Estimation of the Annual Risk of Tuberculous Infection for White Men in the United States

Thomas M. Daniel and Sara M. Debanne

Center for International Health and Department of Epidemiology and Biostatistics, Case Western Reserve University School of Medicine, Cleveland, Ohio

The annual risk of tuberculous infection for white men in the United States was estimated from published tuberculin surveys and found to be related to tuberculous incidence as reflected in the annual case rate during the past 3 decades, with a constant ratio of ~150. It is currently estimated to be 0.03%/year. The technique developed for this estimation is not complex and should be applicable to other segments of the population for which suitable data are available.

Annual risk of infection (ARI) is the term widely used to refer to the annual incidence of tuberculous infection as distinguished from the incidence of tuberculous disease. As calculated from tuberculin skin test surveys, it has become widely accepted as an index of the transmission of tuberculosis within a population and, in many countries, as a more reliable measure of the magnitude of the tuberculosis problem facing those charged with tuberculosis control than the reported incidence of newly active cases of disease [1, 2]. For those interested in modeling the transmission of disease, the ARI is a necessary input variable.

Methods for estimating the ARI from tuberculin skin test surveys have been developed and tested in both high- and low-prevalence populations [1, 3]. In the United States, it has been difficult or impossible in recent years to calculate the ARI because tuberculin skin test surveys capable of providing the necessary input data have not been carried out systematically. The largest and most carefully done American tuberculin survey was conducted with naval recruits from 1958 to 1965 (midpoint, 1962) [4]. Data on lifelong 1-county resident, white men aged 17–21 years (median, 19) were obtained and tabulated in readily accessible form.

Because Styblo [5] has demonstrated a relatively constant ratio between ARI and disease incidence in several populations, we felt it reasonable to postulate that the ARI in the United States would decrease in parallel with decreasing tuberculosis case rates. To test this hypothesis, we projected the ARI calculated from the naval recruit database in parallel with the tuberculosis case rate and compared the projected ARIs with those calculated from a number of available tuberculin skin test surveys.

Methods

Tuberculosis case rates for the United States were taken from the annual reports of the Centers for Disease Control and Preven-
Table 1. Annual risk of tuberculous infection in the United States estimated from selected tuberculin surveys.

<table>
<thead>
<tr>
<th>Year</th>
<th>Recruit population</th>
<th>Annual risk of infection (%/year)</th>
<th>[Reference]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962</td>
<td>White, male, navy</td>
<td>.204</td>
<td>[4]</td>
</tr>
<tr>
<td>1964</td>
<td>White, male, air force</td>
<td>.16</td>
<td>[7]</td>
</tr>
<tr>
<td>1980</td>
<td>All navy and marine</td>
<td>.08</td>
<td>[8]</td>
</tr>
<tr>
<td>1981</td>
<td>All navy and marine</td>
<td>.08</td>
<td>[8]</td>
</tr>
<tr>
<td>1982</td>
<td>All navy and marine</td>
<td>.06</td>
<td>[8]</td>
</tr>
<tr>
<td>1983</td>
<td>All navy and marine</td>
<td>.07</td>
<td>[8]</td>
</tr>
<tr>
<td>1984</td>
<td>All navy and marine</td>
<td>.06</td>
<td>[8]</td>
</tr>
<tr>
<td>1985</td>
<td>All navy and marine</td>
<td>.06</td>
<td>[8]</td>
</tr>
<tr>
<td>1986</td>
<td>All navy and marine</td>
<td>.06</td>
<td>[8]</td>
</tr>
<tr>
<td>1990</td>
<td>White, navy</td>
<td>.04</td>
<td>[9]</td>
</tr>
</tbody>
</table>

The annual risk of tuberculous infection and are expressed as newly reported cases (all forms) per 100,000 population per year. Annual risk of tuberculous infection, expressed as percent per year, was determined using the method of Styblo et al. [3], according to the formula: 

\[
ARI = \left(1 - \frac{Q_p}{Q_p - Q_{100}}\right) \times 100, \quad \text{where} \quad Q = 1 - P, \quad P = \text{percent probability of being infected with Mycobacterium tuberculosis at a given age or year} \ a \ or \ b, \quad a = \text{initial age or year of observation}, \quad b = \text{second age or year of observation}.
\]

The published data from the United States naval recruit surveys [4] were used to determine ARIs for white men in 1962; the positive reactor rate was determined using a 10-mm cutoff point, which minimizes the bias introduced by nonspecific reactivity with environmental mycobacteria. Since skin testing was not available for any person for more than one age, it was assumed that all individuals were tuberculin-negative at birth, and the reactor rate for the average age of the skin test subjects was used in the calculations [1]. A limitation imposed by this method is the inherent assumption that the risk of infection was the same for each year of an individual’s life. Table 1 lists the skin test surveys used and the ARI calculated from each survey.

