Umoya omuhle

Infection prevention and control for tuberculosis in South African primary healthcare clinics

Abstract | The essential information

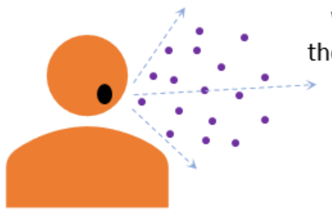
Transmission of *Mycobacterium tuberculosis* (*Mtb*) is common in health facilities in South Africa.
We conducted a four-year study to understand why this is happening.
In 12 clinics, we examined infection prevention and control (IPC) implementation and the broader clinic context.
We then asked South African experts to design and prioritise interventions to reduce transmission.
Using mathematical modelling, we estimate that queue management with outdoor waiting areas will have the largest potential impact on *Mtb* transmission (76%–88% reduction). Ultraviolet germicidal irradiation in waiting areas may be almost as impactful (64%–85% reduction).
All our modelled interventions were cheaper than many things already being done to curb the TB epidemic. They were also highly cost-effective. We strongly recommend investment in some or all of these interventions.

Section 1. Background | Why did we do this study?

We knew that health workers in South Africa are at high risk of tuberculosis (TB). This is partly because:

1. Transmission of *Mtb* is common at health facilities; and
2. TB infection prevention and control (IPC) is not always well implemented.

Mtb transmission: the most important bits



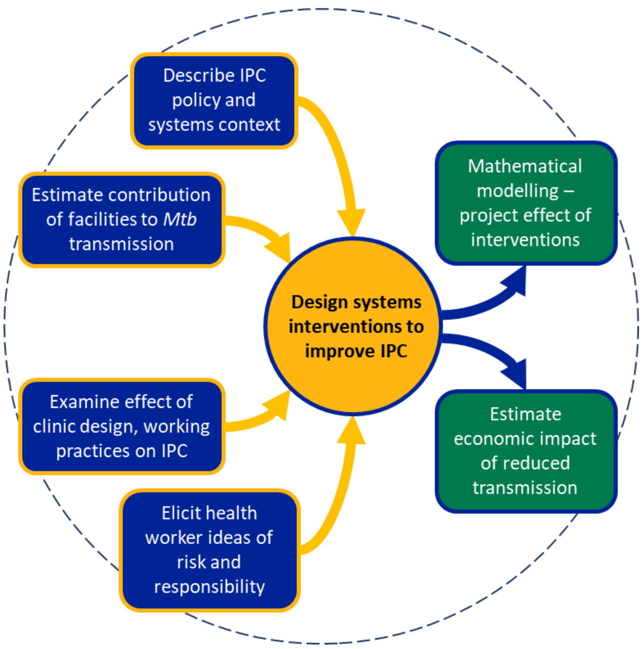
When a person with active TB coughs or speaks, they can release tiny particles of fluid that contain *Mycobacterium tuberculosis* (*Mtb*).

These particles can stay in the air for hours.

If another person inhales these particles, they may become infected.

We therefore set out to examine *Mtb* transmission and IPC at 12 clinics in KwaZulu-Natal and Western Cape. We aimed to develop and model interventions to reduce *Mtb* transmission to health workers and patients.

Section 2. Methods | What did we do?



This study was conducted over four years (2017–2021) and had three stages: **1) observe & measure** (data collection), **2) combine & design** (system dynamics workshops), and 3) **model & cost** (mathematical and economic modelling). All data collection was done before the start of the COVID-19 pandemic.

First, we collected data. We spoke to patients, health workers, members of civil society, and policymakers, as well as specialists in primary care, IPC, and the built environment. We also estimated: 1) how many adults attending clinics had active TB and/or TB symptoms; 2) the ventilation of waiting areas and consultation rooms; and 3) how people moved around clinics and where they spent time.

Second, we used system dynamics modelling (SDM) to bring our data together and design interventions. With researchers, patient and union representatives, practitioners from clinics and hospitals, and policymakers from District, Provincial, and National Departments of Health, we developed 'models' (diagrams) of the system and identified targets for interventions to reduce *Mtb* transmission. Our collaborators prioritised interventions based on how likely they were to be effective and how easily they could be implemented. Our final list was made up of seven interventions.

Finally, we developed mathematical models to estimate how **effective** the seven interventions were likely to be in reducing *Mtb* transmission in clinics. We also estimated their **cost**, including training, equipment, and health worker time. We combined these costs with our modelled estimates of effectiveness to estimate **cost-effectiveness**. This is a key metric used by governments to decide if an intervention is worth paying for.

Section 3. Results | What did we find?

3A. TB IPC has become "everybody's business and nobody's business" | Clinics are complex spaces

Policymakers and other senior stakeholders described widespread confusion around where TB IPC belongs within the broader health system. They also described a general lack of urgency around TB, and spoke about how difficult it is to change established behaviours among patients and staff (for example, around wearing masks and respirators).

At clinic level, we often observed conditions that were likely to increase the risk of *Mtb* transmission.

