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Cost-effectiveness of Hepatitis A and Hepatitis B Vaccination for Jail Inmates

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Cost-effectiveness of Hepatitis A and Hepatitis B Vaccination for Jail Inmates

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COST-EFFECTIVENESS OF HEPATITIS A AND HEPATITIS B VACCINATION FOR JAIL INMATES.

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Despite evidence that viral hepatitis poses a significant risk to public health, universal vaccination has not yet been implemented. The risk for viral hepatitis infection is particularly high among injection drug users and other individuals who do not attend regular health care visits. Jails provide a structural opportunity to vaccinate these high risk individuals. HAV and HBV vaccines administered on an accelerated three week schedule could dramatically decrease the lifetime risk for contracting viral hepatitis among jail detainees. Assuming that 75% of detainees would accept vaccination, 33% have previous exposure to HAV, 25% have previous exposure to HBV, and independent future healthcare costs were US $317,000, the US health care system would save $12 per individual with a vaccinate upon entry program in comparison to no intervention. This savings translates into an economic benefit amounting to about US$ 5,000,000 saved if all new jail inmates in a given year were immunized. A vaccination upon entry program for HAV/HBV in jails should be widely implemented with coordination between the corrections system and public health agencies to reduce the growing cost of viral hepatitis infection.

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This research is dedicated to my friends, family, and all the folks I have met along the way.

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Introduction

Viral Hepatitis Infection in Correctional Settings

Inmates in correctional facilities bear a disproportionately greater burden of infectious disease, including infection with hepatitis viruses, with estimates indicating that 12-39% of all Americans with hepatitis B virus or hepatitis C virus infections were former inmates (1). The Center for Disease Control recently reported that the current or previous prevalence of HBV infection among adult inmates in correctional settings ranges from 13% to 47%,and the prevalence of chronic HBV infection among inmates ranges from 1.0%--3.7%, about five times the prevalence among adults in the general U.S. population (2).

Hepatitis infection outbreaks in correctional settings have unfortunately become common in the past 20 years. In 1985 several inmates at a municipal house of correction in Massachusetts were discovered to have acute onset HBV infection. Subsequent screening of the inmate population revealed that 43% had been exposed to HBV (3). Needle sharing and duration of imprisonment were determined to be the leading causes of transmission within the inmate population. A similar incident occurred in 2000 at a state correctional facility in Georgia and began when a single inmate presented with acute HBV infection (4). A Center for Disease Control and Prevention investigation afterwards revealed that 23% of inmates at the facility had markers of prior exposure to HBV. Among susceptible male inmates, over half reported exposure to at least one risk factor for HBV transmission during incarceration, which were primarily injection drug use and sex with another man.

HAV outbreaks in correctional settings have been also reported (5, 6). Investigations of these outbreaks revealed that prisoners appear to be at greater risk for HAV than the general population due to high prevalence of injection drug use (7). Additionally, correctional settings with a rapid inmate turnover rate can serve as a lingering source of HAV in communities with a high level of intravenous drug use. The high prevalence of chronic hepatitis C among inmates indicates that HAV infection would likely result in poor outcomes such as hepatic failure and death (8).

Highly effective and safe vaccines are available to prevent HAV and HBV transmission (2). By providing viral hepatitis prevention, in addition to ongoing harm- and risk- reduction counseling and substance abuse treatment to reduce risk factors of transmission, the personal and societal cost of hepatitis infection among inmates could be greatly reduced. The most significant challenge, however, is finding a prevention strategy that adequately meets the budgetary constraints of the health care system.

Strategies for Viral Hepatitis Prevention

Vaccination schedules have been proposed to immunize inmates for viral hepatitis. The typical approach is to vaccinate inmates with individual vaccines for HAV at a schedule of 0 and 1 month, and HBV at a schedule of 0, 1, and 6 months. Newer approaches utilize a combined HAV/HBV vaccine. The immunogenicity and safety of the combined HAV/HBV vaccine in comparison with the monovalent vaccines administered at the 0, 1, and 6 months schedule was first examined by a German group in 2000 (9). The study demonstrated that a complete three dose course of the combined vaccine on the standard schedule had no negative influence on the tolerability and improved the

immunogenicity against HAV and HBV relative to the equivalent monovalent vaccine course. The combined vaccination program is also likely to have a positive impact on the compliance rate, comfort, and cost-effectiveness due to the fewer number of injections for the complete course compared to individual monovalent vaccine doses.

While this approach is appropriate in prison settings where the average length of stay by definition exceeds one year and ensures the vaccination schedule is completed, it would not be satisfactory in jail settings as most detainees would be released well before the sixth month (10), thereby limiting the efficacy of vaccination. The reduced time of incarceration in the jail setting compared to a prison setting prevents the standard vaccination approach with a bivalent vaccine to be successful.

A solution to this problem would be to administer the vaccines at an accelerated schedule. A study in 2002 investigated the efficacy of the combined HAV/HBV vaccine in comparison with the monovalent vaccines on an accelerated dose schedule of 0, 7, and 21 days in an adult population (11). The study showed that both vaccination methods produce the same seropositivity rate (>90%) for both anti-HAV and anti-HBs antibodies. Thus, bivalent vaccine or monovalent vaccines administered at an accelerated schedule allows immunization against HAV and HBV in less than a month, with results comparable to those achieved using the normal dosing schedule.

These studies lead to two important conclusions: 1) a combined HAV/HBV vaccine is as effective as monovalent HAV and HBV vaccines in protecting vaccinated individuals against HAV and HBV infection; 2) vaccination at an accelerated schedule of 0, 7, and 21 days results in immunogenicity comparable to vaccination at the standard schedule of 0, 1, and 6 months.

Cost-effectiveness of Viral Hepatitis Prevention Strategies

The cost-effectiveness of vaccination for viral hepatitis has been investigated in several studies. A 2001 article by the Center for Disease Control and Prevention detailed the cost-effectiveness of vaccinating inmates entering prisons against HBV, and how the cost-effectiveness is affected by factors such as the incidence and cost of disease, the rate of recidivism, the cost of the vaccine, the number of doses administered, and the prevalence of infection and intake (12). The paper also examined how economically desirable the program would be for the health system in general. The authors demonstrated the health care system, not the prisons, would be the primary beneficiary of a vaccination program—in 1998, the net savings would amount to about $45,000,000.

There were several limitations to the study: 1) the assumed vaccination protocol was the standard 0, 1, and 6 month schedule, so jail inmates serving short sentences were not accounted for; 2) the model did not consider secondary transmission; 3) no prescreening strategy for HBV markers was considered; and 4) future unrelated health costs were not accounted for in the calculations of cost-effectiveness. Despite these limitations, the calculated benefit to the overall health system is considerable.

Another study looked at the cost-effectiveness of pre-vaccination screening for HAV and HBV (13). Three different prevention protocols were considered: 1) screen and defer vaccination until serology results are known, 2) screen and vaccinate immediately to avoid a missed vaccination opportunity and modify the vaccination strategy after screening results are known, and 3) vaccinate without screening. In nine out of ten analyses, the vaccinate without screening protocol was less costly and as effective as the

screen and begin vaccination protocol. The authors also concluded that pre-vaccination screening may only be effective in conditions where high immunity is likely to be present.

