A Cost-Benefit Analysis of a Potential Supervised Injection Facility in San Francisco, California, USA

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Abstract

Supervised injection facilities (SIFs) have been shown to reduce infection, prevent overdose deaths, and increase treatment uptake. The United States is in the midst of an opioid epidemic, yet no sanctioned SIF currently operates in the United States. We estimate the economic costs and benefits of establishing a potential SIF in San Francisco using mathematical models that combine local public health data with previous research on the effects of existing SIFs. We consider potential savings from five outcomes: averted HIV and hepatitis C virus (HCV) infections, reduced skin and soft tissue infection (SSTI), averted overdose deaths, and increased medication-assisted treatment (MAT) uptake. We find that each dollar spent on a SIF would generate US$2.33 in savings, for total annual net savings of US$3.5 million for a single 13-booth SIF. Our analysis suggests that a SIF in San Francisco would not only be a cost-effective intervention but also a significant boost to the public health system.

Keywords

supervised injection facility, supervised consumption rooms, cost-benefit, cost-effectiveness, people who inject drugs, San Francisco

Introduction

In the past decade, heroin use by young adults has more than doubled in the United States (Centers for Disease Control and Prevention [CDC], 2015c). Heroin overdose deaths rose almost 250 percent from 2010 to 2014, reaching 29 overdoses per day in 2014 (CDC, 2015a). Because many people inject heroin with shared needles and in unsterilized environments, the heroin epidemic also causes immense infection-related medical costs (Sterling, 2015). Although people who inject drugs (PWID) comprise less than 1% of the U.S. population, they

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experience roughly 56% of new hepatitis C virus (HCV) infections and 11% of new HIV infections (CDC, 2014; Klevens, Hu, Jiles, & Holmberg, 2012). Up to one third of PWID suffer from skin and soft tissue infections (SSTIs), the leading cause of hospitalization in some urban emergency rooms (Binswanger et al., 2008; Ciccarone, Kral, & Edlin, 2001; Heinzerling et al., 2006; Takahashi, Maciejewski, & Bradley, 2010). While the combined medical costs of this relatively small population likely exceed US$6 billion every year, this information is hidden in individual medical records, masking the overwhelming need for prevention efforts (Sterling, 2015).

Supervised injection facilities (SIFs) provide a safe, clean place and injection equipment so that PWID can bring in previously obtained drugs and inject in the presence of medical staff (Jozaghi, 2012; Jozaghi & Andresen, 2013; Wood et al., 2005). Roughly 97 SIFs exist in 66 cities across 11 countries; the only SIFs in North America—Insite and the Dr. Peter Centre—are located in Vancouver, Canada (Jozaghi & Reid, 2014, 2015). SIF health outcomes have been extensively evaluated, demonstrating five principal cost-saving benefits (Hedrich, 2004; Kerr, Tyndall, Li, Montaner, & Wood, 2005; KPMG, 2015). First, they reduce both HIV and HCV transmission by preventing needle-sharing and providing education (Bravo et al., 2009; Kerr, Kimber, DeBeck, & Wood, 2007; Kimber & Dolan, 2007; Marshall et al., 2009). As medical staff provide sterile equipment, advice, and basic wound care, they also reduce both the prevalence and seriousness of SSTIs (Lloyd-Smith et al., 2010; Salmon et al., 2009; Small, Wood, Lloyd-Smith, Tyndall, & Kerr, 2008). They prevent clients from dying of overdose, with zero reported overdose deaths in SIFs worldwide after millions of injections (KPMG, 2010; Marshall, Milloy, Wood, Montaner, & Kerr, 2011; Marshall et al., 2012). Finally, by creating a trusting, positive relationship between health workers and PWID, SIFs increase uptake into addiction treatment (DeBeck et al., 2011; Strathdee & Pollini, 2007; Tyndall et al., 2006; Wood, Tyndall, Zhang, et al., 2006).

The purpose of this article is to analyze the potential cost-effectiveness of establishing the first SIF in the United States, in San Francisco. There is substantial interest in establishing a SIF in San Francisco, among both people who use drugs and health officials (Kral et al., 2010; "San Francisco Hepatitis C Task Force," 2011; Wenger, Arreola, & Kral, 2011; Wenger et al., 2011). While SIFs and other service programs should never be judged solely on their financial performance, cost-benefit analysis provides one important perspective on SIF impact. We intend to answer the question: Would a SIF in San Francisco be an effective and efficient use of financial resources?

First, we summarize the literature upon which our study builds: studies on the medical benefits of SIFs and cost-benefit analyses of SIFs elsewhere in the world. Second, we outline the methodology by which we estimate the cost and the savings, which result from five separate health outcomes: averted HIV and HCV infections, reduced SSTI, averted overdose deaths, and increased medication-assisted treatment (MAT) uptake. Third, we present our estimates, which include a sensitivity analysis for each outcome. Finally, we discuss the implications of these results as well as the limitations of this study.

SIF Cost-Benefit Modeling Literature

Previous SIF cost-benefit studies have found that the Insite SIF in Vancouver is cost-saving when considering HIV, HCV, and overdose prevention outcomes (Andresen & Jozaghi, 2012; Pinkerton, 2011). Prior studies have focused on one to three outcomes; none have considered all five outcomes included in this study. So to appropriately compare these studies, in this section, we review the literature by individual outcome.

Table 1. Findings of Previous Mathematical Modeling Studies Predicting HIV and HCV Infections Averted by a SIF or a Consumption Facility in Various Cities.

