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Table of Content: **Volume 7 Number 3 April 2016**

ARTICLE

Full Length Research Paper

Development of an algorithm of haematologic parameters as surrogate markers for CD4 cell count in resource-limited settings

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Total Lymphocyte Count (TLC) has been previously evaluated as a surrogate for CD4 counts in the management of HIV especially in resource-limited settings with varying results. This study developed a clinical algorithm of TLC and other significant haematologic parameters to raise the predictive value of TLC in classifying subjects with CD4 count <350 cells/mm^3. Total samples of 215 HIV-seropositive ARV-naïve patients were studied. The Beckman Counter was used for Complete Blood count (CBC), Beckton Dickinson FACS count for CD4 count, and Westergren method for Erythrocyte Sedimentation Rate (ESR). The variables retained as the most significant predictors (at $p<0.05$) were TLC<2000 cells/mm^3 (sensitivity 71.5%, specificity 73.4%, PPV 69.1%, NPV 78.3%), Hb < 12 g/dl (sensitivity 59.8%, specificity 56.2%, PPV 63.3%, NPV 71%) and ESR>30 mm/h(sensitivity 57%, specificity 71%, PPV 66%, NPV 68%). A three-step algorithm of TLC <2000 cells/mm^3, Hb<12 g/dl, and ESR>30 mm/h for predicting CD4 count<350 cells/mm^3 yielded sensitivity 66%, specificity 82%, PPV 72%, NPV 77% (area under curve AUC 0.79). This algorithm had a higher predictive accuracy making it a better tool than the use of TLC alone in monitoring disease progression in resource-limited settings.

Key words: Human Immunodeficiency Virus (HIV), haematologic parameters, surrogate markers.

INTRODUCTION

The World Health Organization (WHO) estimates that there were 36.9 million [34.3 million–41.4 million] people living with Human Immunodeficiency Virus (HIV) globally by the end of 2014. The burden of the epidemic continued to vary considerably between countries and regions. Sub-Saharan Africa remains the most severely

affected with 25.8 million [24.0 million–28.7 million] people living with HIV (UNAIDS, 2015). In Kenya, the HIV prevalence among adults between 15-64 years old is estimated to be 5.6% (Kenya Demographic and Heath Survey, 2015), having fallen from 6.3% in 2010.

The rapid expansion of antiretroviral therapy (ART) is one of the most remarkable achievements in recent public health history. Enormous progress has been made in the last eight years with the scale-up of ART in low and middle-income countries (Assefa et al., 2014). The aim of this scale up is to reach more people living with HIV and AIDS (PLWHA), who cannot easily access ART services in urban hospitals. CD4 count test is a gold standard test in determining those eligible for ART. The current guidelines development group recommend that national HIV programmes provide ART to all people with a confirmed HIV diagnosis with a CD4 count of 500 cells/mm^3 or less up from 350 cells/mm^3 (WHO, 2013).

However, there are several challenges to this plausible achievement. These include inadequate financial, equipment and human resources. For example, in Kenya, it is estimated that there are 100 machines for CD4 testing (FACSCount ® or FACSCalibre ®), of which only 35 are located in public health facilities (Githinji et al., 2011). The situation is worsened by breakdown of these machines which are costly to repair, and insufficient supply of reagents. Secondly, the transition from initiation of Highly Active Antiretroviral Therapy (HAART) from 350 to 500 cells per mm^3 has not been yet been implemented in Kenya. This transition would result in more patient enrolment for HAART when the donor funds supporting the initiative in Africa continue to dwindle (Mwenda et al., 2015).

In recognition of such challenges, the WHO proposed a public health approach with treatment guidelines for resource-limited settings. They proposed to support and facilitate those patients WHO Clinical stages II or III disease with Total Lymphocyte Count (TLC) of ≤1200 cells/mm^3, where CD4 lymphocyte count was unavailable (World Health Organization, 2006). TLC has been previously studied as a suitable surrogate for CD4 counts in the management of HIV. Several studies assessing the relationship between CD4 count and TLC have been done in sub-Saharan Africa (Githinji et al., 2011; Wondimeneh et al., 2012; Denue et al., 2013; Charles et al., 2014). These studies showed a significant correlation between TLC and CD4 count. However, the sensitivity and specificity of TLC as a marker of levels of CD4 count remains low, making TLC an imperfect predictor of CD4 count. Clinical algorithms that combine TLC with inexpensive laboratory data such as haemoglobin (Hb), Erythrocyte Sedimentation Rate (ESR) and Haematocrit (Hct) in predicting CD4 count, have been shown to increase the sensitivity of TLC (Spacek et al., 2003; Sen et al., 2011; Venkataramana, 2013). Such a clinical algorithm may be useful in settings where laboratory resources are limited to a complete blood count.

