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Premises for patients with drug-resistant TB

The South African Government has adopted a multi-dimensional approach in order to improve the quality of care, which implies "stabilising the hospital sector" (DoH 1999:5).

Even amid greater emphasis on Primary Health Care (PHC) than ever before, hospitals remain the institutional heart of the South African healthcare system. While the clinic or the Community Health Centre (CHC) has gradually emerged as the mainstream unit in the PHC, it is unable to operate properly or to respond to healthcare needs and demands without backup from a first-referral or district hospital. In South Africa the district hospital figures prominently in the struggle against communicable diseases.

Among the communicable diseases, TB (and now drug resistant TB) is the most perilous after HIV/Aids. Globally, the institutionalisation of TB patients contributed to a more rapid decline in TB mortality after 1920, although segregation cannot be separated from other causes.

The historical benefits of TB sanatoria, where segregating patients was central to the treatment of TB, have been questioned. Some have proposed that the segregation lessened the transmission of infection. The overriding objective, however, was to seek pragmatic solutions to the TB epidemic. In articulating its mission on the Tuberculosis Strategic Plan for South Africa, the National Department of Health emphasised the need to prevent TB and to ensure that those who do contract TB have easy access to effective, efficient and high quality treatment and care that reduces suffering.

South Africa is one of the 22 high burden countries that contribute approximately 80% of the total global burden of TB cases, having the seventh highest TB incidence in the world. During the past ten years the incidence of TB has increased in parallel to the increase in the estimated prevalence of HIV in its adult population.

Disease caused by TB bacterium resistant to at least two of the most potent first-line drugs (Isoniazid and Rifampicin), is called multi-drug resistant TB (MDR-TB). MDR-TB is a man-made problem, largely being the consequence of human error in any or all of the following: management of drug supply, patient management, prescription of chemotherapy and patient adherence. Treating MDR-TB takes longer and requires drugs that are more toxic, more expensive, and generally less effective particularly in persons with HIV infection.

The problem of drug resistance in TB has been compounded by the emergence of extensively drug-resistant (XDR) TB, defined as MDR-TB in association with *in vitro* resistance to any of the fluoroquinolones plus one or more of the injectable second-line anti-TB drugs. Patients with XDR-TB are extremely difficult and expensive to treat and exceptionally high mortality (exceeding 90%) has been recorded in XDR-TB patients with HIV co-infection in South Africa.

Given the potential negative social, epidemiological and economic impacts of inadequate treatment of drug-resistant (MDR and XDR) TB, a systematic review of the quality of care delivered by MDR referral facilities has come under focus. Besides the importance of undertaking continuous drug susceptibility tests on all confirmed drug susceptible patients and all MDR and XDR-TB (M(X)DR-TB) patients, the SA National Department of Health's policy is that all confirmed drug-resistant patients are to be referred to M(X)DR-TB facilities for a period of at least six months and thereafter discharged for ambulatory care at the nearest health facility with ongoing treatment and psychosocial support. Discharge from the M(X)DR-TB facility however, being subject to proven TB culture conversion as identified by the supporting diagnostic laboratory service.

ABSTRACT

South Africa faces one of the most devastating *Mycobacterium tuberculosis* (TB) epidemics in the world in terms of TB incidence (or number of cases per capita) and overall TB burden (or total number of cases). Recent studies by the Medical Research Council (MRC) indicate that more than half the TB patients are also HIV-infected, with the co-infection rate approaching 75% in some provinces.

The availability of antiretroviral therapy in Africa brings hope for the management of HIV-associated TB. However, the treatment brings together individuals with undiagnosed TB, or MDR-TB (and now XDR-TB), and immune-suppressed HIV-infected individuals in congregate settings, resulting in high risk to hospital workers and patients.

Little, if any, guidance is currently provided to design teams responsible for the development of appropriate new health facilities or the refurbishing of existing structures. Much needed are guidelines for facility design, environmental infection control measures and functional methods for in-house risk management to prevent airborne infection.

Studies undertaken recently have indicated an urgent need for a significant number of new MDR and XDR-TB beds in South Africa. While projections of need will be refined over time using better prevalence data once the whole system has been strengthened and more comprehensive detection and diagnosis processes are in place, indications are that the need for beds will initially increase over time as surveillance is strengthened before reducing as the

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epidemic is brought under control.

A number of key issues related to the provision of MDR and XDR-TB beds were highlighted in the analysis of need study, which included an analysis of accommodation requirements.