			Infections averted	
Location	Study	Model	HIV	HCV
Vancouver	Andresen and Jozaghi (2012);	Jacobs et al.(1999)	22	
Vancouver	Jozaghi (2014); Jozaghi (2015)	Jacobs et al.(1999)	30	57
Toronto	Bayoumi and Strike (2012); Enns et al. (2016)	Bayoumi and Strike (2012); Enns et al. (2016)	3	20
Toronto	Jozaghi and Reid (2015)	Jacobs et al. (1999)	2	41
Toronto	Jozaghi and Reid (2015)	Kaplan and O'Keefe (1993)	6	
Ottawa	Bayoumi and Strike (2012); Enns et al. (2016)	Bayoumi and Strike (2012); Enns et al. (2016)	10	35
Ottawa	Jozaghi, Reid, Andresen, and Juneau (2014)	Jacobs et al. (1999)	5	48
Ottawa	Jozaghi et al. (2014)	Kaplan and O'Keefe (1993)	7	
Montreal	Jozaghi, Reid, and Andresen (2013)	Jacobs et al. (1999)	14	84
Victoria	Jozaghi, Hodgkinson, and Andresen (2015)	Jacobs et al. (1999)	0.5	3
Victoria	Jozaghi et al. (2015)	Kaplan and O'Keefe (1993)	13	
Saskatoon	Jozaghi and Jackson (2015)	Jacobs et al. (1999)	15	
Saskatoon	Jozaghi and Jackson (2015)	Kaplan and O'Keefe (1993)	14	

Note. HCV = hepatitis C virus; SIF = supervised injection facility.

Savings From Averted HIV and HCV Infections

Multiple cost-benefit analyses have used mathematical models to estimate HIV infections averted by Insite, Vancouver's SIF (Andresen & Jozaghi, 2012; Bayoumi & Zaric, 2008; Pinkerton, 2011). Bayoumi and Zaric's (2008) model estimates roughly 157 averted HIV infections per year, which Des Jarlais, Arasteh, and Hagan (2008) and others have since shown to be unrealistically high. Pinkerton (2011) estimates five to six averted HIV infections per year, but this model considers only infections prevented by the fact that PWID use clean needles inside the SIF. Andresen and Jozaghi's (2012) study includes the additional benefit that the education provided by SIF staff makes PWID less likely to share needles in general, estimating 22 averted infections. Andresen and Jozaghi's study also incorporates a baseline "reality check," comparing the model's estimated total infections in the absence of a SIF with actual public health data.

A number of more recent studies estimate both HIV and HCV infections that could be averted by establishing new SIFs in a range of Canadian cities (see Table 1). These studies calculate averted HIV and HCV infections using Andresen and Jozaghi's (2012) HIV model and more complex compartmental models (Bayoumi & Strike, 2012; Enns et al., 2016). Most of these studies find million-dollar savings from both HIV and HCV prevention outcomes.

Savings From Reduced SSTI

No previous SIF cost-benefit analyses consider savings from reduced SSTI, though studies have demonstrated that SIFs significantly reduce SSTI medical costs (Lloyd-Smith et al., 2010; Salmon et al., 2009; Small et al., 2008). Previous studies have mentioned the possibility of including this outcome in future analyses (Jozaghi & Reid, 2015).

Savings From Averted Overdose Deaths

Two studies estimate the number of overdose deaths averted each year by Insite.In a neighborhood with between 20 and 30 injection drug overdose deaths per year, Andresen & Boyd (2010) estimate that Insite averts 1.08 deaths annually, whereas Milloy et al. (2008) estimate between 1.9 and 11.7. The latter study finds a much larger impact because it includes the fact that education by Insite staff changes clients' behavior even when they are injecting outside the facility, as with needle-sharing (Milloy et al., 2008). As a result, even though roughly 5% of the neighborhood's overdoses occur in Insite, the facility could be preventing between 7% and 43% of the neighborhood's overdoses (Milloy et al., 2008). However, given the uncertainty about the size of this education impact, we choose to omit it, considering only the impact of overdose reversal inside the facility.

Savings From Increased MAT Uptake

Studies of both Insite and the Medically Supervised Injecting Centre (MSIC), the SIF in Sydney, Australia, demonstrate that SIFs significantly increase treatment uptake (MSIC Evaluation Committee, 2003; Wood, Tyndall, Zhang, Montaner, & Kerr, 2007; Wood, Tyndall, Zhang, et al., 2006). However, no previous cost-benefit analyses estimate the savings created by referring SIF clients to treatment, declaring this outcome "unquantifiable" (MSIC Evaluation Committee, 2003).

Method

This study estimates the economic impact of establishing a SIF in San Francisco of the same size and scope as the Insite SIF in Vancouver. We compare the estimated cost of the facility with the following four categories of cost savings: averted HIV and HCV infections, reduced hospitalization for SSTI, averted overdose deaths, and increased MAT uptake.

We also perform a sensitivity analysis to test the models' sensitivity to variance in key variables. For the cost estimate and all four savings estimates, we calculate lower and upper bounds by raising and lowering key variables by 50%, a conservative margin of error.

