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Evaluation of Risk Score Algorithms for Detection of Chlamydial and Gonococcal Infections in an Emergency Department Setting

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Abstract

Objectives: To develop and evaluate screening algorithms to predict current chlamydial and gonococcal infections in emergency department (ED) settings and assess their performance.

Methods: Between 2002 and 2005, adult patients aged 18 to 35 years attending an urban ED were screened for *Chlamydia trachomatis* (Ct) and *Neisseria gonorrhoeae* (GC) and completed a brief demographic and behavioral questionnaire. Using multiple unconditional logistic regressions, the authors developed four separate predictive models and applicable clinical risk scores to screen for infection. They developed models for females and males separately, for Ct and GC infections combined, and for Ct infection alone. The sensitivities and specificities of the clinical risk scores at different cutoffs were used to examine performance of the algorithms.

Results: Among 5,537 patients successfully screened for Ct and GC, the overall prevalence of infection was 9.6%. Age was the strongest predictor of infection. Adjusting for other predictors, the prevalence odds ratio (POR) was 2.2 (95% confidence interval [CI] = 1.7 to 2.8) for Ct and GC combined and 2.9 (95% CI = 2.1 to 4.1) for Ct alone comparing females 25 years and younger to females older than 25 years. Among males, the association was stronger with an adjusted POR of 3.3 (95% CI = 2.3 to 4.7) for Ct and GC combined and 3.2 (95% CI = 2.1 to 4.7) for Ct infection alone.

Conclusions: If the decision to incorporate Ct and GC screening into routine ED care is made, age alone appears to be a sufficient screening criterion.

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Keywords: screening, chlamydial infection, gonorrhea, emergency department, risk score algorithm

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In 2005, approximately 1 million chlamydial infections and 350,000 gonococcal infections were reported to the Centers for Disease Control and Prevention.[1] These estimates only reflect the burden of reported infections. Assuming that not all infections are reported, or even diagnosed, the true burden increases to an estimated 2.8 million Americans infected with *Chlamydia trachomatis* (Ct) and 718,000 infected with *Neisseria gonorrhoeae* (GC) each year.[2]

The majority of Ct and many GC infections do not produce symptoms. Relying on clinic visits for identification and treatment of infected individuals thus has limited effectiveness.[3] Without vigorous public health interventions, the majority of asymptomatic infections will remain untreated, allowing for persistent infection, potential transmission to sex partners, and, in some individuals, progression to serious complications. In addition, inflammatory sexually transmitted infections (STIs), such as chlamydial and gonococcal infections, may increase susceptibility to and transmission of the human immunodeficiency virus (HIV).[4–8]

In recent years, emergency departments (EDs) have been proposed as promising venues for providing screening interventions.[9] EDs often serve as primary care sites for persons who do not have regular access to health care, typically inner-city and difficult-to-reach patient populations.[10] Many of those at highest risk for STIs do not have access to regular health care and, therefore, may be accessible through EDs.[11,12] A handful of studies demonstrating the acceptability and feasibility of Ct and GC screening in EDs have detected prevalences ranging from 8% to 11% for Ct infection and from 2% to 9% for GC infection.[11,13–16] These prevalences are similar to those detected in other more traditional clinical venues where STI testing services are routine.[17–19]

To provide a more accurate understanding of the potential utility of screening for Ct and GC in an ED setting, we developed and evaluated ED-specific clinical risk scores for use as screening criteria. We evaluated the criteria's performance using different screening criteria to provide a starting point for EDs considering incorporating Ct and GC screening into routine care. Using data from a study of patients attending an urban ED, we assessed the effectiveness of screening for undiagnosed Ct and GC infection in this setting.

METHODS

Study Design

This cross-sectional analysis is part of a larger cross-sectional and short duration cohort study of patients presenting at The Johns Hopkins Hospitals (JHH) adult ED in Baltimore, Maryland.[20] Written informed consent was obtained from all study participants. The informed consent procedure emphasized that participation in the study would not affect the quality of care the patient received during his/her ED visit. The institutional review boards of RTI International, JHHs, and the University of North Carolina at Chapel Hill (UNC) approved the study protocol. In compliance with state laws, patients identified with Ct or GC infection were reported to the Baltimore City Health Department.

