Shrinking the gHAT map: identifying target regions for enhanced control of *gambiense* human African trypanosomiasis in the Democratic Republic of Congo

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\textbf{Abstract}

\textbf{Background}

*Gambiense* human African trypanosomiasis (gHAT) is a disease targeted for elimination of transmission (EOT) by 2030, however the likelihood of achieving it is unknown. We utilised modelling to study the impact of currently-available intervention methods on transmission across the Democratic Republic of Congo (DRC) – which accounts for \(~70\%\) of global burden – and highlight regions requiring intensified interventions.

\textbf{Methods}

A model previously fitted to case data in DRC was used to predict cases and new infections under four future strategies in 168 health zones. The strategies comprise of medical interventions – active and passive screening (AS and PS).
– and some include large-scale vector control (VC). In each health zone, we estimate the median year of EOT and the probability of EOT by 2030 under each and compute the least ambitious strategy predicted to achieve EOT by 2030.

**Findings**
The model predicts 42 health zones are very likely to achieve EOT (> 90% probability) using medical-only strategies continued at mean coverage levels; this increases to 52 when AS coverage is increased to maximum previous coverage. In all VC strategies, health zones are predicted to meet EOT by 2030, although there are several where increasing low AS coverage could achieve this.

**Interpretation**
This analysis provides a priority list for consideration for supplementary VC implementation (Bagata, Bandundu, Bolobo, Kikongo, Kwamouth and Masi Manimba in former Bandundu province) in conjunction with the recent AS coverage.

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**Keywords:** gambiense human African trypanosomiasis, modelling, 2030 goals, elimination of transmission, Democratic Republic of Congo

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**Research in context**

**Evidence before this study**
On 30th April 2020 we searched PubMed and ScienceDirect to identify previous predictive modelling studies of gHAT in DRC using the search terms “model” AND “Democratic Republic of Congo” OR “DRC” AND “trypanosomiasis” OR “sleeping sickness”. There are numerous modelling studies which have looked at estimating the impact of a variety of strategies on transmission and elimination, however many utilise infection prevalence categories for performing simulations rather than location-specific data. For DRC, modelling studies have made projections at a province-level (i.e. Bandundu), and for health zones (i.e all of Equateur and some in Bandundu),
concluding that there is high heterogeneity in underlying transmission, consequently whether medical-only strategies will suffice to meet elimination of transmission (EOT) by 2030. They find that supplemental, large-scale vector control would be expected to result in rapid EOT across settings. Two high-endemicity, village-level studies suggest that regular, high-coverage screening is needed to achieve EOT within 15 years without additional interventions.

**Added value of this study**

This study presents predictions for EOT across the whole DRC for the first time. Since DRC has the highest disease burden it is critical to understand how far current tools might go towards achieving this 2030 target across the country, and how strategies may need to be adapted for specific locations in the endgame. It also provides a priority list for regions requiring intensified interventions.

**Implications of all the available evidence**

Our analysis suggests that, whilst many regions of DRC are expected to meet the EOT goal by 2030 with medical-only strategies, for some regions current strategies may need to be bolstered to achieve EOT within the next decade. Although some regions could consider increasing coverage of active screening, vector control appears a desirable supplemental intervention in several specific high-prevalence locations.

1. **Introduction**

The pinnacle of success for an infectious disease programme is to drive to eradication, resulting in complete removal of morbidity and mortality, yet no longer requiring interventions. Of all the human diseases targeted for eradication, only one – smallpox – has currently achieved this objective, yet there are several for which this remains the (potentially illusive) goal (such as polio, Guinea worm, and yaws). Clear lessons that can be learnt from many eradication programmes are: (i) the often slow progress from low to very low case burden, (ii) the ever-increasing effort required per case to tackle remaining infection, and (iii) the question of whether eradication is even epidemiologically or operationally feasible.