Cost of the Facility

Our cost calculations assume a facility of the same size and scope as the Insite SIF. Insite occupies roughly 1,000 square feet, provides 13 booths for clients, and operates 18 hr per day. Insite serves about 1,700 unique individuals per month, who perform roughly 220,000 injections per year (Health Canada, 2008; Pinkerton, 2011). Our estimate of the annual cost of establishing a new SIF combines both upfront and operating costs. As we assume the same staffing levels, equipment needs, and other operating cost inputs as Insite, we calculate the operating costs by multiplying the Insite SIF's US$1.5 million operating costs by a 57% cost of living adjustment between Vancouver and San Francisco (Expatistan Cost of Living Index, 2015; Jozaghi et al., 2015). As the upfront costs would depend on the exact location and extent of renovations required, we make a conservative estimate of US$2 million based on actual budgets for similar facilities and standard per-square-foot renovation costs (Primeau, 2013). We convert this upfront cost into a levelized annual payment by assuming that it was financed with a loan lasting the lifetime of the facility. We determine the levelized annual payment according to the standard financial equation:

$$C = \frac{i(P)}{1-(1+i)^{-N}},$$

where C is the calculated levelized annual cost, i is a standard 10% interest rate, P is the US$2 million estimated upfront cost, and N is the estimated 25-year lifetime of the facility.

Savings From Averted HIV and HCV Infections

We ground our estimate of averted HIV and HCV infections on studies of Insite, the Vancouver SIF. Insite has been shown to decrease SIF client needle-sharing by roughly 70% (Kerr et al., 2005). However, as viral infection does not spread linearly through a population, we cannot simply assume that if SIF clients reduced needle-sharing by 70%, their HCV and HIV infection rates would also drop by 70%.

We use an epidemiological "circulation theory" model, which was developed to calculate how needle exchange programs affect HIV infection among PWID. Kaplan and O'Keefe (1993) realized that as HIV is spread through infected needles, the model should focus not on the client population but on the needle "population." By introducing clean needles onto the street, needle exchanges shorten the amount of time that infected needles are in use, reducing the chance that they will spread HIV. Kaplan and O'Keefe (1993) derived their model from a pair of differential equations, which express the HIV infection rate as a function of the percentage of infected needles, and the percentage of infected needles as a function of the PWID population and needle supply. The model was subsequently adjusted by Jacobs et al. (1999) to account for the fact that if SIF clients shared with multiple partners, the risk of infection would increase exponentially. We use the Jacobs et al. (1999) model to estimate new HIV infection cases:

$$I_{\text{HIV}} = iNsd\left[1-(1-qt)^M\right],$$

where i is the proportion of PWID who are HIV negative, N is the number of needles in circulation, s is the rate of needle-sharing, d is the percentage of injections with unbleached needles, q is the proportion of PWID who are HIV positive, t is the probability of HIV infection from a single injection, and M is the average number of sharing partners. The values for these parameters (and their sources) are shown in Table 2. To estimate averted HIV infections, we calculate the difference between I_{HIV} at the current rate of needle-sharing and at the post-SIF rate, which assumes that the SIF reduces needle-sharing by 70% among its clients.

We have no reason to believe that the transmission of HCV is qualitatively different than that of HIV, except that the prevalence, probability of transmission, and other variable values are higher. As a result, we use the same model for HCV:

$$I_{\text{HCV}} = iNsd\left[1-(1-qt)^M\right],$$

The definitions for these variables are the same as above; the values (and their sources) are shown in Table 3.

Pinkerton (2011) argued that this model is inappropriate for estimating the impact of SIFs, because unlike needle exchange programs, SIFs do not introduce clean needles into circulation. However, this model relies not on the number of clean needles introduced into circulation but rather on the rate of needle-sharing. By reducing the sharing rate according to Kerr et al.'s (2007) study of Insite's impact on the sharing rate, the model can be appropriately used to predict SIF impact on HIV and HCV.

Table 2. Values, Notes, and Sources for Variables Used to Predict HIV Infection Reduction Savings.

Variable	Value	Note	Source
Proportion of PWID HIV− (*I*)	83.00%		Riley et al. (2010)
Number of needles in circulation (*N*)	3,427,284		A. Reynolds (personal communication, July, 23, 2015)
Rate of needle-sharing (*s*)	1.1%	Receptive syringe sharing, per injection	Bluthenthal et al. (2015)
Percentage of needles not bleached (*d*)	100%		Bluthenthal et al. (2015)
Proportion of PWID HIV+ (*q*)	17.00%		Riley et al. (2010)
Probability of HIV infections from a single injection (*t*)	0.67%		Kaplan and O'Keefe (1991); Kwon et al. (2012)
Number of sharing partners (*m*)	1.69	No available SIF data; average of two studies	Kozal et al. (2005); Jacobs et al. (1999);
PWID population (*P*)	22,500		A. Reynolds (personal communication, 2015)
SIF client reduction in needle-sharing	70%	From Insite	Kerr, Tyndall, Li, Montaner, and Wood (2005)
Number of SIF clients	1,700	From Insite	Pinkerton (2011)
Lifetime HIV treatment cost	US$402,000	National data	Centers for Disease Control and Prevention (2015b)

Note. PWID = people who inject drugs; SIF = supervised injection facility.

We test the model by comparing its baseline prediction of HIV and HCV incidence in the absence of a SIF with actual new diagnoses reported by the San Francisco Department of Public Health (SFDPH). The model predicts 60 new PWID-related HIV cases in San Francisco each year in the absence of a SIF, only slightly higher than the 51 diagnoses reported by SFDPH (2015). Because many new HIV cases go undiagnosed, especially in the socially isolated PWID population, 60 is a reasonable baseline estimate. For HCV, the model predicts 356 cases in the absence of a SIF. SFDPH reported 1,267 new diagnoses in 2013, though it is unclear how many of these cases are associated with injection drug use (SFDPH, 2013). Nationally, roughly half of all new cases are PWID related, so our baseline result of 356, which would be 28% of the total, is most likely an underestimate (Wasley, Grytdal, & Gallagher, 2006).

