Prediction Model to Maximize Impact of Syphilis Partner Notification—San Francisco, 2004–2008

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Background: Syphilis cases increased 55% in San Francisco from 2007 (n = 354) to 2008 (n = 548). The San Francisco Department of Public Health interviews syphilis patients to identify sex partners needing treatment, but interviewing resources are limited. We developed and validated a model to prioritize interviews likely to result in treated partners.

Methods: We included data from interviews conducted from July 2004 through June 2008. We used multivariate analysis to model the number of treated partners per interview in a random half of the data set. We applied the model to the other half, calculating predicted and observed proportions of partners successfully treated and interviews conducted if limiting interviews by syphilis patient characteristics.

Results: In 1340 patient interviews, 1665 partners were named; of those, 827 (49.7%) were treated. Ratios of treated partners were significantly higher among patients aged <50 years, compared with ≥50 years (ratio 1.4; 95% confidence interval [CI], 1.0–1.9); patients with primary/secondary syphilis, compared with early latent (ratio 1.4; 95% CI: 1.1–1.8); and patients diagnosed at the municipal sexually transmitted disease clinic, compared with elsewhere (ratio 1.7; 95% CI: 1.4–2.1). Limiting interviews to patients aged <50 years would reduce interviews by 14% and identify 92% of partners needing treatment. Limiting interviews to primary/secondary syphilis patients would reduce interviews by 35% and identify 68% of partners needing treatment.

Conclusions: Our model can provide modest efficiencies in allocating resources for syphilis partner notification. Health departments should consider developing tools to maximize impact of syphilis prevention and control activities.

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After a decade of declines, syphilis rates have steadily increased in the United States, Europe, and Australia since 2000.[1,2] Increases have been concentrated among human immunodeficiency virus (HIV)-infected men who have sex with men (MSM), with the proportion of primary and secondary (P&S) cases in the United States attributable to MSM increasing from 4% in 2000 to 62% in 2004,[2] and the prevalence of HIV infection among syphilis patients at 50% to 75%.[3] In San Francisco, cases of early syphilis (P&S and early latent) increased 55% from 2007 (n = 354)[4] to 2008 (n = 548), with 85% of 2008 cases among MSM, 60% of whom were HIV-infected (San Francisco Department of Public Health, preliminary data, 2008).

In an effort to foster program integration and collaboration, the Centers for Disease Control and Prevention (CDC) released updated partner notification guidelines in 2008 for HIV and sexually transmitted diseases (STDs), emphasizing the need for evidence-based, cost-effective partner services programs.[5] Partner notification—the process of interviewing infected persons to elicit information regarding their partners, who are then notified of their possible exposure, tested, and treated—is used in the majority of syphilis prevention and control programs in the United States, and its effectiveness for syphilis case detection has been well documented.[6–11]

Although partner notification is an effective case-finding activity, it requires a substantial allocation of public health resources.[5,12–14] For successful partner notification programs, resources should be devoted to case management, serologic testing and treatment of partners, and disease intervention specialists' time and travel.[5,13] The cost per partner treated as a result of partner notification is comparable with the costs of other syphilis control efforts (e.g., selective screening based on patients' risk histories, after accounting for the public health impact of prophylactic partner treatment).[13] However, identifying necessary resources for partner notification can be difficult for local health departments' STD control programs.

Prediction models, which aim to predict outcomes for persons with particular characteristics, have been successfully used to increase efficiency and cost-effectiveness of case-finding activities, including home-based screening for *Chlamydia trachomatis* infection,[15] screening of pregnant women for *Chlamydia trachomatis* infection,[16] and screening of tuberculosis contacts.[17] Studies have identified such factors as race/ethnicity and gender of sex partners that are associated with successful partner notification for syphilis, where success has been measured by the number of named, located, or treated partners per patient interviewed.[9–11] However, analyses have primarily focused on factors that are unknown until after the patient has been interviewed, thus limiting their ability to help decision making related to selective interviewing.

