

Prevention of Hepatitis C by Screening and Treatment in U.S. Prisons

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Background: The prevalence of hepatitis C virus (HCV) in U.S. prisoners is high; however, HCV testing and treatment are rare. Infected inmates released back into society contribute to the spread of HCV in the general population. Routine hepatitis screening of inmates followed by new therapies may reduce ongoing HCV transmission.

Objective: To evaluate the health and economic effect of HCV screening and treatment in prisons on the HCV epidemic in society.

Design: Agent-based microsimulation model of HCV transmission and progression of HCV disease.

Data Sources: Published literature.

Target Population: Population in U.S. prisons and general community.

Time Horizon: 30 years.

Perspective: Societal.

Interventions: Risk-based and universal opt-out hepatitis C screening in prisons, followed by treatment in a portion of patients.

Outcome Measures: Prevention of HCV transmission and associated disease in prisons and society, costs, quality-adjusted life years (QALYs), incremental cost-effectiveness ratio (ICER), and total prison budget.

Results of Base-Case Analysis: Implementing risk-based and opt-out screening could diagnose 41 900 to 122 700 new HCV

cases in prisons in the next 30 years. Compared with no screening, these scenarios could prevent 5500 to 12 700 new HCV infections caused by releasees, wherein about 90% of averted infections would have occurred outside of prisons. HCV screening could also prevent 4200 to 11 700 liver-related deaths. The ICERs of screening scenarios were \$19 600 to \$29 200/QALY, and the respective first-year prison budget was \$900 to \$1150 million. Prisons would require an additional 12.4% of their current health care budget to implement such interventions.

Results of Sensitivity Analysis: Results were sensitive to the time horizon, and ICERs otherwise remained less than \$50 000 per QALY.

Limitation: Data on transmission network, reinfection rate, and opt-out HCV screening rate are lacking.

Conclusions: Universal opt-out HCV screening in prisons is highly cost-effective and would reduce HCV transmission and HCV-associated diseases primarily in the outside community. Investing in U.S. prisons to manage hepatitis C is a strategic approach to address the current epidemic.

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In the United States, the prevalence of antibodies to hepatitis C in the noninstitutionalized population is estimated at 1.0% (1). In contrast, the corresponding prevalence in U.S. prisons is 17.3% (2). Liver disease is a frequent cause of death in inmates, as well as in society, and liver disease-related death has recently surpassed death from HIV (3-5). Hepatitis C virus (HCV) infection is also the leading cause of hepatocellular carcinoma and the most common indication for liver transplantation (6).

Approximately 30% of all HCV-infected persons in the United States spend at least part of the year in correctional facilities (2). Most of the movement in and out of confinement is through jails, which are short-stay facilities. However, on a given day, twice as many Americans dwell in prisons, which are long-term facilities for felons (3, 7). Injection drug use (IDU) is the most common mode of HCV transmission, and 20% to 55% of inmates have a history of IDU (8, 9). If infected releasees take up IDU upon return, they could contribute to HCV spread in society (10, 11). The U.S. Preventive Services Task Force recommends that a history of incarceration should trigger HCV testing (12).

New hope to reduce the HCV burden in correctional settings has emerged with the recent availability of highly effective oral direct-acting antiviral agents (DAAs) (13), for which treatment duration is 8 to 24 weeks, contraindications are few, and more than 90% of patients achieved cure. However, the high price of DAAs has drawn criticism from many stakeholders (14, 15). Despite the high price of these agents, HCV treatment in prisons is feasible and meets the standard criteria for cost-effectiveness (16, 17).

However, treatment will reduce disease burden only if HCV-infected patients are identified in the first place. Three quarters of state prisons offer no screening or targeted testing of inmates reporting high-risk behavior, thereby missing many potential patients (2, 18). According to a U.S. Supreme Court ruling (19), prisons cannot be deliberately indifferent to medical

See also:

Web-Only

Supplement

EDITORS' NOTES**Context**

Although the prevalence of hepatitis C virus (HCV) infection in prisons is high, access to HCV testing is extremely limited.

Contribution

An agent-based microsimulation model was used to estimate the impact of risk-based versus universal opt-out HCV testing in prisons on HCV transmission and liver-related deaths.

Caution

Rates of reinfection could not be estimated.

Implication

Universal opt-out HCV testing in prisons would substantially decrease the number of new HCV infections occurring over the next 30 years, primarily in the general population, as well as reducing liver-related deaths from HCV. Such testing would be highly cost-effective.

needs if they are known. Therefore, once a diagnosis is made, a provider may find it difficult to justify not treating diagnosed patients. Because treatment is expensive and prison budgets are often limited, there could be an incentive not to test for HCV.

