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Prevalence and incidence of transfusion-transmissible infections among blood donors in Malawi: A population-level study

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Abstract

Background: Voluntary non-remunerated blood donors (VNRBDs) are essential to sustain national blood supplies. Expanding testing capacity for the major transfusion-transmitted infections (TTI) is crucial to ensure safe blood products. Understanding trends in TTIs can inform prioritisation of resources.

Methods: We conducted a retrospective cohort data analysis of routine blood donation data collected from VNRBDs by the Malawi Blood Transfusion Service from January 2015 to October 2021. Variables included age, occupation; and screening results of TTIs (HIV, Hepatitis B and C, and syphilis). We estimated both prevalence and incidence per person-year for each TTI using longitudinal and spatial logistic regression models.

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AUTHOR CONTRIBUTIONS

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CONFLICT OF INTEREST STATEMENT

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Results: Of the 213 626 donors, 204 920 (95.8%) donors were included in the final analysis. Most donors (77.4%) were males, baseline median age was 19.9 (IQR 18.0, 24.1), 70.9% were students, and over 80.0% were single at first donation. Overall TTI prevalence among donors was 10.7%, with HBV having the highest prevalence (3.4%), followed by syphilis (3.3%), then HIV (2.4%) and HCV (2.4%). Incidence per 1000 person-years for syphilis was 20.1 (19.0, 21.3), HCV was 18.4 (17.3, 19.5), HBV was 13.7 (12.8, 14.7), and HIV was 11.4 (10.6, 12.3). We noted geographical variations with the northern region having lower rates of both prevalence and incidence compared to central and southern regions.

Conclusion: The individual TTI prevalence and incidence rates from this study are consistent with Southern African regional estimates. By identifying geographical variations of TTI prevalence and incidence, these findings could potentially inform prioritisation of blood collection efforts to optimise blood collection processes.

Keywords

blood transfusion; BLOODSAFE Project; cohort data analysis; incidence; prevalence; spatial modelling; transfusion transmissible infections

1 | INTRODUCTION

The World Health Organisation (WHO) is credited for expanding blood transfusion services in the last two decades.[1] This has led to an increased recruitment of voluntary donors and also improved and expanded testing capacity for the major transfusion-transmitted infections, especially in developing countries in Africa. Many transfusion safety studies indicate that the rates of transfusion transmissible infections (TTIs) among donors still remain high.[1–3] With high rates of TTIs, there is a need to conduct targeted blood donation campaigns to minimise exclusions of blood units.

Despite an increase in implementing regionally coordinated training initiatives, and adopting tiered accreditation process, a general decline in funding over the last decade for transfusion safety has strained the sustainability and further improvement of blood transfusion-related services in Africa.[4–6]

In Malawi, the Malawi Blood Transfusion Service (MBTS) is leading the effort to provide safe blood products for the entire country by collecting blood from voluntary non-remunerated donors (VNRBDs), and ensures quality screening for TTIs. Since its inception 2004, MBTS has not been able to meet the annual national demand which is currently estimated at 120000 blood units.[7] Therefore, several hospitals continue to supplement or rely entirely on blood units collected from replacement donors.[8] MBTS has collected up to 50% of the estimated annual blood collection.

Volunteer donors are the cornerstone of the program and strategies to promote regular donation practices are pursued to ensure a steady blood supply. Currently, MBTS hosts community engagement events promoting blood donation, maintains >1000 regular donors, and benefits from significant uptake of donation by secondary school students through school programs. Proper evaluation and use of routinely collected program data has

helped to improve expanded programs, such as HIV prevention and treatment programs in sub-Saharan Africa (SSA), despite the challenges with data completeness.[9,10] An earlier epidemiological evaluation of the MBTS blood donor database was conducted using data covering the period 2011–2015. This evaluation is now old, did not include spatial analysis and only considered prevalence and not incidence of TTIs.[11] Therefore, to further support surveillance of TTIs, we conducted a comprehensive evaluation of epidemiology of HIV, syphilis, hepatitis B and C using routinely collected blood donation data to assess TTI prevalence and incidence over the past 7 years among blood donors in Malawi.

2 | MATERIALS AND METHODS

2.1 | Subjects studied

We conducted a retrospective cohort data analysis of routine blood donation data collected by the MBTS from January 2015 to October 2021. The study population was all voluntary nonremunerated blood donors who donated blood at a MBTS facility or MBTS sponsored blood drive in the period from January 2015 to October 2021. The exclusion criteria for blood donation are extensive and include, among others, health requirements; restrictions on those who engage in behaviour that increase risk for TTIs; age requirements (16–65 years); past medical history suggestive of HIV, hepatitis or syphilis; past or present history of renal, cardiovascular, central nervous system and metabolic disorders such as insulin dependent diabetes; haemoglobin below 12.5 g/dL and weight below 42 kgs. Only individuals who satisfied the national blood donation eligibility criteria were accepted as blood donors, allowed to donate blood and were therefore included in this study.

2.2 | Ethics statement

This study was approved by the National Health Sciences Research Council (NHSRC (Protocol #:20/07/257). It was conducted as part of the BLOODSAFE Project being implemented in Malawi, Kenya and Ghana. The NIH-established Data Safety and Monitoring Board (DSMB) and the Data Coordinating Center (DCC) at University of Minnesota approved the protocol and monitored the study progress.

2.3 | Data collection procedures and management

MBTS captures and enters individual-level data, with every donor assigned a unique identification number that is used at subsequent donation visits. Blood donation data collected by MBTS are entered and stored in the MBTS database and all donations made by each donor are uniquely identifiable and linked to each donor for that particular donation visit.

The following data elements were collected and included analysis: donor identifier, donation date, sex, date of birth, marital status, donation location, donation district, occupation, and results from tests for TTIs (HIV, Hepatitis B and C and syphilis). Districts are the primary subnational administrative units and are collected from a fixed list, hence these were used for all spatial analyses (we have data for 28 districts). Other variables were derived from these variables such as categorization of whether the donor is a first-time donor (FT) or is a

repeat regular donor (RPT); and whether there was TTI seroconversion among repeat/regular donors.

Data were extracted as a comma separated values (CSV) file and was imported into R Software for further cleaning, management and preparation before being analysed in R Software. During data cleaning, we removed duplicate records and excluded any donation record that had inconclusive test results for any of the four TTIs under consideration. Donors who had reactive results during the previous visit were not allowed to donate again. For data cleaning purposes, we removed any donation record that was made after a positive TTI result to avoid two or more positive results for the same TTI. In addition, we removed any record or donor without any testing result. After this data cleaning process, 344 622 unique donation records from 204 920 unique donors (96% of original data) were retained for analysis.

2.4 | Laboratory testing

HIV serology was done using Green screen ULTRA HIV antigen–antibody enzyme immunoassay (EIA) reagents (Bio-Rad, France) via the Evolis semi-automated platform. From August 2015, supplementary testing with Determine antibody rapid test kits (Allere, Japan) was added for those found positive with the EIA algorithm but in 2016 the EIA reagents were replaced with chemiluminiscence immunoassays from Abbot (Germany) on the Architect i2000 platform.

HBV serology was done using Monalisa HBsAg ULTRA EIA (Bio-Rad, France) reagents detecting HBV surface antigen (HBsAg) on the Evolis semi-automated platform were used until the last quarter of 2016 calendar year when they were replaced with CLIA Abbott (German) reagents (detecting the same markers) on the Architect i2000 platform.

