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Storage-related Haematological and Biochemical Changes in Sickle Cell Trait Donor Blood at Kisumu Regional Blood Transfusion Centre, Kenya

Shiundu Meshack [a*], Walekhwa Michael [b], Mangare Caroline [c] and Mbugua Amos [d]

[a] Department of Medical Laboratory Sciences, Kenya Medical Training College, Kenya.
[b] Department of Biomedical Sciences, School of Medicine & Health Sciences, Kabarak University, Kenya.
[c] Department of Medical Laboratory Sciences, School of Health Sciences, South Eastern Kenya University, Kenya.
[d] Department of Medical Laboratory Sciences, School of Health Sciences, Jomo Kenyatta University of Agriculture and Technology, Kenya.

Authors' contributions

This work was carried out in collaboration among all authors. We conceived, designed the study, collected the data, performed and validated the laboratory findings and drafted the manuscript. Moreover, we performed the statistical analysis. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: meshshiundu16@gmail.com;*

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ABSTRACT

Background: Sickle cell trait (HbAS) donor blood, akin to normal hemoglobin (HbAA) blood, undergoes storage-induced hematological and biochemical changes that may impact its efficacy, safety, and viability. Detailed characterization of these changes in HbAS donors' blood remains scarce. This study aimed to elucidate the storage-related hematological and biochemical changes in HbAS compared to HbAA donor blood.

Methods: The study used a prospective, laboratory-based experimental design. Sterile CPDA-anticoagulated blood (150 mL) was drawn into sample pouches attached to the main donor blood bags. Thirty units of HbAS and HbAA donor blood were analyzed for haematological and biochemical parameters. Assays for various parameters were performed at baseline and weekly intervals for four weeks. Statistical analyses were conducted using SPSS and R software, with one-way ANOVA applied to detect statistical differences. A *P*-value < 0.05 was considered statistically significant.

Results: Both sickle cell trait negative (HbAA) and positive (HbAS) donor blood showed notable changes. In HbAA blood, hemoglobin increased from 15.13 g/dL to 15.67 g/dL, hematocrit rose from 37.94% to 41.82%, hemolysis reached 0.54%, and platelet count dropped from 223.45 x 10^9/L to 127.13 x 10^9/L. For HbAS blood, hemoglobin rose from 13.78 g/dL to 15.12 g/dL, hematocrit increased from 40.98% to 45.07%, hemolysis hit 0.78%, and platelets dropped to 99.07 x 10^9/L. LDH, potassium, and plasma bilirubin levels increased more sharply in HbAS blood than HbAA.

Conclusion: HbAS donor blood exhibits higher % hemolysis, more significant declines in RBC, PLT, and TWBC counts, and greater cellular degradation compared to HbAA donor blood.

Keywords: Sickle cell trait; hematological changes; biochemical changes; kisumu.

ABBREVIATIONS

SCT : Sickle Cell Trait
SCD : Sickle cell disease
MOH : Ministry of Health
NACOSTI : National Commission for Science Technology and Innovation
RBTCs : Regional Blood Transfusion Centers
TTIs : Transfusion-Transmissible Infections
WHO : World Health Organization
2,3 BPG : 2,3-biphosphoglycerate
ANOVA : One-Way analysis of variance
ATP : Adenosine triphosphate
Bas : Basophils
CPDA : Citrate Phosphate Dextrose Adenine
Eos : Eosinophils
Hb : Hemoglobin
HCT : Hematocrit
Lymph : Lymphocytes
MCH : Mean cell hemoglobin
MCHC : Mean cell hemoglobin concentration
MCV : Mean cell volume
Mon : Monocytes
KNBTS : Kenya National Blood Transfusion Services
Neut : Neutrophils
Plt : Platelets
RBCs : Red Blood Cells
RDT : Rapid diagnostic Test
P C V : Packed Cell Volume

1. INTRODUCTION

Sickle Cell Trait (SCT), marked by one hemoglobin beta sickle allele (*rs334-T*) and one normal beta allele, is common among Africans and their descendants [1]. About 20 million people globally carry SCT gene, and approximately 300,000 newborns are affected by sickle cell disease (SCD) annually [1]. In Kenya, approximately 18% of children are born with SCT, and 4% of voluntary blood donors carry this trait [2]. In Africa, nearly 7 million blood donations are needed annually, but only half are collected, causing critical shortages [3]. In Kenya, seven people need urgent blood or blood products transfusions every ten minutes [4]. This shortage raises mortality rates, especially for those with sickle cell disease, Iron deficiency anaemia (IDA), and severe maternal bleeding [4]. The over-reliance on close family members and friends as blood donors increases the likelihood of transfusing SCT carrier donor blood [2].

In hypothermic storage (2–8 °C), SCT-negative donor blood's red blood cells exhibit significant changes in deformability, undergoing storage-related hematological and biochemical changes resulting in a limited shelf-life and overall deterioration of blood quality that results from the gradual degradation of certain RBC's components, quality, and recipient's safety [5]. Storage-related biochemical changes in donor blood include but are not limited to pH variation due to glycolysis, variation in ATP production, and adenosine deaminase breakdown [6], 2, 3-Diphosphoglycerate increases due to a decrease in pH resulting in increased oxygen affinity of hemoglobin(Hb) shifting the oxygen dissociation curve to the left [7]. Moreover, there are variations in electrolytes, plasma hemolysis, Lactate dehydrogenase(LDH), Ferritin level and bilirubin level during donor blood storage period [8,9,10]. On other hand, at donation time, donor blood hematological baseline parameters are normally within normal range that is Hb 12.5-18.0g/dl, and plasma hemoglobin- 0g/dl, normal ranges of electrolytes among other baseline parameters.

