH, WBC and PLT counts, and MCV may be some positive APR in the body.

Keywords: Sickle cell diseases, positive acute phase reactants, negative acute phase reactants, chronic endotelial damage, atherosclerosis, body weight, body mass index

Introduction

Chronic endothelial damage may be the major underlying cause of aging and death by causing end-organ insufficiencies in human beings (1-3). Much higher blood pressures (BP) of the afferent vasculature may be the major accelerating factor by causing recurrent injuries on vascular endothelial cells. Probably, whole afferent vasculature including capillaries are mainly involved in the process. Therefore the term of venosclerosis is not as famous as atherosclerosis in the medical literature. Due to the chronic endothelial damage, inflammation, edema, and fibrosis, vascular walls thicken, their lumens narrow, and they lose their elastic nature, \which eventually reduces blood supply to the terminal organs, and increases systolic and decreases diastolic BP further. Some of the well-known accelerating factors of the inflammatory process are physical inactivity, sedentary lifestyle, excess weight, animal-rich diet, smoking, alcohol, chronic inflammations, prolonged infections, and cancers for the development of terminal consequences including obesity, hypertension (HT), diabetes mellitus (DM), cirrhosis, peripheric artery disease (PAD), chronic obstructive pulmonary disease (COPD), coronary heart disease (CHD), chronic renal disease (CRD), mesenteric ischemia, osteoporosis, stroke, dementia, other end-organ insufficiencies, aging, and death (4-7). Although early withdrawal of the accelerating factors can delay terminal consequences, after development of HT, DM, cirrhosis, COPD, CRD, CHD, PAD, mesenteric ischemia, osteoporosis, stroke, dementia, other end-organ insufficiencies, and aging, endothelial changes cannot be reversed completely due to their fibrotic nature. The accelerating factors and terminal consequences are researched under the titles of metabolic syndrome, aging syndrome, or accelerated endothelial damage syndrome in the medical literature, extensively (8-10). On the other hand, sickle cell diseases (SCD) are chronic inflammatory processes on vascular endothelium terminating with accelerated atherosclerosis induced end-organ failures and a shortened survival in both genders (11, 12). Hemoglobin S causes loss of elastic and biconcave disc shaped structures of red blood cells (RBC). Probably loss of elasticity instead of shape is the major problem since sickling is rare in peripheric blood samples of the patients with associated thalassemia minors, and human survival is not affected in hereditary spherocytosis or elliptocytosis. Loss of elasticity is present during the whole lifespan, but exaggerated with inflammation, infection, and various stresses of the body. The hard RBC induced chronic endothelial damage, inflammation, and fibrosis terminate with disseminated tissue hypoxia in whole body (13, 14). As a difference from other causes of chronic endothelial damage, the SCD may keep vascular endothelium particularly at the capillary level (15), since the capillary system is the main distributor of the hard cells into the tissues. The hard RBC induced chronic endothelial damage builds up an advanced atherosclerosis in early decades of life. Vascular narrowing and occlusions induced tissue ischemia and infarctions are the final consequences of the SCD, so the mean life expectancy is decreased by 25 to 30 years in such patients (16). We tried to understand some positive and negative acute phase reactants (APR) in the SCD patients in the present study.

Material and Methods

The study was performed in the Medical Faculty of the Mustafa Kemal University on consecutive patients with the SCD and age and sex-matched control cases between March 2007 and June 2016. The SCD are diagnosed with the hemoglobin electrophoresis performed via high performance liquid chromatography. Medical histories of the SCD patients were learnt. A complete physical examination was performed by the Same Internist. Body mass index (BMI) of each case was calculated by the measurements of the Same Internist instead of verbal expressions. Weight in kilograms is divided by height in meters squared (9). Systolic and diastolic BP were checked after a 5-minute rest in seated position by using the mercury sphygmomanometer (ERKA, Germany), and no smoking was permitted during the previous 2-hours. Cases with acute painful crisis or any other inflammatory event were treated at first, and the laboratory tests and clinical measurements were performed on the silent phase. Check up procedures including routine hematological parameters, fasting plasma glucose (FPG), low density lipoproteins (LDL), high density lipoproteins (HDL), triglycerides (TG), total bilirubin (TB), and lactate dehydrogenase (LDH) were performed. Eventually, the mean body weight, height, BMI, FPG, LDL, HDL, TG, TB, LDH, systolic and diastolic BP, white blood cell (WBC) and platelet (PLT) counts, mean corpuscular volume (MCV), and hematocrit (Hct) level were detected in each group, and compared in between. Mann-Whitney U Test, Independent-Samples t Test, and comparison of proportions were used as the methods of statistical analyses.