One step down from eradication is elimination of transmission (EOT) to humans, acknowledging that transmission pockets could persist in non-human
animal cycles. This goal, arguably, may be almost as challenging and fraught with the same hurdles to overcome as eradication itself. *Gambiense* human African trypanosomiasis (gHAT, sleeping sickness) is one such disease with the EOT goal and within the last decade it was still known to be extant in 15 countries in West and Central Africa. This parasitic infection is transmitted to humans via bites by tsetse, with gHAT symptoms typically increasing in severity over several years and leading to death without treatment. The remarkable progress made to bring down case burden across the continent—falling to below 10,000 cases in 2009 for the first time since the most recent epidemic started in the 1970s, and to only 953 in 2018—has sparked optimism that EOT may be possible and the World Health Organization has set the goal of EOT by 2030. Indeed gHAT fulfils some of the criteria associated with an “eliminable” disease: we have a range of field-proven tools and associated delivery mechanisms as well as means of diagnosis and surveillance. Unlike smallpox, gHAT is not vaccine-preventable, but wide-spread testing, diagnosis, and treatment have worked well to curtail transmission. The key question is whether current tools for gHAT are sufficient to reach EOT in the next ten years, and if so, how expansive might their use have to be to get there.

The Democratic Republic of the Congo (DRC) is the country with the most reported gHAT cases. Due to the concerted efforts of the national sleeping sickness control programme in DRC (PNLTHA-DRC), the number of reported cases dropped below 1,000 in the country in 2018. However, the DRC still accounted for nearly 70% of global cases (660 out of 953 cases) in that year. Therefore, the DRC is the most critical country on which the achievement of EOT by 2030 hinges.

In order to assess EOT feasibility, this study focuses on quantitative forecasting of gHAT across 168 endemic health zones (each have a population of around 100,000 people) in DRC to examine if, how, and when EOT could be expected under strategies based on currently available tools. Previous DRC-specific predictive modelling studies have provided insights into expected timelines to EOT in Equateur province, and parts of Bandundu province under continuation of medical-based strategies with or without vector control. From these studies it is clear that a one-size-fits-all approach is unlikely to be sufficient to meet this highly ambitious target in the next decade. Although coverage of active screening has been driven by local numbers of cases, additional data-driven guidance could help to further tailor...
strategy selection.

In this article, we enlarge the geographical scope of previous predictions to include the whole country, utilising the results of previous fitting\textsuperscript{13} to examine the strategies of active screening (AS) with or without supplemental, large-scale vector control (VC) on top of the local passive surveillance (PS) system to stop gHAT transmission by 2030 in DRC. A graphical user interface (GUI, see S2 GUI) to complement this article was set up to provide full model outputs. In this analysis we aim to identify regions which are likely to be successful in achieving local EOT on their current trajectory, and ones where enhanced control may be required to meet this target. Furthermore, we provide a priority list of health zones where intensification of strategies is most urgent based on past intervention coverage and projected timelines to EOT.

2. Methods

2.1. Forward projections

We used a previously developed variant (“Model 4”) of the Warwick gHAT model\textsuperscript{8,9,13} to predict gHAT dynamics by considering transmission among humans, tsetse, and non-reservoir animals. This anthroponotic transmission model with low-risk and high-risk humans is supported by patterns observed in longitudinal human case data in DRC\textsuperscript{8} and captures systematic non-participation of high-risk groups in the population – anecdotally believed to be working-age people spending time near tsetse habitat, and away from villages during active screening activities. Detailed model illustration and complete mathematical descriptions are available in S1 Model details.

