

Title:

An evaluation of the compliance to the ventilation aspects of airborne infectious disease control in Cape Town, South Africa.

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In partial fulfillment of the MMED in Emergency Medicine FACULTY OF HEALTH SCIENCES

University of Cape Town

DEPARTMENT OF EMERGENCY MEDICINE

University of Cape Town

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1. DECLARATION

I, CONRAD GROENEWALD, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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2. Abstract:

An evaluation of the compliance to the ventilation aspects of airborne infectious disease control in Cape Town, South Africa.

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Abstract:

Background: Tuberculosis (TB) is a major healthcare problem worldwide and is endemic to Cape Town, South Africa. Health Care Workers in Emergency Centers (ECs) are at high risk of nosocomial TB infection. The aim of this study was to determine whether the isolation rooms (IRs) in emergency centers, for patients with diagnosed or suspected TB, comply with set National Core Standards.

Methods: This was a cross-sectional descriptive study of ECs in the Cape Town Metropolitan area. The characteristics of IRs with regards to air changes per hour (ACH), negative pressure ventilation with relation to the surrounding areas and appropriate discharge of air outdoors or via filters before recirculation was measured using standard objective engineering methods.

Results: 19 IRs in 8 ECs were evaluated, none of which complied with the National Core Standard's ideal requirements for IRs. Five complied with minimal requirements. Eleven (57,9%) IRs were designed to have negative pressure; and 8 (42,1%) rooms were not designed for isolation purposes. IR volumes ranged from 15,5 m³ to 67,2 m³ (median 35,6 m³).

Five (26,3%) IRs were under negative pressure; 7 (36,8%) had erratic air flow; and 7 (36,8%) showed positive airflow from the IR into adjacent clinical areas. Fifteen (78,9%) IRs had central provision of air via a ventilation system; 6 (31,6%) had central air extraction; 6 (31,6%) had local extraction; and 7 (36,8%) used natural ventilation only. Four local extraction units had zero flow rate. Airflow in naturally ventilated IRs was significantly lower than flow with other systems ($p = 0,0002$). The ACH ranged from 0 ($n=4$) to 112.37 (median 11,9); and was significantly greater in rooms ventilated with central extraction compared to other systems ($p = 0,00002$).

Discussion: The ventilation aspects of airborne infectious disease control are generally poorly implemented. This may contribute to, and fail to mitigate, the high risk of nosocomial transmission of airborne infectious diseases to staff and other patients utilising emergency facilities in the TB endemic areas of Cape Town.

Conclusion: Existing ECs should improve adherence to standards of airborne infectious disease transmission prevention in order to protect patients and staff from nosocomial airborne transmitted diseases, such as TB. New Hospitals should place a high priority on the amount, positioning and maintenance of IRs when planning their facility.

3. Acknowledgements:

A special thanks to the following people for the role they played in the production of this document:

Dr. WAJ Meintjes (*Senior lecturer and Head of Department for Infectious Disease Control at Stellenbosch University*) for providing support, enthusiasm, the equipment, practical plans to put this project together and evaluating the data produced.

Brenda Morrow (*Associate Professor. Department of Paediatrics and Child Health. University of Cape Town*) for providing expert guidance with regards to the logistics, effort and details that goes into such a project, as well as her help with data analysis.

4. Publication Format:

4.1. Chapter 1: Introduction and Literature review.

Research question:

Do the rooms currently being used to isolate patients with known or suspected tuberculosis (TB) or other airborne diseases in Emergency Centers in Cape Town, South Africa (SA) comply with prescribed local safety requirements?

Objectives of the literature review:

To describe:

- Airborne disease and how it spreads.
- How TB causes disease, latent vs. active TB.
- Force of TB infection
- Global and local (South African and Western Cape) burden of TB disease (including Multi-Drug resistant (MDR-TB) and Extensive-Drug resistant TB (XDR-TB).
- The burden of TB on Health Care Workers.
- The role of the employer in ensuring a safe working environment.
- TB prevention strategies according to the World Health Organisation (WHO).
- The importance of ventilation in infection control.
- Current SA guidelines relating to the placement of a patient with known or suspected TB.
- Current status of evidence around Emergency Centre practices for infectious disease safety.

Literature search strategy:

The following databases were searched:

- PubMed / Medline
- Scopus
- Science Direct
- Google Scholar
- PLOS one

Key words used:

- Tuberculosis, health care workers, infection
- Prevention, airborne disease, health facilities, infection control

- Western Cape, Cape Town, South Africa, TB, burden
- Developing countries, ventilation, WHO, Emergency Department

Results (Narrative data synthesis)

Airborne disease - how it spreads:

Throughout history, human beings have been exposed to airborne diseases, which at times have led to epidemics of respiratory infections ⁽¹⁾. An airborne disease is any disease caused by a pathogen transmitted to a human or animal through the air. When inhaled, these pathogens may or may not cause physical disease, depending on factors such as virulence and host immunity ⁽²⁾. The presentation of disease can range from minor to serious and may cause marked morbidity and even mortality. For transmission from one individual to another, there need not be personal contact with the primary source and transmission of microorganisms via the airborne route can occur a large distance away from the infective source ⁽³⁾. Airborne pathogens are usually spread via coughing or sneezing by the infected source. Expired bio-aerosols can travel over fair distances and remain airborne for an extended period of time. This is particularly true when droplet diameters are too large for diffusive deposition (>200 nm) or too small for gravitational deposition (<2 μ m) ^(4, 5).

Clear examples of the potential threat of airborne transmission include the dramatic spread of measles in the pre-vaccination era and the high death rate caused by airborne anthrax. ^(6, 7) There are many known potentially pathogenic microorganisms that are spread via the aerosol route (Table 1) ⁽⁸⁾.

| Table 1: Potentially human pathogenic microorganisms associated with airborne route of exposure (alphabetical) | |
|--|---|
| Organism | Source |
| <i>Aspergillus fumigatus</i> | Mould-contaminated building, compost |
| <i>Aspergillus versicolor</i> | Mould-contaminated building |
| <i>Bacillus Anthracis</i> | Bio-terrorism, animal handlers, veterinarians |
| <i>Francisella Tularensis</i> | Potential WMD*, infected rodents |
| <i>Legionella Pneumophilia</i> | Aerosols from water spray, water reservoirs |
| <i>Mycobacterium Tuberculosis</i> | Person-to-person |
| <i>Penicillium species</i> | Mould-contaminated building |
| <i>Strachybotrys chartarum</i> | Mould-contaminated building |
| <i>Trichoderma species</i> | Mould-contaminated building |
| <i>Variola Virus</i> | Potential WMD* |
| <i>Yersinia Pestis</i> | Potential WMD*, infected fleas |

*WMD – weapon of mass destruction ⁽⁹⁾

How TB causes disease, latent vs. active TB:

TB is transmitted, with rare exception, by the respiratory route, including droplet spread and as true aerosolisation into micro-particles ^(10, 11). Patients with active disease expel *Mycobacterium tuberculosis* (MTB) in liquid droplets during coughing, sneezing, and vocalizing. A single cough or a 5-minute conversation with a person who has TB can produce about 3000 infectious droplets, and a sneeze can produce even more ⁽¹²⁾. Once inhaled the process is described in 5 stages on a cellular host response level ⁽²⁾. Persons with *latent TB* infection do not feel sick and are asymptomatic. They are infected with

MTB, but do not have TB disease. Once infected, one of three clinical courses can be expected (fig 1).