Routine hepatitis case finding and treatment in U.S. state and federal prisons in the era of DAAs could substantially reduce HCV disease in prisons as well as in the general population. However, studies have not evaluated the effect of such interventions on prevention of HCV transmission and disease burden (10). In addition, the economic benefits to both prisons and the outside community of such programs, and the burden on state and federal budgets, are not known (10, 20). Therefore, we evaluated the health and economic benefits of several HCV screening strategies in U.S. prisons on HCV prevention in the general population.

METHODS

We developed the TapHCV (treatment as prevention of hepatitis C virus) model, an agent-based microsimulation model that projects the long-term benefits and costs of different HCV screening and treatment scenarios in U.S. prisons. Our model includes HCV disease transmission, the natural history of HCV based on a previously validated Markov model (21), HCV screening in inmates, treatment of HCV infection with DAAs, and movement of people in and out of prisons. We simulated the disease and its progression both in prisons and in the general population to understand the complex dynamics between prison-related interventions and disease burden in society as a whole (Figure 1). The model was developed in the Java programming language (Oracle Java SE Development Kit 7) from a societal perspective with a 30-year time horizon using

monthly cycles (see **Supplement**, available at www.annals.org).

Baseline Population

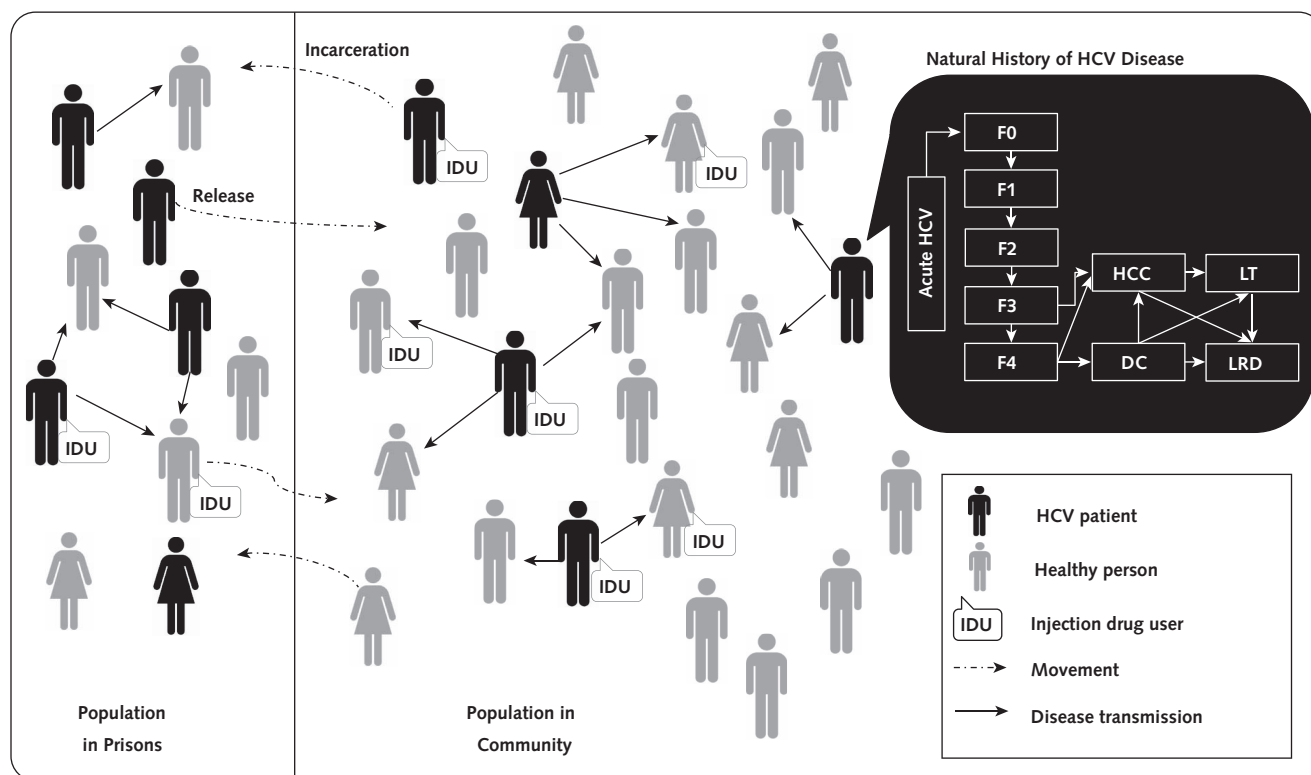
We simulated 2 million heterogeneous individuals representing the U.S. population inside and outside of prisons in 2015. Patient characteristics included age, sex, drug use behavior (active or former IDU versus non-IDU), and imprisonment status (incarcerated in state or federal prisons versus general population). Prisoners constituted 0.5% of the total U.S. population, and 91% were male (**Supplement Tables 1 and 2**, available at www.annals.org) (22). We stratified HCV prevalence by individuals' characteristics. We also defined the baseline distribution of common U.S. HCV genotypes (1, 2, 3, and 4), chronic HCV stage using METAVIR fibrosis scores (no fibrosis [F0], portal fibrosis without septa [F1], portal fibrosis with few septa [F2], numerous septa without cirrhosis [F3], or compensated cirrhosis [F4]), and treatment history (previously treated or treatment-naive) using published studies (**Supplement Tables 3 and 4**, available at www.annals.org). In the base case, we assumed that 25% of HCV-infected patients in prisons and 50% outside were aware of their disease status through prior community or prison screening. A more detailed description of the baseline population is provided in the **Supplement**, available at www.annals.org.