The fitted model takes into account previous advances in medical, diagnostic, and control systems; posterior parameters were found by fitting to health-zone level data for the period 2000–2016\textsuperscript{13}. Major changes include better PS systems in the former province of Bandundu and Bas Congo, improved active case confirmation by video recording of diagnostics in Mosango and Yasa Bonga in Bandundu from 2015, and implementation of large-scale VC in Yasa Bonga since mid-2015. Based on the continuation of the current PS system, we considered four strategies for projections from 2017 to 2050, which included different coverage of AS and whether or not to implement VC from 2020. As summarised in Table 1, AS is assumed be either at the recent (2012–2016) mean level achieved or at the maximum level (maximum
achieved during 2000–2016), and hence depend on the historical data in each health zone. Except for Yasa Bonga (which had a reported effectiveness of 90%[14]), a fixed effectiveness of 80% tsetse reduction after one year was used in the strategies with VC. Other tsetse reductions (i.e. 60% and 90%) were examined in sensitivity analyses in [S1 Model details]. Further model assumptions include: (1) in Yasa Bonga only strategies with VC are considered as it is already in place pre-2017; (2) video confirmation of parasitological diagnosis was launched in 2018 in Bandundu health zones to remove false positives in AS; (3) diagnostic algorithms will be improved to 100% specificity outside Bandundu when the detected case numbers are close to the expected incidence of false positive detections (see [S1] for further details).

The data set finished in 2016 and so forward projections were performed from 2017 to 2050, independently for each health zone. Parameter uncertainty was presented by 1,000 randomly selected sets of parameters from the health-zone-specific posteriors in the fitted model. Observational uncertainty in predicted case numbers each year was considered by drawing ten random samples from the predicted mean dynamics for each set of parameters. In model outputs, 10,000 samples for observable variables such as active and passive cases, and related metrics were generated. On the other hand, unobservable variables like new infections and the year of EOT were predicted by the 1,000 model realisations (parameter uncertainty but no sampling uncertainty).

Table 1: Strategies considered for projections (2017–2050). VC effectiveness is determined by the proportional reduction in tsetse population after one year of implementation. Results of sensitivity analysis on VC effectiveness are available in [S1 Model details] and [S2 GUI]. Strategies without VC are not considered in Yasa Bonga because VC has been implemented since the middle of 2015.

| Strategy name | AS coverage from 2017 | VC effectiveness from 2020 | PS coverage from 2017 |
|---------------|----------------------|---------------------------|----------------------|
| MeanAS        | Mean (2012–2016)     | 0%                        | Same as 2016         |
| MaxAS         | Max (2000–2016)      | 90% for Yasa Bonga        | Same as 2016         |
| MeanAS+VC     | Mean                 | 90% for Yasa Bonga        | Same as 2016         |
| MaxAS+VC      | Max                  | 80% everywhere else       | Same as 2016         |
2.2. Measuring elimination of transmission

As there is no direct way to observe EOT, WHO suggest a primary indicator of zero reported cases to measure the achievement of EOT. However, the number of reported cases depends largely on the strength of medical interventions, so other methods to assess progress towards EOT are desirable to complement imperfect case indicators.

Fortunately, mechanistic modelling provides the means to both infer and predict the unobservable transmission dynamics to assess EOT. Here, we calculated the number of underlying new infections each year in the epidemiological model. Unlike the discrete nature of populations, the outputs of deterministic models are continuous and whilst they can asymptote to zero they will never reach it. Therefore, to identify a realistic point at which EOT has been achieved, we introduced a proxy threshold (= 1) for annual new infections and assume that EOT is achieved when the number of new infections is below the threshold (see SI for more details).

2.3. Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

3. Results

3.1. Projection trends in different risk settings

Forward projections in 168 health zones are reported in this study; non-endemic health zones, and those with little intervention, and/or case reporting were excluded from the original model fitting and hence from these projections.

Figure 1 shows assumed numbers of people screened and model outputs (i.e. active and passive cases, new infections, and probability of EOT) for the four strategies in two example health zones: Kwamouth (former Bandundu province) and Tandala (former Equateur province). Both health zones had significant numbers of cases in the early 2000s and still have ongoing transmission despite annual AS. Kwamouth, with 1068 reported cases in 2012–2016 (estimated 2015 population of 127,205), falls within WHO’s definition of a “high-risk” category for gHAT (1–10 cases/1,000 per year averaged over
five years), while Tandala is only “low-risk” (38 reported cases in 2012–2016 and estimated 2015 population of 274,945 — i.e. 1–10 cases/100,000 per year). Historical AS data shows that Kwanouth had substantially higher proportions of people screened than Tandala. Despite very high coverage of AS in Kwanouth, achieving EOT by 2030 is predicted to only be possible when VC is added — the model suggests that transmission will be interrupted completely within four years once VC begins. Unlike Kwanouth, Tandala appears extremely likely to achieve EOT by 2030 by MaxAS strategy and EOT even occurs in 60% of projections under the less intensive MeanAS strategy.

