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Author manuscript

*Ann Am Thorac Soc.* Author manuscript; available in PMC 2021 May 05.

Published in final edited form as:

*Ann Am Thorac Soc.* 2020 November ; 17(11): 1401–1412. doi:10.1513/AnnalsATS.201908-623OC.

## Tuberculosis among Newly Arrived Immigrants and Refugees in the United States

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### Abstract

**Rationale:** U.S. health departments routinely conduct post-arrival evaluation of immigrants and refugees at risk for tuberculosis, but this important intervention has not been thoroughly studied.

**Objectives:** To assess outcomes of the post-arrival evaluation intervention.

**Methods:** We categorized at risk immigrants and refugees as: with recent completion of treatment for pulmonary tuberculosis disease overseas (including Mexico and Canada); with suspected tuberculosis disease (chest radiograph/clinical symptoms suggestive of tuberculosis) but negative cultures overseas; or with latent tuberculosis infection diagnosed overseas. Among 2.1 million US-bound immigrants and refugees screened for tuberculosis overseas during 2013–2016, 90,737 were identified as at risk for tuberculosis. We analyzed a national dataset of these at risk immigrants and refugees, and calculated rates of tuberculosis disease for those who completed post-arrival evaluation.

**Measurements and Main Results:** Among 4,225 persons with recent completion of treatment for pulmonary tuberculosis disease overseas, 3,005 (71.1%) completed post-arrival evaluation within 1 year of arrival; of these, 22 were diagnosed with tuberculosis disease (732 cases/100,000 persons): 4 sputum culture-positive cases (133 cases/100,000 persons), 13 sputum culture-negative cases (433 cases/100,000 persons), and 5 cases with no reported sputum culture results (166 cases/100,000 persons). Among 55,938 with suspected tuberculosis disease but negative cultures overseas, 37,089 (66.3%) completed post-arrival evaluation; of these, 597 were diagnosed with tuberculosis disease (1610 cases/100,000 persons): 262 sputum culture-positive cases (706 cases/100,000 persons), 281 sputum culture-negative cases (758 cases/100,000 persons), and 54 cases with no reported sputum culture results (146 cases/100,000 persons). Among 30,574 with latent

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**Authors' contributions:** Mr. Liu and Drs. Phares, Posey, Maloney, Cain, Weinberg, Schmit, Marano, and Cetron developed the project idea and plan of analysis. Mr. Liu created the analysis datasets and conducted the statistical analyses. All authors were involved with the interpretation of the results from the data analysis. Mr. Liu wrote the first draft of the manuscript. All other authors (Drs. Phares, Posey, Maloney, Cain, Weinberg, Schmit, Marano, and Cetron) reviewed the draft and provided critical comments and suggestions to Mr. Liu. All authors reviewed the draft manuscript and provided input for revision. All authors have read and approved the final manuscript.

tuberculosis infection diagnosed overseas, 18,466 (60.4%) completed post-arrival evaluation; of these, 48 were diagnosed with tuberculosis disease (260 cases/100,000 persons): 11 sputum culture-positive cases (60 cases/100,000 persons), 22 sputum culture-negative cases (119 cases/100,000 persons), and 15 cases with no reported sputum culture results (81 cases/100,000 persons). Of 21,714 persons for whom treatment for latent tuberculosis infection was recommended at post-arrival evaluation, 14,977 (69.0%) initiated and 8,695 (40.0%) completed treatment.

**Conclusions:** Post-arrival evaluation of at risk immigrants and refugees can be highly effective. To optimize yield and impact of this intervention, strategies are needed to improve completion rates of post-arrival evaluation and treatment for latent tuberculosis infection.

### Keywords

post-arrival evaluation; latent tuberculosis infection; treatment

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### Introduction

Finding and treating tuberculosis (TB) disease and latent TB infection (LTBI) in foreign-born persons are crucial to achieving TB elimination in the United States (1, 2, 3, 4). In 2018, TB incidence was 2.8 cases per 100,000 persons in the United States, and 69.5% (6,276) of 9,029 new TB cases were among non-U.S.-born persons (5). Incidence of TB disease among foreign-born persons is highest within the first year of arrival in the United States (6, 7). During 2013–2016, persons within 1 year of arrival accounted for 16.5% of non-U.S.-born TB cases and 24.8% of non-U.S.-born multidrug-resistant TB (MDR-TB) cases (8). To reduce the importation of TB to the United States, U.S.-bound immigrants and refugees are required to undergo screening for TB overseas (including Mexico and Canada) and, when indicated, receive directly observed therapy to cure (9, 10, 11). Before 2007, the overseas screening used a sputum smear-based algorithm that could not diagnose smear-negative but culture-positive TB (10). In 2007, the U.S. Centers for Disease Control and Prevention (CDC) developed a new algorithm to include mycobacterial culture for persons with a chest radiograph suggestive of TB and directly observed therapy for those diagnosed with TB disease (11). Implementation of the new culture-based algorithm began in 2007 and was scaled up to all countries by 2013.

In addition to reducing importation of TB through treatment of TB disease overseas, the implementation of culture-based screening also identifies a large number of persons at risk for TB (11). Among 2,102,415 arrivals of immigrants and refugees during 2013–2016, 90,737 were identified overseas as at risk for tuberculosis. CDC routinely notifies state and local health departments of at risk immigrants and refugees entering their jurisdictions so they can follow up to screen for TB during domestic medical examination (9, 10, 11, 12). We analyze the outcomes from these post-arrival evaluations conducted during a 4-year period.

## METHODS

### Definition of immigrants and refugees

Immigrants, also known as lawful permanent residents or green card recipients, are persons who have been granted lawful permanent residence in the United States. In this analysis, “immigrants” referred to newly arrived persons admitted as immigrants from overseas. Newly arrived immigrants are distinct from adjustment-of-status immigrants, which refers to persons who enter the United States in a non-immigrant status, and later adjust their status to lawful permanent residents. Refugees are persons who are unable or unwilling to return to their country of nationality because of persecution or a well-founded fear of persecution due to race, religion, nationality, membership in a particular social group, or political opinion. Refugees apply for refugee status outside the United States. In this analysis, “refugees” referred to persons admitted from overseas as refugees including follow-to-join refugees (eligible relatives of previously admitted refugees). U.S.-bound immigrants and refugees are required to have overseas medical examination, and adjustment-of-status immigrants are required to have medical examination in the United States. This analysis does not include adjustment-of-status immigrants.

During 2013–2016, there were 2,102,415 arrivals of immigrants and refugees, and 1,772,281 adjustment-of-status immigrants (not including refugees) in the United States (data were from the U.S. Department of Homeland Security).