Study Setting and Population

Between November 2002 and February 2005, trained interviewers approached adult patients in the JHH ED waiting area to assess study eligibility. Patients were eligible to participate in the study if they were between the ages of 18 and 35 years, English-speaking, and sexually active in the past 90 days. Patients who were critically ill or presenting to the ED for acute psychiatric or STI-related care, as well as Johns Hopkins employees and students, were excluded.

Study Protocol

Participants completed a brief demographic and behavioral questionnaire using touchscreen audio computer-assisted self-interview (ACASI) technology and provided specimens for nucleic acid amplification testing for Ct and GC. All participants were provided instruction and supplies for self-collecting a urine specimen. In addition, female participants were provided instruction and supplies for providing a self-collected vaginal swab specimen. Contact information was collected from all patients who provided specimens to locate and follow-up with those who tested positive. Participants received a $10 food coupon for their participation. Analyses presented in this report focus on participants who successfully completed the ACASI questionnaire and provided a specimen with a valid test result during their ED visit. Details of the larger short duration cohort study are described elsewhere.[20]

From the time of study initiation in November 2002 until June 2003, a ligase chain reaction (LCR) assay (Abbott Laboratories, North Chicago, IL) was used to test for Ct and GC from urine specimens collected from all participants. In addition to the LCR assay performed on the urine specimens, a polymerase chain reaction (PCR) assay (Roche Diagnostic Systems, Indianapolis, IN) was used to test for both organisms from self-collected vaginal swabs provided by female participants. All specimens collected in the JHH ED were stored at approximately 4°C until being shipped for processing and testing at the UNC Microbiology Laboratory. Abbott Laboratories discontinued production of the LCR testing kits in 2003.[21] As a result, all specimens collected after July 2003 were tested by PCR only.

Data Analysis

All analyses were conducted using Stata Version 8.0 (StataCorp, College Station, TX). We developed four separate predictive models to screen for Ct and GC infections in the ED. The four outcomes of the predictive models are: 1) Ct and GC infection combined among females, 2) Ct infection only among females, 3) Ct and GC infection combined among males, and 4) Ct infection only among males. Ct and GC infection combined includes patients infected with Ct only, patients infected with GC only, and patients dually infected with Ct and GC. We chose to evaluate these four models separately for two reasons. First, the clinical consequences of untreated infections between females and males are inherently different, which may require gender-specific screening criteria. Second, screening for GC is generally not recommended in settings where Ct screening is not already in place, given the higher

prevalence of Ct infection in virtually all settings. Therefore, stand-alone GC screening criteria are not of practical use in an ED. However, stand-alone Ct criteria may be useful in an ED setting where cost is an issue.

The set of possible predictor variables included demographics (age, education, and current marital status), sexual behaviors (condom use, number of sex partners, and time of last new sex partner), partner characteristics (sexual contact with an STI-infected person and sexual contact with a person who has concurrent partners), health care utilization (current insurance status, primary health care–seeking behaviors, reason for ED visit, and antibiotic use), and STI health status (history of Ct/GC infection and genitourinary symptoms indicative of an STI).

We examined the crude association between each predictor variable and the four possible outcomes using unadjusted prevalence odds ratios (PORs) and their associated 95% confidence intervals (CI). Variables for which $p < 0.20$ were selected for evaluation in multiple unconditional logistic regression.[22] The first model, or ''reference model,'' included all predictors identified during bivariable analyses. Variables were removed from the reference model based on the Wald chi-square p-value in the unconditional logistic model, beginning with the variable with the highest p-value.[23] We used receiver operating characteristic (ROC) curves and likelihood ratio tests to assess model performance during the model building process. Changes in the area under the ROC curve were used to assess variations in model performance due to collapsing across categories or removing variables. In addition, likelihood ratio tests were used to evaluate significant changes in model performance due to removal of variables. The modeling procedures were limited to those persons with complete data for all variables in the reference model. The final model, or ''reduced model,'' includes all predictors for which $p < 0.05$.