HCV Transmission and Progression

During each month, infected individuals could transmit the virus to uninfected individuals. We modeled 2 kinds of transmissions, separately in prisons and community: 1) IDU-related and 2) all other types of transmission. The probability of transmission depended on the following factors: awareness status, active IDU, history of IDU, and prior HCV treatment (**Supplement Table 5**, available at www.annals.org, and **Supplement**). We calibrated transmission-related measures that were not directly available by choosing those that produced incidence results observed and published by the Centers for Disease Control and Prevention (**Supplement**). We assumed that the likelihood of HCV transmission was 50% lower for persons who were aware of their infection status.

All newly infected individuals started with the acute phase of HCV infection, which could develop into the chronic phase. We defined the natural history of HCV using Markov health states, which was based on our previously published models (21, 23). The chronic disease progressed to different stages of fibrosis, as defined by METAVIR fibrosis scores, from F0 to F4 (Figure 1). Patients at METAVIR score F3 and F4 could develop decompensated cirrhosis, hepatocellular carcinoma, or both. Patients with decompensated cirrhosis or hepatocellular carcinoma might receive a liver transplant or die of a liver-related condition (**Supplement Table 6**, available at www.annals.org). We also applied a background mortality adjusted by age, sex, and IDU (**Supplement**).

Figure 1. Model schematic of HCV disease transmission and progression in prisons and in the general population.



The schematic of our agent-based model shows the prison population and general population and the dynamic movement between two groups (dashed arrows). Each person is defined by demographic characteristics, liver stage, and injection drug use. As time progresses, the following characteristics are updated: age, injection drug use status, HCV infection status (infected individuals shown in black), stage of liver disease, and location (inside or outside prison). HCV-infected persons can transmit disease to others in their immediate network (solid arrows). The natural history of chronic HCV disease is represented by Markov states (top right insert). Stages of chronic HCV disease are defined by METAVIR fibrosis scores. Advanced liver disease stages are decompensated cirrhosis, hepatocellular carcinoma, liver transplantation, and liver-related deaths. D C = decompensated cirrhosis; F0 = no fibrosis; F1 = portal fibrosis without septa; F2 = portal fibrosis with few septa; F3 = numerous septa without cirrhosis; F4 = compensated cirrhosis; HCC = hepatocellular carcinoma; HCV = hepatitis C virus; IDU = injection drug user; LRD = liver-related death; LT = liver transplantation; METAVIR = Meta-Analysis of Histologic Data in Viral Hepatitis.

HCV Screening

Unaware patients could be diagnosed through HCV testing. We evaluated 5 screening scenarios in prisons starting from the year 2015: no screening; 1-time risk-based screening of currently incarcerated persons and entrants with active or former IDU for 1 year (1Yr-Risk); and 1-time opt-out universal HCV screening of currently incarcerated inmates followed by opt-out screening of all incoming inmates for up to 1 year (1Yr-All), 5 years (5Yr-All), and 10 years (10Yr-All). We assumed that the uptake rate of risk-based screening was 75% (on the basis of the Arrestee Drug Abuse Monitoring jail study) and that the rate of opt-out HCV screening was 90%, similar to that of HIV opt-out screening in prisons (24, 25). In the general population, we implemented a combination of birth-cohort and risk-based screening, the current standard of care (Supplement Table 7, available at www.annals.org).

HCV Treatment

Inmates diagnosed with HCV were eligible for treatment with recently approved DAAs. In the base case, we assumed that only those with METAVIR fibrosis

scores of F3 and F4 would receive treatment and that others would wait because of limited resources. We assumed that those in stages F0 to F2 would undergo annual aspartate aminotransferase-to-platelet ratio index test and become eligible for treatment if they advanced to F3 (26). Patients were assigned to treatment with oral DAAs, as defined by the clinical guidelines (27). Because the sustained viral response (SVR) rates of the available oral drugs are similar to each other, we used the SVR rates of sofosbuvir-based therapies as a reference. Treatment regimen depended on HCV genotype, previous treatment outcomes, and presence of cirrhosis (Supplement Table 8, available at www.annals.org). We assumed that in 2030, generic drugs would become available and that all patients would be eligible for treatment with low-cost drugs regardless of their fibrosis stage (28).

