Constructing and evaluating alternative prediction models for identifying clinically relevant cases in an STD clinic

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Abstract

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Background:

Many STD clinics have incorporated "express visits" – testing-only visits without a clinician evaluation. To identify which patients can safely receive express care at the Public Health–Seattle & King County (PHSKC) STD Clinic, we constructed and evaluated alternative triage algorithms based on computer assisted self-interview (CASI) responses.

Methods:

We evaluated the performance of the current triage algorithm, constructed optimized algorithms, and compared the performance of the current and optimized algorithms to a simpler, and potentially easier to implement, algorithm. We used CASI responses from all new problem visits between October 2010 and June 2015 to reconstruct a triage status using the current algorithm, which considers age, gender, symptoms, contact to STD, and health service needs. The outcome measure, need for a standard visit, included report of key symptoms, receipt of empiric treatment, or diagnosis with an infection that could have been diagnosed and treated at the visit. We estimated the sensitivity, specificity, and area under the receiver operating curve (AUC) of the current algorithm, by gender, to appropriately triage patients. We used Classification and

Regression Tree (CART) analysis to construct and validate gender-specific optimized triage algorithms, considering 11 potential predictors of the outcome. We compared the sensitivity, specificity, and AUC of the current algorithm, optimized algorithms, and a simple algorithm based only on symptoms and contact to STD.

Results:

Between October 2010 and June 2015, patients completed the CASI at 32,113 visits, including 7,639 women (23.8%) and 24,474 men (76.2%). The current algorithm appropriately triaged 6,259 women (81.9%) and 21,337 men (87.2%). For women, the current triage algorithm had 97.9% sensitivity, 33.0% specificity, and AUC=0.65 (95%CI=0.64-0.67). For men, the current triage algorithm had 94.6% sensitivity, 71.9% specificity, and AUC=0.83 (95%CI=0.83-0.84). In the validation sample of 2,342 women and 6,984 men, the optimized algorithm appropriately triaged 2,136 women (91.2%) and 6,282 men (89.9%), and the simple algorithm appropriately triaged 2,123 women (90.6%) and 6,150 men (88.1%). For women, the optimized algorithm had 93.2% sensitivity, 86.4% specificity, and AUC=0.90 (95%CI=0.88-0.91). For men, the optimized algorithm had 93.5% sensitivity, 82.9 specificity, and AUC=0.88 (95%CI=0.87-0.89). For women, the simple algorithm had 92.9% sensitivity, 85.0% specificity, and AUC=0.89 (95%CI=0.87-0.90). For men, the simple algorithm had 90.8% sensitivity, 82.6% specificity, and AUC=0.87 (95%CI=0.86-0.88). The simple and optimized algorithms triaged more patients to express care (optimized=31.4%, simple=32.6%) than the current algorithm (23.3%).

Conclusions:

The sensitivity of the current triage algorithm was very high for both men and women; however, the specificity was low, leading to reduced efficiency. In most settings, the simple algorithm would be preferred over the optimized algorithm due to its simplicity and comparable

performance. The current algorithm can be implemented to maximize disease detection, while the simple algorithm can be implemented to maximize clinic efficiency.

Background

Sexually transmitted disease (STD) clinics are a key component of the national infrastructure for the control of STDs. STD clinics in the United States diagnose approximately 25-50% of primary and secondary syphilis infections, 15-35% of gonococcal infections, 10-35% of HIV infections, and 5-20% of chlamydial infections.[1] Moreover, STD clinics often serve uninsured and marginalized persons, provide tests and services unavailable elsewhere, employ Disease Intervention Specialists who counsel patients and assist in partner notification and referral to care, lead sentinel surveillance efforts, train medical providers, and conduct high-impact STD research.[1,2]

Due to dwindling resources for STD clinics[3] and the inability of some clinics to meet the current demand for services, many STD clinics have incorporated "express visits" – testing-only visits without an evaluation by a clinician – in order to streamline visits. There is increasing evidence that express care can reduce the utilization of services that provide minimal personal or public health benefit, such as physical exams for asymptomatic patients. This can reduce long-term costs, but the impact on disease detection and quality of care is unclear.

While the express care approach has many potential advantages, it also may miss infections of public health importance that could be detected through clinician interview and exam in a standard STD clinic visit. Erroneously triaging patients with disease to express visits would delay diagnosis and treatment, which could, in turn, lead to ongoing transmission. The converse, triaging patients without disease to standard visits, would unnecessarily utilize clinician time and resources that could have otherwise been reserved for patients with disease.[4] Thus, evaluating the ability of alternative triage models to appropriately identify clinically relevant cases is crucial for determining which STD clinic service models maximize population-level impact, quality of care, and clinic efficiency.[1]

Express care is often facilitated by technological modernizations, including computer-assisted self-registration, computer-assisted self-interview (CASI), and web-based platforms that provide test results.[5] CASI has been found to improve reporting of sensitive risk behaviors (e.g. transactional sex, drug use, same sex partners, anal sex) compared to clinician interview[6,7,8,9,10], suggesting that an STD clinic triage algorithm based on CASI could accurately triage patients and facilitate high quality care. STD clinics have implemented a variety of express care models, each with its own method of history collection, triage process, and distinct set of criteria for determining patients' visit types.

The Public Health – Seattle & King County (PHSKC) STD Clinic in Seattle, Washington is an ideal setting to evaluate an express care model that incorporates a comprehensive CASI for collecting patient history and an automated triage system. This STD clinic implemented triage to express care in 2010[11], but, due to the staffing model in the clinic, all patients received a clinician evaluation irrespective of triage status. In most express care models, the patient would not see a clinician for an express visit, and this clinical judgment would not factor into the services provided. Thus, the PHSKC STD Clinic is uniquely positioned to evaluate the impact of express care on disease detection. The clinic has collected 5 years of data on patient-reported risk and exposure information along with the outcomes of clinician assessments for each patient.