To maximize public health impact in a resource-limited environment, we developed and validated a tool to help prioritize partner notification interviews of patients among whom syphilis is newly diagnosed. According to CDC guidelines, a principal goal of partner notification is timely treatment of sex partners, whether curative or prophylactic.[5] Therefore, we aimed to develop a model that maximized the number of treated partners per interview (i.e., the number of partners who were seroreactive and treated for syphilis or who had likely exposure and were prophylactically treated). Objectives of this analysis were to identify factors associated with the successful treatment of partners and to develop an algorithm to prioritize patient interviews.

METHODS

We examined data from all partner notification interviews of San Francisco residents among whom early syphilis was diagnosed from July 2004 through June 2008. By using a multistage process, we identified interviews likely to result in more treated partners. First, we randomly split the interview data into 2 sets—a derivation set and a validation set—to assess how well the model predicted more treated partners per interview in data not used to develop the model.[18] We created a multivariate regression model with the derivation set to identify patient characteristics associated with more treated partners. We then applied the model to the validation set to calculate the predicted number of successfully treated partners in a new set of patient data. Finally, factors that predicted more treated partners, as determined in the model, were used in the validation set to develop algorithms for selectively assigning partner notification interviews. To estimate real-world impact, we calculated the proportion of interviews conducted and predicted and observed proportions of partners needing treatment who would have been successfully identified if each algorithm were implemented.

Partner Notification Process

The San Francisco Department of Public Health (SFDPH) investigates all reported reactive serologic tests for syphilis among San Francisco residents. Most cases that are diagnosed outside of the municipal STD clinic are initially reported as reactive tests by local laboratories, with the remaining cases reported by diagnosing providers. After reporting of reactive tests, SFDPH staff contact providers to obtain patients' titer results and ages, which are analyzed to prioritize patients for interview who are most likely to be newly infected with syphilis.[19,20] During interviews, field staff elicit contact information for sex partners on the basis of CDC methods, and standardized case definitions are used to classify primary, secondary, and early latent syphilis.[5]

Named partners (sex partners for whom contact information is provided) are located, notified of their possible exposure, and encouraged to obtain testing for syphilis and treatment if seroreactive. Partners who are not tested for syphilis or who are not seroreactive are treated prophylactically if they were named as sexual contacts during the critical period in which the patient was likely to have acquired or transmitted syphilis. That period is based on the stage of disease at the time of diagnosis—3 months for primary syphilis, 6 months for secondary syphilis, and 12 months for early latent syphilis. In a few cases, interviewers might shorten those critical periods on the basis of timing of recent negative serology, symptoms, or treatment for syphilis. Interviewers collect demographic data (e.g., sexual orientation and race/ethnicity), and HIV-infection status is assessed by self-report if test results are not documented. For this analysis, we also used our electronic records to assess whether patients had been interviewed for a previous syphilis infection.

Identification of Predictors

We used a random-number generator to assign half of the sample to a derivation data set and the other half to a validation data set, and we used the derivation set to fit the model. Because the goal of this analysis was to identify a pragmatic tool for prioritizing interviews, we assessed as potential predictors only the factors collected from the diagnosing provider or case report before interview assignment—age (which we categorized as <30, 30–39, 40–49, or ≥50 years), stage of syphilis, sex, and type of health-care setting in which syphilis was diagnosed (municipal STD clinic, private doctor's office, Managed care organization, HIV-care clinic at public hospital, other clinics at public hospital, gay men's health clinic, community health center, or other). We also examined the number of days between the date of the diagnostic syphilis test and being assigned for interview (≤1 week or >1 week) as an approximation of the time since diagnosis. We did not examine factors that might predict a successful partner notification interview but were not ascertained until the interview itself (e.g., HIV-infection status or sexual orientation).

The initial model included all factors previously described. We collapsed categories for age (<50 or ≥50 years), syphilis stage (P&S or early latent), and health-care setting (municipal STD clinic or other) because analyzing the subcategories separately did not produce different results, and we aimed to maximize model efficiency and statistical power. By using a multivariate log-linear model with a Poisson distribution, we calculated adjusted risk ratios of treated partners and 95% confidence intervals (CI) to identify predictors of more treated partners per interview for each syphilis patient characteristic. Thus, in this model, the ratio of treated partners represented the ratio of the number of treated partners per interview in one category of a predictor variable, compared with the number of treated partners per interview in the referent category, adjusting for the other factors in the model. To simplify the model, we removed variables that were not statistically significant (P >0.05) when doing so did not negatively impact model fit, as measured by log-likelihood tests (P <0.05).