Admission and Release of Prisoners

We simulated movement of people from the community to prisons and vice-versa (Figure 1). The probability of being incarcerated and lengths of sentence at admission were estimated from pooled data from the

Bureau of Justice Statistics and published reports (**Supplement and Supplement Tables 9 and 10**, available at www.annals.org).

Costs and Utilities

Our model included the cost of HCV testing, antiviral treatment, and management of chronic HCV disease (**Supplement Table 11**, available at www.annals.org). Screening costs included those of HCV antibody, HCV RNA, and HCV genotype testing and of the FibroSure test (LabCorp). Treatment costs included the wholesale acquisition costs of sofosbuvir (\$7000 per week), ledipasvir (\$1125 per week), and ribavirin (\$309 per week) (29), and we considered drug discounts in sensitivity analysis (30). Costs of HCV disease management included the cost associated with chronic HCV infection, decompensated cirrhosis, hepatocellular carcinoma, and liver transplantation. All costs were converted to 2014 U.S. dollars.

To each individual in our model, we assigned health-related quality-of-life weights, with 0 denoting death and 1 denoting perfect health, and adjusted them by IDU, age, and sex (**Supplement Table 12**, available at www.annals.org). We assumed that the quality of life of patients who achieved SVR was equivalent to that of uninfected persons if they had METAVIR scores of F0 or F1 and was worse than that of uninfected persons otherwise.

Model Outcomes

For each screening scenario, we projected the number of HCV cases diagnosed, the number of new HCV infections resulting from the release of untreated, HCV-infected inmates; quality-adjusted life years (QALYs); and total cost to prisons and society, including the cost of HCV screening, antiviral treatment, and HCV disease and its sequelae (such as cases of decompensated cirrhosis, hepatocellular carcinoma, liver transplantation, and liver-related deaths). We further estimated the benefits gained in the community due to screening in prisons. Finally, we estimated the incremental cost-effectiveness ratios (ICERs) of all screening scenarios. We applied a standard 3% annual discount rate to all future costs and QALYs and ran our model 40 times (Monte Carlo runs) to estimate 95% CIs of outcomes. Our analysis followed the recommendations of the U.S. Panel on Cost-Effectiveness in Health and Medicine (31).

We also performed a subgroup cost-effectiveness analysis by excluding any health benefits gained while the individual was incarcerated and considered only the benefits gained while the individual was in the community that were due to screening in prisons.

To evaluate the robustness of the model results to uncertainty in input parameters, we performed sensitivity analyses on baseline population characteristics, transition probabilities, behavior inputs, quality-of-life utilities, SVR rates, all costs (including the cost of treatment), and patent expiration year. We also conducted scenario analyses on the time of HCV treatment in prisons.

Validation

We performed external validation of TapHCV model by comparing intermediate model outcomes with known data. Specifically, we validated the natural history of HCV in the model by comparing the projected incidence rates of hepatitis C sequelae to the reported range of a large clinical study (**Supplement and Supplement Table 13**, available at www.annals.org). We also validated the projected number of admissions to U.S. prisons with the Bureau of Justice Statistics data (**Supplement and Supplement Table 14**, available at www.annals.org).

Role of the Funding Source

The funding source had no role in the design, conduct, or analysis of the study or the decision to submit the manuscript for publication.

