A multidisciplinary approach: Mapping potential TB transmission 'hot spots' in high burden communities.

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ABSTRACT

Global control of the tuberculosis (TB) epidemic remains poor, especially in high burden settings where ongoing transmission sustains the epidemic. In such settings, a significant amount of transmission takes place outside of the household and practical approaches to understanding transmission at a community level are needed. We introduce a novel multidisciplinary approach to identify and map potential TB transmission 'hot spots' within high burden communities.

Our community assessment draws on data that qualitatively describes public gathering places in a high burden community in Cape Town, South Africa. Established transmission principles are applied to grade the potential TB transmission risk posed by these gathering places, then Geographic Information Systems (GIS) technology is used to create a visual map; locating potential transmission 'hot spots' within the community.

Drinking places (*shebeens),* clinics and churches (often found to be gathering in confined homes) emerge as gathering places that potentially pose a high transmission risk, particularly if located in overcrowded and impoverished areas of the community.

This proof of concept study demonstrates that combining qualitative techniques with GIS mapping may improve our understanding of potential TB transmission at a community level and guide public health interventions to enhance TB control efforts.

Word Count: 196 (200)

INTRODUCTION

South Africa has one of the highest tuberculosis (TB) incidence rates in the world despite formally adopting the directly observed therapy short course (DOTS) strategy in 1996 (1). In poverty stricken township areas of Cape Town, high rates of drug resistance among children with TB suggest that the problem is deepening (2, 3). A key factor sustaining the TB epidemic in such settings is our inability to break an ongoing transmission cycle; the high infection pressure in township areas is reflected by high annual rates of infection (calculated at 3.8% in one township community of Cape Town[*]) and high rates of re-infection disease among adults (4-6).

Molecular strain typing methods provide evidence that a significant part of the disease burden in TB endemic areas results from re-infection events (4-6). Importantly, these methods also show that infection/re-infection frequently occurs outside of the household (7, 8). Verver *et al*. (8) demonstrated that the majority of transmission among adults occurs as a result of extensive social mixing, cautioning that active case finding among household members is likely to have limited impact in high burden communities, as more than three-quarters of transmission leading to active TB would be missed. Researchers have also documented the important influence of community environmental factors on TB transmission; in particular how poverty, crowding and poor ventilation encourages transmission (9, 10).

Although social mixing and local environment have been identified as significant factors fuelling the TB epidemic, traditional TB control efforts focus almost exclusively on the individual patient. Multidisciplinary initiatives that assess TB transmission emphasize the relevance of local surroundings. For example, a study conducted in Texas successfully combined biology, epidemiology and network analysis to demonstrate that public places rather than individual people are key to understanding TB transmission (11). Further, combinations of spatial and molecular analyses have identified TB transmission patterns which show a geographical clustering of TB cases that stretches beyond individual households (12, 13).

[*] Personal communication with Professor Nulda Beyers, Director of the Desmond Tutu TB Centre of Stellenbosch University.

Combining rapid qualitative appraisal techniques with geographic information systems (GIS) technology offers an efficient multidisciplinary method to assess TB transmission at a community level. Within the social sciences, qualitative appraisal techniques have been developed to capture information about social systems in rapid and effective ways (14). GIS technology provides the ability to crystallise locally specific information in a visual format that is easily able to communicate spatial information about disease (15). This paper introduces a novel multidisciplinary approach that integrates rapid qualitative appraisal methods, basic TB transmission principles and GIS technology to identify, grade and map potential TB transmission 'hot spots' within communities.

METHODS

Study setting

Data collected during June of 2005 from a geographically distinct population in Cape Town, South Africa, is drawn upon for our community assessment. The community was one of 24 sub-Saharan African sites included in a cluster randomized trial that evaluates the efficacy of different public health interventions to reduce TB prevalence (16). The specific community selected for this assessment was chosen due to the availability of GIS data and the particularly high burden of ongoing TB transmission (TB incidence >600/100 000 population/annum).