The same group also examined the cost-effectiveness of bivalent HAV/HBV vaccination for prison inmates (14). This investigation determined that in settings where HAV prevalence rates are greater than 200%, 100%-200%, and less than 100% of the national average, the declines in HAV treatment costs would offset 137%, 88%, and 40% of the additional cost of a bivalent vaccine, respectively. Several limitations must be noted though: 1) the study assumed that hepatitis A rates would decline annually by 2.1% based on trends of past decades, 2) vaccine efficacy was based on clinical trial data, 3) the study did not consider that HAV vaccination would reduce work loss among former prisoners, and 4) the study did not assess continued HAV transmission from non-vaccinated former prisoners to other members of society. The study is useful, however, in demonstrating that a bivalent vaccination program can be cost-effective in situations where the HAV prevalence is high.

Statement of Purpose

Inmates in correctional facilities bear a disproportionately greater burden of infectious disease with recent documented outbreaks of HAV and HBV (1, 4, 6, 15-17). Highly effective and safe vaccines are available to prevent HAV and HBV transmission (2). Access to prevention and medical treatment can provide lasting benefits to communities by reducing disease transmission and by facilitating rehabilitation (18).

Public health officials recognize the need to include incarcerated populations in community-based disease prevention and control strategies. But HAV and HBV prevention at the jail level is particularly challenging since most inmates are detained for fewer than the six months required for the standard viral hepatitis immunization schedule (10). Administration of monovalent HAV and HBV vaccines or a combined vaccine on an accelerated dose schedule at 0, 7, and 21 days has demonstrated immunization rates equal to those realized with the standard schedule (11). This accelerated schedule would be particularly useful in jails since detainees could be immunized in less than a month despite the high rate of detainee turnover. The purpose of this investigation was to determine the cost-effectiveness of accelerated vaccination programs for jail detainees.

Methods

Analytic Overview

The U.S. healthcare system is defined to be the set of health care providers and agencies that would manage the health needs of detainees before, during, and following incarceration. Inmates are assumed to be an underinsured or uninsured population and were assumed to be unable to afford the costs for medical treatment. For the purpose of this study, then, the U.S. healthcare system would bear all costs associated with vaccine program administration, viral hepatitis infection outcomes, as well as future independent healthcare costs for jail inmates.

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The U.S. healthcare system is defined to be the set of health care providers and agencies that would manage the health needs of detainees before, during, and following incarceration. Thus, for the purpose of this study, the U.S. healthcare system would bear all costs associated with vaccine program administration and viral hepatitis infection outcomes. ¶

Prevalence of and risk for HAV and HBV

History of prior viral hepatitis infection were based on studies indicating HAV prevalence of 33% (16) and HBV prevalence of 25% (19) on entry to jail. The lifetime

risk of infection with HAV and HBV for detainees was estimated by assuming a steady state prevalence of viral hepatitis in the general jail population. With this steady state assumption of viral hepatitis prevalence in the general jail population, the lifetime risk for non-infected jails inmates of infection with HAV was estimated to be 33% and HBV 25%.

Infection Outcomes

The likelihood and costs of specific medical outcomes due to viral hepatitis infection were based on prior studies (Table 1)(12, 14). Independent future health costs estimated at $317,000 were added to the cost of all infection outcomes that did not lead to death (20). Secondary infection outcomes, defined as infection of non-incarcerated community members by released HAV or HBV positive detainees, were not considered.

All infection outcomes HAV infection outcomes were separated into two categories: asymptomatic (22%) and symptomatic (78%). Symptomatic HAV infections were then divided into two categories: those requiring hospitalization (85%) and those not requiring hospitalization (15%). HAV infections requiring hospitalizations were further divided into two categories: those with infections that were fatal (2%) and those which were not fatal (98%).

HBV infection outcomes were separated into two categories: asymptomatic (60%) and symptomatic (40%). Asymptomatic infections were divided into those that resolved (94%) and those which became chronic infections (6%). Chronic infections were then separated into two categories: those which resulted in a health carrier (85%) and those which produced liver disease (15%). Symptomatic infections were divided into those

requiring hospitalization (12%) and those not requiring hospitalization (88%). Symptomatic infections requiring hospitalization were further divided into those which became fulminant (4%) and those that did not become fulminant (96%). Those which were not fulminant were further divided two categories: fulminant disease which resolved completely (94%) or produced chronic disease (6%). Chronic disease was then further separated into that which produced liver disease (15%) and that which produced a healthy carrier (85%). Symptomatic HBV infections requiring hospitalization due to fulminant disease were further divided into those which led to death (70%), those which resolved completely (24%), and those which produced chronic disease (6%). Chronic disease was again divided into two categories: that which produced liver disease (15%) and that which produced a healthy carrier (85%). All HBV scenarios of liver disease were divided into four possible outcomes: 1) chronic active hepatitis (25%), chronic persistent hepatitis (25%), cirrhosis (25%), and hepatocellular carcinoma (25%).

Table 1. Viral hepatitis infection outcomes by percentage likelihood and cost

HAV Outcomes	**%**	**Cost ($)**
Asymptomatic	22	--
Symptomatic		
Not hospitalized	66.3	449
Hospitalized		
Not Fatal	11.5	8121
Fatal	0.2	24363
HBV Outcomes	%	Cost ($)
Asymptomatic		--
Resolve	56.4	--
Chronic		
Healthy carrier	3.06	--
Liver disease	0.54	82415
Symptomatic		
Not hospitalized	35.20	--

Hospitalized		
Fulminant		
Death	0.13	24363
Resolve	0.05	8121
Chronic	0.01	19265
Not fulminant		
Resolve	4.33	8121
Chronic	0.28	19265

Vaccine Immunogenecity

Immunogenecity conferred due to number of vaccine doses administered on the accelerated schedule were based on prior studies (Table 2)(13, 21, 22). The seroprotection rates of the bivalent vaccine were assumed to be equivalent to the monovalent vaccines. The monovalent HAV vaccine was estimated to confer 94% seroprotection against HAV at one dose, and 99% seroprotection against HAV at two doses. The monovalent HBV vaccine was estimated to confer 30% seroprotection against HBV at one dose, 77% seroprotection against HBV at two doses, and 98% seroprotection against HBV at three doses. The bivalent vaccine was estimated to provide 94% seroprotection against HAV and 30% seroprotection against HBV at one dose, 99% seroprotection against HAV and 77% seroprotection against HBV at two doses, and 99% seroprotection against HAV and 98% seroprotection against HBV at three doses.

Table 2. Seroprotection rates for bivalent and monovalent vaccines based on doses given at the accelerated schedule

Vaccine	**1 dose**	**2 doses**	**3 doses**
HAV vaccine	0.94	0.99	0.99
HBV vaccine	0.30	0.77	0.98

Vaccination program costs

Costs for monovalent (Havrix: $18.50, Engerix-B: $24.25) and bivalent (Twinrix: $36.91) vaccines were assumed to be equivalent to the public sector cost per dose (23). The cost of screening was estimated solely by the cost for antibody tests for anti-HAV ($17.31) and anti-HBs ($15.01), which were based on national Medicaid fees (24).

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Consent and Length of Stay

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The study assumed that 75% of inmates would accept an offer for vaccination, and 90% would consent to screening (25). Inmates who declined vaccination were assumed to have a 33% lifetime risk of infection with HAV and 25% with HBV, as per the steady state assumption of HAV and HBV prevalence in the population. The amount of time available for vaccination or screening was estimated by length of stay data: 15% would be released within one week, 10% in two weeks, 15% in three weeks, and 60% would be released after three weeks (10).