The objective of this study was to construct and evaluate alternative prediction models to determine the approach that best identifies clinically relevant cases in the PHSKC STD Clinic while minimizing resources dedicated to services with little personal or public health benefit. To achieve this objective, we conducted 3 separate analyses: (1) determined the number and proportion of patients who needed a standard visit but would have been inappropriately triaged by the PHSKC STD Clinic's current algorithm to receive express visits, and characterized these "missed" patients; (2) constructed and validated gender-stratified, optimized algorithms to predict whether patients need a standard visit; and (3) compared the performance of the current and optimized algorithms with a "simple" algorithm based only on whether the patient has symptoms and/or had sexual contact with a person diagnosed with an STD or HIV (hereafter referred to as “contact to STD”).

This analysis will help the PHSKC STD Clinic improve disease control efforts and efficiency, as well as help guide other STD clinics that are considering implementing a triage system. The results will be particularly relevant in settings where the demand for clinic services far exceeds program capacity and large numbers of patients must be turned away.

Methods

This cross sectional study included all patients at the PHSKC STD Clinic who completed the CASI at new problem visits between October 1, 2010 and June 30, 2015. Two versions of the CASI were utilized during the analysis period. From October 2010 to January 2012, patients completed the first CASI system (CASI 1), and, from May 2012 through June 2015, patients completed the second CASI system (CASI 2). CASI 1 and 2 were programmed through different data management platforms but requested almost identical information from patients. Of note, CASI 1 did not include an option for women to request emergency contraception; for the purposes of this analysis, we assumed that women who completed CASI 1 were not seeking emergency contraception.

Although a triage status was assigned to each patient at the time of the clinic visit according to an automated algorithm based on CASI responses, all patients saw a clinician for their visit irrespective of their triage status. The clinician used his or her clinical judgement to determine what services were needed; thus, the clinician assessment was considered the gold standard for this analysis.

Based on a medical record review, which reflected the clinician assessment, we created a binary outcome variable for each new problem visit to indicate whether the patient needed a standard visit or could have received an express visit. We defined patients as needing to receive a standard visit if they reported genital symptoms, abdominal pain, or body rash;

received empiric treatment for contact to an STD or otherwise; or were diagnosed with an infection or disease syndrome that clinic standards dictate should be diagnosed and treated at the time of the initial visit. Such infections meet two criteria: (1) they are possible to diagnose with clinical exam and point of care testing alone and (2) they are of public health importance due to the potential for ongoing transmission or health consequences of delayed treatment. These include primary or secondary syphilis, urethral or cervical *Neisseria gonorrhoeae* detected on Gram stain, non-gonococcal urethritis, epididymitis, proctitis, mucopurulent cervicitis, pelvic inflammatory disease, bacterial vaginosis (BV), vaginal candidiasis, trichomoniasis, urinary tract infection, genital ulcer of unknown etiology, soft tissue infection, and herpes simplex virus (HSV). If the patient did not meet any of the conditions indicating a standard visit, we defined them as eligible to receive express care. Patients who would have been triaged standard visits but were eligible for express care based on the clinician assessment were considered "overtriaged". Patients who would have been triaged to express care but needed a standard visit based on the clinician assessment were considered "undertriaged".

This project was approved by the University of Washington Human Subjects Division. Analyses were conducted in Stata 13 (StataCorp, College Station, Texas) and the Salford Predictive Modeler 7 (Salford Systems, San Diego, California).

Evaluation of the STD Clinic's Current Triage Algorithm

Measures & Definitions

To determine and describe the number and proportion of patients who needed a standard visit but would have been inappropriately triaged by the PHSKC STD Clinic's current algorithm to express visits, we evaluated all new problem visits with a completed CASI from October 1, 2010 to June 30, 2015. We reconstructed a triage status using responses to the CASI according to the clinic's algorithm criteria as of October 1, 2015 (**Table 1**). The algorithm, which incorporates both disease control and patient service priorities, triages patients to standard visits if they are under 18 years old, have any symptoms, have a positive STD result from another provider and need treatment, have a sex partner with symptoms, have had known contact to STD, have been diagnosed with HIV but have not had an HIV care visit in the past 9 months, have Hepatitis C and want a referral for care, have genital HSV and want preventive or suppressive medications, are transgender, or have ever had transgender sex partners. Additionally, women are triaged to standardized visits if they request emergency contraception, want to discuss contraception, or are age 21 or older and have not had a Pap test in the past year.

Statistical Methods

The number and proportion of patients who would have been mistriaged by the current algorithm was calculated. For patients who were overtriaged to standard visits, we examined the CASI triage criteria leading to this triage status. For patients who were undertriaged to express care, we examined the clinical outcomes that indicated the need for a standard visit. These “missed” patients were characterized by their age, race, ethnicity, gender/sexual orientation, and CASI version utilized (CASI 1 vs. CASI 2). We used chi-squared tests to compare characteristics of patients undertriaged to express care to all other patients. In particular, whether these patients reported symptoms to the CASI and/or during the clinician interview was evaluated, in order to evaluate the sub-hypothesis that missed patients will tend to have misreported their symptoms to the CASI. Finally, we estimated the sensitivity, specificity, and area under the receiver operating curve (AUC) of the algorithm to appropriately triage patients, stratified by gender.

Construction of Optimized Algorithms and Comparison of the Current, Optimized, and Simple Algorithms

Measures & Definitions

To construct and validate an optimized algorithm, we evaluated the sample of new problem visits described above with two restrictions. We excluded transgender persons because they are not currently eligible to receive express care at the PHSKC STD Clinic. Among individuals who had more than one new problem visit during the analysis period, we randomly selected one visit for inclusion in the analysis to maintain independence of observations. Separately for men and women, the resulting sample of new problem visits was randomly divided in half, resulting in gender-specific development and validation samples.