Model Application

We applied the final model to the validation set to calculate the predicted number of treated partners in patient data that were not used to fit the model. We then calculated the proportion of interviews conducted and the predicted and observed proportions of partners needing treatment who would have been successfully identified if partner notification had been limited to patients with all possible combinations of the predictors remaining in the final model.

All statistical analyses were conducted with SAS 9.1 (SAS Institutes, Cary, NC). These were deidentified surveillance data used for public health improvement; therefore, this study was considered exempt from human subjects considerations in accordance with the Code of Federal Regulations, Title 45.

RESULTS

From July 2004 through June 2008, a total of 1755 residents of San Francisco were assigned for partner notification interview subsequent to a new syphilis infection. Of those, 1340 (76.4%) were interviewed, 251 (14.3%) could not be located, 149 (8.5%) refused interview, and 15 (0.9%) were still open cases at the time of this analysis. The majority of inter-

TABLE 1. Distribution of Interviewed Syphilis Patients and Their Treated Partners by Syphilis Patient Characteristics—San Francisco, July 2004–June 2008

	Interviewed Syphilis Patients		Treated Partners by Syphilis Patient Characteristics	
	n	%	n	%
Syphilis patient characteristic	1340	100.0	827	100.0
Stage of syphilis*				
Primary	303	22.6	197	23.8
Secondary	567	42.3	389	47.0
Early latent	470	35.1	241	29.1
Sex*				
Male	1302	97.2	811	98.1
Female	18	1.3	9	1.0
Transgender	20	1.5	7	0.8
Sexual orientation				
Gay	1196	89.3	776	93.8
Bisexual	68	5.1	26	3.1
Straight	65	4.9	20	2.4
Unknown	11	0.8	5	0.6
Race/ethnicity				
White	778	58.1	542	65.5
Hispanic	264	19.7	145	17.5
Black	144	10.7	58	7.0
Asian	116	8.7	57	6.9
Other or unknown	38	2.8	25	3.0
Age, yr*				
<30	219	16.3	164	19.8
30–39	466	34.8	281	34.0
40–49	460	34.3	304	36.8
≥ 50	195	14.6	78	9.4
HIV status				
Infected	796	59.4	525	63.5
Uninfected	504	37.6	285	34.5
Unknown	40	3.0	17	2.1
Time from test to assign date				
≤ 1 wk	658	49.1	499	60.3
>1 wk	680	50.7	327	39.5
Prior syphilis interview				
Yes	266	19.9	236	28.5
No	1074	80.1	591	71.5
Health-care setting of diagnosis*				
STD clinic	507	37.8	438	52.9
Private doctor's office	338	25.2	166	20.1
Gay men's health clinic	113	8.4	53	6.4
Managed care organization	100	7.5	40	4.8
Community health center	85	6.3	40	4.8
Public hospital (HIV care)	62	4.6	30	3.6
Public hospital (other)	27	2.0	10	1.2
Other	108	8.1	50	6.0

*These factors were collected before the interview from diagnosing providers and case reports.

viewed syphilis case-patients were in P&S stage (64.9%), male (97.2%), gay or bisexual (94.4%), white (58.1%), and HIV-infected (59.4%) (Table 1). The median age was 39 years (25%–75% interquartile range, 33–45). Approximately half (49.1%) were assigned for interview within 1 week of syphilis diagnosis, and 19.9% had been previously interviewed by SFDPH as a result of a prior syphilis diagnosis. The most frequent health-care settings in which syphilis was diagnosed were the municipal STD clinic (37.8%), private doctors' offices (25.2%), and the gay men's health clinic (8.4%).