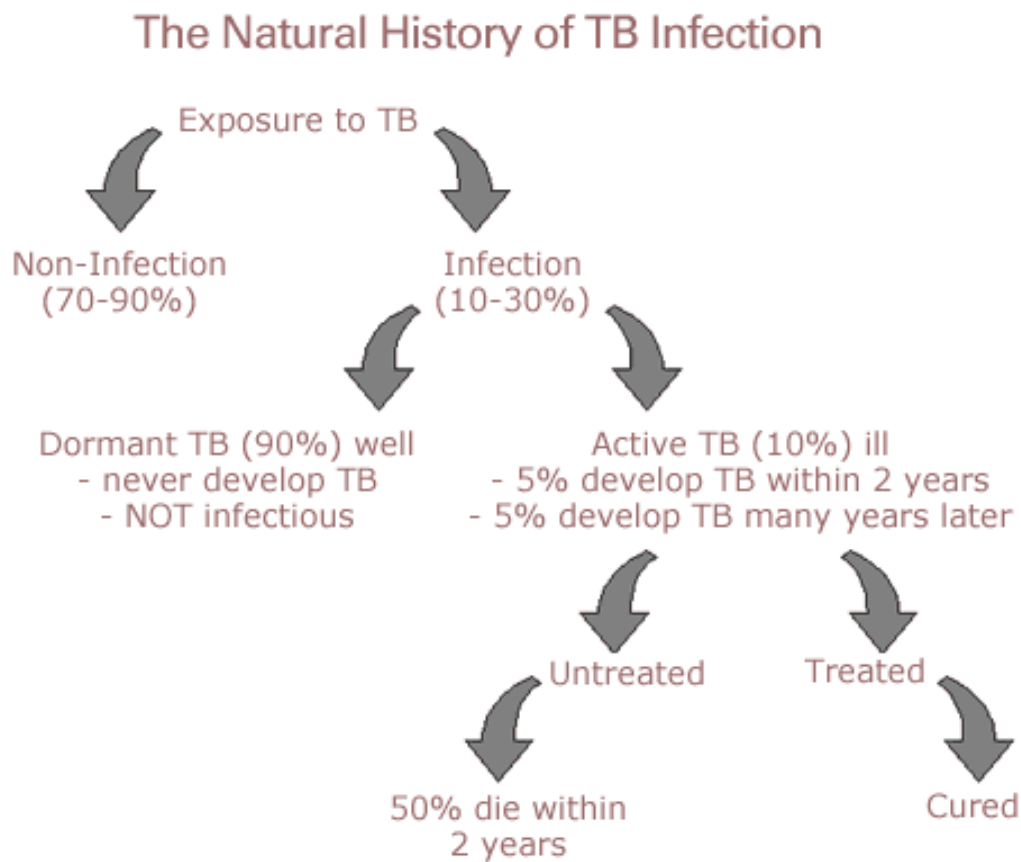


Figure 1: Natural Progression of TB after exposure.⁽¹⁴⁾

First, a minority (< 5%) develops a rapidly progressive disease that may or may not be proven with tissue or sample culture (evidence of bacterial replication) and is referred to as 'active' primary TB.

By contrast, the majority of infected persons remain asymptomatic while harbouring the organism but develop an effective acquired immune response – they are referred to as having 'latent' TB, on the basis of a positive tuberculin skin test (TST) or in *vitro* assay of T-cell function (interferon gamma release assay, IGRA)⁽¹⁵⁾. As a third possible outcome, a proportion of those 'latently' infected (1%–2% per year) might reactivate infection and develop the disease years to decades later (post primary TB)⁽¹⁶⁾. Persons with latent TB infection are not infectious and cannot spread TB to others⁽¹⁷⁾.



Diagnostics for Tuberculosis: Global Demand and Market Potential/TDR, FIND SA. WHO 2006.⁽¹⁸⁾

Current TB burden of disease worldwide and in South Africa (including Multi-Drug resistant (MDR-TB) and Extensive-Drug resistant (XDR-TB):

TB is currently the world's second leading cause of death from infectious disease, and approximately one third of the world's population has been infected with MTB ⁽¹⁹⁾.

In 2014, 9.6 million people contracted TB and 1.5 million died from the disease. Over 95% of TB deaths occur in low- and middle-income countries, and it is among the top 5 causes of death for women aged 15 to 44. In 2014, an estimated 1 million children became ill with TB and 140 000 children died of TB. TB is a leading killer of HIV-positive people: in 2015, one in three HIV deaths were due to TB. Globally in 2014, an estimated 480 000 people developed multidrug-resistant TB (MDR-TB) ⁽²⁰⁾.

In 2015 the 20th edition of a global annual TB report was published. This report provides a comprehensive up-to-date assessment of the TB epidemic and progress in implementing and financing TB prevention, care, control and research at global, regional and country levels. The report used data from over 200 countries that account for more than 99% of the world's TB cases ⁽²⁰⁾. Of these 200 countries, South Africa ranked highest in incidence rate (IR) of TB with an IR of 860 per 100 000 people (figure 2) ⁽²⁰⁾. TB was also the leading cause of death in 2013 in South Africa with over 40,542 deaths notified ⁽²¹⁾. With an estimated annual case load of 13,000 MDR-TB cases, South Africa is placed 4th among countries where MDR-TB is highly prevalent ⁽²²⁾. South Africa is also known to have one of the worlds highest number of extensive drug resistant (XDR-TB) cases⁽²⁰⁾.