These include the following:

- There is a need for a fast track process to ensure that beds are made available as soon as possible within the period (2008-2010).
- The design of M(X)DR centres must recognise special needs of staff, support staff retention and the needs of specialised patients care through providing:
 - Safe, functional and attractive working conditions.
 - Where appropriate, staff accommodation.
 - Rigorous infection control requirements; and
 - The special needs of patients undergoing severe medical treatment.

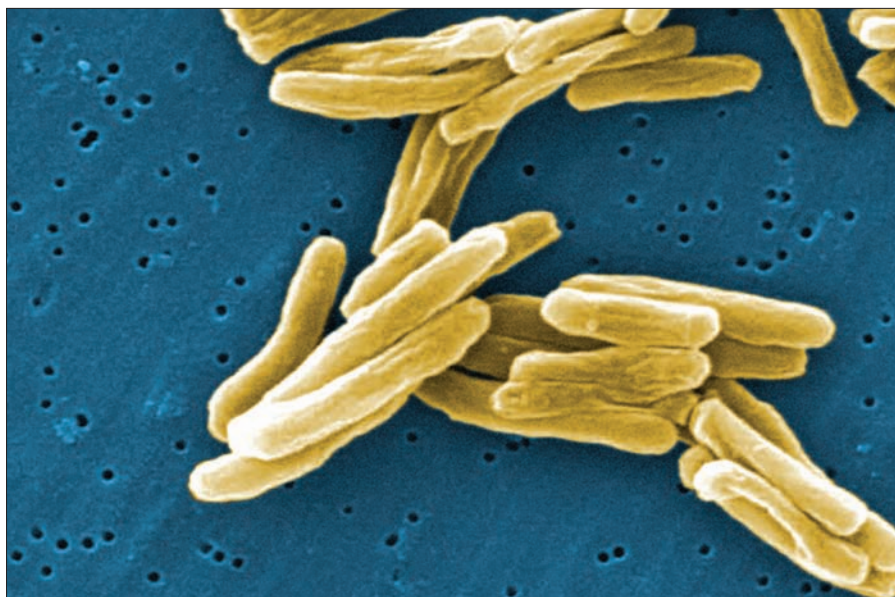
In addition to establishing appropriate infrastructure to support the roll-out of the National TB Control Programme with specific relevance to managing drug-resistant TB strains, objectives are to develop, publish and promote strategies, initiatives and guidelines to assist administrators of TB programmes, health service and facility planners and designers, healthcare managers, healthcare workers, and other stakeholders in the public, private and non-governmental health sector, involved with the planning for the provision of inpatient care for MDR-TB and XDR-TB patients, to become mindful of the fundamental facility design and management requirements that will reduce possible cross infection or transmission of the disease.

Understanding transmission of *M. tuberculosis*

The bacterium *M. tuberculosis* becomes aerosolised in small droplets of water or bodily fluid when a person with the disease of the lung coughs, sneezes, laughs or sings. Many of the smallest respiratory droplets dry into "droplet nuclei" and become airborne following room air currents as described below.

After ejection from the mouth and nose, even the smallest droplets begin to fall. (The actual rate of fall is determined by its aerodynamic diameter). Generally, the large particle droplets greater than five micrometers fall to the ground where they become mixed with, and in part adherent to,

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High magnification of *Mycobacterium tuberculosis*.

the heterogeneous mixture of particulate animal, vegetable and mineral debris which constitutes household dust. The fate of the smaller droplets is quite different. As droplets present a large surface they tend to evaporate rapidly in the air. (The speed of evaporation will therefore depend on the size of the droplet.)

As droplets fall through the air, they evaporate and those below a certain aerodynamic diameter fall sufficiently slowly and lose water sufficiently rapidly to evaporate almost instantaneously. In this way the droplet diminishes in size until the concentration of dissolved substances is such that the vapour pressure which the droplet exerts equals that of the atmosphere.

The residue of the droplet after evaporation, which may contain the organism(s) originally present when expelled from the respiratory tract, has been called the droplet nucleus. Droplet nuclei are so light that they may not settle in the gentlest of moving air of occupied spaces and may remain suspended until they are removed by dilution ventilation or possibly by some disinfection method.

Infection can occur when the bacterium or droplet nuclei are inhaled. *M. tuberculosis* infection is however, different from TB disease. People having the infection (without disease) have been infected by the *M. tuberculosis* bacterium. They are not symptomatic because their bodies' immune system has encapsulated the infectious material in the lung, where it is held dormant. They cannot spread the bacterium or disease to others when in this phase. However, people with infection may reactivate a dormant focus leading to disease in the future. The infection then spreads, usually within the lung and possibly to other areas of the body. People with drug-susceptible and resistant strains of tuberculosis disease can therefore transmit the disease to not only those who are not

infected, but also those already infected.

