Impact of treatment on hepatitis C virus transmission and incidence in Egypt: A case for treatment as prevention

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Abstract
Egypt has launched a hepatitis C virus (HCV) treatment programme using direct-acting antivirals (DAAs). Our aim was to assess the impact of five plausible programme scale-up and sustainability scenarios for HCV treatment as prevention in Egypt. We developed and analysed a mathematical model to assess programme impact using epidemiologic, programming and health economics measures. The model was parametrized with current and representative natural history, HCV prevalence and programme data. HCV incidence in Egypt is declining, but will persist at a considerable level for decades unless controlled by interventions. Across the five programme scenarios, 1.75-5.60 million treatments were administered by 2030. Reduction in incidence (annual number of new infections) by 2030 ranged between 29% and 99%, programme-attributed reduction in incidence rate (new infections per susceptible person per year) ranged between 18% and 99%, number of infections averted ranged between 42,393 and 469,599, and chronic infection prevalence reached as low as 2.8%-0.1%. Reduction in incidence rate year by year hovered around 7%-15% in the first decade of the programme in most scenarios. Treatment coverage in 2030 ranged between 24.9% and 98.8%, and number of treatments required to avert one new infection ranged between 9.5 and 12.1. Stipulated targets for HCV by 2030 could not be achieved without scaling-up treatment to 365,000 per year and sustaining it for a decade. In conclusion, DAA scale-up will have an immense and immediate impact on HCV incidence in Egypt. Elimination by 2030 is feasible if sufficient resources are committed to programme scale-up and sustainability. HCV treatment as prevention is a potent and effective prevention approach.

KEYWORDS
Egypt, hepatitis C virus, incidence, mathematical model, treatment as prevention

1 | INTRODUCTION

Viral hepatitis has been estimated as the 7th leading cause of mortality globally.1 About half of this mortality is attributed to hepatitis C virus (HCV), a virus that causes acute hepatitis, fibrosis, cirrhosis and liver cancer among other disease sequelae.2-3 HCV was estimated to affect 1%-3% of the population in most countries,4,5 but higher prevalence was found in few countries such as Egypt with an antibody prevalence of about 10%,6-8 apparently the highest worldwide.8

Abbreviations: DAA, direct-acting antiviral; EDHS, Egypt Demographic and Health Surveys; GDP, gross domestic product; HCV, hepatitis C virus; SM, supplemental material; TasP, treatment as prevention; UI, uncertainty interval; WHO, World Health Organization.

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Recent breakthroughs in HCV treatment, namely the highly efficacious oral direct-acting antiviral (DAA) therapy, have opened opportunities for controlling HCV infection, reducing burden and cost of managing liver-related conditions, and even elimination of HCV as a public health concern. Importantly, treatment of chronic infection will reduce the pool of infected persons, thereby preventing further transmission.

The World Health Organization (WHO) has recently formulated the “Global Health Sector Strategy on Viral Hepatitis, 2016-2021” and established service coverage targets to eliminate HCV as a public health threat by 2030.10,11 The new strategy calls for scale-up of HCV diagnosis and treatment by 2030 for a target coverage of 90% and 80%, respectively, and an 80% reduction in incidence by 2030.10,11

With DAA availability, Egypt has launched an ambitious new national treatment programme in 2014,12-14 with the goal of reducing chronic HCV prevalence to <2% in 10 years, in line with global targets. Egypt has also managed to attain price breaks of up to 99% in the cost of branded DAA 15 and aimed to treat 250,000 persons annually up to 2020 as a first phase in their treatment programme.12

Against this background, and following success of the concept of treatment as prevention (TasP) for HIV infection,16 we aimed in this study to assess the impact and implications of the concept of TasP for HCV infection as demonstrated in an application for Egypt. Specifically, we developed a dynamic forecasting mathematical model to (i) assess the impact of Egypt’s treatment scale-up on HCV incidence using different scenarios of scale-up and sustainability, (ii) assess the treatment scale-up and sustainability that is required to achieve 90% reduction in HCV incidence by 2030 (a slight modification of the 80% global target) and (iii) assess the scale-up and sustainability that is required to achieve HCV elimination by 2030—where elimination is defined as an incidence rate <1 per 100,000 persons per year by 2030. Our overarching goal is to examine whether HCV-TasP is a strategic prevention approach in the context of a generalized HCV epidemic, complementing primary prevention approaches of interventions such as injection safety, blood screening and infection control.