We created applicable weighted clinical risk scores for each of the four outcomes using the β-coefficients corresponding to each predictor in the reduced model. We assigned different weights to each predictor based on the distribution of the β-coefficients. For all four models, we assigned a weight of 1 to predictors with $\beta < 0.74$ and a weight of 2 to predictors with $\beta \geq 0.74$. The β-coefficients for the models ranged from 0.30 to 1.18, with 0.74 being the midpoint. Weights were determined post hoc based on the distribution of the β-coefficients. These individual weights were summed to create an overall clinical risk score for each of the four outcomes for each patient. We used 1,000 bootstrap samples with replacement to validate our model and risk score performance.[22]

We examined sensitivity and specificity characteristics of the screening algorithms across all possible risk score cutpoints. We calculated the area under the ROC curve using the risk scores for each outcome. We also examined the percentage of the population that would be screened using each cutpoint. All performance characteristics were examined at the actual prevalence of infection in the study population.

As a final step in our analyses, we assessed the performance of previously developed criteria derived in the same ED setting[11] to predict the likelihood of infection in our ED sample. The previously developed criteria proposed using any one of the following factors to screen for Ct and GC infection among 18- to 31-year-olds: previous history of STI, more than one partner in the past 3 months, or age less than 25 years. Restricting to females, the previously proposed screening criteria were previous history of STI or having a new sexual partner in the past 90 days. We used the criteria proposed in the previous study in our study population and compared the performance characteristics of the algorithms.

RESULTS

Study Population

A total of 7,532 eligible patients were approached to participate, of whom 6,195 patients consented to enroll (82% response rate). Of the consenting participants, 494 patients (8% of those consenting) did not complete the ACASI questionnaire and 164 patients (3%) did not provide a specimen or provided an unusable specimen (e.g., specimen leaked during transport). Only participants who completed the ACASI questionnaire during their ED visit and provided a urine or self-collected vaginal swab specimen with a valid test result are included in these analyses (n = 5,537; 74%).

Characteristics of the Study Population

Overall, 9.6% of participants screened in the ED tested positive for Ct, GC, or both, and 7.1% tested positive for Ct only (Table 1). Most participants screened in the ED were African American (82.4%), and slightly more than half (55.6%) were female. The mean (±SD) age was 25.9 ± 5.2 years. Almost 30% of participants reported having more than one sexual partner in the past 3 months, while 16% reported that their partners had other sexual partners. Only 22% of participants reported using condoms consistently during the last five sex acts. Roughly 40% reported having a prior Ct/GC infection. Almost one-fourth of the participants reported using the ED as their primary source for health care, while 57% reported having some type of health insurance.

Bivariable Analyses

In this ED population, age was the predictor most strongly associated with all four outcomes. Among females, the odds of infection for participants 25 years and younger was 2.4 (95% CI = 1.9 to 3.0) times as high for Ct and GC infections combined and 3.4 (95% CI = 2.5 to 4.7) times as high for Ct infection alone, compared to females older than 25 years. Among males, the odds of infection was nearly four times as high for participants who were 25 years and younger compared to older males for both outcomes (Ct and GC combined OR 3.9, 95% CI = 2.8 to 5.4; and Ct alone OR 3.9, 95% CI = 2.7 to 5.7).

Predictive Models for Females

Among females, younger age, not being married, having a high school education or less, having a new sexual partner within the past 2 years, not reporting the

Table 1
Population Characteristics by Ct and GC Infection Status, Restricted to Complete Cases