### Overseas TB screening

TB screening is a major component of the mandatory medical examination for U.S.-bound immigrants and refugees (9, 10, 11). The examination is performed overseas by “panel physicians”, licensed local physicians who are appointed by U.S. embassies and consulates (13). CDC provides technical instructions and quality oversight for the examination. The culture-based algorithm, which is used in TB screening and treatment, requires all persons aged ≥ 15 years to have a chest radiograph, and those aged 2–14 years in countries with a TB incidence ≥ 20 cases/100,000 population/year to undergo a tuberculin skin test or interferon- $\gamma$  release assay and, if positive, to have a chest radiograph (11). Persons with a chest radiograph or clinical signs or symptoms suggestive of TB must provide 3 sputum specimens to undergo microscopy for acid-fast bacilli, culture for mycobacteria, confirmation of the mycobacterium species at least to the mycobacterium tuberculosis complex level, and drug susceptibility testing for positive cultures. Completion of directly observed therapy is required for those diagnosed with pulmonary TB disease (11). Details of the culture-based screening algorithm and its TB classifications for U.S.-bound immigrants and refugees are described elsewhere (11).

### Study population

The study population of this analysis included arrivals of immigrants and refugees during 2013–2016 who 1) recently completed treatment for pulmonary TB disease overseas; 2) had suspected TB disease (chest radiograph/clinical symptoms suggestive of TB) but negative cultures overseas; or 3) had LTBI diagnosed overseas. We excluded 254 persons with suspected extrapulmonary tuberculosis disease but negative cultures overseas. Data from

overseas screening and post-arrival evaluation within 1 year of arrival were obtained from the CDC's Electronic Disease Notification (EDN) database (14). All persons aged 2–14 years in countries with a World Health Organization (WHO)-estimated TB incidence 20 cases/100,000 population/year received a tuberculin skin test or interferon- $\gamma$  release assay, while other persons received this testing if panel physicians determined their risk for TB warranted testing.

### **Post-arrival evaluation in the United States**

CDC routinely notifies state and local health departments of arriving at-risk immigrants and refugees via its EDN database (10, 11, 14). Health department physicians use a worksheet developed by CDC in post-arrival evaluation of at risk immigrants and refugees, assign a TB diagnosis, treat TB disease, may recommend and offer treatment to persons with LTBI, and enter the evaluation data directly to CDC's EDN database (10, 11, 14).

For persons whom health department physicians suspect pulmonary TB disease, 3 sputum specimens are obtained on 3 consecutive days for mycobacterial culture. Drug susceptibility testing is conducted for those who have positive culture results. Based on the results of sputum culture and chest radiograph/clinical symptoms, health department physicians assign a TB diagnosis for immigrants and refugees. In this analysis, we categorized persons with TB disease as sputum culture-positive, sputum culture-negative, and culture results not reported.

### **Ethics review**

The study protocol was reviewed for human subjects concerns by CDC and found to be consistent with CDC's public health surveillance activities and not human subjects research; therefore, review by an institutional review board was not required.

### **Statistical analysis**

We calculated the proportions of completion of post-arrival evaluation, and rates of TB disease for newly arrived at risk immigrants and refugees. For persons who were recommended for LTBI treatment at post-arrival evaluation, we calculated the proportions of initiation and completion of treatment.

We applied a modified Poisson regression approach (i.e., Poisson regression with a robust error variance) to assess risk factors for sputum culture-positive TB disease among newly arrived at risk immigrants and refugees in the United States (15). We also applied the modified Poisson regression approach to evaluate risk factors for 1) non-completion of post-arrival evaluation among at risk immigrants and refugees, 2) non-initiation of LTBI treatment among persons for whom treatment was recommended at post-arrival evaluation, and 3) non-completion of LTBI treatment among persons who initiated treatment at post-arrival evaluation (15). These models included year of arrival, visa type, sex, age, country of birth, and overseas TB classification.

## RESULTS

### Post-arrival evaluation in the United States

During 2013–2016, 64.5% (58,560) of 90,737 immigrants and refugees at risk for TB completed post-arrival evaluation. Median time between overseas medical examination and initiation of post-arrival evaluation was 98 days (interquartile range 79–120) for persons with completion of treatment for pulmonary TB disease overseas, 99 days (interquartile range 77–123) for those with suspected TB disease but negative cultures overseas, and 123 days (interquartile range 79–174) for those with LTBI diagnosed overseas.

Of 4,225 persons with recent completion of treatment for pulmonary TB disease overseas, 3,005 (71.1%) completed post-arrival evaluation (Figure 1). Post-arrival evaluation identified 22 TB cases (732 cases/100,000 persons): 4 sputum culture-positive cases (133 cases/100,000 persons), 13 sputum culture-negative cases (433 cases/100,000 persons), and 5 cases with no reported sputum culture results (166 cases/100,000 persons; Table 1).

Among 55,938 persons with suspected TB disease but negative cultures overseas, 37,089 (66.3%) completed post-arrival evaluation (Figure 1). Post-arrival evaluation identified 597 TB cases (1610 cases/100,000 persons): 262 sputum culture-positive cases (706 cases/100,000 persons), 281 sputum culture-negative cases (758 cases/100,000 persons), and 54 cases with no reported sputum culture results (146 cases/100,000 persons; Table 1).

Among 30,574 persons with LTBI diagnosed overseas, 18,466 (60.4%) completed post-arrival evaluation (Figure 1). Post-arrival evaluation identified 48 TB cases (260 cases/100,000 persons): 11 sputum culture-positive cases (60 cases/100,000 persons), 22 sputum culture-negative cases (119 cases/100,000 persons), and 15 cases with no reported sputum culture results (81 cases/100,000 persons; Table 1). Rates per 100,000 persons for sputum culture-positive TB were 46 and 264 for those aged 2–14 and 15 years, with LTBI diagnosed overseas, respectively; Table 1).

Among 30,574 persons with LTBI diagnosed overseas, 29,735 (97.3%) had data on testing for immune response to *Mycobacterium tuberculosis* antigens; of these, 28,803 (96.9%) were tested by tuberculin skin tests, 625 (2.1%) tested by interferon- $\gamma$  release assays, and 307 (1.0%) tested by both tuberculin skin tests and interferon- $\gamma$  release assays.

Among 18,418 persons with LTBI diagnosed overseas who completed post-arrival evaluation and were not diagnosed with TB disease, 12,834 (69.7%) were retested by tuberculin skin tests, interferon- $\gamma$  release assays, or both before a recommendation for LTBI treatment was made. Of 5,016 persons retested by tuberculin skin test, 67.8% (3,403) were positive. Of 9,173 persons retested by interferon- $\gamma$  release assay, 28.8% (2,638) were positive.