Stored RBCs exhibit significant changes in deformability during storage. Oxidative damage manifests itself in RBCs, which are particularly vulnerable to stress evidenced by increased osmotic fragility during storage, resulting in the release of intracellular enzymes such as hemoglobin (Hb). Platelets that lose viability rapidly, WBCs and its differentials, RBCs counts, Packed cell volume (PCV), and RBCs indices (MCV, MCH, MCHC, hematocrits) are significantly altered in stored donors' blood [11,12]. These changes reduce RBCs' lifespan, quality, and recipients' safety. These storage-related changes result in the gradual degradation of RBCs' components, leading to a loss of potency of about 17.6% [13]. During donors' blood storage, the increased potassium levels in RBCs may lead to arrhythmia when neonates or infants are transfused with large volumes of stored donor blood [14]. The interaction of plasma Hb with nitric oxide may cause endothelial dysfunction which is a risk factor for vasoconstriction, leucocyte adhesion, and intravascular thrombosis [15]. The decrease of ATP concentration during donor blood storage period causes the cellular reactions requiring energy i.e. phospholipids membrane distribution, active transport, and antioxidant reactions, to also decrease significantly [16]. Moreover, when the donors' blood is stored in plastic blood bags, glycolysis kicks off almost immediately [1]. Adenosine deaminase breakdown adenosine into inosine and ammonia. An increase in protons leads to a decrease in donor blood's pH, resulting in altered glycolytic metabolism [1]. A decrease in pH decreases the level of 2,3-diphosphoglycerate and simultaneously increases the production of ATP. Glycolysis slows down, ATP levels drop as acid accumulates, and the shape of RBCS gradually changes from discoid/biconcave to echinocyte formation. This change in erythrocytes is attenuated when the stored donor blood is rejuvenated and reversed when the blood is warmed [1].

During hypothermic storage, separating red blood cells (RBCs) from plasma and suspending them in an acidic solution containing glucose exposes it to plasticizers, oxygen, and further acidification during storage [17]. Red blood cells have evolved to cope with oxidative and mechanical stresses, but no physiological countermeasures have been developed to deal with stress that causes storage damage. The RBC's memory impairment can be attributed to RBCs separation, plasma dilution with additive solutions, and long-term cryopreservation in closed blood bags. Oxidative stress and loss of biochemical countermeasures are the main causes of storage damage in stored erythrocytes. Metabolic impairment of stored RBCs occurs due to the removal of RBCs from the donor's circulation, separation from plasma, and storage in hypothermia and volume-limited

acidic solutions. This leads to the degradation of important substrates, accumulating metabolic waste products, and impaired activity of key enzymes that provide energy and antioxidant defenses [1].

Transfusion of stored donor blood induces significant hematological and biochemical changes recipients; hypothermic donor blood storage depletes ATP, 2,3-DPG, GSH, and NAD(P)H within 2-3 weeks, disrupting ion homeostasis and membrane integrity, leading to cytoskeletal rearrangements and oxidative stress [18,19,20]. Stored RBCs accumulate senescent cells with reduced antioxidant capacity, morphological changes, and increased osmotic fragility [21,17]. These alterations impair NO-mediated vasodilation and induce inflammatory responses post-transfusion [22,23]. Rapid clearance of transfused RBCs and iron overload can lead to organ dysfunction and endothelial damage [24,25]. While general effects of donor blood storage are known, specific changes in stored SCT donor blood are not well-explored [26].

Sickle Cell trait positive (HbAS) donor blood, like normal hemoglobin donors' blood, when stored, it undergoes storage-related hematological and biochemical changes. The depletion of important nutrients and energy sources, accumulation of harmful substances, and altered RBC deformability could be more drastic in SCT positive donor blood due to the lack of normal membrane deformability, fluidity, and flexibility witnessed in normal haemoglobin donor blood [27,5]. Screening for SCT is crucial to enhance safety and reduce SCT positive donor blood transfusion associated risks [13]. This study analyzed storage-related hematological and biochemical changes in SCT positive donor blood in comparison to SCT negative donor blood at Kisumu Regional Blood Transfusion Centre(RBTC), Kenya, to enhance its safety, quality, and efficacy.

2. MATERIALS AND METHODS

2.1 Study Design

This was a prospective laboratory-based experimental study design [28]. The study involved 336 volunteer blood donors sampled using convenient purposive sampling. A final sample of 60 donors (30 SCT positive and 30 SCT negative) was selected using Cochran's formula. Hematological and biochemical parameters of the blood were assessed at baseline and at four intervals (baseline, days 7, 14, 21, and 28) using automated biochemistry/haematology analyzers.

2.2 Study Location

The research was carried out at the Kisumu Regional Blood Transfusion Centre in Kisumu County, Kenya (RBTC), strategically positioned on geographical coordinates -0.0868146°S and 34.7716936°E, within Kisumu County-Kenya. Kisumu County is renowned for being a significant area of SCT endemicity where the prevalence of sickle cell trait is significant [29,2].

2.3 Donor Selection and Study Population

The study involved 336 volunteer blood donors at Kisumu RBTC, sampled by convenient purposive sampling method in reference to inclusion criteria [30]. Cochran's formula was used to determine a sample size of 60 subjects (30 SCT positive and 30 SCT negative) from a study population of 336 blood donors. This was based on a prevalence (p) of 4%, a confidence level (z) of 1.96, and a margin of error (e) of 0.05. Participants consented and enrolled into the study.

2.3.1 Inclusion-criteria

The study included 30 sickle cell trait positive (HbAS) and 30 sickle cell trait negative (HbAA) donor blood units. These units were free from transfusion transmissible infections and met specific baseline hematological and biochemical parameters: hemoglobin levels of 12.5-18.00 g/dl, no plasma hemoglobin, and normal specific baseline ranges for plasma sodium, potassium, and LDH.