Savings From Reduced SSTI

In the absence of a SIF, uninsured PWID normally wait until an infection becomes serious enough to be admitted to the emergency room. Where SIFs exist, SIF medical staff provide wound care and medical referrals to treat these infections before they become serious. A Canadian study from Vancouver found that the hospital stays of Insite users were on average 67% shorter (Lloyd-Smith et al., 2010). We predict infection care savings according to the following equation:

$$S_{\mathrm{SSTI}} = NhLrC,$$

where S_{SSTI} represents the annual savings from SIF infection care, N is the number of people using the SIF, h is the hospitalization rate for SSTI, L is the average length of infection-related

Table 3. Values, Notes, and Sources for Variables Used to Predict HCV Infection Reduction Savings.

Variable	Value	Note	Source
Proportion of PWID HCV− (I)	25%		Bluthenthal et al. (2015); Riley et al. (2010)
Number of needles in circulation (N)	3,427,284		A. Reynolds (personal communication, 2015)
Rate of needle-sharing (s)	1.1%	Receptive syringe sharing, per injection	Bluthenthal et al. (2015)
Percentage of needles not bleached (d)	100%		Bluthenthal et al. (2015)
Proportion of PWID HCV+ (q)	75%		Bluthenthal et al. (2015); Riley et al. (2010)
Probability of HCV infections from a single injection (t)	3%		Kwon et al. (2012); Kaplan and O'Keefe (1991)
Number of sharing partners (m)	1.69	No available SIF data; average of two studies	Kozal et al. (2005); Jacobs et al. (1999)
PWID population (P)	22,500		A. Reynolds (personal communication, 2015)
SIF client reduction in needle-sharing	70%	From Insite	Kerr et al. (2005)
Number of SIF clients	1,700	From Insite	Pinkerton (2011)
Lifetime HCV treatment cost	US$68,219	Adjusted for inflation	Razavi et al. (2013)

Note. HCV = hepatitis C virus; PWID = people who inject drugs; SIF = supervised injection facility.

hospital stays for PWID, r is the 67% stay reduction for SIF users, and C is the average daily cost of a hospital stay. The values and sources for each variable are given in Table 4.

Data are limited on San Francisco PWID exposure to SSTI, but it is high. While Lloyd-Smith et al. (2005) find that 22% of PWID reported an SSTI in the past 6 months in Vancouver, studies of San Francisco PWID find rates over 32% (Fink, Lindsay, Slymen, Kral, and Bluthenthal, 2013; Binswanger, Kral, Bluthenthal, Rybold, and Edlin, 2000). As no recent studies have attempted to measure SSTI hospitalization in San Francisco, we conservatively use the same SSTI hospitalization rate as Vancouver: 6.07% per person-year by Lloyd-Smith et al. (2010). We then reduce the estimated cost savings by 33% to account for the impact of Integrated Soft Tissue Infection Services (ISIS) Clinic, which treats SSTIs for PWID and has reduced costs by a third (Harris & Young, 2002).

With no data on the average cost of a day in the hospital for PWID SSTI specifically, we used the average hospital day cost for the general population. Most likely the true average cost of PWID SSTI hospital days is higher, because PWID are a high-risk population well-known to require intensive care and close monitoring in hospitals (Ding et al., 2005).

Savings From Averted Overdose Deaths

We estimate averted overdose deaths slightly differently than previous studies. Rather than relying on the poorly understood frequency of overdose in the neighborhood, we rely on Milloy et al.'s (2008) intuitive finding that overdoses are equally likely both inside and outside the SIF. As medical staff revive anyone who overdoses in a SIF, we expect that the share of the city's overdoses prevented by the SIF would be the same as the share of citywide injections taking place inside the SIF. Our estimate only includes direct overdose prevention in the SIF, as we lack

Table 4. Values, Notes, and Sources for Variables Used to Predict SSTI Reduction Savings.

Variable	Value	Note	Source
Hospitalization rate for SSTI (*h*)	6.07%	From Vancouver, which has a lower rate of SSTI	Lloyd-Smith et al. (2010); Lloyd-Smith et al. (2005); Fink, Lindsay, Slymen, Kral, and Bluthenthal (2013)
Reduction in SSTI for PWID who visit SIF (*r*)	67.00%	From Insite	Lloyd-Smith et al. (2010)
Average length of skin infection-related hospital stay for PWID (*L*)	6 days	From Vancouver and Baltimore	Lloyd-Smith et al. (2010); Stein and Sobota (2001); Palepu et al. (2001); Y. H. Hsieh (personal communication, July 23, 2015)
Average hospital cost per day (*C*)	US$4,000	Average cost per inpatient day, not specifically for PWID SSTI	Rosenthal (2013); Helfand (2011)

Note. SSTI = skin and soft tissue infection; PWID = people who inject drugs; SIF = supervised injection facility.

Table 5. Values, Notes, and Sources for Variables Used to Predict Savings From Averted Overdose Deaths.

Variable	Value	Note	Source
Total annual injections in the SIF (*I*)	213,621	Based on Insite capacity and use	Health Canada (2008); Milloy et al. (2008)
PWID population (*P*)	22,500		A. Reynolds (personal communication, 2015)
Average number of injections per person per year (*N*)	508.8		Bluthenthal et al. (2015)
Average number of annual overdose deaths in San Francisco (*D*)	13	As of 2012, most recent data from SIF medical examiner	Coffin (2012)
Estimated value per overdose death averted (*V*)	US$1.17 million	Adjusted for California per capita income	Andresen and Boyd (2010)

Note. SIF = supervised injection facility; PWID = people who inject drugs.

data on SIF education changing overdose behavior outside the SIF. As a result, we model SIF overdose prevention savings according to the following equation:

$$S_o = \frac{I}{PN} DV,$$

where S_o is the annual savings due to averted overdose deaths, I is the total number of annual injections in the SIF, P is the total number of people injecting drugs in San Francisco, N is the average number of injections per person per year, D is the average number of annual injection drug overdose deaths, and V is the estimated value per overdose death averted. The values and sources for each variable are given in Table 5.