2 MATERIALS AND METHODS

2.1 Mathematical model

We constructed a deterministic dynamical mathematical model, based on extension of earlier models 17,18 and modelling guidelines for best practice,19 to describe HCV transmission in a given population—in this case the population of Egypt (Fig. S1 in Supplemental Material (SM)). The model consists of a set of coupled nonlinear differential equations and stratifies the population by age, HCV status, stage of infection and level of risk of exposure to the infection (SM). HCV natural history in the model is divided into three stages: primary acute infection, secondary acute infection and chronic infection.20

The model disaggregates Egypt’s population into three age groups: children (1-14 years old), adults (15-59 years old) and elders (>60 years old). To account for heterogeneity in exposure risk, the model incorporates five risk groups, starting from lower to higher levels of exposure risk (one being the lowest and five being the highest). We did not model explicitly specific modes of transmission, and each risk group collectively represents different transmission pathways of similar level of exposure risk. Given the hierarchy of exposure risk, risk of reinfection among the highest risk group (such as people who inject drugs (PWID)) can be considerable, but is minimal among the healthy general population. The distribution of exposure risk across risk groups follows a power-law function, while the distribution of the population across risk groups follows a gamma distribution, as informed by earlier modelling work.21-27 The duration that an individual spends in a specific risk group was set through a hierarchy starting from 12 years for the highest risk group (say a PWID injecting career of 12 years 28) up to 40 years for the lowest risk group. Individuals who leave their risk group are distributed proportionally across all risk groups.

The mixing between individuals in different risk groups is dictated by a mixing matrix that allows a range of mixing behaviours varying from fully assortative (only with individuals in the same risk group) to fully proportionate (no preferential bias for any risk group).29,30 The force of infection is expressed in terms of the effective rate of contacts conducive for transmission, HCV transmission probability and mixing among risk groups (SM). Further details on model structure and assumptions can be found in SM.

2.2 Data sources and model fitting

We parameterized the model using current data for HCV transmission and natural history (Table 1 and Table S1 in SM), as well as nationally representative population-based data for HCV antibody prevalence in Egypt, those of the 2008 and 2015 Egypt Demographic and Health Surveys (EDHS).6,7 As there are no nationally representative data among those >60 years of age, we assumed that HCV prevalence among them in 2015 is given by HCV prevalence among those 55-59 years of age in the 2008 EDHS (40%).7 Demographics such as total population size and its future projections were obtained from the database of the Population Division of the United Nations Department of Economic and Social Affairs,21 and these projections were reproduced by our model (Fig. S2 in SM).

The model was fitted to HCV prevalence trend data using a nonlinear, least-square fitting method. This technique was implemented in MATLAB® 32 using the Nelder-Mead simplex algorithm.33 To fit the model to Egypt’s trend data, the population-average exposure risk was assumed to vary during the epidemic. Further details on data sources and model fitting can be found in SM.

2.3 Epidemiologic, programming and health economics measures

The impact and implications of Egypt’s treatment programme were assessed through epidemiologic, programming and health economics measures. Chronic infection prevalence was projected along with incidence, defined as number of new infections per year, and incidence rate, defined as number of new infections per susceptible person per year.

Incidence or incidence rate reductions were estimated using two approaches, each for a specific purpose. In the first one, incidence reduction was assessed by comparing incidence at a given time with...
the incidence in 2010, before programme launch. This estimate was used to define targets such as the 90% incidence reduction by 2030.

In the second approach, incidence rate reduction was assessed by comparing incidence rate at a given time in the presence of intervention, with that in the no-intervention counterfactual scenario. This estimate was used to quantify incidence rate reduction that is strictly attributed to the programme. Of note, the incidence rate in Egypt is on a trajectory of decline even in the absence of any treatment intervention (Figure 2A). This necessitated this approach to disentangle incidence rate reduction attributed to the programme from that due to “natural” epidemic course.

Annual reduction in incidence rate was also calculated to assess progress year by year. This was calculated by comparing incidence rate at a given time with that exactly one year earlier. Of note, this measure reflects reductions due to both intervention impact and natural epidemic course.

