Evaluating Strategies to Improve HIV Care Outcomes in Western Kenya

*Running Head: Strategies to Improve HIV Care Outcomes in Kenya (41 characters).*

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*Word Count = Aim is 4,000 words*

# Abstract

## Background:

## Methods & Findings:

## Conclusions:

# Introduction (*1000 words*)

“Thunderous HIV epidemic” – use this phrase somewhere.

The predominant focus of HIV funding over the last decade has been on improving access to antiretroviral therapy (ART); with the latest reports indicating that over 9 million people are receiving ART in sub-Saharan Africa{UNAIDS:2014ta}. With proper adherence, treatment can increase life-expectancy such that it approaches that of an HIV-negative individual{Nakagawa:2013cv}. Therefore, we might expect that with access to ART, the life-expectancy of HIV-positive individuals would increase dramatically; yet this does not appear to be the case, with life-years still being lost to HIV{Collaboration:2008ed}. Additionally, patients are initiating ART late with CD4 counts far lower than current treatment guidelines recommend (102 cells/μl at treatment initiation reported in South Africa between 2001 and 2009, when guidelines recommend initiation when CD4 decreases below 200 cells/μl{Boulle:2014uj}), highlighting potential failures in pre-ART care{Boulle:2014uj}. The consequences of late treatment initiation are suboptimal treatment outcomes for patients. This has recently caught the attention of donors organisations, as budget constraints have forced a shift in focus towards maximising the effectiveness of current ART-programmes[[UNAIDS Gap Report 2014](http://www.unaids.org/en/media/unaids/contentassets/documents/unaidspublication/2014/UNAIDS_Gap_report_en.pdf)].

Accumulating evidence suggests that HIV care is suboptimal not at one particular point, but across all stages of ART-programmes, as “cascading losses” have been reported throughout care{Rosen:2011ii}. However, this issue is not confined to sub-Saharan Africa; substantial losses in care have also been reported in highly developed countries too{Nachega:2014ks}. In 2011, a systematic review by Rosen and Fox illustrated that, in sub-Saharan Africa, the median proportion of patients retained from HIV testing to receipt of CD4 test results was just 59%. Of the individuals that received CD4 test results, 46% were retained until they were eligible for ART, and finally of those retained until they were eligible for ART, 68% were retained until they initiated ART. This review marked the first time that losses across the whole of pre-ART care had been quantified on a large scale. Previous studies assessing ART care in Mozambique illustrated that, 43.5% of patients were lost between HIV-testing and enrolling in pre-ART care. Of those that did enroll in pre-ART care, 22.9% were lost before receiving CD4 testing and of those who were found to be eligible for ART, 68.7% failed to initiate ART{Micek:2009hs}. Addressing why patients disengage from care, together with identifying means of returning them will improve patient outcomes by allowing for the on-time initiation of ART and retention in ART care.

Visualising the events and pathways taken by individuals through care is important step in understanding where losses are occurring and how to prevent them. Often termed, the “Cascade of Care”, this conceptualisation of an ART-programme allows us to link patient outcomes to events in time{Kilmarx:2013iy, Hallett:2013ig}. The Cascade of Care begins with the identification of HIV-positive individuals through HIV-testing. This involves the patient either seeking care voluntarily at a voluntary counselling and testing clinic (VCT), or in a healthcare setting through provider-initiated counselling and testing (PICT). Alternatively, the patient may be sought by a home-based counselling and testing team (HBCT) and diagnosed in their home. Alerting individuals to their HIV-status is still a challenge in sub-Saharan Africa, with current estimates showing only 45% of people living with HIV are aware of their status{UNAIDS:2014ta}. Kenya has made progress towards its goal of 80% awareness of HIV status, with 72% achieved in 2007{NASCOP:2012tp}. However, the marginal opportunity cost of identifying individuals increases substantially *[exponentially?]* as the pool of undiagnosed HIV-positive individuals decreases. Additionally, gaining insight into the drivers behind care-seeking behaviour may help inform future HIV-testing strategies{Moses:1994tg}.