Previous evaluations of averted overdose death savings have wrestled with the issue of assigning a value to human lives saved. Health economists often estimate the value of a life using average wages. Some use life earnings estimates for the general population, which center on US$2 to US$3.1 million per life (Andresen & Boyd, 2010; Jozaghi et al., 2015; SAHA, 2008). They argue

that the value of a life should be roughly constant across a given society, not directly tied to a person's earnings. Other studies use estimates for the average wages for SIF clients themselves. As SIF clients are more likely to be unemployed or earning below the poverty line than the general population, this method yields significantly lower values for their lives, ranging from US$387,000 to US$660,000 (Andresen & Boyd, 2010; MSIC Evaluation Committee, 2003). The difference in value is so large that many studies remove the value of lives saved from their overall calculation of benefits. We use the method from a Vancouver SIF cost-benefit study because it covers a similar urban PWID population, except we replace British Columbia's GDP per capita with that of California (Andresen & Boyd, 2010; Sisney & Garosi, 2015).

Savings From Increased MAT Uptake

MAT programs, principally methadone and buprenorphine maintenance, have been shown to decrease the use of heroin and other drugs. As a result, MAT programs reduce both patients' health care needs and their criminal activity to get money to buy drugs (Barnett, 1999; CDC, 2002; Flynn, Porto, Rounds-Bryant, & Kristiansen, 2002; Zaric, Barnett, & Brandeau, 2000). Studies estimate that they save taxpayers US$4 to US$13 for every US$1 spent (Cartwright, 2000; Center for Health Program Development and Management [CHPDM], 2007; Gerstein et al., 1994; Harris, Gospodarevskaya, & Ritter, 2005; Health Canada, 2008). Research on Insite shows that SIF clients are significantly more likely than non-SIF-clients to accept referrals to MAT (Wood et al., 2007; Wood, Tyndall, Zhang, et al., 2006). In Sydney's SIF, 5.8% of SIF clients accepted MAT referrals per year. We estimate the financial benefits of SIF referrals to MAT programs, considering both health care and crime costs, according to the model

$$S_{\text{MAT}} = Nr(b-1)T,$$

where S_{MAT} is the annual savings due to the SIF increasing MAT uptake, N is the number of PWID who use the SIF, r is the percentage of SIF clients who access MAT as a result of SIF referrals, b is the cost-benefit ratio for MAT, and T is the cost of 1 year of MAT.

As Table 6 shows, to ensure a conservative estimate, we use a relatively low cost-benefit ratio of 4.5:1 and annual MAT cost of US$4,000 (Schwartz et al., 2014). As this cost-benefit ratio incorporates savings from both reduced crime and health costs, it includes reductions in HIV, HCV, and SSTI infection due to decreases in injection drug use. Although MAT uptake could slightly change the overall HIV and HCV prevalence, such interaction effects would be minor and are beyond the scope of this study.

More significantly, the SIF's success in recruiting PWID into MAT depends on the preexisting local prevalence of MAT uptake and availability and other neighborhood-level factors. As a result, the 5.8% increase found in Sydney may differ significantly from the potential increase from a SIF in San Francisco.

The true financial benefits of starting PWID on MAT are not well understood. Scholars have found significantly different values for cost-benefit ratios of MAT, largely due to disagreements on how to quantify savings from reduced crime. For ease of calculation, our model assumes that referrals lead to an average MAT usage time of 1 year.

Results

Cost of the Facility

Our estimate of the total annual cost is US$2.6 million, which includes US$2.4 million in operating costs and US$220,000 in annualized upfront costs. In our sensitivity analysis, raising the total cost by 50% to US$3.9 million lower the cost-benefit ratio from 2.33 to 1.56 and net annual

Table 6. Sources for Variables Used to Predict Savings From MAT Referrals.

Variable	Value	Note	Source
The number of SIF users (*N*)	1,700	From Insite	Pinkerton (2011)
Percentage of SIF users who access MAT as a result of SIF referrals (*r*)	5.78%	From MSIC	MSIC Evaluation Committee (2003)
Cost-benefit ratio for MAT (*b*)	4.5		Cartwright (2000); Health Canada (2008); Harris, Gospodarevskaya, and Ritter (2005); CHPDM, 2007
Average cost of one year of MAT (*T*)	US$4,000		Schwartz et al. (2014)

Note. MAT = medication-assisted treatment; SIF = supervised injection facility; MSIC = Medically Supervised Injecting Centre; CHPDM = Center for Health Program Development and Management.

savings from US$3.5 to US$2.2 million. Lowering the total cost by 50% to US$1.3 million raises the cost-benefit ratio to 4.67 and net savings to US$4.8 million.