3.2. Timelines to, and certainty of, EOT

The year of elimination of transmission (YEOT) is defined as the first year that the EOT criterion (i.e. number of new infections is less than one) is met. Health zone maps of the median YEOT under the four strategies are shown in Figure 2. It is possible for different strategies to have very similar YEOT distributions within a health zone if EOT is expected to have already occurred. Using the value of median YEOT, health zones can be classified into three categories: on track (YEOT \(\leq\) 2030), slightly behind schedule (2030 < YEOT \(\leq\) 2040), and greatly behind schedule (YEOT > 2040) to meet the EOT goal. We predict 74 health zones are on track, 29 are slightly behind the schedule, and 65 are greatly behind schedule under MeanAS strategy. An extra seven health zones are on track while 62 remain greatly behind schedule under MaxAS strategy. Data shows low coverage of AS (defined as lower than 25% for mean coverage and 40% for maximum coverage) may be responsible for predicted delays in EOT in health zones outside the former Bandundu province. With VC starting in 2020, all health zones are predicted to achieve EOT by 2024. MaxAS+VC strategy could further bring forward YEOT by up to one year (although the five years data bins in Figure 2 obscure this nuance).

The median YEOT provides an average of when to expect EOT but not the certainty that the goal will be met by 2030. The probability of elimination of transmission (PEOT) by 2030, which highly depends on the distribution of YEOT, captures the uncertainty of model predictions. Consequently, low values of median YEOT cannot guarantee EOT by 2030. One example is Inongo in the former Bandundu province, which has a median YEOT of 2019 but the PEOT by 2030 is < 1 under both MeanAS and MaxAS strategies.
Figure 3 shows PEOT by 2030 in each health zone under four strategies. Three uncertainty categories of model predictions are particularly interesting: EOT is very likely to be met by 2030 if $PEOT > 0.9$, EOT by 2030 is highly uncertain when $0.3 < PEOT < 0.7$, and EOT is very unlikely to be met if $PEOT < 0.1$. The model predicts 42 health zones are very likely to meet the goal and 61 are almost certain to miss it under MeanAS strategy. High uncertainty in EOT is reported in 33 health zones. Despite the distribution of YEOT being shifted forward under MaxAS strategy, only ten extra health zones become very likely to meet the goal by 2030 while 24 health zones remain highly uncertain because of their wide YEOT distributions. With VC starting in 2020, a tight distribution of YEOT means EOT by 2030 is extremely likely everywhere even if its median is quite close to 2030.

### 3.3. Prioritising health zones

Decision-making for gHAT strategy is challenging; programmes have the flexibility to implement nuanced, spatially-heterogeneous interventions, however they must adhere to more general WHO recommendations and budget constraints. In the present study we rank strategies by how ambitious the use of additional interventions is and examine the minimum required to meet the 2030 EOT goal in each health zone – referred to here as the “preferred strategy”. The preferred strategy maps under different levels of certainty in EOT as predicted by the model are shown in Figure 4. Under the criterion of $PEOT > 0.9$ (left map), preferred strategies are defined as the strategies which achieve EOT by 2030 in at least 90% of simulations. The criterion of $PEOT = 1$ (right map) further restricts preferred strategies to achieve the goal by 2030 in all simulations. According to the ordered ranking (MeanAS, MaxAS, MeanAS+VC, and MaxAS+VC), the least ambitious strategy among all that meet the PEOT criterion is selected as the preferred strategy. This order of ambition ranking was based on the following principles: MeanAS represents the continuation of current intervention, MaxAS is the highest level of intervention implemented to date, and VC is a new intervention to all health zones except Yasa Bonga. Notably MaxAS+VC is absent in any of the preferred strategy maps because all health zones are expected to achieve the EOT goal by 2030 under MeanAS+VC strategy which requires less resources. Maps showing lower PEOT thresholds (from $PEOT = 0.5$ upwards) can be found in the GUI (see S2 GUI) and far less intensification would be required if a 50% probability of meeting the goal by 2030 is considered to be sufficient.
Switching to intensified strategies is generally expected to increase confidence that EOT will be achieved, although the model predicts very few health zones will eliminate transmission by medical-only strategies with high probability (31% under PEOT > 0.9 and 17% under PEOT = 1). We used the historical data in conjunction with model assumptions to understand the causes of apparent high need for VC and further suggest where and what kind of intensified interventions are needed to achieve EOT by 2030.