HCV serology was done using Monalisa anti-HCV EIA (Bio-Rad France) antibody reagents on the Evolis semi-automated platform were used until the last quarter of 2016 calendar year where they were replaced with chemiluminiscence Immunoassays Abbott (Germany) anti-HCV reagents on the Architect i2000 platform.

Syphilis serology was done using Bio-Rad (France) manual Treponema Pallidum Haemaglutination Assay (TPHA) reagents. Micro plates were used until the last quarter of 2016 calendar year when they were replaced with chemiluminiscence immunoassays from Abbott (Germany) reagents detecting the same markers on the Architect i2000 platform.

All the algorithms for testing HIV, HBV, HCV and syphilis involved repeating in duplicate all initial positives and interpreting results based on the concordant two of the three. Concordant TTI reactive results were then used to calculate seroprevalence and incidence.

2.5 | Statistical analysis

Descriptive analyses were conducted for donor characteristics, including age in years, sex, first-time donation status, repeat donor status, marital status, occupation and district (of first donation). For consistency, First-time (FT) donors were defined as those with only one donation record in the dataset. Repeat (RPT) donors were defined as those with two or more

donations during the study period. For data summaries, we used counts and percentages for binary and categorical variables, and medians (with first and third quartiles) for continuous variables. The frequencies and percent of missing or unknown data were also presented for each characteristic.

Seroprevalence was determined as the proportion of individual blood donors who tested reactive among all donors tested for each of the four TTIs. A binary response was constructed for each individual TTI (HIV, HCV, HBV and syphilis) and overall TTI reactivity was considered if any individual TTI was reactive. To determine annual prevalence for each TTI and for overall TTIs respectively, we estimated the seroprevalence for each individual TTI (HIV, HCV, HBV and syphilis) and for overall TTIs and their corresponding 95% confidence intervals for each year.

To determine factors which are predictive of TTI test outcome, multiple logistic regression models were fit that accounted for donations coming from the same donor using an independence correlation structure and generalised estimating equations. These models were fit to all donations. The models included fixed effects for age (categorised into three levels: 16–25, 26–35 and over 35), sex, student status, marital status (categorised as single, married and other), year of donation, and district where the donation took place. In the model, the reference points were chosen as follows: a category with a smaller n was chosen as reference for age, sex, student status except for marital status where we wanted to compare between *married* and *single*; while for calendar year, the first year was chosen and for a district, the district at the centre of the country was chosen.

To estimate the prevalence of each TTI and any TTI overall, spatial logistic regression models were fit to the district level TTI rates which averaged over all years. The spatial component was modelled using a stationary isotropic exponential correlation function. The centroids of the 28 districts in Malawi were computed and used to measure the spatial proximity (and therefore the correlation) of geographical regions. Parameter estimates were obtained using Monte Carlo maximum likelihood.[12] These models were used to predict the prevalence in each district and 95% confidence intervals (CIs) were produced to summarise the uncertainty of the estimates. The PrevMap package for R was used to estimated prevalence.[12]

We also defined seroconversion as new case of TTI reactivity for an individual donor after returning a nonreactive result in the previous donation visit. We estimated the incidence of each TTI as well as overall incidence for each district using a Poisson regression model. Incidence was defined as the number of new seroconversions per 1000 Person-Years (PYs). For categorical variables, we fitted survival models and used a logrank test (*survival package*) to compare the number of seroconversions. For each TTI (HIV, HCV, HBV and syphilis), maps were used to plot both crude and spatially-smoothed estimated incidence at the district-level in order to highlight districts with higher and lower incidence.

Less than 5% of the data records were missing and were dropped from the final analyses using complete-case analysis. All analyses were conducted with the statistical software package R using the following packages: *rgeos*, *rgdal* and *geoR* for manipulation of spatial

objects in R, *PrevMap* package for geostatical modelling, and *ggplot* package for plotting. We also reported 95% CI for each estimate and assessed significance of results using $p < 0.05$.

3 | RESULTS

3.1 | Characteristics of blood donors

Of the 213 626 donors who donated over the 7-year period, data for 204 920 (95.8%) donors were included in the final analysis. Among the 204 920 donors, 77.4% were males, and 30.4% donated twice or more (Table 1). At baseline, median age was 19.9 (IQR 18.0, 24.1), 70.9% were students, and over 80% of donors were single.

3.2 | Trends over time in the number of blood donations

The number of donations were at peak during school calendar months. The number of donations varied over time from a low of 21 520 (18% of national need) in 2016 to a high of 62 717 (52% of national need) in 2019 (Table 2), with the proportion of first-time donors increasing from 11.3% in 2015 to 18.1% in 2018 but later decreased to 14.6% in 2020 (Table 1). Donations were lower during the years of the COVID-19 pandemic with a 16% reduction in 2020 compared to 2019. The number of donations improved from 2020 to 2021 but was still down 10% from the peak in 2019 (Table 2).

3.3 | Epidemiology of any TTI

The overall TTIs seroprevalence among donors was 10.7%, with hepatitis B (HBV) having the highest prevalence (3.4%; 95% CI: 3.3, 3.5), followed by syphilis (3.3%; 95% CI: 3.2, 3.4), HIV (2.4%; 95% CI: 2.3, 2.4) and hepatitis C (2.4%; 95% CI: 2.3, 2.4). The incidence per 1000 person-years for HIV was 11.4 (95% CI: 10.6, 12.3), HBV was 13.7 (95% CI: 12.8, 14.7), hepatitis C (HCV) was 18.4 (95%CI: 17.3, 19.5), and syphilis was 20.1 (95% CI: 19.0, 21.3).

The prevalence of reactive tests for overall TTIs decreased over time (Table 2). The highest rate was in 2017 with 8.6% of donations testing reactive and the lowest rate was in 2021 with 4.9% of donations testing reactive. Males had significantly higher rates than females (OR = 1.18, 95% CI: 1.13, 1.23) and students were less likely to test reactive than non-students (OR = 0.59, 95% CI: 0.56, 0.61). Married donors were more likely to test reactive than single donors (OR = 1.08, 95% CI: 1.03, 1.14). Repeat donors had significantly lower risk of TTI reactivity compared to one-time donors (age and sex adjusted OR: 0.45, 95% CI: 0.43, 0.46).

The mean prevalence of all TTIs varied between districts from 3.8% (Chitipa in the northern region) to 13.7% (Kasungu in central region). The geostatistical model performed very little smoothing. The estimated prevalences from the geostatistical model varied from 4.8% (Chitipa, 95% CI: 3.7%–6.0%) to 13.0% (Kasungu, 95% CI: 10.7%–15.4%) as seen in Table 3.

Overall, 3635 seroconversions of any TTI were observed among 62 367 donors over 59133.1 person-years (PYs), resulting in a cumulative incidence rate (CIR) of 61.5 (59.5, 63.5) per

1000 PYs. There was some smoothing by the spatial model but it did not change the overall distribution of mean district-level TTI incidence, which was highest in Mchinji (102 per 1000 PYs), Kasungu and Nkhota-kota (in central region) and Mwanza, Neno (in southern region) and lowest in Chitipa (CIR of 22 per 1000 PYs). For all four TTIs, the northern region had lower incidence rates compared to other regions (Figure 2). The overall TTI incidence rate was higher in male and non-student donors, and decreased with increasing age (Table 4).