Characteristics	Ct and/or GC Positive	Ct Positive Only	Total
Overall	534 (9.6)	391 (7.1)	5,537
Demographics			
Gender			
Female	346 (11.2)	230 (7.5)	3,080 (55.6)
Male	188 (7.7)	161 (6.6)	2,457 (44.4)
Race			
African American	484 (10.6)	354 (7.8)	4,561 (82.4)
Non-African American	50 (5.1)	37 (3.8)	974 (17.6)
Marital status			
Single	458 (10.6)	344 (8.0)	4,306 (77.8)
Married	28 (4.0)	17 (2.4)	706 (12.8)
Divorced/widowed/separated	48 (9.2)	30 (5.8)	522 (9.4)
Education			
Less than high school	230 (10.8)	165 (7.8)	2,125 (38.5)
High school	234 (10.1)	180 (7.8)	2,325 (42.1)
More than high school	70 (6.5)	46 (4.3)	1,071 (19.4)
Age (years), mean ± SD	23.2 (4.6)	22.8 (4.3)	25.9 (5.2)
18–20	189 (17.7)	148 (13.9)	1,067 (19.3)
21–25	204 (11.4)	154 (8.7)	1,789 (32.3)
26–30	87 (6.6)	57 (4.3)	1,314 (23.7)
31–35	54 (4.0)	32 (2.3)	1,367 (24.7)
Sexual behaviors and partner characteristics			
Condom use			
Five of last five times	99 (8.2)	76 (6.3)	1,208 (22.0)
Less than five of last five times	432 (10.1)	313 (7.3)	4,288 (78.0)
Partners in the past 3 months			
Three or more	111 (12.9)	88 (10.3)	860 (15.5)
Two partners	93 (11.6)	63 (7.9)	805 (14.6)
One partner	265 (8.6)	192 (6.3)	3,078 (55.6)
None	65 (8.2)	48 (6.1)	794 (14.3)
Last new partner			
Past 3 months	207 (12.0)	148 (8.6)	1,723 (32.1)
3 to 24 months	218 (10.9)	168 (8.4)	2,005 (37.4)
2+ years	97 (5.9)	64 (3.9)	1,639 (30.5)
Suspect concurrent partners			
Yes/don't know	330 (11.6)	249 (8.8)	2,853 (51.8)
No	203 (7.6)	142 (5.4)	2,660 (48.2)
Partner previously diagnosed with STI			
Yes/don't know	162 (10.1)	120 (7.5)	1,600 (29.0)
No	372 (9.5)	271 (6.9)	3,927 (71.0)
Health care utilization and STI health status			
Health coverage			
No coverage	223 (9.4)	169 (7.1)	2,370 (43.0)
Medicare/Medicaid/HMO/private	308 (9.8)	219 (7.0)	3,146 (57.0)
Primary source for health care			
Non-ED	429 (10.0)	321 (7.5)	4,278 (77.3)
ED	105 (8.3)	70 (5.6)	1,259 (22.7)
Antibiotic use in past month			
No	464 (10.0)	343 (7.4)	4,625 (84.0)
Yes	68 (7.7)	48 (5.5)	881 (16.0)
Prior Ct/GC infection			
Ct	94 (10.7)	63 (7.2)	881 (16.0)
GC	79 (10.8)	55 (7.5)	733 (13.3)
Ct and GC	67 (12.6)	45 (8.5)	531 (9.6)
No	291 (8.6)	226 (6.7)	3,368 (61.1)
Females: dysuria or discharge			
Past 3 months	147 (13.4)	99 (9.1)	1,096 (35.9)
No or >3 months	197 (10.0)	130 (6.7)	1,962 (64.1)
Females: pain during intercourse or bleeding			
Ever	157 (12.2)	103 (8.0)	1,283 (41.8)
Never	188 (10.5)	127 (7.1)	1,784 (58.2)
Males: dysuria, discharge, or pain			
Past 3 months	50 (14.2)	39 (11.1)	353 (14.7)
No or >3 months	134 (6.6)	118 (5.8)	2,043 (85.3)

Data are reported as number (%).
Ct = Chlamydia trachomatis; GC = Neisseria gonorrhoeae; ED = emergency department; HMO = health maintenance organization.

ED as the primary source for health care, not using antibiotics in the past month, reporting a prior Ct/GC infection, experiencing dysuria or discharge in the past 3 months, and ever experiencing any pain during intercourse or bleeding between menstrual cycles were predictors of Ct and GC infection combined in the reference model (Table 2). Demographic predictors of Ct alone were similar to predictors of Ct and GC infection combined, whereas predictors relating to sexual behaviors and genitourinary symptoms differed. In the reference model for Ct alone, the number of sexual partners and suspecting concurrent partners were predictors, while experiencing painful intercourse and bleeding between menstrual cycles were not. We used the area under the ROC curve as a measure of model performance. The ROC areas for the female reference models were 0.6765 for Ct and GC combined and 0.7192 for Ct alone.

The reduced model to predict the likelihood of infection with Ct and GC combined included age less than 25 years, high school education or less, having a new sexual partner within the past 2 years, and experiencing dysuria or discharge in the past 3 months (Table 3). Predictors for Ct alone were similar, with the addition of not reporting the ED as the primary source for health care. There was some loss in model performance resulting in ROC areas of 0.6484 and 0.6944 for the reduced Ct and GC combined and Ct alone models, respectively.