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Protocol for No Intervention Model

The model accounted for the likelihood of infection with HAV, HBV, or both over the course of a detainee's lifetime, and the expected medical cost of infection outcomes. At intake, inmates were divided into two categories: likelihood of exposure to HAV prior to intake (33%) and likelihood of no prior exposure to HAV (67%). Inmates with prior exposure to HAV were further categorized by probability of prior exposure to HBV (25%) and probability of no prior exposure to HBV (75%). If an inmate turned out to be positive for HBV under this circumstance, only HBV infection outcomes and their

associated costs were considered. Inmates who were positive for HAV exposure and negative for HBV exposure were further separated by lifetime likelihood of acquiring HBV (25%) and lifetime likelihood of not acquiring HBV (75%). If an HAV positive and HBV negative inmate were exposed to HBV following incarceration, then only HBV infection outcomes and associated costs were considered. If an HAV positive and HBV negative inmate avoided exposure to HBV following incarceration, then only HAV infection outcomes and associated costs were considered.

Inmates with no prior exposure to HAV were further categorized by probability of prior exposure to HBV (25%) and probability of no prior exposure to HBV (75%). If an inmate turned out to be positive for HBV under this circumstance, only HBV infection outcomes and their associated costs were considered. Inmates who were negative for HAV exposure and negative for HBV exposure were further separated by lifetime likelihood of acquiring HBV (25%) and lifetime likelihood of not acquiring HBV (75%). If an HAV negative and HBV negative inmate were exposed to HBV following incarceration, then only HBV infection outcomes and associated costs were considered. If an HAV negative and HBV negative inmate were not exposed to HBV following incarceration, then those inmates were further separated by lifetime likelihood of exposure to HAV following incarceration (33%) and lifetime likelihood of no exposure to HAV following incarceration (67%). An HAV negative, HBV negative inmate who acquired HAV after incarceration faced HAV infection outcomes and their associated costs. An HAV negative and HBV negative inmate who avoided exposure to both HBV and HAV faced only future unrelated health costs.

Protocol for Vaccinate on Entry using Monovalent Vaccines

Inmates were assigned to three categories based on expected percentages of how many would stay in jail for one (15%), two (10%), or three (75%) doses of the vaccine. In the next step of the model, inmates were separated on whether they would accept vaccination (75%) or decline vaccination (25%). Inmates who accepted vaccination received the prearranged number of monovalent vaccine doses based on expected length of stay in jail. An inmate could receive a maximum of three doses of the monovalent HBV vaccine and two doses of the monovalent HAV vaccine.

These inmates were then divided into two categories: likelihood of exposure to HAV prior to intake (33%) and likelihood of no prior exposure to HAV (67%). Inmates with prior exposure to HAV were further categorized by probability of prior exposure to HBV (25%) and probability of no prior exposure to HBV (75%). Inmates positive for both HAV and HBV were arranged to face only HBV infection outcomes. HAV positive inmates who were HBV negative were then divided into two categories: those protected from HBV based on number of monovalent HBV vaccine doses administered (one dose 30%, two doses 77%, three doses 98%), and those not protected from HBV despite vaccination based on number of vaccine doses administered (one dose 70%, two doses 23%, three doses 2%). Inmates who were HAV positive and protected from HBV faced HAV infection outcomes. HAV positive inmates who were not protected from HBV despite vaccination were further divided into those who would be infected with HBV following incarceration (25%) and those who would not be infected with HBV following incarceration (75%). Inmates who were HAV positive, were not protected from HBV despite vaccination, and were infected with HBV following incarceration were estimated

to face only HBV infection outcomes. Inmates who were HAV positive, were not protected from HBV despite vaccination, and avoided infection by HBV following incarceration faced only HAV infection outcomes.

Inmates with no prior exposure to HAV were further categorized by probability of prior exposure to HBV (25%) and probability of no prior exposure to HBV (75%). Inmates negative for HAV and positive HBV faced only HBV infection outcomes. HAV negative inmates who were HBV negative were then divided into two categories: those protected from HBV based on number of vaccine doses administered (one dose 30%, two doses 77%, three doses 98%), and those not protected from HBV despite vaccination based on number of vaccine doses administered (one dose 70%, two doses 23%, three doses 2%). Inmates who were HAV negative and protected from HBV were then categorized into two groups: those protected from HAV based on number of vaccine doses administered (one dose, 94%; two doses, 99%), and those not protected from HAV despite vaccination based on number of vaccine doses administered (one dose, 6%; two doses, 1%). HAV negative and HBV negative inmates who were protected against HAV and HBV faced future unrelated health costs. HAV negative and HBV negative inmates who were protected against HBV but not against HAV were further divided into those who would acquire HAV after incarceration (33%) and those who would avoid HAV infection after incarceration (67%). HAV negative and HBV negative inmates who were protected against HBV but not against HAV and were then exposed to HAV after incarceration faced HAV infection outcomes. HAV negative and HBV negative inmates who were protected against HBV but not against HAV and avoided HAV infection after incarceration faced future unrelated health costs. HAV negative and HBV negative

inmates who were not protected against HBV despite vaccination were further divided into those who would acquire HBV after incarceration (25%) and those who would avoid HBV infection after incarceration (75%). HAV negative and HBV negative inmates who were not protected against HBV despite vaccination and acquired HBV after incarceration faced HBV infection outcomes. HAV negative and HBV negative inmates who were not protected against HBV despite vaccination and avoided HBV infection after incarceration were separated into two groups: those protected from HAV based on number of vaccine doses administered (one dose 94%, two doses 99%), and those not protected from HAV despite vaccination based on number of vaccine doses administered (one dose 6%, two doses 1%). HAV negative and HBV negative inmates who were not protected against HBV despite vaccination but avoided HBV infection after incarceration and were protected against HBV faced only future unrelated health costs. HAV negative and HBV negative inmates who were not protected against HBV despite vaccination but avoided HBV infection after incarceration and were not protected against HAV were divided into two categories: those who would acquire HAV infection after incarceration (33%) and those who would avoid HAV infection after incarceration (67%). HAV negative and HBV negative inmates who were not protected against HBV despite vaccination, avoided HBV infection after incarceration, were not protected against HAV despite vaccination, and acquired an HAV infection after incarceration faced HAV infection outcomes. HAV negative and HBV negative inmates who were not protected against HBV despite vaccination, avoided HBV infection after incarceration, were not protected against HAV despite vaccination, and avoided HAV infection after incarceration faced only future unrelated health costs.

Protocol for Vaccinate on Entry using Bivalent Vaccines

Inmates were assigned to three categories based on expected percentages of how many would stay in jail for one (15%), two (10%), or three (75%) doses of the vaccine. In the next step of the model, inmates were separated on whether they would accept vaccination (75%) or decline vaccination (25%). Inmates who accepted vaccination received the prearranged number of bivalent vaccine doses.