South Africa

| Population 2014 | | 54 million |
|--|---------------------|-------------------------------|
| Estimates of TB burden * 2014 | | |
| | Number (thousands) | Rate (per 100 000 population) |
| Mortality (excludes HIV+TB) | 24 (22–26) | 44 (41–48) |
| Mortality (HIV+TB only) | 72 (58–89) | 134 (107–164) |
| Prevalence (includes HIV+TB) | 380 (210–590) | 696 (390–1 088) |
| Incidence (includes HIV+TB) | 450 (400–510) | 834 (737–936) |
| Incidence (HIV+TB only) | 270 (240–310) | 509 (439–584) |
| <hr/> | | |
| Case detection, all forms (%) | 68 (61–77) | |
| <hr/> | | |
| Estimates of MDR-TB burden * 2014 | | |
| | New | Retreatment |
| % of TB cases with MDR-TB | 1.8 (1.4–2.3) | 6.7 (5.4–8.2) |
| MDR-TB cases among notified pulmonary TB cases | 4 700 (3 700–5 900) | 1 500 (1 200–1 800) |
| <hr/> | | |
| TB case notifications 2014 | | |
| | New ** | Relapse |
| Pulmonary, bacteriologically confirmed | 155 473 | 7 430 |
| Pulmonary, clinically diagnosed | 106 482 | 2 693 |
| Extrapulmonary | 33 522 | 566 |
| <hr/> | | |
| Total new and relapse | 306 166 | |
| Previously treated, excluding relapses | 12 027 | |
| Total cases notified | 318 193 | |

Figure 2: WHO report: TB statistics in South Africa. ⁽²⁰⁾

The Burden of TB in the Western Cape and Cape Town, SA

The Western Cape province of South Africa has the highest incidence rate of all forms of TB in the country, and Cape Town has one of the highest TB case burdens of any city in the world ⁽²³⁻²⁵⁾. These figures may be an under-estimation as the WHO is dependent on reporting of TB cases to national TB programs (NTP's). Many sites in South Africa and the rest of the world have similar problems with underreporting ⁽²⁶⁾. TB is either the leading or second most common cause of death in all races and sexes in people under the age of 65 in Cape Town ⁽²¹⁾.

Force of TB infection:

The force of infection is a term used to describe the proportion of individuals uninfected by TB that become newly infected per annum, and is determined by the prevalence of infectious TB cases and the number of secondary cases that can be attributed to each infectious case ⁽²⁵⁾.

A TB prevalence survey of a random sample of the general population was conducted in a Cape township in 2005. The prevalence of laboratory-proven TB among HIV-uninfected and infected adults was 0.47% and 5.2% respectively. ⁽²⁷⁾ After the community scale-up of

antiretroviral therapy (ART), the prevalence of TB among the HIV-uninfected population did not change, but the prevalence among HIV-infected adults decreased from 5.2% to 1.3% ⁽²⁸⁾.

Studies conducted in Cape Town estimated the force of TB to be between 4% and 8% per annum ^(27, 29, 30).

Effective TB control interventions that produced small reductions in the force of infection in Cape Town could produce large benefits in transmission reduction. Reduction of the force of infection to 1% would decrease the proportion of the population exposed to multiple TB exposures from over 50% to <0.5% and the proportion acquiring primary infection would decrease from 75% to <30% ⁽²⁵⁾. The high force of TB rates in Cape Town also highlights that Cape Town is a high-risk site for the uninfected.

Burden of TB on Health Care Workers:

There is good evidence to prove that a large amount of new TB cases are due to nosocomial contraction of MTB and there are real concerns about the alarming incidence of TB contracted by health care workers (HCWs) ⁽³¹⁻³⁴⁾. TB remains a significant occupational risk for HCWs in LMICs and in some institutions in high-income countries, with a reported high incidence of latent TB in South African HCWs ⁽³¹⁾. Risk of TB infection in HCW is likely to be particularly high when there is increased exposure combined with inadequate infection control measures ⁽³⁵⁻³⁷⁾. It has also been found that there is a higher incidence of nosocomial TB acquisition in the younger age groups, associated with poor treatment outcomes ⁽³⁸⁾.

Once a HCW is diagnosed with TB, there is a large strain on the individual due to emotional distress, the disease itself, treatment side effects, and the potential sequelae of chronic symptoms and pulmonary dysfunction⁽³⁹⁾. Affected and infected HCWs may also be likely to leave the profession or transfer to another field, which would result in loss of skill in an area where there is already scarce skills and limited work force ⁽⁴⁰⁾. Furthermore the employer would be faced with the financial and service delivery burden of workforce loss, combined with the obligation to supply continuous compensation, as stipulated in the Compensation for Occupational Injuries and Diseases Act ⁽⁴¹⁾. Compensation due to HCWs contracting TB ranked 3rd in the occupational diseases reported to the Compensation Fund for the non-mining sector of South Africa ⁽⁴²⁾

The role of the employer in ensuring a safe working environment:

In South Africa, The Regulations for Hazardous Biological Agents provides detailed descriptions and guidance on the protection of employees against infective agents ⁽⁴³⁾. These regulations also place the responsibility on the employer to “ensure the workplace is safe and without risk to health”. The need for occupational health and infection control programs is also mandated by the Department of Health in all healthcare facilities in South Africa, as described in the “National Core Standards for Health Establishments of South Africa” ⁽⁴⁴⁾. Poor or absent infection control in health care facilities is considered unacceptable, contrary to set national standards and also illegal.

The South African National Policy on Infection Control (SANPIC) presents minimal national standards for the effective prevention and management of healthcare associated infections, for both patients and HCW’s. This policy document states that every health-care setting should have a TB infection control program in place, as part of an overall infection control program ⁽⁴³⁾.

TB prevention strategies according to the World Health Organisation:

All health care facilities, both public and private, that care for patients with TB or persons suspected of having TB, should implement measures to minimize the nosocomial transmission of MTB.

SANPIC includes the outlines and guidelines as set by the Centers for Disease Control (CDC) and the World Health Organisation (WHO) for TB control in resource rich and resource-limited programs. These include a 3-tiered approach for infection control: 1) administrative controls; 2) engineering or ventilation controls; and 3) personal protective equipment for HCWs. ^(45, 46)

Administrative controls are needed to ensure that people with TB symptoms are rapidly identified and, if thought to be infectious, can be separated into an appropriate environment and treated. Administrative controls aim to minimize patient and health care worker contact time and should aim to discourage unnecessary admission to hospital, decrease overcrowding in wards and waiting areas and to limit the number of hospital visits. Emergency department (ED) overcrowding is a global problem with many potential sequelae, including prolonged ED stay of a patient who may be a source of infection. This

impacts on the implementation of administrative control measures, and leads to the ED being the potential focus of unrecognized nosocomial transmission ⁽⁴⁷⁻⁴⁹⁾.

Administrative controls should be complemented by environmental controls and use of personal protective equipment, as these measures contribute to a further reduction in TB transmission ⁽⁴⁶⁾. The environmental controls implemented will depend on building design, construction, and renovation and use, which in turn must be tailored to local climatic and socioeconomic conditions. Installation of ventilation systems should be a priority, because ventilation reduces the number of infectious particles in the air. Natural ventilation, mixed-mode and mechanical ventilation systems can be used, supplemented with ultraviolet germicidal irradiation (UVGI) in areas where adequate ventilation is difficult to achieve ⁽⁴⁵⁾. Personal protective equipment (particulate respirators) should be used with administrative and environmental controls in situations where there is an increased risk of transmission ⁽⁴⁶⁾.