Eleven (11) predictors of need for a standard visit were selected for consideration in the analyses based on simplicity and epidemiologic evidence for inclusion in the model (**Table 1**). All 11 predictors are self-reported information collected by the CASI. We selected predictors that have been highly associated with infections and/or syndromes that we determined would require a standard visit, including young age[12,13,14], symptoms[15], a positive STD result from another provider, contact to STD or sex partner with symptoms[14,15,16], sex of sex partners[15], number of recent sex partners[14], recent drug use[17], and transactional sex[14,17]. Of note, symptoms were divided into two categories: “key symptoms” and sore throat. Key symptoms included genital symptoms, a body rash, and abdominal symptoms (for women). Key symptoms are one of the indicators of need for a standard visit (i.e. part of the outcome definition) because any patient seeking care for these types of symptoms should have those symptoms evaluated by a clinician. While we did not anticipate that sore throat would be associated with the outcome, we included it as a predictor because the current and simple algorithms consider any symptoms, and we wanted to be sure that by restricting this criterion to key symptoms we would not be limiting the predictive ability of the algorithm.

As previously mentioned, key symptoms are part of the outcome definition and, therefore, would be 100% predictive of the outcome if included in the development of the prediction models. For this reason, we created development and validation “sub-samples” that excluded individuals with key symptoms, which were utilized to develop the initial prediction models that were subsequently combined with the key symptoms criterion. The final optimized algorithms were evaluated in the complete validation sample, which included individuals with key symptoms. The “simple” algorithm considered in the final comparison triages patients to a standard visit if they have any symptoms (including sore throat) and/or report contact to STD.

Statistical Methods

The gender-specific development sub-samples were subjected to Classification and Regression Tree (CART) analysis[18] (Salford Systems) to develop gender-specific maximal risk stratification trees and sequences of nested trees to identify predictors of the need for a standard visit among individuals without key symptoms. CART analysis is a non-parametric, empiric statistical method based on binary recursive partitioning. It creates a decision tree composed of progressive binary splits based on the most useful predictors; each parent node in the decision tree produces two child nodes, which can then become parent nodes producing additional child nodes. CART analysis can consider categorical and continuous predictors; for continuous variables, the cut-point that yields the greatest predictive ability for each split (yields the most “pure” child nodes) is considered. The optimal tree for each gender was selected from the maximal and nested trees; the best sub-tree was the one with the lowest misclassification error rate when the trees were applied to the corresponding validation sub-samples. The decision criteria from the optimal tree for each gender were then programmed into Stata and combined with the key symptoms criterion to create the final gender-specific optimized algorithms.

The PHSKC STD Clinic's current algorithm, the new optimized algorithms, and the simple algorithm were then applied to the new problem visits in the full validation sample for each gender, which included individuals with key symptoms, to produce three triage scenarios. The predictive ability of each algorithm was evaluated by estimating the sensitivity, specificity, and AUC to appropriately triage patients. In addition, the number and proportion of express visits was calculated to approximate the efficiency of the algorithm; the ideal algorithm would triage a substantial proportion of visits to express care without missing any patients who need a standard visit. For the optimized and simple algorithms, the mistriaged patients were examined to identify who would be missed by each algorithm and who would be unnecessarily receiving standard visits.

Results

Evaluation of the STD Clinic's Current Triage Algorithm

Between October 1, 2010 and June 30, 2015, 18,660 patients completed the CASI at 32,113 new problem visits, including 7,639 visits among women (23.8%) and 24,474 visits among men (76.2%). Characteristics of the study sample are presented in **Table 2**. Patients completed CASI 1 at 10,461 visits (32.6%) and CASI 2 at 21,652 visits (67.4%). Male patients were, as a group, older than female patients and were more likely to be white and Hispanic. For just over half (55%) of visits among men, the patient reported sex with men in the past year. The patient-reported reason for each visit is presented in mutually exclusive and hierarchical categories in **Table 3**. At 1,342 visits (4.2%), the patient reported having a positive STD test result from another provider for which they were seeking treatment. Of visits for patients who did not have a positive STD result, 17,349 (54.0%) were among patients with key symptoms. Of the visits remaining, 3,104 (9.7%) were among patients who reported contact to an STD. Overall, women were more likely to seek care due to symptoms, and men were more likely to report contact to STD. Of 19,059 visits where the patient reported key symptoms to either the CASI or the clinician, key symptoms were reported to the CASI at 18,148 visits (95.2%).

The current algorithm appropriately triaged 6,259 women (81.9%) and 21,337 men (87.2%) (**Table 4**). The algorithm would have overtriaged 1,260 women (16.5%) and 2,244 men (9.2%) to standard visits and undertriaged 120 women (1.6%) and 893 men (3.6%) to express care. The reasons for overtriage to standard visits are presented in mutually exclusive and hierarchical categories in **Table 5**. Among women overtriaged to standard visits, not having had a Pap test in the past year (50.6%) accounted for the greatest proportion of overtriaged visits, followed by reporting contact to STD and wanting contraception (each 14.8%). Among men overtriaged to standard visits, reporting contact to STD but not subsequently receiving treatment (53.0%) accounted for the greatest proportion of overtriaged visits. Reporting a sore throat (17.6%) also accounted for a number of men overtriaged to standard visits.

The reasons for undertriage to express care are presented in mutually exclusive and hierarchical categories in **Table 6**. Among women undertriaged to express care, patients most frequently ended up needing a standard visit due to diagnosis with a key infection (45.8%) and report of key symptoms to the clinician but not the CASI (31.7%). The majority of infections/syndromes diagnosed among these women were BV (72.7%). Among men undertriaged to express care, patients most frequently ended up needing a standard visit due to report of key symptoms to the clinician that were not reported to the CASI (51.5%) and receipt of empiric treatment for either contact to STD or otherwise (41.7%). Hispanic patients ($p=0.004$), men ($p<0.0005$), and patients who completed CASI 1 ($p < 0.0005$) were significantly more likely to be undertriaged to express care (**Table 7**).