These inmates were then divided into two categories: likelihood of exposure to HAV prior to intake (33%) and likelihood of no prior exposure to HAV (67%). Inmates with prior exposure to HAV were further categorized by probability of prior exposure to HBV (25%) and probability of no prior exposure to HBV (75%). Inmates positive for both HAV and HBV were arranged to face only HBV infection outcomes. HAV positive inmates who were HBV negative were then divided into two categories: those protected from HBV based on number of bivalent vaccine doses administered (one dose 30%, two doses 77%, three doses 98%), and those not protected from HBV despite vaccination based on number of bivalent vaccine doses administered (one dose 70%, two doses 23%, three doses 2%). Inmates who were HAV positive and protected from HBV faced HAV infection outcomes. HAV positive inmates who were not protected from HBV despite vaccination were further divided into those who would be infected with HBV following incarceration (25%) and those who would not be infected with HBV following incarceration (75%). Inmates who were HAV positive, were not protected from HBV despite vaccination, and were infected with HBV following incarceration were assigned to face only HBV infection outcomes. Inmates who were HAV positive, were not

protected from HBV despite vaccination, and avoided infection by HBV following incarceration were assigned to face only HAV infection outcomes.

Inmates with no prior exposure to HAV were further categorized by probability of prior exposure to HBV (25%) and probability of no prior exposure to HBV (75%). Inmates negative for HAV and positive HBV were arranged to face only HBV infection outcomes. HAV negative inmates who were HBV negative were then divided into two categories: those protected from HBV based on number of bivalent vaccine doses administered (one dose 30%, two doses 77%, three doses 98%), and those not protected from HBV despite vaccination based on number of bivalent vaccine doses administered (one dose 70%, two doses 23%, three doses 2%). Inmates who were HAV negative and protected from HBV were then categorized into two groups: those protected from HAV based on number of bivalent vaccine doses administered (one dose, 94%; two doses, 99%, three doses, 99%), and those not protected from HAV despite vaccination based on number of bivalent vaccine doses administered (one dose, 6%; two doses, 1%, three doses, 1%). HAV negative and HBV negative inmates who were protected against HAV and HBV faced future unrelated health costs. HAV negative and HBV negative inmates who were protected against HBV but not against HAV were further divided into those who would acquire HAV after incarceration (33%) and those who would avoid HAV infection after incarceration (67%). HAV negative and HBV negative inmates who were protected against HBV but not against HAV and were then infected with HAV after incarceration faced HAV infection outcomes. HAV negative and HBV negative inmates who were protected against HBV but not against HAV and avoided HAV infection after incarceration faced future unrelated health costs. HAV negative and HBV negative

inmates who were not protected against HBV despite vaccination were further divided into those who would acquire HBV after incarceration (25%) and those who would avoid HBV infection after incarceration (75%). HAV negative and HBV negative inmates who were not protected against HBV despite vaccination and acquired HBV after incarceration faced HBV infection outcomes. HAV negative and HBV negative inmates who were not protected against HBV despite vaccination and avoided HBV infection after incarceration were separated into two groups: those protected from HAV based on number of bivalent vaccine doses administered (one dose, 94%; two doses, 99%, three doses, 99%), and those not protected from HAV despite vaccination based on number of bivalent vaccine doses administered (one dose, 6%; two doses, 1%, three doses, 1%). HAV negative and HBV negative inmates who were not protected against HBV despite vaccination but avoided HBV infection after incarceration and were protected against HBV faced only future unrelated health costs. HAV negative and HBV negative inmates who were not protected against HBV despite vaccination but avoided HBV infection after incarceration and were not protected against HAV were divided into two categories: those who would acquire HAV infection after incarceration (33%) and those who would avoid HAV infection after incarceration (67%). HAV negative and HBV negative inmates who were not protected against HBV despite vaccination, avoided HBV infection after incarceration, were not protected against HAV despite vaccination, and acquired an HAV infection after incarceration faced HAV infection outcomes. HAV negative and HBV negative inmates who were not protected against HBV despite vaccination, avoided HBV infection after incarceration, were not protected against HAV despite vaccination, and avoided HAV infection after incarceration faced only future unrelated health costs.

Protocol for Screen and Defer Vaccination

This model examined the scenario in which inmates would first be screened for exposure to HAV and HBV, and would then be vaccinated based on the screening results. Inmates were first organized into two categories: those who would accept an offer to screen for prior HAV and HBV infection (90%) and those who would decline an offer to screen for prior infection (10%), with the assumption that the screening results would be made available after one week.

The model then categorized inmates into those who had been exposed to HAV (33%) and those who had not be been exposed to HAV (67%). These inmates were further organized based on likelihood of prior HBV exposure (25%) and no prior HBV exposure (75%). Inmates who were found to be HAV positive and HBV positive based on screening results would not be eligible for vaccination and faced HBV infection outcomes. Inmates who were HAV positive and HBV negative were separated by likelihood of accepting vaccination (75%) and declining vaccination (25%). Inmates who declined vaccination were separated by likelihood of exposure to HBV after incarceration (25%) and no exposure to HBV after incarceration (75%). HAV positive and HBV negative inmates who declined vaccination and were infected with HBV after incarceration faced HBV infection outcomes. HAV positive and HBV negative inmates who declined vaccination and avoided HBV infection after incarceration faced HAV infection outcomes.

HAV positive and HBV negative inmates who accepted vaccination were then categorized by the number of monovalent HBV vaccine doses to be administered based

on anticipated length of stay after results of the viral hepatitis screening were available: those who would receive three doses of the monovalent HBV vaccine (60%), those who would receive two doses of the HBV vaccine (15%), those who would receive one dose of the HBV vaccine (10%), and those who would be released from jail before receiving a single dose of the HBV vaccine (15%). The model then accounted for the likelihood of protection against HBV based on number of doses of the HBV vaccine administered: three doses (98% protected, 2% not protected); two doses (77% protected, 23% not protected); one dose (30% protected, 70% not protected); no dose (0% protected, 100% not protected). Inmates who were not protected against HBV were further divided into those who would acquire HBV after incarceration (25%) and those who would avoid HBV infection after incarceration (75%). HAV positive and HBV negative inmates who would be vulnerable to HBV despite vaccination and were exposed to the virus faced HBV infection outcomes. HAV positive and HBV negative inmates who would be vulnerable to HBV despite vaccination and avoided HBV infection after incarceration faced HAV infection outcomes only.

Inmates who were found to be HAV negative and HBV positive would be eligible for the HAV vaccine and were categorized into those who would accept the HAV vaccine (75%) and those who would decline the HAV vaccine (25%). Inmates who declined vaccination faced HBV infection outcomes. Inmates who accepted the HAV vaccine were separated by number of doses of vaccine to be administered based on the expected length of stay following the report of the screening: two doses (75%), one dose (10%), and no dose (15%). All of these inmates, regardless of post-incarceration exposure to HAV, faced HBV infection outcomes.

Inmates who were found to be HAV negative and HBV negative would be eligible for the bivalent HAV/HBV vaccine and were categorized by those who would accept the vaccine (75%) and those who would decline the vaccine (25%). Those who declined the vaccine were next divided into two categories: those who would be infected with HBV after incarceration (25%) and those who would avoid HBV infection after incarceration (75%). HAV negative and HBV negative inmates who declined vaccination and were exposed to HBV after incarceration faced HBV infection outcomes. HAV negative and HBV negative inmates who declined vaccination and avoided exposure to HBV after incarceration were further categorized based on likelihood of exposure to HAV after incarceration (33%) and no exposure to HAV after incarceration (67%). HAV negative and HBV negative inmates who declined vaccination and avoided exposure to HBV but were infected by HAV after incarceration faced HAV infection outcomes. HAV positive and HBV negative inmates who declined vaccination and avoided both HAV and HBV infection after incarceration faced only future unrelated healthcare costs.