Using the WHO’s risk categories based on data from 2012–2016, health zone can be classified as: moderate- or high-risk (≥ 1 case per year on average per 10,000), or low- or very low-risk (≥ 1 but < 100 cases per year on average per 1,000,000). The 125 low- or very low-risk health zones are expected to be on track to meet EOT by 2030. However, the model predicts the majority of them (87 health zones) need VC to achieve EOT by 2030 with more than 95% probability. The apparent discrepancy comes from large uncertainty in model predictions due to limited information arising from low AS coverage. AS provides precious information on quantifying the underlying transmission and affects model predictions. In order to maximise resource efficiency, reductions in AS commonly happen when fewer cases are reported. More than 95% of the low- or very low-risk health zones screened a total of less than 50% of its population in the last five years (i.e. less than 10% annually). As a result, VC is favored in model predictions due to lack of information and may be unnecessary in practice in low- or very low-risk health zones.

For moderate- or high-risk health zones, the model predicts nearly all health zones (37 out of 43) need VC to meet EOT by 2030 with more than 95% probability. Although VC seems a reasonable tool in moderate- or high-risk health zones, unfortunately it is unlikely to be practical to roll out large-scale VC in all of them in this short timeframe. In health zones outside former Bandundu province that are greatly behind schedule the maximum observed coverage was 40%. When this value was applied as a threshold; Bagata, Bandundu, Bolobo, Kikongo, Kwamouth, and Masi Manimba in the former Bandundu province are on the shortlist of health zones where VC is highly recommended by mathematical modelling. More than 95% of health zones have mean AS coverage lower than 25%, therefore a secondary suggestion is to increase the coverage of AS to at least 25% especially in the moderate- or high-risk health zones.
Figure 1: Time series of key model outputs in two example health zones. Kwanmouth (left panels) in former Bandundu province and Tandala (right panels) in former Equateur province represent a high-risk and a low-risk health zone, respectively. The top row shows the number of people actively screened, the middle rows show three direct model outputs (active cases, passive cases and underlying new infections from top to bottom), and the bottom row shows the probability of achieving EOT by year. Black lines and box plots indicate data and model fits in the last five years (2012–2016), coloured dashed lines denote the assumed AS starting in 2017, and colour box plots and circles present the predictions for four strategies (as defined in Table 1). Box plots with whiskers showing 95% prediction intervals summarise parameter and observational uncertainty. Full model outputs (2000–2050) of all 168 analysed health zones are available online (see S2 GUI).
Figure 2: **Health zone median year of elimination of transmission (YEOT) maps for the DRC.** The median YEOT provides the year in which 50% of model simulations reach EOT in each health zone. The top two maps show strategies without VC (except for Yasa Bonga health zone which is shown with VC in all maps) and the bottom maps have VC strategies with 80% vector reduction. The left maps simulate continuation of the mean AS coverage and the right two simulate maximum AS coverage. The uncertainty of YEOT is not shown in these maps (only the average prediction). The exact median values and 95% prediction intervals for YEOT are available online (see S2 GUI).
Figure 3: Health zone probability of elimination of transmission (PEOT) by 2030 maps for the DRC. PEOT reveals the uncertainty of model predictions about whether EOT will occur. Health zones with PEOT > 0.9 (dark blue) will be very likely to achieve EOT by 2030, and PEOT < 0.1 (dark red) will be very unlikely to meet it. Health zones with mid-range PEOT (0.3–0.7) have high uncertainty in the success or failure of the strategy to meet the goal either because (1) the median YEOT is close to 2030, or (2) the wide distribution in the predicted YEOT. The two identical maps (with PEOT = 1 everywhere) at the bottom show that VC is an efficient tool which ensures EOT has extremely high certainty. Maps of PEOT by other years are available online (see S2 GUI).
Figure 4: **Health zone preferred strategy maps for EOT by 2030 in the DRC.**