Once diagnosed, individuals need to be linked to pre-ART care; meaning they must attend a clinic to be bled for a CD4 test in order to determine their eligibility for ART. Kranzer *et al.* define linkage to HIV care as attending for a CD4 count measurement within 6 months of diagnosis to assess ART eligibility{Kranzer:2010hp}. In this study, they found that among 885 individuals tested between 2004 and 2009 in Cape Town, South Africa, 62.6% were successfully linked to care{Kranzer:2010hp}. In contrast, we have received data illustrating that only 8.7% of patients newly tested through HBCT are linked to care within six months of diagnosis in western Kenya (AMPATH, unpublished).

After successful linkage to care, where the patient is bled for an initial CD4 count, the patient must return at a later date to receive the results of the test. This is due to CD4 tests in sub-Saharan Africa being predominantly lab-based, where the sample must be processed centrally, with a turn around time of up to two weeks{Larson:2012dq}. In resource-limited settings travelling to the HIV clinic is expensive and many individuals have to take a day off work to travel from remote areas, having a negative impact on their salary{Geng:2010fh}. A study by Larson *et al*. (2010) found that among individuals who received CD4 tests at a clinic in Johannesburg and were not immediately eligible for ART, 65% failed to return to receive the results of their CD4 test within 12 weeks{Larson:2010dz}. Unfortunately, insights into the role of care seeking behaviour are currently relatively limited; unlike in tuberculosis (TB) research where several studies have attempted to identify the drivers behind health care seeking behaviour{Buregyeya:2011fi, Salaniponi:2000tc, Pronyk:2001uk}. Although, the distance and cost associated with travelling to an HIV-clinic have already been cited as reasons why patients disengage from care{Geng:2010fh, Yu:2007wh, Ware:2009id}. In many cases, pre-ART care can be rather prolonged, with the patient enduring multiple CD4 tests and clinic visits prior to ART initiation. This can lead to care-fatigue, where patients disengage with care as they are not receiving any therapeutic benefit. This is backed up by findings from Kenya, in which a CD4 count of >200 cells/μl at enrollment into pre-ART care was shown to result in a 3.49 fold increase in the odds of being lost from care{Geng:2010du}.

Eligibility for treatment is determined by country-specific guidelines. The latest guidelines from the World Health Organization released for adoption in June 2013 state ART should be initiated when a patient’s CD4 count drops below 500 cells/μl{WorldHealthOrganization:2013we}. After receiving confirmatory CD4 test results determining ART eligibility, patients must undergo counselling before initiating ART. In some settings, owing to the significant losses occurring upstream in pre-ART care, only 18% of tested individuals have been shown to be successfully retained in care until ART initiation{Rosen:2011ii}, combined with multiple large scale studies illustrating CD4 counts of patients initiating ART being far lower than recommended treatment guideline values at the time{Nash:2011ki, Boulle:2014uj}, indicate pre-ART care, in many settings, to be poor at retaining healthy individuals until they become eligible for treatment.

ART initiation marks the start of lifelong ART care, where a successful treatment outcome can be achieved through retention in care and adherence to ART. Unfortunately, this does not appear to be the case in sub-Saharan Africa where 46-85% of patients are retained 24 months after initiation{Rosen:2007hd}. Another large study analysing over 200 thousand individuals in sub-Saharan Africa showed that retention in ART care fell from 77.4% at 12 months, to 75% at 24 months and finally to 70.5% at 36 months since ART initiation{Fox:2010gt}. After 24 months attrition averaged around 5% per year, highlighting long term retention on ART as an obstacle to achieving optimal patient outcomes in resource-limited settings{Fox:2010gt}.

Substantial evidence now highlights deficiencies in both pre-ART and ART care, challenging the traditional idea of linear flow through the cascade in which patients move sequentially between events. The reported structural failures and discrepancies of current ART-programmes therefore suggest that care is perhaps more cyclical than linear; with this “churn” of patients engaging and disengaging over time{Gill:2009dj, Hallett:2013ig, Miller:2014ba}. If patients’ initiate ART late, with very low CD4 counts, after being lost from care, the route back into care becomes an important target for interventions. Hallett & Eaton termed these re-engagement routes as “side doors” into care, to supplement the traditional “front door” route into care through which care naïve individuals enter{Hallett:2013ig}. This “side door” distinguishes patients with no previous care experience from those reconnecting with care, thus allowing us to understand the different dynamics of these two routes into care. Gaining insight into how these patients lost from care re-engage, and how care-naïve individuals engage for the first time is vitally important in terms of repairing and reinforcing care.