HAV and HBV negative inmates who declined vaccination and were exposed to HBV following incarceration faced HBV infection outcomes. HAV and HBV negative inmates who declined vaccination and avoided HBV infection following incarceration were then separated based on likelihood of exposure to HAV after incarceration (33%) and no exposure to HAV after incarceration (67%). HAV and HBV negative inmates who declined vaccination, avoided HBV infection after incarceration, and were infected with HAV after incarceration faced HAV infection outcomes; those who avoided HAV infection faced only future unrelated health costs.

HAV negative and HBV negative inmates who accepted vaccination were separated by number of doses to be administered based on estimated length of incarceration following screening: three doses (60%), two doses (15%), one dose (10%), and no doses (15%). Inmates without previous exposure to HAV or HBV who received no doses of the bivalent vaccine were separated by likelihood of exposure to HBV following incarceration (25%) and no exposure to HBV following incarceration (75%). HAV and HBV negative inmates who received no vaccine doses and were exposed to HBV after incarceration faced HBV infection outcomes. HAV and HBV negative inmates who received no vaccine doses and avoided HBV infection after incarceration were further organized according to likelihood of exposure to HAV after incarceration (33%) and no exposure to HAV after incarceration (67%). HAV and HBV negative inmates who received no vaccine doses, avoided HBV infection but suffered an HAV infection after incarceration faced HAV infection outcomes. HAV and HBV negative inmates who received no vaccine doses and avoided exposure to both HAV and HBV faced only future unrelated healthcare costs.

HAV and HBV negative inmates who would receive vaccine doses were divided by the expected protection against HAV and HBV based on number of doses of the bivalent vaccine administered: three doses (98% protected against HBV, 2% not protected against HBV; 99% protected against HAV, 1% not protected against HAV), two doses (77% protected against HBV, 23% not protected against HBV; 99% protected against HAV, 1% not protected against HAV), one dose (30% protected against HBV, 70% not protected against HBV; 94% protected against HAV, 6% not protected against HAV). Inmates who were not protected against HBV despite vaccination were further

divided into those who would acquire HBV after incarceration (25%) and those who would avoid HBV infection after incarceration (75%). HAV and HBV negative inmates who would be vulnerable to HBV despite vaccination and were exposed to the virus faced HBV infection outcomes. HAV and HBV negative inmates who would be vulnerable to HBV despite vaccination and avoided HBV infection after incarceration, and were vulnerable to HAV despite vaccination were further separated based on likelihood of exposure to HAV after incarceration (33%) and no exposure to HAV after incarceration (67%). HAV and HBV negative inmates vulnerable to HAV and HBV despite vaccination and avoided HBV infection after incarceration, but were exposed to HAV after incarceration faced HAV infection outcomes. HAV and HBV negative inmates vulnerable to HAV and HBV despite vaccination but avoided infection by both HAV and HBV after incarceration faced only future unrelated healthcare costs.

Sensitivity Analysis

To account for variations in estimated values for the variables in the model, sensitivity analysis was performed to evaluate the effect on the cost effectiveness analysis due to 1) prevalence of HAV and HBV exposure at intake, 2) lifetime risk of HAV and HBV infection, 3) HAV and HBV vaccine immunogenicity, and 4) independent future healthcare costs. Sensitivity analyses were performed with the SensIt plugin for Microsoft Excel.

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Results

Cost-effectiveness

The expected cost of each program to the U.S. healthcare system over the lifetime of detainees is listed in Table 3, with the estimate of 420,000 new jail detainees per year (26). Cost per detainee was calculated by subtracting independent future health costs estimated at $317,000. The vaccinate on entry programs proved to be the least expensive compared to no intervention and screen and defer vaccination. Screen and defer vaccination was more expensive than no intervention. Of the two vaccinate on entry programs, using a bivalent vaccine was marginally less costly than using monovalent vaccines. Over the lifetime of the detainees, a vaccinate on entry program using monovalent vaccines would save US $4,560,000 over the expected cost of \no intervention, while a vaccinate on entry program using bivalent vaccines would save US $4,970,000. A screen and defer program would cost US $1,900,000 above the expected cost of a no intervention program.

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Table 3. Expected costs of jail vaccination programs for viral hepatitis over lifetime of detainees

Program	Cost per detainee ($)	Overall cost ($)
No intervention	371	155,862,288
Vaccinate on Entry with Bivalent Vaccines	359	150,893,173
Vaccinate on Entry with Monovalent Vaccine	360	151,305,508
Screen and Defer Vaccination	376	157,764,657

Infections Averted

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The anticipated number of viral hepatitis infections averted for each vaccination scenario is listed in Table 4. These results are for an expected cohort of 420,000 jail

inmates in a given year (26) and represent viral hepatitis infections averted over the course of the lifetimes of the detainees within the cohort. No intervention would allow 26,247 new HAV infections, 12,135 new HBV infections, and 66,615 new HAV/HBV co-infections. A vaccinate on entry program would allow 4,935 new HAV infections, 7,630 new HBV infections, and 19,499 new HAV/HBV co-infections. A screen and defer vaccination program would allow 10,174 new HAV infections, 8,150 new HBV infections, and 30,254 new HAV/HBV co-infections. In terms of the number of infections averted, this translates to 21,312 HAV infections, 4,505 HBV infections, and 47,115 HAV/HBV co-infections averted by a vaccinate on entry program; and 16,073 HAV infections , 3,985 HBV infections, and 36,360 HAV/HBV co-infections averted by a screen and defer vaccination program. Both vaccination scenarios avert hepatitis infections, but the number averted is clearly higher in the vaccinate on entry scenario.

Table 4. Expected Number of Infections Averted per Vaccination Scenario

Infection Type	Vaccinate on Entry	Screen and Defer
HAV	21,312	16,073
HBV	4,505	3,985
HAV/HBV	47,115	36,360

Sensitivity Analysis

For both vaccination scenarios, prior HAV exposure had a higher effect on cost savings than prior HBV exposure. Additionally, lifetime risk of infection with HAV had a greater effect on cost savings compared to lifetime risk of HBV infection. A vaccinate on entry program would also no longer generate cost savings over no intervention if at least 42% of inmates at intake had prior HAV exposure, or at least 36% of inmates had prior HBV exposure. A vaccinate on entry program also would no longer generate cost savings if the lifetime risk of HAV infection was less than 25%, or if the lifetime risk of infection with

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HBV was less than 8% (Figure 1). A screen and defer vaccination program would generate cost savings over no intervention if at most 28% of inmates at intake had prior HAV exposure, or at most 16% of inmates had prior HBV exposure. A screen and defer vaccination program would also no longer generate cost savings over no intervention if the lifetime risk of HAV infection was less than 37%, or if the lifetime risk of infection with HBV was less than 34% (Figure 2).