For women, the triage algorithm had 97.9% sensitivity and 33.0% specificity for predicting the visit type needed, and AUC=0.65 (95%CI=0.64-0.67). For men, the triage algorithm had 94.6% sensitivity, 71.9% specificity, and AUC=0.83 (95%CI=0.83-0.84).

Construction of Optimized Algorithms and Comparison of the Current, Optimized, and Simple Algorithms

The development and validation samples for women contained 2,343 and 2,342 patients, respectively. The development and validation sub-samples for women, which excluded women with key symptoms, contained 873 and 857 patients, respectively. The development and validation samples for men each contained 6,984 patients. The development and validation sub-samples for men contained 3,443 and 3,344 patients, respectively. The optimized CART trees to predict the need for a standard visit among women and men without key symptoms are presented in **Figures 1 and 2**, respectively. The decision rules in each tree were combined with the key symptoms criterion to form the final optimized algorithms (**Table 8**).

When evaluated in the complete validation sample, which included patients with and without key symptoms, the optimized algorithm appropriately triaged 2,136 women (91.2%) and 6,282 men (89.9%) (**Table 9**). The optimized algorithm would have overtriaged 92 women (3.9%) and 397 men (5.7%) to standard visits and undertriaged 114 women (4.9%) and 305 men (4.4%) to express care. In the complete validation sample, the simple algorithm, which considered only symptoms and contact to STD, appropriately triaged 2,123 women (90.6%) and 6,150 men (88.1%) (**Table 10**). The simple algorithm would have overtriaged 101 women (4.3%) and 404 men (5.8%) to standard visits and undertriaged 118 women (5.0%) and 430 men (6.2%) to express care.

The overall performance of the current, optimized, and simple algorithms for determining which patients needed a standard visit and which were eligible for express care, among all visits in the validation dataset for each gender, is presented in **Table 11**. For women, the optimized algorithm had slightly higher sensitivity and specificity compared to the simple algorithm; however, the AUC was almost identical for the two algorithms (optimized AUC=0.90, simple AUC=0.89). For men, the optimized algorithm had slightly higher sensitivity compared to the simple algorithm; however, the specificity and AUC were almost identical for the two algorithms (optimized AUC=0.88, simple AUC=0.87). For both men and women, the current algorithm had higher sensitivity, lower specificity, and lower AUC. The optimized algorithms and simple algorithm triaged a similar proportion of patients to express care (optimized=31.4%, simple=32.6%), while the current algorithm triaged a smaller proportion of patients to express care (23.3%). For women, a particularly low proportion of visits were triaged to express care by the current algorithm (11.1%). Women were more likely to attend the clinic due to symptoms and had more service-related indications in the current algorithm than men.

Among women and men overtriaged to standard visits by the optimized algorithm, reporting contact to STD but then not receiving empiric treatment for contact to STD at the visit (women=69.6%, men=80.4%) accounted for the greatest proportion of overtriaged visits, followed by report of a sex partner with symptoms (women=27.2%, men=16.4%; **Table 12**). Similarly, among women and men overtriaged to standard visits by the simple algorithm, reporting contact to STD but then not receiving empiric treatment for contact to STD at the visit (women=84.2%, men=75.2%) accounted for the greatest proportion of visits, and the remaining individuals were all overtriaged due to report of sore throat (women=15.8%, men=24.8%; **Table 13**).

For both the optimized and simple algorithms, the reasons that women who were undertriaged to express care most frequently ended up needing a standard visit were the same: diagnosis with a key infection (optimized=44.7%, simple=44.9%) and report of key symptoms to the clinician after reporting no symptoms to the CASI (optimized=33.3%, simple=27.1%; **Tables 14 and 15**). Among men undertriaged to express care by the optimized algorithm, patients most frequently end up needing a standard visit due to report of key symptoms to the clinician after reporting no symptoms to the CASI (46.6%) and receipt of empiric treatment for a reason other than contact to STD (26.9%). Among men undertriaged to express care by the simple algorithm, patients most frequently ended up needing standard visits due to receipt of empiric treatment for a reason other than contact to STD (36.0%), followed by report of key symptoms to the clinician after reporting no symptoms to the CASI (34.4%).

Discussion

The PHSKC STD Clinic's current triage algorithm performed well overall. It had high sensitivity for men and women but poor specificity, particularly for women. Thus, almost all patients who needed a standard visit were triaged to standard visits, but many patients who were eligible for express care were also triaged to standard visits, limiting the efficiency of the algorithm. The current algorithm disproportionately undertriaged men and Hispanic patients to express care. Although the absolute difference in the proportion of visits undertriaged to express care versus otherwise was not large for either characteristic, this could be a signal of a language barrier for some Hispanic patients. The low specificity of the current algorithm is primarily driven by the inclusion a variety of health service indications as criteria in the algorithm. In particular, over half of women overtriaged to a standard visit were overtriaged because they indicated that they were over age 21 years and hadn't had a Pap test in the past year. Pap tests are used to screen for precancerous or cancerous cervical cells, which are caused by human papillomavirus, an STD. STD clinics can decide to provide this screening service for women, as they may not seek it elsewhere; however, since implementation of the Affordable Care Act of 2010, preventive services such as Pap tests are provided at no cost in the primary care setting[19]. Women therefore have other options for receiving this service, and STD clinics may not be the ideal setting to provide only Pap tests. In addition, of the women triaged to standard visits on the basis of not having had a Pap test in the past year, only a small minority (12.1%) actually received a Pap test at that visit. This likely reflects the complexity of Pap guidelines, which do not depend solely on time since the last Pap test, but also factors not captured in the CASI such as the patient's past history of dysplasia, degree of dysplasia and subsequent evaluation and whether or not HPV co-testing was performed. Whether or not a potential health service indication should be included in the criteria for standard visits depends on the STD clinic's patient population, availability of the service elsewhere, use of the service elsewhere and at the STD clinic, and competing demands on clinic resources.