2.4 Laboratory Procedures

Kenya National Blood Transfusion Services Questionnaire (KNBTSQ) was used to collect demographic data of donors and phlebotomy performed on 336 voluntary donors who met inclusion criteria and consented to participate in the study during data collection period. Blood was collected into double blood bags and CPDA-1 anticoagulant allowed into the sample pouch attached to the main donor blood bag, filled with the 150 ml of whole blood for the study. Thoroughly, mixed whole blood samples (2x4ml) were drawn aseptically into EDTA vacutainer tubes and plain glass vacutainer tube (Dusseldorf, Germany) respectively for

biochemical and haematological analysis on days 0(baseline), 7, 14, 21, and 28 [11]. Portion of the blood was used to perform sickling test (*Sodium Metabisulfite*), Malaria rapid test (*Bioline Abbott*), Sickle SCAN (*BioMedomics, USA*) test and screen for transfusion transmitted infections(TTIs) including HIV 1/2, hepatitis B surface antigen, Hepatitis C antigen and Treponema pallidum using (*Liaison XL-Diasorin, Italy*).

2.5 Sickling Test Screening and Sickle SCAN confirmatory Test

The sickling test was performed by mixing 10µL of fresh whole blood with 50µL (2%) sodium metabisulphite ($Na_2S_2O_5$), cover slipped, and airtight-sealed it with wax mold at incubating at 37 degrees Celsius for 2-3 hours, according to the standard operating procedure [31]. Sickle SCAN test kit (*Qualitative lateral flow immunoassay-BioMedomics, USA*) was used to detect the presence of defective hemoglobin, allowing rapid distinguishing between normal, carrier, and sickle cell samples to confirm positive sickling test positive samples, using five microliters of donor blood [32].

2.6 Determination of Haematological Changes

Automated Hematology Analyzer (*Mindray BC-5000, China*) was used to evaluate hematological parameters (Hb level, RBC Count, RBC indices (MCV, MCH, MCHC, HCT), Total WBC count and PLT on day 0 (baseline), day 7(week 1), day14(week 2), day 21(week 3) and day 28(week 4) in reference to the standard operating procedure.

Determination of percentage hemolysis: Whole blood was drawn from donor blood units aseptically into EDTA vacutainers tubes and used to calculate and determine the percentage of hemolysis on day 0 (baseline), day 7, day 14 day 21, and day 28 [33]. The % hemolysis in RBC was determined on days 0, 7, 14, 21 and lastly on day 28 using the formulae below:

(100- HCT) x plasma Hemoglobin (g dl-1) / Total Hb (g dl-1).

2.7 Determination of Biochemical Changes

The fully Automated Biochemistry Analyzer (*Cobas Integra 400 plus, Switzerland*) was used to evaluate biochemical changes (Ferritin level, Sodium, potassium, Bilirubin level, LDH, and Glucose) on day 0(baseline), day 7(week 1), day14(week 2), Day 21(week3) and day 28(week 4) as per the standard operating procedure.

2.8 Data Processing and Statistical Analysis

Data were entered into Microsoft Excel 2023, analyzed using R and statistical analysis involved One-way ANOVA to compare haematological/biochemical changes over four weeks' storage period, with significance set at $P<0.05$. Results were presented in tables, graphs, and charts.

3. RESULTS

3.1 Storage-related Hematological Changes in SCT Positive and SCT Negative Donor Blood

Table 1 outlines the weekly average hematological changes in sickle cell trait negative (SCT negative) and sickle cell trait positive (SCT positive) donor blood over four weeks of storage. For SCT negative (HbAA) blood shows a gradual increase in Hb levels from 15.13 on Day 0 to 15.67 by Week 4 (Fig. 6), hemolysis starts at 0.00% on day 0 and rises to 0.54% by day 28, indicating a gradual increase in cell breakdown as shown in Fig. 1. Hematocrit (HCT) values increase from 37.94% to 41.82%, likely due to plasma volume reduction (Fig. 3). Mean corpuscular hemoglobin concentration (MCHC) decreases from 30.9 g/dL to 27.5 g/dl, while mean corpuscular volume (MCV) rises from 76.96 fL to 88.06 fL (Fig. 2). Plateletcrit (PCT) declines from 0.24% to 0.11%, and platelet count drops significantly from 223.45 x 10^9/L to 127.13 x 10^9/L (Fig. 5). Red blood cell (RBC) count decreases from 5.03 x 10^12/L to 4.23 x 10^12/L, and total white blood cell (TWBC) count drops from 5.64 x 10^9/L to 2.36 x 10^9/L (Fig. 4).

For SCT positive (HbAS) blood, hemolysis increases from 0.00% on day 0 to 0.78% by day 28 (Fig. 1). HCT values rise from 40.98% to 45.07% (Fig. 3). MCHC decreases from 33.68 g/dL to 30.6 g/dl, and MCV increases from 79.54 fL to 87.78 fL (Fig. 2), PCT declines from 0.21% to 0.09%, and platelet count drops from 223.65 x 10^9/L to 99.07 x 10^9/L (Fig. 5). RBC count decreases from 4.98 x 10^12/L to 3.78 x 10^12/L, and TWBC count declines from 5.99 x

10^9/L to 3.36 x 10^9/L (Fig. 4). Sickle cell trait positive donor blood exhibits an increase in Hb levels, starting at 13.78g/dl on day 0 and reaching 15.12 g/dl by Week 4 (Fig. 6).