The particulate nature of airborne infection has a number of important consequences. First, a particular volume of air is infectious only so far as it contains a particle capable of giving rise to infection. As a result, the factors which affect the concentration of infectious particles in the air become of paramount importance in determining whether a person exposed to the air becomes infected or not. Respiratory droplets, with their limited flight, range and dependence on the simultaneous presence of source and subject, behave as a form of contact and so, for similar reasons, do droplet nuclei. It was for this reason that Wells called droplet-nucleus-borne infection "airborne contagion".

The risk for an individual of becoming infected with tubercle bacilli depends therefore on the concentration of organisms in the air of the indoor space being occupied, the duration of exposure to air contaminated with tubercle bacilli and the aerodynamics of the droplet nuclei.

In healthcare settings, physicians, nurses, general hospital personnel, as well as other patients are at a high risk for infection because they share the same breathing space as infectious patients.

Need to design for infection control

Various international agencies such as the World Health Organization, and Centers for Disease Control and Prevention in the USA, provide policy guidance for infection control practices. Common to all is the need to base these practices on the hierarchy of control measures. These include:

Administrative (managerial and policy) control measures

The first and most important level of control is the use of administrative control measures to prevent droplet nuclei from being

generated and thus reducing the exposure of healthcare workers (HCWs), and patients to *M. tuberculosis*.

Ideally, if the risk of exposure can be eliminated, no further controls are needed. Unfortunately, the risk usually cannot be eliminated, but it can be significantly reduced with proper administrative control measures. Important administrative control measures include early diagnosis of potentially infectious TB patients, prompt separation or isolation of infectious TB patients, and the prompt initiation of appropriate anti-tuberculosis treatment.

Other important administrative control measures include an assessment of the risk of transmission in the facility, the development of a TB Infection Control Plan that details in writing the measures that should be taken in a given facility, and adequate training of HCWs to implement the plan.

Appropriate architectural design to support the functional and operational processes required for the first level of the hierarchy of control, namely the administrative measures, must be investigated and ensured via the design of the facility. This requirement in turn should not be inhibited by unilateral management decisions without consultations with all role players in the design and operational needs of any facility.

Personal protective equipment (respiratory protection)

In addition to administrative and environmental control measures (discussed below), the recommended personal control measure for protection of the HCW, from inhaling infectious droplets in high-risk M(X)DR-TB settings, is the use of respiratory protective devices. These are designed to fit over the mouth and nose and filter out infectious TB particles.

Environmental control measures

Since the exposure to infectious droplet nuclei usually cannot be eliminated, various environmental control measures can be used in high-risk areas to reduce the concentration of droplet nuclei in the air. Such measures include:

- Direct source control using local exhaust ventilation.
- Controlling the airflow within buildings to prevent contamination of air in areas adjacent to the infectious source, via contaminant source isolation techniques when designing appropriate ventilation systems.
- Dilution and removing contaminated air

via controlled (artificial), ventilation systems.

- The removal of contaminants from the air via filtration. The US Centres for Disease Control (CDC) allow the use of portable High Efficiency Particulate Arrestance (HEPA) filter units in TB isolation rooms, as a means of achieving the desired air change rate for the occupied space, thus augmenting the mechanical ventilation system.

Acceptable levels of room “air cleaning” in most South African healthcare facilities cannot be accomplished by artificial dilution air ventilation alone. Its efficacy is limited by engineering constraints and by cost. The removal of diluted air contaminated with infectious particles requires extremely large ventilation rates to minimise risk.

While the disadvantages of reliance on natural ventilation for infection control may include climate dependence and impact on patient comfort, the low cost of installation, operation and maintenance should be considered. The rapid recent escalation in the cost of electricity and frequent power outages especially in rural health settings further support the need to design, wherever possible, for natural rather than artificial ventilation.

For natural ventilation to work effectively, it must be considered from the earliest stages of the facilities design development. Focused on must be desired airflow patterns, the principal driving forces which enable these patterns to be achieved, and the size and location of openings (windows).