General observations	Observations around staff and working relationships
People waiting for a long time in areas that could be better ventilated	Not always enough technical expertise to translate national policy into action
Overcrowding and bottlenecks in patient flow	Rigid hierarchy in operations
Limited triaging & separation of people with TB symptoms	Limited teamwork and communication, with tensions and conflicts between various groups, including between staff and patients.
Inconsistent use of personal protective equipment	

3B. People with TB may not have TB symptoms | Air flow and patient flow are highly variable

14/20 (70%) people with *Mtb* in their sputum had no TB symptoms.

We randomly selected around 2000 adults attending clinics in rural KwaZulu-Natal. Twenty of them (about 1%) had *Mtb* in their sputum and may have been infectious. **Alarmingly, 70% of people with *Mtb* in their sputum did not have any symptoms suggestive of TB.** This means that symptom-based screening (e.g., cough triage) may miss many people who have infectious TB, which may increase the risk of transmission in 'general' spaces such as waiting areas.

Air flow experiments showed variation in how different spaces were ventilated. Smaller spaces (such as consultation rooms) generally had less air flow than larger spaces (such as waiting areas). **On average, opening the windows and doors doubled the ventilation.**

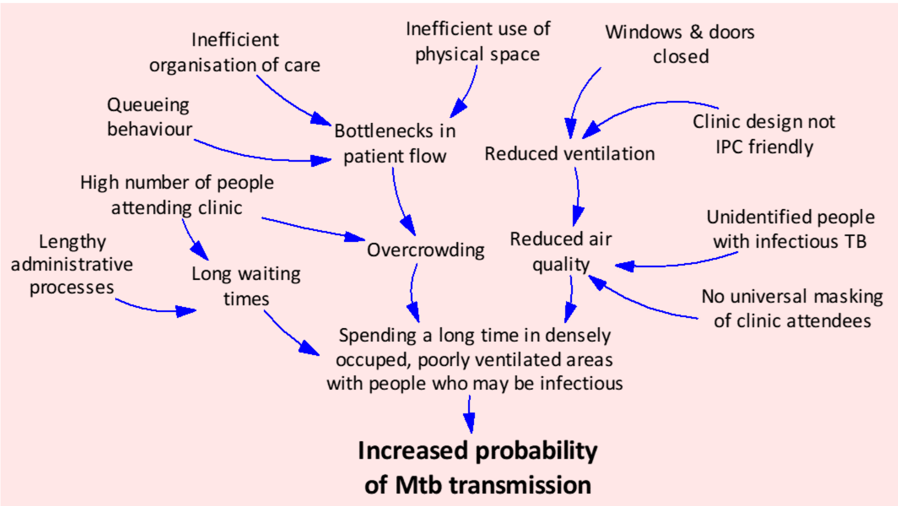
When measuring patient flow (how people moved around the clinic), we found that early queues were common – almost half of attendees had arrived by 09h00. **People who arrived earlier usually waited for longer**. People also spent more time outdoors (where the risk of transmission is lower) when the clinic used an outdoor waiting area.

Experts in building design and infection control suggested that a major challenge in improving ventilation is to maintain the comfort of people using the building, as opening windows and doors can make the room too cold or too hot. Careful planning is needed before making changes to clinic or care processes, as these changes can create problems that may increase risk of transmission, such as bottlenecks in flow and longer waiting times.

3C. System dynamics modelling: mapping the drivers of *Mtb* transmission

This an example of the kind of diagram produced during the workshops. In it, we can see the wide variety of factors and processes that may have an effect on *Mtb* transmission in clinics.

Some of these factors are more difficult to change, such as the design of the clinic, but others may be easier, such as improving ventilation, using masks and respirators, and reducing bottlenecks in patient flow.



3D: Seven interventions to reduce *Mtb* transmission in clinics

Our interventions focused on three areas:

1) improving ventilation & air quality; **2)** wearing protective equipment; & **3)** reducing overcrowding & waiting times

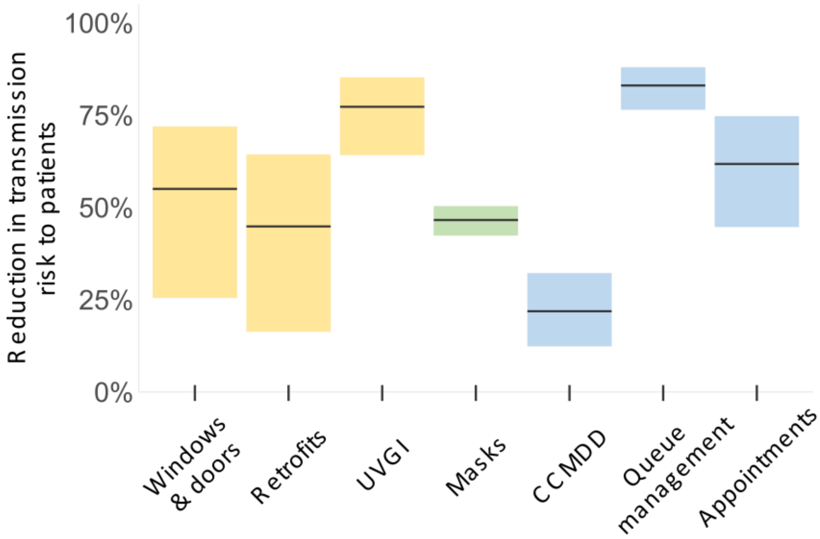
	1	2	3	4	5	6	7
Seven identified interventions and their mechanisms	**Opening doors and windows to improve ventilation**	**Making simple changes to buildings ('retrofits') to improve ventilation**	**Using ultraviolet germicidal irradiation (UVGI) to clean the air in waiting areas**	**Recommending surgical masks for patients & respirators for staff to reduce exposure to *Mtb***	**Strengthening CCMDD to reduce overcrowding and waiting times**	**Using a queue management system to reducing overcrowding and waiting times**	**Using date-time appointments to reduce overcrowding and waiting times**