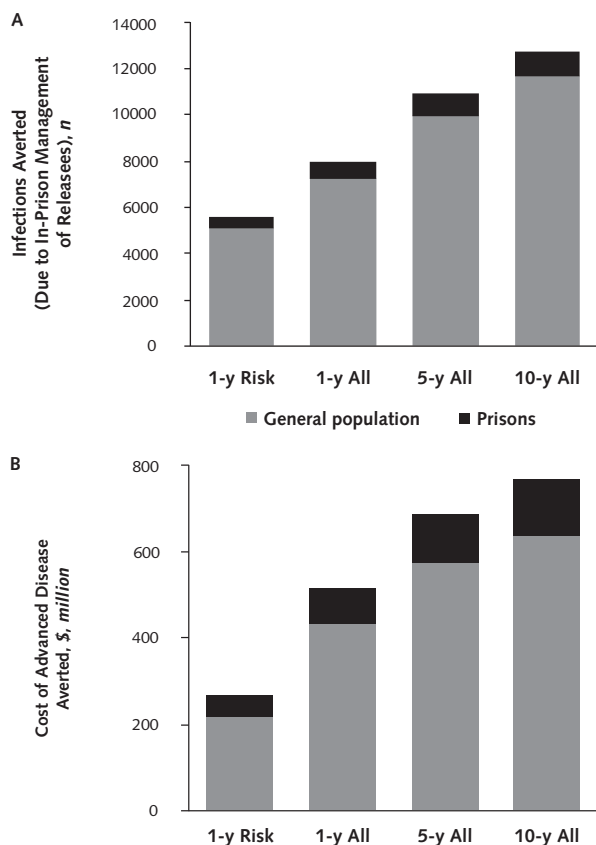
RESULTS

HCV Diagnosis in Prisons

Implementing risk-based screening of entering and currently incarcerated active or former IDUs for 1 year (1Yr-Risk) could diagnose 41 900 (CI, 40 700 to 43 200) new HCV cases among prisoners in the next 30 years. In comparison, 1Yr-All, 5Yr-All, and 10Yr-All scenarios could diagnose 81 100 (CI, 79 600 to 82 700), 106 600 (CI, 104 700 to 108 500), and 122 700 (CI, 120 800 to 124 600) new HCV cases, respectively, of which 70 700 (CI, 69 000 to 72 300) of those would be diagnosed among inmates currently incarcerated. The screening cost per case identified under 1Yr-Risk, 1Yr-All, 5Yr-All, and 10Yr-All would be \$880, \$1300, \$1680, and \$2030, respectively.

Prevention of HCV Disease

Compared with the no-screening scenario, 1Yr-Risk, 1Yr-All, 5Yr-All, and 10Yr-All scenarios would prevent 5500 (CI, 4400 to 6600), 8000 (CI, 6800 to 9000), 10 900 (CI, 9700 to 12 000), and 12 700 (CI, 11 500 to 13 900) new HCV infections, respectively, in the next 30 years. Of these cases prevented by prison screening programs, 89% to 92% of averted infections would have occurred in the general population (**Figure 2, A**). For all scenarios, infections averted would peak between years 2020 and 2024 and decline afterward (**Supplement Figure 1**, available at www.annals.org). Interventions in prisons would reduce the number of HCV-infected people in prisons over time, and the benefits of screening would peak around year 2035 and decline afterward (**Supplement Figure 2**, available at www.annals.org). Furthermore, compared with no screening, HCV screening in prisons could prevent 4200 to 11 700 liver-related deaths, 300 to 900 liver transplantations, 3000 to 8600 cases of hepatocellular carcinoma, and 2600 to 7300 cases of decompensated cirrhosis in the next 30 years. Of note, among liver-related deaths averted, 80% would have occurred in the outside community.

Figure 2. Projected reduction of HCV transmission and HCV-associated costs.

A. Projected reduction of new infections over 30 y owing to HCV screening of inmates compared with no screening. Screening of inmates reduces new infections both inside the prisons and in the general U.S. population (owing to the spread of infection via released inmates), and 89% to 92% of total reductions occur in the general population. B. Cost of advanced HCV diseases averted because of screening of inmates in the next 30 y in prisons and in the general population. Compared with no screening, screening of inmates reduced costs of HCV disease by averting advanced stages of disease. Note that future cost savings from averted disease were discounted at 3% annually. 1-y Risk = 1-time risk-based screening of currently incarcerated and entrants with active or former injection drug use for 1 y; 1-y All = 1-time opt-out screening of currently incarcerated inmates and entrants for 1 y; 5-y All = 1-time opt-out screening of currently incarcerated inmates and entrants for 5 y; 10-y All = 1-time opt-out screening of currently incarcerated inmates and entrants for 10 y; HCV = hepatitis C virus; No screening = no screening inside prisons.

Reduction in HCV Disease Cost

Compared with the no-screening scenario, the 1Yr-Risk, 1Yr-All, 5Yr-All, and 10Yr-All scenarios would reduce HCV disease cost due to in-prison management of infected releasees by \$260 (CI, \$220 to \$300) million, \$510 (CI, \$470 to \$560) million, \$680 (CI, \$620 to \$740) million, and \$760 (CI, \$700 to \$820) million, respectively (Figure 2, B). Reductions in HCV disease cost that were realized in the general population constituted 82% to 84% of the total savings stemming from screening in prisons. Of the total cost savings, 42% to 44% were due to fewer cases of decompensated cirrhosis, 39% were due to fewer cases of hepatocellular carcinoma,

and 17% to 19% were due to fewer liver transplantations.