Some patients (4.8%) did not report having symptoms to the CASI but subsequently reported symptoms to the clinician. This "misreporting" of symptoms limits the ability of any triage algorithms to predict which type of visit is needed. While the reason for misreporting symptoms is unknown, it could include discomfort with disclosing symptoms to the CASI, a priming of effect of the CASI that increases the likelihood of symptom report to clinician, or a shortcoming of the CASI questionnaire. Regardless of the causes, there appears to be a benefit to asking this question in person, presumably due to the opportunity to field questions. Other studies in STD clinics have similarly found that questions related to STD symptoms elicit more reports of symptoms when asked by a clinician compared to a CASI[6,8]. However, it is important to note that multiple studies in STD clinics have identified increased reporting of sensitive risk behaviors to a CASI compared to a clinician interview[6,7,8,9,10]. Thus, the benefits of more accurately obtaining sensitive risk information must be considered when weighing the potential for misreported symptoms with a CASI. To yield the benefits of the CASI for collecting sensitive information while also minimizing misreport of STD symptoms, it may be advantageous to combine the CASI with a brief screening interview by a staff member to confirm whether or not the patient has symptoms.

The performance of the optimized algorithms did not differ substantially from the performance of the simple algorithm. In most settings, the benefit of having a simple triage algorithm would outweigh the minute gain in sensitivity with the optimized algorithms. Whether the current or simple algorithm is most appropriate depends on the primary motivation for implementing a triage process. If the primary goal is to improve efficiency, the simple algorithm is superior for both men and women. While it has lower sensitivity than the current algorithm, its sensitivity is still high and its overall ability to appropriately triage patients between express care and standard visits (AUC) is superior. In contrast, if the primary goal is to maximize disease detection (sensitivity), the current algorithm would be superior, particularly if implemented in combination with a clinic staff member asking the patient if they are experiencing key symptoms.

These analyses were subject to a few important limitations. First, it was assumed that all patients received a clinician evaluation despite the implementation of the triage system in October 2010; however, it is possible that some patients could have incomplete outcome information if only the triage status were considered when determining which services to provide. This is expected to be very rare because, under the current staffing model, all patients saw a clinician who reviewed their CASI responses and used their clinical judgement to determine which services were needed. In addition, patients who completed the CASI 1 were missing information on one of the current algorithm's triage criteria (requesting emergency contraception); it was assumed that none of the CASI 1 women were seeking emergency contraception. Any effect of this misclassification is expected to be small because, based on the women who completed CASI 2, we estimate that less than 5% of women who completed CASI 1 would have requested emergency contraception on the CASI. Patients who did not complete the CASI were not included in this analysis and are likely different than patients who complete the CASI, so this restriction limits generalizability of the algorithm to an entire STD clinic population. These algorithms are primarily intended for use with a clinical CASI, so this restriction was appropriate for the optimization of the algorithms. Moreover, the algorithms should be evaluated in other clinic populations, as the PHSKC STD Clinic patient population may differ in important ways from other urban areas. The PHSKC STD Clinic serves a predominantly MSM population in the Pacific Northwest; the performance of these algorithms may differ in a clinic that sees predominantly women or is in a different geographic region. Finally, utilizing prediction models to triage patients does not incorporate patient preferences, which will ultimately influence the success of any service delivery model.

Despite these limitations, our analyses had substantial strengths. We evaluated 5 years of data from an STD clinic and based our evaluation of the triage algorithm on a disease outcome. Previous evaluations of STD clinic triage algorithms have primarily focused on the impact of the algorithm on clinic efficiency[20,21,22] or have compared STD diagnosis rates between express visits and standard visits in the entire clinic population[21,22,23,24,25,26] or before and after introducing express visits[21,27]. Our evaluation builds on the existing literature by assessing the test characteristics of the current and alternate algorithms and examining characteristics of the patients overtriaged to standard care and undertriaged to express care in detail. Additionally, to our knowledge, this is the first formal optimization of a triage algorithm for an STD clinic that considers the predictive ability of self-reported criteria such as contact to STD, sex of sex partners, number of sex partners, and other STD risk factors. Finally, the analysis utilizes an extremely comprehensive electronic clinical dataset, which is not readily available for this type of analysis in most STD clinics.

This analysis summarizes the performance of three different triage algorithms for PHSKC STD Clinic leadership to consider as they seek to improve disease control efforts and clinic efficiency through optimization of their express care model. We have shown that express care triage algorithms can achieve acceptable sensitivity for screening purposes in an STD clinic. Moreover, we have demonstrated use of the CART method to rigorously develop prediction models for identifying clinically relevant cases in an STD clinic. Finally, we have identified different sets of triage criteria that can be implemented in STD clinics to achieve goals of either improved disease detection or improved clinic efficiency.

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Figures and Tables

Table 1**:** The PHSKC STD Clinic current triage algorithm criteria for needing a standard visit and predictors selected for consideration in optimization of the algorithm.