This study aimed at validating the use of TLC by raising the TLC cut-off, and determining the relationship between CD4 count and other haematologic parameters. Further, this study sought to ascertain if they can be used in an algorithm as a surrogate marker for CD4 count <350 cells/mm^3. This would provide a cheaper valid tool for monitoring of the immune process in HIV patients in resource-limited settings like Kenya. Provision of inexpensive alternative markers is of utmost urgency. This is especially so as Governments in sub-Saharan Africa prepare to take full control of HIV treatment programmes in their respective countries remembering that even with massive support from donors like PEPFAR, more than half of these countries still reported ART coverage of less than 50% as at 2010 (Mwenda et al., 2015).

MATERIALS AND METHODS

Study area and period

The study was conducted at the comprehensive care clinic of Thika Level 5 Hospital, Kenya, during the period of August 2013 to February 2014.

Target population and sample size

A prospective cross-sectional study was carried out to investigate a population of two hundred and fifteen HIV ARV-naive patients between 18-64 years attending the HIV clinic. All participating patients provided a written informed consent. Ethical approval for the study was granted by the Institutional Ethics and Research Committee and the Kenyatta National Hospital Ethical Review Committee.

Exclusion criteria

Patients presenting viral and bacterial infections as well as pregnant women were excluded from the study.

Laboratory analysis

The Beckman Coulter Automated Haematology Analyser was used to determine the complete blood count. The CD4 T-lymphocytes count was determined by the Becton Dickinson (BD) FACSCount system. The ESR was measured using Westergren method.

Data analysis

Categorical variables were described using percentages while continuous variables were described using the mean, median and Interquartile ranges (IQR). Statistical Package for Social Sciences (SPSS version 16, Chicago, IL, USA) and Stata (version 13.1) at 5% statistical level of significant were used to analyse the data. The spearman correlation coefficient was used to establish a correlation between the parameters and CD4 count to statistically assess significant predictors of CD4 count. Two by two tables were

Table 1. WHO clinical staging (WCS) and CD4 count categories of the study population.

Variables	CD4 Categories (mm^3)		Total
WCS	<350	>350	
I, II	111 (51.6%)	80 (37.2%)	191 (88.8%)
III, IV	22 (10.3%)	2 (0.9%)	24 (11.2%)
	133 (61.9%)	82 (38.1%)	215 (100%)

Table 2. Mean and standard deviation of CD4 count and haematologic parameters of the study population.

Variables	Mean ±SD
CD4 count (cells/mm^3)	295.4 ± 224.9
TLC (cells/mm^3)	1899.6 ±919.7
Hb (g/dl)	12.4 ±2.5
ESR (mm/h)	25.3 ±27.8
PLT(*10^9/L)	294.9 ±105.4
WBC (* 10^9/L)	5.5 ±2.2
RBC (*10^9/L)	4.5 ±0.8
HCT (%)	39.2± 7
MCV (fl)	85 ±9.5
MCH pg)	27.5± 15.9

constructed to determine sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the correlating parameters at different given cut-off points to predict CD4 count <350 mm/^{3}. These were used to compute receiver operating curves (ROC) so as to determine the predictive accuracy for each of the parameters and in the final algorithm.

RESULTS

Demographic and clinical characteristics of the study population

A total of 215 patients were included, among which 65.6% were females while 34.4% were males with a median age of 37 years (IQR 30, 42.5). The majority of the patients (88.8%) were in WHO clinical stage I and II and of these, 51.6% had CD4 count <350 cells/mm^3. Overall 61.9% of the patients demonstrated CD4 counts of 350 cells/mm^3 and less. A summary of the WHO clinical staging (WCS) categorized under the two CD4 count categories of therapy <350 and >350 cells/mm^3 is presented in Table 1.