3.4 | Prevalence and Incidence of HIV among blood donors

The prevalence of HIV among donors varied over time with a high of 2.6% in 2017 and a low of 1.4% in 2021 with no consistent trend. Results from multiple logistic regression models indicate that donations from those who were aged 16–25 were less likely to test reactive for HIV than those aged 26–35 and the age group of those over 35 (OR = 0.79, 95% CI: 0.70, 0.89). Also, students were significantly less likely to test reactive for HIV compared to non-students (OR = 0.55, 95% CI: 0.51, 0.61). However, there was not a significant difference between male and female donors (OR = 0.97, 95% CI: 0.89, 1.04), and also no significant difference between those who were single compared to those who were married (OR = 1.09, 95% CI: 0.99, 1.20).

The mean district-level prevalence of HIV over the study period varied from 1% (Chitipa) to 2.9% (Mchinji, Blantyre, Zomba). The geostatistical model did very little smoothing of the district level prevalences (see Figure 1). The estimated prevalences from the geostatistical model varied from 1.1% (Chitipa, 95% CI: 0.8%–1.4%) to 2.9% (Blantyre, 95% CI: 2.7%–3.0%, and Mchinji, 95% CI: 2.4%–3.3%) as seen in Table 3. HIV prevalence varied significantly by district.

The mean district-level HIV incidence rate was 11.4 per 1000 PYs (10.6, 12.3), with a total of 675 new HIV seroreactive cases among donors who donated more than once during the study period. The spatial smoothing did not change the pattern, with seroconversion (incidence) rates higher in Mwanza (in the south), Ntchisi, Salima and Dowa (in central region), and lowest in Nkhata-bay and Karonga in the north (Figure 2).

3.5 | Prevalence and incidence of hepatitis B among donors

The prevalence of hepatitis B among donors steadily declined from 3.4% in 2015 to 1.5% in 2021. While the multiple logistic regression model did not identify a difference in the years immediately after 2015, all years from 2018 forward had significantly lower prevalence rates than in 2015. There was no difference in terms of age but donations from males had a significantly higher odds of testing reactive (OR = 1.37, 95% CI: 1.28, 1.47). Donations from students were less likely to test reactive (OR = 0.66, 95% CI: 0.61, 0.72). Donations from married donors were more likely to test reactive than from single donors (OR = 1.12, 95% CI: 1.03, 1.22).

The mean district-level prevalence of hepatitis B over the study period varied from 1.5% (Chitipa) to 5.2% (Salima). In contrast to what was observed with HIV, the geostatistical model performed extensive smoothing and detected 2 major regions: a region of low prevalence in the north and a region of higher prevalence in the south (Figure 1). The

estimated prevalences from the geostatistical model varied from 2.6% (Chiptia, 95% CI: 2.0%–3.1%) to 3.6% (Machinga, 95% CI: 2.9%–4.2% and Salima, 95% CI: 2.9%–4.2%) as seen in Table 3. All of the 95% prediction intervals overlapped indicating that after adjustment for spatial proximity there are no significant differences among the districts in hepatitis B rates.

A total of 809 new cases of hepatitis B were observed during the study period. The mean district-level incidence rate of hepatitis B was 13.7 per 1000 Pys (12.8, 14.7). The spatial smoothing removed the initial geographical patterns observed in crude estimates (Figure 2).

3.6 | Prevalence and incidence of hepatitis C among blood donors

The prevalence of hepatitis C among donors varied over the study period with the lowest level of 0.9% in 2015 and a peak of 2.7% in 2018. While there was a significant decline to 2.0% in 2019, 2.5% tested reactive in 2020. This returned to the low level of 1.3% in 2021. In multiple logistic regression models, many of these year to year differences were significant. These models also identified a significantly higher rate among those 16–25 compared to those over 35 (OR = 1.42, 95% CI: 1.24, 1.63). The percentage was significantly higher among males (OR = 1.47, 95% CI: 1.35, 1.60) and significantly lower among students (OR = 0.81, 95% CI: 0.74, 0.89). Married donors were more likely to test reactive than single donors (OR = 1.35, 95% CI: 1.21, 1.51).

The mean district-level prevalence of hepatitis C over the study period varied from 0.7% (Chitipa) to 5.1% (Nkhata-Bay). The geostatistical model performed some spatial smoothing and identified a spatial gradient that goes from a high prevalence region in the west central portion of the country to lower prevalence regions in the north and the south (Figure 1). The estimated prevalences from the geostatistical model varied from 1.3% (Chitipa, 95% CI: 0.7%–1.8%) to 3.7% (Kasungu, 95% CI: 2.4%–4.9%) as seen in Table 3. As these prediction intervals indicate, there are some significant differences among districts in terms of the rate of hepatitis C reactivity.

There were a total of 1088 new cases of hepatitis C seroreactivity among repeat donors. The mean district-level incidence rate of hepatitis C was 18.4 (17.3, 9.5). There was little spatial smoothing, the patterns remaining the same with the rates higher in Nkhotakota (in central), lowest in Chitipa and Karonga in the north region (Figure 2).

3.7 | Prevalence and incidence of syphilis among blood donors

The lowest level of reactive syphilis tests was observed in the final year at 1.6% in 2021. The highest rate was in 2017 at 2.8% and there was no discernible trend over the study period. Many of the year to year differences were statistically significant in logistic regression models. Both of the younger age groups had significantly lower rates than the group of donors aged greater than 35 (OR = 0.70, 95% CI: 0.63, 0.78 for 16–25 compared to over 35, and OR = 0.9, 95% CI: 0.83, 0.98 for 26–35 compared to over 35). The percentage testing reactive was similar across the sexes (OR = 1.04, 95% CI: 0.98, 1.11) but students were less likely to test reactive compared to non-students (OR = 0.45, 95% CI: 0.42, 0.49). There was no difference by marital status.

The mean district-level prevalence of syphilis over the study period varied from 0.9% (Chitipa) to 4.9% (Chikwawa). The geostatistical model performed very little spatial smoothing for syphilis as can be seen in Figure 1, however it smoothed all estimates more towards the district-level mean compared to the results from the model for HIV. The estimated prevalences from the geostatistical model varied from 1.3% (Chitipa, 95% CI: 0.9%–1.8%) to 4.4% (Chikwawa, 95% CI: 3.2%–5.6%) as seen in Table 3. These prediction intervals indicate that there are many districts with different rates of syphilis among donors.

A total of 1188 new cases of syphilis were observed during the study period. The mean district-level incidence rate of syphilis was 20.1 per 1000 Pys (19.0, 21.3). The geospatial model did little smoothing, with the incidence rates higher in Neno (in the south), and lowest in Chitipa and Karonga (Figure 2).

4 | DISCUSSION

Our study is an extension of a previous study in Malawi on seroprevalence of HIV, syphilis, hepatitis B and C utilising blood donation data from 2011 to 2015.[11] But, it is the first study to report incidence of TTIs among blood donors in Malawi. Our analysis showed that the seroprevalence and incidence of overall TTI reactivity was 6.8% and 62 per 1000 PYs respectively. The overall TTI incidence rate was higher in male and non-student donors, and decreased with increasing age. We also observed geographical variations in the distribution of overall TTI reactivity, HIV, syphilis and hepatitis C. The observed patterns on overall TTIs must be interpreted with caution as risk factors for individual TTIs differ from one TTI to another. The patterns observed are mostly influenced by different TTIs for different risk factors.

The overall TTIs are important for estimating national blood needs and estimating the country's blood donation potential. High overall TTI seroprevalence results in wastage of consumables for blood collection and staff time. The reported prevalence is for blood donors who have passed pre-donation screening. The common practice when estimating blood donation potential is to reduce the number of potential blood donors by the population-level prevalence of TTIs. However, when estimating blood needs, the overall TTI prevalence (any TTI reactivity) in the blood donor population itself must be factored in to avoid underestimating what must be collected in order to meet national needs for usable units of blood. Since we expect TTI levels to be lower than the general population (donors are younger and are screened for TTI risk), using the general population prevalence could lead to overestimation of TTI rates and setting donation targets needlessly high.