### Drug resistance

Of 277 sputum culture-positive TB cases, 11 (4.0%) had MDR-TB, 16 (5.8%) were mono-resistant to isoniazid, and 12 (4.3%) resistant to a non-isoniazid and non-rifampin first-line drug (Figure 1).

### **Risk factors for sputum culture-positive TB at post-arrival evaluation**

Among immigrants and refugees from the 10 birth countries with the most reported non-U.S.-born TB cases in the United States in 2016, risk for sputum culture-positive TB was higher among persons born in the Philippines (adjusted risk ratio [RR] 5.8, 95% confidence interval [CI] 2.5–13.2), India (adjusted RR 6.2, 95% CI 2.4–16.0), Vietnam (adjusted RR 6.6, 95% CI 2.8–15.5), China (adjusted RR 3.4, 95% CI 1.3–9.2), Haiti (adjusted RR 7.7, 95% CI 2.2–27.1), Ethiopia (adjusted RR 7.6, 95% CI 2.6–21.9), and Myanmar (adjusted RR 6.3, 95% CI 2.3–17.8) than among those born in Mexico (Table 2). Persons with suspected TB disease but negative cultures overseas had a higher risk for sputum culture-positive TB than those with recent completion of treatment for pulmonary TB disease overseas (adjusted RR 6.6, 95% CI 2.4–17.9; Table 2).

### **Treatment for LTBI at post-arrival evaluation**

Of 21,714 persons for whom LTBI treatment was recommended at post-arrival evaluation, 14,977 (69.0%) initiated treatment and 8,695 (40.0%) completed treatment (Table 3).

### **Factors associated with non-completion of post-arrival evaluation**

Non-completion of post-arrival evaluation was more likely among immigrants than among refugees (adjusted RR 1.4, 95% CI 1.3–1.4; Table 4). Compared with persons born in Mexico, non-completion of post-arrival evaluation was less likely among those born in the Philippines (adjusted RR 0.9, 95% CI 0.8–0.9), India (adjusted RR 0.8, 95% CI 0.8–0.9), Vietnam (adjusted RR 0.8, 95% CI 0.8–0.9), Haiti (adjusted RR 0.8, 95% CI 0.7–0.9), and Myanmar (adjusted RR 0.8, 95% CI 0.7–0.8), but more likely among those born in China (adjusted RR 1.1, 95% CI 1.1–1.2; Table 4). Compared with persons with completion of treatment for pulmonary TB disease overseas, non-completion of follow-up evaluation was more likely among those with LTBI diagnosed overseas (adjusted RR 1.3, 95% CI 1.2–1.4; Table 4).

### **Factors associated with non-initiation of LTBI treatment at post-arrival evaluation**

Non-initiation of LTBI treatment was more likely among immigrants than among refugees (adjusted RR 1.5, 95% CI 1.3–1.6; Table 5). Compared with persons aged  $\geq 65$  years, non-initiation of treatment was less likely among those aged 2–14 years (adjusted RR 0.7, 95% CI 0.6–0.8), 15–44 years (adjusted RR 0.8, 95% CI 0.8–0.9), and 45–64 years (adjusted RR 0.8, 95% CI 0.8–0.9; Table 5). Compared with persons born in Mexico, non-initiation of treatment was more likely among those born in the Philippines (adjusted RR 1.2, 95% CI 1.1–1.3), Vietnam (adjusted RR 1.3, 95% CI 1.2–1.4), and China (adjusted RR 1.4, 95% CI 1.3–1.5), but less likely among those born in Haiti (adjusted RR 0.7, 95% CI 0.6–0.9; Table 5).

### **Risk factors associated with non-completion of LTBI treatment at post-arrival evaluation**

Non-completion of LTBI treatment was less likely among immigrants than among refugees (adjusted RR 0.9, 95% CI 0.8–0.9; Table 5). Non-completion of treatment was less likely among persons aged 15–44 years (adjusted RR 0.9, 95% CI 0.8–0.9) and 45–64 years (adjusted RR 0.9, 95% CI 0.8–0.9) than among those aged  $\geq 65$  years (Table 5). Compared

with persons born in Mexico, non-completion of treatment was less likely among those born in the Philippines (adjusted RR 0.8, 95% CI 0.7–0.8), Haiti (adjusted RR 0.7, 95% CI 0.6–0.9), and Myanmar (adjusted RR 0.7, 95% CI 0.6–0.8; Table 5).

## DISCUSSION

Overseas TB screening has two goals: to find and treat U.S.-bound immigrants and refugees with TB disease overseas, and to identify those at risk for developing TB disease after arrival in the United States. The effect of overseas TB screening on finding and treating U.S.-bound immigrants and refugees has been evaluated by a previous study (11). Our analysis demonstrated that post-arrival evaluation can be highly effective but completion rates need to be improved. During 2013–2016, post-arrival evaluation of immigrants and refugees within 1 year of arrival in the United States diagnosed 667 TB cases (277 sputum culture-positive, 316 sputum culture-negative, and 74 with sputum culture results not reported). However, 35.5% of 907,373 newly arrived at risk immigrants and refugees did not complete post-arrival evaluation or their evaluation data were not reported to CDC. Had these persons completed follow-up evaluation, by using the tuberculosis rates in Table 1, we estimated that 344 cases of active tuberculosis (142 culture-positive cases, 163 culture-negative, and 39 cases with no/not reported culture results) could have been diagnosed.

We found a high proportion of sputum culture-negative TB among cases diagnosed at post-arrival evaluation, 53.3% (316 of 593 cases with sputum culture results) overall and 76.5% (13 of 17 cases with culture results) for those with recent completion of treatment for pulmonary TB disease overseas. According to the U.S. National TB Surveillance System, 39.0% (1,431) of 3,667 cases with sputum culture results among non-U.S.-born persons within 1 year of arrival during 2013–2016 did not have positive cultures (data were from Division of TB Elimination, CDC). The high proportion of culture-negative cases provides reassurance the overseas screening program is succeeding in reducing the importation of overt, culture-positive, infectious TB. Possible explanations for this finding include overdiagnosis of TB disease; diagnosis at an early stage of disease by active screening; overrepresentation of conditions associated with extrapulmonary disease such as recurrent disease following treatment failure, or certain comorbidities; or some combination of these above factors. Key information from the post-arrival examination, such as detailed documentation of clinical decision-making and additional tests that may have been performed (e.g., molecular tests), is not captured by CDC's EDN database. New studies with additional data are needed to further evaluate the high proportion of culture-negative TB diagnosed at post-arrival evaluation.