Cost-Effectiveness Analysis

Compared with the no-screening scenario, the 1Yr-Risk, 1Yr-All, 5Yr-All, and 10Yr-All scenarios would increase the total QALYs by 41 900 (CI, 37 700 to 46 100), 75 600 (CI, 69 600 to 81 600), 95 800 (CI, 89 000 to 102 700), and 105 700 (CI, 99 200 to 112 200), respectively. The corresponding increase in total costs would be \$820 (CI, \$760 to \$890) million, \$1520 (CI, \$1440 to \$1590) million, \$2000 (CI, \$1920 to \$2090) million, and \$2290 (CI, \$2220 to \$2370) million, respectively. The ICERs of 1Yr-Risk, 1Yr-All, 5Yr-All, and 10Yr-All were \$19 600, \$20 600, \$24 000, and \$29 200 per additional QALY, respectively (Table).

Next, we estimated the benefit of interventions in prison on the society exclusively by excluding the QALYs gained inside prisons and considering only QALYs gained in the community. The estimated increase in QALYs due to 1Yr-Risk, 1Yr-All, 5Yr-All, and 10Yr-All screening were 35 600 (CI, 31 500 to 39 600), 64 900 (CI, 59 300 to 70 500), 82 100 (CI, 75 900 to 88 400), and 90 300 (CI, 84 300 to 96 300), respectively. The corresponding ICERs were \$23 100, \$23 600, \$28 200, and \$35 400 per additional QALY, respectively.

Budget Effect on Prison System

The first-year cost of HCV screening, treatment, and management of chronic hepatitis C management in 2015 under risk-based screening and opt-out screening would be \$900 million and \$1146 million, respectively, spread over the prison systems in all states. The corresponding costs would decrease below 66 million after 15 years (Figure 3 and Supplement Figure 3, available at www.annals.org). The first-year budget needed to implement universal opt-out screening followed by treatment with DAAs would require an additional 12.4% over the current health care budget of state and federal prisons (32, 33). However, after 15 years, prisons would need only an additional 0.7% of the current health care budget because of a decrease in HCV prevalence in both prisons and society.

Sensitivity Analysis

We performed 1-way sensitivity analysis on all key model parameters (Supplement Tables 15 to 19, available at www.annals.org). Time horizon was the most sensitive parameter and could influence the cost-effectiveness of opt-out HCV testing (Figure 4). For all other parameters, the ICERs always remained less than \$50 000 per QALY, indicating that uncertainty in model parameters did not influence the cost-effectiveness results. Of note, discounts on antiviral drugs would make HCV screening highly cost-effective. Treatment of HCV in early stages and immediately after diagnosis also resulted in ICERs less than \$50 000 per QALY (Supplement Tables 20 and 21, available at www.annals.org).

Table. 30-y Cumulative Incidences of Infection, Advanced Diseases, and Results of Cost-Effectiveness Analysis*

Variable	No Screening	1-y Risk vs No Screening	1-y All vs. No Screening	5-y All vs. No Screening	10-y All vs. No Screening
30-y cumulative incidences					
Total HCV infections	166 084	-5508	-8041	-11 005	-12 607
Decompensated cirrhosis	633 235	-2476	-4532	-6218	-6908
Hepatocellular carcinoma	730 683	-2930	-5665	-7519	-8602
Liver transplantations	92 596	-187	-595	-702	-809
Liver-related deaths	780 803	-4310	-7942	-10 368	-11 730
30-y total cost, \$ million					
Screening cost	0.0	+37	+107	+178	+249
Treatment cost	59 035	+816	+1480	+1951	+2190
Cost of advanced HCV complications	94 326	-30	-71	-128	-148
Cost-effectiveness analysis					
	No Screening	1-y Risk vs. No Screening	1-y All vs. 1-y Risk	5-y All vs. 1-y All	10-y All vs. 5-y All
QALY	5 677 199 951	+41 905	+33 696	+20 201	+9898
Total cost, \$ million	153 361	+823	+693	+486	+289
ICER, \$ per QALY	-	19 635	20 571	24 046	29 234

1-y Risk = 1-time risk-based screening of currently incarcerated and entrants with active or former injection drug use for 1 y; 1-y All = 1-time opt-out screening of currently incarcerated inmates and entrants for 1 y; 5-y All = 1-time opt-out screening of currently incarcerated inmates and entrants for 5 y; 10-y All = 1-time opt-out screening of currently incarcerated inmates and entrants for 10 y; HCV = hepatitis C virus; ICER = incremental cost-effectiveness ratio; No screening = No screening inside prisons; QALY = quality-adjusted life-year.