The importance of ventilation in infection control:

Although many global TB management strategies have focused on treatment roll out programs, the single most important way to reduce transmission and prevent disease is to interrupt institutional transmission ⁽⁵⁰⁾. Airborne infection control strategies to prevent all forms of TB have long been a neglected component of TB infection control programs, with grave worldwide consequences ⁽⁵¹⁾. The WHO strongly recommend ventilation to be prioritized and states that the benefits of implementation of ventilation systems outweigh the disadvantages ⁽⁴⁶⁾. Furthermore, available evidence reinforces the need to design and implement simple, effective, and affordable TB infection-control programs in health-care facilities in resource-limited countries ⁽³¹⁾.

Current standards relating to the placement of a patient with known or suspected TB:

According to South African guidelines, a patient with suspected or confirmed TB should be placed in a private room, ideally with: 1) continuous monitored negative air pressure in relation to surrounding areas, 2) minimum of 6-12 air changes per hour, and 3) appropriate discharge of contaminated air to an area of safety or a monitored high efficiency filtration of room air before circulation. If those conditions cannot be met, then the patient should be placed in a room with a simple extraction fan allowing at least 6 air changes per hour and/or a room with an open window and adequate ventilation. ⁽⁴³⁾

Current status of evidence around Emergency Centre practices for infectious disease safety:

Current literature states that Emergency Department staff are exposed to an unexpectedly large TB burden in the workplace, resulting in a high rate of TB infection and therefore TB infection control should be prioritized in EDs, especially in high-prevalence settings^(35, 36, 49). There is however a paucity of literature surrounding the standard of practice and adherence to standards regarding infectious disease control.

Problem Statement:

The clear and present health risk, along with the emergence of newer drug resistant strains of TB, highlight the importance of good infection control measures in South African healthcare institutions. Despite the clear importance and need, the current adherence to WHO and national standards of airborne infection control has not been studied in the South African Emergency Center context.

Objective:

The objective of this study is therefore to establish if TB isolation rooms in public emergency centers in the Western Cape comply with set National Core Standards regarding the ventilation aspects of airborne infectious disease control.

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4.2. Chapter 2: Publication-Ready Manuscript

An evaluation of the compliance to the ventilation aspects of airborne infectious disease control in Cape Town, South Africa.

Dr. Conrad Groenewald (*Registrar in Emergency Medicine, University of Cape Town*); Dr. Jack Meintjes (*Head: Unit for Infection Prevention and Control, University of Stellenbosch*); Ass. Prof Brenda Morrow (*Associate Professor, Department of Paediatrics, University of Cape Town*);

Abstract:

Background: Tuberculosis (TB) is a major healthcare problem worldwide and is endemic to Cape Town, South Africa. Health Care Workers in Emergency Centers (ECs) are at high risk of nosocomial TB infection. The aim of this study was to determine whether the isolation rooms (IRs) in emergency centers, for patients with diagnosed or suspected TB, comply with set National Core Standards.

Methods: This was a cross-sectional descriptive study of ECs in the Cape Town Metropolitan area. The characteristics of IRs with regards to air changes per hour (ACH), negative pressure ventilation with relation to the surrounding areas and appropriate discharge of air outdoors or via filters before recirculation was measured using standard objective engineering methods.

Results: 19 IRs in 8 ECs were evaluated, none of which complied with the National Core Standard's ideal requirements for IRs. Five complied with minimal requirements. Eleven (57,9%) IRs were designed to have negative pressure; and 8 (42,1%) rooms were not designed for isolation purposes. IR volumes ranged from 15,5 m³ to 67,2 m³ (median 35,6 m³).

Five (26,3%) IRs were under negative pressure; 7 (36,8%) had erratic air flow; and 7 (36,8%) showed positive airflow from the IR into adjacent clinical areas. Fifteen (78,9%) IRs had central provision of air via a ventilation system; 6 (31,6%) had central air extraction; 6 (31,6%) had local extraction; and 7 (36,8%) used natural ventilation only. Four local extraction units had zero flow rate. Airflow in naturally ventilated IRs was significantly lower than flow with other systems ($p = 0,0002$). The ACH ranged from 0 ($n=4$) to 112.37 (median 11,9); and was significantly greater in rooms ventilated with central extraction compared to other systems ($p = 0,00002$).

Discussion: The ventilation aspects of airborne infectious disease control are generally poorly implemented. This may contribute to, and fail to mitigate, the high risk of nosocomial transmission of airborne infectious diseases to staff and other patients utilising emergency facilities in the TB endemic areas of Cape Town.

Conclusion: Existing ECs should improve adherence to standards of airborne infectious disease transmission prevention in order to protect patients and staff from nosocomial airborne transmitted diseases, such as TB. New Hospitals should place a high priority on the amount, positioning and maintenance of IRs when planning their facility.

Introduction:

Tuberculosis (TB) is a top infectious disease killer worldwide ⁽¹⁾. TB is known to be a major healthcare problem globally, with particularly high prevalence in the Western Cape region of South Africa (SA) ⁽²⁻⁶⁾.

There is good evidence to prove that a large proportion of new TB cases are due to nosocomial contraction of *MTB* and there are real concerns about the alarming incidence of TB contracted by health care workers (HCW's) worldwide and in SA ⁽¹⁰⁻¹⁵⁾. Emergency Department (ED) staff specifically are exposed to an unexpectedly large TB burden in the workplace, with a resulting high rate of nosocomial TB infection. Therefore, TB infection control measures should be prioritized in EDs, especially in high-prevalence settings ⁽⁹⁾.

Infection-control strategies to prevent airborne transmission of *Mycobacterium tuberculosis (MTB)* have long been a neglected component of TB control programs, with grave worldwide consequences ⁽⁷⁾. The World Health Organisation (WHO) strongly recommends ventilation to be prioritized and sees that the benefits of implementation of ventilation systems outweigh the disadvantages ⁽⁸⁾. There is an urgent need for effective non-medical TB control strategies in Emergency Centers ⁽⁹⁾.

In SA, the "Regulations for Hazardous Biological Agents" document provides detailed descriptions and guidance on the protection of employees against infective agents ⁽¹⁶⁾. The need for occupational health and infection control programs is also mandated by the Department of Health in all healthcare facilities in South Africa, as described in the "National Core Standards for Health Establishments of South Africa" ⁽¹⁷⁾. Poor or absent infection control in health care facilities is considered unacceptable, contrary to set national standards and also illegal.

According to South African guidelines, a patient with suspected or confirmed TB should be placed in a private room, ideally with: 1) continuous monitored negative air pressure in relation to surrounding areas, 2) a minimum of 6-12 air changes per hour, and 3) appropriate discharge of contaminated air to safety or a monitored high efficiency filtration of room air before circulation. If those conditions cannot be met, then the patient should be placed in a room with a simple extraction fan allowing at least 6 air changes per hour and/or a room with an open window and adequate ventilation ⁽¹⁸⁾.

Despite the clear importance and need, the current adherence to WHO and national standards for ventilation aspects of airborne infection control has not been studied in the

South African Emergency Center context. This study therefore aimed to evaluate the compliance of ED isolation rooms to prescribed engineering standards for airborne infection control, in the Western Cape metropole, South Africa.

