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Blood transfusion-transmissible malaria and its cost analysis in Hawassa regional blood bank, Southern Ethiopia

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Abstract

Background: Blood transfusion is an intervention used to save life particularly for those patients who survive only with receiving blood. Establishing effective diagnostic test menus concerning the screening of transfusion-transmissible infections in the blood banks play a vital role to safeguard recipients from transfusion-transmissible infections.

Objective: The aim of this study was to assess blood transfusion-transmissible malaria and its screening cost analysis in Hawassa regional blood bank, Hawassa, Sothern Ethiopia.

Methods: An institutional-based cross-sectional study was conducted from April to May 2018 among 414 voluntary blood donors. Each participant's blood sample was screened for most transfusion-transmissible infections using antigen/antibody tests, while rapid diagnostic test and microscopy were used for malaria screening and confirmation. In addition, the cost screening of transfusion-transmissible infections was calculated using activity-based costing method.

Results: The overall seropositivity of transfusion-transmissible infections was 7.0% and the positivity rate of hepatitis B virus, syphilis, and *Plasmodium falciparum* was 5.6%, 1.0%, and 0.5%, respectively. The cost per test of each transfusion-transmissible infection was US$5.04 for human immunodeficiency virus, US$4.61 for hepatitis B virus, US$5.11 for hepatitis C virus, and US$4.75 for syphilis, while the cost per test of malaria rapid diagnostic test was US$4.74 and this is comparatively lower than the cost per test of other transfusion-transmissible infections except for hepatitis B virus. In addition, total cost of laboratory incurred for transfusion-transmissible infections screening is estimated to be US$213,634.5 per year, while it becomes US$265,537.5 if the malaria screening cost is added. This means 19.54% of the total cost of laboratory incurred per year or US$51,903.

Conclusion: The positivity rate of malaria parasites among voluntary blood donors was 0.5%, and it might be increased if the study was conducted in high transmission seasons. A cost of malaria screening is comparatively lower than costs of other transfusion-transmissible infections except for hepatitis B virus. Therefore, the screening of malaria parasites should be considered as one of the test menus of transfusion-transmissible infections in blood banks, especially in malaria-endemic areas.

Keywords

Cost analysis, transfusion-transmitted infections, malaria, donors, blood screening, Hawassa blood bank

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Background

Malaria is a protozoan disease, and an infected female Anopheles mosquito is an intermediate host for *Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale*, and *Plasmodium malariae* species. In addition to the bite of an infected female Anopheles mosquito, malaria could also be transmitted through blood transfusion from malaria-infected donors' blood to recipients.[1] Besides, malaria parasite was reported as a transfusion-transmissible infection (TTI) for the first time in 1911.[2]

Blood transfusion is an intervention that is used to save patients' life for those who survive only with receiving

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blood; therefore, all donated blood in the blood banks should be screened for major TTIs like human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV), and syphilis. The screening of major TTIs requires the detection of antibodies, antigens, or the parasite itself.[3] Based on epidemiological evidence, the screening of malaria parasite, Chagas disease, and human T-cell lymphocytic viruses is also highly recommended to control further spread of these infectious diseases from donors to recipients.[4] Blood banks of most sub-Saharan countries utilize microscopic method for the diagnosis of malaria.[5] In addition, malaria rapid diagnostic tests (RDTs) are used as an alternative and cost-effective screening method when compared to other diagnostic approaches particularly in resource-limited African settings.[6]

World Health Organization (WHO) recommends malaria screening from blood donors who are living in malaria-endemic countries.[7] However, few blood bank centers in sub-Saharan Africa implemented malaria screening due to a lack of evidence about the economic feasibility of screening methods.[8] The screening of transfusion-transmissible malaria (TTM) from donors' blood requires the application of standard methods like microscopic detection and or rapid diagnostic kits in malaria-endemic areas.[6,9,10]

The overall 8-year prevalence of malaria in Sidama zone, Southern Ethiopia, was 21.8% with yearly declining trends of infection from 2010 to 2017: 54.6%, 42%, 28%, 22.7%, 18.7%, 12.7%, 9.0%, and 5%, respectively.[11] About 27.5% of blood donors in Cameroon,[12] 1% in Northern Ethiopia,[13] and 0.3% in Southern Ethiopia[14] were specifically infected with malaria. Concerning the diagnostic sensitivity, 168 of 187,564 blood donors were positive for malaria infection by enzyme-linked immunosorbent assay (ELISA), which means 0.089% of the total participants, while 164 of 187,564 (of the same samples) were positive by thick blood film microscopy, which means 0.087% of the total participants.[15]

Southern Ethiopia is one of malaria-endemic regions in Ethiopia, so blood donors might be more susceptible to the risks of malaria infection; yet, there is no established practice of malaria screening and still not comprised as one of the test menus in blood bank. Therefore, this study was aimed to assess TTM and its screening cost analysis in Hawassa regional blood bank, Hawassa, Southern Ethiopia.