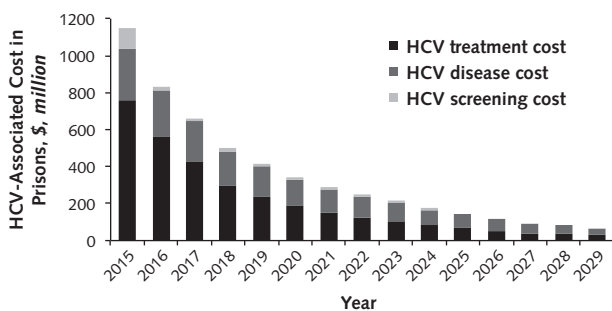
* Compared with no screening, HCV screening and treatment in prison could reduce the cumulative incidence of new infections and cases of advance diseases. The screening costs and treatment costs increased as more intensive screening strategies were applied. However, HCV disease management costs decreased because of decreased number of HCV-related complications. Note that for the cost-effectiveness analysis, we presented incremental QALYs and total costs, and each scenario was compared to its less intensive scenario. Note that any discrepancies in ICERs may be due to rounding.

DISCUSSION

Our results suggest that the universal opt-out screening of inmates for HCV is highly cost-effective for at least 10 years and would reduce ongoing HCV transmission, the incidence of advanced liver diseases, and liver-related deaths. Most of the benefits of interventions in prisons would accrue in the community because a larger proportion of releasees to the community would have been cured of the disease. However, to achieve these benefits, the government needs to provide additional resources to prison health care, which will be a good investment for society.

Earlier research found that HCV treatment with DAAs is cost-effective in prison settings (16). However, the benefits of treatment would be incurred only if an effective screening policy is in place and HCV cases are diagnosed in a timely manner. To our knowledge, our study is the first to evaluate the society-wide benefits and cost-effectiveness of opt-out hepatitis C screening in prisons. We developed a comprehensive mathematical model to simulate HCV transmission and interactions between prisons and community, thereby evaluating complex emergent dynamics that otherwise could not be predicted (34).

Figure 3. Total cost of HCV screening and treatment in prisons, 2015-2029.

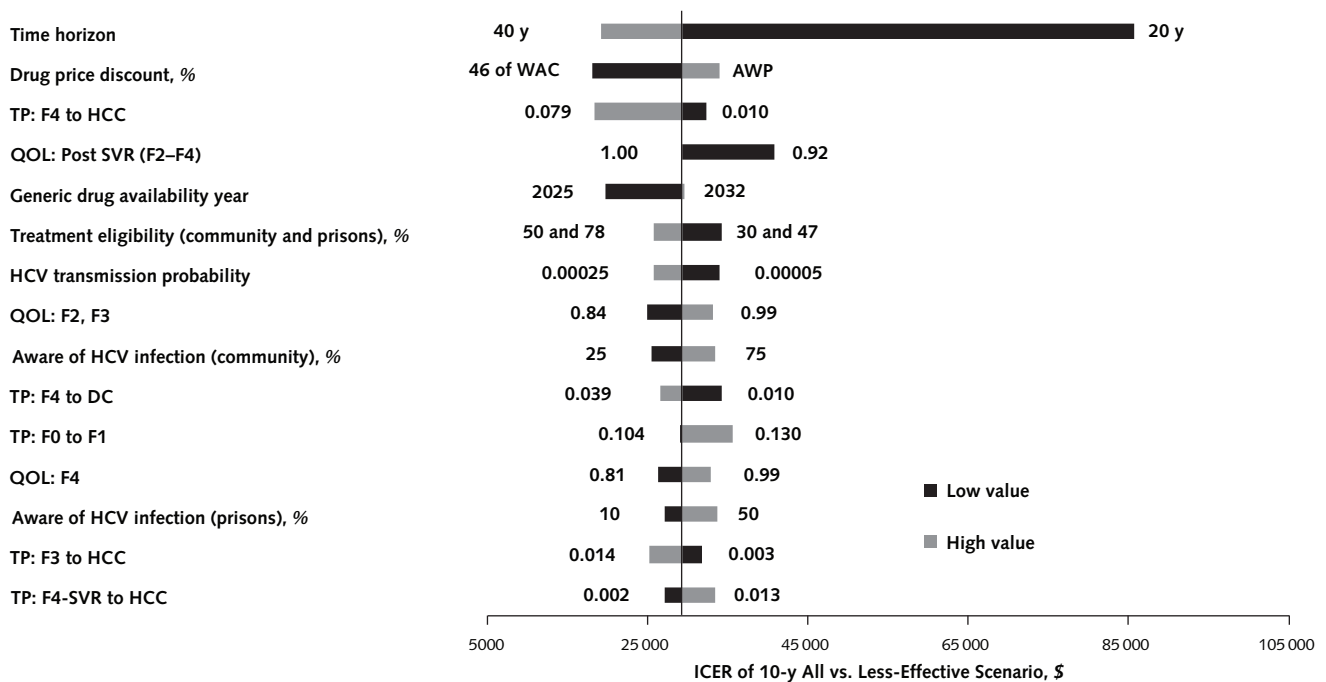


Shown is the budget needed to screen, treat HCV infection, and manage chronic hepatitis C in prisons under 1-time opt-out universal screening of currently incarcerated inmates and entrants for 10 y (10-y All scenario). The annual budget decreased substantially from 2015 to 2029 because of a decrease in prevalence and discounting of future expenditures at 3% annually. 10-y All = 1-time opt-out screening of currently incarcerated inmates and entrants for 10 y; HCV = hepatitis C virus.