Methods:

A cross-sectional descriptive study design was performed. Standardised data collection forms (Appendices 1 and 2), developed according to WHO recommendations and the National Department of Health's Core Standards for Health Establishments in South Africa (2011), were used to evaluate compliance with a number of stipulated engineering control requirements for airborne infection control.

Measurements:

A single operator (CG) conducted all measurements in a standardised fashion. To measure the dimensions of a room, the measuring technique described in the methodology in Annexure B of the Draft National Infection Prevention and Control Policy for TB, MDR-TB and XDR-TB was followed, as described in Annexure C ⁽¹⁹⁾.

A validated device (Lutron Anemometer Model AM-4203) was used to evaluate the velocity of airflow over areas contributing to the airflow of the room. If the room made use of natural ventilation, then a measurement was taken over 10 minutes using averaged values for one-minute interval recordings.

The number of air changes in the room per hour was calculated using standard methods, which have been described previously ⁽²⁰⁾. Air flow visualization was done using the dry ice method ⁽²¹⁾.

Study population and Sampling:

All 10 emergency centers (EC) located in tertiary (n=2), regional (n=3), and district (n=5) hospitals within the Cape Metropole were eligible for inclusion, in order to represent all public sector centers in the Cape Metropole with regular emergency physician cover. The exact locations of the sites are not provided in order to maintain centre anonymity.

Ethical Considerations:

The general ethical concerns related to health research do not apply directly to this study, since no human study participants were involved. Approval was obtained from the Human Research Ethics Committee (HREC) of the University of Cape Town (UCT) (HREC REF 305/2015) and hospital superintendents consented to the evaluation of their emergency centers.

Data Management and analysis:

Data collected at each facility was captured on a standardised data capture sheet (Appendices 1 and 2) and transcribed onto a Microsoft Excel spreadsheet. Accuracy of data entry was confirmed independently. Data were tested for normality using the Shapiro-Wilks W test. Data were found to be nonparametric and are therefore presented as median (interquartile range, IQR) throughout. Hypothesis testing was performed using the Chi-squared or Fishers Exact test, and differences between multiple groups (ventilation types) were determined using Kruskal-Wallis ANOVA by ranks, with post-hoc Mann Whitney U tests in the event of significant between-groups differences. A significance level of 0.05 was used for all hypothesis testing.

Data analysis was conducted using both the PhStat add-in for Microsoft Excel (version 2.5) and Stata/IC (Statacorp) for Windows, version 12.1.

Results:

Section A: Participating facilities and room characteristics.

Two of the identified EC could not be included as superintendent consent was not obtained. Of the eight hospitals that participated, a total of 19 EC rooms used for isolating patients (range 1 to 5 per institution) were evaluated. Eleven (57,9%) of the isolation rooms were designated to function as isolation rooms with negative pressure ventilation, and 42,1% (n=8) were makeshift isolation rooms, having been initially built for a different purpose including fracture management and gynaecological examination. All the doors used provided an acceptable seal when closed. Only two of the isolation rooms had an

en-suite bathroom (with a toilet and shower). None were fitted with ante-rooms. Isolation room volumes ranged from 15,5 m³ to 67,2 m³ (median 35,6 m³).

Section B: Ventilation systems evaluation.

Air pressure with relation to surrounding areas: Five (26,3%) of the total rooms were under negative pressure and seven had erratic air flow. Seven rooms (36,8%) showed positive airflow from the isolation room into adjacent clinical areas. Of the 11 rooms designated to be isolation rooms only 3 proved to have negative pressure ventilation (Figure 1).

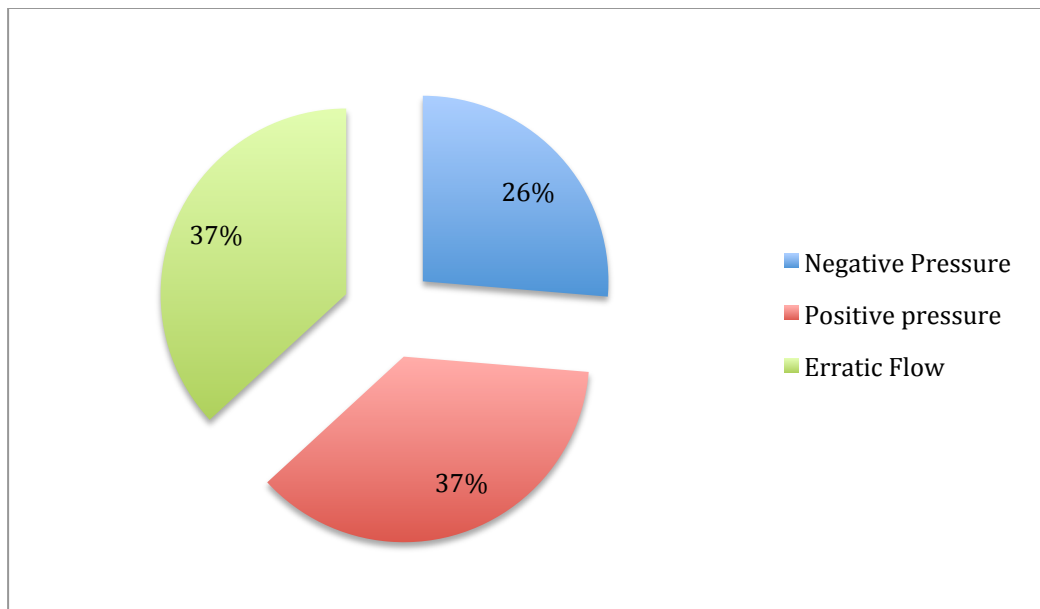


Figure 1: Isolation room airflow and pressure in relation to surrounding areas

Type of ventilation systems:

Fifteen of the facilities (78,9%) had central provision of air via an air handling (ventilation) system, with flow rates between zero and 4,6 m/s; six (31,6%) had central extraction of air via a ventilation system, with five of these rooms augmented by local extraction and one additional isolation room with local extraction (n=6, 31,6% local extraction); and seven (36,8%) isolation rooms made use of natural ventilation only (Table 1). All of the local extraction units were fitted to the window or wall of the room and air was thus directed outside. Four local extraction units had a zero flow rate: two were not switched on, whilst

the other two were broken. Flow rates of working ventilation units are presented in Table 1. Airflow in naturally ventilated isolation rooms was significantly lower than flow with other systems ($p = 0,0002$; Figure 2).