HIV prevalence in this cohort was 1.5% compared to a national HIV prevalence of 8.9% in the general adult population (15 years and older) in Malawi.[13] Studies in other countries in the sub-Saharan Africa reported similar HIV prevalence in blood donor populations; Tanzania[15] (1.7%), DRC[16] (1.6%), Malawi[11] (1.9%), except for Lidenge et al.[17] in Tanzania who reported prevalence as high as 4.2%. In this cohort, younger blood donors (16–25 yrs) and student donors had lower risk of HIV reactivity, and HIV prevalence significantly decreased from 2015. The HIV cumulative incidence rate in our cohort was estimated at 1.14% over 7 years (approx. 0.16% per year) which is lower compared to the 0.21% per

year from the recent nationwide population HIV survey done between 2020 and 2021. The lower prevalence and incidence of HIV infections among blood donors could be attributed to enhanced screening procedures that are used before donation as they discourage those with risk factors for TTIs from donating blood. In addition, donors are a self-selected population and only those who perceive themselves as low risk for infections come forward for donation.

Syphilis seroprevalence among blood donors in Malawi was 2.1% which is similar to 2% from antenatal national program data in Malawi[8] and which was also similar to 2019 estimates from retrospective studies from Malawi and Tanzania.[11,15] There was no clear pattern of syphilis prevalence over the years but the rates were significantly higher in 2017 and 2018 compared to 2015 rates. Student as well as donors younger than 36 years had a reduced risk of syphilis reactivity, echoing the results by an earlier study.[11] However, we did not find any gender differences in risk of syphilis reactivity as reported in an earlier study in Malawi.[11] The syphilis incidence in this cohort was 20 per 1000 PYs (equivalent to annual incidence of 0.29%). Considering the pre-donation screening (with a questionnaire) in blood donors, the similar prevalence with pregnant women, who do not undergo pretesting screening should be surprising. The same pattern is not observed in other sexually transmitted infections such as HIV where prevalence in blood donors is lower than in pregnant women at 1.5% and 6% (ANC data, 2022)[16] respectively. The similar prevalence of syphilis in these two population groups is most likely due to the screening tests used in both groups as they detect IgG antibodies which persist in circulation for up to 20 year after the infection has been resolved.

The overall seroprevalence of Hepatitis B was 2.1% while year to year prevalence steadily declined from 3.4% in 2015 to 1.5% in 2021. Hepatitis B prevalence also showed a decline trend over the period 2011–2015.[12] The sustained decline despite change of test kits could be due to the protective effect of introducing routine hepatitis B vaccination into the vaccination schedule for Malawi that occurred in 2002.[18] During the study period, two studies from Tanzania also reported high prevalence rates of 4.1% in 2019[15] and 7.3% in 2020.[17] Based on our recent unpublished systematic review looking at prevalence of TTIs in Southern African Development Community (SADC) region, hepatitis B was the most prevalent TTI in the region (pooled estimates: HBV prevalence = 3.0%; 95% CI: 2.0–5.0; and HIV, HCV, and Syphilis was 2.0%, 1.0% 2.0% respectively).[19] Male donors and also married or divorced donors were at increased risk of HBV reactivity. Other studies in the region also reported these significant gender and marital status differences among first-time donors.[20,21] The predominance of young unmarried donors in our blood donor population and the similar HIV and syphilis risk among male and female donors suggests that the sexual route may not be responsible for the higher HBV risk in male blood donors. Close shaves in barbershops and traditional circumcision could be responsible for the observed pattern although our geospatial modelling did not show geographical hotspots in regions which practice traditional circumcisions. The HBV incidence in our study was 13 per 1000 PYs which was lower than the incidence reported in DRC.[22]

Hepatitis C prevalence was higher than what was reported in the earlier study (1.5% in 2021 vs. 1% in 2015, $p < 0.001$).[11] Younger donors (16–25), male and married donors had

significantly higher risk of HCV reactivity. The HCV prevalence peaked at a high of 2.7% in 2018 and dropped thereafter. Hepatitis C results reported in this study needs to be interpreted with caution. With no confirmatory testing, Abbott reagents may have detected more false positives than BioRad. In an earlier study, M'baya et al.[10] have discussed extensively the issue of false positives of the enzyme immunoassays and their implications. Like other infections, students had lower risk of HCV reactivity. When comparing rates in the SADC region, two studies from DRC[21] and another from Tanzania[17] reported higher prevalence rates but other studies in Tanzania,[15] South Africa[23] and Madagascar[24] reported similar or lower rates compared to Malawi. Hepatitis C virus transmission is mainly through the parenteral route and commonly via intravenous drug use, unsterile medical procedures and unsafe blood transfusions.[25] Unlike HBV infection where a small percentage of infections develop clinical disease, a higher proportion of HCV infections produce clinical disease which usually progresses to chronic liver disease. The lack of risk factors for HCV infection in the predominantly-student blood donor population and low burden of both clinical hepatitis and chronic liver disease in Malawi supports findings of other studies in Malawi and beyond, of high false HCV reactive results on EIA-based laboratory testing algorithms which do not include confirmatory testing.[26–29]

Geographical patterns emerged across the country in crude analyses for prevalence and incidence estimates. For prevalence maps, use of geostatistical modelling did very little smoothing for any TTI, HIV and syphilis with the pattern remaining the same as in the crude estimates. Also for incidence, spatial smoothing did not alter the general pattern of district-level incidence for overall TTI, HIV, syphilis and hepatitis C. This shows a disproportionate burden of the TTIs across the country. For both prevalence and incidence maps, HIV and syphilis tended to follow similar geographical patterns probably as a consequence of their mainly sexual route of transmission. In the last two decades, studies have continually reported increasing rates of HIV and syphilis co-infections.[30–32] As such, many national standard HIV care programs encourage regular syphilis serology testing.[29] For example, in Malawi all women attending an antenatal clinic are screened for both HIV and syphilis as part of standard HIV care. The use of spatial methods in mapping TTIs in national blood donor programs is not common in SSA region but these methods have been widely applied in other program settings for general population such as HIV programs,[33,34] TB program[35] and malaria programs.[36,37] The use of spatial tools have evidently been crucial in helping the program frontline staff and policy makers to prioritise areas where there is high burden.

Like any other studies, our study has some limitations. First, the testing algorithm did not include confirmatory testing which might have inflated the prevalence and incidence due to false reactives. Seroprevalence and incidence rates observed in Malawian blood donor population were similar to those reported in previous studies in Malawi and other countries.[38] Second, we used a routine program dataset that had incomplete data for 2016 blood donation figures compared to the annual program report,[39] likely due to the database migration to a new system. We did not have a comprehensive list of donor characteristics, hence we did not conduct an exhaustive assessment of other risk factors for the TTIs which may have influenced our findings. However, for the factors included in the study, our results were similar to results reported in other studies from the region. Lastly, there are concerns about utility of routine longitudinal program data (accuracy, reliability and completeness).

Despite these concerns, routine data have been used to potentially inform and facilitate recruitment in randomised and to customise program implementation.[40–42]

In conclusion, the TTI prevalence and incidence rates among blood donors from this study are consistent with estimates from other countries in sub-Saharan Africa.[14,20,38] We were able to identify subgroups of blood donors at high risk of testing reactive for a TTI and this risk was lower if a donor was a repeat donor. By identifying geographical variations of TTI prevalence and incidence, these findings could potentially inform further studies to identify hotspots within districts with high burden of disease which could be sparingly targeted for blood collection activities to optimise usage of resources. As countries are putting in place strategies and interventions to improve safety of blood transfusions, it is important that TTI surveillance studies are strengthened to ensure effective monitoring of more prevalent TTIs.