To help ensure U.S. TB control programs best understand who receives overseas TB treatment to cure, the 2018 update to CDC's TB Technical Instructions for Panel Physicians created "Class B0 TB" for persons with recent completion of treatment for pulmonary TB disease overseas through the panel physicians' rigorous directly observed therapy program (16). Our analysis showed that this new classification could be an effective tool for U.S. health department physicians to stratify risk and manage these patients. The creation of Class B0 TB could help health departments prioritize more resources to newly arrived immigrants and refugees with suspected TB disease but negative cultures overseas.

Previous studies have reported that recurrent TB rates range from 0.1% to 10.3%, depending on treatment regimens and time intervals of follow-up (17, 18, 19, 20). In our analysis, 4 (0.1%) of 3,005 persons with recent completion of treatment for pulmonary TB overseas were re-diagnosed with sputum culture-positive TB by post-arrival evaluation shortly after arrival (1 had multidrug-resistant TB). All four of these sputum culture-positive cases had received directly observed therapy overseas by panel physicians (one took self-administered therapy before presenting for the panel physician examination and then enrolled in the panel physician's directly observed therapy program for the remainder of treatment, but did not have MDR-TB at post-arrival evaluation). Since the culture-based screening and treatment algorithm requires directly observed therapy overseen by a panel physician, a low risk of relapse or reinfection in the short time between completion of overseas treatment and post-arrival evaluation would be expected.

We found that MDR-TB was in 4.0% (11) of 277 sputum culture-positive TB cases at post-arrival evaluation. In comparison, the U.S. National TB Surveillance System reported that MDR-TB was in 3.0% (83) of 2,811 foreign-born sputum culture-positive TB cases within 1 year of arrival during 2013–2016 (8). To treat TB disease and LTBI effectively, more studies on drug-resistance in immigrants and refugees are needed.

Foreign-born persons in the United States have a high prevalence of LTBI (15.9% with positive interferon- $\gamma$  release assay or 20.5% with tuberculin skin test  $\geq 10$ mm) (21). To eliminate TB in the United States, finding and treating LTBI among foreign-born persons is critical (2, 3, 4, 22, 23, 24, 25, 26). During our analysis period, the culture-based overseas screening required a tuberculin skin test or interferon- $\gamma$  release assay overseas only for children (2–14 years) in high-burden countries (11, 20). Expanding interferon- $\gamma$  release assay requirement (tuberculin skin tests were disallowed in 2018) to include adults, as part of a comprehensive evaluation for TB disease consistent with U.S. recommendations and clinical practices, could help overseas screening identify more persons at risk for TB, leading to additional TB cases diagnosed at post-arrival evaluation. In our analysis, 3 cases of (264 cases/100,000 persons) sputum culture-positive TB were diagnosed in 1,135 adults ( $\geq 15$  years) with LTBI diagnosed overseas. All 3 cases of sputum culture-positive TB were diagnosed in 612 adults without recent contact of a known TB case. Since our sample size is relatively small, adults with LTBI diagnosed overseas need to be further studied.

Tuberculin skin tests were commonly used in the overseas TB screening program for children during the study period. Of those with LTBI diagnosed overseas, less than a third (28.8%) were positive when retested by interferon- $\gamma$  release assays at post-arrival evaluation. This could be one reason that many persons with LTBI diagnosed overseas were not recommended for preventive treatment at post-arrival evaluation. On October 1, 2018, the overseas medical examination for children started requiring testing by interferon- $\gamma$  release assays only, and disallowed tuberculin skin tests. It is hoped the overseas diagnosis of LTBI will thus be more reliable, leading to an increase in the proportion of persons with LTBI diagnosed overseas to be offered preventive treatment at post-arrival evaluation.

Treating LTBI in refugees overseas and in newly arrived immigrants and refugees have been shown to be cost-effective (27, 28). However, ensuring completion of treatment for LTBI can



be challenging (29). For example, in the United States and Canada, a completion rate of 49.3% was reported among foreign-born persons who initiated LTBI treatment during 2007–2008 (30). In our analysis, completion rate was 58.1% for immigrants and refugees who initiated treatment. Shorter, rifamycin-based, treatment regimens (31, 32, 33, 34), and active outreach policies (35) can improve the completion rate.

Our analysis found that 35.5% of at risk immigrants and refugees did not complete follow-up evaluation in the United States. There are elevated rates of TB disease post-arrival among persons with all three overseas TB classifications. The yield and impact of the post-arrival evaluation interventions depend on the number of at risk immigrants and refugees who complete the evaluation. Health departments and CDC need to be vigorous in implementing strategies to increase the completion rates of post-arrival evaluation. Our multivariate analysis showed non-completion of post-arrival evaluation was associated with several factors. Non-completion of post-arrival evaluation was more likely among persons born in Mexico and China than among those born in the rest of the 10 birth countries with most TB cases reported in the United States. Non-completion of post-arrival evaluation was more likely among persons with LTBI diagnosed overseas than among those with recent completion of treatment for pulmonary TB overseas. Non-completion of post-arrival evaluation was less likely among refugees than among immigrants, likely because they have 8 months of federally-funded medical assistance after arrival and also receive supports from domestic refugee health programs. Previous studies have reported that active outreach policies can improve the completion rates of post-arrival evaluation (9, 36, 37). For example, of newly arrived at risk immigrants and refugees, 82.9% of those who had an appointment with health department clinics and 81.0% of those who received the telephone numbers of their county health department's TB programs at the port of entry completed post-arrival evaluation, but only 38.4% of those who did not have a referral at the port of entry completed post-arrival evaluation (37). Education about TB for immigrants and refugees could increase their willingness to complete a post-arrival evaluation. For example, during overseas screening, panel physician can communicate with at risk immigrants and refugees and encourage them to complete post-arrival evaluation in the United States. Post-arrival evaluation could also be improved if 1) state and local health departments have access to a fully electronic and complete record of the examination and treatment, if any, provided by panel physicians overseas for newly arrived at risk immigrants and refugees in their jurisdictions, and 2) the linkage is available for data of TB cases between the U.S. National TB Surveillance System and the CDC's EDN database..

Data used in this analysis have several limitations. Diagnosis of sputum culture-negative TB based on chest radiograph findings and/or clinical symptoms is difficult and therefore misclassification of TB cases might have occurred at the post-arrival evaluation. Post-arrival evaluation data were unavailable for 35.5% of at-risk immigrants and refugees, and sputum culture results were unknown for 11.1% of TB cases. Our data only captured TB cases that occurred in the short time between overseas medical examination and post-arrival evaluation shortly after arrival; cases that might have occurred later were not identified in this analysis, but would be reported through the U.S. National TB Surveillance System.