In 2012, the U.S. Preventive Services Task Force and the Centers for Disease Control and Prevention updated their HCV screening policy to include persons born between 1945 and 1965 (12, 35). Modeling studies have shown that HCV screening in the birth cohort is cost-effective for the general population (36). In contrast, most HCV-infected individuals in prisons may no longer be among this birth cohort because new cases of HCV are rising among youth who inject drugs (37, 38). For this reason, we did not confine screening of hepatitis C in prisons to members of the baby boom generation.

Our findings suggest that interventions in prisons provide an even better value for money when compared with the current screening recommendations for the general U.S. population. The cost of the screening per case identified with opt-out screening in prisons (\$900 to \$2000) was lower than that identified with the birth-cohort screening in the general population (\$2900) (36). In addition, the ICER of opt-out screening in prisons was lower than that of the birth-cohort screening in the general population, which ranged

Figure 4. One-way sensitivity analysis showing top 15 most sensitive parameters in cost-effectiveness analysis comparing the scenario with 1-time opt-out universal screening of currently incarcerated inmates and entrants for 10 y (10-y All) with a less effective scenario.



The dark bars show the change in incremental cost-effectiveness ratio from the base case, when the lower value of an input was used while all other input parameters were kept constant, and the light bars show the change when the higher value was used. 10-y All = 1-time opt-out screening of currently incarcerated inmates and entrants for 10 y; AWP = average wholesale price; DC = decompensated cirrhosis; F0 = no fibrosis; F1 = portal fibrosis without septa; F2 = portal fibrosis with few septa; F3 = numerous septa without cirrhosis; F4 = compensated cirrhosis; HCC = hepatocellular carcinoma; HCV = hepatitis C virus; ICER = incremental cost-effectiveness ratio; QOL = quality of life; SVR = sustained viral response; TP = transition probability; WAC = wholesale acquisition cost.

from \$35 700 to \$65 700 per QALY (36, 39-41). Even after exclusion of all health benefits gained during time spent in prison, opt-out HCV screening still remained highly cost-effective. Our conclusions are based on wholesale acquisition costs of HCV treatment; however, in practice, several prisons would get drug discounts that would make HCV testing even more cost-effective.

Because U.S. correctional systems cannot display deliberate indifference to apparent health care needs (19, 42), without adequate health care budgets health administrators in prisons may be reluctant to identify all HCV cases (42). Our study emphasizes the benefits of state or federal government allocating additional resources to prisons to screen for and treat HCV infection. Such investment in prisons is beneficial from the societal perspective because early detection and treatment in correctional settings could prevent future need for treatment, which would occur predominantly in society among releasees. Furthermore, these interventions would prevent ongoing viral transmission in the general community.

Our study has several limitations. First, not all parameters were available or up to date, including the incidence of HCV infection inside prisons and arrest rates among people who inject drugs. Therefore, we indirectly estimated these parameters through calibra-

tion and tested them in the sensitivity analysis. Second, we made simplifying assumptions about future trends in incarceration, risk behavior, and birth and death rates, which could affect our results. Third, the effectiveness of new therapies in prison settings is unknown. However, studies of earlier treatments suggest that in-prison outcomes would be similar to those in clinical trials (17, 43). Opt-out HCV screening rate in prisons is not known; therefore, we assumed the rate to be similar to that of HIV testing in prisons. In addition, we ended our simulation at the end of 30 years with no additional benefit, which tends to underestimate the benefits of screening.

Because of lack of data on HCV transmission, we made simplifying assumptions about the modes of HCV transmission and types of social network structure. We did not model advanced social networks of IDUs or sexual contacts. We modeled IDU transmission explicitly and all other transmissions grouped separately (see Supplement). We used a simplified temporal network of IDUs and assumed that age and sex have no effect on IDU mixing. Finally, we did not consider the possibility of future new antiviral therapies, which could be even more effective and less expensive.

In conclusion, screening the incarcerated population would play an important role in reducing HCV bur-

den society-wide. Therefore, HCV prevention efforts should have an increased focus on prison inmates. From a societal perspective, investing in U.S. prison health care to manage hepatitis C would be money well spent.

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Reproducible Research Statement: *Study protocol:* Not applicable. *Statistical code and Data set:* Available from Dr. Chhatwal (JagChhatwal@mgh.harvard.edu).

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