Savings From Averted HIV and HCV Infection

For HIV, we predict 3.3 averted cases per year. With a lifetime treatment cost of more than US$402,000, this translates to annual savings of US$1.3 million. For HCV, we estimate that a SIF would prevent an average of 19 cases per year. At a lifetime treatment cost of US$68,000, as reported in other HCV costing studies, this also translates to annual savings of US$1.3 million. We conduct a sensitivity analysis on the needle-sharing prevalence. Increasing the prevalence by 50%, from 1.1% to 1.6%, raises averted infections to 4.6 for HIV and 27 for HCV, each generating savings of US$1.8 million. As a result, the overall cost-benefit ratio for the SIF increases from 2.33 to 2.73 and net savings increase from US$3.5 to US$4.5 million. Decreasing the prevalence by 50%, from 1.1% to 0.6%, lowers averted infections to 1.8 for HIV and 10 for HCV, reducing savings for each to US$700,000. In this scenario, the overall cost-benefit ratio declines to 1.86 and net savings fall to US$2.3 million. The range for this sensitivity analysis should be considered conservative, as the prevalence of needle-sharing is well documented for PWID in San Francisco (Bluthenthal et al., 2015; Coffin, Jin, Huriaux, Mirzazadeh, & Raymond, 2015).

Savings From Reduced SSTI

We estimate that SIF SSTI care will reduce total PWID SSTI-related hospital stays by 415 days per year, which translates to savings of roughly US$1.7 million. We conduct a sensitivity analysis on the SSTI hospitalization rate. Increasing the rate by 50%, from 6.07% to 9.11%, raises averted hospital days to 622 and savings to US$2.5 million. As a result, the overall cost-benefit ratio for the SIF increases from 2.33 to 2.65 and net annual savings rise from US$3.5 to US$4.3 million. Decreasing the rate to 3.04%—well below the 4.43% rate that Y. H. Hsieh (personal communication, 2015) found in Baltimore—lowers averted hospital days to 207 and reduces savings to US$830,000. In this scenario, the overall cost-benefit ratio declines to 2.02 and net savings fall to US$2.7 million.

Savings From Averted Overdose Deaths

We estimate conservatively that SIF overdose prevention will save an average of 0.24 lives per year, which translates to US$284,000 in savings for society. We conduct a sensitivity analysis of total drug overdose deaths, as deaths fluctuate from year to year. Increasing the total 50% from

Table 7. Summary of Sensitivity Analysis Impact for Individual Components.

Result	Dollar value (US$ million)			Health indicator value			
Component	Base case	Low case	High case	Base case	Low case	High case	Unit
Total cost	2.6	3.9	1.3				
HCV savings	1.3	0.70	1.8	19	10	27	Cases
HIV savings	1.3	0.70	1.8	3.3	1.8	4.6	Cases
SSTI savings	1.7	0.83	2.5	415	207	622	Hospital days
Overdose deaths	0.28	0.14	0.43	0.24	0.12	0.36	Deaths
MAT savings	1.5	0.77	2.3	110	55	165	New patients

Note. HCV = hepatitis C virus; SSTI = skin and soft tissue infection; MAT = medication-assisted treatment.

13 to 20 raises estimated lives saved to 0.36 and financial savings to US$425,000. This raises the overall cost-benefit ratio for the SIF from 2.33 to 2.39 and net savings from US$3.5 to US$3.6 million. Lowering the total by 50% to 7% would reduce estimated lives saved to 0.12 and financial savings to US$142,000, for an overall cost-benefit ratio of 2.28 and net savings of US$3.4 million.

Savings From Increased MAT Uptake

We estimate that roughly 110 PWID will enter MAT as a result of the SIF every year, resulting in a financial benefit to society of US$1.5 million. We conduct a sensitivity analysis of the referral rate for MAT, as the San Francisco value will depend on the existing prevalence, reputation, and availability of MAT. Raising the rate by 50%, from 5.78% to 8.67%, would raise new people in treatment from 110 to 165 and financial savings to US$2.3 million. This would increase the overall cost-benefit ratio from 2.33 to 2.63 and net annual savings from US$3.5 to US$4.3 million. Lowering the rate by 50%, to 2.89%, would reduce new people in treatment to 55 and financial savings to US$769,000, for an overall cost-benefit ratio of 2.04 and net savings of US$2.7 million.

Overall Cost-Benefit Ratio

We compare the impact of each outcome on the overall cost-benefit comparison in Tables 7 and 8. Table 7 gives the dollar value for each outcome (as well as the health indicator values for each area of savings), whereas Table 8 gives the overall cost-benefit ratio and net savings in the base, low, and high cases for each outcome.

We find remarkably similar savings for HIV, HCV, SSTI, and MAT—between US$1.3 and US$1.7 million per year in the base case scenario. Each of these four outcomes generates enough savings to offset half of the total cost on its own.

Discussion

Cost of the Facility

Tables 7 and 8 highlight the key role of the facility's operating cost in this analysis. The operating cost is both large, due to the high cost of living in San Francisco, and uncertain, as the operating cost will depend on staffing levels, services provided, and the size and location of the facility, all of which will depend partly on local regulations. Although our sensitivity analysis of the facility's cost finds robust benefits in all cost scenarios, we recommend maximizing the cost-benefit ratio by avoiding undue, expensive requirements, such as requiring ambulance calls for every overdose

Table 8. Summary of Sensitivity Analysis Impact on Overall Results.

Result	Cost-benefit ratio			Net savings (US$ million)		
Component	Base case	Low case	High case	Base case	Low case	High case
Total cost	2.33	1.56	4.67	3.5	2.2	4.8
HCV savings	2.33	1.86	2.73	3.5	2.3	4.5
HIV savings	2.33	1.86	2.73	3.5	2.3	4.5
SSTI savings	2.33	2.02	2.65	3.5	2.7	4.3
Overdose deaths	2.33	2.28	2.39	3.5	3.4	3.6
MAT savings	2.33	2.04	2.63	3.5	2.7	4.3

Note. HCV = hepatitis C virus; SSTI = skin and soft tissue infection; MAT = medication-assisted treatment.

incident (as with Insite), requiring doctors in roles better suited to nurses, or requiring nurses in roles better suited to peers.