3.2 Storage-related Biochemical Changes in SCT Positive and SCT Negative Donor Blood

From Table 2, Storage-related changes in average weekly LDH levels showed a steady increase in both SCT positive and SCT negative groups, with the SCT positive group peaking at 202% at week 4 compared to baseline. Baseline plasma potassium levels were similar but increased steadily until week 3, followed by a sharp rise in both groups, with higher levels in the SCT positive group. Plasma sodium levels decreased at comparable rates in both groups. Plasma ferritin levels increased consistently, with slightly higher average weekly increases in the SCT-negative group. Baseline plasma glucose levels were similar, increasing until week 1 and then declined steadily. Plasma bilirubin levels increased similarly, with the SCT-positive group showing slightly higher average weekly increased (Table 2).

Table 1. Average hematological storage- related changes values at different points in time

SCT STATUS variables	Day 0	(Week 1)	(Week 2)	(Week 3)	(Week 4)
a) Sickle Cell trait negative	0.00	0.16	0.35	0.44	0.54
Percentage haemolysis(%)					
HCT(%)	37.94	40.07	41.02	41.26	41.82
MCHC(g/dl)	30.9	29.49	28.26	28.04	27.5
MCV(fL)	76.96	83.95	86.07	86.68	88.06
PCT(%)	0.24	0.19	0.16	0.14	0.11
PLT(x 10^9/L)	223.45	198.34	168.43	153.5	127.13
RBC(x 10^12/L)	5.03	4.53	4.32	4.28	4.23
TWBC (x 10^9/L)	5.64	3.94	2.99	2.58	2.36
Hb(g/dl)	15.13	15.24	15.35	15.49	15.67
b) Sickle cell trait positive(HbAS) donor blood					
Percentage haemolysis(%)	0.00	0.44	0.58	0.67	0.78
HCT(%)	40.98	43.18	44.17	44.48	45.07
MCHC(g/dl)	33.68	32.36	31.18	31.02	30.6
MCV(fL)	79.54	84.59	86.13	86.53	87.78
PCT(%)	0.21	0.17	0.14	0.11	0.09
PLT(x 10^9/L)	223.65	193.43	158.73	138.9	99.07
RBC(x 10^12/L)	4.98	4.28	3.78	3.77	3.78
TWBC(x 10^9/L)	5.99	4.74	4.07	3.88	3.36
Hb(g/dl)	13.78	14.03	14.32	14.71	15.12

Abbreviations: Hb=Haemoglobin, RBC=Red blood cells, TWBC=Total white blood cells, HCT=Hematocrit, MCHC=Mean cell haemoglobin concentration, MCV=Mean cell volume, PCT=Plateletcrit, PLT=Platelets

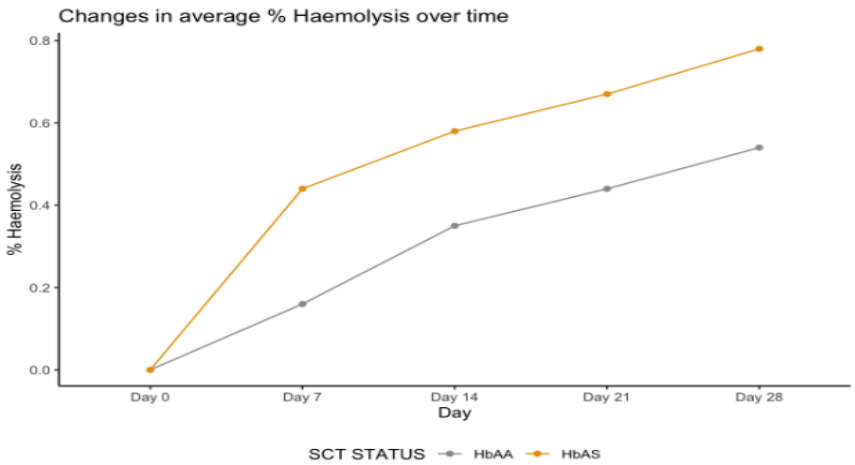

Fig. 1. Changes in average percentage Haemolysis (%) over time (day 0-day 28) for both Sickle cell trait donor(HbAS) blood and sickle cell trait negative (Hb AA) donor blood

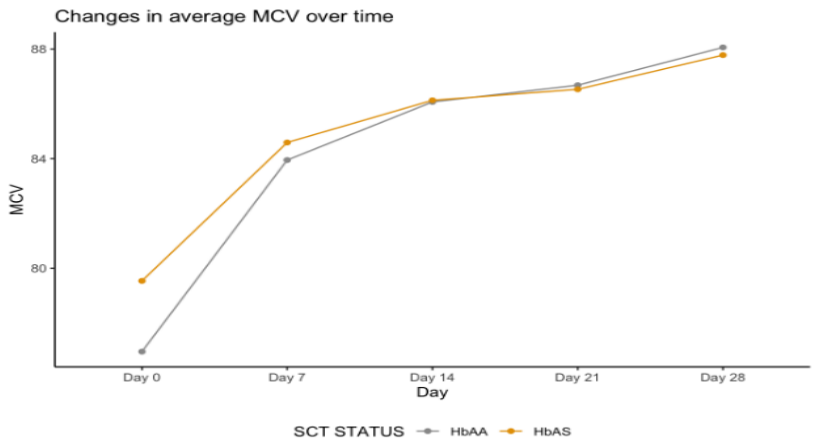

Fig. 2. changes in average Mean cell volume(fL) over time (day 0-day 28) for both Sickle cell trait donor(HbAS) blood and sickle cell trait negative (Hb AA) donor blood