Study design

The collection of qualitative data commenced with a meeting of a local Community Advisory Board (CAB); community representatives were asked to list places where people gather in groups and then to direct research assistants (using a map of their community) on a walk transecting the community in a way that would provide research assistants with as much of a representation of the community as possible. After the meeting, these 'transect walks' (Figure 1) were conducted over a two day period to produce a qualitative 'snapshot' description of gathering places identified. This initial 'snapshot' component of the fieldwork comprised plotting the Global

Positioning Systems (GPS) coordinates of gathering places observed along the walks and filling in an observation checklist detailing the structure of the building and listing activities taking place (Table 1). The data captured on the observation checklist was therefore qualitative in the sense that it assessed types of places relative to one another i.e. bigger or smaller, busier or quieter etc. These were supplemented with photographs and informal open-ended conversations held with locals along the transect walks. Conversations were recorded using activity reports, which were constructed from field notes.

Following the transect walks, research assistants observed key gathering places during different times of the day for longer periods. During these observation periods, daily time charts were completed with differing groups of women, men and youth. This second qualitative component provided coarse ethnographic descriptions of who gathered where, for what reason and for how long. All fieldwork was conducted prior to the initiation of trial interventions.

To guide an objective ranking of the TB transmission risk posed by different social gathering places, we created a score card using well-established TB transmission principles (Table 2). The score card was designed around three significant factors related to transmission; 1) the likelihood of an infectious TB patient (source case) being present, 2) the risk of airborne transmission (intensity and duration of exposure) taking place and 3) the number of people exposed. We used age as a surrogate of the likelihood that an infectious source case may be present. Owing to the fact that in this community the age category 25-54 years is most severely affected by highly infectious cavitatory TB, a multiplier of 2 was applied to gathering places where people from this age-group were likely to congregate. Children <8 years of age tend to have pauci-bacillary TB and rarely transmit the organism (17), which explains why 0 was used as the multiplier in settings where young children tend to congregate. The presence of an infectious adult, such as an adult teacher with smear positive TB, poses a serious transmission risk in these settings because young children are particularly susceptible to TB infection. To account for the vulnerability of young children we increased the multiplier in places where young children and adults congregate.

The risk of airborne transmission is mainly determined by the following variables: effective aerolisation of the organism i.e. from coughing and/or singing; the size of the airspace and/or proximity to the source case; the frequency of air exchange (ventilation); exposure to UV light and the length of time spent in the environment. The observation checklists were used in conjunction with ethnographic descriptions to assign a relative transmission risk score to each public gathering place identified, ranging from 0 (negligible) to 11 (high). The score was then adjusted according to the age of persons likely to gather in that type of gathering place, providing a final score that ranged between 0 (negligible) and 22 (high). Table 1 summarizes the scorecard used to quantify the TB transmission risk posed by various gathering places. Results were mapped using GIS technology to demonstrate the geographic distribution of gathering places within the community and the transmission risk assigned to each.

Fieldnotes from the transect walks explained how unofficial settlement[†] areas, that have no municipal services, form pockets within the larger community. These are particularly poor and over-crowded areas, within which boundaries between public and private spaces are extremely blurred (if even existent); people live and socialise in cramped makeshift structures that are very poorly ventilated. Owing to the high concentration of people, confined spaces, and amount of ongoing social mixing found, an increased transmission risk for these areas (relative to the wider community area) is implied.

The confidentiality of participants has been ensured in order to protect their privacy; actual site and place names are avoided. This study was approved by the Ethics Review Board of Stellenbosch University.

RESULTS

[†] Referred to by locals as ‘informal’ settlements.

The following were identified by research assistants as public gathering places in the community: Unlicensed drinking places (locally known as *shebeens*), pre-schools (crèches), clinics, churches[‡], community halls, schools, waterpoints, markets, container shops, welfare grant payout points, libraries, game shops/jukeboxes (places were youth often gather to listen to music and play games), *braais* (areaswhere meat is barbequed), supermarkets, sports grounds, cash stores, hair salons, taxi ranks, public libraries, Non Governmental Organisations (NGOs), old age homes, industrial work areas and hostels (previously compounds used to house miners, now derelict buildings providing over crowded shelter and business space).

