HHS Public Access

Author manuscript

Sex Transm Dis. Author manuscript; available in PMC 2023 November 01.

Published in final edited form as:

Sex Transm Dis. 2023 May 01; 50(5): 252–257. doi:10.1097/OLQ.0000000000001767.

Evaluation of Sexually Transmitted Disease Surveillance System Electronic Laboratory Processing in Florida: Automating Case Creation, Reporting, and Closure of Chlamydia and Gonorrhea Cases

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Abstract

Background: Each year, Florida Department of Health staff process hundreds of thousands of electronically received laboratory results for chlamydia (CT) and gonorrhea (GC). These processing steps are currently performed manually in Florida's surveillance system and divert from other sexually transmitted disease prevention efforts. We developed processes that would automate these procedures and evaluated the impact on potential programmatic time savings.

Methods: We evaluated 575,952 electronic CT/GC laboratory results from January 2019 to December 2021. Laboratory results were processed through the newly automated procedures and algorithms. Expected time savings were projected using conservative estimates of 1 minute saved every time an automated process replaced a current manual procedure: profile matching, profile creation, event record creation, case review, and case reporting. Exceptions to automatic case reporting applied to certain higher-priority populations needing intervention.

Results: During this period, 297,348 electronic CT/GC laboratory results were received for people with no previous recorded history of sexually transmitted diseases and required profile creation. In total, 386,763 new surveillance infection records were created for reporting. Of reported cases, 127,345 were from higher-priority groups. The proposed automations would have saved an estimated 33,121 hours of staff time, about 11,040 hours or the work of 5.3 full-time staff annually.

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Conflict of Interest and Sources of Funding: None declared.

Disclaimer: The findings, opinions, and conclusions in this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the authors' affiliated institutions.

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Conclusions: Automating current CT/GC laboratory processing would save thousands of personnel hours that could be redirected to higher-priority activities. Flexibility in prioritization criteria for automated case reporting allows programs to adjust automation to disease prevention priorities and resources. Similar automation procedures could be developed by other jurisdictions or health programs.

In 2020, there were 100,030 *Chlamydia trachomatis* (CT) and 40,788 *Neisseria gonorrhoeae* (GC) infections reported among Florida residents.[1] Healthcare providers and laboratories are required to report positive CT and GC laboratory results per Florida Administrative Code, Rule 64D-3.029.[2] The Florida Department of Health (FDOH) also receives thousands of additional CT and GC results from duplicate laboratory reports, follow-up testing, and tests of cure.[3–5]

Historically, case and laboratory reports of CT and GC were reported by telephone, mail, or fax; however, the alignment of electronic messaging between laboratories and health departments now allows for the transmission of these results electronically without human resources.[6–8] The number of laboratories reporting test results through electronic laboratory reporting (ELR) continues to expand in Florida and nationally.[9] In addition to ELR expansion, both CT and GC testing underwent major changes in the primary method of pathogen detection, opting to use more sensitive testing methods like urine-based nucleic acid amplification tests over site-specific swab cultures.[10,11] Each of these changes increased the likelihood of a case of CT or GC being detected and reported to the health department, as well as improved the potential timeliness of the infection being reported.[12,13]

Currently, FDOH receives most CT and GC results through ELR (91%). These results from the laboratory are sent to an integration broker (a third-party management intermediary that translates data between different applications together) that translates the laboratory results into a laboratory holding table. Stored procedures in the statewide FDOH sexually transmitted diseases surveillance system (STDSS) identify CT and GC laboratory results to transfer from the holding table to the STDSS laboratory results table. Local program area staff are then able to view the CT and GC laboratory results among residents of their program area.

Local staff compare person-data (e.g., name, date of birth, sex, race/ethnicity) of newly received CT and GC results to determine if the results belong to a person already in the STDSS (person-data matching). They then either match the laboratory result to a previously known individual or create a new profile to attach the laboratory results. Laboratory results are assessed based on the person's history in STDSS to determine whether the results constitute a new infection. The results of the infection are then assigned a case outcome (disposition) and morbidity status (whether the infection constitutes a reportable case). This outcome is reviewed by a frontline supervisor or area manager. Finally, those CT and GC infections that count toward morbidity numbers are reported to the Centers for Disease Control and Prevention (CDC) for surveillance purposes.