In conclusion, our analysis demonstrated that post-arrival evaluation of newly arrived immigrants and refugees at risk for TB can be highly effective, but strategies are needed to improve the completion rate of post-arrival evaluation. Our analysis also suggests that the newly introduced overseas TB classification “Class B0 TB”, indicating persons recently treated by directly observed therapy for pulmonary TB disease overseas, will lead to improved risk stratification. Finally, our analysis highlights the need to improve the completion rate of treatment for persons with LTBI.

## Acknowledgments:

We thank Dr. Alawode Oladele of the DeKalb County Tuberculosis Program and Dr. Mary Naughton of CDC’s Division of Global Migration and Quarantine for helpful discussions on preventive treatment for immigrants and refugees diagnosed with latent tuberculosis infection at U.S. follow-up evaluation. We also thank Dr. Joanna Regan of CDC’s Division of Global Migration and Quarantine for reviewing information of overseas diagnosis and treatment for some sputum culture-positive tuberculosis cases; Mr. Robert Pratt of CDC’s Division of Tuberculosis Elimination for providing us data from the U.S. National Tuberculosis Surveillance System on tuberculosis cases with sputum culture results among non—U.S.-born persons within 1 year of arrival during 2013–2016; Mr. Wei-Lun Juang of CDC’s Division of Global Migration and Quarantine for providing computer programming supports; the staff of CDC’s EDN team for updating and managing CDC’s notification system for tuberculosis in immigrants and refugees; the staff of CDC’s Quarantine Stations for collecting information of overseas medical examination; the panel physicians for performing overseas tuberculosis screening; and the staff of state and local health departments for conducting follow-up evaluations.

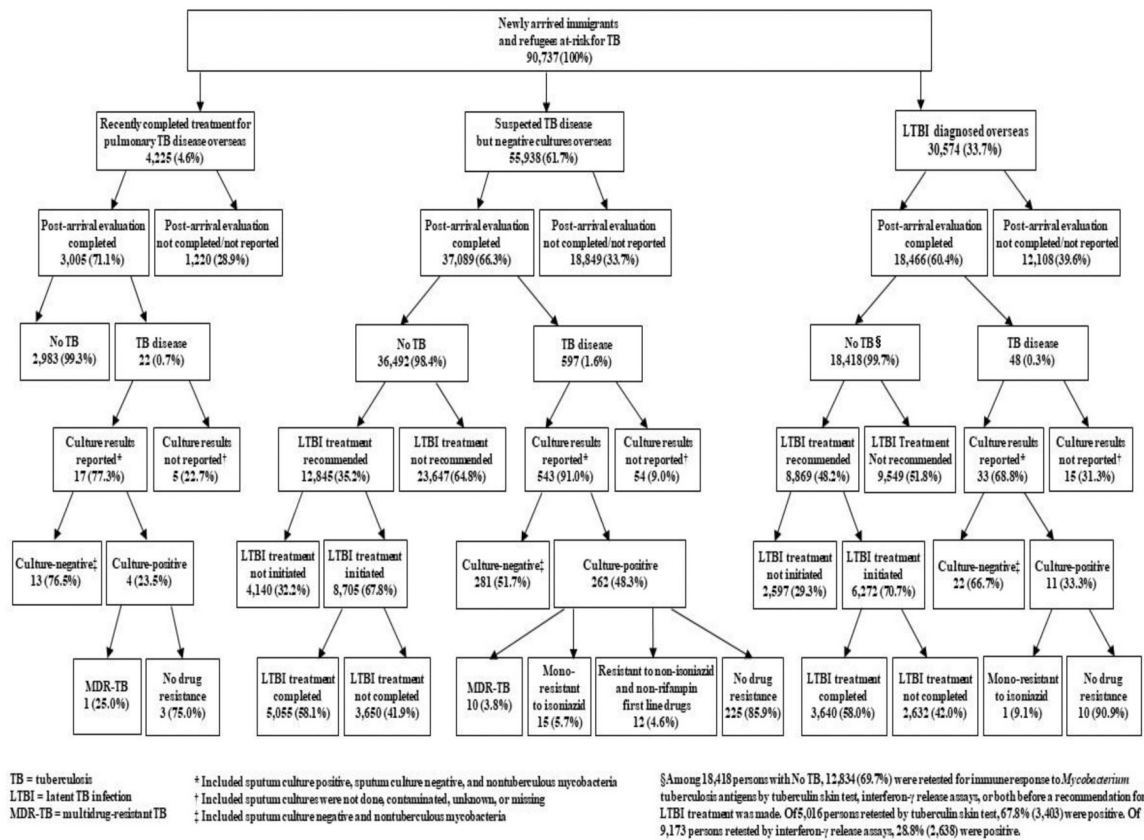
The findings and conclusions of this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention (CDC).

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TB = tuberculosis  
 LTBI = latent TB infection  
 MDR-TB = multidrug-resistant TB

\* Included sputum culture positive, sputum culture negative, and nontuberculous mycobacteria  
 † Included sputum cultures were not done, contaminated, unknown, or missing  
 ‡ Included sputum culture negative and nontuberculous mycobacteria

§ Among 18,418 persons with No TB, 12,834 (69.7%) were retested for immune response to *Mycobacterium tuberculosis* antigens by tuberculin skin test, interferon- $\gamma$  release assays, or both before a recommendation for LTBI treatment was made. Of 5,016 persons retested by tuberculin skin test, 67.8% (3,403) were positive. Of 9,173 persons retested by interferon- $\gamma$  release assays, 28.8% (2,638) were positive.

**Figure 1.** Post-arrival evaluation of newly arrived immigrants and refugees at risk for TB in the United States, 2013–2016.

**Table 1.** Rates of TB disease among immigrants and refugees who completed post-arrival evaluation within 1 year of arrival in the United States, 2013–2016.