TB 'transmission risk' scores calculated for the different types of gathering places, guided by the scorecard shown in Table 2, are reflected in Table 3. The scores assigned to gathering places before the cumulative 'transmission risk' score reflects a relative value (rather than an absolute value) for the average gathering place of this description i.e. from the scorecard we can conclude that, in general, *shebeens* have less ventilation than hair salons which in turn have less ventilation than taxi ranks. For gathering places with insufficient data to assign scores, TB transmission risk was not calculated. *Shebeens*, with a score of 22, emerged as places that potentially pose the highest transmission risk. Clinics and churches were also identified as gathering places that potentially pose a high TB transmission risk in this community. Figure 3 presents a visual portrayal of the geographic distribution and TB transmission risk of gathering places that were successfully scored and mapped using GIS. Unofficial settlement areas need to be noted as 'high risk' areas, but cannot be compared to the public gathering places identified due to the blur between public and private space found there i.e. they are not public gathering places as such. Instead of assigning a transmission score to the unofficial settlements, we have demarcated them on the map and acknowledge that they potentially compound the transmission risk associated with *shebeens* and other 'high risk' places of social mixing that overlap or are in close proximity to the unofficial settlement area.

[‡] Refers to Churches which gather in private homes and in public structures.

DISCUSSION

It is well recognized that the TB epidemic persists in geographically distinct poverty-stricken pockets of society (13, 18) and the importance of public health strategies that respond to both physical and social environments has been emphasised (19). Yet, it remains difficult to combine medical, environmental and social science approaches to tackle TB in an effective and locally sensitive way; multidisciplinary approaches are often hampered by poor cross-discipline communication and may appear overwhelming in complexity (20, 21). Our community assessment is an attempt to bring methods and disciplines together to demonstrate the potential application of similar approaches that are more refined. Combining rapid social appraisal techniques with basic infectious disease principles and GIS technology can not only provide an avenue to improve our understanding of TB transmission, but also an environmentally and socially informed platform to guide public health intervention. Once further developed, application of similar methodologies may aid attempts to break the cycle of TB transmission within communities.

The significance of public gathering places in facilitating the transmission of TB has been documented in other studies (11). Drinking places have previously been shown to pose high TB transmission risks (22, 23); Classen *et al*. (24) used DNA fingerprinting techniques in conjunction with in-depth interviews to document the high transmission risk posed by *shebeens.* Our findings allow accurate spatial mapping of multiple gathering places as potential transmission "hot spots" within the community; they also allow for comparison between various public gathering places, suggesting that *shebeens*, clinics and churches pose a higher transmission risk than public libraries, schools*, braai*s and taxi ranks in this research area. Further, our methodology allows for the unofficial settlement areas to be indentified as 'high-risk' zones.

The observational data collected in this study is biased towards activities and respondents present in the community during a winter's working day. However, to provide a more comprehensive overview and to limit this potential bias, we included one evening observation.

Daily time charts conducted with representative groups of the community also proved useful to assess the frequency at which key gathering places were visited and the duration of the visits outside (and inside) of the 'working week'. In areas where seasonal variation notably affects community life, we would recommend conducting activity charts that reflect how gathering places may differ from season to season.

From some of the qualitative data collected, it is apparent that adults usually seek employment outside of the research site during the day; gathering places linked to employment (or the search for employment) were not assessed along the transect walks. We also failed to assess the TB transmission risk posed by traveling within an overcrowded taxi, the usual mode of transport to and from areas of employment. Although studies in other settings have documented the high transmission risk posed by work environments (25), previous research in the Cape Town area suggests that recreational contact within the community is probably the most important contributor to ongoing transmission (24). Gross unemployment, a large unregulated economy and the volatility of short term contract work (often situated outside the geographical boundaries of this research site) make it difficult to unravel how places of employment may contribute to TB transmission. This emphasises that while fieldwork conducted in a "snap shot" fashion may be the most efficient method for gathering large amounts of relevant data about the social fabric of a community in a short period of time, it does not provide deep ethnographic accounts, which may be needed in order to comprehensively understand certain social factors (such as unemployment or employment) linked to gathering places (26). Moreover, other important risk factors for TB exposure and infection linked to social interaction, such as internal mobility, may be significant for TB control (27).