In total, the 1340 interviewed patients provided contact information for 1665 sex partners (mean number of named sex partners per patient = 1.2). Among the 453 (33.8%) interviews yielding at least 1 treated partner, the median number of treated partners was 1 (range, 1–26; interquartile range, 1–2); the number and proportion of treated partners by syphilis patient characteristics are presented in Table 1. Of the 1665 partners, 702 (42.2%) were prophylactically treated for syphilis; 213 (12.8%) could not be located; 197 (11.8%) refused services; 188 (11.3%) had already been treated for this syphilis exposure

TABLE 2. Characteristics Predicting More Treated Partners Among Interviewed Syphilis Patients—San Francisco, July 2004–June 2008

	Derivation Set (n = 677)
Syphilis Patient Characteristic	Adjusted Ratio of Treated Partners* (95% Confidence Interval)
Primary or secondary syphilis, compared with early latent	1.4 (1.1–1.8)
Aged <50 yr, compared with ≥50 yr	1.4 (1.0–1.9)
Diagnosed at STD clinic, compared with other settings	1.7 (1.4–2.1)

*Ratios were adjusted for stage of syphilis, age, and health-care setting of diagnosis.

or episode; 158 (9.5%) tested negative and were not treated because they were past the period in which they could have been incubating syphilis; 125 (7.5%) were seroreactive and treated for a new syphilis infection; 37 (2.2%) were not within the jurisdiction; 20 (1.2%) were still open cases at the time of this analysis; and the remaining 25 (1.5%) had other outcomes.

Identification of Predictors

In multivariate analysis of the derivation set, the ratio of treated partners was significantly higher among patients who were aged <50 years, compared with ≥50 years (ratio of treated partners 1.4; 95% CI: 1.0–1.9), those with P&S syphilis, compared with early latent (ratio of treated partners 1.4; 95% CI: 1.1–1.8), and those who received their diagnosis at the municipal STD clinic, compared with other settings (ratio of treated partners 1.7, 95% CI: 1.4–2.1) (Table 2). For example, compared with patients aged ≥50 years, patients aged <50 years had 1.4 times the number of treated partners, adjusting for stage of syphilis and health-care setting in which syphilis was diagnosed. The sex of the patient and the time from the date of the diagnostic syphilis test to interview assignment were not significantly associated with the number of treated partners.

Model Application

The proportion of interviews conducted and predicted and observed proportions of partners successfully treated, if interviews were restricted on the basis of all possible combinations of the patient characteristics in the final model, are illustrated in Figure 1. In the validation set, limiting interviews to patients aged <50 years would have reduced the total number of partner notification interviews by 14% and identified 92% of partners needing treatment. Limiting interviews to patients with diagnosed P&S syphilis would have reduced the number of interviews by 35% and identified 68% of partners needing treatment. Variation between the predicted and observed proportions of treated partners captured in the validation set was 0% to 8%.

DISCUSSION

In this analysis, we used local, routinely collected, public health surveillance data relating to early syphilis cases to develop and validate a tool for prioritizing partner notification interviews likely to maximize the successful treatment of partners. We identified 3 patient factors that predicted more treated partners per interview—aged <50 years, P&S stage of syphilis, and receiving a diagnosis at the municipal STD clinic. The model performed similarly in a second set of locally derived data, indicating that we can use those criteria prospectively to reduce interviews while maximizing the number of partners treated.