Haematologic characteristics of the study population

The mean (SD) of CD4 count was 295.4 cells/mm^3 (±224.9), mean Hb 12.4 g/dl (±2.5) while the mean TLC

1899.6 cells/mm^3 (±919.7) (Table 2). Presentation of the other haematologic parameters (Haematocrit (Hct), ESR, Platelets (Plt), White Blood Cell (WBC) count, Red Blood Cell (RBC) count, Mean Cell Volume (MCV), Mean Cell Haemoglobin (MCH), Mean Cell Haemoglobin Concentration (MCHC)) are seen in Table 2.

Correlation between CD4 Count and haematologic parameters of the study population

After statistical analysis, some degree of correlation was found between CD4 count and TLC, Hb, Hct, ESR and RBC. There was no significant correlation between CD4 and MCH, MCHC, and platelets. A summary of the correlation is presented in Table 3. The diagnostic performance of each correlating variable in predicting TCD4+ cell counts of <350 cell/unit is shown in Table 4. Sensitivity, specificity, PPV and NPV at various cut-off points have been presented in the table. Cut-offs with high specificity had low sensitivity and vice versa. TLC of 1200 cells/mm^3 was found to be a poor predictor with specificity of 96.4% and low sensitivity of 12.4% while a TLC cut-off of <2000 mm^3 had maximized sensitivity and specificity (71.5 and 73.4% respectively). Overall, the variables with optimal sensitivity and specificity were TLC <2000 cells/mm^3, Hb <12 g/dl and ESR >30 mm/h. The variables with the best optimal cut-off point from this data

Table 3. Spearman's Rank Order Correlation of CD4 + T-Cells with Haematologic Parameters of the Study Population.

Variables	Spearman rank order correlation (r)	P value
TLC	0.3995	<0.001*
HB	0.2902	<0.001*
ESR	-0.2.948	<0.001*
PLT	0.0788	0.14
WBC	0.0951	0.1649
RBC	0.2607	<0.001*
HCT	0.2791	<0.001*
MCV	0.1029	0.1325
MCHC	0.1213	0.076
MCH	-0.0272	0.6918

Classification of correlation coefficient(r): upto 0.1: trivial correlation; 0.1-0.3: small correlation: 0.3-0.5; moderate correlation: 0.5-0.7; large correlation: 0.7-0.9; very large correlation: 0.9-1.0; near perfect correlation: 1.0; perfect correlation: *p value statistically significant.

Table 4. Validity and predictive value for Correlating surrogate markers of CD4 count<350 cells/mm^3 of the study population at given cut-off Points at 95% confidence interval.

Marker	Se	Sp	PPV	NPV
CD4Count<350				
TLC<1200 mm^3	12.4	96.4	60.3	58.5
TLC <1400 mm^3	27.7	86.6	61	59
TLC<1600 mm^3	43	73	58	62
TLC<1800 mm^3	58.6	56.3	65.3	68.8
TLC<2000 mm^3	**71.5**	**73.4**	**69.1**	**78.3**
TLC<2200 mm^3	69.3	48	62.4	49
Hb <8 g/dL	95	11.4	54.3	62.8
Hb<10 g/dl	36.1	78.1	62.5	54.4
Hb<12 g/dl	**59.8**	**56.2**	**63.3**	**62**
Hb >12 g/dl	12	78.9	77	53.7
HCT<30%	14.7	94.8	63.7	61.1
HCT<40%	19.3	88.4	67.4	48.6
HCT<50%	24	79.6	62	55.7
ESR>20 mm/h	81.2	21.3	58	39.9
ESR >30 mm/h	**57**	**71**	**66**	**68**
ESR>40 mm/h	55.2	63.3	11.1	52
RBC Count <2.5*10^{12}/L	34.6	75.4	64.2	52.4
RBC count <3.5*10^{12}/L	18	94	61	60

se=sensitivity, sp=specificity, PPV=positive predictive value, NPV=negative predictive value.

when both sensitivity and specificity were given equal weight were TLC ≤2000 cells/mm^3, ESR>30 mm/h and HB<12 g/dL. Therefore, a three-step algorithm was used to assess CD4 count of <350 cells/mm^3 (eligibility to HAART) comprising of the above three variables. The overall multivariable model of TLC<2000 mm^3, ESR>30 mm/h and Hb<12 g/dl constructed had a high specificity (82%) and fair sensitivity (66%) as seen in Table 5. The

predictive values of the individual parameters are lower than the optimal model. The area under curve (AUC) of this model was = 0.7926 (good) (Figure 1) better performing than that of TLC, Hb, and ESR individually.