In retrospect, certain components of the data collection tool could have been more appropriately designed. The observation checklist would have been more effective if completed after the TB transmission scorecard variables had been determined. This would have narrowed the focus of the qualitative data collected on the transect walks and ensured that there were not too much ‘missing’ data - ultimately allowing more gathering places to be scored. GIS data for certain types of gathering places were lacking, preventing them from being mapped accurately and therefore displayed visually. Should we have had a ‘full’ set of GIS data or alternatively collected more GIS data from the site, all of the gathering places would have been mapped.

In practise, TB control strategies have primarily focused on case-finding i.e. on the individual patient. Our research responds to many arguments that multidisciplinary efforts are needed to evaluate and curb disease contributing factors operating beyond the control of the individual patient (18, 28, 29, 30, 31). The scoring of transmission ‘hotspots’ suggests that substituting ‘case-finding’ with ‘place-finding’ - previously proposed by Klovdahl *et al.* (11) - deserves urgent consideration in high burden endemic areas where social mixing plays a significant role in the transmission of TB. As an adjunctive strategy, ‘place-finding’ would enhance applied research; it need not neglect the importance of diagnosing and treating individual ‘cases’ while assessing a disease prone environment. Moreover, the locally nuanced ‘snapshot’ of public gathering places that the transect walks and scoring provides, can rapidly inform both further research and pilot interventions.

CONCLUSION

At a time when the HIV epidemic is rampant and primary transmission of extensively drug-resistant (XDR) TB is increasing, innovative responses to the tuberculosis epidemic are a matter of urgency (32, 33). Our study serves as proof of principle that combining qualitative techniques alongside GIS technology efficiently delivers valuable insight; potential transmission dynamics of TB are assessed at a community level. These techniques, if further refined and validated, may also offer powerful tools to direct targeted public health interventions.

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Figure 1
Routes followed by research assistants (guided by locals) on transect walks through the community.