Although ELR initially automated a significant portion of sexually transmitted disease (STD) surveillance, most of the subsequent steps in the process remain manual. Electronic

laboratory reporting has created additional case volume for local staff, by increasing the number and type of consistent reporting from laboratories, as well as timeliness of laboratory results reported. However, STDSSs have not been correspondingly improved to maximize possible technological benefits.[5,8,12–14] Person-data matching methods used by a variety of industries to assist in business practices could also be used by the STDSS to aid in laboratory results matching to person-data within the STDSS.[8,9,15,16] Moreover, other disease surveillance programs have identified algorithms that process laboratory results and determine new infections aligned with respective case definitions.[17–19] Only a few groups of people with CT and GC infections in Florida are considered priority for investigation (i.e., children younger than15 years, pregnant women, county health department patients, grant-specified enhanced surveillance cases, rectal infections, certain repeat infections, people diagnosed with other STD comorbidities). Therefore, programs could modify their surveillance system procedures and protocols, such as reassessing which infections need supervisory review, to align with program priorities and available staff resources.[5,8,13,14]

Florida Department of Health STD surveillance staff recognized inefficiencies in laboratory-to-person-data matching, case creation and reporting, and case prioritization; resource capacity issues for processing the volume of CT and GC ELR results; and opportunities to improve their STDSS to address these issues and inefficiencies. The goal was to develop procedures to match incoming laboratory results to historical STD person-data, create an algorithm for processing results to align with current case definitions (including additional laboratory results associated with the same infection), and implement processes for autoclosing and reporting lower-priority infections to surveillance stakeholders.

Before implementation, we assessed these potential automations using historical CT and GC laboratory data to assess their prospective benefit in terms of laboratory results modified through each step in the STDSS. We translated these processed laboratory results into potential time savings for the STD program staff. Finally, we compared investigation and treatment outcomes for nonprioritized CT and GC cases that would have been auto processed for case reporting to assess potential outcomes in treatment verification for the STD program.

METHODS

Data Source and Variables

Deidentified ELR CT and GC laboratory results received from January 2019 to December 2021 were collected for this analysis. Variables collected for each laboratory result included profile ID, surveillance infection record ID, laboratory record ID, specimen source, test type, test result, infection tested for, case reporting status, disposition code/description describing the patient's status after investigation (e.g., brought to treatment, treatment not documented, not investigated), sex, age, race/ethnicity, pregnancy status, public or private ordering provider, and system processing dates and statuses for the laboratory result generated by the STDSS.

Changes in ELR Processing Steps

Most of the processes for incorporating ELR into the STDSS are manual after receiving laboratory results into the laboratory holding table. The proposed changes in these processes aim to automate these functions in 3 main phases (Fig. 1), with multiple steps in each phase, to be run nightly.

Phase 1 matches laboratory data to existing person-data in the STDSS. These processes begin with formatting and preparing the ELR laboratory results to be inserted into the STDSS. Laboratory results pulled from the holding table experience a series of mapping transformations relating to providers, ordering facilities, specimen types, and laboratory accession numbers. They are then inserted into the STDSS's laboratory results table. Next, the system performs a person-data matching search in the STDSS to determine whether the person has an existing profile using an exact match of first name, last name, and date of birth. A new profile is created if there is no existing profile, and profile information is updated for existing profiles if the incoming laboratory result contains new information (e.g., updated home address, additional race/ethnicity data).

Phase 2 determines whether the laboratory result meets the CDC and the Council of State and Territorial Epidemiologists case definition for a CT or GC infection.[20,21] Algorithms in the STDSS assess whether the laboratory result is positive or negative. For positive results, the system determines if the patient has a history in the STDSS and generates a surveillance infection record for those with no history of any infection, as a positive result without history would meet the surveillance definition. Among those with a history of the same disease, the current specimen collection date is compared against the most recent of the previous treatment date or specimen collection date. A new surveillance infection record is generated for those meeting the case definition, whereas those not meeting the case definition (e.g., duplicate reports, reports with specimen collection dates less than 30 days apart) are appended to the previous related record. Negative laboratory results are only processed for individuals with a history in the STDSS. A negative laboratory result will either have a record generated, indicating a "not infected" event, or be appended to an existing surveillance infection record (e.g., tests of cure, multisite testing). Negative laboratory test results are ignored for persons without a known STD history.