Variable	Persons with recent completion of treatment for pulmonary TB disease overseas						Persons with suspected TB disease but negative cultures overseas						Persons with LTBI diagnosed overseas					
	TB disease diagnosed at post-arrival evaluation						TB disease diagnosed at post-arrival evaluation						TB disease diagnosed at post-arrival evaluation					
	Culture-positive		Culture-negative*		Culture results not reported†		Culture-positive		Culture-negative*		Culture results not reported†		Culture-positive		Culture-negative*		Culture results not reported†	
	No.	Rate‡	No.	Rate‡	No.	Rate‡	No.	Rate‡	No.	Rate‡	No.	Rate‡	No.	Rate‡	No.	Rate‡	No.	Rate‡
Year of arrival	Total						Total						Total					
2013	1	139	1	139	1	139	62	743	62	743	20	240	2	41	7	145	3	62
2014	1	126	2	253	3	379	65	777	69	825	12	144	3	69	8	185	9	208
2015	2	269	5	672	0	0	61	674	69	762	13	144	3	66	5	111	0	0
2016	0	0	5	668	1	134	74	653	81	715	9	79	3	63	2	42	3	63
Visa type	Total						Total						Total					
Immigrant	1	47	4	189	4	189	216	797	180	665	33	122	3	20	12	80	9	60
Refugee	3	336	9	1,009	1	112	46	460	101	1,010	21	210	8	228	10	285	6	171
Gender	Total						Total						Total					
Male	3	171	10	571	2	114	130	712	150	822	23	126	6	65	10	108	7	76
Female	1	80	3	239	3	239	132	701	131	696	31	165	5	54	12	130	8	87
Age	Total						Total						Total					
<2	3	0	0	0	0	0	0	0	0	0	1	8333	0	0	0	0	0	0
2–14	106	0	1	943	2	1,887	3	562	13	2,434	6	1,124	8	46	22	127	15	87
15–44	1,449	2	138	414	2	138	102	826	117	947	20	162	2	237	0	0	0	0
45–64	1,045	2	191	478	0	0	98	651	93	618	22	146	0	0	0	0	0	0
65	402	0	1	249	1	249	59	645	58	635	5	55	1	1,724	0	0	0	0
Two age groups	Total						Total						Total					
2–14	106	0	1	943	2	1,887	3	562	13	2,434	6	1,124	8	46	22	127	15	87

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Variable	Persons with recent completion of treatment for pulmonary TB disease overseas						Persons with suspected TB disease but negative cultures overseas						Persons with LTBI diagnosed overseas												
	TB disease diagnosed at post-arrival evaluation						TB disease diagnosed at post-arrival evaluation						TB disease diagnosed at post-arrival evaluation												
	No.	Rate <sup>‡</sup>	Culture-positive	No.	Rate <sup>‡</sup>	Culture results not reported <sup>†</sup>	No.	Rate <sup>‡</sup>	Culture-positive	No.	Rate <sup>‡</sup>	Culture-negative*	No.	Rate <sup>‡</sup>	Culture-negative*	No.	Rate <sup>‡</sup>	Culture-positive	No.	Rate <sup>‡</sup>	Culture-negative*	No.	Rate <sup>‡</sup>	Culture results not reported <sup>†</sup>	
Recent contact <sup>§</sup>	1	0	0	0	0	0	0	0	0	0	0	1	25,000	0	0	0	0	0	0	0	0	0	0	0	0
No recent contact	105	0	0	1	952	1,905	3	566	12	2,264	6	1,132	259	709	268	1	625	1	625	1	625	47	129	3	264
15	2,896	4	138	12	414	104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recent contact <sup>§</sup>	16	0	0	0	0	0	1	625	1	625	1	625	258	709	267	734	46	126	3	490	0	0	0	0	0
No recent contact	2,880	4	139	12	417	104	3	104	3	104	3	104	36,543	3,334	6	180	15	450	3	90	2,386	0	0	0	0
Country of birth//	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mexico	1,011	1	99	1	99	1	99	1,005	54	548	12	122	9,846	99	1,005	54	548	12	122	8,684	1	12	8	92	5
Philippines	37	0	0	1	2,703	0	0	949	13	881	4	271	1,476	14	949	13	881	4	271	137	1	730	0	0	0
India	702	0	0	1	142	2	285	1,115	26	724	5	139	3,589	40	1,115	26	724	5	139	703	0	0	0	0	1
Vietnam	139	0	0	1	719	0	0	556	11	556	1	51	1,979	11	556	11	556	1	51	252	0	0	0	0	1
China	1	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	80	0	0	0	0	0
Guatemala	23	0	0	0	0	0	0	1,356	8	2,712	1	339	295	4	1,356	8	2,712	1	339	223	0	0	0	0	0
Haiti	40	0	0	0	0	1	2,500	1,046	10	1,495	5	747	669	7	1,046	10	1,495	5	747	374	1	267	1	267	2
Ethiopia	1	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	69	0	0	0	0	0
Honduras	451	2	443	5	1,109	0	0	624	32	1,051	3	99	3,044	19	624	32	1,051	3	99	639	4	626	1	156	1
Burma	547	1	183	4	731	1	183	484	112	875	20	156	12,801	62	484	112	875	20	156	4,919	4	81	12	244	5
Other																									
TB incidence																									

Variable	Persons with recent completion of treatment for pulmonary TB disease overseas						Persons with suspected TB disease but negative cultures overseas						Persons with LTBI diagnosed overseas							
	TB disease diagnosed at post-arrival evaluation						TB disease diagnosed at post-arrival evaluation						TB disease diagnosed at post-arrival evaluation							
	Culture-positive		Culture-negative*		Culture results not reported <sup>†</sup>		Culture-positive		Culture-negative*		Culture results not reported <sup>†</sup>		Culture-positive		Culture-negative*		Culture results not reported <sup>†</sup>			
Total	No.	Rate <sup>‡</sup>	No.	Rate <sup>‡</sup>	No.	Rate <sup>‡</sup>	Total	No.	Rate <sup>‡</sup>	No.	Rate <sup>‡</sup>	Total	No.	Rate <sup>‡</sup>	No.	Rate <sup>‡</sup>	Total	No.	Rate <sup>‡</sup>	
in country of birth <sup>**</sup>																				
0–19	1	0	0	0	0	0	527	2	380	0	0	0	218	0	0	1	459	0	0	0
20–99	262	0	0	1	382	0	10,118	32	316	52	514	6	4,999	2	40	5	100	5	100	100
100	2,742	4	146	12	438	5	26,436	228	862	229	866	48	13,244	9	68	16	121	10	76	76
No estimate	0	0	0	0	0	0	8	0	0	0	0	0	5	0	0	0	0	0	0	0
Recent contact <sup>§</sup>																				
Yes	17	0	0	0	0	0	164	1	610	2	1220	1	744	0	0	0	0	0	0	0
No	2,988	4	134	13	435	5	36,925	261	707	279	756	53	17,722	11	62	22	124	15	85	85
Total	3,005	4	133	13	433	5	37,089	262	706	281	758	54	18,466	11	60	22	119	15	81	81

\*Sputum culture-negative<sup>†</sup>; included negative-culture results or nontuberculous mycobacteria

<sup>†</sup>Sputum culture results not reported<sup>†</sup>; included culture results reporting as not done, contaminated, unknown, or missing

<sup>‡</sup>Number of cases per 100,000 persons

<sup>§</sup>A recent contact of a known TB case

<sup>||</sup>The 10 birth countries of the most reported TB cases among non-U.S.-born persons in the United States in 2016

<sup>\*\*</sup>2016 WHO-estimated TB incidence for country of birth



**Table 2.**

Evaluation of risk factors for sputum culture-positive TB among newly arrived at risk immigrants and refugees in the United States, 2013–2016\*.