Results

The study included 193 patients with the SCD (98 females and 95 males) and 132 control cases (67 females and 65 males). Although the mean body weight and BMI were retarded in the SCD patients, significantly (58.9 versus 71.1 kg and 21.5 versus 26.8 kg/m2, respectively, $p<0.000$ for both), the mean body heights were similar in both groups (164.8 versus 162.8 cm, $p>0.05$). Parallel to the retarded mean body weight and BMI, FPG (93.4 versus 102.4 mg/dL, $p=0.025$), LDL (70.4 versus 98.1 mg/dL, $p<0.000$), HDL (24.2 versus 35.8 mg/dL, $p<0.000$), and systolic (117.6 versus 127.9 mmHg, $p=0.001$) and diastolic BP (77.3 versus 86.0 mmHg, $p<0.000$) were all retarded in the SCD patients, significantly. On the other hand, mean TB and LDH values were both increased (4.0 versus 0.7 mg/dL and 638.9 versus 268.4 U/L, respectively, $p<0.000$ for both) in the SCD patients, significantly (Table 1). Similarly, the mean WBC and PLT counts (16.338 versus 7.407 /µL and 421.424 versus 268.612 /µL, respectively) and MCV (90.3 versus 78.3 fL) were all increased whereas the mean Hct level was decreased (23.2 versus 36.6%) in the SCD patients, significantly ($p<0.000$ for all) (Table 2).

Table 1: Characteristic features of the study cases

Variables	Patients with SCD*	*p*-value	Control cases
Number	193		132
Mean age (year)	31.6 ± 9.7 (10-59)	Ns†	31.6 ± 12.4 (9-60)
Female ratio	50.7% (98)	Ns	50.7% (67)
Weight (kg)	*58.9 ± 12.2 (31-100)*	*0.000*	*71.1 ± 17.3 (31-120)*
Height (cm)	164.8 ± 9.7 (145-194)	Ns	162.8 ± 9.0 (134-185)
BMI‡ (kg/m²)	*21.5 ± 3.7 (14.5-35.8)*	*0.000*	*26.8 ± 6.5 (15.2-49.3)*
FPG§ (mg/dL)	*93.4 ± 13.2 (56-119)*	*0.025*	*102.4 ± 42.2 (71-447)*
TB‖ (mg/dL)	*4.0 ± 3.0 (0.6-23.4)*	*0.000*	*0.7 ± 0.6 (0.1-3.8)*
LDL¶ (mg/dL)	*70.4 ± 28.2 (20-164)*	*0.000*	*98.1 ± 40.8 (21-208)*
*HDL** (mg/dL)*	*24.2 ± 8.7 (9-60)*	*0.000*	*35.8 ± 13.3 (5-72)*
TG*** (mg/dL)	118.8 ± 54.6 (31-348)	Ns	123.1 ± 74.5 (24-382)
*LDH**** (U/L)*	*638.9 ± 462.5 (108-2.842)*	*0.000*	*268.4 ± 180.7 (101-1.318)*
*Systolic BP***** (mmHg)*	*117.6 ± 18.5 (80-170)*	*0.001*	*127.9 ± 21.1 (90-200)*
Diastolic BP (mmHg)	*77.3 ± 12.0 (50-120)*	*0.000*	*86.0 ± 12.9 (60-120)*

*Sickle cell diseases †Nonsignificant (p>0.05) ‡Body mass index §Fasting plasma glucose ‖Total bilirubin ¶Low density lipoproteins **High density lipoproteins ***Triglycerides ****Lactate dehydrogenase *****Blood pressures