Phase 3 determines which laboratory results require staff follow-up versus automated closure and reporting. For the purposes of our algorithm, prioritized groups (i.e., children younger than 15 years, pregnant women, county health department patients, grant-specified enhanced surveillance cases, rectal infections, certain repeat infections, people diagnosed with other STD comorbidities) were designated (prioritized and nonprioritized categories are not currently part of STDSS processing) and excluded from the automated case closure and reporting step. Prioritized cases are assigned to a field staff to follow-up based on program directives. Prioritized CT and GC cases will be investigated and reported by field staff after program interventions such as treatment and partner services are provided. Cases not meeting any priority criteria listed previously will have the surveillance infection record completed with a disposition of "infected" and closed by the system, reported as a case, and counted toward Florida's morbidity numbers.

Analyses and Estimates

The frequency for which each CT or GC ELR laboratory result was processed through each of the automated steps in Figure 1 was assessed. With the use of a retrospective data set, we determined laboratory matches to person-data within the STDSS by checking if a new profile was generated from an initial laboratory attachment to the profile. Case status was determined using the assignment of morbidity by FDOH staff, following CDC/Council of State and Territorial Epidemiologists case definitions for CT and GC reporting. Prioritized populations were assessed, and frequencies were determined sequentially in the following order: county health department patients (public providers), pregnant women, children younger than 15 years, cases flagged for grant-funded follow-up interviews (10% of randomly selected GC cases), rectal infections, and cases with an HIV or syphilis comorbidity. Comorbidity with HIV was determined as a positive HIV status any time before the current CT or GC infection, whereas syphilis infection comorbidity was defined as having a positive syphilis laboratory result with the same date as the current CT or GC infection. If a laboratory result was found to belong to a priority population in the order shown previously, it was prioritized for follow-up and not included in further algorithm automations.

Estimated potential programmatic time savings were projected by using a conservative estimate of 1 minute saved every time the algorithm would have automated each step: laboratory/surveillance system person-data matching, new person-data profile creation, new infection criteria determination, new surveillance infection record creation, new negative laboratory result record creation or appending of current laboratory result to previous surveillance infection record, and closure/reporting of surveillance infection record for nonprioritized populations. The maximum estimated time that could be saved from one ELR laboratory result requiring a new person-data profile creation in the STDSS would be 5 minutes, and for one result *not* requiring a new profile creation would be 4 minutes, if all automated steps were required (Fig. 1). Furthermore, whole study estimated time savings were assessed as full-time employees (FTEs) and estimated annual cost savings. Full-time employees were calculated as the number of annual hours saved divided by 2080 (i.e., the number of work hours in a year). Annual cost savings were calculated as the number of FTEs multiplied by the average salary, including overhead (i.e., $40,000 salary plus 25% overhead [$10,000] = $50,000), for a person doing this work. Finally, we compared the frequencies and percentages of all investigation and treatment outcomes between CT and GC infections for nonprioritized population surveillance infection records during the study period. Investigation and treatment outcomes were categorized as follows: investigated and appropriately treated, investigated and received nonstandard treatment, investigated and treatment not documented, not investigated, and other.

Statistical Analysis System version 9.4 (SAS Institute, Cary, NC) was used for all analyses. All data captured in this analysis are part of routine STD surveillance activities. The project was reviewed by the FDOH Institutional Review Board Office and classified as “exempt” and determined to be public health practice quality improvement, not research involving human subjects.

RESULTS

The flow of all reviewed CT and GC laboratory results through the automation process, along with accompanying numbers and percentages, is shown in Figure 1. From January 1, 2019, to December 31, 2021, there were 575,952 CT and GC laboratory results electronically received and imported into the STDSS. Of these, 297,348 results (52%) were for people with no previous recorded history of STDs and required a new person-data profile creation in the system. The remaining 278,604 results (48%) received matched existing profiles.

New surveillance infection records were automatically created for each positive laboratory result that did not have matching person-data in the STDSS with a history of disease (n = 297,348). Of the 278,604 laboratory results that did have matching person-data in the STDSS, 89,415 results (15% of total laboratory results) were determined to be new infections and a surveillance infection record was created. The remaining 189,189 results (33% of total laboratory results) did not meet the criteria for a new infection and were either appended to an existing surveillance infection record (n = 79,511 [14% of total laboratory results]) or were negative laboratory results from follow-up testing, and a new negative laboratory result record was generated (n = 109,678 [19% of total laboratory results]).