Methodology

Study settings and study population

This institutional-based cross-sectional study was conducted from April to May 2018 among voluntary blood donors in Hawassa regional blood bank, Southern nations, nationalities, and people's region (SNNPR). The study was conducted in one of the malaria-endemic seasons in the study area. Hawassa regional blood bank was established in May 2013 with US$209,609.16 cost for building, and now it serves as a center for other blood banks that are found in the region. In addition, the blood bank supplies the donated blood to governmental as well as private hospitals that are found in Sidama zone, Gedio zone, Halaba zone, and other nearby sites in the region. The blood bank mainly performs the screening of major TTIs like HIV, HBV, HCV, and syphilis from donated blood before distributing to different public/private health institutions. Moreover, Southern Ethiopia is one of malaria-endemic areas in the country and donors come from such malaria-endemic locations, yet malaria screening is not practical in the blood bank as one of the test menus of TTIs.

Sample size and sampling procedure

Due to the absence of malaria prevalence rate among voluntary blood donors, the sample size was calculated using the assumption of 50% proportion by a single population proportion formula at a 95% confidence interval (CI)

$$n = \frac{(Z\alpha_{/2})^2 \times p(q)}{d^2} = \frac{(1.96)^2 \times 0.5(1-0.5)}{(0.05)^2} = 384$$

where n is the required sample size, $Z\alpha/_2$ (Z alpha over 2) is 1.96 at 95% CI, p is the proportion of malaria infection, q = 1 – p, and d is the marginal error (5%). In addition, a 10% non-response rate was considered and the final sample size was calculated to be 422.

All voluntary blood donors who came to the blood bank during the study period were eligible for the study using a convenient sampling technique. However, the blood donors incapable to donate due to different reasons based on the donation criteria were excluded from the study.

Assessments and measurements

Currently, replacement type of blood donation is not applicable in Ethiopia according to the national policy of blood bank and that is why the study included only voluntary donors who were eligible to donate blood as per blood bank criteria. The questionnaire and consent form were adopted from the national blood bank information sheet. In addition, socio-demographic status was obtained from the questionnaire of blood bank, and the result of TTIs was obtained from the laboratory logbook except for the results of malaria.

Malaria diagnosis using RDT and microscopic examination

Malaria screening and the result confirmation were done using RDT kits and microscopic examination for each donor, respectively. The CareStart™ Malaria HRP-2/pLDH(*Pf*/*Pv*) combo RDT kits (Access Bio, Inc., Somerset, NJ, USA) were used to screen malaria parasites. The RDT is an immunochromatographic test coated with monoclonal antibodies in two separate

bands to distinguish malaria-specific antigens. The one is histidine-rich protein-2 (HRP-2) antigen for detecting *Plasmodium falciparum* malaria and the other is plasmodium lactate dehydrogenase (pLDH) antigen for detecting *Plasmodium vivax* malaria. About 5 µL of each donor blood sample was added using a loop supplied with the kit. The test procedure and results of malaria test kits interpretation were done as per the manufacturer's directions. The presence of two visible bands (one in the test area and one in the control area) or three visible bands (two in the test area and one in the control area) indicates the presence of malaria parasite infection. However, only one visible line appears in the control area within 20 min if a test is negative for malaria parasite infection.

Both thick and thin smears from each donor"s blood were prepared in the same grease-free and clean microscopic glass slide and labeled properly. In addition, these thick and thin blood smears were allowed to air dry in a dustless and pest-free place. Then, thin smears were fixed with absolute methanol and stained with 10% Giemsa solution for 12–15 min using staining jars. Finally, *Plasmodium* species examination and identification were done using both thick and thin blood films by two laboratory technologists independently.