Table 1: Flow rates of isolation rooms

| Type of ventilation | Number of Rooms | Median (IQR) Flow Rate (m/s) | Median (IQR) surface area (m²) |
|----------------------------|------------------------|-------------------------------------|--|
| Central Provision | 15 | 1,60 (1,15 – 1,90) | 0,1 (0,08 – 0,10) |
| Central Extraction | 6 | 2,9 (2,1 – 3,6) | 0,39 (0,39 – 0,39) |
| Local Extraction | 6 | 4,0 (2,9 – 5,5) | 0,09 (0,09 – 0,09) |
| Natural Ventilation | 7 | 0,09 (0,04 – 0,37) | 0,77 (0,71 – 1,1) |
| P | | 0,004 | <0,0001 |

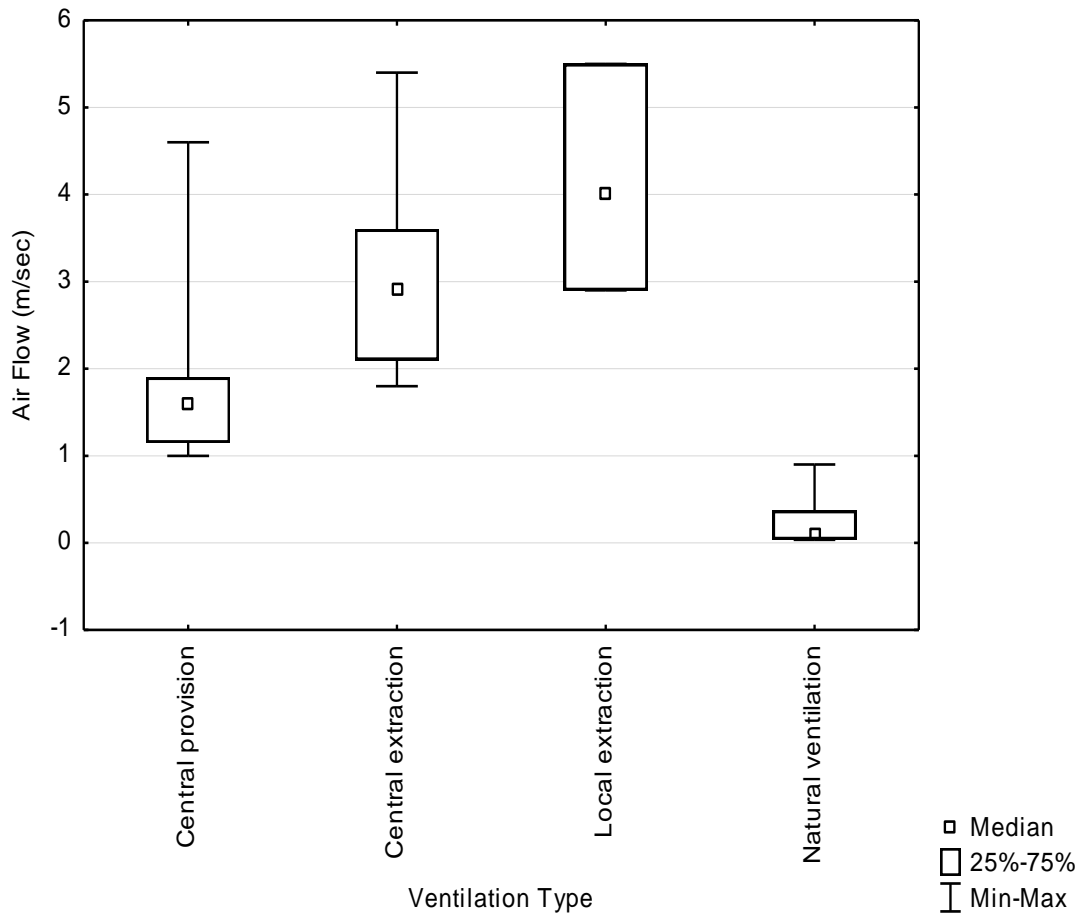


Figure 2: Difference in airflow amongst different ventilation systems ($p = 0,004$; difference between natural ventilation and other systems $p = 0,0002$).

Air changes per hour (ACH): The number of air changes per hour ranged from zero ($n=4$) to 112.37 (median 11,9; Table 2). Whether the contaminated air was vented to a safe area could only be verified in rooms where local extraction ventilation was provided. There was a significant difference in the number of ACH amongst different ventilation systems ($p = 0,0026$); with the number of ACH significantly greater in rooms ventilated with central extraction compared to other systems ($p = 0,00002$) (Figure 3).

Table 2. Number of air changes per hour measured in the isolation rooms, by type of ventilation system used ($p = 0,0026$).

| Type of ventilation | Median (IQR) |
|---------------------|--------------------|
| Central provision | 12.6 (1.5 - 23.9) |
| Central extraction | 24 (12.5 - 39.5) |
| Local extraction | 12.8 (12.0 - 29.3) |
| Natural ventilation | 7.73 (4.2 - 21.7) |

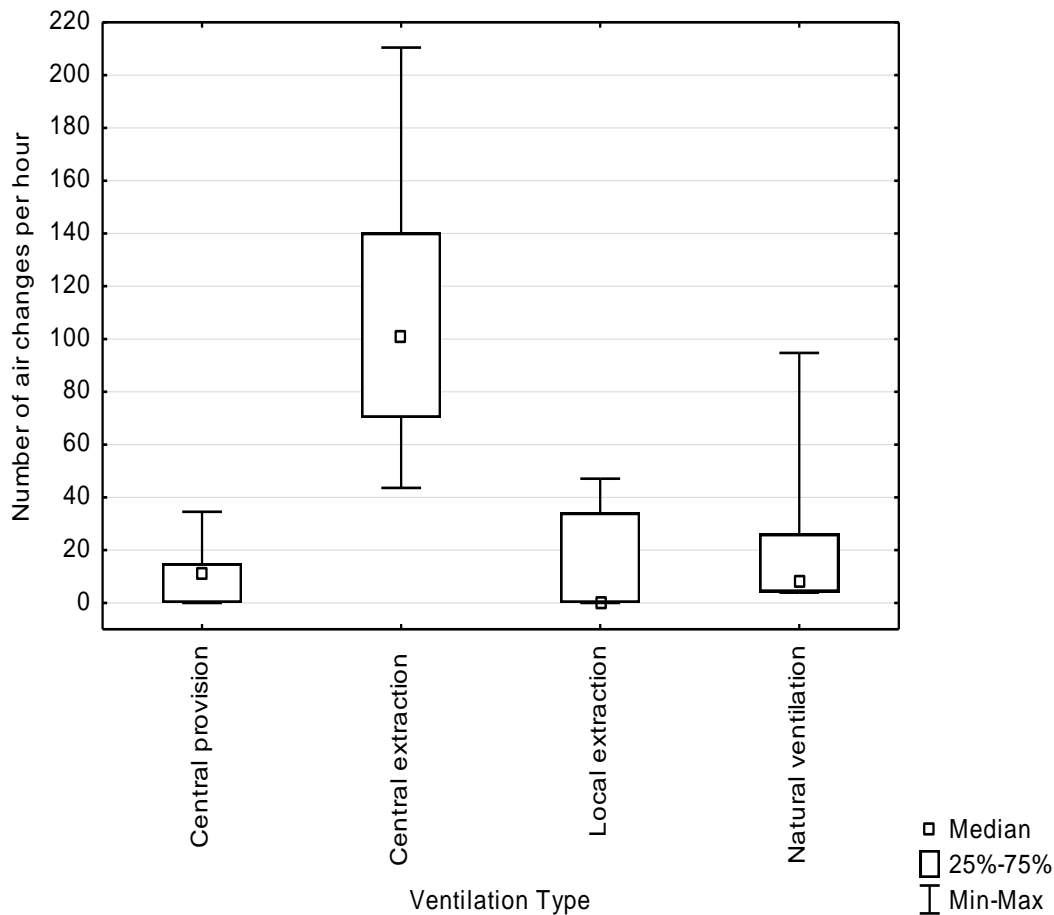


Figure 3: Number of air changes per hour amongst different ventilation types ($p = 0,0026$; difference between central extraction and other systems $p = 0,00002$).