Table 2: Routine hematological parameters of the study cases

Variables	Patients with SCD*	*p*-value	Control cases
WBC† count (/µL)	*16.338 ± 7.417 (1.580-48.500)*	*0.000*	*7.407 ± 3.620 (1.760-37.550)*
Hct‡ level (%)	*23.2 ± 5.2 (8-39)*	*0.000*	*36.6 ± 8.6 (12-54)*
MCV§ (fL)	*90.3 ± 11.8 (55-124)*	*0.000*	*78.3 ± 12.7 (45-128)*
PLT‖ count (/µL)	*421.424 ± 204.693 (52.000-1.029.000)*	*0.000*	*268.612 ± 125.529 (12.000-929.000)*

*Sickle cell diseases †White blood cell ‡Hematocrit §Mean corpuscular volume ‖Platelet

Discussion

SCD affects all vascular systems of the body (17, 18). Aplastic crises, sequestration crises, hemolytic crises, acute chest syndrome, avascular necrosis of the femoral and humeral heads, priapism and infarction of the penis, osteomyelitis, acute papillary necrosis of the kidneys, CRD, occlusions of retinal arteries and blindness, pulmonary HT, bone marrow necrosis induced dactilitis in children, chronic punched-out ulcers around ankles, hemiplegia, and cranial nerve palsies are only some of the several presentation types of the SCD. Eventually, the median ages of death were 42 years in males and 48 years in females in the literature (16). Delayed diagnosis, delayed initiation of hydroxyurea therapy, and inadequate RBC supports during emergencies may decrease the expected survival time in the SCD patients further (19). Actually, RBC supports must be given immediately during all medical or surgical events in which there is evidence of clinical deterioration in the SCD (20). RBC supports decrease sickle cell concentration in the circulation and suppress bone marrow about the production of such abnormal RBC. So it decreases sickling induced endothelial damage and inflammation all over the body. Due to the great variety of clinical presentation types, it is not surprising to see that the body weight and BMI were significantly retarded in the SCD in the present study. As an opposite finding to some other reports (21, 22), the body heights were similar in the SCD and control cases, here. Parallel to the significantly retarded body weight and BMI, FPG, LDL, HDL, and systolic and diastolic BP were also suppressed in the SCD in the present study, which can be explained by definition of the metabolic syndrome (23, 24).

Higher BP indicates that heart and blood vessels are being overworked. In most people with HT, increased peripheral vascular resistance (PVR) accounts for HT while cardiac output remains normal (25). The increased PVR is mainly attributable to structural narrowings of small arteries and arterioles, although a reduction in the number of capillaries may also contribute (26). HT is rarely accompanied by symptoms in the short-term. Symptoms attributed to HT in that period may actually be related with associated anxiety rather than HT itself. However, HT may be the major risk factor for CHD, CRD, cirrhosis, COPD, stroke, dementia, and PAD-like end-organ insufficiencies in long-term. For example, a reduction of the BP by 5 mmHg can decrease the risk of stroke by 34% and CHD by 21%, and reduce the likelihood of dementia, heart failure, and mortality from cardiovascular diseases (27). On the other hand, the physicians can not detect any absolute cause in the majority of patients with HT. Physical inactivity, sedentary lifestyle, animal-rich diet, excess weight, smoking, alcohol, chronic inflammations, prolonged infections, and cancers may be found among the possible risk factors of HT by means of the accelerated atherosclerotic process.