Cost analysis procedure

All direct variables and fixed costs were computed, and the fixed costs included the costs of building, equipment, and personnel salary, while variable costs included materials and the supply cost. The cost of plant assets was calculated by deducting the depreciation cost from the original cost of the asset, and the overhead cost was assigned using an appropriate allocation rate. Besides, the straight-line depreciation method was used to compute the current value or the book value of assets for the building of useful life. It was estimated for 50 years by engineers and it requires US$209,609.16 to build it. The useful life for all types of equipments was estimated based on biomedical engineers' information and the cost of purchasing, whereas the original cost of materials and equipment supplies was obtained from the respective voucher and based on the current study period market value (Table 1, Panel A). Moreover, the direct labor cost was the salary of laboratory technicians and technologists, while indirect labor cost was the salary of the chief executive officer (CEO), the cleaner, and the security guard. This direct labor cost was distributed for tests performed per month to get a salary per test (Table 1, Panel B).

The utility expense was computed by dividing the annual budget for 365 days of the year to get an estimated utility amount per day and distributed to the number of samples performed per day to get the utility cost per sample (Table 2, Panel A). In addition, the variable cost of each TTI includes materials and supplies which were used by each test incurred and this cost varies from one test to another. Furthermore, the variable unit cost was computed by dividing the total cost by the number of supplies or materials required per test (Table 2, Panel B).

Operational definition

- *Screening cost per test of each TTI*: it is the sum of fixed cost per test and variable cost per test of each TTI.
- *Screening cost per test of malaria*: it is the sum of fixed cost per test and variable cost per test of malaria.
- *Activity-based costing (ABC)*: it is a costing that provides decision-making information by computing the cost of a product/test by focusing on assigning the costs contributing to specific tests and by allocating overhead costs accordingly.[16]
- *Cost to be added for malaria screening/total malaria screening cost*: it is the total cost of laboratory minus total TTI screening cost.
- *Fixed costs*: these are costs that do not vary with the number of goods or services a company produces like building, equipment, and personnel salary costs.
- *Variable costs*: these are costs that fluctuate as the level of production or service changes like utility expense, materials, and supply costs.
- *Depreciation cost*: it is the physical deterioration of an asset over a period that spans several years.
- *Book value*: it is the current value of an asset after deducting the accumulated depreciation from the original cost of an asset.
- *Blood donation*: it refers to the process of collecting, testing, preparing, and storing blood and blood components.
- *Blood transfusion*: it is the procedure of transfer of blood or blood products from one person (donor) into another person's bloodstream (recipient).
- *Transfusion-transmissible malaria (TTM)*: it is a malaria infection caused by the transfusion of *Plasmodium species*–infected blood to recipients.
- *Overhead costs*: these are indirect costs that cannot be traced back to a specific product as well as ongoing administrative expenses.

Data quality assurance

RDT kits and microscopic examination quality assurance were managed according to the standard operating procedure (SOP) using both malaria-positive and -negative quality control samples. Malaria-positive and -negative patients' blood was taken from a nearby hospital to assess the agreements between RDT kits and microscopic examination. In addition, microscopic examination of blood films was maintained by double-blind examination using expert laboratory technologists.

Statistical analysis

Initially, all data were visually checked and entered into an excel sheet and then exported to the Statistical Package for Social Sciences (SPSS, version 20) for statistical analysis. Data were described using descriptive statistics, and the

Table 1. Cost plant asset and labor costs of Hawassa regional blood bank.

Panel A: Accumulated depreciation assets of Hawassa regional blood bank from 2013 to 2018

Asset	Life span in years	Cost	Accumulated depreciation year				Book value
			2014	2015	2016	2017	
Building	50	209,609.16	4192.18	8384.36	12,576.54	16,768.72	192,840.43
ELISA reader	7	1648.15	235.45	470.9	706.35	941.8	706.35
ELISA washer	7	1648.15	235.45	470.9	706.35	941.8	706.35
Autoclave	12	1055.55	87.96	175.3	263.88	351.85	703.7
Incubator	10	1037.04	103.70	207.4	311.1	414.8	622.24
Shaker	10	814.80	81.48	162.96	244.44	325.92	488.88
Micropipette	10	55.55	5.56	11.12	16.68	22.22	33.33
Water bath	10	1055.55	105.56	211.2	316.68	422.4	633.15
Centrifuge	7	740.74	74.07	148.14	222.21	296.28	444.46
Refrigerator	12	925.93	77.16	154.32	231.48	308.64	617.29
	12	1481.48	123.46	246.91	370.38	493.83	987.65