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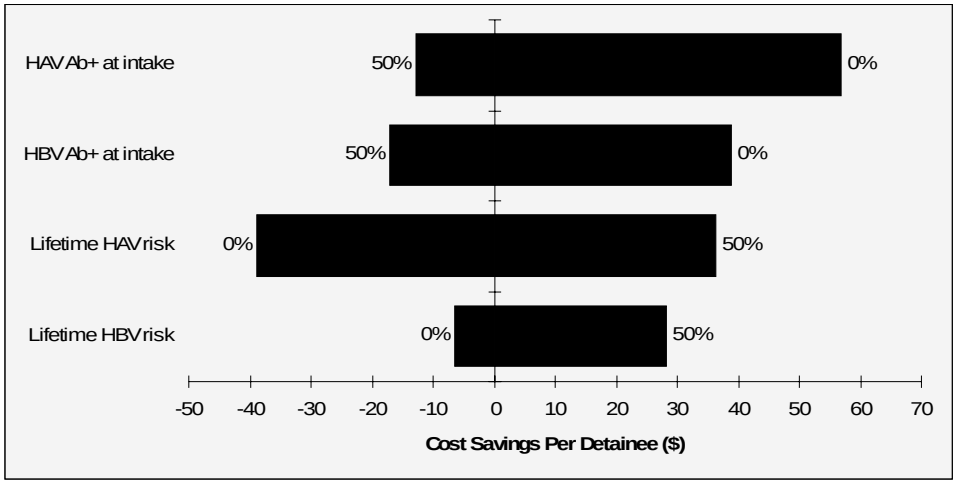

Figure 1. Sensitivity Analysis: Effect of Viral Hepatitis Prevalence at Intake and Lifetime Viral Hepatitis Infection Risk on Cost Savings Per Detainee for a Vaccinate on Entry Program. A vaccinate on entry program would no longer generate cost savings when HAV prevalence at intake exceeded 42%, or HBV prevalence exceeded 36%. The program would also generate cost savings if inmates' lifetime risk of infection with HAV was greater than 25% or lifetime risk of infection with HBV was greater than 8%.

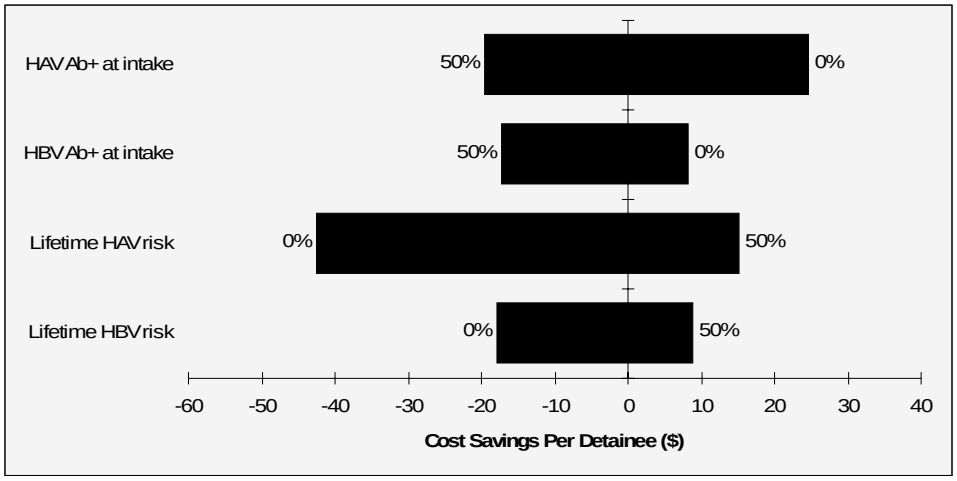

Figure 2. Sensitivity Analysis: Effect of Viral Hepatitis Prevalence at Intake and Lifetime Viral Hepatitis Infection Risk on Cost Savings Per Detainee for a Screen and Defer Vaccination Program. A screen and defer vaccination program would generate cost savings if HAV prevalence at intake did not exceed 28% or HBV prevalence at intake did not exceed 16%. The program would also generate cost savings if inmates' lifetime risk of infection with HAV was greater than 37%, or lifetime risk of infection with HBV was greater than 34%.

All vaccination programs decreased in cost savings as expected vaccine immunogenicity decreased (Figure 3). A vaccinate on entry program with the monovalent vaccines would no longer generate cost savings over no intervention if the conferred immunogenicity was 88% of the expected values. A vaccinate on entry program with the bivalent vaccine would no longer generate cost savings over no intervention if the conferred immunogenicity was 87% of the expected. A screen and defer vaccination program would not produce cost savings over no intervention at any reduced vaccine immunogenicity.

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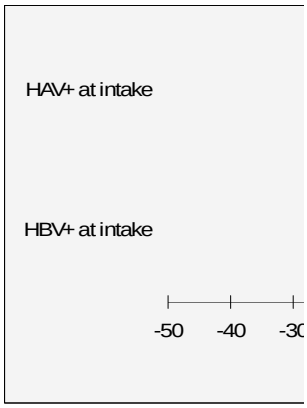

Figure 1. Sensitivity Analysis: Effect of Viral Hepatitis Prevalence at Intake on Cost Savings Per Detainee for a Vaccinate on Entry Program. A vaccinate on entry program would no longer generate cost savings when HAV prevalence at intake exceeded 42%, or HBV prevalence exceeded 36%.¶

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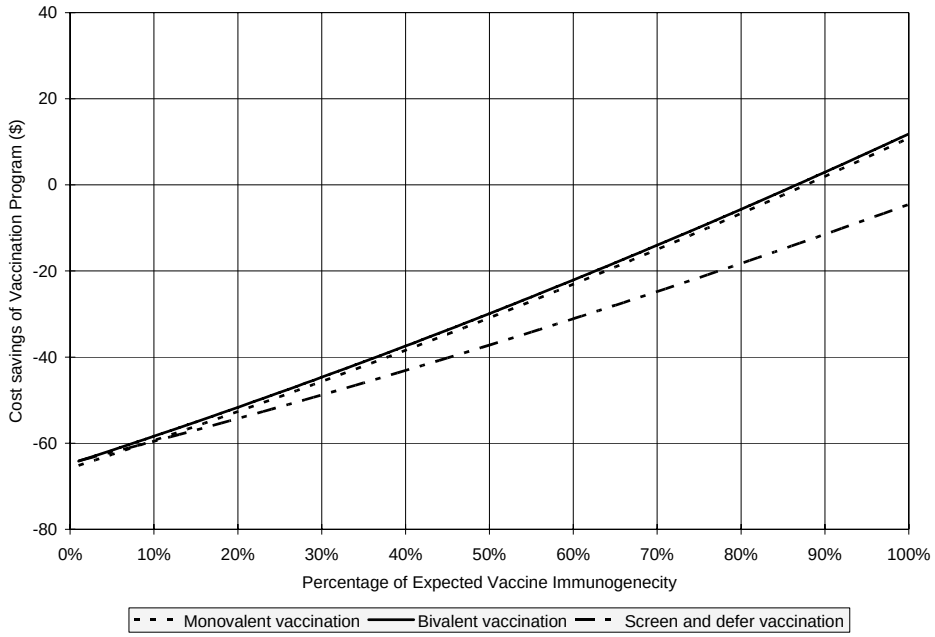

Figure 3. Effect of Change in Vaccine Immunogenecity on Cost Savings. A vaccinate on entry program would no longer generate cost savings if vaccine immunogenicity at the accelerated schedule was less than 88% of the standard schedule. Screen and defer vaccination would not generate cost savings regardless of vaccine immunogenicity.

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Cost savings for all vaccination programs decreased as future health care costs increased (Figure 4). A vaccinate on entry program would not realize cost savings if independent future healthcare costs exceeded US $358,000. A screen and defer vaccination program would not generate cost savings if independent future healthcare costs exceeded US $294,000. Both programs would realize greater cost savings to the overall healthcare system if future healthcare costs decreased.