Variable	Total	Persons with sputum culture-positive TB		No. of Persons with no TB	Adjusted RR (95% CI) <sup>‡</sup>
		No.	No. of cases per 100,000 persons		
Year of arrival					
2013	13,803	65	471	13,738	Reference
2014	13,372	69	516	13,303	1.1 (0.8–1.6)
2015	14,215	66	464	14,149	1.0 (0.7–1.4)
2016	16,780	77	459	16,703	0.9 (0.7–1.3)
Visa type					
Immigrant	43,915	220	501	43,695	1.5 (0.9–2.5)
Refugee	14,255	57	401	14,198	Reference
Gender					
Male	29,065	139	478	28,926	1.1 (0.9–1.4)
Female	29,105	138	474	28,967	Reference
Age					
<2	75	0	0	75	-
2–14	17,851	11	62	17,840	0.5 (0.1–2.5)
15–44	14,497	106	731	14,391	1.3 (0.9–1.9)
45–64	16,211	100	617	16,111	0.9 (0.7–1.3)
65	9,536	60	629	9,476	Reference
Country of birth <sup>‡</sup>					
Mexico	5,755	6	104	5,749	Reference
Philippines	19,460	101	519	19,359	5.8 (2.5–13.2)
India	1,632	15	919	1,617	6.2 (2.4–16.0)
Vietnam	4,959	40	807	4,919	6.6 (2.8–15.5)
China	2,356	11	467	2,345	3.4 (1.3–9.2)
Guatemala	110	0	0	110	-
Haiti	532	4	752	528	7.7 (2.2–27.1)
Ethiopia	1,064	8	752	1,056	7.6 (2.6–21.9)
Honduras	97	0	0	97	-
Myanmar	4,092	25	611	4,067	6.3 (2.3–17.8)
Other	18,113	67	370	18,046	3.6 (1.5–8.5)
Overseas TB classification					
Recent completion of treatment for pulmonary TB disease overseas	2,987	4	134	2,983	Reference
Suspected TB disease but negative cultures overseas	36,754	262	713	36,492	6.6 (2.4–17.9)
LTBI diagnosed overseas	18,429	11	60	18,418	1.1 (0.2–7.3)

\* Excluded 316 sputum culture-negative TB cases and 74 TB cases with no reported culture results

<sup>†</sup>Estimated by using a modified Poisson regression approach (i.e., Poisson regression with a robust error variance), RR = risk ratio, CI = confidence interval

<sup>‡</sup>The 10 birth countries of the most reported TB cases among non-U.S.-born persons in the United States in 2016

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**Table 3.**

Initiation and completion of LTBI treatment among immigrants and refugees for whom treatment was recommended at post-arrival evaluation in the United States, 2013–2016.

Variable	Persons for whom treatment was recommended	Initiation of treatment		Completion of treatment		
		No.	% of persons for whom treatment was recommended	No.	% of persons who initiated treatment	% of persons for whom treatment was recommended
Year of arrival						
2013	5,589	3,979	71.2	2,084	52.4	37.3
2014	5,164	3,598	69.7	2,056	57.1	39.8
2015	5,109	3,441	67.4	2,183	63.4	42.7
2016	5,852	3,959	67.7	2,372	59.9	40.5
Visa type						
Immigrant	15,803	10,260	64.9	6,078	59.2	38.5
Refugee	5,911	4,717	79.8	2,617	55.5	44.3
Gender						
Male	11,083	7,719	69.6	4,499	58.3	40.6
Female	10,631	7,258	68.3	4,196	57.8	39.5
Age						
<2	27	20	74.1	11	55.0	40.7
2–14	8,389	5,940	70.8	3,422	57.6	40.8
15–44	4,869	3,523	72.4	2,111	59.9	43.4
45–64	5,729	3,867	67.5	2,271	58.7	39.6
65	2,700	1,627	60.3	880	54.1	32.6
Country of birth*						
Mexico	2,107	1,462	69.4	768	52.5	36.4
Philippines	6,945	4,369	62.9	2,732	62.5	39.3
India	587	389	66.3	226	58.1	38.5
Vietnam	1,767	1,079	61.1	611	56.6	34.6
China	899	503	56.0	258	51.3	28.7
Guatemala	38	29	76.3	18	62.1	47.4
Haiti	299	232	77.6	152	65.5	50.8
Ethiopia	574	416	72.5	234	56.3	40.8
Honduras	40	31	77.5	19	61.3	47.5
Myanmar	1,411	1,140	80.8	700	61.4	49.6
Other	7,047	5,327	75.6	2,977	55.9	42.2
TB incidence in countries of birth <sup>†</sup>						
0–19	205	128	62.4	74	57.8	36.1
20–99	5,334	3,628	68.0	2,041	56.3	38.3
100	16,171	11,219	69.4	6,579	58.6	40.7
No estimate	4	2	50.0	1	50.0	25.0
Overseas TB classification						

Variable	Persons for whom treatment was recommended	Initiation of treatment		Completion of treatment		
		No.	% of persons for whom treatment was recommended	No.	% of persons who initiated treatment	% of persons for whom treatment was recommended
Recent completion of treatment for pulmonary TB disease overseas	N/A	N/A	N/A	N/A	N/A	N/A
Suspected TB disease but negative cultures overseas	12,845	8705	67.8	5,055	58.1	39.4
LTBI diagnosed overseas	8,869	6272	70.7	3,640	58.0	41.0
Total	21,714	14,977	69.0	8,695	58.1	40.0

\* The 10 birth countries of the most reported tuberculosis cases among non-U.S.-born persons in the United States in 2016

<sup>†</sup> 2016 WHO-estimated tuberculosis incidence for country of birth

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**Table 4.**

Evaluation of risk factors for non-completion of post-arrival evaluation in the United States of at risk immigrants and refugees, 2013–2016.