Number of averted infections was calculated by subtracting number of new infections since programme launch from that in the no-intervention counterfactual scenario. Effectiveness of HCV-Tasp as an intervention was defined as number of treatments required to avert one new infection. This measure was calculated by dividing number of treatments by number of infections averted over a chosen time horizon. Programme treatment coverage was calculated by dividing number of living treated persons at a given time by number of living chronically infected persons at that time. We applied an annual discount rate of 3% on future savings (infections averted).34 Cost-effectiveness of HCV-Tasp was defined as the cost to avert one infection. This measure was calculated by dividing cost of programme since its launch by number of infections averted in this time horizon. All costs were calculated in USD. We assumed a total cost of $900 per treatment, mainly covering branded DAAs direct costs. Following convention, we applied an annual discount rate of 3% on future expenditures.35

**Table 1** Key HCV natural history and transmission parameters

| Parameter                                      | Value   | Justification                                                                 | Sources |
|------------------------------------------------|---------|-------------------------------------------------------------------------------|---------|
| Transmission probability per contact in chronic infection stage | 0.048   | Combination of empirical data and quantitative estimates                      | 17-45-49|
| Transmission probability per contact in primary acute infection | 0.1296  | Based on the relative level of viral load with respect to chronic infection stage | 46      |
| Transmission probability per contact in secondary acute infection | 0.0648  | Reduction of 50% in viral load during secondary acute infection with respect to initial primary acute infection | 50      |
| Duration of primary acute HCV infection stage | 16.5 wks | Direct measurement from a prospective cohort study                            | 51      |
| Duration of secondary acute HCV infection stage | 4.125 wks | Direct measurement from prospective cohort studies                           | 50,52   |
| Fraction of individuals who clear their primary acute HCV infection spontaneously (first infection) | 38.5%   | Estimated value by fitting HCV RNA prevalence among antibody-positive individuals per Egypt Demographic and Health Surveys data. This estimated value is within the range of other estimates such as those coming from observational studies.6,7,18 | 6,7,18  |
| Fraction of individuals who clear their secondary acute HCV infection spontaneously (reinfection) | 83%     | Direct measurement from a prospective cohort study                           | 50      |

2.4 | Treatment programme scenarios

We modelled Egypt’s epidemic and scale-up of the programme initiated in 2014. Informed by programme data,11-13 stakeholder discussions and experiences with similar scope programmes,26,37 the treatment programme was assumed to start with a scale-up phase that lasts up to 2020, followed by a sustainability phase starting from 2021 up to 2030, the target year for elimination. Any chronically infected person 15 years of age or older, regardless of liver disease stage, was assumed eligible for treatment. Treatment success (sustained virologic response) rate of 90% was assumed.38

Five programme scenarios were explored (Figure 1):

2.4.1 | Baseline scale-up scenario

We assumed 250 000 treatments annually between 2014 and 2020, in line with scale-up plan in Egypt.12,13 After 2020, no sustainability phase was assumed and the programme is halted. This scenario is the least ambitious for the programme.

2.4.2 | Scale-up and sustainability scenario

We assumed that the programme starts with the baseline scale-up scenario up to 2020, but then is followed by a sustainability phase from 2021 to 2030 in which the annual number of treatments is sustained at 250 000.

2.4.3 | Target 80% incidence reduction scenario

We assumed that the programme starts with the baseline scale-up scenario up to 2020, but then is followed by a sustainability phase from 2021 to 2030 in which the annual number of treatments is set at a level that can achieve 80% incidence reduction by 2030.

2.4.4 | Target 90% incidence reduction scenario

We assumed that the programme starts with the baseline scale-up scenario up to 2020, but then is followed by a sustainability phase from 2021 to 2030 in which the annual number of treatments is set at a level that can achieve 90% incidence reduction by 2030.
2.4.5 | Elimination scenario

We assumed that the programme starts with the baseline scale-up scenario up to 2020, but then is followed by a sustainability phase from 2021 to 2030 in which the annual number of treatments is set at a level that can yield an incidence rate <1 per 100,000 persons per year by 2030. This is the most ambitious scenario explored here and would virtually eliminate HCV incidence in Egypt.

2.5 | Uncertainty and sensitivity analyses

We conducted multivariable uncertainty analyses to determine the ranges of uncertainty in incidence rate reduction and HCV-TasP effectiveness by 2030 with respect to variations in the model structural parameters including scale parameter of the risk-group gamma distribution, duration spent in a specific risk group, exponent parameter of the power-law function of exposure risk and degree of mixing assortativeness. We implemented 1000 model runs applying at each run Monte Carlo sampling from uniform probability distributions assuming 25% uncertainty around the point estimates (Table S1 in SM). Each set of sampled parameters was used to recalculate incidence rate reduction and HCV-TasP effectiveness by 2030. Means of calculated measures and associated 95% uncertainty intervals (UIs) were calculated and reported for each scenario.