The preferred strategy is defined as the least ambitious strategy which is predicted to achieve EOT by 2030 with a prescribed confidence level (90%, 95% and 100%). The order of ambition ranking is MeanAS, MaxAS, MeanAS+VC and MaxAS+VC. All health zones are predicted to achieve EOT by 2030 (PEOT = 1) under MeanAS+VC strategy so MaxAS+VC is absent here. MeanAS and MaxAS strategies were not considered in Yasa Bonga because VC started in mid-2015. Preferred strategy maps for smaller PEOT thresholds are available online (see S2 GUI).
4. Discussion

The integration of data, model assumptions, and model predictions identifies a priority shortlist of six health zones Bagata, Bandundu, Bolobo, Kikongo, Kwamouth, and Masi Manimba in the former Bandundu province (all of which have maximum AS coverage $\geq 40\%$) as regions where VC is predicted to be a necessary supplementary tool for eliminating transmission by 2030 (see S1 Model details). Other health zones predicted to miss the 2030 EOT goal could also benefit from this tool, although careful consideration is required to assess whether scaling up medical interventions is easier to implement than introducing large-scale VC. The reported effectiveness of VC is high in general but the variations between locations are non-negligible. According to our sensitivity analysis on the effectiveness of VC (see S1 Model details), the time difference in achieving EOT could be several years longer with only 60% tsetse reduction, but this is still substantially faster than with medical-only interventions in many settings. Our model forecasting would be more accurate if the location-specific effectiveness of VC was taken into account (which is yet unknown in most health zones). Pessimistic model predictions can be found in some health zones where the coverage of AS is very low recently or historically. Low AS coverage creates additional uncertainty in model outputs and therefore can make model predictions overly pessimistic (i.e. they could overstate the need for VC in low- or very low-risk health zones). Exploring the minimum AS coverage required to achieve EOT by 2030 would be another mathematical modelling approach to address where and what kind of intensified interventions are needed to achieve EOT.

The presented model predictions are based on the model fitted to 2000–2016 case data[13] and assumptions of different strategies starting from 2017. When the new data from 2017 onward becomes available, we will be able to use it to validate our model by changing assumed AS coverage to actual numbers of people screened and then comparing the predicted active and passive cases to reported cases. Subsequent re-fitting to the recent case data would further refine model predictions presented here and is an important step in the continuous process of modelling to support policy (see S1 Model details for details on how this study meets NTD-PRIME principles[18]). Our model framework is flexible and could be used to predict the impact of unexpected future changes by estimating how they could alter observable (i.e. reported cases and deaths) and unobservable variables (i.e. new infections); in the present climate of the COVID-19 pandemic and recent Ebola outbreaks in
gHAT-endemic parts of DRC, this is particularly relevant and could provide support in planning whether subsequent gHAT interventions should be altered due to unforeseen interruptions.

The impact of other factors such as the screening of high-risk populations and possible animal reservoirs on gHAT transmission have been studied by mathematical modelling. Recruiting high-risk individuals can, unsurprisingly, improve the effectiveness of AS and bring down the YEOT substantially. The present framework could be extended to quantify the impact of this type of improved AS. Models considering an animal reservoir have largely been inconclusive about the presence of zoonotic transmission (when using longitudinal human case data) however they have indicated that animal reservoirs are unlikely to maintain the infection by themselves. An analysis including animal reservoirs could yield different results for YEOT predictions presented here, although our previous work suggests that we would probably not expect large qualitative differences. Another concern is asymptomatic humans maintaining transmission, although a few modelling studies have utilised frameworks explicitly incorporating asymptomatic human infections, there is limited observational data to parameterise them with high certainty, and it is unclear how their inclusion in this study would impact projections.