Current Algorithm Criteria	Predictors Selected for Optimization of the Algorithm
Any of the following indicates need of a standard visit: • < 18 years old • Has symptoms • Has a positive STD result and needs treatment • Has a sex partner with symptoms • Has had known contact to partner with an STD or HIV • Has HIV and has not had an HIV care visit in the past 9 months • Has Hepatitis C and wants a referral for care • Has genital herpes and wants preventive or suppressive medication • Is a female requesting emergency contraception • Is a heterosexually active female and wants to discuss contraception • Is a female age 21+ who hasn't had a Pap test in the past year • Identifies as transgender • Has transgender sex partners	• Age • Has symptoms (any except sore throat) • Has sore throat • Has a positive STD result from another provider and needs treatment • Has a sex partner with symptoms • Has had known contact to partner with an STD or HIV • Has had a same sex partner in the past year • Number of sex partners in the past 2 months • Has used methamphetamine or poppers in past year* • Has used crack in past year • Has ever had transactional sex

***** Popper use not included for women or men who report sex with women only.

Table 2: Characteristics of the Study Sample, Overall & by Gender

Characteristic	Total N (%)	Women N (%)	Men N (%)
Overall	32,113 (100)	7,639 (100)	24,474 (100)
Age (n = 3 missing)			
≤ 18	372 (1.2)	184 (2.4)	188 (0.8)
19-24	5,742 (17.9)	2,090 (27.4)	3,652 (14.9)
25-29	7,261 (22.6)	1,944 (25.5)	5,317 (21.7)
≥ 30	18,735 (58.4)	3,421 (44.8)	15,314 (62.6)
Race & Ethnicity			
White	19,186 (59.8)	3,662 (47.9)	15,524 (63.4)
Black	6,360 (19.8)	2,166 (28.4)	4,194 (17.1)
Native American / Alaskan Native	366 (1.1)	142 (1.9)	224 (0.9)
Asian / Pacific Islander	2,521 (7.9)	711 (9.3)	1,810 (7.4)
Multiple Races	1,192 (3.7)	475 (6.2)	717 (2.9)
Other or Unknown	2,488 (7.8)	483 (6.3)	2,005 (8.2)
Hispanic ethnicity (n = 1,359 missing)	2,754 (9.0)	498 (6.9)	2,256 (9.6)
Gender / Sexual Orientation (n = 2 missing)			
Men who have sex with men	13,456 (41.9)	-	13,456 (55.0)
Men who have sex with women	11,016 (34.3)	-	11,016 (45.0)
Female	7,639 (23.8)	7,639 (100)	-
CASI Data Source			
CASI 1	10,461 (32.6)	2,831 (37.1)	7,630 (31.2)
CASI 2	21,652 (67.4)	4,808 (62.9)	16,884 (68.8)
Transgender	11 (0.03)	4 (0.05)	7 (0.03)

Table 3: Reason for visit, Overall & by Gender; Mutually Exclusive & Hierarchical Categories

Characteristic	**Total** N (%)	**Women** N (%)	**Men** N (%)
Overall	32,113 (100)	7,639 (100)	24,474 (100)
Positive STD result	1,342 (4.2)	240 (3.1)	1,102 (4.5)
Key symptoms	17,349 (54.0)	5,014 (65.6)	12,335 (50.4)
Contact to an STD/HIV	3,104 (9.7)	308 (4.0)	2,796 (11.4)
Other	10,318 (32.1)	2,077 (27.2)	8,241 (33.7)

Table 4: Evaluation of the ability of the current CASI triage algorithm to predict which patients needed a standard visit and which were eligible for express care

	Needed a Standard Visit N = 22,256	**Could have had an Express Visit** N = 9,857
Females (N = 7,639)		
Triaged to Standard Visit	5,638	1,260
Triaged to Express Care	120	621
Males (N = 24,474)		
Triaged to Standard Visit	15,605	2,244
Triaged to Express Care	893	5,732

Table 5: Reason for overtriage to a standard visit by the current CASI algorithm, Overall & by Gender; Mutually Exclusive & Hierarchical Categories

Characteristic	**Total** N (%)	**Women** N (%)	**Men** N (%)
Overall	3,504 (100)	1,260 (100)	2,244 (100)
Symptoms (all reported sore throat)	446 (12.7)	50 (4.0)	396 (17.6)
Positive STD result	61 (1.7)	11 (0.9)	50 (2.2)
Contact to STD/HIV	1,164 (33.2)	187 (14.8)	977 (43.5)
Partner with symptoms	270 (7.7)	58 (4.6)	212 (9.4)
Out of HIV care	40 (1.1)	0 (0)	40 (1.8)
Out of Hepatitis C care	40 (1.1)	3 (0.2)	37 (1.6)
Wants medication for HSV	162 (4.6)	44 (3.5)	118 (5.3)
Wants contraception	187 (5.3)	187 (14.8)	-
Wants emergency contraception	26 (0.7)	26 (2.1)	-
Age 21+ & no Pap in past year	638 (18.2)	638 (50.6)	-
Age ≤ 18	132 (3.8)	29 (2.3)	103 (4.6)
Ever had transgendered sex partner	334 (9.5)	24 (1.9)	310 (13.8)
Transgendered	4 (0.1)	3 (0.2)	1 (0.04)

Table 6: Reason for undertriage to express care by the current CASI algorithm, Overall & by Gender; Mutually Exclusive & Hierarchical Categories

Characteristic	**Total** N (%)	**Women** N (%)	**Men** N (%)
Overall	1,013 (100)	120 (100)	893 (100)
Symptoms reported to kiosk (except sore throat)	-	-	-
Symptoms reported to clinician (except sore throat)	498 (49.2)	38 (31.7)	460 (51.5)
Empiric treatment for contact to STD/HIV	173 (17.1)	11 (9.2)	162 (18.1)
Diagnosed with a key infection	115 (11.4)	55 (45.8)	60 (6.7)
Empiric treatment for other	227 (22.4)	16 (13.3)	211 (23.6)

Table 7: Characteristics of patients undertriaged to express care by the current CASI algorithm compared to other patients