Panel B: Labor cost of Hawassa regional blood bank in 2018

Variable	A	B	C = (A*B)/30	D	E = C/D
Staffs salary	Salary per month (30 days)	No. of staffs	Salary per day	No. of samples per day	Salary per sample
Salary of CEO	371.26	1	12.37	30	0.41
Salary of lab technologist	298.4	3	29.84	30	0.99
Salary of lab technician	144.78	1	4.82	30	0.16
Salary of cleaner	42.67	3	4.27	30	0.14
Salary of security	42.67	4	5.69	30	0.19

ELISA: enzyme-linked immunosorbent assay; CEO: chief executive officer.
Cost assessment was done in US$; US$1 is equal to 27 Ethiopian Birr during the study period. "A" is the salary scale paid for 30 days (a 1-month salary in Ethiopia situation); salary per day = salary scale (A) × number of staffs (B) divided by 30 days for each row.

results were summarized as frequencies and percentages. In addition, the cost analysis was computed using ABC costing method.[16]

Results

Socio-demographic characteristics of the study participants

Totally 422 blood donors approached and of them, 414 (98.1%) were included in the study; 228 (55.1%) donors were females, 87.4% were students, and 51.9% of the donors aged 19–24 years (Table 3).

TTIs and the costs of laboratory tests

The blood bank annually performs 10,950 tests per type of infection (HBV, HIV, HCV, and syphilis) other than malaria, which means around 43,800 tests per year. The overall seropositivity of TTIs was 29 (7.0%). The positivity rate of HBV, syphilis, and malaria (*Plasmodium falciparum*) was 23 (5.6%), 4(1.0%), and 2(0.5%), respectively. However, the donors were seronegative for HIV, HCV, and other species of malaria infections. Both RDT kits and blood smears showed the same results for malaria parasite infection.

The current cost of the building (book value) was estimated to be US$192,840.43. Therefore, the building cost for each sample was calculated through dividing the book value by the total number of samples per year and it was found to be US$17.6. Subsequently, the building cost was distributed to all tests including malaria and it was US$3.52 per test. Other fixed costs of the equipments were calculated based on the utilized tests and most TTI screening shared equipments equally, and this cost was distributed for each TTI (Table 4).

The indirect cost, such as the salary of CEO and the supportive staff, was distributed for all TTIs including malaria and it was US$0.15 per test. The labor cost for each TTI per test was calculated to be US$ 0.44, while the estimated labor cost per test of malaria screening was calculated to be US$0.16. In addition, the utility expense for each TTI per test except malaria was US$0.0125 (0.05/4), while the variable cost per test was found to be US$0.73 for HIV, US$0.8 for HCV, US$0.3 for HBV, US$0.44 for syphilis, and US$0.86 for malaria. Moreover, the variable cost of

Table 2. The utility expense and variable costs of Hawassa regional blood bank, Hawassa, 2018.

Panel A: The utility expense of Hawassa regional blood bank					
Utility	Annual expense	Average expense	Expense per day	Test done per day	Utility per sample
Electricity	703.70	58.64	1.96	30	0.016
Water	555.56	46.30	1.54	30	0.013
Telephone	954.00	79.50	2.65	30	0.022
Panel B: The variable cost of Hawassa regional blood bank					
Materials and supplies	Quantity	Total cost		Quantity per test	Unit cost
RDT kit	25	21.60		1	0.86
HIV ELISA kit	96	70.00		1	0.73
HCV ELISA kit	96	77.00		1	0.80
HBV ELISA kit	96	28.80		1	0.30
Syphilis ELISA kit	96	42.00		1	0.44
EDTA tube	50	8.96		1	0.18
Micropipette tips	500	35.00		1	0.07

RDT: rapid diagnostic test; HIV: human immunodeficiency virus; ELISA: enzyme-linked immunosorbent assay; HCV: hepatitis C virus; HBV: hepatitis B virus; EDTA: ethylenediaminetetraacetic acid.
Cost assessment was done in US$; US$1 = 27 Ethiopian Birr during the study period. EDTA tube + micropipette tips unit cost was divided to 5 TTIs: 0.25/5 = 0.05, and the variable cost of the materials used for each TTI including malaria became US$0.05).