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DATA AVAILABILITY STATEMENT

Due to confidentiality agreements, data used in this analysis can be made available upon request to bona fide researchers subject to a non-disclosure agreement. Details of the data and how to request access are available through the corresponding author.

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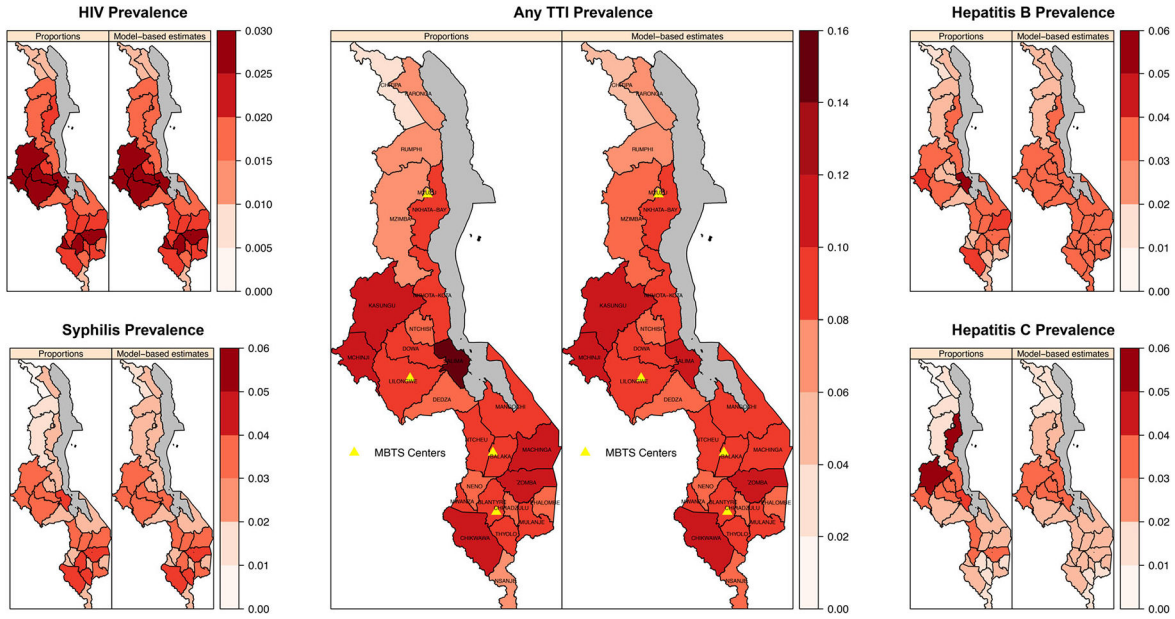

FIGURE 1.

Sample proportions and model-based spatially smoothed estimates of donors testing reactive for any TTI, HIV, syphilis, hepatitis B and hepatitis C.

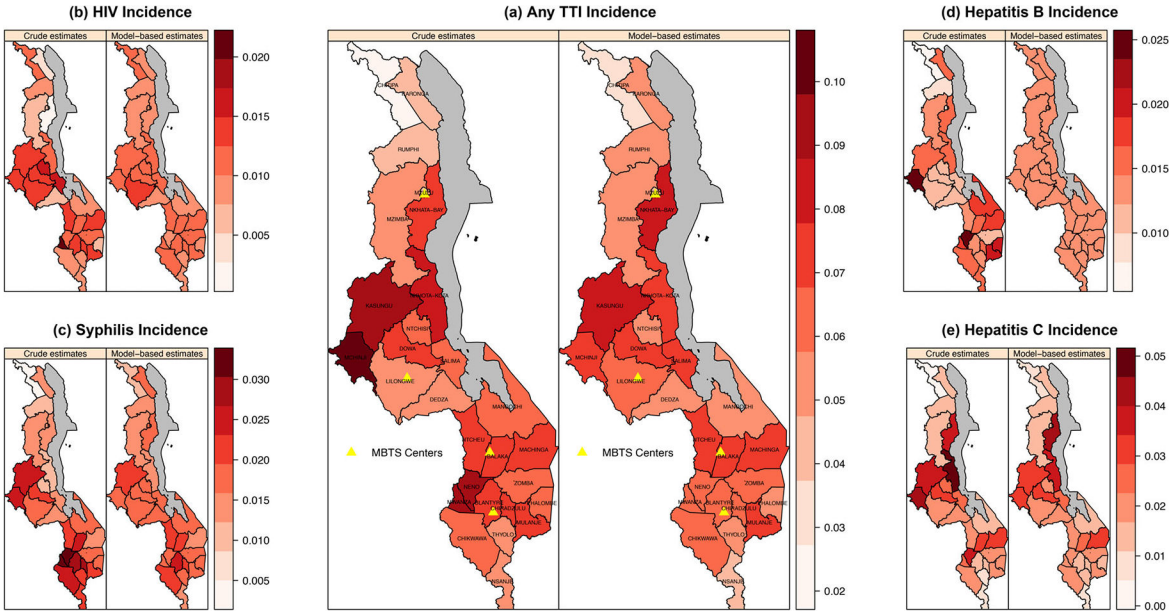

FIGURE 2.

Crude incidence and model-based spatially smoothed estimates of incidence for any TTI, HIV, syphilis, hepatitis B and hepatitis C.

TABLE 1

Characteristics of donors in the MBTS dataset.

Characteristics	One-time donors	Repeat donors	Overall
N donations on record	133 681 (26.4)	373 406 (73.6)	507 087
N donations during study period	133 681 (38.8)	210 941 (61.2)	344 622
N donors	133 681 (65.2)	71 239 (34.8)	204 920
Sex			
Female	32 536 (24.3)	13 876 (19.5)	46 412 (22.6)
Male	101 145 (75.7)	57 363 (80.5)	158 508 (77.4)
Age in years	20.1 (18.1, 25)	19.5 (17.8, 22.9)	19.9 (18, 24.1)
Age category			
16–25	103 058 (77.1)	58 869 (82.6)	161 927 (79)
26–25	18 244 (13.6)	8163 (11.5)	26 407 (12.9)
≥36	12 379 (9.3)	4207 (5.9)	16 586 (8.1)
Occupation			
Unknown	8824 (6.6)	2064 (2.9)	10 888 (5.3)
Student	89 242 (66.8)	56 143 (78.8)	145 385 (70.9)
Other	35 615 (26.6)	13 032 (18.3)	48 647 (23.7)
Marital status			
Divorced	630 (0.5)	182 (0.3)	812 (0.4)
Married	25 275 (18.9)	7553 (10.6)	32 828 (16)
Separated	277 (0.2)	75 (0.1)	352 (0.2)
Single	107 160 (80.2)	63 278 (88.8)	170 438 (83.2)
Widow	339 (0.3)	151 (0.2)	490 (0.2)
Donation per donor	1	3 (2, 5)	1 (1,2)
Time between donations (months)	-	6 (4, 12)	-
Regular donor at any time since 2015	-	49 303 (69.2)	-
Lapsed donor at any time since 2015	-	27 611 (38.8)	-
Year of first donation			
<2015	0(0)	20 092 (28.2)	20 092 (9.8)
2015	15 157(11.3)	6659 (9.3)	21 816 (10.6)
2016	8041 (6)	2720 (3.8)	10 761 (5.3)

Characteristics	One-time donors	Repeat donors	Overall
2017	20 528 (15.4)	10 460 (14.7)	30 988 (15.1)
2018	24 197(18.1)	12 300 (17.3)	36 497 (17.8)
2019	21 690(16.2)	9847 (13.8)	31 537(15.4)
2020	19 457 (14.6)	6246 (8.8)	25 703 (12.5)
2021	24 611 (18.4)	2915 (4.1)	27 526 (13.4)

Note: Descriptive statistics are presented as *N*(%) or Median (Q1, Q3).