An exponential function was fitted to the case rates over time using the formula: 

\[
y = e^{a + b t}, \quad \text{where} \quad e = \text{the case rate} \quad t = \text{the year}.
\]

Fitted model parameters were 

\[
a = 52.343 \quad b = -.063.
\]

The model fit the data well \((R^2 = .942, F_{1,40} = 654.66, P < .0001)\); 95% confidence intervals were also computed.

Results

In Figure 1, the actual tuberculosis case rate for white men in the United States for 1953 through 1993 is plotted along with a least squares–fitted exponential curve with its 95% confidence limits. The annual risks of tuberculous infection determined from the tuberculin skin test surveys listed in table 1 are also plotted as individual points.

In 1962, the tuberculosis new case rate was 30.1/100,000/year for white men in the United States. The ARI for white men determined from the 1962 naval recruit survey was 0.204%/year. The ratio of case rate to ARI was 147.5. Using an estimated value of the ARI for 1962 of 0.193 derived from the least squares–fitted curve of tuberculosis case rates, the ratio was 155.8. In 1990, the ARI for white men derived from naval recruits was 0.04%/year (table 1). The case rate was 8.6/100,000/year, leading to an estimated ARI of 0.06%/year. All of the ARI values in table 1 fall within the confidence limits of the fitted case rate curve shown in figure 1; that is, within 95% confidence limits, the ratio of 147.5 between annual tuberculous case rates and ARI is constant for white men in the United States for 1962–1990.

Discussion

The relationship between tuberculosis incidence and ARI demonstrated in this study and presented in figure 1 is surprisingly robust, with a ratio between the two parameters of ~150. Different techniques of skin testing and different antigens were used in the various studies included in table 1. However, these differences did not lead to variations outside the 95% confidence limits of the incidence curve. We attempted to avoid the effect of geographically dependent nonspecific reactions in the skin test surveys by using the reactor rate based on a 10-mm cutoff point for positive reactions. Potential bias was introduced into our analysis by the inclusion of nonwhite recruits in some of the studies included in table 1; the effect of removing this bias would have been to improve the fit of the measured ARI to that projected. Some of the later surveys also included women recruits, but the numbers of women were too small to have had a significant impact on our analysis.
The observation that the ARI is related to the new active case rate for tuberculosis for white men in the United States allows one to estimate the ARI for the current time by dividing the case rate by ~150. Thus, with a current case rate (1995) of 4.2/100,000 [6], the ARI for white men is estimated to be 0.03%/year. Although data to support generalizing this approach to other individual segments of the population are lacking, it seems reasonable to suppose that one could apply the same approach to estimating current ARI for geographic or ethnic segments of the population for which case rate data are available and for which reliable skin test data for at least one point in time can be obtained. The published reports of the Centers for Disease Control and Prevention have distinguished tuberculosis in white and nonwhite segments of the United States population since the inception of individual case reporting in 1953. Hispanic population tuberculosis morbidity data reporting began in 1984. Unfortunately, there are few or no published studies of tuberculosis incidence that can be readily applied to nonwhite or Hispanic populations in the United States.

Throughout the time period covered by our analysis, the ARI has been low in relation to the new case rate in the United States. Styblo [5] has observed an empiric ratio of new cases of sputum smear–positive pulmonary tuberculosis per 100,000 population per year to an ARI of ~40–50 to apply in many countries. We have observed a ratio three times that figure in the United States. Even if corrected for different tuberculosis case definitions (sputum smear–positive vs. all forms), it remains one and one-half to two times that found by Styblo. This finding would imply that diseased persons infect susceptible white men in the United States less frequently than diseased persons infect susceptible persons in other populations elsewhere, and it would be consistent with the low and rapidly falling tuberculosis incidence in white men in the United States during the last half of the 20th century. It would predict that tuberculosis incidence will continue to fall rapidly in this population.

Alternatively, the difference between our observed relationship to tuberculosis incidence and that found in Styblo’s studies may simply reflect the fact that all of our ARIs were calculated from birth and, as noted above, assumed a fairly uniform exposure risk throughout life. Styblo’s work was based on surveys done at two different ages, usually of school children. If the exposure risk of American white male military recruits occurred chiefly during a few years of their lives, then the actual ARI would be higher than we calculated it to be and the ratio between incidence and ARI smaller. The constancy of the relationship between incidence and ARI would remain a valid observation.

References