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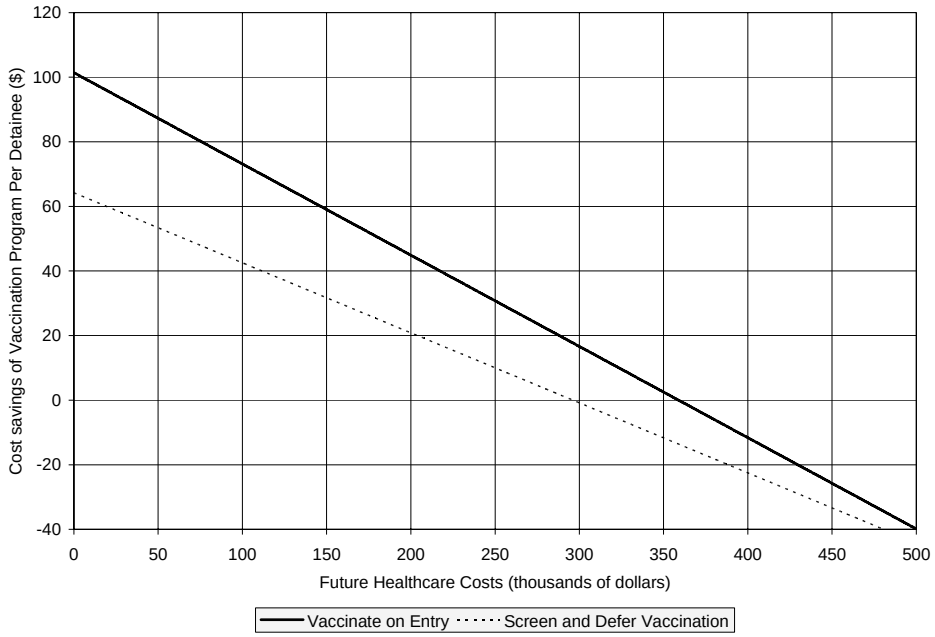

Figure 4. Sensitivity Analysis: Effect of Future Healthcare Costs on Vaccination Program Cost Savings. Increased future unrelated healthcare costs would offset the cost savings realized in a vaccination program.

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Discussion

Not vaccinating jail inmates for HAV and HBV would cost the U.S. healthcare system US$ 371 per detainee over a lifetime course assuming future unrelated healthcare cost of US $317,000 per detainee. Screening for prior infection and deferring vaccination until infection history was determined would cost about US $376 per detainee. Vaccination for HAV and HBV with a combined vaccine on an accelerated dosing schedule would cost US$ 359 per detainee; immunization at an accelerated schedule with a maximum of three doses of HBV vaccine and two doses of HAV vaccine would cost US$ 360 per detainee. A vaccinate on entry program averts more HAV infections, HBV infections, and HAV/HBV co-infections than a screen and defer vaccination program. The overall healthcare system would save about US$ 12 per detainee with a vaccinate on

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entry program with a bivalent vaccine compared to no intervention. This savings translates into an economic benefit amounting to about US$ 5,000,000 saved by the U.S. healthcare system in the long-term if such a program were implemented for all new jail inmates in a given year. Screen and defer vaccination did not generate cost savings.

Both vaccinate on entry and screen and defer vaccination program would generate cost savings if the exposure rate of HAV or HBV at entry was lower than expected or if the lifetime risk of infection with either virus was higher than expected. Immunogenicity is a critical factor in estimating overall cost savings, as vaccinate on entry programs would no longer produce cost savings if conferred immunogenicity from either monovalent or bivalent vaccines was below 90% of the expected values. Future healthcare costs also proved to be important in predicting cost savings; if independent future healthcare costs were greater than US $358,000 a vaccinate on entry program would no longer generate costs savings.

There are several important limitations to these models. First, lifetime risk of infection was assumed to be constant, though this risk would likely increase as detainees face repeated encounters with jails and prisons (27). The models also assumed a lifetime risk of infection equal to that of the general population, though correctional inmates demonstrate markedly higher amounts of risk behaviors that would increase the likelihood of viral transmission. Increased rates of infection due to recidivism and risky behaviors would in turn increase expected infection costs of non-immunized detainees, which would make vaccination programs more cost-effective as demonstrated in the sensitivity analyses. The models also did not account for other causes of poor viral hepatitis infection outcomes. Jail and prison inmates have been demonstrated to have a

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high burden of HIV and HCV, and associated substance abuse problems compared to the general population (7, 28-31). Co-infection with HIV or HCV would increase rates of HAV and HBV morbidity (32). Liver damage secondary to substance abuse, particularly alcohol abuse, would also contribute to poor HAV and HBV outcomes. Co-infection and substance abuse would therefore increase the cost of medical complications secondary to HAV and HBV infection. Jail inmates may have other health concerns that would result in a decreased seroprotection rate compared to subjects involved in controlled vaccine trials. As the sensitivity analysis demonstrated, however, a vaccinate on entry program would realize cost savings provided that seroprotection against HAV and HBV was at least 40% of the expected rates. The models did not consider the broader societal risks averted by HAV and HBV prevention. Infected detainees could transmit HAV or HBV to non-infected sex partners and other close contacts. Prevention of secondary infections increases the cost-effectiveness of vaccination, as the U.S. healthcare system also benefits from infections averted in the non-incarcerated population. The model also assumed that the future unrelated healthcare costs of jail inmates were equal to the national average of US $317,000. It is likely, however, that jail inmates as a vulnerable population would have greater healthcare needs than the non-incarcerated poplution. Thus, future unrelated healthcare costs of US $317,000 per detainee may be an underestimation. The cost savings would not be as significant if the future unrelated healthcare costs were much higher than the estimated value for this study.

Most major limitations of the study would in fact increase the expected savings of a vaccination program over no intervention, resulting in greater overall savings. Nationwide effort and guidelines should be made to implement immunization programs

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with the monovalent or combined HAV/HBV vaccines on an accelerated dosage schedule for jail detainees in order to realize significant savings to the healthcare system. To accomplish this goal, the public health and correctional systems must work collaboratively to develop public health interventions within jail systems.

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A screen and defer vaccination program generate cost savings over no intervention if at most 28% of inmates at intake had prior HAV exposure, or at most 16% of inmates had prior HBV exposure.

