The uncertainty, challenges, and variability in tuberculosis congregate setting investigations: The concentric circle model revisited

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A B S T R A C T

In the United States tuberculosis programs routinely conduct congregate setting contact investigations in locations such as schools, workplaces, social/recreational sites, nursing homes and prisons. Both documented and anecdotal reports describing these investigations have indicated, in many cases, the unnecessary testing of large numbers of individuals. This article revisits the concentric circle model and its application in congregate setting investigations. In its simplest form this model, despite imperfections, offers tuberculosis programs an opportunity to utilize this approach as a secondary tool to assist in the identification of contacts at both the highest and lowest level of risk due to exposure based on time and place to an infectious or potentially infectious patient. The methodology described here offers a prudent and viable alternative to not allowing a congregate setting investigation to be viewed as a general screening activity where excessive numbers of individuals are needlessly tested.

1. Introduction

Tuberculosis (TB) is an airborne infectious disease produced by the causative agent Mycobacterium tuberculosis. Since respiratory TB is communicable, identification of exposed persons plays a pivotal role controlling this disease. A contact investigation (CI) attempts to identify, locate, and refer appropriate contacts for medical evaluation. As such, CIs have been described as a priority activity in TB programs in the United States and represent one of several active case-finding strategies [1,2]. The objective of the CI is to identify and treat TB contacts with infection or disease preventing future disease or further transmission.

As part of the CI process in the United States, TB programs also routinely conduct congregate setting investigations (CSI). A congregate setting is an environment where a number of people reside, meet, or gather in close proximity for either a limited or extended period of time. Examples include prisons, nursing homes, schools, and workplaces [3]. Similar to the CI, the primary objective of the CSI is to identify and prevent additional cases of TB.

There have been reports describing CSIs that have identified hundreds of contacts oftentimes as a result of exposure to a single individual diagnosed with pulmonary TB [4–7]. CSIs have diverse circumstances coupled with their own array of complexities; however, it may be beneficial to highlight core concepts of TB as related to CSIs to better focus the investigation.

Important aspects of CSIs offer distinct variables including the level of infectiousness of the TB patient, the environment where potential exposure occurred, the frequency and duration of the exposure, and additional individual risk factors associated with contacts [8]. As a result of these four primary elements coupled with the absence of a universal, definitive method of contact identification, investigations of congregate setting exposures are reliant upon the experience of local health departments and TB programs for the on-site assessment of exposure environments and the subsequent identification of contacts.

2. Concentric circle model

To assist programs in CSIs, the concentric circle model, despite imperfections and limitations, remains a useful and practical methodology to be considered for application during the process of contact identification [8] (Fig. 1). This approach, although not new, is a method which ideally limits the scope of CIs and helps to establish priorities based on the risk of TB transmission to identified contacts. In general, those contacts with the greatest duration and intensity of exposure are tested first. If there is no evidence of recent transmission in these contacts, expanding the investigation may not be warranted. However, if recent transmission is identified, testing can be extended progressively to lower-risk contacts until the levels of infection approximate.
the levels of infection in the community where exposure has occurred. Once the infection rate in the group tested does not exceed the infection rate that is generally expected of the local community, testing may stop. The advantage of this approach is its simplicity and the fact that contacts with less exposure are not evaluated until evidence of transmission exists. However, there are disadvantages associated with this model including using household contacts as predictors of transmission for non-household contacts, the vulnerability of lower-risk contacts not fully being considered, and unknown background TB infection prevalence in a community [8]. Additionally, while the concentric circle approach emphasizes levels of exposure in terms of time shared with the TB patient (most to least), TB programs should be careful not to exclude environmental characteristics, such as crowding and poor ventilation, that may contribute to transmission in those contacts who present with less frequent exposure. Similarly, contacts with less exposure but who present with high risk medical conditions should be considered for testing. Despite imperfections, this model places reliance on individual program standards of practice that are generally applied when identifying contacts in a congregate setting. Once the contact identification process is complete, the concentric circle model lends guidance to public health programs in setting parameters and defining limits of the investigation, assisting in identifying contacts at risk of exposure and allowing the investigation to proceed in an orderly fashion while highlighting the variables of time, place, and space as they relate to exposure from the TB patient. This model is considered a tool to guide CIs while priorities have been established based on the perceived and or observed risk of transmission as determined by a TB program [9]. There is no national standard either in establishing criteria for hours of exposure that places an individual at risk or in differentiating high from low-risk contacts [2]. Therefore, local health departments and state TB programs may address this important element as they deem appropriate within their own standards of practice. While it is presumed that the likelihood of infection depends upon the intensity, frequency, and duration of exposure, no safe exposure to TB has been established and even the briefest exposure potentially may present a theoretical risk [8]. Still, TB programs should focus resources on identifying and testing only those exposed individuals who are more likely to be infected based on investigative findings.