Savings From Averted HIV and HCV Infection

If a single SIF can avert three HIV and 19 HCV infections in an average year, as we predict, it would become a major part of San Francisco's infection prevention efforts. Although three HIV infections may sound insignificant, it is roughly 6% of the city's total annual PWID-related HIV infections. Without reliable data on PWID-related HCV infections, we estimate that 19 HCV infections comprise roughly 3% to 5% of the city's total annual PWID-related HCV infections. Again, this is a significant percentage for a single facility.

Although the SIF would be unlikely to receive federal grants given the facility's uncertain status under federal law, its HIV prevention benefits align with the priorities of the National Institute on Drug Abuse (NIDA) and the White House's National HIV/AIDS Strategy. NIDA's 2017 priorities focus on shoring up the continuum of care: to "seek, test, treat, and retain" (STTR) those infected with HIV, particularly among hard-to-reach populations including PWID (Gardner, McLees, Steiner, del Rio, & Burman, 2011; NIDA, 2016). Establishing a SIF would create a natural center for locating PWID, providing them with testing, connecting them directly with treatment providers, and monitoring them long-term to retain them in treatment. Although federal grantmaking bodies would likely shy away from supporting SIFs initially, the clear STTR benefits could attract significant private funding from foundations that share these priorities. If the city began creating guidelines for the country's first SIF, the project might capture donors' interest.

To maximize its HIV and HCV prevention impact across the continuum of care, a SIF should provide needle exchange, safer injecting education, testing, and linkage to treatment services on-site both to direct PWID immediately into treatment and to facilitate long-term monitoring to retain them in treatment. Facility setup should enable researchers to recruit PWID on-site to participate in health and behavior studies. Effective recruitment at Insite has improved such research in Vancouver and could do the same in San Francisco (Linden, Mar, Werker, Jang, & Krausz, 2013).

The recent HIV/HCV outbreak in Scotts County, Indiana, underscores the benefits of providing routine, harm reduction services to PWID (Adams, 2015; Strathdee & Beyrer, 2015). Within the context of San Francisco, where community-based syringe exchange programs already provide millions of clean syringes a year, the benefits of a single SIF are still substantial. Few locales in the United States have the level of syringe coverage observed in San Francisco (Tempalski et al., 2008); so although our results are significant for San Francisco, benefits are likely to be substantially higher in other urban settings where many PWID reside.

Savings From Reduced SSTI

No previous SIF cost-benefit studies have considered SSTI prevention, but our analysis suggests that the outcome generates significant savings. It should be noted that our savings estimate of 415 days of hospital beds—in addition to operating rooms and other costs—comes from preventing SSTI among a relatively small group of "frequent fliers."

While SSTI savings may be particularly high in San Francisco—due to the prevalence of black tar heroin and the city's high hospital rates—SSTI is clearly an outcome worth including in future studies for other cities as well (Mars, Bourgois, Karandinos, Montero, & Ciccarone, 2016). Although SSTI does not attract funders' attention on a national scale like HIV infection, the existence of a SIF would increase its prominence by facilitating robust SSTI research studies. Furthermore, there are few, low-cost prevention programs for preventing SSTIs among PWID, and the existing programs have not been widely disseminated (Bhattacharya, Naik, Palit, & Bhattacharya, 2006; Grau, Arevalo, Catchpool, & Heimer, 2002). Prior studies have demonstrated that SIFs reduce injection practices such as reusing syringes, not cleaning injection sites prior to use, and sharing injection materials that great increase the risk for SSTIs (Stoltz et al., 2007). To maximize SSTI benefits, the SIF should train staff to educate clients in these best practices to reduce SSTI, as well as to monitor clients for warning signs of SSTI, perform wound care on-site, and refer clients for follow-up medical care as appropriate.

Savings From Averted Overdose Deaths

The estimated prevention of overdose deaths—one person every 4 years—provides the smallest monetary benefit of the five outcomes. By already implementing forward-thinking naloxone access and Good Samaritan policies, San Francisco reduced heroin overdose deaths from 120 in 2000 to 13 in 2012. Baltimore, by comparison, has a smaller population of PWID but lost 192 people to heroin overdose in 2014 (Maryland Department of Health and Mental Hygiene [DHMH], 2015). In areas where naloxone distribution has lagged (i.e., many American cities), overdose-related savings would be significantly higher, perhaps larger than the other outcomes. To maximize overdose prevention benefits, in addition to reversing overdoses on-site, SIFs should provide overdose prevention education and dispense naloxone to high-risk clients.

Our overdose death prevention estimate is limited by our conservative assumption that a SIF would not reduce overdose deaths outside the SIF, as discussed above. If more SIF studies demonstrate a reduction in outside deaths, our analysis should be updated accordingly. However, unless total overdose deaths in San Francisco increase significantly—a possibility due to the growth of fentanyl- and carfentanyl-laced heroin—there are few overdose deaths to prevent.

Savings From Increased MAT Uptake

It is significant that a SIF could bring 110 PWID—many of whom are long-term users—into MAT every year. This number will depend on the availability and social acceptability of treatment. In San Francisco, MAT is available and clients could be referred directly through SIF staff. To maximize treatment uptake, the city should increase MAT capacity, SIF staff should be trained in making treatment referrals, and the SIF should be co-located with treatment providers, both to initially receive referrals and to follow up with existing patients.