However, the drivers behind patients’ disengagement and reengagement are ambiguous, and while it has been hypothesised that the development of symptomatic HIV is likely to be key in pushing individuals to seek care, data on individuals lost from care is scarce. Currently available data highlights the need for a consistent definition of “lost to follow-up”, together with the need for high resolution longitudinal data that will enable us to map the individual pathways taken by patients through care.

Fortunately, a select few facilities in sub-Saharan Africa are beginning to collect and distribute this type of data, thereby allowing us to disentangle the web of routes through care and accurately calibrate mathematical models to provide insight into the dynamics of the cascade of care. In this paper we evaluate an ART-programme in western Kenya. Through the use of mathematical modelling, we identify weaknesses resulting in suboptimal patient outcomes and demonstrate how interventions targeting different points of care can improve health benefits for patients.

*Potential things to include in introduction:*

* The interplay between patient behaviour, economic factors and the availability of health services plays an important role in determining a person's propensity to seek and be retained in care{Burns:2014jz}.
* This “cascade” of losses across all stages of HIV-care means that the benefits afforded by ART are not fully realised.
* The current state of care differs if you consider it from the clinic’s viewpoint or the community’s viewpoint. [introduce idea of looking down the pipe here?]
* The widespread scale-up of HIV-testing during the last decade together with the increased availability of treatment has shifted bottlenecks in care away from the availability of testing and treatment to the logistics and organisation of HIV care.
* With renewed focus on cutting costs and funding constraints on large donors, existing HIV care programmes must be strengthened to improve the cost-effectiveness of treatment.
* WHO Guide and Tools for programme managers to collect data on Cascade [[link](http://applications.emro.who.int/dsaf/EMROPUB_2014_EN_1639.pdf)]
* Inclusion of Jain et al. (2014) paper on ART delivery among asymptomatic people initiating with CD4 >350 cells. [Not randomized and likely only treatment-KEEN people].

*→ Clinic level programmatic measures of success (if the intervention is successful, what will the clinic see? Increase in throughput? More drug stockouts? Higher CD4 at entry to care / ART initiation?) [this will be useful for the figure 2 narrative.*

# Methods *(500 words)*

*Overview*

We constructed an individual-based micro-simulation to capture the experience of individuals as they move through the various stages of HIV care. The first step involved developing a mathematical model that described the progression of HIV infection with declining health status and associated mortality. This HIV natural history model was then expanded to capture the events that make up an ART-programme, the so-called HIV Cascade of Care.

The natural history model was calibrated using surveillance data from the literature to accurately describe HIV progression and mortality prior to ART initiation and immunoreconstitution after ART initiation. Calibrating the flow of individuals through HIV care in the cascade model was undertaken by utilising high resolution longitudinal data from AMPATH in western Kenya, thus allowing us to model the current state of this specific ART-programme. To understand how costs accrue in an ART-programme, data was sought that described the cost of the individual components of care (e.g. Rapid HIV-test or pre-ART clinic appointment).

To assess where care is suboptimal in this specific ART-programme in western Kenya, the calibrated model was used to replicate the HIV epidemic together with the scale up of treatment from 2004 onwards. Output metrics are DALYs averted and cost between 2010 and 2030. In the absence of any interventions, we were able to define baseline values for impact and cost. We then explored the impact of a range of interventions acting at various points along the care pathway. The impact of each intervention in relation to the baseline scenario indicates the extent to which health outcomes can be improved for patients, along with the cost of these improvements. A univariate analysis identified the most impactful intervention, before multivariate analysis explored intervention combinations.

## Model description

The mathematical model we constructed can be described as two submodels: The Natural History Model and The Cascade Model. These two models work to describe the health status of an HIV-positive individual and their movements through care.