TABLE 2

Comparison of TTI screening results across all donations by selecting demographic factors.

		HIV screening		Hep. B screening		Hep. C screening		Syphilis screening		All TTI screening	
Characteristics	***N* (%)**	**%Reactive**	**Adj. OR (95% CI)**	**%Reactive**	**Adj. OR (95% CI)**	**%Reactive**	**Adj. OR (95% CI)**	**%Reactive**	**Adj. OR (95% CI)**	**%Reactive**	**Adj. OR (95% CI)**
Age at donation											
16–25	267 422 (77.6)	1.2	0.79 (0.7, 0.89)	2	1.07 (0.96, 1.19)	1.5	1.42 (1.24, 1.63)	1.6	0.7 (0.63, 0.78)	6	0.93 (0.87, 0.99)
26–35	48 342 (14)	2.5	1.04 (0.94, 1.16)	2.7	1.08 (0.98, 1.19)	1.4	1.02 (0.89, 1.16)	3.3	0.9 (0.83, 0.98)	9.2	1 (0.94, 1.06)
≥36	28 858 (8.4)	2.6	Ref.	2.8	Ref.	1.7	Ref.	4	Ref.	10.2	Ref.
Sex											
Female	66 630 (19.3)	1.4	Ref.	1.6	Ref.	1.1	Ref.	1.8	Ref.	5.7	Ref.
Male	277 992 (80.7)	1.5	0.97 (0.89, 1.04)	2.3	1.37 (1.28, 1.47)	1.6	1.47 (1.35, 1.60)	2.1	1.04 (0.98, 1.11)	7.1	1.16 (1.13, 1.23)
Student status											
Non-student	84 265 (28.2)	2.3	Ref.	2.7	Ref.	1.7	Ref.	3.6	Ref.	9.5	Ref.
Student	247 402 (71.8)	1.1	0.55 (0.51, 0.61)	1.8	0.66 (0.61, 0.72)	1.4	0.81 (0.74, 0.89)	1.4	0.45 (0.42, 0.49)	5.6	0.59 (0.56, 0.61)
Marital status											
Single	288 896 (83.8)	1.3	Ref.	2	Ref.	1.4	Ref.	1.7	Ref.	6.1	Ref.
Married	53 163 (15.4)	2.7	1.09 (0.99, 1.2)	3.1	1.12 (1.03, 1.22)	2	1.35 (1.21, 1.51)	3.6	0.96 (0.88, 1.04)	10.4	1.08 (1.03, 1.14)
Other	2563 (0.7)	2.9	1.49 (1.15, 1.93)	3	1.32 (1.03, 1.7)	1.5	1.11 (0.79, 1.57)	4.6	1.48 (1.21, 1.82)	10.6	1.35 (1.16, 1.56)
Year of donation											
2015	41 230 (12)	1.7	Ref.	3	Ref.	0.8	Ref.	2	Ref.	7	Ref.
2016	21 520 (6.2)	1.4	0.83 (0.73, 0.96)	2.9	0.98 (0.89, 1.08)	0.9	1.26 (1.06, 1.51)	2	0.99 (0.88, 1.12)	6.8	0.99 (0.93, 1.05)
2017	48 401 (14)	2.2	1.37 (1.24, 1.51)	3	0.97 (0.9, 1.05)	1.2	1.5 (1.31, 1.73)	2.8	1.39 (1.27, 1.53)	8.6	1.22 (1.16, 1.28)
2018	61 518 (17.9)	1.4	0.87 (0.78, 0.97)	2.4	0.77 (0.71, 0.84)	2.3	2.81 (2.47, 3.2)	2.3	1.15 (1.05, 1.26)	7.9	1.11 (1.06, 1.17)
2019	62 717 (18.2)	1.2	0.76 (0.68, 0.85)	1.7	0.57 (0.52, 0.62)	1.6	2.05 (1.8, 2.35)	1.7	0.86 (0.78, 0.94)	6	0.83 (0.79, 0.88)

		HIV screening		Hep. B screening		Hep. C screening		Syphilis screening		All TTI screening	
Characteristics	***N* (%)**	**%Reactive**	**Adj. OR (95% CI)**	**%Reactive**	**Adj. OR (95% CI)**	**%Reactive**	**Adj. OR (95% CI)**	**%Reactive**	**Adj. OR (95% CI)**	**%Reactive**	**Adj. OR (95% CI)**
2020	52 814 (15.3)	1.5	0.8 (0.72, 0.89)	1.6	0.47 (0.43, 0.52)	2.1	2.61 (2.29, 2.98)	2.2	0.95 (0.87, 1.05)	6.8	0.87 (0.83, 0.92)
2021	56 422 (16.4)	1.2	0.72 (0.64, 0.8)	1.3	0.39 (0.35, 0.43)	1.1	1.25 (1.08, 1.44)	1.6	0.79 (0.72, 0.88)	4.9	0.65 (0.61, 0.68)
District											
Dedza	3895 (1.1)	1.3	Ref.	2.2	Ref.	2	Ref.	1.8	Ref.	7.1	Ref.
Dowa	5789 (1.7)	2.2	1.49 (1.06, 2.09)	2.3	0.95 (0.72, 1.27)	2.7	1.25 (0.93, 1.68)	2.8	1.31 (0.97, 1.77)	9.3	1.18 (1, 1.39)
Kasungu	11 506 (3.3)	2	1.52 (1.11, 2.09)	2.8	1.24 (0.96, 1.6)	3.8	1.9 (1.46, 2.46)	2.4	1.21 (0.91, 1.61)	10.4	1.45 (1.25, 1.68)
Lilongwe	72 017 (20.9)	2	1.12 (0.84, 1.5)	2.6	0.91 (0.72, 1.15)	1.8	0.85 (0.66, 1.09)	2.5	0.93 (0.72, 1.21)	8.2	0.9 (0.78, 1.03)
Mchinji	6236 (1.8)	2.2	1.75 (1.25, 2.45)	3.1	1.37 (1.04, 1.81)	2.6	1.36 (1.01, 1.82)	2.3	1.28 (0.94, 1.75)	9.6	1.39 (1.18, 1.64)
Nkhota-kota	4442 (1.3)	1.1	0.99 (0.66, 1.5)	2.7	1.37 (1.02, 1.84)	3	1.5 (1.1, 2.04)	1.9	1.25 (0.89, 1.75)	8.3	1.3 (1.09, 1.55)
Ntcheu	9827 (2.9)	1.5	1.1 (0.78, 1.54)	1.9	0.83 (0.63, 1.09)	1.9	1 (0.75, 1.33)	1.9	1.02 (0.76, 1.36)	6.9	0.94 (0.8, 1.1)
Ntchlsi	1580 (0.5)	1.8	1.71 (1.04, 2.81)	1.8	1.03 (0.66, 1.62)	2.5	1.37 (0.92, 2.06)	1.6	1.02 (0.64, 1.64)	7	1.18 (0.92, 1.51)
Salima	5624 (1.6)	2.2	1.36 (0.96, 1.93)	4.1	1.57 (1.2, 2.05)	3.2	1.57 (1.18, 2.1)	3.1	1.31 (0.97, 1.77)	11.4	1.42 (1.21, 1.66)
Chitipa	5382 (1.6)	0.7	0.61 (0.38, 0.98)	0.9	0.44 (0.3, 0.65)	0.4	0.24 (0.15, 0.39)	0.5	0.34 (0.22, 0.53)	2.5	0.37 (0.29, 0.47)
Karonga	7095 (2.1)	0.7	0.55 (0.36, 0.83)	2.1	0.95 (0.7, 1.29)	1.2	0.67 (0.47, 0.95)	1.3	0.79 (0.56, 1.11)	5.1	0.73 (0.61, 0.88)
Mzimba	15 113 (4.4)	1	0.81 (0.58, 1.12)	1.8	0.77 (0.59, 1.01)	1.2	0.63 (0.47, 0.83)	1.2	0.63 (0.46, 0.85)	5	0.68 (0.58, 0.79)
Mzuzu	19 710 (5.7)	0.9	0.65 (0.47, 0.89)	1.4	0.54 (0.42, 0.7)	0.8	0.48 (0.36, 0.64)	1.2	0.58 (0.43, 0.77)	4.2	0.52 (0.45, 0.61)
Nkhata-Bay	2740 (0.8)	1.3	1.17 (0.75, 1.81)	2.7	1.34 (0.94, 1.92)	3.9	2.14 (1.55, 2.96)	1.8	1.15 (0.77, 1.73)	8.9	1.42 (1.16, 1.74)
Rumphi	6505 (1.9)	1.1	0.89 (0.61, 1.31)	1.8	0.78 (0.58, 1.06)	1.2	0.62 (0.43, 0.89)	1.2	0.68 (0.48, 0.97)	5.1	0.71 (0.59, 0.85)
Balaka	12 059 (3.5)	1.4	1.08 (0.78, 1.5)	2.2	0.97 (0.75, 1.26)	1.6	0.81 (0.61, 1.07)	2.1	1.1 (0.82, 1.46)	6.8	0.93 (0.8, 1.09)