Other services that could be housed nearby to minimize the barriers to entry for SIF clients include counseling, mental health and health care, harm reduction, housing, and other social services. Vancouver's Insite has had great success with this wrap-around service provider approach.

Overall Cost-Benefit Ratio

Our analysis suggests that a SIF would save roughly US$2.33 for every dollar spent, making it an extremely cost-effective health intervention. However, cost-effectiveness will hardly be at the center of the decision to establish such a ground-breaking facility. City officials should focus instead on the benefit in human life: one life saved every 4 years, 3.3 HIV and 19 HCV infections averted every year, 415 days in the hospital for SSTI prevented, and 110 people enrolled into MAT. Opponents of a SIF are unlikely to oppose it on financial grounds but rather due to unsubstantiated fears of increased drug use, local objections of "Not In My Backyard," or the unlikely possibility of federal or state lawsuits. Advocates should conduct surveys and arrange meetings with stakeholders, including local residents and businesses, to evaluate and address their concerns proactively.

Limitations

This cost-benefit analysis faces a number of limitations.

Cost of the Facility

Without physical plans for a SIF facility in San Francisco, we consider our facility cost estimate to be a conservative "back-of-the-envelope" calculation. Accurate cost estimates will only be possible when a site and construction plan is proposed. Once the San Francisco Department of Health has established regulations for a SIF, this cost analysis should be updated to reflect required staffing, service, and facility costs.

Savings From Averted HIV and HCV Infection

The accuracy of our HIV and HCV estimates are limited by the quality of data available for PWID. In particular, resources have not been devoted to accurately measuring the San Francisco PWID population's HCV incidence. Without trustworthy HCV incidence data, we cannot check our model's baseline against actual results. The average number of sharing partners is another area of significant uncertainty.

Savings From Reduced SSTI

The greatest limitation for our SSTI estimate is the lack of recent data on the rate at which PWID in San Francisco are hospitalized for SSTI. No studies have estimated this rate or the resulting costs since the ISIS Clinic was established to counteract this problem. While we were able to estimate today's rate by combining pre-ISIS estimates with data on the impact of ISIS, a new study would improve our understanding of SSTI costs.

Savings From Increased MAT Uptake

The most important limitation for our MAT estimate is that without knowing how SIF staff will handle MAT referrals, we cannot reasonably estimate the rate at which SIF clients will be referred to MAT. We recommend that a San Francisco SIF adopt the best practices from Insite in Vancouver and MSIC in Sydney, Australia.

Overall Cost-Benefit Ratio

Finally, we do not consider a number of small interaction effects. These include interactions between HIV and HCV infection, interactions between viral infection and SSTI, and second-order

interaction effects—for example, that increasing MAT uptake would slightly reduce the HIV prevalence rate, subsequently affecting the HIV model. However, as these changes are extremely small when considered in the general population, we do not expect these interaction effects to bias our results to a significant degree, particularly in comparison with data uncertainties.

Conclusion

Our cost-benefit analysis supports the establishment of a SIF in San Francisco, as we find that it would significantly reduce costs associated with health care, emergency services, and crime. We estimate that establishing a single Insite-sized SIF facility would save roughly US$6.1 million per year. It would be cost-effective; as the facility would cost roughly US$2.6 million per year, we estimate that every dollar spent would generate US$2.33 in savings. A single facility would have a large impact citywide, given the significant net savings of US$3.5 million.

As the SIF health savings are diversified almost equally across four areas—HIV, HCV, SSTI, and MAT—our sensitivity analysis found that the results are quite robust to changes in individual health variables. Even when raising and lowering key health variables by 50%, the cost-benefit ratio only varied between 1.86 and 2.73, and net savings from US$2.3 to US$4.5 million. The primary factor affecting the overall cost-benefit ratio is the facility's operating cost; our sensitivity analysis of facility cost found a cost-benefit ratio between 1.56 and 4.67 and annual net savings between US$2.2 and US$4.8 million.

As the health costs associated with the relatively small population of PWID are currently hidden in individual health records, the city should consider tracking PWID health care costs before and after establishing a SIF to rigorously evaluate the facility's impact. In addition to demonstrating the impact of the SIF, such a project would expose the magnitude of health costs associated with this high-risk population.

It is worth noting in conclusion that in addition to the five outcomes estimated in this study, SIFs present significant public health benefits that could not be quantified for this study. Studies have shown that they reduce risky injecting behavior, 911 overdose calls, public drug use, and syringe littering (DeBeck et al., 2011; Marshall et al., 2011; Marshall et al., 2012; Wood et al., 2004). They bring out a hidden and hard-to-reach population, which allows service providers to effectively reach PWID and allows researchers to conduct high-quality PWID studies (Urban Health Research Initiative [UHRI], 2015). They accomplish all of these things without creating crime, increasing drug use, or attracting new users (Kerr et al., 2006; Wood, Tyndall, Lai, Montaner, & Kerr, 2006; Wood, Tyndall, Montaner, & Kerr, 2006).

We hope that this study helps generate a robust debate on the costs and benefits of establishing a SIF in San Francisco. We also hope that it starts conversations in other American cities with significant numbers of PWID. Where the availability of HIV/HCV treatment, sterile syringe and naloxone distribution, and availability of medically assisted treatment is substantially lower, a SIF would bring even greater benefits. Consideration of how SIFs fit into the national effort to combat the heroin epidemic in the United States is desperately needed.

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