The Natural History Model is described in more detail in the appendix but briefly, we model infection progression upon HIV acquisition in terms of declining CD4 counts, the development of WHO Stage defining conditions and associated mortality prior to ART initiation. Upon initiating and adhering to ART, CD4 count decline reverses and the individual recovers from their WHO Stage defining conditions. Mortality hazards are associated with each health state, so as ART improves health, the mortality hazard decreases. However, if an individual fails to adhere to ART, their health declines as if they were not on ART.

We begin the model in 1970 and create an initial cohort of HIV-negative individuals with an age distribution matching that of Kenya in the same year. We model population growth, by allowing new individuals to be born each year. Individuals are exposed to the annual hazard of acquiring HIV from 1975 onwards, with this hazard updating each year to drive HIV incidence[[link](http://www.unaids.org/en/dataanalysis/datatools/spectrumepp2013/)]. We start testing HIV-positive and negative individuals in 2004 along with rolling out ART for eligible individuals. We used the 2004 WHO Treatment Eligibility Guidelines of a CD4 count <200 or WHO Stage IV {WorldHealthOrganization:2005ws}. This is updated in 2011 to a CD4 count of <350 or WHO Stage III/IV{WorldHealthOrganization:2010wj}.

The Cascade Model, shown in figure 1, describes the events and pathways through care for HIV-positive individuals. Care seeking behaviour in this model is driven by declining health in The Natural History Model. As described above, the model begins with care naïve individuals of undetermined serostatus. Individuals are then tested from 2004 onwards through one of three routes: HBCT where individuals are sought and tested at home, VCT where individuals voluntarily attend an HIV-clinic or PICT where individuals seek care due to being symptomatic or having had previous healthcare experience. If an individual is found to be HIV-negative, they do not progress any further through care. They may be tested multiple times throughout their lives and care will only progress if they are found to be HIV-positive. The Cascade Model is described in detail in the appendix.

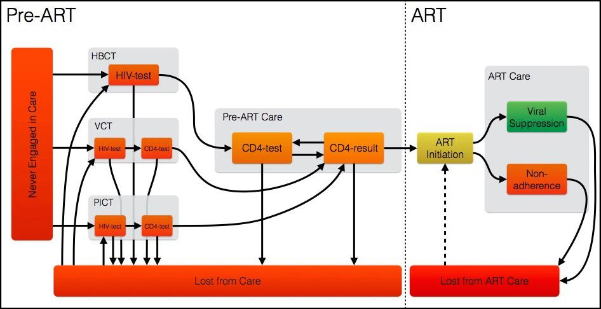


Figure 1. Model Representation of the Cascade of Care

## Natural History Calibration

The Natural History Model was calibrated using surveillance data sourced from the literature. A review of the literature was conducted to identify relevant studies that would enable us to calibrate every aspect of the Natural History Model. Where possible, data from cohort studies was utilised; although, in some situations data from observational studies was used. The full description of each data source used for calibration of The Natural History Model can be found in the appendix.

## Cascade of Care Calibration

To calibrate the Cascade Model describing the experience of HIV-positive individuals as they move through the various stages of HIV care, we utilised a unique high resolution longitudinal dataset from western Kenya. The Academic Model for Providing Access To Healthcare (AMPATH), based in Eldoret, is made up of Moi University, Moi Teaching and Referral Hospital and a consortium of North American academic health centers led by Indiana University working in partnership with the Government of Kenya.

Since launching in 2006, the AMPATH Medical Record System (AMRS) has been collecting individual-level data on the AMPATH AIDS-control system, which has been described as a model of sustainable development{Einterz:2007js, Tierney:2007th}. Service delivery occurs through public sector hospitals and health centers run by the Ministry of Health{Einterz:2007js}. AMPATH has very well established VCT and PICT programmes, and after trailing the use of HBCT in 2007, officially rolled it out in 2010{Wachira:2013dc}. Recently, AMPATH is extending this with their Find-Link-Treat-Retain programme (FLTR); involving finding all HIV-infected individuals, linking each to care, treating them with ART and retaining them in care for life)[[website](http://news.medicine.iu.edu/releases/2014/05/ampath-abbvie-hiv-testing.shtml)].