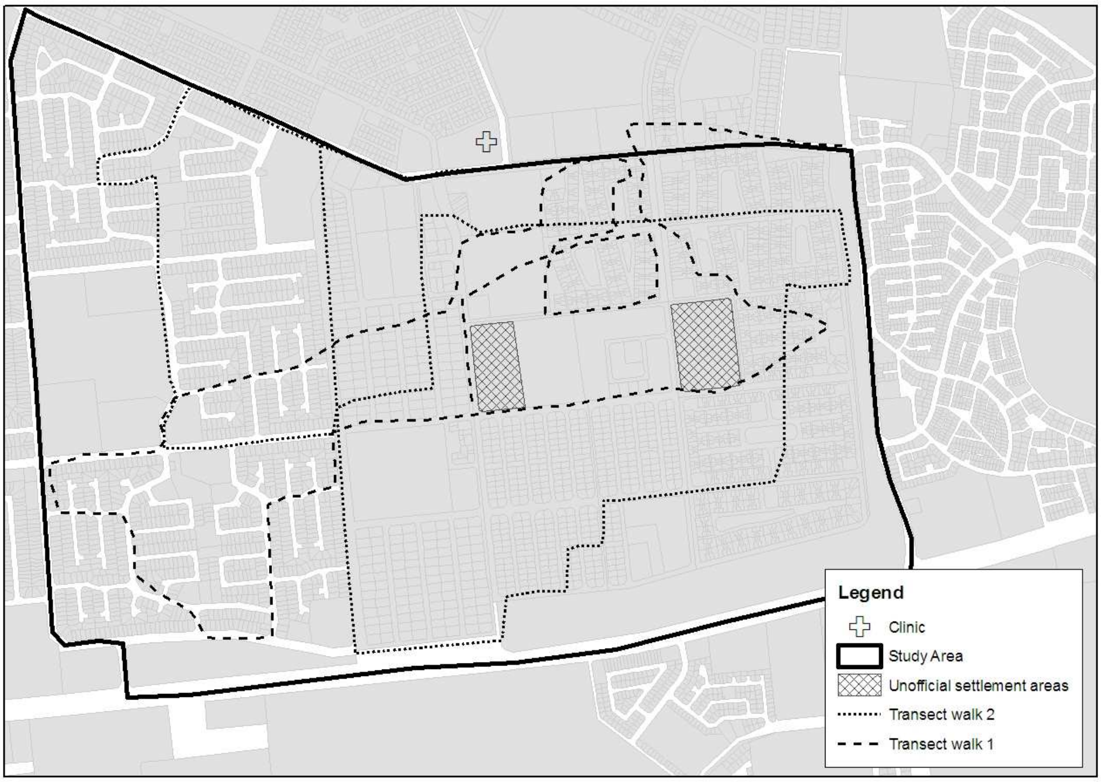

Figure 2

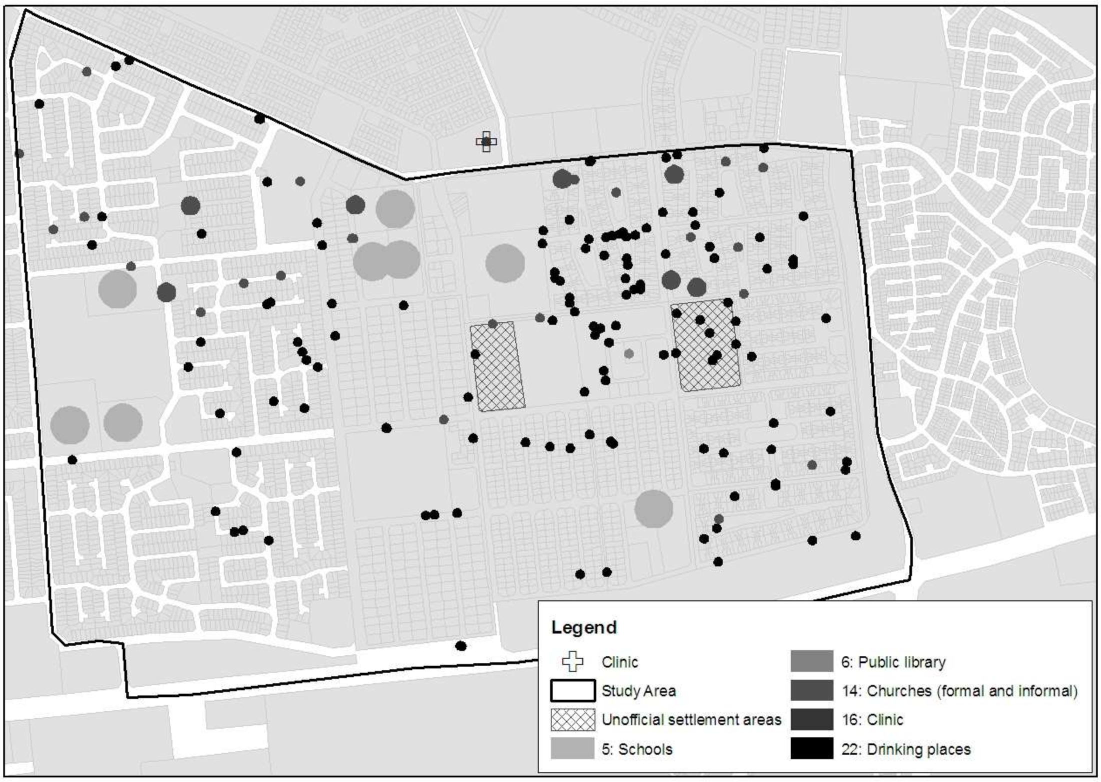

Table 1
Example of the Observation Checklist filled in by research assistants at gathering places identified.