In total, 386,763 (n = 297,348 + 89,415) new surveillance infection records (67% of total laboratory results) were created. Of these, 259,418 records (45% of total laboratory results) would not have been considered priority cases, resulting in automatic closure and reporting as a new infection. The remaining 127,345 records (22% of total laboratory results) were among one of the priority population groups and would have been assigned to a local field staff to conduct an investigation: county health department patients (n = 60,911), pregnant women (n = 15,481), children younger than 15 years (n = 5163), cases flagged for grant-funded follow-up interviews (n = 26,764), rectal infections (n = 29), those with HIV comorbidity (n = 15,294), and those with syphilis comorbidity (n = 5422; Fig. 1).

An estimated 33,121 hours would have been saved from start to finish of automation for CT and GC laboratory reporting over the 3 years, and annualizing the estimated time savings would result in a total of 11,040 hours saved per year (Table 1). The annualized time savings from automating these processes equates to an estimated 5.3 FTEs per year. Furthermore, if the FTE time savings were transposed into cost savings, it would result in an estimated $265,394.50 saved annually.

Stage 1 accounts for the largest amount of time savings, with its focus on person-data matching and profile creation having 14,555 hours saved (n = 9599 hours from laboratory/surveillance system person-data matching and 4956 hours from new person-data profile creation), not including potential time savings from updating person-data. Stage 2's new infection criteria determination, creation of new surveillance infection records, and creation of new negative laboratory result records or appending of current results to existing surveillance infection records showed 14,243 hours saved (n = 4643 + 6446 + 3153). Finally, stage 3 is estimated to save 4324 hours by automatically completing, closing, and reporting surveillance infection records for nonprioritized populations.

Most of the nonprioritized infections in the study period were CT infections (73.1%; Table 2). Among nonprioritized CT and GC infections, nearly 60% (n = 153,662) were not investigated by staff. Among those investigated, 6662 (6.3%; 2.6% of all nonprioritized infections) did not have known treatment documented. Persons without documented treatment were slightly more common among investigated CT (6.8%) than GC (5.1%).

DISCUSSION

Our evaluation of the proposed automation shows that there are several STDSS processes that can be automated for CT and GC surveillance. The automations are estimated to save thousands of personnel hours per year (or hundreds of thousands of dollars in program budgeting). This is important not only because of time savings but also because of reduced work for staff on repetitive tasks, and ability to redirect or prioritize additional program activities and to provide consistency across local programs. The saved hours and dollars could be redirected toward higher-priority STD prevention activities, collecting higher-quality data on cases, syphilis and HIV case management, and partner services. In addition, although not assessed, these automated processes might reduce manual data entry errors, improve data quality, save time spent on quality assurance, and improve job satisfaction of personnel.[22]

Errors could occur from the automated processes (e.g., not matching to the appropriate existing profile), but the problems and solutions would be more systematic than the current manual processes and can be specifically identified and addressed. Incorporating automation in disease surveillance may not be novel, but this study highlights the value of evaluating these changes before implementation.[23–25]

Time and cost savings are estimates and would vary by program based on salary/overhead projections, case definition complexity, and surveillance data processing procedures. Programs outside of the United States have also automated surveillance processes to prevent reporting duplication and implement timely and priority interventions.[26,27] Other programs found cost savings from automating aspects of their surveillance systems with lower volume than this evaluation.[18,19,28] Furthermore, time savings in this evaluation should be viewed as conservative estimates. Using 1-minute per step of automation method is certain to be an underestimation of some of the processes. The difference in repetitive processing times between human and machine is difficult to quantify, as there are aspects of human nature to consider when performing repetitive tasks.[29] For example, a person performing person-data entry and matching might get interrupted talking to coworkers or responding to emails, require bathroom/lunch breaks, or need a few minutes to rest their eyes from staring at a computer screen. Alternatively, machines can do these processes continuously with zero downtime. The time needed to complete tasks that would be automated are, on average, underestimated as matching and updating person-data and completing case investigations may involve acquiring data from outside sources (e.g., public records/electronic health databases, directly from healthcare provider offices). Finally, we were unable to assess some automations that might save additional time, such as the updating of person-data (e.g., addresses, telephone numbers) for matched individuals.

In contrast, there are possibilities for time savings reduction that were not assessed. De-duplication efforts may increase from the automation processes if duplicate records are created, due to small spelling, spacing, or punctuation differences. However, a person may duplicate exact match profiles that the automated matching process would not. Prioritization of surveillance infection records for persons with multiple previous STD infections, not assessed in this evaluation, will reduce savings based on how often this occurs. These aspects, including updated time savings, could be further evaluated after automation implementation.