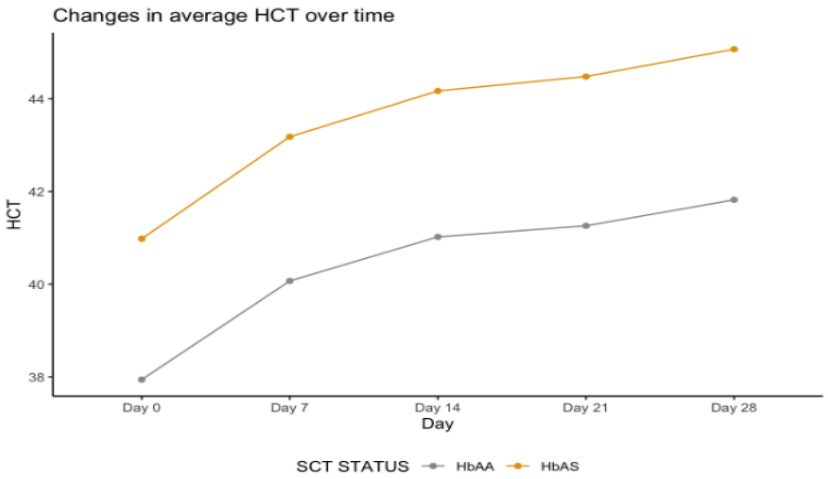

Fig. 3. Changes in average Hematocrit (%) over time (day 0-day 28) for both Sickle cell trait donor(HbAS) blood and sickle cell trait negative (Hb AA) donor blood

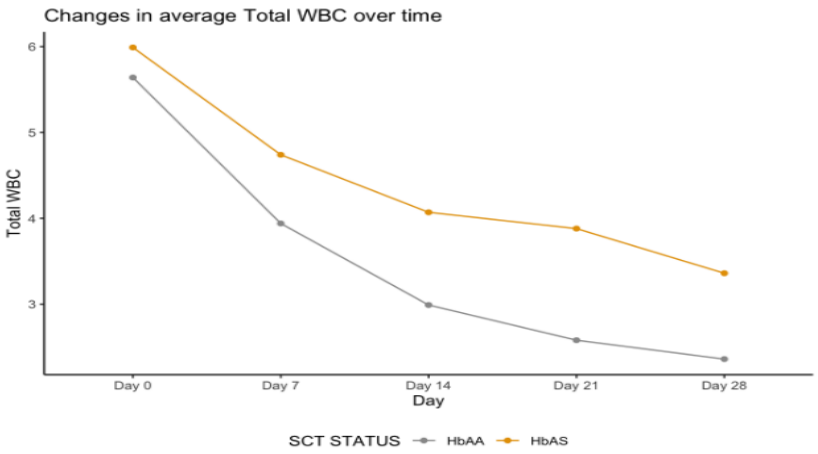

Fig. 4. Changes in average Total white blood cells (x 109/L) over time (day 0-day 28) for both Sickle cell trait donor(HbAS) blood and sickle cell trait negative (Hb AA) donor blood

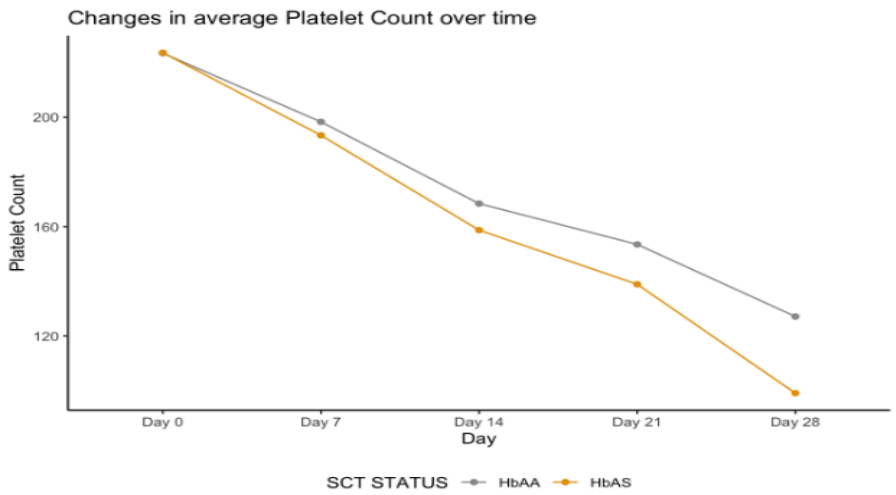

Fig. 5. Changes in average platelet count over time for both Sickle cell trait donor(HbAS) blood and sickle cell trait negative (Hb AA) donor blood

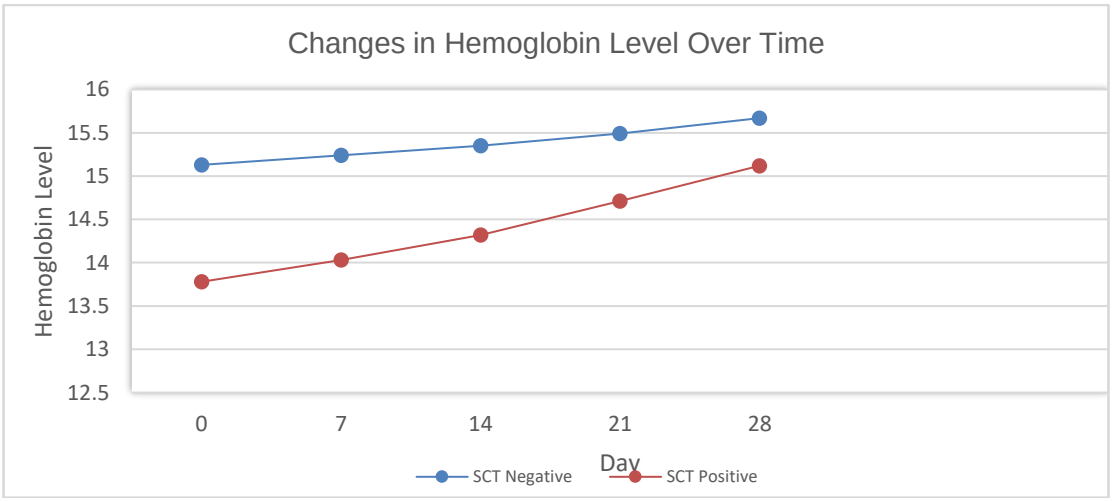

Fig. 6. Changes in average Haemoglobin level over time for both Sickle cell trait donor (HbAS) blood and sickle cell trait negative (Hb AA) donor blood