Potential for increased risk

The following situations and design features have been identified as potential for increased risk of M(X)DR-TB transmission in healthcare settings:

- **Congregate settings:** Any setting (usually waiting areas) where large groups of patients are kept in close proximity to each other are potentially high risk areas. The highest risk is usually in admission, main outpatient, emergency or pharmacy waiting areas where undiagnosed or untreated patients congregate, but smaller waiting areas or other functional areas, such as in X-ray departments or even multi-bed patient rooms can equally pose a risk.
- **Restricted/inadequate ventilation:** High levels of ventilation are important, especially in congregate settings or other direct contact areas, such as dining

facilities, occupational therapy areas, etc. Waiting areas need to be adequately ventilated at all times in order to dilute concentrations of infectious airborne bacteria. Areas such as those for consulting, examination, counselling or treatment, where staff spend long times in relatively small spaces in close proximity to patients, should be considered high risk areas. Minimum openable window areas are regulated but often not met. The design of the window is also important to promote natural ventilation. The WHO guidelines indicate a target of 20% open window area to space floor area. However, improved ventilation alone is usually not enough to reduce risk in that the directional flow of air to and from adjacent areas needs to be addressed.

- **Shape and volume:** The shape and volume of a space can also be a risk indicator. Occupied spaces with inadequate floor to ceiling height (often found in multi-storey buildings) are generally higher risk areas than those with a shaped ceiling to high level clear storey windows. Shape and volume usually is linked to ventilation. The position and ease of opening of both high and low level windows is important as is staff awareness of the need to keep windows open to allow unobstructed ventilation.
- **Adjacency:** The distance between carriers and staff or other patients is a risk factor. Congregate areas where patients are sitting close together is an obvious situation and settings where close contact occurs such as during consultation, examination and treatment are risk situations. Bed spacing and multi-bed wards are risk situations.

Guiding principles

Much of the focus in dealing with an urgent need for accommodation often falls on delivery by any means possible in order to ensure that additional beds are made available as quickly as possible to cater for the large demand for hospitalisation. This is often through the decanting of beds and reuse of existing accommodation or through adaptation of existing facilities. It was therefore necessary to balance the real and urgent need for additional accommodation with ensuring that the beds provided would achieve an acceptable healing environment in a resource limited context.

While specific focus has been given in preceding sections to ventilation as a key risk factor that must be clearly researched and addressed in the design of M(X)DR-TB facilities, research has identified a number of broad guiding principles that must inform planning and design of new facilities and the adaptive reuse of existing facilities. These principles can be grouped into the following broad categories: risk management, healing environment, affordability and sustainability, and rapid delivery.

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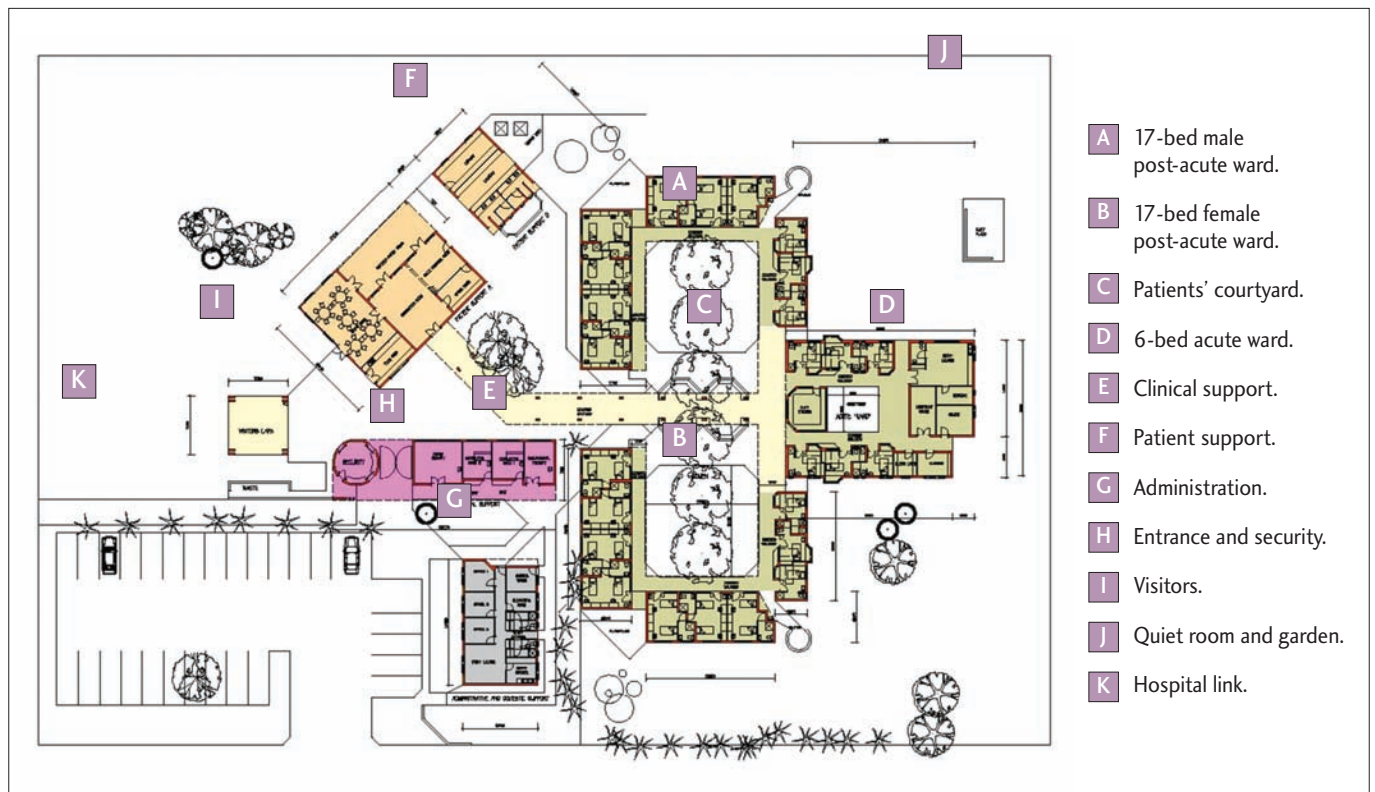