Another reason for follow-up evaluation after implementation is to examine the processing of priority populations. One limitation of this evaluation was that CT and GC laboratory results and treatment outcomes were reviewed retrospectively. This may have affected which results would have been excluded from automation based on investigation of those meeting priority criteria. In addition, persons without documented treatment might have not been treated or may have received unreported treatment. Furthermore, not all processes are fully assessed at this time (e.g., persons with multiple previous STD infections). There may be modification to processes and procedures during implementation or additional factors not considered in this evaluation. One benefit to the logic involved in prioritizing populations is that it is fully modifiable to address meeting different client and program needs and outcomes. Another limitation is that many of the laboratory results received were missing specimen source information. This is likely a result of these data not being transmitted or received, instead of data entry error. Improvements in capturing this data would result in more prioritized cases needing follow-up by local staff.

Although the automation saves time processing and closing cases, the automated closure of nonprioritized cases from private providers risks negative reproductive health outcomes if patients are not treated properly. Missed treatment, particularly for CT, could lead to pelvic inflammatory disease and result in ectopic pregnancy or infertility.[30,31s] Furthermore, inappropriate treatment may increase the risk of untreatable GC and treatment failure because of antibiotic resistance.[32s,33s] Automated closure of CT and GC cases could result in fewer persons with reported infections receiving appropriate treatment and follow-up. These added risks of automatic case closures are minimized; however, given that most infections in nonprioritized populations are currently not investigated, and of those that were investigated, the majority was found to have been treated appropriately. Other studies have also shown that most GC is properly treated, without local health department intervention.[34s,35s] Future work should evaluate a subset analysis of these nonprioritized cases after implementation to quantify the benefits of treatment verification compared with the benefits of automated case closure.

Although it is anticipated to save time and money in the coming years, there are large up-front costs with this type of automation, stemming from funding a high-quality development team and dedicating program staff as subject matter experts. Saving time with automated processes will shift some work toward more technical tasks of planning, testing, and maintaining these systems. Qualified staff often require higher salaries and might be more difficult to recruit.

Although the programmatic code might not translate directly across STDSSs or programs, this approach provides a framework where similar automation concepts could be adapted to fit specific STD program goals and needs of other jurisdictions. Likewise, this type of approach could be used beyond CT and GC to automate processes and procedures surrounding the integration and incorporation of other diseases, including those with more complex laboratory-based criteria. Automating more complex criteria, such as syphilis or hepatitis surveillance, would be proportionally more difficult but could have even greater time savings. This evaluation is an important reminder that jurisdictions should continue to assess implemented changes and share their outcomes with others as they continue investing in STD surveillance informatics.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments:

The authors appreciate all the disease intervention specialists, frontline supervisors, area managers, and sexually transmitted disease program staff across Florida for their work in chlamydia and gonorrhea disease reporting, surveillance, and data quality efforts.

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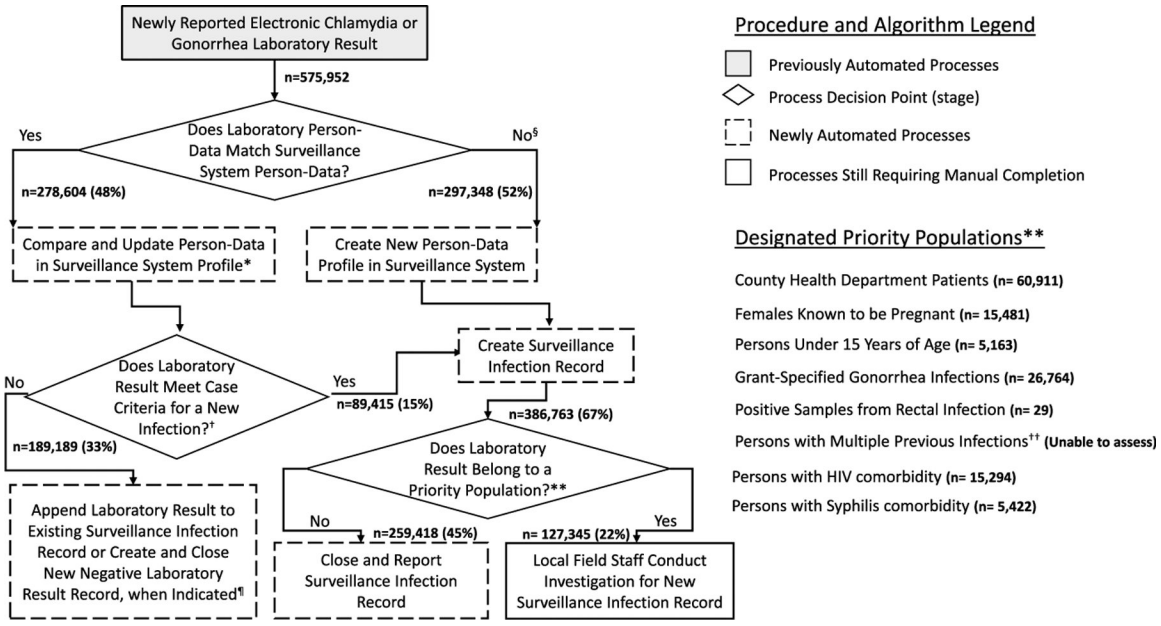