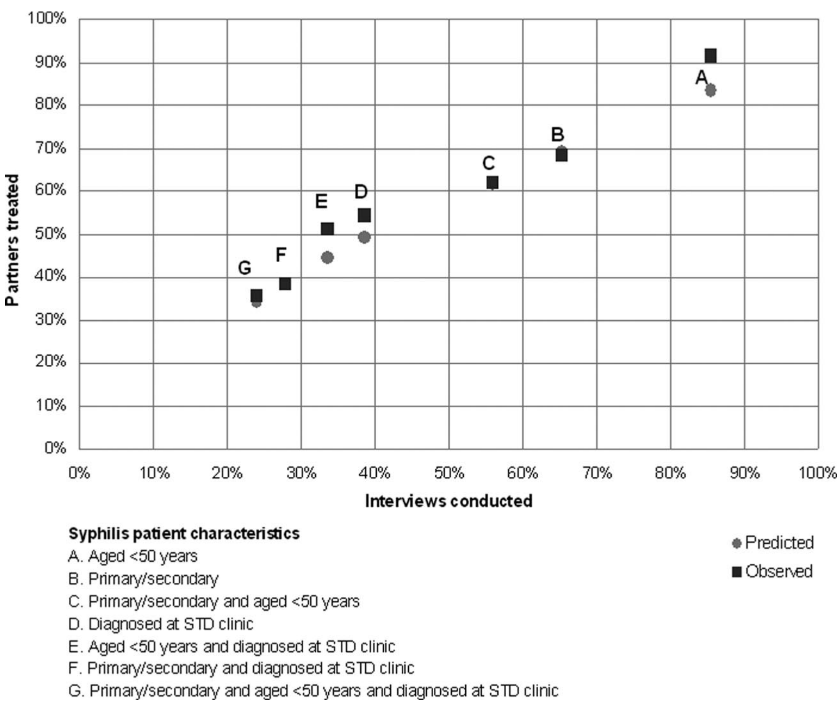

Figure 1. Proportion of interviews conducted and predicted and observed proportions of partners successfully treated if limiting interviews by various combinations of syphilis patient characteristics in validation data set—San Francisco, July 2004–June 2008. For algorithms C and F, the predicted and observed proportions of partners successfully treated were the same.

The tool we developed provides only modest efficiencies in prioritizing partner notification interviews. In our least selective interviewing algorithm, limiting interviews to patients aged <50 years reduced interviews by 14% and missed 8% of partners needing treatment. Assuming that randomly reducing 14% of interviews would result in missing 14% of treated partners, this algorithm provides only a 6% improvement over chance. The ability of prediction models to prioritize interviews depends on the magnitude, as well as the statistical significance, of the estimated effects of variables included in the model. The magnitudes of the effects of the variables included in our model were modest (ratios of treated partners <2). Prediction models might perform better in other localities where magnitudes of effects of variables included in models are greater.

Although prediction models are most commonly used for diagnosis and prognosis in clinical settings,[21] they have also been used to develop selective screening criteria to target case-finding activities to patients at highest risk for infection. An analysis that identified the predictors of hepatitis C infection among San Diego STD clinic patients resulted in implementation of a selective screening algorithm in that clinic.[22] Similarly, an STD clinic in Canada identified predictors of hepatitis B infection and implemented a selective screening rule to serologically test patients at highest risk.[23]

Evidence-based program guidelines are particularly critical in an environment of limited public health resources.[5] Partner notification is an effective way to identify persons who have been infected with or exposed to syphilis and other STDs, but it requires a substantial amount of labor and expense. Algorithms can aid priority setting in situations in which decreased resources force reductions in the number of interviews conducted. Models can also assist in implementing reductions in interviews. Using the previous example, a policy restricting interviews to syphilis patients aged <50 years might be programmatically simpler to implement than a random 14% reduction in the number of interviews conducted. Furthermore, this type of analysis is flexible, easily updated, and can be conducted in any setting with data from local cases. The predictors we examined here were based on information that is routinely collected for public health surveillance in San Francisco and likely to be available in other jurisdictions.

This analysis should be considered in light of its limitations. First, we used data relating to the patient's stage of syphilis at the time of the partner notification interview. In a few cases, stage of syphilis might have been reclassified as a result of information collected during the interview; therefore, the algorithms developed here might not be as predictive if based on syphilis stage collected from the diagnosing provider or case report before the interview. Second, factors associated with more treated partners are likely based on local epidemiology; thus, specific results of our analysis might not be generalizable to other geographic areas. However, our methods can be replicated in other settings, allowing for site-specific strategies to improve interview efficiency.[24] Third, we did not assign weights to prophylactically treated partners according to the patient's stage of syphilis. New syphilis infections have been identified among partners of early latent case-patients, suggesting that prophylactically treating those partners plays a role in preventing transmission[7]; however, if partners of patients with primary syphilis were more likely to be infected,[25] accounting for this in the model might have yielded different results. Fourth, the outcome of more treated partners did not account for the other potential benefits of partner notification, including risk-reduction counseling for patients and the collection of epidemiologic data.[26] Finally, in San Francisco, the syphilis epidemic is almost exclusively among MSM. In a locality with a more heterogeneous syphilis patient population, the methodology described here might perform differently.

As syphilis rates increase and public health resources for STD prevention continue to decline, innovative strategies for cost-effective disease control are warranted. Here, we developed an evidence-based tool to help prioritize assignment of syphilis partner notification interviews in San Francisco. Other health departments might consider developing similar algorithms with the goal of efficiently allocating resources while maximizing syphilis control and prevention.

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