Probably excess weight may be the most common cause of vasculitis, worldwide, and the leading cause of major health problems in the century. It leads to both structural and functional abnormalities in many organ systems of the body (28). Adipose tissue produces leptin, tumor necrosis factor-alpha, plasminogen activator inhibitor-1, and adiponectin-like cytokines, all of those behave as APR in the plasma (29). Excess weight induced chronic low-grade vascular endothelial inflammation may play a significant role in the pathophysiology of disseminated atherosclerosis all over the body (1, 2). On the other hand, excess weight may cause an increased blood volume as well as an increased cardiac output thought to be the result of an increased oxygen need of the excessive fat tissue. The prolonged increase in the blood volume may lead to myocardial hypertrophy, terminating with a decreased cardiac compliance. Combination of these cardiovascular risk factors will eventually terminate with an increased left ventricular stroke work and higher risks of arrhythmias, cardiac failure, and sudden death. Similar to the present study, FPG and total cholesterol (TC) increased parallel to the increased BMI (30). Additionally, the prevalence of CHD and stroke increased parallel to the increased BMI in another study (31), and risk of death from all causes including cancers increased throughout the range of moderate to severe weight excess in all age groups (32). The relationship between excess weight, increased BP, and higher plasma TG was described in the literature, extensively (33). Similarly, prevalence of smoking (42.2 versus 28.4%, $p<0.01$), excess weight (83.6 versus 70.6%, $p<0.01$), DM (16.3 versus 10.3%, $p<0.05$), and HT (23.2 versus 11.2%, $p<0.001$) were all higher in the hypertriglyceridemia group in another study (34). Interestingly, the greatest number of deteriorations in the metabolic parameters was observed just above the plasma TG value of 60 mg/dL (35). In our opinion, although excess weight does not affect each individual with the same severity, durations of overweight, obesity, severe obesity, and morbid obesity should be added to the calendar age with various scores during calculation of physiological age. Although the obvious consequences of excess weight on health, nearly three-quarters of cases above the age of 30 years have excess weight (36). The prevalence of excess weight increases by decades, particularly after the third decade, up to the eighth decade of life (36). So 30th and 70th years of age may be the breaking points of life for body weight, and aging may be the major determining factor of excess weight. Relatively decreased physical and mental stresses after the age of 30 years, and debility and comorbid disorders induced restrictions after the age of 70 years may be the major causes for the changes of BMI at these ages. Interestingly, the mean age increased up to the plasma TG value of 200 mg/dL and BMI increased just up to the plasma TG value of 150 mg/dL in the above study (35). So smoking remained as the major underlying factor for the hypertriglyceridemia above the plasma TG value of 200 mg/dL. Beside that, the mean BMI values were 24.6, 27.1, 29.4, 29.9, and 30.0 kg/m2 in the five study groups, respectively (35). In other words, only cases with the plasma TG values lower than 60 mg/dL had a normal BMI (35). On the other hand, the mean age and TG value of the first group were 35.6 years and 51.0 mg/dL, respectively (35). They were 43.6 years and 78.3 mg/dL in the second, 47.7 years and 122.2 mg/dL in the third, and 51.2 years and 174.1 mg/dL in the

fourth groups, respectively (35). In another definition, TG values increased about 7.8 mg/dL for each year of aging up to 200 mg/dL in the plasma (35). So aging alone may be another risk factor for chronic low-grade inflammation on vascular endothelium all over the body.

Although their normal limits could not been determined clearly yet, high plasma TG values may be significant indicators of the metabolic syndrome (7). Due to the significant association between high plasma TG values and CHD, Adult Treatment Panel (ATP) III adopts lower cutpoints for TG abnormalities than did ATP II (8, 9). Although ATP II determined the normal upper limit of TG as 200 mg/dL in 1994, World Health Organisation in 1999 (10) and ATP III in 2001 reduced the normal upper limit as 150 mg/dL (9). Although these cutpoints are usually used to define borders of the metabolic syndrome, there are suspicions about whether or not much lower limits provide additional benefits for human health remains unclear (37). Similar to the recent study (38), prevalence of smoking was the highest in the highest TG having group in the above study (35) which may also indicate the inflammatory role of smoking on vascular endothelium since TG may behave as APR in the plasma. BMI, FPG, HT, DM, COPD, and CRD increased parallel to the increased plasma TG values from the first up to the fifth groups in the above study, continuously (35). Just as an opinion, significantly increased mean age by the increased plasma TG values may be secondary to aging induced decreased physical and mental stresses, which eventually terminates with excess weight and its consequences. Interestingly, although the mean age increased from the lowest TG having group up to TG value of 200 mg/dL, then it decreased (35). The similar trend was also seen with the mean LDL values (35). These trends may be due to the fact that although the borderline high TG values (150-199 mg/dL) are seen together with physical inactivity and overweight, the high TG (200-499 mg/dL) and very high TG values (500 mg/dL or higher) may be secondary to genetic factors, smoking, and terminal consequences of the metabolic syndrome including obesity, DM, HT, COPD, cirrhosis, CRD, PAD, CHD, and stroke (9). But although the underlying causes of the high and very high plasma TG values may be a little bit different, probably risks of the terminal endpoints of the metabolic syndrome do not change in them. For example, prevalence of HT, DM, and COPD were the highest in the highest TG having group in the above study (35). Eventually, although some authors reported that lipid assessment can be simplified by measurement of TC alone (39), most of the other studies indicated a causal relationship between higher TG values and irreversible end-points of the metabolic syndrome (40).