AMPATH’s ability to look back at the care history of individual patients, through tracing their unique identification number allowed us to ask very specific questions regarding the flow of individuals through care. Using data from the Port Victoria catchment area, data analysts at AMPATH calculated the losses occurring at each stage of HIV care from 2007 to June 2014, and together with the average delay between each event we were able to extract parameter values that were directly inputted into the model, together with calibration points such as the distribution of CD4 counts at ART initiation. Calibration was undertaken systematically to ensure we were accurate in capturing the changing dynamics of care. Full details of the Cascade Model calibration can be found in the appendix.

## Cost Derivation

The cost of the individual components of care was included in the model. The majority of costs, including the cost of ART care, pre-ART clinic visits and CD4 lab-based tests, were derived from a multi-country analysis of 161 treatment facilities across five countries in sub-Saharan Africa[[MATCH](http://thedata.harvard.edu/dvn/dv/chaighf/faces/study/StudyPage.xhtml?studyId=85882&tab=catalog)]. The remaining costs were sourced from the literature. All costs were adjusted for inflation and location by using the gross domestic product deflator from the International Monetary Fund. Including the cost of the individual components of care in the model allows us to understand how costs accrue in an ART-programme. Additionally, when interventions are applied, we can see the financial implications of improving care. Further details of the breakdown of cost in the model can be found in the appendix.

## Output Metrics

The output metrics from the model were DALYs averted and cost accrued between 2010 and 2030. We weighted DALYs according to current HIV-positive health state and ART status. We also looked at the care experience of individuals who died from HIV-related deaths between 2010 and 2030. Further details can be found in the appendix.

## Assessing Losses in Care

To assess the current state of our specific ART-programme in western Kenya, we assessed the total number of DALYs and cost of care that accrue between 2010 and 2030. This was conducted in the absence of HBCT, so the only means of entering care was through VCT or PICT. HBCT was removed as home-based counselling and testing is not currently found in most ART-programmes in sub-Saharan Africa, therefore providing a more representative baseline scenario.

The care experience of individuals who died from HIV-related deaths was also studied in the baseline scenario to identify, for example, the proportion of individuals who never seek care prior to dying from HIV. This can be thought of as the “view” from the community. It allows us to consider all HIV-positive individuals and their personal experience of care prior to an HIV-related death. This is easy to quantify in the model, but it is more difficult to accurately assess cause-specific mortality in the field. Additionally, the care experienced by individuals who suffer HIV-related deaths is likely to be significantly altered by interventions aimed at strengthening care. Therefore, we also consider the “view” from the clinic; looking at the care experience of all individuals initiating ART. It allows us to understand from the clinics perspective the experience of patients who have engaged with care. This can easily be measured by an ART clinic to assess the current state of practice. The impact of interventions aimed at improving care can also be measured by assessing changes from both the community’s and the clinic’s perspective. Changes brought about by interventions can be calculated by the model and if an intervention were to be rolled out, a clinic would be able to validate the intervention against the model output.

The differences between these two viewpoints is important for assessing the current state of an ART-programme. From the clinic’s perspective, an individual’s first contact with the clinic is to receive either an HIV-test or to be bled for their initial CD4 count. The clinic can easily trace patients from this point onwards. However, the clinic is unaware of HIV-positive individuals that never seek care. Thus, the community’s viewpoint allows us to look at the larger denominator of all HIV-positive individuals and their experience of care. Figure 2 illustrates the different perspectives of the clinic and the community.