Characteristics	*N* (%)	HIV screening		Hep. B screening		Hep. C screening		Syphilis screening		All TTI screening	
		%Reactive	Adj. OR (95% CI)	%Reactive	Adj. OR (95% CI)	%Reactive	Adj. OR (95% CI)	%Reactive	Adj. OR (95% CI)	%Reactive	Adj. OR (95% CI)
Blantyre	80 594 (23.4)	1.4	0.91 (0.68, 1.22)	1.8	0.65 (0.52, 0.83)	1	0.48 (0.37, 0.62)	2	0.84 (0.65, 1.09)	5.8	0.67 (0.58, 0.76)
Chikwawa	5239 (1.5)	1.5	0.99 (0.68, 1.44)	2.7	1.08 (0.81, 1.44)	1.7	0.82 (0.59, 1.14)	3.3	1.53 (1.13, 2.07)	8.5	1.05 (0.89, 1.25)
Chiradzulu	7235 (2.1)	1.3	1.16 (0.81, 1.66)	2	0.87 (0.65, 1.16)	1	0.52 (0.37, 0.75)	1.5	0.94 (0.68, 1.31)	5.5	0.82 (0.69, 0.97)
Machinga	4937 (1.4)	1.6	1.36 (0.93, 1.97)	2.9	1.32 (0.99, 1.77)	2	1.06 (0.76, 1.47)	2.1	1.34 (0.97, 1.85)	8.1	1.22 (1.02, 1.45)
Mangochi	7850 (2.3)	1.2	0.95 (0.66, 1.36)	2.3	1.05 (0.79, 1.39)	1.6	0.85 (0.63, 1.15)	1.7	1.01 (0.74, 1.39)	6.4	0.93 (0.79, 1.1)
Mulanje	6184 (1.8)	1.6	1.4 (0.98, 2.01)	2.1	0.94 (0.7, 1.27)	1.6	0.91 (0.65, 1.27)	2.7	1.72 (1.27, 2.34)	7.6	1.17 (0.98, 1.38)
Mwanza	4031 (1.2)	1.2	1.14 (0.76, 1.73)	1.2	0.6 (0.4, 0.89)	1.3	0.65 (0.44, 0.95)	1.4	0.93 (0.64, 1.36)	4.8	0.75 (0.61, 0.92)
Neno	2761 (0.8)	0.8	0.73 (0.44, 1.23)	1.4	0.67 (0.42, 1.06)	1.5	0.75 (0.49, 1.16)	1.1	0.69 (0.43, 1.1)	4.6	0.68 (0.53, 0.87)
Nsanje	6960 (2)	0.6	0.56 (0.36, 0.87)	1.4	0.64 (0.46, 0.87)	0.7	0.35 (0.24, 0.51)	1.2	0.81 (0.57, 1.14)	3.8	0.56 (0.47, 0.68)
Phalombe	3603 (1)	0.9	0.89 (0.56, 1.39)	2.1	0.99 (0.7, 1.41)	0.8	0.42 (0.27, 0.66)	1.3	0.86 (0.57, 1.3)	5	0.75 (0.6, 0.93)
Thyolo	13 813 (4)	1.2	0.83 (0.6, 1.16)	1.8	0.76 (0.58, 0.99)	0.8	0.41 (0.3, 0.56)	2.9	1.42 (1.08, 1.86)	6.4	0.82 (0.71, 0.96)
Zomba	11 895 (3.5)	2	1.37 (1.0, 1.87)	2.7	1.2 (0.93, 1.56)	2.2	1.04 (0.79, 1.37)	3.2	1.5 (1.14, 1.97)	9.5	1.24 (1.07, 1.44)

Note: Odds ratios are adjusted for all factors presented and were estimated by GEE logistic models which accounted for repeated measures.

TABLE 3

Sample proportions of donors testing positive for HIV, syphilis, hep B and hep C along with model-based spatially-smoothed estimates and their corresponding 95% confidence intervals.