Table 3. Socio-demographic characteristics of blood donors who donated blood in Hawassa regional blood bank, Hawassa, Ethiopia, April–May 2018.

Variable	Frequency (N = 414)	%
Age (years)		
18	157	37.9
19–24	215	51.9
>25	42	10.1
Sex		
Male	186	44.9
Female	228	55.1
Address		
Hawassa	255	61.6
Dilla	47	22.2
Halaba	92	11.4
Yirgalem	20	4.8
Occupation		
Student	362	87.4
Employee	52	12.6

materials used for all TTIs per test including malaria was US$0.05(0.25/5). Therefore, the cost per test was US$5.04 for HIV, US$4.61 for HBV, US$5.11 for HCV, and US$4.75 for syphilis, while the cost per test of malaria was US$4.74, which is relatively lower than the cost per test of other TTIs except for HBV (Table 5).

Cost to be added for malaria screening

The total cost of laboratory incurred for the screening of TTI except for malaria was estimated to be US$21,3634.5 per year, while the cost becomes US$265,537.5 if malaria screening cost is included. This reflects the addition of US$51,903 in the total cost of laboratory incurred per year or 19.54% of the total cost (Table 6).

Discussion

Blood transfusion can be a life-saving technique, but it has risks of containing infectious and noninfectious agents. The infectious agents can be transmitted through transfusion easily and that is why all the donated blood requires the screening of major TTIs like HIV, HBV, HCV, and syphilis in the blood banks. In addition, based on the epidemiological evidence and endemic nature of the infection, the donated blood should also be screened for malaria particularly in endemic areas to prevent its transmission through transfusion.[3,4] However, the provision of adequately safe blood transfusion is a big challenge in developing countries including Ethiopia. That is why the WHO urges voluntary donation rather than the replacement one for minimizing the risks of TTIs.[4]

The current study indicated that the overall seropositivity of TTIs among voluntary blood donors was 7.0%. This is in line with the reports of previous studies that were conducted in different regions of Ethiopia: 7.0% in Yirgalem,[17] 7.06% in Dire Dawa,[18] 6.6% in Harari,[19] and 6% in Bahir Dar.[20]

On the contrary, the rate was lower than the reports of several studies conducted in Ethiopia and Africa settings like 12.4% in Eastern Ethiopia,[21] 11.5% in Jigjiga,[9] 12.6% in South Gondar,[22] 10.1% in Zambia,[23] 15.9% in Tanzania,[24] 18.9% in Ghana,[25] 26.2% in Cameroon,[26] and 19.3 % in Nigeria.[27] The findings of this study were also higher than the rates reported from Eritrea[28] and Namibia[29] which were

Table 4. The cost per test of fixed assets in Hawassa regional blood bank, Hawassa, 2018.

Assets	Book value	No. of days per year	No. of samples per day	Cost per sample	No. of tests share it	Cost per test
Building	192,840.43	365	30	17.6	5	3.52
ELISA reader	706.35	365	30	0.064	4	0.016
ELISA washer	706.35	365	30	0.064	4	0.016
Autoclave	703.7	365	30	0.064	4	0.016
Incubator	622.24	365	30	0.06	4	0.014
Shaker	488.88	365	30	0.04	4	0.010
Refrigerator	1604.94	365	30	0.14	4	0.040
Micropipette	33.33	365	30	0.004	4	0.002

ELISA: enzyme-linked immunosorbent assay.
Cost assessment was done in US$; US$1 is equal to 27 Ethiopian Birr during the study period.

Table 5. Total cost per test of each TTI in Hawassa regional blood bank, Hawassa, Ethiopia, 2018.

Test type	Building cost/test	Equipment cost/test	Indirect cost/test	Labor cost/test	Utility expense/test	Material cost/test	Variable cost/test	Total cost/test
HIV	3.52	0.14	0.15	0.44	0.0125	0.05	0.73	5.04
HCV	3.52	0.14	0.15	0.44	0.0125	0.05	0.80	5.11
HBV	3.52	0.14	0.15	0.44	0.0125	0.05	0.30	4.61
Syphilis	3.52	0.14	0.15	0.44	0.0125	0.05	0.44	4.75
Malaria	3.52	_	0.15	0.16	_	0.05	0.86	4.74