Figure 1.

*This process and procedure are needed in the final design for automation but are not assessed in this evaluation that used deidentified data. †C trachomatis or N gonorrhea identified by nucleic acid amplification test or by culture and no evidence of previous infection or evidence of previous infection but new specimen collection was >30 days from treatment for previous infection when treatment was determined or >30 days from previous specimen collection when treatment was not determined for previous infection. ¶Negative laboratory results are only appended for persons with a history of reported infection within Florida's STD Surveillance System. Negative result records are not created for individuals without an infection history. **Priority populations as determined by the Florida Department of Health STD Program to address meeting client and program outcomes. ††Persons with multiple previous chlamydia and gonorrhea infections consist of an algorithm to identify persons with 3 or more infections automatically closed without investigation and every other infection for persons with 3 or more infections in the preceding 12 months. Because this process is not yet in place, this cohort has not been evaluated to determine the frequency of assignment to local field staff. Further evaluation will be required upon implementation. §Negative laboratory test results are not brought into the STDSS for persons not already in the system with a known STD history. Thus, all laboratory results with this determination (n = 297,348) are positive and will move to the next step to create a new surveillance infection record. Note that the percentages shown represent the percentage of the total number of laboratory results received (n = 575,952).

TABLE 1.

Time Savings Estimates* for Each Electronic Chlamydia or Gonorrhea Laboratory Result Requiring Newly Automated Processes or Procedures

Process or Procedure	No. Events	Hours Saved†	FTE's Saved‡
Laboratory/surveillance system person-data matching	575,952	9599	4.6
New person-data profile creation	297,348	4956	2.4
Update existing person-data§	N/A	N/A	N/A
New infection criteria determination	278,604	4643	2.2
New surveillance infection record created	386,763	6446	3.1
New negative laboratory result record created or current laboratory result appended to previous surveillance infection record	189,189	3153	1.5
Close and report surveillance infection records for low-priority populations	259,418	4324	2.1
Local field staff conduct investigation for new surveillance infection records for high-priority populations	127,345	N/A	N/A
Total (3 y)		**33,121**	**15.9**
Total annualized		**11,040**	**5.3**

*Time savings estimates were made conservatively using a 1-minute estimate per event that was automated during processing of laboratory result. Not all processes or procedures were performed on each laboratory result.

†The numbers for "hours saved" were calculated by dividing the "number of events" by 60 (minutes).

‡The numbers for "FTEs saved" were calculated by dividing the "hours saved" by 2080 (work hours in a year).

§The number of laboratory events requiring this process or procedure was not able to be calculated using a deidentified data set from the study design.

TABLE 2.

Investigation and Treatment[*] Outcomes for Nonpriority Population Chlamydia and Gonorrhea Surveillance Infection Reports[†] in Florida, 2019 to 2021

Investigation and Treatment Outcome	Chlamydia Infections		Gonorrhea Infections		Total Infections	
Investigated, appropriately treated	69,896	26.9%	27,998	10.8%	97,894	37.7%
Investigated, received nonstandard treatment	95	<0.1%	1047	0.4%	1142	0.4%
Investigated, treatment not documented	5091	2.0%	1571	0.6%	6662	2.6%
Not investigated	114,768	44.2%	38,894	15.0%	153,662	59.2%
Other[‡]	44	<0.1%	14	<0.1%	58	<0.1%
Total	**189,894**	**73.1%**	**69,524**	**26.8%**	**259,418**	**100.0%**

[*] Treatment was defined using the CDC 2021 STI treatment guidelines.

[†] Positive infection reports counted toward Florida's morbidity numbers.

[‡] For STD programs, "other" consisted of the following dispositions: administrative closure, refused examination, refused partner services, refused preventive treatment, unable to locate, patient deceased, preventive treatment, and previously treated for this infection.