DISCUSSION

According to the WHO guidelines for decision making in

Table 5. Sensitivity, specificity, PPV NPV and AUC of individual optimal parameters and the optimal diagnostic algorithm of the study population.

Marker	Se	Sp	PPV	NPV	AUC (%)
CD4Count<350					
TLC<2000 cells/mm^3	71.5	73.4	69.1	78.3	76
Hb<12 g/dl	59.8	56.2	63.3	62	69
ESR >30 mm/h	57	71	66	68	65
OPTIMAL MODEL (TLC <2000 cells/mm^3, Hb<12 g/dl, ESR>30 mm/h)	**66**	**82**	**72**	**78**	**79**
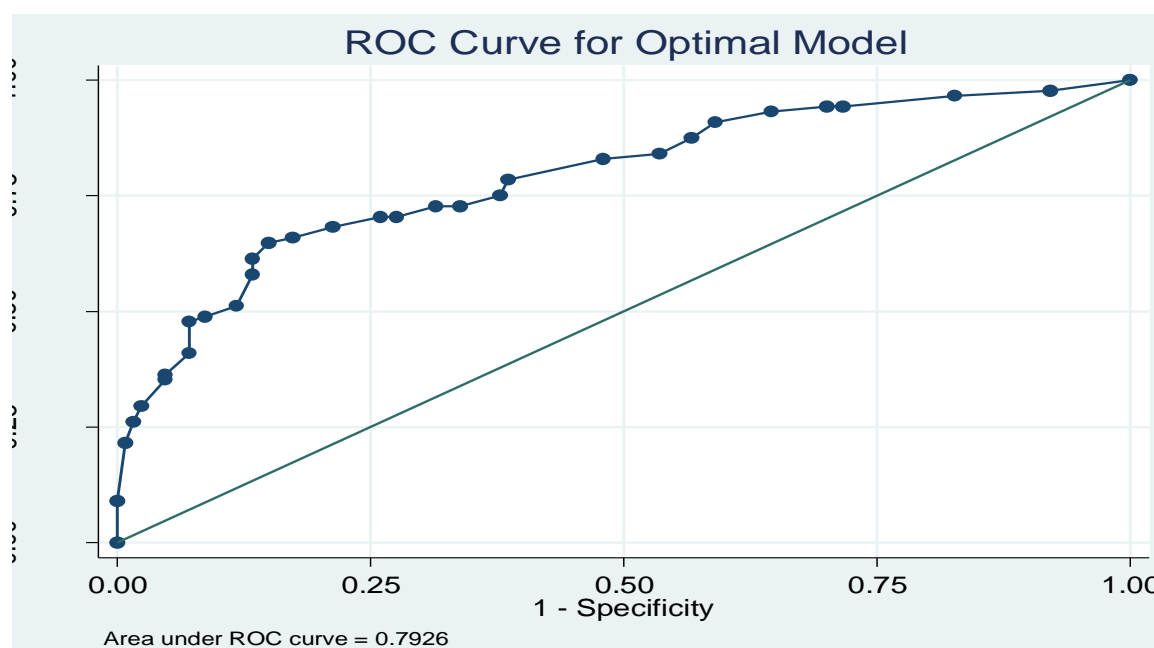
Figure 1. Receiver operator curve roc curve of the optimal diagnostic algorithm model of the study population.

HIV-infected patients, the scarcity of flow cytometry should not be a cause of delay for antiretroviral therapy while there is access to TLC and clinical staging of the patient (WHO, 2006). Currently, the WHO guidelines state that all HIV-positive patients should go onto ART immediately, regardless of the CD4 count status (WHO, 2013). However, in a resource-constrained setting like Kenya, this is not practical.

In trying to substitute a suitable model for resource-limited settings, this study examined the correlation between CD4 and TLC, and other essential haematologic parameters. The Mean±SD values of hematological parameters obtained in this study (Table 2) bore slight similarity with those from other African studies (Denue et al., 2013, Charles et al., 2014). However, CD4^{+} T cells value of 294.9±224 µL^{-1} obtained from this study was significantly higher than of the afore-mentioned studies. Haemoglobin and haematocrit also exhibited higher mean values.