## Intervention Development

To further understand where care in western Kenya is suboptimal, we designed 12 interventions targeting various points throughout HIV-care. Each intervention is summarised in table 1 and detailed in full in the appendix. Where possible, each intervention has two scenarios: a “maximum impact” scenario illustrating the best possible impact of the intervention and a “realistic impact” scenario which aims to demonstrate the impact of a more obtainable intervention. Interventions were implemented in the model from 2010 onwards and their impact on DALYs averted, costs accrued and the care experience of individuals dying from HIV-related deaths quantified.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Intervention type** | **Intervention** | **Maximum Impact** | **Realistic Impact** | **Cost**  **(2013 USD)** |
| *Testing* | ***HBCT*** | Every four years, 90% coverage of population. 100% linked to care. | Every four years, 90% coverage. 5.4% linked if never diagnosed, else 20%. | $18 per HBCT person tested |
| *Testing* | ***Enhanced VCT*** | The rate of HIV testing is twice that of baseline. | The rate of HIV testing is 125% that of baseline. | $50 per person tested. |
| *Linkage* | ***HBCT (with POC)*** | Ever four years, 90% coverage of population. POC CD4 reduces risk of not linked to 0%. | Every four years, 90% coverage of population. POC CD4 reduces risk of not linked by 50%. | $60 per HBCT person tested |
| *Linkage* | ***VCT POC*** | At VCT testing, a POC CD4 test is given to patients reducing the risk of not linking to 0%. | - | $80 per POC CD4 test |
| *Linkage* | ***Facilitated Linkage*** | The risk of failure-to-link is reduced to 0% | The risk of failure-to-link is reduced by 50%. | No additional costs applied. |
| *Pre-ART Retention* | ***Pre-ART Outreach*** | In the middle of each year, 100% of tested individuals lost from care are returned. | In the middle of each year, 20% of tested individuals lost from care are returned. | $19.55 per patient sought. |
| *Pre-ART Retention* | ***Improved Care*** | The risk of a patient missing an appointment is reduced to 0%. | The risk of a patient missing an appointment is reduced by 50%. | No additional costs applied. |
| *Pre-ART Retention* | ***POC*** | A POC CD4 test reduces loss from care between CD4 test and result by 100%, as bleeding and result are instantaneous. | - | $70 per POC CD4 test. |
| *On-ART Retention* | ***On-ART Outreach*** | In the middle of each year, 100% of patients who have initiated ART and been lost from care are returned. | In the middle of each year, 40% of patients who have initiated ART and been lost from care are returned. | $19.55 per patient sought. |
| *On-ART Retention* | ***Adherence*** | At ART initiation, all individuals adhere to ART and become virally suppressed. | At ART initiation, 87.5% of individuals adhere to ART and become virally suppressed. | $33.54 per person per year. |
| *Sweeping Changes* | ***Immediate ART*** | No pre-ART care, all individuals who enter care are treated immediately. | - | No additional costs applied. |
| *Sweeping Changes* | ***Universal Test & Treat*** | Immediate ART + HBCT | - | $18 per HBCT person tested. |

Table 1. Summary of interventions applied from 2010 to 2030.

# 

# Results *(1000 words)*

* ***What questions am I attempting to answer? Let this guide the analysis.***
* After simulating individuals over time from 1970 onwards, we allowed HIV-testing and treatment to start in 2004 with the treatment guidelines <200 or WHO stage IV. These guidelines changed in 2011 to <350 and WHO stage III or IV.
* Illustrate current functioning of ART programme in western Kenya in the absence of interventions (i.e. without large scale HCT).
* Discuss losses in care from clinic and community viewpoints. Discuss what the model shows us that just “eyeing the data” cannot - how losses accumulate across the cascade, ability to quantify impact of care through LYL due to HIV.
* Assess definitions of successful patient outcomes - use as baseline values to compare results of interventions with.
* Demonstrate impact of interventions when applied from 2010 onwards.
* The results of running the model without any interventions applied (baseline) was then compared to a model run with an individual intervention applied. The results are shown in figure 3.
* Discuss results…
* Figure 4, illustrates the impact of building up interventions to achieve maximum impact. Figure 4 illustrates this in three scenarios: (1) building up interventions from the start of pre-ART care towards ART care (for example, a testing intervention followed by a linkage intervention, a retention intervention and then an ART intervention), (2) the second scenario looks at building the interventions that show the greatest impact by averting the most DALY’s between 2010 and 2030. The third scenario (3) involves building up interventions by considering the cost of each intervention and applying in order, the interventions with the lowest cost per DALY averted.