Cholesterol, TG, and phospholipids are the major lipids of the body. Cholesterol is an essential structural component of animal cell membrane, bile acids, adrenal and gonadal steroid hormones, and vitamin D. TG are fatty acid esters of glycerol, and they are the major lipids transported in the blood. The bulk of fat tissue deposited all over the body is in the form of TG. Phospholipids are TG that are covalently bound to a phosphate group. Phospholipids regulate membrane permeability, remove cholesterol from the body, provide signal transmission across the membranes, act as detergents, and help in solubilization of cholesterol. Cholesterol, TG, and phospholipids do not circulate freely in the plasma instead they are bound to proteins, and transported as lipoproteins. There are five major classes of lipoproteins including chylomicrons, very low density lipoproteins (VLDL), intermediate density lipoproteins (IDL), LDL, and HDL in the plasma. Chylomicrons carry exogenous TG from intestine to liver via the thoracic duct. VLDL are produced in the liver, and carry endogenous TG from the liver to the peripheral organs. In the capillaries of adipose and muscle tissues, 90% of TG is removed by a specific group of lipases. So VLDL are converted into IDL by removal of TG. Then IDL are degraded into LDL by removal of more TG. So VLDL are the main sources of LDL in the plasma. LDL deliver cholesterol from the liver to other parts of the body. Although the liver removes the majority of LDL from the circulation, a small amount is uptaken by scavenger receptors on macrophages which may migrate into arterial walls and become the foam cells of atherosclerotic plaques. HDL remove fats and cholesterol from cells, including within arterial wall atheroma, and carry the cholesterol back to the liver and steroidogenic organs including adrenals, ovaries, and testes for excretion, reutilization, and disposal. All of the carrier lipoproteins in the plasma are under dynamic control, and are readily affected by diet, illness, drug, body weight, and BMI. Thus lipid analysis should be performed during a steady state. But the metabolic syndrome alone is a low-grade inflammatory process on vascular endothelial cells all over the body. Thus the metabolic syndrome alone may be a cause of the abnormal lipoproteins levels in the plasma. On the other hand, although HDL are commonly called 'the good cholesterol' due to their roles in removing excess cholesterol from the blood, and protecting the arterial walls against atherosclerosis (41), recent studies did not show similar results, and low plasma HDL levels should alert the physicians about additional pathologies in the body (42, 43). Normally, HDL may show various anti-atherogenic properties including reverse cholesterol transport and anti-oxidative and anti-inflammatory properties (43). However, HDL may become 'dysfunctional' in pathological conditions which means that relative compositions of lipids and proteins, as well as the enzymatic activities of HDL are altered (42). For example, properties of HDL may be compromised in DM due to the oxidative modification and glycation as well as the transformation of HDL proteomes into proinflammatory proteins. Similarly, the highly effective agents of increasing HDL levels such as niacin, fibrates, and cholesteryl ester transfer protein inhibitors did not reduce all cause mortality, CHD mortality, myocardial infarction, or stroke (44). While higher HDL levels are correlated with cardiovascular health, medications used to increase HDL did not improve the health (44). In other words, while high HDL levels may correlate with better cardiovascular health, specifically increasing one's HDL values may not increase cardiovascular health (44). So they may just be some APR instead of being the main actors of the process. Beside that, HDL particles that bear apolipoprotein C3 are associated with increased risk of

CHD (45). Additionally, BMI, FPG, DM, and CHD were the lowest between the HDL values of 40 and 46 mg/dL, and the prevalence DM was only 3.1% between these values against 22.2% of outside of these limits in the other study (46). In another definition, the moderate HDL values may also be the results instead of the causes of the better health parameters.

As a conclusion, body weight, BMI, FPG, LDL, HDL, systolic and diastolic BP, and Hct may be some negative whereas TB, LDH, WBC and PLT counts, and MCV may be some positive APR in the body.

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