Table 2. Analysis of biochemical parameters in the blood donor groups stored over time

variables	Day 0	Day 7	Day 14	Day 21	Day 28
a) Sickle cell negative (HbAA) donor blood					
Ferritin Level(ng/ml)	65.34	70.55	76.57	83.71	91.81
Glucose Level(mmol/L)	5.95	11.79	8.89	7.45	4.86
LDH(U/L)	196.09	247.36	309.45	403.76	530.69
Potassium level(mmol/L)	4.53	6.04	8.11	10.42	14.92
Sodium level(mmol/L)	137.16	133.74	130.23	129.21	126.82
Bilirubin level(ng/dl)	4.9	6.1	7.8	9.72	13.48
b) Sickle cell trait positive(HbAS) donor blood					
Ferritin level(ng/ml)	92.16	96.43	101.51	107.57	113.19
Glucose Level(mmol/L)	6.98	14.21	10.18	6.69	4.26
LDH (U/L)	210.87	267.88	339.35	449.75	635.8
Potassium level(mmol/L)	4.98	7.66	10.11	12.52	19.28
Sodium level(mmol/L)	138.03	135.22	132.12	129.25	127.09
Bilirubin level (ng/dl)	6.78	8.35	10.86	14.07	19.98

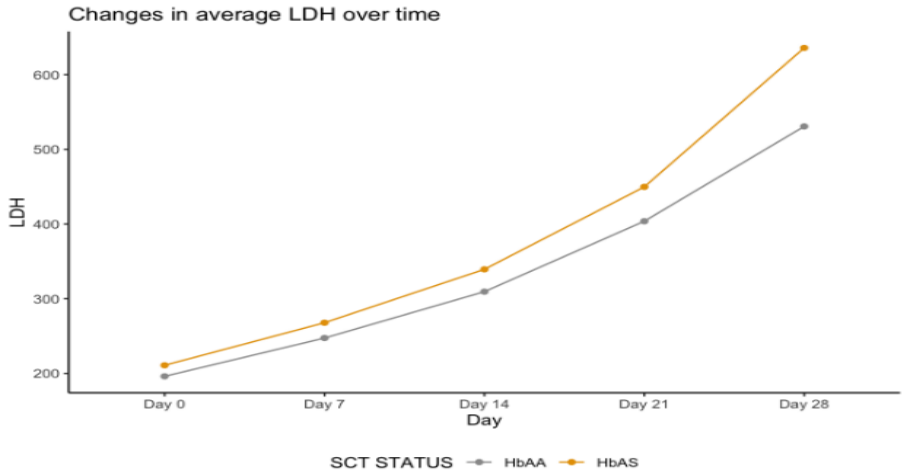

Fig. 7. Changes in average Lactate dehydrogenase(U/L) over time (day 0-day 28) for both Sickle cell trait donor(HbAS) blood and sickle cell trait negative (Hb AA) donor blood

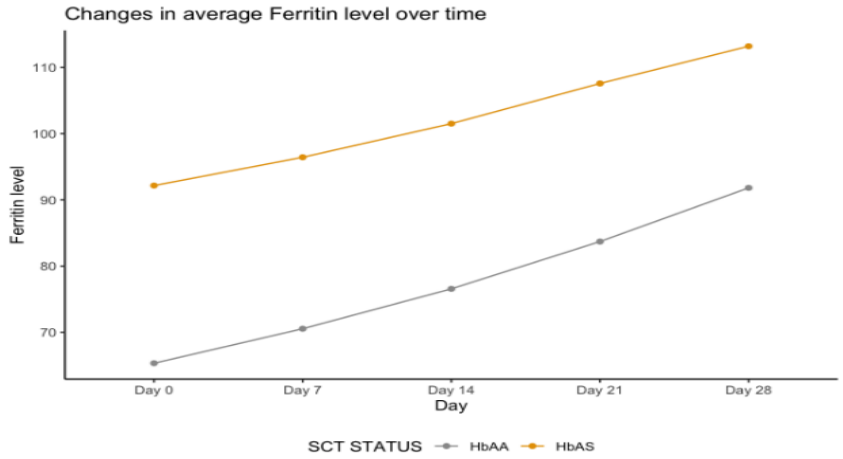

Fig. 8. Changes in average Ferritin level (ng/ml) over time (day 0-day 28) for both Sickle cell trait donor(HbAS) blood and sickle cell trait negative (Hb AA) donor blood

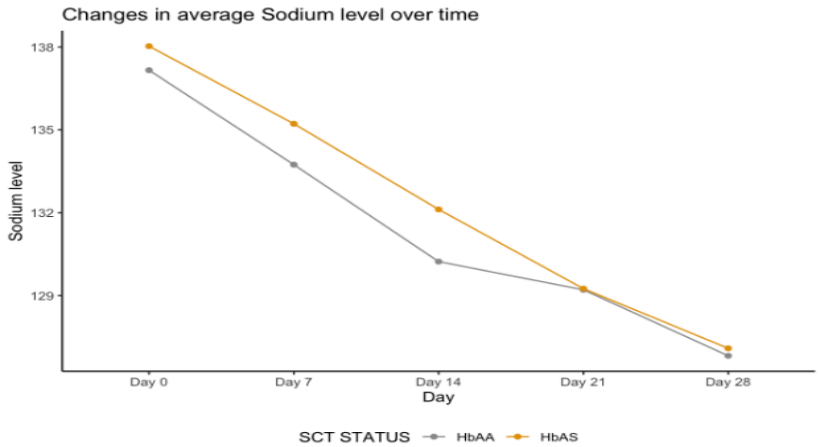

Fig. 9. changes in average Sodium level (mmol/L) over time (day 0-day 28) for both Sickle cell trait donor (HbAS) blood and sickle cell trait negative (Hb AA) donor blood