To assess how HCV-TasP effectiveness may potentially vary for settings at lower incidence rate than Egypt, we conducted a sensitivity analyses.
analysis by calculating HCV-TasP effectiveness by 2030 as a function of incidence rate. This calculation was implemented using Egypt's model, but by lowering HCV population-average exposure risk to yield a lower incidence rate.

3 | RESULTS

Figure 2 shows model projections up to 2030 for the trend in HCV antibody prevalence among children, adults and elders compared to EDHS data (Figure 2A), trend in HCV antibody prevalence in the total population (Figure 2B) and trend in HCV antibody incidence rate in the total population (Figure 2C). HCV prevalence was predicted to be in a trajectory of decline, even in the absence of mass treatment programme. While HCV prevalence in the total population was estimated at 9.3% in 2015, it was projected to decline to 5.8% by 2030. Similarly, while HCV incidence rate was estimated at 110 per 100 000 persons per year in 2015, it was projected to decline to 74 per 100 000 persons per year by 2030, a 33% reduction over this time horizon.

Table 2 and Figure 3 show the predicted impact of the five programme scenarios among the total population of Egypt, and Fig. S3 in SM shows the predicted impact among only adults 15-59 years of age. In the baseline scale-up scenario, a total of 1.75 million treatments were administered up to 2020, when the programme was halted, contributing to an incidence reduction of 21% by 2020 and 29% by 2030 compared to 2010 incidence. Incidence rate reduction strictly attributed to the programme was estimated at 17.2% in 2020 and 18.4% in 2030. Annual reduction in incidence rate hovered around 7% per year up to 2020, when the programme was halted, and declined thereafter. Number of infections averted was 42 393 by 2020 and 183 760 by 2030. Chronic infection prevalence declined to 4.0% by 2020 and 2.8% by 2030 in this scenario, compared to 5.4% in 2020 and 4.0% in 2030 in the no-treatment-intervention scenario.

In the scale-up and sustainability scenario, a total of 1.75 million treatments were administered by the end of the scale-up phase, and a total of 4.25 million by the end of the feasibility phase. These contributed to an incidence reduction of 21% by 2020 and 66% by 2030 compared to 2010 incidence. Programme-attributed incidence rate reduction was estimated at 17.2% in 2020 and 64.0% in 2030. Annual reduction in incidence rate hovered around 7-9% per year up to 2025 and then increased rapidly thereafter as the pool of chronically infected persons became depleted. Number of infections averted was 42 393 by 2020 and 350 883 by 2030. Chronic infection prevalence declined to 4.0% by 2020 and 2.8% by 2030 in this scenario, compared to 5.4% in 2020 and 4.0% in 2030 in the no-treatment-intervention scenario.

In the target 80% incidence reduction scenario, a total of 1.75 million treatments were administered by the end of the scale-up phase, and a total of 4.95 million by the end of the feasibility phase. These contributed to an incidence reduction of 21% by 2020 and 80% by 2030 compared to 2010 incidence. Programme-attributed incidence rate reduction was estimated at 17.2% in 2020 and 80% in 2030. Annual reduction in incidence rate hovered around 7-12% per year up to 2025.
and then increased rapidly thereafter. Number of infections averted was 42,393 by 2020 and 408,340 by 2030. Chronic infection prevalence declined to 4.0% by 2020 and 0.6% by 2030, compared to 5.4% in 2020 and 4.0% in 2030 in the no-treatment-intervention scenario.

In the target 90% incidence reduction scenario, a total of 1.75 million treatments were administered by the end of the scale-up phase, and a total of 5.40 million by the end of the feasibility phase. These contributed to an incidence reduction of 21% by 2020 and 90% by 2030 compared to 2010 incidence. Programme-attributed incidence rate reduction was estimated at 17.2% in 2020 and 91% in 2030. Annual reduction in incidence rate hovered around 7-15% per year up to 2025 and then increased rapidly. Number of infections averted was 42,393 by 2020 and 450,491 by 2030. Chronic infection prevalence declined to 4.0% by 2020 and 0.3% by 2030, compared to 5.4% in 2020 and 4.0% in 2030 in the no-treatment-intervention scenario.