TTIs: transfusion-transmissible infections; HIV: human immunodeficiency virus; HCV: hepatitis C virus; HBV: hepatitis B virus; RDT: rapid diagnostic test; EDTA: ethylenediaminetetraacetic acid.
Cost assessment was done in US$; US$1 is equal to 27 Ethiopian Birr during the study period. Utility cost: malaria RDT diagnosis does not require utility and equipment, so the expense was distributed to the rest of four TTIs. Material cost is the cost of EDTA test tube and micropipette, which was 0.25/5 = 0.05. The number of donors was assessed in the blood bank for averaging the number of daily donation and the average was 30 per day, 10,950 per year, 10,950 tests required for each TTI, and 43,800 tests per year for all TTIs except for malaria. A cost pertest was calculated by the summation of variable cost and fixed cost. Building (book value) was estimated to be US$192,840.43; the allocation of this cost per test = 192,840.43 / (10,950 × 5 types of TTIs) = 3.52 for each including malaria. Equipment cost was estimated to be US$5943.4; the allocation of this cost per test = 5943.4 / (10,950 × 4 types of TTIs) = 0.14 for each because malaria RDT does not require equipments. In addition, similar manner was applied to calculate other types of cost per test.

Table 6. Costs of each TTI and a cost to be added for malaria screening in Hawassa regional blood bank, Hawassa, 2018.

Type of tests	Fixed cost per test	Fixed cost/year	Variable cost per test	Variable cost/year	Total cost/year
HIV	4.31	47,194.5	0.73	7993.5	55,188
HCV	4.31	47,194.5	0.8	8760	55,954.5
HBV	4.31	47,194.5	0.3	3285	50,479.5
Syphilis	4.31	47,194.5	0.44	4818	52,231.5
Malaria	3.88	42,486	0.86	9417	51,903

Costs	Total fixed cost/year	Total variable cost	Total cost/year
Estimated cost of the lab per year (without including malaria screening cost)	188,778	24,856.5	213,634.5
Total cost of the lab per year (with including malaria the screening cost)	231,264	34,273.5	265,537.5
A cost to be added for malaria screening per year	42,486	9417	51,903

TTIs: transfusion-transmissible infections; HIV: human immunodeficiency virus; HCV: hepatitis C virus; HBV: hepatitis B virus.
Total cost of the lab = total fixed cost + total variable cost.
Total fixed cost = book value of assets + labor cost.
Variable cost = utility expense + material and supplies cost.
Variable cost per year for each type of test = (variable cost per test × 30 tests/day × 365 days/year).
Fixed cost per year for each type of test = (fixed cost per test × 30 tests/day × 365 days/year).

3.6% and 1.4%, respectively. The variations could be attributed to differences in the studies' sample size, geographical locations for the disease distribution, donation type (replacement or voluntary), the study design, and behavioral condition of the population across locations. In addition, the sensitivity and specificity levels of the diagnostic kits might have a contribution to the variations of seropositivity rates between the studies.

Studies conducted in different regions of Ethiopia revealed different seropositivity rate of HIV and HCV: 1.24% and 0.96% in Dire Dawa,[18] 0.5% and 0.6% in Bahir Dar,[20] 2.6% and 4.2 % in South Gondar,[22] and 1.4% and 1% in Eastern Ethiopia.[21] On the contrary, we found that none of the blood donors were positive for HIV and HCV. Both voluntary and replacement type of donations were involved in the depicted studies, while only voluntary blood donors were included in the current study and this might be a reason for the rate inconsistency between the studies.

The current study indicated a 5.6% seropositivity rate of HBV infection. Similarly, the study conducted by Negash et al.[22] indicated that 5.8% of the blood donors were infected with HBV in 2019. However, the finding was lower than the rate reported from different African countries: 10.5% in Ghana,[30] 10.6% in Mozambique,[31] 10.9% in Nigeria,[32] and 8.8% in Tanzania.[24] The tradition of society, the geographical distribution of disease-causing agents, and individuals' sexual behaviors might be the plausible factors for the variations.

We found 1.0% seropositivity rate of syphilis and this was almost comparable with the rate reported by Shiferaw et al.[20] from Bahir Dar, Awan et al.[33] from Islamabad, and Siraj et al.[28] from Eritrea, which were 1.2%, 0.75%, and 0.6%, respectively.