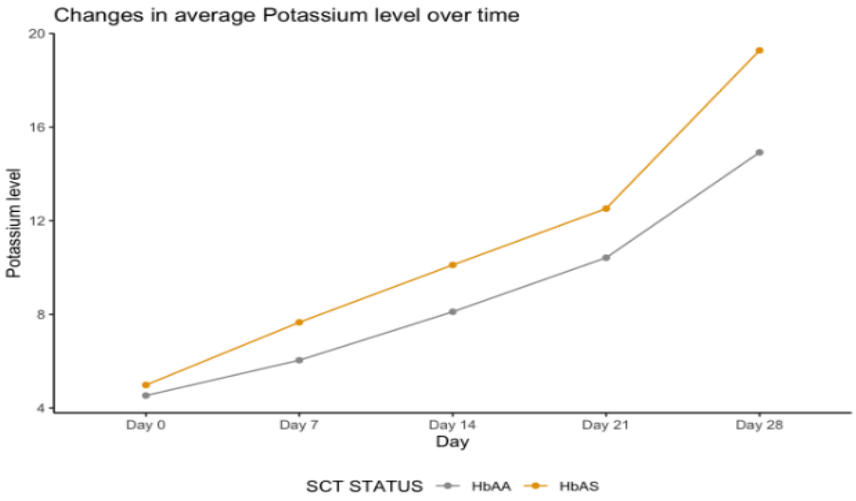

Fig. 10. Changes in average Potassium level (mmol/L) over time (day 0-day 28) for both Sickle cell trait donor (HbAS) blood and sickle cell trait negative (Hb AA) donor blood

4. DISCUSSION

The long-term storage and preservation of blood cells is crucial for ensuring a steady supply of safe blood and blood products [34]. Understanding storage-related changes in donor blood is essential for maintaining transfusion efficacy and recipients' safety. This study examined the hematological and biochemical alterations in sickle cell trait (SCT) positive (HbAS) and SCT negative (HbAA) blood over a 28-day period, revealing distinct patterns between the two groups that indicated differential susceptibility to storage-induced changes [5]. Previous researches has shown that storage negatively affects the morphology and functions of vital blood cells [8,9]. This study observed similar changes, with more pronounced effects in SCT positive donor blood. Both hematocrit (HCT) and mean cell volume (MCV) increased in SCT positive and negative blood, reflecting RBC's dehydration and swelling, respectively. SCT positive donor blood exhibited higher baseline HCT values and more significant increases over time, suggesting differences in erythrocyte stability and water homeostasis [35]. The rise in HCT indicates morphological changes during storage, which can reduce the potency of donor blood [13].

The decline in mean cell hemoglobin concentration (MCHC) was more pronounced in SCT-positive donor blood, indicating greater hemoglobin dilution and potential for altered oxygen-carrying capacity during storage. Similarly, significant reductions were observed at all-time points in SCT positive donors' blood, with the greatest drop at day 28. Research by [26,12] supports these findings, highlighting the vulnerability of SCT-positive donor blood RBCs to storage-induced changes. Hemoglobin (Hb) levels increased over time in both sickle cell trait negative and positive donor blood groups during storage period. Initially, sickle cell trait negative blood had higher Hb levels compared to HbAS blood. However, by Week 4, the increase in Hb levels in HbAS blood (from 13.78 to 15.12) was more pronounced than in sickle cell trait negative blood (from 15.13 g/dl to 15.67 g/dl).

For SCT negative donor blood, percentage differences in percentage hemoglobin (Hb) levels were 0.73% at day 7, 1.45% at day 14, 2.38% at day 21, and 3.57% at day 28. Percentage differences in hemoglobin (Hb) levels were higher in SCT positive donor blood group compared to SCT negative donor group, with 1.81% at day 7, 3.92% at day 14, 6.75% at day 21, and 9.72% at day 28. This indicates a greater rate of change in Hb levels for HbAS donor blood group compared to HbAA over the same storage period. Hematological alterations in MCV and MCHC result from a deregulated cell volume pathway, increasing the volume of RBCs. The data indicates that hemoglobin (Hb) levels in sickle cell trait positive (HbAS) donor blood exhibit a greater percentage increase over time compared to sickle cell trait negative (HbAA) donor blood. By day 28, HbAS shows a 9.72% increase, significantly higher than the 3.57% increase in HbAA. This suggests that HbAS donor blood undergoes more pronounced

changes in Hb levels during storage period. These findings are crucial for donor blood storage protocols, as they highlight the need to consider the genetic background of voluntary blood donors in maintaining blood quality and effectiveness for blood and blood products transfusions. These changes were accompanied by slow elevations in potassium ions and lactate dehydrogenase(LDH) levels during storage, as well as gradual increases in plasma hemoglobin due to enhanced RBC's breakdown [36] Plasma hemoglobin, a potent nitric oxide (NO) scavenger, can decrease NO bioavailability, reduce organ perfusion, and contribute to injury and mortality in patients with sepsis, organ failure, and septic shock [37]. These findings may relate to the fragility of hemoglobin S erythrocytes after hemoglobin S polymerization, decreased deformability, and reduced elasticity [38]. The platelet (PLT) count decreased significantly in both donor groups, with a more pronounced reduction in SCT positive blood, indicating a heightened susceptibility to storage-induced platelet degradation. This phenomenon may compromise transfusion efficacy, particularly in contexts requiring platelet-rich products. [26] and [38] highlighted the rapid disintegration of platelets during storage, corroborating these findings [39]. White blood cell (WBC) count decreased markedly in both groups, with SCT positive donor blood showing a more rapid decline with a significant difference *(P* < .05). This reduction could impact the immunomodulatory effects of transfused blood, potentially affecting recipient immune responses. Studies by [11,40] demonstrated similar trends in WBC degradation during storage. The storage of donor blood collected from SCT donors was significantly associated with RBC lysis, elevated plasma hemoglobin, and increased % hemolysis [26,38]. The interaction of plasma hemoglobin with nitric oxide can cause endothelial dysfunction, vasoconstriction, leucocyte adhesion, and intravascular thrombosis [15]. Hemolysis is a critical parameter for evaluating the quality and potency of stored donor blood as shown by [33].