A new oral drug to treat gHAT, fexinidazole has now been approved for use in DRC, and is being utilised in the country. Despite the obvious advantages for patients, ease of transport and administration, it is not deemed suitable for use in individuals without parasitological case confirmation, and hence is unlikely to greatly impact on transmission as part of a strategy. A second oral drug, acoziborale, hoped to be a safe single-dose cure, is under clinical trial and could, in principle, radically change the paradigm of diagnostic and treatment algorithms, especially in an AS setting. The non-toxic compound used in acoziborale may allow mobile screening teams to “overtreat” RDT-positive, gHAT suspects without parasitological confirmation. Mathematical modelling could be used to estimate the impact of several potential diagnostic and treatment algorithms and predict the impact of such strategies using acoziborale on EOT before they begin. These types of novel interventions could be particularly helpful as we approach the endgame for gHAT.

AS planning by PNLTHA-DRC is guided at a village level by WHO recommendation. This includes stopping AS after three years of zero case de-
tection and then switching to “reactive AS” when new cases arise in PS\textsuperscript{27}.

In the present study our four strategies were assumed to carry on indefinitely without any stopping, however the economic gains and health risks of cessation should be examined. A previous health economic analysis concluded that VC can be cost-effective at low willingness-to-pay thresholds per disability-adjusted life year averted in high-risk settings\textsuperscript{25}. Taking account of the PNLTHA-DRC algorithm of reactive screening, a novel health economic analysis based on predicted model dynamics would allow for the examination of cost-effective strategies rather than the “preferred strategy” presented here based on a cruder ranking of “ambition”.

Looking across at other infections targeted for elimination, the enormity of the challenge ahead becomes apparent – with many of these programmes reaching ever lower levels of disease, but failing to meet elimination deadlines. Modelling in this study suggests that, even though elimination of gHAT in the near future may be epidemiologically feasible with current tools, its wide-spread, low-level persistence across the DRC could prove operationally challenging for achievement of the goal in the short-term. In many regions there is considerable uncertainty whether current interventions are sufficient to meet EOT in the next ten years, yet the prospect of intensifying strategies in dozens of health zones may pose a large, or even insurmountable, burden on resources (financial and personnel). As further progress is made towards elimination of gHAT, it will become increasingly crucial to use data-driven methods to optimise the endgame pathway based on practical strategies and use these methods to quantify success.

**Contributors**

CH, REC, and KSR developed the software and performed the analyses. REC, CH, and PB visualised the results. REC, EMM, and CS analysed the data. KSR developed the methods. CH and KSR wrote the original draft. KSR, SEFS, and MJK conceptualised the study. All authors reviewed and approved the final version for publication.

**Declaration of interests**

We declare no competing interests.

**Data sharing**

Data of the Atlas of human African trypanosomiasis can be requested by writing to: Jose Ramon Franco (francoj@who.int) or Gerardo Priotto (pri-
Data sharing is subject to WHO data-sharing policies and data-use agreements with the participating research centres. All model code is available at Open Science Framework (see [S3 Model Code](https://osf.io/jza27/?view_only=d523cb1edf9c4828bc63cb197e5000b2)).

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**Supplementary Information**

**S1 Model details.** Additional information on mathematical modelling methodology.

**S2 GUI.** Results for each health zone level projection can be viewed at: [https://hatmepp.warwick.ac.uk/projections/v1](https://hatmepp.warwick.ac.uk/projections/v1).

**S3 Model Code.** The code used to simulate this work is available from: [https://osf.io/jza27/?view_only=d523cb1edf9c4828bc63cb197e5000b2](https://osf.io/jza27/?view_only=d523cb1edf9c4828bc63cb197e5000b2).

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