As previously seen in the results section, there was a significant correlation between CD4 count and TLC (r=0.3995, p-value <0.001). This was almost similar to the value of r=0.494 reported by Denue in Nigeria in 2013. The correlation in this study between TLC and CD4 count was weaker than that observed in other studies in Kenya r=0.76 (Gitura et al., 2007), r=0.66 (Githinji et al., 2011), r=0.582 (Mwenda et al., 2015). One factor that could blunt the correlation between TLC and CD4 T cell count besides opportunistic infections, is that TLC captures both B and T cell subsets. Thus, a person with a low CD4 T cell count may show relatively high TLC if high amounts of B cells are expressed due to immune hyperactivation from exposure to the wide variety of circulating antigens, consequent on varieties of infections in HIV patients with severe immunosuppression (Denue et al., 2013).

At a TLC cut-off point of 1200 cells/mm^3, this study reported very low sensitivity (12.4%) and a specificity of

96.4% for predicting CD4 count of <350 cells/mm^{3}. A limited sensitivity result is an underestimation of disease prevalence (Spacek et al., 2003). The risk of false negative results in this study (87%), made TLC of less than 1200 cell/mm^{3} a relatively insensitive predictor of the CD4 cell count <350 cells/mm^{3}. This is in agreement with several other studies (Buseri et al., 2012; Denue et al., 2013; Venkataramana, 2013). On adjusting the TLC using different cut-off points, there was a balance between the detection of patients qualifying for HAART and the burden of over-classifying people as requiring treatment at <2000 cells/mm^{3} (sensitivity 71.5%, specificity 73.4%, PPV 69.1%), implying the ability to detect 7 in 10 patients in need of HAART. Similarly, a recent study by Mwenda in 2015 in Kenya, found a TLC cut-off of 2000 cells/ mm[3] to best predict CD4 500 cells/mm^{3} or less (sensitivity of 78.1%, specificity of 35.9% PPV 66.1%) concluding that TLC still retains some usefulness in detecting CD4 counts of less than 500 cells/mm^{3}. Nonetheless, most authors have recommended TLC with a higher cut-off be used in areas with limited access to CD4 count until a cheaper alternative is found (Karanth et al., 2014). Other studies have shown TLC to be an imperfect predictor of CD4 count (Charles et al., 2014).

Current study results showed a small significant correlation of Hb to CD4 count which correlated well with several studies in Africa (Obirikorang and Yeboah, 2009; Owiredu et al., 2011; Wisaksana et al., 2011). In this study, a cut-off point of 10 g/dl had very low sensitivity. This low sensitivity would misclassify many patients who had CD4 count <350 cells/unit. When the cut-off point was increased to 12 g/dl, the sensitivity and specificity increased though not exhibiting optimal values at a false negative rate of 42%, which is clinically unacceptable. These results clearly indicated that Hb alone should not be used as a surrogate marker. However, an Indonesian study showed a good correlation of anaemia with reduced CD4 cell counts which observed high specificity(77.48%) and accuracy in predicting CD4 cell counts<200 cells/mm^{3} (Wisaksana et al., 2011). A small weak correlation with Hct and RBC count was also observed consistent with Alavi in 2009 who demonstrated Hct was not a valid test for predicting CD4 count with 21% sensitivity. In his study, of sixty-two patients, 21 had Hct<30% and CD4<200 cells/µL whereas, 41 had Hct>30% and CD4>200 cells/µL. Of 38 patients, 24 had Hct>30%, but CD4<200 cells/µL, whereas 14 patients had Hct<30%, but CD4>200 cells/µL (Alavi et al., 2009). There was no correlation observed between RBC indices (MCH, MCHC and MCV) in this study. In contrast, in two different studies of RBC parameters and HIV, there was a significant decrease in RBC, RBC indices MCV and MCH (Obirikorang and Yeboah, 2009; Tagoe and Asantewaa, 2011). The results of this study exhibited no correlation of platelets to CD4 counts. This is in agreement with a study done by Omoregie in 2009 where the platelet count did

not differ significantly between those with CD4 count <200 cells/unit, and those with >200 cells/unit (Omoregie et al., 2009). Despite having a significant correlation with CD4 count, the diagnostic performance of ESR value of >30 mm/h in the current study was low with a false negative rate of 43%. In contrast, there was a raised ESR in a study done in Nigeria which correlated well with CD4 cell counts (accuracy 67.87%) and could predict CD4 counts<350 cells/mm^{3} making it suitable for use as a guide to the initiation of HAART (Ndakotsu et al., 2009). However, other studies showed no correlation between ESR and CD4 count (Morpeth et al., 2007; Sen et al., 2011).