In the elimination scenario, a total of 1.75 million treatments were administered by the end of the scale-up phase, and a total of 5.6 million by the end of the feasibility phase. These contributed to an incidence reduction of 21% by 2020 and 99% by 2030 compared to 2010 incidence. Programme-attributed incidence rate reduction was estimated at 17.2% in 2020 and 91% in 2030. Annual reduction in incidence rate hovered around 7-15% per year up to 2025 and then increased rapidly thereafter. Number of infections averted was 42,393 by 2020 and 469,599 by 2030. Chronic infection prevalence declined to 4.0% by 2020 and 0.1% by 2030, compared to 5.4% in 2020 and 4.0% in 2030 in the no-treatment-intervention scenario.

Figure 3 shows key programme indicators for the five scenarios. Treatment coverage in 2030, which reached 25.3% in 2020 in all scenarios, ranged between 24.9% in the baseline scale-up scenario and 98.8% in the elimination scenario (Figure 4A). HCV-TasP effectiveness, number of treatments required to avert one new infection, hovered around 41 by 2020, 20 by 2025 and 12 by 2030 in all scenarios (Table 2 and Figure 4B). The cost per infection averted was $35,967 by 2020 and declined to around $10,000 by 2030 in the various scenarios. Total programme cost by 2030 ranged between $1.527 billion in the baseline scale-up scenario and $4.888 billion in the elimination scenario.

The impact of HCV-TasP was generically explored in settings at lower incidence rate than Egypt (Fig. S5 in SM). Number of treatments required to avert one new infection by 2030 was found to increase steadily with lower incidence rate; for example, in a setting at half of Egypt’s incidence rate, 20 treatments would be needed to avert one new infection by 2030.

4 | DISCUSSION

HCV treatment is indicated at the individual level to prevent disease sequelae such as fibrosis, cirrhosis and liver cancer. Less obvious,
however, is the treatment’s impact at the population level in controlling onward transmission. We demonstrated and quantified the latter effect. Our results highlighted a strong rationale for the concept of HCV-TasP as a potent tool to achieve global targets for HCV elimination by 2030, even in the absence of other interventions. Our findings show that HCV-TasP is a compelling and effective prevention intervention against transmission, acting in a sense as a “post-exposure” vaccination, just as it is a potent, cost-effective and cost-saving treatment intervention against disease sequelae. HCV-TasP is a strategic prevention approach in settings of generalized HCV epidemics and complements primary prevention approaches.

The benefits of HCV-TasP were demonstrated for Egypt, the nation most historically affected by this virus. HCV incidence in this country was found to be on a trajectory of decline (Figure 2), but will continue at considerable level for decades if not controlled by interventions (Figure 3). All explored scenarios achieved sizable if not immense impact on incidence and chronic infection prevalence. By 2030, incidence reduction ranged between 29% and 99%, programme-attributed incidence rate reduction ranged between 18% and 99%, and chronic infection prevalence reached as low as 2.6%-0.1% (Table 2 and Figure 3). The impact was also immediate with incidence rate reduction hovering around 10% per year in the first few years of scale-up (Figure 3). By reaching virtually universal treatment coverage by 2030, 5.6 million people would have been treated, and nearly half a million infections averted (Table 2). For every 12 DAA treatments, one infection would be prevented by 2030, at direct drug costs of about $10,000 (Table 2; about three times per capita gross domestic product (GDP)).

While these findings demonstrate the relevance of HCV-TasP in Egypt, our generic results for settings at lower incidence rate suggest that HCV-TasP should also be considered and examined as a potential intervention in other countries (Fig. S5 in SM). HCV-TasP may prove to be as successful, if not more successful, than HIV TasP in controlling onward transmission and potentially eliminating, or even eradicating this infection. As opposed to HIV treatment, DAA treatment is curative and has a shorter duration and therefore potentially improved adherence and easier scale-up. Nevertheless, screening and cost factors, and access to at risk populations such as PWID, may limit HCV-TasP expansion.