Figure 1: Concept layout for a 40-bed M(X)DR-TB facility.

Risk management

Facilities design must assist with reducing opportunities for patient-to-patient and patient-to-staff infection transmission. A reduction in contact opportunities is seen as essential. Careful design of ventilation measures, and the ongoing management of these, is required. Pressure variations can be used to create safe zones. A variety of tools are being used including computational fluid dynamics for airflow and ventilation modelling of patient rooms and congregate areas to ensure that window designs and positions, and room shapes, are optimised. Other assessment tools include those for solar gain and heat load, shading and lighting optimisation.

Healing environment

There is strong evidence from research studies (Ulrich *et al* 2008) as to the importance of health facility design as a means to improve health outcomes. Environmental factors such as large windows with high levels of daylight, views of nature and low noise levels all reduce stress and depression and promote healing. In order to ensure compliance with treatment regimes, patients need to be kept under treatment in M(X)DR-TB facilities for prolonged periods of six months or more. During their stay they move from being ill and in need of normal hospital acute care to being well and only requiring supervised medication. The provision of patient support accommodation and social counselling and support (visits from relatives and friends) is essential to promote a sense of wellbeing and purpose.

Facilities are also provided for further education and learning and a small business hub is provided as many patients need to keep their businesses running while under treatment. The more supportive the environment the less chance there will be of patients absconding and infecting others while still in an infectious stage of the disease.

Another important consideration in the design has been the need to protect staff through providing safe working environments.

Affordability and sustainability

While a lower than normal capital cost is expected due to the use of a lightweight steel frame system building, the selection of finishing materials is being carefully considered to ensure an optimised life-cycle cost. The use of natural ventilation and lighting is aimed to further reduce ongoing utility costs. Opportunities for the use of grey

water and rainwater will be sought in individual site-specific designs. By creating a high standard and safe environment for staff it is hoped to improve staff retention and reduce turnover.

Rapid delivery

Two key initiatives are being introduced to fast-track project delivery: reviewing current contracting strategies and fast-tracking the construction process.

This will link to the use of a lightweight steel frame and a cast *in situ* lightweight concrete infill system as opposed to the standard brick and mortar process normally used in South Africa. The structure is designed from dimensioned plans and sections using special CAD software which sizes all framing and roof members as well as predetermines machine punching of holes for wet and electrical service runs through the structure. Standard finishes are used providing a robust, solid and durable structure. Despite the current high price of steel, steel frame construction costs are lower than for conventional construction.

It is anticipated that a combination of these two initiatives will cut construction delivery time by more than half, allowing the four pilot projects to be completed within an optimised timeframe required to ensure service delivery.

The above principles have been used in the design of a standardised prototype facility developed by the CSIR. The design (Fig. 1) is currently being analysed and optimised before construction.

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Conclusion

The emergence of drug-resistant strains of TB has posed a serious threat to public health. In many respects it is preferable to invest money not in addressing M(X)DR-TB once it is manifest as illness but in preventing the spread of the disease.

Unless urgent and effective action is taken, however, the epidemic will undoubtedly worsen.

Investment in safe and appropriate building infrastructure that will support necessary infection control measures where needed, and in a timely manner, is essential for supporting all service delivery endeavours: be they prevention or treatment. ■

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