Few studies have been done suggesting the use of different multiple parameters as surrogate markers for the CD4 count. The primary benefit of using these parameters in an algorithm is to increase the predictive accuracy of individual parameters in predicting CD4 count. This study developed a three-step algorithm using the three variables with best predictive accuracy (TLC, HB, ESR) which had a good predictive performance (79% accuracy) implying that this algorithm classified 8 out of 10 patients in need of HAART. Few studies have been done indicating similar, if not more convincing results on the use of algorithms to predict CD4 counts. Spacek in 2003 combined the use of TLC below 1200 cells/mm and Hb <12 g/dl which greatly increase sensitivity to 78% for men (specificity, 80%; PPV, 84%; NPV, 72%) and to 86% for women (specificity, 73%; PPV, 75%; NPV, 84%) (Spacek et al., 2003). Similarly, another study reported 91% sensitivity, 73% specificity, and 88% PPV for predicting a CD4 cell count of 200 cells/mm^{3} using a multivariate model with similar parameters (TLC, haemoglobin level, platelet count, and sex) than when TLC was used alone (Chen et al., 2003). The most recent study in Nigeria demonstrated optimal sensitivity at 96.0% (SP, 82.7%; PPV,80%; NPV,96.7%) with the use of multiple parameters, TLC1.2×103/µL, haemoglobin<10 g/dL, and platelets <150×103/L to predict CD4 count <200 cells/unit (Denue et al., 2013). In contrast, a study in Nigeria combined correlation of total lymphocyte count, haemoglobin and haematocrit with CD4 and concluded that haematological parameters are not suitable for representing CD count (Charles et al., 2014). There is scanty data on the use of an algorithm of parameters to predict CD4 count in resource-limited settings. Although the diagnostic performance of the algorithm in this study is not 100%, it can still be used in resource-limited settings with no cheaper or feasible alternatives.

CONCLUSION AND RECOMMENDATIONS

While most studies have used TLC alone to provide an alternative tool, this study enhanced the performance TLC by using other parameters in an algorithm to act as a

guide to make decisions on initiation of treatment of HIV patients. Our study provides a cheaper tool using inexpensive and easily available parameters to be used in resource-limited countries like in Sub-Saharan Africa where the governments are preparing to take full control of HIV treatment programmes. Further, larger studies need to be done to evaluate this algorithm to predict the new higher WHO treatment cut-offs of CD4 counts below 500 cells/mm^3 to meet the current guidelines for initiation of HAART.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Alavi S, Ahmadi F, Farhadi M (2009). Correlation between Total Lymphocyte Count, Hemoglobin, Hematocrit and CD4 Count in HIV/AIDS Patients. Acta Med. Iran 47:1-4.

Assefa Y, Alebachew A, Lera M, Lynen L, Wouters E, Wim VD (2014). Scaling up antiretroviral treatment and improving patient retention in care: Lessons from Ethiopia 2000-2013. BMC Health Serv. Res. 14:43-45.

Buseri F, Mark D, Jeremiah Z (2012).Evaluation of absolute lymphocyte count as a surrogate marker for CD4 cell count for the initiation of antiretroviral therapy in resource-limited settings. Int. J. Biomed. Lab. Sci. 1:44-49.

Charles IE, Shemaiah OO, Joshua OO, Emuchay CI, Okeniyi SO, Okeniyi JO (2014). Correlation Between Total Lymphocyte Count, Hemoglobin, Hematocrit and CD4 Count in HIV Patients in Nigeria. Pak. J. Biol. Sci. 17(4):570-573.

Chen R, Westfall A, Hardin J, Miller HC, Stringer J, Raper J, Vermund S, Gotuzzo E, Allison J, Saqq M (2003). Complete blood count as a surrogate CD4 marker for HIV monitoring in resource-limited settings.J. Acq. Immun. Def. Syndr. 44:525-530.