Variable	Persons at risk for TB	Persons who did not complete post-arrival evaluation in the United States		Adjusted RR (95% CI)*
		No.	% of persons at risk for TB	
Year of arrival				
2013	20,804	6,907	33.2	Reference
2014	20,600	7,125	34.6	1.0 (1.0–1.1)
2015	21,997	7,690	35.0	1.0 (1.0–1.1)
2016	27,336	10,455	38.2	1.1 (1.1–1.2)
Visa type				
Immigrant	71,221	27,064	38.0	1.4 (1.3–1.4)
Refugee	19,516	5,113	26.2	Reference
Gender				
Male	45,122	15,855	35.1	1.0 (0.9–1.0)
Female	45,615	16,322	35.8	Reference
Age				
<2	116	40	34.5	0.9 (0.7–1.1)
2–14	29,614	11,704	39.5	0.9 (0.9–1.0)
15–44	21,379	6,737	31.5	0.9 (0.9–1.0)
45–64	24,514	8,183	33.4	0.9 (0.9–1.0)
65	15,114	5,513	36.5	Reference
Country of birth <sup>†</sup>				
Mexico	10,082	4,309	42.7	Reference
Philippines	30,799	11,258	36.6	0.9 (0.8–0.9)
India	2,502	852	34.1	0.8 (0.8–0.9)
Vietnam	7,469	2,475	33.1	0.8 (0.8–0.9)
China	4,352	1,982	45.5	1.1 (1.1–1.2)
Guatemala	186	76	40.9	0.9 (0.8–1.1)
Haiti	825	284	34.4	0.8 (0.7–0.9)
Ethiopia	1,617	534	33.0	0.9 (0.8–1.0)
Honduras	170	73	42.9	0.9 (0.7–1.1)
Myanmar	5,352	1,218	22.8	0.8 (0.7–0.8)
Other	27,383	9,116	33.3	0.9 (0.9–1.0)
Overseas TB classification				
Recent completion of treatment for pulmonary TB disease overseas	4,225	1,220	28.9	Reference
Suspected TB disease but negative cultures overseas	55,938	18,849	33.7	1.1 (1.0–1.2)
LTBI diagnosed overseas	30,574	12,108	39.6	1.3 (1.2–1.4)

\* Estimated by using a modified Poisson regression approach (i.e., Poisson regression with a robust error variance), RR = risk ratio, CI = confidence interval

† The 10 birth countries of the most reported tuberculosis cases among non-U.S.-born persons in the United States in 2016

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Table 5.

Evaluation of risk factors for non-initiation and non-completion of LTBI treatment among immigrants and refugees for whom treatment was recommended at post-arrival evaluation in the United States, 2013–2016.

Variable	Initiation of LTBI treatment*				Completion of LTBI treatment†			Adjusted RR (95% CI) ‡
	Persons for whom treatment was recommended	Persons who did not initiate treatment		Persons who initiated treatment	Persons who did not complete treatment		Adjusted RR (95% CI) ‡	
		No.	% of persons for whom treatment was recommended		No.	% of persons who initiated treatment		
Year of arrival								
2013	5,589	28.8	1,610	28.8	3,979	1,895	47.6	Reference
2014	5,164	30.3	1,566	30.3	3,598	1,542	42.9	0.9 (0.8–0.9)
2015	5,109	32.6	1,668	32.6	3,441	1,258	36.6	0.8 (0.7–0.8)
2016	5,852	32.3	1,893	32.3	3,959	1,587	40.1	0.8 (0.8–0.9)
Visa type								
Immigrant	15,803	35.1	5,543	35.1	10,260	4,182	40.8	0.9 (0.8–0.9)
Refugee	5,911	20.2	1,194	20.2	4,717	2,100	44.5	Reference
Gender								
Male	11,083	30.4	3,364	30.4	7,719	3,220	41.7	1.0 (0.9–1.0)
Female	10,631	31.7	3,373	31.7	7,258	3,062	42.2	Reference
Age								
<2	27	25.9	7	25.9	20	9	45.0	1.1 (0.6–1.7)
2–14	8,389	29.2	2,449	29.2	5,940	2,518	42.4	1.0 (0.9–1.1)
15–44	4,869	27.6	1,346	27.6	3,523	1,412	40.1	0.9 (0.8–0.9)
45–64	5,729	32.5	1,862	32.5	3,867	1,596	41.3	0.9 (0.8–0.9)
65	2,700	39.7	1,073	39.7	1,627	747	45.9	Reference
Country of birth§								
Mexico	2,107	30.6	645	30.6	1,462	694	47.5	Reference
Philippines	6,945	37.1	2,576	37.1	4,369	1,637	37.5	0.8 (0.7–0.8)
India	587	33.7	198	33.7	389	163	41.9	0.9 (0.7–1.0)
Vietnam	1,767	38.9	688	38.9	1,079	468	43.4	0.9 (0.8–1.0)
China	899	44.0	396	44.0	503	245	48.7	1.0 (0.9–1.2)

Variable	Initiation of LTBI treatment*			Completion of LTBI treatment <sup>†</sup>		
	Persons for whom treatment was recommended	Persons who did not initiate treatment		Persons who initiated treatment	Persons who did not complete treatment	
		No.	% of persons for whom treatment was recommended		No.	% of persons who initiated treatment
Guatemala	38	23.7	9	29	11	0.8 (0.5–1.4)
Haiti	299	22.4	67	232	80	0.7 (0.6–0.9)
Ethiopia	574	27.5	158	416	182	1.1 (0.9–1.3)
Honduras	40	22.5	9	31	12	0.8 (0.4–1.4)
Myanmar	1,411	19.2	271	1,140	440	0.9 (0.8–1.1)
Other	7,047	24.4	1,720	5,327	2,350	1.0 (0.9–1.2)
Overseas tuberculosis classification	N/A	N/A	N/A	N/A	N/A	N/A
Recent completion of treatment for pulmonary TB disease overseas	12,845	32.2	4,140	8,705	3,650	Reference
Suspected TB disease but negative cultures overseas	8,869	29.3	2,597	6,272	2,632	1.0 (0.9–1.2)
LTBI diagnosed overseas						Reference
						0.9 (0.8–1.0)

\* Included persons for whom LTBI treatment was recommended at post-arrival evaluation in the United States

<sup>†</sup> Included persons who initiated LTBI treatment at post-arrival evaluation in the United States

<sup>‡</sup> Estimated by using a modified Poisson regression approach (i.e., Poisson regression with a robust error variance), RR = risk ratio, CI = confidence interval

<sup>§</sup> The 10 birth countries of the most reported TB cases among non-U.S.-born persons in the United States in 2016