Characteristic	Total N (%)	Undertriaged N (%)	Other N (%)	P-value
Overall	32,113 (100)	1,013 (100)	31,100 (100)	N/A
Age (n = 3 missing)*				
19-24	5,742 (18.1)	170 (16.8)	5,572 (18.1)	
25-29	7,261 (22.9)	235 (23.2)	7,026 (22.9)	0.545
≥ 30	18,735 (59.0)	608 (60.0)	18,127 (59.0)	
Race & Ethnicity				
White	19,186 (59.8)	598 (59.0)	18,588 (59.8)	
Black	6,360 (19.8)	196 (19.4)	6,164 (19.8)	
Native American / Alaskan Native	366 (1.1)	14 (1.4)	352 (1.1)	0.023
Asian / Pacific Islander	2,521 (7.9)	77 (7.6)	2,444 (7.9)	
Multiple Races	1,192 (3.7)	25 (2.5)	1,167 (3.8)	
Other or Unknown	2,488 (7.8)	103 (10.2)	2,385 (7.7)	
Hispanic ethnicity (n = 1,359 missing)	2,754 (9.0)	112 (11.6)	2,642 (8.9)	0.004
Gender / Sexual Orientation (n = 2 missing)*				
Men who have sex with men	13,456 (41.9)	464 (45.8)	12,992 (41.8)	
Men who have sex with women	11,016 (34.3)	429 (42.4)	10,587 (34.0)	< 0.0005
Female	7,639 (23.8)	120 (11.9)	7,519 (24.2)	
CASI Data Source				
CASI 1	10,461 (32.6)	431 (42.6)	10,030 (32.3)	< 0.0005
CASI 2	21,652 (67.4)	582 (57.5)	21,070 (67.8)	
Transgender	11 (0.03)	0 (0)	11 (0.04)	0.549

* Age ≤18 years and transgender categories not included here because those are part of the current CASI algorithm triage criteria.

Figure 1: Optimized CART tree for prediction of need for a standard visit among women without key symptoms, among visits in the female validation sub-sample.

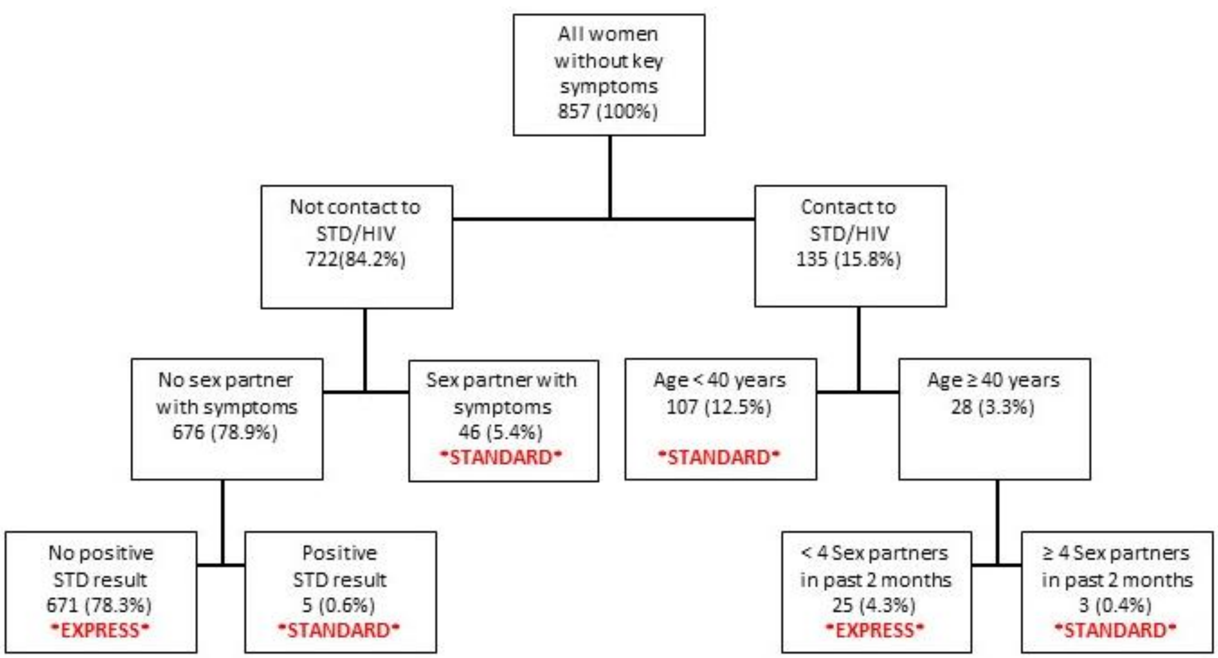

Figure 2: Optimized CART tree for prediction of need for a standard visit among men without key symptoms, among visits in the male validation sub-sample.