During donor blood storage, significant biochemical changes occurred in levels of lactate dehydrogenase (LDH), potassium, sodium, glucose, ferritin, and bilirubin. LDH levels, indicative of red blood cells (RBC) degradation and hemolysis, steadily increase in both SCT positive and negative blood. SCT positive donor blood shows higher LDH levels throughout storage, reflecting greater erythrocyte fragility and oxidative stress susceptibility, as noted by [18]. Most day pairs showed significant differences, indicating a progressive increase over time. Similarly, the HbAS group exhibited significant LDH variation (ANOVA: $P < .05$), with the highest increase (202%) on day 28. Potassium levels rose progressively in both donor groups, with SCT positive donor blood showing higher averages. For SCT negative donors, potassium levels varied significantly (ANOVA: $P < .05$). Similar patterns were observed in the SCT positive donor group (ANOVA: $P < .05$). This elevation results from increased hemolysis and platelet degradation, releasing intracellular potassium into the plasma, which can pose hyperkalemia risks in recipients [14].

Sodium levels significantly decreased in both donor groups over the storage period. In the SCT negative group, sodium levels showed substantial variation (ANOVA: $P < .05$), with the largest decrease on day 28. The SCT positive group exhibited similar trends (ANOVA: $P < .05$). The inoperative sodium-potassium pump during storage allows potassium ions to exit and sodium ions to enter cells [16]. Glucose levels initially rose and then declined in both groups, indicating early metabolic activity followed by glucose utilization or degradation. The HbAA donor group showed significant glucose variation (ANOVA: $P < .05$), with increases on day 7 and decreases from day 14 to 28. The HbAS group displayed similar trends (ANOVA: $P < .05$), reflecting diminished metabolic capacity over time [6]. Ferritin and bilirubin levels consistently increased in both SCT positive and negative donor groups, indicating ongoing RBC's breakdown and the release of iron and heme products into the plasma. For SCT negative donors' group, total bilirubin levels did not vary significantly (ANOVA: $P = 0.28$), while SCT positive donors showed significant variation (ANOVA: $P < .05$). Ferritin levels did not significantly vary in either group (HbAA: ANOVA: $P = 0.106$; HbAS: ANOVA: $P= 0.609$). However, SCT positive donor blood exhibited slightly lower ferritin levels increases but higher bilirubin levels, likely due to differential rates of heme catabolism and iron sequestration [41].

Transfusing sickle cell trait positive (HbAS) donor blood can have adverse effects on recipients due to significant storage-related hematological and biochemical changes. Studies have shown that HbAS donor blood undergoes more pronounced alterations, including increased hematocrit(HCT),

mean cell volume(MCV), and a higher rate of hemoglobin(Hb) rise compared to sickle cell trait negative (HbAA) donor blood [5,35]. The heightened susceptibility of HbAS donor blood to storage-induced changes such as greater percentage hemolysis, higher lactate dehydrogenase (LDH) levels, and increased plasma hemoglobin can lead to reduced oxygen-carrying capacity and potential complications like hyperkalemia and endothelial dysfunction [34,37]. Therefore, tailored SCT positive donor blood storage practices and careful monitoring are essential to ensure transfusion safety and efficacy [8,9].

5. CONCLUSION

Storage-related haematological and biochemical changes were more pronounced in SCT-positive donor blood than in SCT-negative. SCT-positive blood exhibited higher hemolysis rates, increased potassium level, lactate dehydrogenase (LDH), and haemoglobin levels (Hb), and significant reductions in platelet and white blood cell counts over the storage period. These findings suggest greater erythrocyte fragility and oxidative stress susceptibility in SCT-positive blood. The distinct storage profiles between SCT-positive and negative blood highlight the need to consider genetic factors in blood and blood products transfusion management.

6. RECOMMENDATION

The blood banks should implement differential storage protocols for SCT positive (HbAS) and SCT negative (HbAA) donor blood. SCT positive donor blood, showing increased hemolysis, LDH, and potassium levels, along with reduced platelet and WBC counts, requires shorter storage durations to maintain transfusion efficacy and minimize risks like hyperkalemia and platelet dysfunction. Furthermore, periodic monitoring of key biomarkers such as hemoglobin, ferritin, and glucose levels is crucial to ensure blood quality. Additionally, pre-transfusion testing for hemolysis markers is advised to optimize patient safety, especially in vulnerable recipients.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

CONSENT

Written informed consent was obtained from each voluntary blood donor attending Kisumu RBTC during the study period (2nd January, 2024 to 3rd April 2024). All authors declare that written informed consent was obtained from the study participants. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal."

ETHICAL APPROVAL

Ethical approval of this study was granted by JKUAT Institutional Scientific and Ethics Review committee (Approval number: *JKU/ ISERC/ 02316/1091*) and data collection permit sought from NACOSTI (License No: *NACOSTI/ P/23/31896*). Moreover, written informed consent was obtained from each voluntary blood donor attending Kisumu RBTC during the study period (2nd January, 2024 to 3rd April 2024). The study participants' data privacy and confidentiality was adhered to.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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