The rate of malaria in this study was 0.5%. This finding is comparable with the study reported from Bangladesh,[34] which was 0.76%. However, the rate was higher than the two studies conducted in Pakistan, which were 0.02%[33] and 0.07%.[35] The variation might be attributed to differences in malaria diagnostic methods between the studies, seasonal situations for mosquito breeding, and malaria outbreaks. Our study finding indicates around 50 individuals per 10,000 blood donors will be infected with malaria parasites if the blood transfusion was done without malaria screening. In other expression, about 50 individuals per 10,000 recipients have a probability to be infected with malaria parasites through unscreened blood transfusion. This may increase the risks of comorbidity with malaria infection. In addition, the outcome of such transfusion might lead to bad consequences such as fatality in pediatric and gynecology cases which may occur unknowingly due to the high susceptibility rate of infections.

This study indicates the same result for malaria infections using both RDT kits and microscopic examination and the finding is comparable with the study reported by Torresa et al.[36] The current study indicates the cost per test of malaria RDT is about US$4.74, which is relatively lower than the cost per test for other TTIs except for HBV. Most studies suggested that RDT is cost-effective when compared to microscopic examination and expected to be cost-effective when compared to presumptive diagnosis.[37–39] In addition, the study from Afghanistan indicated the cost-effectiveness of RDT kit utilization in resource-limited areas.[37] Moreover, malaria RDTs are a potential alternative when compared to both clinical assessment and microscopic diagnosis, and it is easier to diagnose, needs limited training, and has high accuracy.[37,40–43] In support, poor performance of routine microscopy has been widely known, even in developed countries,[44] and high investment assets of microscopy make it more costly than RDT in areas where malaria infection is very low.[45]

The current study indicates about US$51,903 of an estimated cost or 19.54% of the total cost of the laboratory incurred per year to be added if malaria screening cost is considered. In addition, this cost is somehow lower than the costs of other TTIs except for HBV; and malaria screening from blood donors is vital if it could be comprised as one of the test menus in a blood bank. However, the lower cost per test for malaria was reported from Kenya and the computed cost per test for malaria screening was US$0.03.[46] The cost variations might be attributed to materials accessing opportunities, inside the production of diagnostic supplies, and the period of the studies conducted.

Limitations of the study

First, we only analyzed the cost of RDT kits that was one of malaria screening methods and the costs of alternative malaria screening methods like microscopic diagnosis, ELISA, and polymerizing chain reaction (PCR) were not assessed. Second, this study used a convenient sampling technique, which is a non-probability sampling technique for participants' inclusion and it might be exposed to the effect of outliers. Third, this study was conducted in a moderate malaria transmission season, but the increased rate might be observed if the study was conducted during a high transmission season, which means from October to January. Regardless of the described limitations, this study eventually adds helpful information concerning the rate of TTM in the limited data situation of African countries including Ethiopia.

Conclusion

The cost to be added for malaria screening is 19.54% of the laboratory incurred per year, and the cost per test for malaria RDT is relatively lower than the total screening cost per test and the cost per test of other TTIs except for HBV. In addition, a 0.5% of malaria positivity rate was observed in one of the malaria transmission seasons in the study site. However, this rate might be increased if the study was conducted during a high transmission season, which means from October to

January. Still, malaria diagnosis is not applicable in the blood bank as one of the TTI test menus, and this might expose individuals for the receipt of malaria parasites through malaria parasite–infected blood transfusion. Therefore, the diagnostic efforts should be done to avoid TTM through dedicated malaria screening among blood donors mainly in malaria-endemic areas and its screening should be incorporated in the blood bank protocol for the benefit of blood recipients and the donors as well. Moreover, the cost analysis that is untaken in this article suggests the utilization of RDT kits in terms of cost-effectiveness and its suitability to screen malaria infection.

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Author contributions

All listed authors participated in this project. K.D. conceptualized the idea of this work; S.T. contributed to study design, data collection, and data analysis; K.D., F.H., and Z.A. were advisors throughout the project; and A.T.H. contributed to manuscript preparation, compulsory analysis, and appraisal. All authors read and approved the final version of the manuscript.

Declaration of conflicting interests

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Availability of data and materials design

The authors declare that all important data are fully described in the manuscript.

Ethical approval

Ethical approval was obtained from departmental research and ethical review committee of Addis Ababa University, Department of Medical Laboratory Science (AAU/March-2018). Following this, an official support letter was submitted to Hawassa regional blood bank.

Informed consent

Written informed consent was obtained from all participants before the study. All the study participants were well informed about the procedure of the study, and confidentiality of the data was well kept.

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