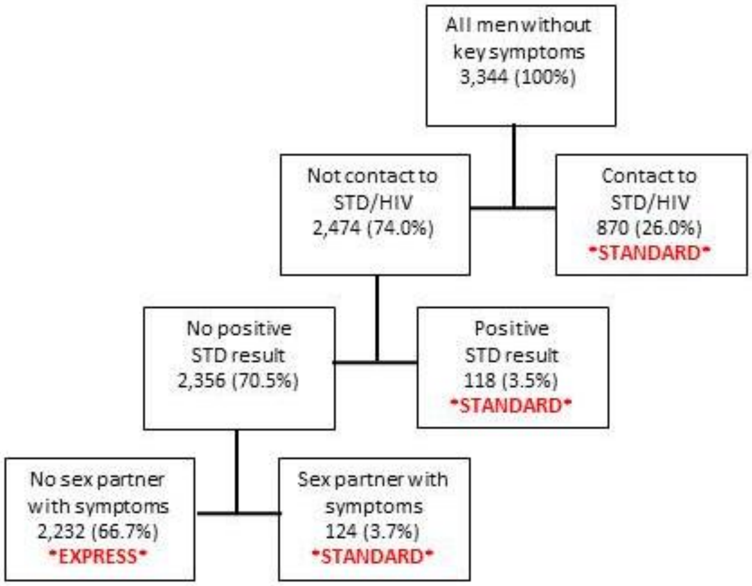

Table 8**:** The criteria for the final optimized algorithms

Optimized Algorithm - Women	**Optimized Algorithm - Men**
Any of the following indicates need of a standard visit: • Key symptoms • Contact to an STD/HIV and either age < 40 years or ≥ 4 sex partners in the past 2 months • Sex partner with symptoms, in the absence of contact to STD/HIV • Positive STD result from another provider, in the absence of contact to STD/HIV or sex partner with symptoms	Any of the following indicates need of a standard visit: • Key symptoms • Contact to an STD/HIV • Has a positive STD result from another provider • Has a sex partner with symptoms

Table 9: Evaluation of the ability of the optimized algorithm to predict which patients needed a standard visit and which were eligible for express care

	Needed a Standard Visit N = 6,328	**Could have had an Express Visit** N = 2,998
Optimized Algorithm		
Females (N = 2,342)		
Triaged to Standard Visit	1,554	92
Triaged to Express Care	114	582
Males (N = 6,984)		
Triaged to Standard Visit	4,355	397
Triaged to Express Care	305	1,927

Table 10: Evaluation of the ability of the simple algorithm to predict which patients needed a standard visit and which were eligible for express care

	Needed a Standard Visit N = 6,328	**Could have had an Express Visit** N = 2,998
Simple Algorithm		
Females (N = 2,342)		
Triaged to Standard Visit	1,550	101
Triaged to Express Care	118	573
Males (N = 6,984)		
Triaged to Standard Visit	4,230	404
Triaged to Express Care	430	1,920

Table 11: Comparison of the performance of the current, optimized, and simple algorithms for determining which patients needed a standard visit and which were eligible for express care, among visits in the validation dataset for each gender

	Current Algorithm*	**Optimized Algorithm**	**Simple Algorithm**
Women (N = 2,342)			
Sensitivity	97.7	93.2	92.9
Specificity	32.9	86.4	85.0
Express Visits, N (%)	260 (11.1)	696 (29.7)	691 (29.5)
AUC (95% CI)	0.65 (0.64-0.67)	0.90 (0.88-0.91)	0.89 (0.87-0.90)
Men (N = 6,984)			
Sensitivity	94.9	93.5	90.8
Specificity	71.9	82.9	82.6
Express Visits, N (%)	1,911 (27.4)	2,232 (32.0)	2,350 (33.6)
AUC (95% CI)	0.83 (0.82-0.84)	0.88 (0.87-0.89)	0.87 (0.86-0.88)
Women & Men (N = 9,326)			
Express Visits, N (%)	2,171 (23.3)	2,928 (31.4)	3,041 (32.6)

* Differs slightly from Aim 1 results because this evaluation is restricted to the validation sample of new problem visits.

Table 12: Reason for overtriage to a standard visit by the optimized algorithms, Overall & by Gender; Mutually Exclusive & Hierarchical Categories

Characteristic[†]	**Total** N (%)	**Women** N (%)	**Men** N (%)
Overall	489 (100)	92 (100)	397 (100)
Symptoms reported to kiosk (except sore throat)	-	-	-
Contact to STD/HIV	383 (78.3)	64 (69.6)	319 (80.4)
Positive STD result	16 (3.3)	3 (3.3)	13 (3.3)
Sex partner with symptoms	90 (18.4)	25 (27.2)	65 (16.4)
Age < 40 years*	0 (0)	0 (0)	-
≥ 4 sex partners in past 2 months*	0 (0)	0 (0)	-

* Included in female optimized algorithm only.

Table 13: Reason for overtriage to a standard visit by the simple algorithm, Overall & by Gender; Mutually Exclusive & Hierarchical Categories

Characteristic	**Total** N (%)	**Women** N (%)	**Men** N (%)
Overall	505 (100)	101 (100)	404 (100)
Symptoms (all reported sore throat)	116 (23.0)	16 (15.8)	100 (24.8)
Contact to STD/HIV	389 (77.0)	85 (84.2)	304 (75.2)

Table 14: Reason for undertriage to express care by the optimized algorithms, Overall & by Gender; Mutually Exclusive & Hierarchical Categories

Characteristic	**Total** N (%)	**Women** N (%)	**Men** N (%)
Overall	419 (100)	114 (100)	305 (100)
Symptoms reported to kiosk (except sore throat)	-	-	-
Symptoms reported to clinician (except sore throat)	180 (43.0)	38 (33.3)	142 (46.6)
Empiric treatment for contact to STD/HIV	68 (16.2)	7 (6.1)	61 (20.0)
Diagnosed with a key infection	71 (16.9)	51 (44.7)	20 (6.6)
Empiric treatment for other	100 (23.9)	18 (15.8)	82 (26.9)

Table 15: Reason for undertriage to express care by the simple algorithm, Overall & by Gender; Mutually Exclusive & Hierarchical Categories

Characteristic	**Total** N (%)	**Women** N (%)	**Men** N (%)
Overall	548 (100)	118 (100)	430 (100)
Symptoms reported to kiosk (except sore throat)	-	-	-
Symptoms reported to clinician (except sore throat)	180 (32.8)	32 (27.1)	148 (34.4)
Empiric treatment for contact to STD/HIV	119 (21.7)	18 (15.3)	101 (23.5)
Diagnosed with a key infection	79 (14.4)	53 (44.9)	26 (6.0)
Empiric treatment for other	170 (31.0)	15 (12.7)	155 (36.0)