Predictive Models for Males

Among males, younger age, not being married, having three or more sexual partners in the past 3 months, having a new sexual partner within the past 2 years, not having health coverage, no antibiotic use in the past month, and experiencing dysuria or discharge in the past 3 months were predictors of Ct and GC infection

Table 2
Adjusted* Prevalence ORs and Associated 95% CIs for Variables Included in the ''Reference'' Models to Predict Undetected Ct and GC Infections Combined and Ct Infection Alone, by Gender

	Females		Males	
Predictor	Ct and/or GC, Area Under ROC = 0.6765	Ct only, Area Under ROC = 0.7192	Ct and/or GC, Area Under ROC = 0.7483	Ct Only, Area Under ROC = 0.7447
Demographics				
Age	0.64 (0.49, 0.83)	0.64 (0.46, 0.88)	0.97 (0.65, 1.45)	1.14 (0.73, 1.78)
Marital status				
Single	1.40 (0.87, 2.25)	1.65 (0.87, 3.13)	1.41 (0.82, 2.41)	1.46 (0.81, 2.62)
Divorced/widowed/separated	1.85 (1.03, 3.33)	1.86 (0.85, 4.11)	1.0 (ref)	1.0 (ref)
Married	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Education				
High school or less	1.49 (1.08, 2.07)	1.82 (1.19, 2.79)	NIM	1.25 (0.73, 2.13)
More than high school	1.0 (ref)	1.0 (ref)		1.0 (ref)
Sexual behaviors and partner characteristics				
Number of partners past 3 months				
Two or more partners	NIM	1.20 (0.86, 1.65)	1.36 (0.98, 1.89)	1.25 (0.87, 1.80)
One or no partners		1.0 (ref)	1.0 (ref)	1.0 (ref)
Last new partner				
Within past 2 years	1.64 (1.24, 2.17)	1.59 (1.11, 2.28)	1.74 (1.06, 2.85)	1.67 (0.97, 2.88)
Longer than 2 years	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Suspect concurrent partners				
Yes/don't know	NIM	1.16 (0.85, 1.58)	NIM	1.23 (0.83, 1.82)
No		1.0 (ref)		1.0 (ref)
Healthcare utilization and STI health status				
Healthcare coverage				
No coverage	NIM	NIM	1.41 (1.01, 1.97)	1.33 (0.93, 1.91)
Medicare/Medicaid/HMO/private			1.0 (ref)	1.0 (ref)
Primary source for health care				
Non-ED	1.37 (0.96, 1.94)	2.01 (1.25, 3.25)	NIM	NIM
ED	1.0 (ref)	1.0 (ref)		
Antibiotic use				
Not in past month	1.33 (0.97, 1.85)	1.34 (0.90, 2.00)	1.84 (1.05, 3.22)	1.95 (1.05, 3.61)
Past month	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Prior Ct/GC infection				
Within past year	1.18 (0.93, 1.51)	1.36 (0.92, 2.01)	NIM	NIM
No or > 1 year	1.0 (ref)	1.0 (ref)		
Dysuria or discharge				
Past 3 months	1.32 (1.03, 1.70)	1.35 (1.01, 1.81)	2.37 (1.64, 3.41)	1.97 (1.32, 2.95)
No or > 3 months	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Pain during intercourse or bleeding				
Ever	1.15 (0.90, 1.48)	NIM	NIM	NIM
Never	1.0 (ref)			

*Adjusted for all other variable in the model.
Ct = Chlamydia trachomatis; GC = Neisseria gonorrhoeae; ED = emergency department; ROC = receiver operating characteristic; HMO = health maintenance organization; NIM = not in model; ref = reference.