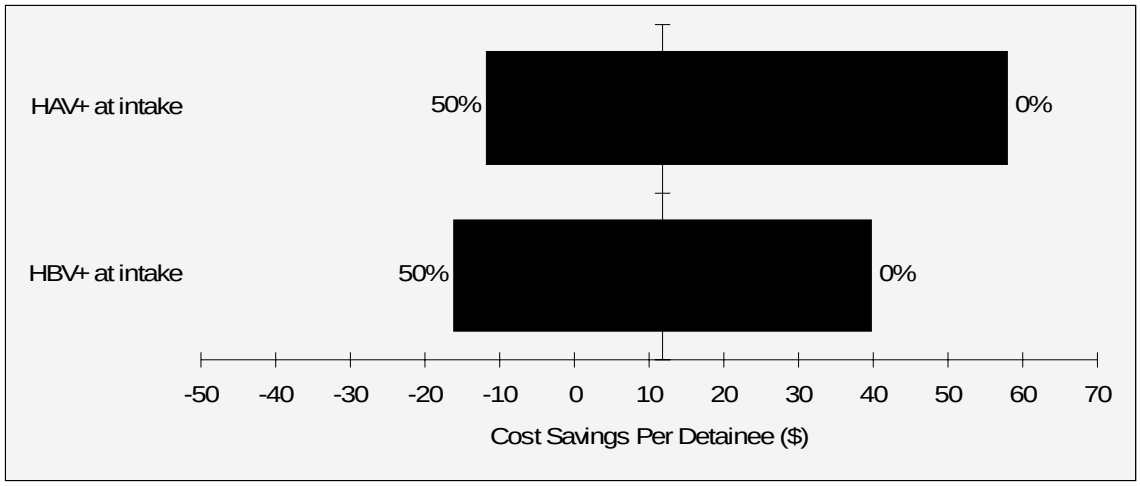
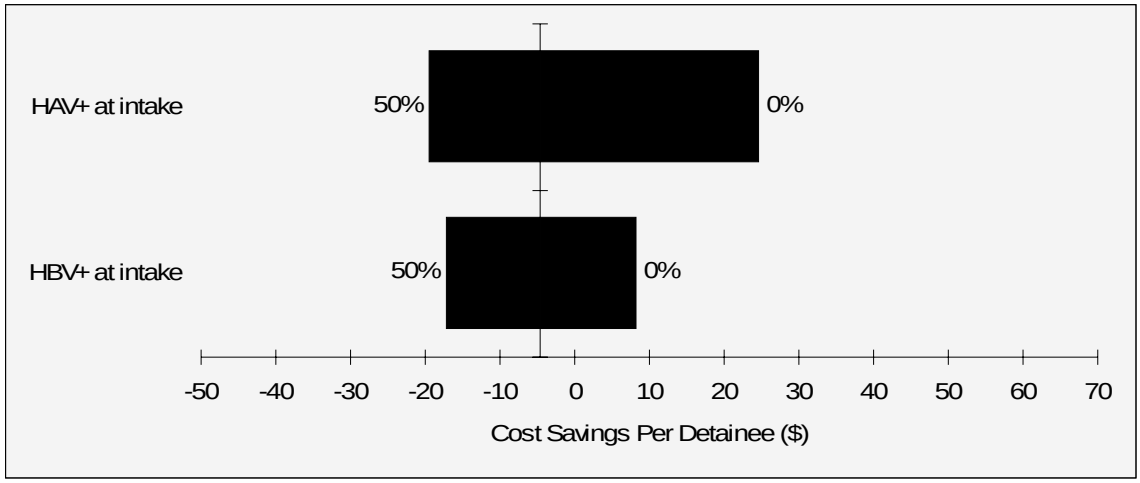


Figure 1. Sensitivity Analysis: Effect of Viral Hepatitis Prevalence at Intake on Cost Savings Per Detainee for a Vaccinate on Entry Program. A vaccinate on entry program would no longer generate cost savings when HAV prevalence at intake exceeded 42%, or HBV prevalence exceeded 36%.



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Lifetime risk of infection with HAV had a greater effect on cost savings compared to lifetime risk of HBV infection (Figures 3 & 4). A vaccinate on entry program would no longer generate cost savings if the lifetime risk of HAV infection was

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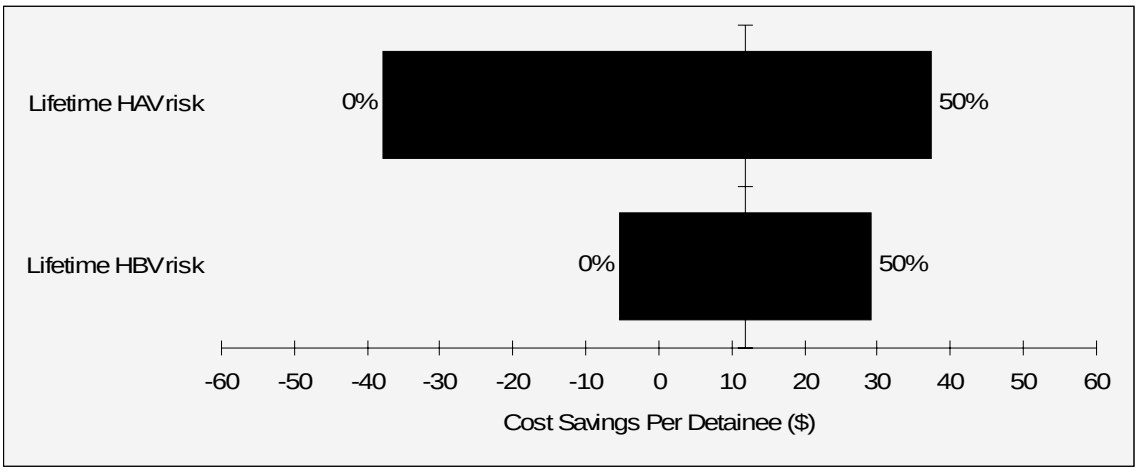

Figure 3. Sensitivity Analysis: Effect of Viral Hepatitis Lifetime Risk of Infection on Cost Savings Per Detainee for a Vaccinate on Entry Program. A vaccinate on entry program would generate cost savings if inmates' lifetime risk of infection with HAV was greater than 25% or lifetime risk of infection with HBV was greater than 8%.

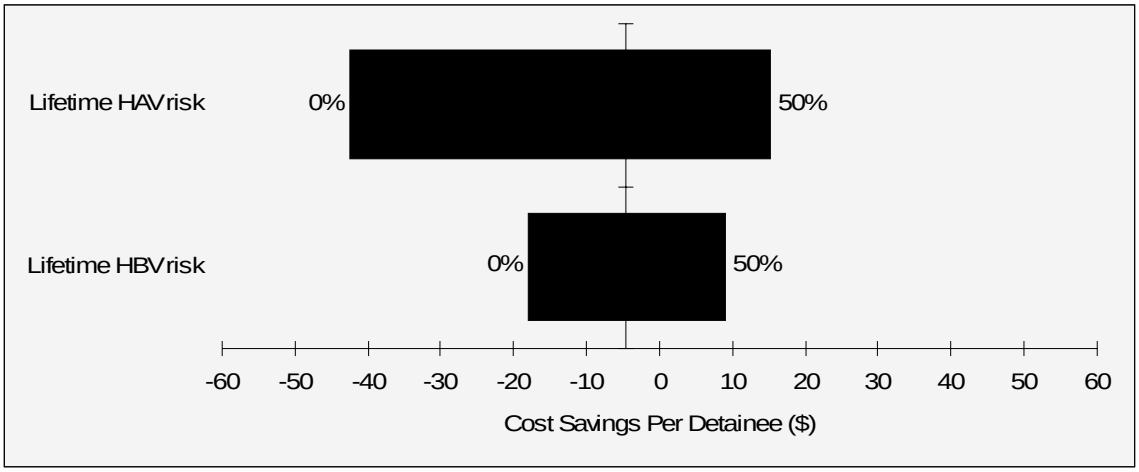

Figure 4. Sensitivity Analysis: Effect of Viral Hepatitis Lifetime Risk of Infection on Cost Savings Per Detainee for a Screen and Defer Program. A screen and defer vaccination program would generate cost savings if inmates' lifetime risk of infection with HAV was greater than 37%, or lifetime risk of infection with HBV was greater than 34%.