	HIV			Syphilis			Hep B			Hep C			Any TTI		
District	Sample proportion	Estimated prevalence	95% CI	Sample proportion	Estimated Prevalence	95% CI	Sample proportion	Estimated prevalence	95% CI	Sample proportion	Estimated prevalence	95% CI	Sample proportion	Estimated prevalence	95% CI
Balaka	0.024	0.024	(0.021, 0.027)	0.035	0.034	(0.025, 0.043)	0.037	0.034	(0.029, 0.04)	0.027	0.027	(0.018, 0.035)	0.114	0.112	(0.091, 0.133)
Blantyre	0.029	0.029	(0.027, 0.03)	0.04	0.038	(0.028, 0.047)	0.035	0.033	(0.028, 0.037)	0.018	0.021	(0.015, 0.027)	0.113	0.111	(0.091, 0.131)
Chikwawa	0.021	0.021	(0.017, 0.025)	0.049	0.044	(0.032, 0.056)	0.04	0.032	(0.027, 0.038)	0.026	0.021	(0.014, 0.029)	0.126	0.121	(0.098, 0.145)
Chiradzulu	0.022	0.023	(0.02, 0.027)	0.025	0.026	(0.018, 0.034)	0.034	0.033	(0.028, 0.038)	0.016	0.02	(0.014, 0.025)	0.094	0.095	(0.076, 0.114)
Chitipa	0.01	0.011	(0.008, 0.014)	0.009	0.013	(0.009, 0.018)	0.015	0.026	(0.02, 0.031)	0.007	0.013	(0.007, 0.018)	0.038	0.048	(0.037, 0.06)
Dedza	0.016	0.019	(0.015, 0.023)	0.022	0.023	(0.016, 0.031)	0.027	0.033	(0.028, 0.039)	0.024	0.028	(0.018, 0.038)	0.085	0.088	(0.07, 0.106)
Dowa	0.027	0.026	(0.022, 0.03)	0.035	0.034	(0.025, 0.043)	0.029	0.033	(0.028, 0.039)	0.032	0.032	(0.022, 0.043)	0.115	0.112	(0.091, 0.134)
Karonga	0.011	0.011	(0.009, 0.014)	0.02	0.022	(0.016, 0.029)	0.029	0.027	(0.022, 0.032)	0.017	0.015	(0.009, 0.021)	0.073	0.078	(0.062, 0.094)
Kasungu	0.027	0.026	(0.023, 0.03)	0.031	0.031	(0.022, 0.039)	0.038	0.033	(0.027, 0.039)	0.05	0.037	(0.024, 0.049)	0.137	0.13	(0.107, 0.154)
Lilongwe	0.027	0.027	(0.026, 0.029)	0.035	0.034	(0.025, 0.042)	0.037	0.034	(0.028, 0.04)	0.024	0.028	(0.019, 0.038)	0.115	0.113	(0.092, 0.133)
Machinga	0.024	0.024	(0.019, 0.028)	0.034	0.033	(0.023, 0.042)	0.044	0.036	(0.029, 0.042)	0.029	0.026	(0.017, 0.036)	0.123	0.119	(0.096, 0.142)
Mangochi	0.018	0.019	(0.016, 0.023)	0.027	0.028	(0.02, 0.036)	0.036	0.035	(0.029, 0.041)	0.027	0.028	(0.018, 0.038)	0.103	0.102	(0.083, 0.122)
Mchinji	0.029	0.029	(0.024, 0.033)	0.03	0.03	(0.021, 0.039)	0.04	0.034	(0.028, 0.04)	0.033	0.031	(0.02, 0.043)	0.125	0.121	(0.098, 0.144)
Mulanje	0.022	0.021	(0.018, 0.025)	0.039	0.037	(0.026, 0.047)	0.029	0.032	(0.027, 0.037)	0.021	0.019	(0.013, 0.025)	0.106	0.105	(0.084, 0.125)
Mwanza	0.025	0.025	(0.019, 0.03)	0.029	0.029	(0.02, 0.039)	0.024	0.031	(0.026, 0.037)	0.028	0.025	(0.016, 0.033)	0.1	0.1	(0.079, 0.122)
Mzimba	0.016	0.016	(0.014, 0.019)	0.018	0.02	(0.014, 0.025)	0.026	0.029	(0.024, 0.035)	0.019	0.024	(0.015, 0.032)	0.076	0.08	(0.064, 0.095)

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	HIV			Syphilis			Hep B			Hep C			Any TTI		
District	**Sample proportion**	**Estimated prevalence**	**95% CI**	**Sample proportion**	**Estimated Prevalence**	**95% CI**	**Sample proportion**	**Estimated prevalence**	**95% CI**	**Sample proportion**	**Estimated prevalence**	**95% CI**	**Sample proportion**	**Estimated prevalence**	**95% CI**
Mzuzu	0.016	0.017	(0.014, 0.019)	0.02	0.022	(0.016, 0.028)	0.025	0.029	(0.024, 0.034)	0.014	0.021	(0.014, 0.028)	0.073	0.077	(0.062, 0.092)
Neno	0.02	0.024	(0.019, 0.029)	0.025	0.026	(0.017, 0.036)	0.027	0.032	(0.027, 0.037)	0.031	0.026	(0.017, 0.034)	0.097	0.098	(0.076, 0.121)
Nkhata-Bay	0.02	0.018	(0.014, 0.022)	0.025	0.026	(0.018, 0.035)	0.035	0.03	(0.024, 0.035)	0.051	0.027	(0.018, 0.036)	0.118	0.114	(0.091, 0.138)
Nkhota-Kota	0.015	0.017	(0.013, 0.021)	0.027	0.027	(0.019, 0.035)	0.037	0.033	(0.027, 0.039)	0.037	0.034	(0.022, 0.046)	0.11	0.108	(0.087, 0.129)
Nsanje	0.012	0.014	(0.011, 0.017)	0.024	0.026	(0.018, 0.033)	0.027	0.031	(0.025, 0.037)	0.014	0.017	(0.01, 0.024)	0.075	0.08	(0.063, 0.097)
Ntcheu	0.023	0.023	(0.02, 0.027)	0.033	0.032	(0.023, 0.041)	0.031	0.033	(0.028, 0.039)	0.031	0.028	(0.019, 0.038)	0.112	0.11	(0.089, 0.131)
Ntchisi	0.022	0.023	(0.017, 0.028)	0.021	0.024	(0.015, 0.032)	0.023	0.033	(0.027, 0.038)	0.032	0.034	(0.023, 0.045)	0.089	0.092	(0.07, 0.113)
Phalombe	0.018	0.021	(0.016, 0.025)	0.022	0.024	(0.016, 0.032)	0.037	0.034	(0.028, 0.039)	0.015	0.02	(0.013, 0.027)	0.087	0.09	(0.071, 0.11)
Rumphi	0.017	0.016	(0.013, 0.019)	0.018	0.021	(0.014, 0.027)	0.026	0.027	(0.022, 0.033)	0.016	0.017	(0.011, 0.024)	0.074	0.078	(0.062, 0.095)
Salima	0.026	0.025	(0.021, 0.029)	0.04	0.037	(0.027, 0.047)	0.052	0.036	(0.029, 0.042)	0.04	0.033	(0.022, 0.045)	0.144	0.136	(0.111, 0.162)
Thyolo	0.019	0.019	(0.017, 0.022)	0.046	0.042	(0.031, 0.053)	0.028	0.032	(0.027, 0.037)	0.013	0.018	(0.012, 0.023)	0.101	0.101	(0.082, 0.12)
Zomba	0.029	0.028	(0.024, 0.031)	0.047	0.043	(0.032, 0.054)	0.039	0.034	(0.029, 0.04)	0.03	0.024	(0.017, 0.031)	0.136	0.129	(0.106, 0.152)

TABLE 4

Overall TTI incidence by demographic characteristics of blood donors.

Characteristic		Total donors	No. of new cases	Person time (years)	Incidence per year (95% CI)	*p*-Value
Overall		62 367	3635	59133.1	0.0615 (0.0595, 0.0635)	N/A
Sex						
	Female	12 066	484	11374.3	0.0426 (0.0388, 0.0465)	<0.001
	Male	50 301	3151	47758.8	0.0660 (0.0637, 0.0683)	
Age						
	16–25	51 931	2801	45709.4	0.0613 (0.0500, 0.0636)	<0.001
	26–35	6772	568	8681.6	0.0654 (0.0602, 0.0710)	
	≥36	3664	266	47,42.1	0.0561 (0.0496, 0.0633)	
Marital status						
	Married	6880	499	7806.4	0.0639 (0.0584, 0.0698)	0.05
	Single	55 487	3136	51326.7	0.0611 (0.0590, 0.0633)	
Occupation						
	Student	49 636	2700	45397.3	0.0595 (0.0573, 0.0618)	0.7
	Non-student	12 731	935	13735.8	0.0681 (0.0638, 0.0726)	