3. Case study

A 20-year-old male college student with confirmed TB had a four-month history of cough. His chest x-ray revealed a cavitary pneumonia in the right upper lobe with sputum smear reported as acid-fast positive (4+). Initial interview identified three household and two social contacts. In addition, school exposure during the estimated infectious period was considered. The university undergraduate enrollment was 13,462. The patient attended 11 classes during the fall and spring semesters which encompassed the infectious period. Two hundred and sixty-five students and 10 faculty members were potentially exposed. A typical class met twice per week for 1.25 hours, for a total of 2.5 exposure-hours per week per class. A schedule of all 11 classes with student and faculty names was requested by the TB program. A review of class rosters revealed names of students and faculty sharing multiple classes with the patient during both semesters. The classrooms ranged from 396–1136 square feet with ceiling heights of 12 feet. During the fall semester, several classrooms were identified as measuring 400 square feet and as spaces where student desks were approximately two feet apart representing a relatively crowded environment. Total classroom exposure hours during the infectious period were calculated ranging from a minimum of 20 to a maximum of 108 hours for each student and faculty member.

4. CI/CSI outcomes

The review of class rosters, hours of exposure, and classroom environments allowed for configuring a concentric circle which categorized layers of exposure of students and faculty ranging from the most to fewest hours exposed. Nineteen students and 1 faculty member with 80–108 exposure hours during the fall semester (16 weeks/106 potential contacts) were identified as high-risk contacts over the spring semester (8 weeks/169 potential contacts) based on overall time shared with the TB patient (Fig. 2).

A frequency distribution based on exposure time was used to identify cut points for the remaining concentric circles. Two of three household contacts were diagnosed with TB infection and two social contacts were negative for a 40% positivity rate. Of 20
university-related contacts, one was diagnosed with infection, one was unable to be located and one was documented as previously infected. The remaining 17 contacts were initial and post-exposure test negative indicating an overall 5.5% positivity rate for university-related contacts (Fig. 3).

Despite a potential TB exposure to 275 students and faculty, applying the concentric circle methodology was instrumental in categorizing both high and low-risk contacts based upon hours of exposure (time) and a review of classroom environments (place and space). With little evidence of transmission to those contacts who shared the most exposure in a particular environment, it was deemed unnecessary to test lower-risk contacts who shared less exposure and who did not present with any known high risk medical conditions. As a result, the CSI was closed with no expansion of the concentric circle for testing.

5. Discussion

A primary objective of the CSI is to distinguish between high-risk and low-risk contacts, the often referred to “other than close contacts” or the worried well. A CSI should not be regarded as a general screening activity where everyone (high and low-risk contacts and the worried well) is tested at the same time. It is a dedicated activity that, when
possible, attempts to separate high from low-risk contacts, and begins by testing those at high risk. Testing should not be expanded to the next group of contacts if there is no evidence of recent transmission [10]. If the CSI is to identify transmission resulting from recent exposure, it is counter-productive and offers no value to simultaneously test high and low-risk contacts. Additionally, testing the worried well is ill-advised and should be avoided in any CSI because the wider the net is cast for more testing, the more likely false-positive test results and unrelated infections may be reported. Excessive testing of large numbers of individuals does not necessarily correlate to a quality investigation. Bigger is not always better. In the example of the university exposure, it was the function of the initial investigative steps to review class rosters and of collecting environmental data that was instrumental in identifying both high and low-risk contacts. The role of the concentric circle model is designed to allow an investigator to clarify and to visualize in the circles provided the number of high and low-risk contacts compiled as a result of an investigative process. Once investigative data is collected and evaluated, the testing of appropriate contacts can begin. While it is generally understood that increased exposure potentially increases the likelihood of recent infection in contacts, TB testing cannot differentiate recent from remote (previous, unrelated) infection [8]. Consequently, those with positive test results with either minimal or no exposure more likely represent previous infection or a false positive result. Such findings confound the results of an investigation and send a mixed message about how TB is and is not characteristically transmitted. The overall advantage of the concentric circle model is its straightforwardness and emphasis on not testing contacts who present with less exposure until there is evidence of transmission in those with typically the most exposure.

Despite the absence of fixed standards to guide programs through the intricacies of investigations, it would appear unfair to allow the number of contacts identified in a CSI as either right or wrong but rather as prudent or imprudent. A prudent approach to the identification of contacts should not be influenced by background noise outside of TB programs that can be evident in CSIs. Parents, management officials at sites of exposure, media, politicians, and the worried well may individually or collectively insist, and in some cases, demand wide-scale testing [9]. It is the obligation of those in public health programs who are in the lead position of these investigations to provide information and education to the misinformed, and to stand firm in their decision of who is, and who is not, recommended for testing based on environmental and available high risk medical risk conditions.

6. Conclusion

While some CSIs may be considered routine and uncomplicated, others may be complex and require careful thought. Regardless of the size and scope of any investigations, all should be the result of comprehensive planning. As described here, the concentric circle model as a secondary tool can play an instrumental role in the planning and eventual provision of clarity in the identification of individuals requiring testing. While there are uncertainties, challenges, and variability inherent in most CSIs, the concentric circle model offers a reasonable method to limit the scope of contact identification and to assist in establishing priorities for investigations based on the risk of transmission. The practical application of this model is designed to alleviate the unnecessary testing of large groups of individuals. For many TB programs, the perception may be that it is safer and easier to take the path of least resistance and to test all rather than small. The concentric circle model offers a logical and methodical approach which can help minimize unnecessary testing of low risk individuals.

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Conflict of interest

This manuscript has not been previously published nor is being considered for publication elsewhere. No Human Subjects Review by an Institutional Review Board is required. There is no potential conflicts of interest by any of the authors and there has been no similar or related work submitted or published elsewhere.

Ethical statement

I have reviewed the Duties of Authors and am in accordance with all accompanying reporting standards.

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