Denue BA, Abja AU, Kida IM, Gabdo AH, Bukar AA, Akawu CB (2013). Evaluating Total Lymphocyte Counts And Other Hematological Parameters As A Substitute For Cd4 Counts In The Management Of HIV Patients In Northeastern Nigeria. Retr. Res. Treat. 5:9-16.

Githinji N, Obimbo E, Nderitu M, Wamalwa D, Ngacha D (2011). Utility of total lymphocyte count as a surrogate marker for CD4 counts in HIV-1 infected children in Kenya. BMC Infect. Dis. 11:259.

Gitura B, Joshi M, Lule J, Anzala O (2007). Total Lymphocyte count as a surrogate marker for CD4+ T cell count in initiating antiretroviral therapy at Kenyatta National Hospital, Nairobi. East Afr. Med. J. 84:466-472.

Karanth SS, Rau NR, Gupta A, Kamth A, Shanbhoque V, Pruthvi BC (2014). Utility of total lymphocyte count as a surrogate for absolute CD4 count in the adult Indian HIV population: A prospective study. Avicenna J. Med. 4:1-4.

Kenya demographic and health survey (2015). Central Bureau of statistics (KNBS) Nairobi. pp. 89-91.

Mwenda V, Njuguna J, Musa M (2015). Efficacy of total lymphocyte count as a surrogate for CD4 cell counts in HIV-infected adults in the era of higher treatment cutoffs and less funding: A cross-sectional study. East Cen. Afr. Med. J. 2:84-88.

Ndakotsu M, Salawu L, Durosinmi M (2009). Relation between erythrocyte sedimentation rate, clinical and immune status in HIV-infected patients. Nig. J. Med. 18:208-210.

Obirikorang C, Yeboah FA (2009). Blood haemoglobin measurement as a predictive indicator for the progression of HIV/AIDS in resource-limited setting. J. Biomed. Sci. 16:102.

Omoregie R, Osakue SI, Ihemeje V, Omokaro EU, Ogefere H0 (2009). Correlation of CD4 count with platelet count, Prothrombin time and activated partial thromboplastin time among HIV patients in Benin City, Nigeria. West Ind. Med. J. 58(5)437-440.

Owiredu W, Quaye L, Amidu N, Addai-Mensah O (2011). Prevalence of anaemia and immunological markers among Ghanaian HAART-naïve HIV-patients and those on HAART. Afr. Health Sci. 11:2-15.

Sen S, Akshat V, Sunil S, Shanmuganandan K, Gupta R, Kapila B, Praharaj A, Kumar S, Batra R (2011). Correlation of CD4+ T-cell Count with Total Lymphocyte Count, Haemoglobin and Erythrocyte Sedimentation Rate Levels in Human Immunodeficiency Virus Type-I Disease. Med. J. Arm. Forces Ind. 67:15-20.

Spacek LA, Griswold M, Quinn TC, Moore RC (2003). Total lymphocyte count and hemoglobin combined in an algorithm to initiate the use of highly active antiretroviral therapy in resource-limited settings. J. Int. AIDS Soc. 17:1311-1317.

UNAID/WHO (2015). AIDS epidemic factsheet.

Venkataramana K (2013). A study of biological markers in HIV disease progression and management in the highly active antiretroviral therapy (HAART) era. Am. J. Biosci. Bioeng. 1:24-37.

Wisaksana R, Sumantri R, Indrati A, Zwitser A, Hadi J, Mast Q, Crevel R, Andre V (2011). Anemia And Iron Homeostasis In A Cohort Of HIV-Infected Patients In Indonesia: BMC Infect. Dis. 11:213.

Wondimeneh Y, Ferede G, Yismaw G, Muluye D (2012). Total Lymphocyte Count as surrogate marker for CD4 Cell Count in HIV-Infected Individuals in Gondar University Hospital, Northwest Ethiopia. AIDS Res. Ther. 9(1):21.

World Health Organization (WHO) (2006). Antiretroviral Therapy For HIV Infection In Adults And Adolescents: Recommendations For A Public Health Approach.

World Health Organization (WHO) (2013). Consolidated guidelines on the use of antiretroviral drugs for treating and preventing HIV infection: Recommendations for a public health approach. 2013 revision. Accessed April, 2015. Available at: http://www.who.int/hiv/pub/guelines/artadultguidelines.pdf

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