<table>
<tr><td colspan="4">Gathering Place Number:</td></tr>
<tr><td colspan="4">Date plotted:</td></tr>
<tr><td>GPS co-ordinate:</td><td></td><td colspan="2">Description of Gathering Place:</td></tr>
<tr><td rowspan="3">Name of gathering place:</td><td rowspan="5"></td><td>Structure</td><td>New/Old
Permanent/ Temporary
Large / small (estimate in metres)
Well ventilated/ not well ventilated / open air</td></tr>
<tr><td>Building materials</td><td>Brick, concrete, grass, mud, plastic, makeshift, other</td></tr>
<tr><td>Crowding</td><td>Busy/Quiet
Cramped/ Spacious</td></tr>
<tr><td rowspan="2">Type of gathering Place:</td><td>People</td><td>Activities taking place
Estimate number of men / women / children
Estimate average age of children / youth/ adults/ elderly present</td></tr>
<tr><td>Other</td><td>Include any other significant features</td></tr>
</table>

Size of circles (‘spots’) reflects approximate surface area of gathering place.
Colour of ‘spots’ represents the calculated transmission risk – see legend.

Figure 3
Map showing the geographic location and TB transmission risk posed by social gathering places within the community.

Table 2
Score card used to rank the TB transmission risk of various gathering places.

VARIABLES	SCORE
A) SIZE of AIRSPACE	
> 4x4x2m	0
< 4x4x2m	1
B) VENTILATION	
Completely Open	0
Open windows/doors	1
Closed windows/doors	2
C) UV LIGHT	
Open air/daytime	0
Night time/shielded from light	1
D) SINGING	
No	0
Yes	1
E) DURATION of EXPOSURE	
< 2hrs/ week	0
2 hrs/ week	1
4-10hrs/ week	2
> 10 hrs/week	3
F) NUMBER/DENSITY of PEOPLE	
Few people (<10)	0
Moderate number of people (10-30)	1
Many people (>30) / loosely packed	2
Many people (>30)/ tightly packed	3
G) AGE of PEOPLE (multiplier)	
<8yrs	0
< 8yrs (majority) & adult(s) between 20-49yrs	2
8-19yrs	1
20-49yrs	2
>50yrs	1

Table 3
TB transmission score for the various public gathering places identified

Public gathering places identified	A	B	C	D	E	F	Total score (A+B+C+D+ E)	x G	Calculated transmission risk
Drinking Places (incl. *shebeens*)	1	2	1	1	3	3	11	2	22
Clinics	0	2	1	0	2	3	8	2	16
'Home' Churches (held in private homes)	1	1	1	1	2	1	7	2	14
Churches	0	1	1	1	1	3	7	2	14
Community Halls	0	1	1	1	1	2	6	2	12
Container Shops[!]	1	1	1	0	1	2	6	2	12
Supermarkets[!]	0	2	1	0	1	2	6	2	12
Cash Stores[!]	0	1	1	0	2	2	6	2	12
Hair Salons[!]	1	1	1	0	0	2	5	2	10
Braai Areas[!]	0	0	0	0	2	2	4	2	8
Taxi Ranks[#]	0	0	0	0	1	3	4	2	8
Public Libraries	0	1	1	0	1	0	3	2	6
Schools	0	1	0	0	2	2	5	1	5
Pre-schools (chreches)[!]	0	2	0	1	3	0	6	2	12
NGOs*									
Sports Grounds*									
Old Age Homes*									
Industrial Work Areas*									
Game Shops*									
Grant Payout Points*									
Hostels*									
Market Areas*									
Waterpoints*									

[!]Gathering places that were scored, but not included on the GIS map as a result of insufficient distribution data.
*Gathering places that were identified but unable to be scored as a result of incomplete data.
[#]The transmission risk posed by spending time inside a minibus taxi was not considered.
Data behind the scores reflected here were collected in the winter. The final transmission scores may vary in the summer.