Table 3
Adjusted* ORs and Associated 95% CIs for Variables Included in the ''Reduced'' Models to Predict Undetected Ct and GC Infections Combined and Ct Infection Alone, by Gender

	Females		Males	
Predictor	Ct and/or GC, Area Under ROC = 0.6484	Ct Only, Area Under ROC = 0.6944	Ct and/or GC, Area Under ROC = 0.7193	Ct only, Area Under ROC = 0.7145
Demographics				
Age				
≤25 years	2.18 (1.70, 2.81)	2.94 (2.12, 4.09)	3.25 (2.25, 4.69)	3.15 (2.13, 4.68)
>25 years	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Marital status				
Single	NIM	NIM	1.72 (1.01, 2.92)	1.79 (1.00, 3.18)
Married/divorced/widowed/separated			1.0 (ref)	1.0 (ref)
Education				
High school or less	1.60 (1.16, 2.21)	2.05 (1.35, 3.12)	NIM	NIM
More than high school	1.0 (ref)	1.0 (ref)		
Sexual behaviors				
Last new partner				
Within past 2 years	1.82 (1.39, 2.40)	1.97 (1.41, 2.77)	2.06 (1.28, 3.31)	2.04 (1.22, 3.40)
Longer than 2 years	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Healthcare utilization and STI health status				
Primary source for health care				
Non-ED	NIM	2.03 (1.26, 3.27)	NIM	NIM
ED		1.0 (ref)		
Antibiotic use				
Not in past month	NIM	NIM	1.88 (1.08, 3.30)	1.97 (1.06, 3.64)
Past month			1.0 (ref)	1.0 (ref)
Dysuria or discharge				
Past 3 months	1.34 (1.06, 1.70)	1.38 (1.04, 1.83)	2.38 (1.66, 3.42)	2.06 (1.39, 3.06)
No or > 3 months	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)

*Adjusted for all other variables in the model.
OR = odds ratio; CI = confidence interval; Ct = Chlamydia trachomatis; GC = Neisseria gonorrhoeae; ROC = receiver operating characteristic; ED = emergency department; NIM = not in model; ref = reference.

combined in the reference model (Table 2). Predictors for Ct alone were similar, with the addition of education level and knowing or suspecting that the current sexual partner had other sexual partners. For the male reference models, the ROC area was 0.7483 for Ct and GC combined and 0.7447 for Ct alone.

The reduced model to predict the likelihood of Ct and GC infection combined included age less than 25 years, being single, having a new sexual partner within the past 2 years, no antibiotic use in the past 3 months, and experiencing dysuria or discharge in the past 3 months (Table 3). Predictors for Ct alone were similar. The ROC areas for the reduced Ct and GC combined and Ct alone models were 0.7193 and 0.7145, respectively.

Clinical Risk Score Algorithms

We developed weighted clinical risk scores using the predictors from the final reduced models. For the Ct and GC combined female model, age less than or equal to 25 years was weighted with a score of 2 and having at least a high school education, having a new sexual partner in the past 2 years, and experiencing dysuria or discharge in the past 3 months were weighted with a score of 1. The weights were determined using the

Table 4
Summary of Weighted Clinical Risk Scores and β-Coefficients from Final Reduced Models for Ct and GC Infections Combined and Ct Infection Alone, by Gender

	Females		Males	
	Ct and/or GC	Ct	Ct and/or GC	Ct
Age ≤ 25	2 (0.78)	2 (1.08)	2 (1.18)	2 (1.15)
Single			1 (0.54)	1 (0.58)
High school or less	1 (0.47)	1 (0.72)		
New sex partner within past 2 years	1 (0.60)	1 (0.68)	1 (0.72)	1 (0.71)
Non-ED as primary source for health care		1 (0.71)		
No antibiotic use past month			1 (0.63)	1 (0.68)
Dysuria or discharge past 3 months	1 (0.30)	1 (0.32)	2 (0.87)	1 (0.72)

Ct = Chlamydia trachomatis; GC = Neisseria gonorrhoeae; ED = emergency department.
Weighted risk score calculated assigned a weight of 1 to predictors with $\beta < 0.74$ and a weight of 2 to predictors with $\beta \geq 0.74$.

distribution of the β-coefficients from the final models. The individual risk scores were summed to create an overall clinical risk score algorithm for Ct and GC combined with a range of scores between 0 and 7. For example, a 20-year-old patient reporting that she had experienced dysuria or discharge in the past 3 months would be assigned a risk score of 3. For the Ct only model, age less than or equal to 25 years was assigned a score of 2, and the other four predictors from the final model were weighted with a score of 1 (Table 4).

For males, the predictors in the clinical risk score algorithms were similar for Ct and GC combined and Ct alone, while the weighting differed slightly. For both models, age less than 25 years was weighted with a score of 2 and being single, having a new sexual partner in the past 2 years, and not using antibiotics in the past month were weighted with a score of 1. For the Ct and GC combined model, experiencing dysuria or discharge in the past 3 months was weighted with a score of 2 while it was weighted with a score of 1 for the Ct only model.