# Discussion *(1500 words)*

* Review existing interventions acting to strengthen care (from literature) focusing on individual interventions acting on care.
* Highlight how a combination of interventions will be crucial to maximising health benefits and being cost effective in doing so... strength of the approach shown in figure 4.
* Many current interventions only focus on one area of the cascade and don’t consider the downstream impacts.
* Future interventions could be designed to impact the cascade in its entirety - e.g. integration of HIV services, food incentives, patient navigators.
* Lack of current studies testing interventions aimed at key populations
* Discuss care cascade in other infections: TB, Malaria etc.
* Argue why modelling the cascade is much more important than simply “eyeing the data”.
* To mention: if you look at the relative time spent in each stage.. perhaps indicative that ART care is more important to focus on as it is LT - However, this is not the case as so few individuals actually ever initiate ART (~13%).
* Illustrate how figure 4 shows the various pathways to improving health outcomes, improving patient survival, reducing HIV-related deaths in three scenarios, with the third being the most cost effective.

→ Shift in HIV thinking… acquiring characteristics of LT chronic disease and non-lethal. {vanSighem:2010gw} [useful!?]

→ How does time impact the relative importance of leaks in care - i.e. is a small leak in ART care worse than a large leak in pre-ART care, as people spend many years in ART care?

* **Strengths** of this work:
  + Model accurately describes natural history of HIV
  + Cascade events are calibrated using unique dataset that enables us to track individual patients through time allowing us to understand the various pathways taken through care.
  + Model replicates national HIV prevalence for Kenya from 1970 onwards.
  + The model allows us to apply interventions to reduce the losses occurring in care and quantify the impact.
  + Applying an intervention at one point may have considerable downstream effects, something that only a model can elude to.
* **Limitations** of this work:
  + Only focuses on one location (how generalisable is this to the whole of Kenya? / SSA?).
  + Could the structure / construction of the model biased in anyway?
  + Assumptions regarding care seeking behaviour? (major driver behind getting individuals into care) - mention that future work will focus on this.

→ The hypothesis of treatment fatigue has been raised, in which patients that feel “healthy” may discontinue treatment or fail to initiate as they feel it unnecessary{Nachega:2014ks, Katz:2011er}. [Useful for discussion / limitations of interventions on care].

* Clinical relevance:
  + Are these interventions feasible?
  + If the funding were available, how can this be implemented by planners on the ground? (suggest implementation strategies / time frames)
    - Could even look into a graded roll-out of interventions over time. Say, the addition of a new intervention each year?
* Key implications of this research:
  + Weaknesses exist in this specific ART-programme in western Kenya.
  + Current funding for ART could be more impactful if these weaknesses in care were addressed and resolved.
  + Multiple interventions acting on various aspects of care are likely to be more effective than a single intervention.
* Generalisability:
  + This research only focuses on one location so the results are not generalisable to the entirety of sub-Saharan Africa.
  + However, these results provide some insight into the likely situation of many ART-programmes.
  + Future research in different locations will allow for interventions to be tailored for a specific site, and also to provide a more up to date picture of the state of ART-programmes in sub-Saharan Africa.
* How can future research build on these observations:
  + AMPATH are highly unique in having collected a large database from many sources that has the ability to link patients from various stages of care. This has allowed them to track an individual patient over time from initial diagnosis through the various events that make up HIV-care.
  + The ability to track patients over time is key, more studies are required reporting this type of data.
  + This will allow us to track population health over time, as well as assess the impact of interventions that may be being rolled out.
  + Future research can identify losses in care in other locations in SSA, together with identifying whether a different set of interventions may be more impactful in another location.
  + Future research may also test the impact of the interventions suggested in this location to further validate the model results.
* Future work:
  + Calibration of model to a new location.
  + Comparison between two or more locations.
  + Detailed investigation into role of health care seeking behaviour.
  + Assessing the value of the proposed WHO “monitoring and evaluation” indicators.

# Acknowledgements

# References

# Figure Legends

*Figure 1 - Flow diagram of the cascade of care*

*Figure 2 - Status quo scenario from the perspectives of the clinic and the community*

*Figure 3 - Cost Impact plot illustrating the cost and impact of various interventions*

*Figure 4 - Combination of approaches for improving health outcomes for patients*

*Table 1 - Summary of interventions acting on the cascade of care*

# Supporting Information