In our intervention packages, we included supportive activities ('enablers') to help with implementation and sustainability. These included patient surveys, training, monitoring & evaluation, and community workshops.

3E. Mathematical and economic modelling: effectiveness, cost, and cost-effectiveness

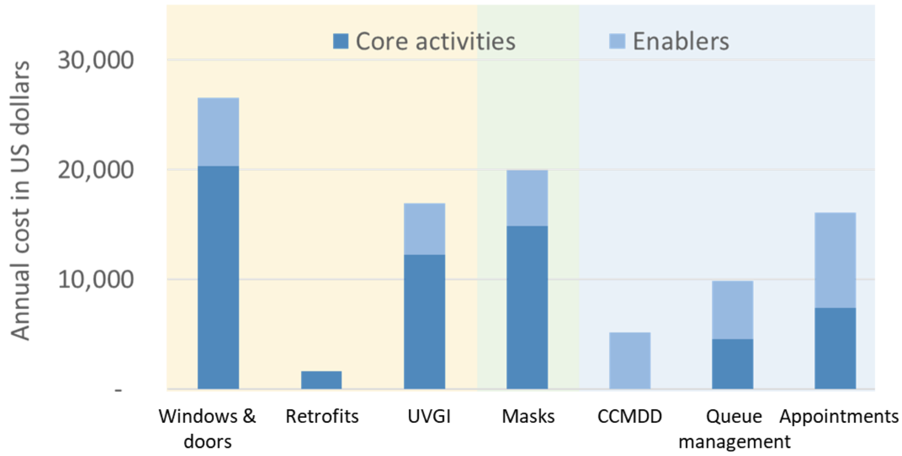
We created two models to estimate effectiveness.

- The first model suggested that these interventions could reduce *Mtb* transmission to patients by 22%–83%.
- Queue management (combined with outdoor waiting areas) had the largest potential impact (76%–88% reduction),
- UVGI in waiting areas was almost as impactful (64%–85% reduction) and may be more feasible in some clinics.
- All interventions are shown in the figure, where the heights of the boxes reflects the uncertainty of the estimates (taller box equals more uncertainty).



The second model asked a different question, namely "*How much TB in the community is because of transmission in clinics, and how much could these IPC interventions reduce TB levels in the community?*" The modelling showed that between 4% and 14% of TB disease in the community is because of transmission in clinics. Using any one of these interventions in clinics could lead to a 3%–8% reduction in the number of people who get TB between the years 2021 and 2030.

Costing: All seven interventions were much cheaper than many TB interventions that are already in place.



Opening doors and windows was the most expensive intervention, as it needed a lot of valuable health worker time. Installing retrofits (simple changes to buildings) was cheapest, but this can be difficult and time-consuming. Strengthening existing CCMDD practices was also very cheap, as many of the structures already exist. Queue management, appointments, UVGI, and mask-wearing were all priced in the mid-range.

When we combined our cost and effectiveness modelling to look at cost-effectiveness, we found that all the interventions were highly cost-effective. When we compared our estimates to other TB control interventions, such as intensified case-finding, we found that our TB IPC packages provide very high value for money.

Section 4. Discussion | What does all this mean?

1. **TB IPC belongs to everyone** – almost every activity at a clinic can have a positive or negative effect on IPC, from prescribing ART, to organising the filing system, to maintaining the building.
2. **'Good' IPC is more likely to happen in a safe and 'healthy' clinic** – i.e., a working environment where relationships, communication, and teamwork are prioritised and valued. Effective leadership is also critical.
3. **Waiting areas are complex and busy spaces**, and can be high risk for *Mtb* transmission. Improving the safety of waiting areas is likely to reduce the risk of transmission in the clinic.
4. **Many people with infectious TB do not have symptoms** and cannot easily be identified when they enter a clinic. Therefore, using universal precautions that apply to everyone are likely to be most effective; for example, improving ventilation and air quality, reducing the number of people spending time indoors, and ensuring 'source control' and personal protection.
5. **All seven measures we modelled are very efficient investments** for reducing *Mtb* transmission in clinics and reducing the levels of TB in the wider community.

Please visit our website for more information: https://www.lshtm.ac.uk/research/centres-projects-groups/uo

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