Performance Characteristics of Risk Score Algorithms

Across all four models, screening using a lower risk score cutpoint is more sensitive, while screening using a higher risk score cutpoint is more specific (Table 5). In other words, using a lower risk score cutpoint means that more patients who are actually infected would be screened given the higher sensitivity of the algorithm, but it also entails screening a larger proportion of the population. While screening using a higher risk score cutpoint involves screening fewer patients, the specificities using the highest risk score cutpoint are still relatively low.

In all four models, screening using a risk score of ≥2 is equivalent to screening using age alone. Screening females for both Ct and GC combined using age as the criterion has a sensitivity of 94% and a specificity of 18% and would result in screening 83% of the target population (Table 5). If females were screened for Ct only using age as the criterion, the sensitivity would be 99% and the specificity would be 5%, and 95% of the target population would be screened. To screen males for both Ct and GC combined using age has a sensitivity of 99% and a specificity of 9% and would involve screening 92% of the population, while screening for Ct alone has a sensitivity of 100% and a specificity of 9% and 91% of the population would be screened.

Validation of Previously Developed Criteria

To assess the performance of criteria previously developed in the same ED setting,[11] we used the previous criteria in our study population and examined the performance characteristics of the algorithms. Screening using any one of the risk factors, as proposed in the previous study, in our study sample resulted in models with lower sensitivity, 92% compared to 93% for the 18- to 31-year-old model and 69% compared to 78% for the 18- to 31-year-old model restricted to females, and higher specificity, 21% versus 12% and 42% versus 38%, respectively.

DISCUSSION

We assessed the effectiveness of screening for Ct and GC in a busy urban adult ED. Using demographic and behavioral data, we developed four separate ED-specific risk score algorithms to predict current undiagnosed infections. While data suggest that EDs may represent high-yield screening venues, consideration must be given to the logistics of implementing and sustaining routine screening in EDs in the absence of research studies.

We detected levels of infection within the range of prevalences reported in previous studies conducted in ED settings.[11,13,16,24] While screening in the ED appears to

Table 5
Performance Characteristics of the Risk Score Algorithms for Ct and GC Infection Combined and for Ct Alone, by Gender, across All Risk Scores (RS), Given the Prevalence of Infection in the Current Study Population

Characteristics	RS ≥ 1	RS ≥ 2	RS ≥ 3	RS ≥ 4	RS ≥ 5	RS ≥ 6	RS ≥ 7
Females							
Ct and/or GC			Area under ROC = 0.6437				
Sensitivity	0.99	0.94	0.78	0.56	0.22		
Specificity	0.03	0.18	0.42	0.65	0.90		
Percentage of population tested	0.99	0.83	0.61	0.37	0.12		
Ct only			Area under ROC = 0.6883				
Sensitivity	1.00	0.99	0.95	0.81	0.60	0.23	
Specificity	0	0.05	0.23	0.46	0.68	0.91	
Percentage of population tested	1.00	0.95	0.79	0.56	0.34	0.10	
Males							
Ct and/or GC			Area under ROC = 0.7176				
Sensitivity	1.00	0.99	0.92	0.80	0.70	0.21	0.17
Specificity	0.01	0.09	0.29	0.51	0.66	0.94	0.96
Percentage of population tested	0.99	0.92	0.73	0.51	0.37	0.07	0..05
Ct only			Area under ROC = 0.7118				
Sensitivity	1.00	1.00	0.91	0.80	0.64	0.14	
Specificity	0.01	0.09	0.30	0.54	0.69	0.96	
Percentage of population tested	0.99	0.91	0.72	0.48	0.33	0.05	

Ct = Chlamydia trachomatis; GC = Neisseria gonorrhoeae; ROC = receiver operating characteristic.

detect levels of infection comparable to other high-risk settings, several operational hurdles exist that make implementing and sustaining routine Ct and GC screening in EDs a significant public health undertaking. The most significant obstacle is the shortage of human resources required to provide the necessary follow-up and treatment for patients identified as infected. This may be offset in the future, were point-of-care Ct and GC assays to gain greater acceptance. However, other barriers would remain, as have been seen with efforts to implement routine point-of-care HIV testing in EDs.[25–27]

If the decision to implement routine Ct and GC screening in an ED is made, our study provides ED-specific screening criteria that perform reasonably well for predicting infection. Our analyses confirm that age is the strongest predictor of infection. For all four risk score algorithms, screening using age alone is equivalent to screening using a risk score of ≥2 (of a maximum of 7). Given the small increment in predictive power when other screening criteria are included, age alone appears to be a sufficient screening criterion in an ED setting.