Egypt has been rapidly scaling up its DAA programme since its launch in 2014. More than 800,000 treatments have been administered by September 2016. Treatment eligibility has been expanded to include all adults with chronic infection. Treatment is being provided through 54 designated government centres and through 50 additional health insurance hospital centres. Our results indicate, however, that the targets of reducing chronic infection prevalence to <2% in 10 years, and reducing incidence by 90% by 2030, cannot be achieved unless the number of annual treatments reaches 365,000 and is sustained at this level for at least a decade. The cumulative direct drug costs may reach as much as $5 billion by 2030, which is a large sum for a developing nation like Egypt, but this cost is minimal when...
seen in the context of the historical toll of this infection in this country, and averted future direct healthcare costs and indirect costs of loss of productivity and earnings with disability and premature mortality. It was estimated recently that these costs can add up, in the absence of the treatment programme, to as much as $5 billion annually and $90 billion cumulatively by 2030.38

Furthermore, the introduction of locally produced generics into the programme in 2016 has reduced drug costs by a large proportion, to as low as $100 per drug regimen.39 With this price reduction, programme cost may be reduced by over 80%, thereby enhancing the feasibility of scale-up and sustainability leading to elimination by 2030. Even though Egypt is facing economic challenges, with health spending being only 5.6% of GDP,35 the vast reduction in programme cost will render this programme affordable. Egypt today has the opportunity to “close the book” on HCV after enduring an epidemic similar in scale and consequences to that of the large HIV epidemics in sub-Saharan Africa.

As Egypt expands its programme, screening for HCV will play a critical role. Only 7.1% of Egyptians 1-59 years of age reported being ever tested for HCV in the 2015 EDHS,6 and it was estimated recently that <25% of those chronically infected are aware of their infection.38 Without active case finding, the programme will not be able to function at its capacity and future potential. Screening can be expanded through awareness campaigns and fixed and mobile testing units and should be targeting initially birth cohorts and geographic localities with higher HCV prevalence.41 Encouragingly, the Egypt Ministry of Health and Population plans to launch a national screening campaign of 10 million Egyptians.39,42

There are several limitations in our study. Our study focused on HCV-TasP, and we did not model other prevention approaches, such as injection safety, nor did we study synergies of interventions. We assumed that all chronically infected persons could be treated, but treatment may not be recommended for all patients. For example, vertical transmission is not an insignificant mode of transmission in Egypt,43 but current guidelines do not recommend treatment of pregnant women. We did not incorporate previous treatments (prior to 2014) by old regimen, but treatment coverage has been very low up to initiation of the DAA programme.6,38

Our estimated impact of treatment is possibly conservative, as we did not incorporate disease-related mortality. However, the relative risk of mortality with HCV infection is not large enough to impact significantly our projections.44 For simplicity, we assumed that the duration spent in each risk group is age independent, but this assumption is not likely to affect our results, as exposure risk is already age-dependent in our model, thereby capturing implicitly a duration variation effect. Most HCV biological parameters found in the literature and used in the model are from studies conducted on PWID, and it is unknown whether these are generalizable to the general population. We assumed that HCV transmission probability in acute infection does not vary by symptoms, but this is not likely to affect our results as the proportion who are symptomatic is small and acute infection lasts for only few months. In the absence of data, we assumed an assortativeness in mixing between risk groups at a level similar to that used in HIV models,45 but variation in this parameter through sensitivity analysis did not affect our results (not shown).

We used an elaborate mathematical model to capture HCV transmission dynamics, but projections can depend on model structure and quality of input data. To account for uncertainties, we conducted a multivariable uncertainty analysis which affirmed our findings (Fig. S4). Incidence projections were generated by fitting current trends, but future incidence can be influenced by factors that are difficult to predict, such as scale-up of other interventions. As the programme is scaled up in Egypt, it would be important to collect primary data that may help estimate incidence as part of a monitoring and evaluation component of the programme, and compare and validate results with modelling estimates. Egypt is suited for such monitoring and evaluation framework given the existing capacity for epidemiologic surveillance and study infrastructure.

In conclusion, we assessed the implications of various scenarios of scale-up and sustainability for HCV-TasP in Egypt. Projected epidemiologic, programming and health economics measures demonstrated that HCV-TasP is a potent and effective prevention intervention that can lead us to elimination by 2030. Despite a painful HCV epidemic history in this nation, Egypt has an opportunity today to avert half a million new infections and eliminate HCV and much of its disease sequelae by 2030, by scaling-up and sustaining its recently launched DAA treatment programme.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

AUTHORS’ CONTRIBUTIONS

HA designed the mathematical model, conducted the analyses and wrote the first draft of the paper. LJA-R conceived and led the design of the study and model, analyses and drafting of the article. All authors have read and approved the final manuscript.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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