As noted, the added burden of time involved in routine screening may be overwhelming to already overburdened ED staff. Additionally, the economic cost of purchasing and testing the assays themselves, outside the context of a research study, must be absorbed by either the ED or the local public health infrastructure. As with any screening program, budgetary constraints will ultimately be the deciding factor in whether or not to implement Ct and GC screening in resource-limited ED settings.

Routine screening rates are relatively low even in settings where resources are available. Analysis of the 1999–2000 Health Plan Employer Data and Information Set determined that despite increases in screening by both commercial and Medicaid health insurance plans, screening rates are low.[28] In 2001, among sexually active females aged 16 to 26 years enrolled in commercial health insurance plans, 26% were screened for chlamydial infection, while 38% of 16- to 26-year-olds in Medicaid plans were screened. These proportions represent increases of 6 and 10%, respectively, over the percentages screened in 1999. Despite the increase, these percentages fall well below current recommendations to routinely screen all sexually active females younger than 26 years.

Despite the operational and financial obstacles involved in routine screening, the cost of missed infections can be substantial. Undetected infections can cause serious clinical sequelae. In women, untreated Ct and GC infections can ascend from the vagina or cervix into the upper genital tract and cause infections in the endometrium, fallopian tubes, and contiguous structures resulting in pelvic inflammatory disease (PID). The tubal scarring associated with PID can lead to complications such as infertility, ectopic pregnancies, and chronic pelvic pain. If these infections are not treated adequately, 20% to 40% of Ct infected women and 10% to 40% of GC infected women may develop PID.[2] With Ct infections, undertreatment can also lead to recurrent or persistent infections.[29–32] Furthermore, infants born to infected mothers are susceptible to conjunctivitis and neonatal pneumonia, and in men, untreated infections increase the risk of urethritis, prostatitis, and epididymitis.[33] Additionally, undetected and untreated infections may be transmitted to sex partners.

LIMITATIONS

There was a high uniformity of race in our population. We did not include race information during the development of the risk score algorithms due to the potential sensitivity of proposing screening criteria based on an individual's racial and ethnic background. However, we did evaluate our models including race to evaluate its impact, and there was no detectable difference. Because certain racial backgrounds are associated with higher risk of infection, it is possible that our population as a whole is at elevated risk, making identifying factors that would put a patient at even higher risk difficult. The high uniformity of race in our study population could help explain the poor predictive performance of our models. This study was conducted at a single, urban ED with specific demographic characteristics, thus limiting the potential generalizability of our results to other settings and patient populations.

Similar to previous ED studies, we relied on dedicated study personnel and funding to conduct all screening activities. Given this, our research does not provide an accurate representation of the effectiveness of fully integrating STI screening into routine ED practices.

The weights attributed to each risk factor in our final risk score algorithms were determined post hoc and using the distribution of the β-coefficients in our final models. While it is possible that our weighting scheme may have resulted in overweighting age, using the more common practice of rounding the β-coefficient to the nearest integer and multiplying by 10 would have also resulted in age being the most heavily weighted predictor and a more complicated risk score algorithm. Finally, the algorithms presented in this report should be considered in the development of screening programs for asymptomatic populations and should not be interpreted as guidelines for the treatment of individual patients.

CONCLUSIONS

Our findings suggest that age alone appears to be a sufficient criterion for screening in a busy ED. While this approach necessitates selectively screening a larger proportion of the population, using more specific screening criteria and multiple risk factors results in not screening a substantial number of infected patients. Ultimately, the decision to implement routine screening for Ct and GC in an ED will be determined by the availability of resources. However, given that the prevalence of Ct and GC remains high despite screening efforts in traditional clinical settings and the significant clinical sequelae of untreated infections, ED screening may warrant being moved to the forefront of nonclinic STI screening programs.

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