Maintenance: In all cases where air was provided and extracted centrally, staff members were not able to verify whether fresh air was provided or whether the air was filtered and re-circulated. No unit was able to provide accurate information on the last date on which the ventilation systems were serviced or maintained, whether filtration systems were used and (if present) when these were last serviced.

Regulatory requirements: None of the isolation rooms used in any of the facilities met the "ideal requirements" stipulated in the "Regulations for Hazardous Biological Agents" ⁽¹⁶⁾. Five of the facilities (26,3%) met requirements without implementing negative pressure ventilation monitoring, and the same five met minimal standards.

Discussion:

This study demonstrates that the ventilation aspects of airborne infectious disease control

have been largely neglected in emergency centers in the Cape Metropole, despite the high local prevalence of such diseases, especially TB. This neglect is in keeping with known literature ^(7, 9, 22). Airborne infectious diseases remain a very important occupational risk for HCWs and non-clinical workers working in these areas, and the risk is increased with inadequate infection control strategies ⁽²³⁾. These findings show there is a high risk for the nosocomial transmission of airborne infectious diseases to all staff and patients utilizing ECs in the Cape Metropole, as is the case in other parts of the world ^(10, 23).

None of the isolation rooms evaluated fulfilled the required legislative requirements and only a handful of facilities complied with the minimal requirements. It was striking that none of the staff could indicate when the last check was done, and did not know whom to contact regarding evaluation thereof, suggesting that the lack of compliance has been long standing. Due to the lack of negative pressure monitors in all the rooms, there was no way that staff could evaluate airflow, which further complicates adherence to suggested standard practice.

Our results suggest that many patients with known or suspected TB are placed in rooms that are not designed to be used for isolation purposes. It is the author's impression that the number of patients with known or suspected TB may outnumber the rooms available to accommodate them. These patients would then spend long durations in the emergency center, thereby increasing the duration of exposure to non-infected individuals.

Despite the high prevalence of airborne infectious diseases locally, very few emergency facilities have isolation rooms designed to manage such patients, which is not in keeping with worldwide architectural guidelines ^(24, 25). Amongst facilities that were specifically designed to provide negative pressure ventilation, some actually provided positive pressure ventilation. Having a room under positive pressure places staff, patients and visitors under high risk for infection when they are in the immediately adjacent area.

Just over one third of the isolation rooms used natural ventilation only, which was not always associated with negative pressure and has drawbacks such as unpredictable flow direction and closure of windows during tumultuous weather conditions ^(26, 27), further complicating adherence to ventilation standards. In addition, our results show poor air flow and low ACH with natural ventilation compared to other systems. By contrast, central extraction systems showed the highest number of ACH with adequate air flow rates, with 50% of the rooms that make use of central extraction complying with minimal standards ⁽²⁸⁾. The choice of environmental controls is intimately related to building design,

construction, renovation and use, which in turn must be tailored to local climatic and socioeconomic conditions ⁽²⁹⁾. Our results suggest that airborne infection control standards are likely to be best achieved with the use of Central Extraction.

It is clear that the design, layout, implementation, maintenance, and monitoring of airborne infection control is generally poorly implemented in ECs in Cape Town. This may predispose to the nosocomial spread of airborne infections diseases, including TB, and may be a contributing factor to the documented failure of TB infection control programmes ⁽⁶⁾. There is an urgent need for action to be taken to redress the lack of compliance to the engineering aspects of airborne infection control.

Strengths and Weaknesses:

Observations were conducted on a single day for each facility, which may not accurately reflect variation within facilities over time. Observations were also done over a period when the weather was mild and sunny ⁽³⁰⁾, which could influence natural ventilation measurements.

The potential of bias was minimised by using standardised, objective measurement techniques.

Recommendations:

New emergency centers should consider local disease prevalence and plan the building of their facilities accordingly, whilst existing facilities should look at ways to improve compliance to ideal airborne infection control measures. Installation of negative pressure monitors for isolation rooms is strongly advocated.

This study focused on infection control measures for patients with known or suspected airborne infectious diseases being managed in isolation facilities of EC. Future studies should also focus on airborne infection control measures for the whole facility, to protect patients and staff from nosocomial transmission of pathogens from asymptomatic individuals managed in general clinical areas. We also advise that future research be conducted to evaluate HCW's knowledge of infection control for airborne disease spread.

This study did not measure or record nosocomial infection rates within each centre, and

this would be useful to audit in future studies to determine the association between compliance to airborne infection control measures and nosocomial infection rates of airborne pathogens such as TB.

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4.3 Appendices:

Appendix 1: HREC approval letter:



UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee



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Grooteschoor Hospital
Observatory 7925
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18 June 2015

HREC REF: 305/2015

A/Prof B Morrow
Paediatrics & Child Health
5th Floor
Red Cross Children's Hospital

Dear A/Prof Morrow

PROJECT TITLE: AN EVALUATION OF COMPLIANCE TO AIRBORNE INFECTION CONTROL STANDARDS IN EMERGENCY CENTERS IN THE WESTERN CAPE PROVINCE OF SOUTH AFRICA (MMed candidate - Dr C Groenewald)

Thank you for your response letter, addressing the issues raised by the Human Research Ethics Committee (HREC).

It is a pleasure to inform you that the HREC has formally approved the above-mentioned study.

Approval is granted for one year until the 30th June 2016.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC reference no in all your correspondence.

We acknowledge that the following student: Dr Conrad Groenewald is also involved in this project.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Yours sincerely

Signed

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

Hrec/ref:305/2015

This serves to confirm that the University of Cape Town Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP) and Declaration of Helsinki guidelines.

The Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

Hrec/ref:305/2015

Appendix 2: Protocol:

2.1 Background and literature review

South Africa is known to suffer the 3rd highest incidence rate of tuberculosis (TB) in the world, with an estimated incidence rate for 2012 being 1000 or more cases per 100 000 people¹. Within South Africa, the Western Cape province has the highest incidence rate of all forms of TB cases in the country². However, even these figures are not providing a true reflection of the burden of TB disease. The statistics provided by the World Health Organization are dependent on data captured into the national TB register (upon notification by health care practitioners). Previous studies have indicated that a large number of cases are never reported. The concerns expressed about the high number of multidrug resistant TB cases among South African health care workers (HCW) highlights the importance of adequate control measures³. It is therefore clear that *Mycobacterium tuberculosis* is a major healthcare problem in Southern Africa, which affects both patients and HCW. The risk of transmission of *M. tuberculosis* from patients to HCW is a neglected problem in many low- and middle-income countries (LMICs)⁴.

In the emergency care setting, it has been suggested that staff working in areas of high TB prevalence are frequently exposed to *M. tuberculosis*, yet infection control measures may be neglected and/ or harder to implement. Recent studies have reported that the incidence of occupational- acquired TB in health care workers from low and high- income countries was consistently higher than that of the general population; and was related to both the degree of TB exposure and TB infection control measures in place^{2,4}.

The socio-economic implications of TB and multi-drug resistant (MDR) TB in HCW have important repercussions to the individual as well as the employer and the health service as a whole. This encompasses health concerns to the individual, loss of work hours and a large financial implication to the employer and individual. The procedures for the management of a HCW who has contracted active TB are stipulated in Circular Instruction 178 (2003), issued by the Department of Labour in terms of the Compensation for Occupational Injuries and Diseases Act, 1993⁵.

The Regulations for Hazardous Biological Agents (published in terms of Section 43 of the Occupational Health and Safety Act, 1993) provides detailed prescriptions and guidance on the protection of employees against infective agents⁶. These regulations also place the responsibility on the employer to “ensure that the workplace is safe and without risks to health”. The need for occupational health and infection control programs is also

mandated by the Department of Health in all healthcare facilities in South Africa, as described in the “National Core Standards for Health Establishments in South Africa”⁷. Poor or absent infection control programs in health care facilities is considered unacceptable, contrary to set national standards and also illegal. The South African National Policy on Infection Control presents minimum national standards for the effective prevention and management of healthcare associated infections, for both patients and HCW. This policy document states that every health-care setting should have a TB infection control program in place, as part of an overall infection-control program. These include administrative, environmental and respiratory protection policies and measures to prevent health-care associated transmission of *M. tuberculosis*⁸.

The Centers for Disease Control (CDC) and the World Health Organization (WHO) have also formulated TB infection control guidelines for resource rich and resource limited nations on the basis of a 3-tiered approach⁹ comprising 1) administrative or work practice controls; 2) environmental controls; and 3) personal protective equipment.

Airborne infection-control strategies to prevent MTB transmission have long been a neglected component of TB infection control programs, with grave worldwide consequences¹⁰. TB infection control builds on the implementation of general infection control efforts (“standard precautions”) and those aimed at controlling airborne infection. This may also help to de-stigmatize TB infection, because the focus of the public health interventions is on providing universal access for patients with symptoms of communicable diseases (in particular, respiratory infections, rather than TB only). The WHO strongly recommends ventilation to be prioritized and sees that the benefits of implementation of ventilation systems outweigh the disadvantages⁹. In South Africa, minimum standards for airborne infection control include a simple extraction fan allowing at least six air changes per hour and/or a room with an open window and adequate ventilation. Under ideal circumstances, it is recommended that rooms have monitored negative air pressure relative to surrounding areas, with 6-12 air changes per hour and with appropriate discharge of air outdoors or a monitored high-efficiency filtration of room air before recirculation⁶.

The clear and present health risk, along with the emergence of newer drug resistant TB strains highlight the need for strengthened infection control measures. Despite the clear importance and need, the current adherence to WHO and National standards of airborne infection control, has not been studied in the South African emergency center context.

2.2 Research Aim:

The primary aim of this study is to evaluate the compliance of emergency centers throughout the Cape Metropolitan region to predefined engineering control requirements for airborne infection control.

Engineering control measures are further defined as measures that remove or reduce the exposure of persons at the workplace by means of engineering methods ⁶.

2.3 Motivation for the study:

Considering the potential impact of TB transmission to health care workers from patients, and between patients in the Western Cape, it is necessary to conduct an audit to determine current standards of airborne infection control in emergency centers throughout this high- TB prevalence region. The results of this study could then form a basis for monitoring and practice improvement initiatives in the Western Cape Tertiary, Regional and District Hospitals.

2.4 Purpose of the study:

If the evaluation finds the systems to be in keeping with recommended guidelines, the investigation could serve as partial fulfillment of the obligation of the Department of Health (in terms of Regulation 12 of the Regulations for Hazardous Biological Agents) to maintain engineering control measures to prevent spread of airborne diseases ⁶. In addition the strengths of compliant institutions could be appraised with positive feedback.

If the evaluation finds the ventilation systems to be lacking or not complying with the recommendations, then there is a need to address this crucial part of infection control, through targeted practice improvement initiatives, in order to reduce health care worker and patient exposure to airborne diseases. This is further in accordance with the National Health Act 61 of 2003 ¹¹, which emphasizes the need to establish structures to monitor compliance of health care establishments with health care standards. Ultimately, by improving compliance with infection control standards, the aims of the National Core Standards document (2011) will be upheld – to reduce unintended harm to health care users and staff in terms of preventing or minimizing health-care associated infectious diseases (including TB) ⁷.

2.5 Methodology:

2.5.1 Study Design:

A prospective descriptive study design will be used.

2.5.2 Study population and sampling:

No patient data will be used for this study. The district and regional hospitals in the Cape Town Metropole area with emergency centers will be purposively sampled. The 9 emergency centers were purposively sampled; as they represent all the Emergency Physician led units or Family Physician units with regular Emergency Physician cover. The findings of this study will lead to education and system improvements driven through the Division of Emergency Medicine. Thus these units allow us to implement changes based on the study and in future the division could evaluate the impact of these changes.

Specific centers to be studied are:

- Tertiary Hospitals: Groote Schuur Hospital C15 unit and Tygerberg Hospital F1 unit
- Regional hospitals: Victoria Hospital Wynberg, New Somerset Hospital and Paarl
- District Hospitals: Mitchell's Plain, Khayalitsha,, Helderberg, Eerste River and Karl Bremer.

2.5.3 Research procedures and data collection

The research team will be evaluating facilities (engineering controls) for patients who are *known* to suffer (or there is a very high suspicion for) airborne diseases. If the facility does not have an isolation room, the room in which such patients will be treated by the staff will be evaluated. A standardized data collection form (Appendix 1), developed according to the World Health Organization (WHO) recommendations ⁹ and National Department of Health's Core Standards for Health Establishments in South Africa (2011) ⁷, will be used to evaluate compliance with a number of stipulated engineering control requirements for airborne infection control.

These include:

- a) Building structure – including the presence, number, location and adequate functioning of isolation rooms.
- b) Ventilation systems – including the presence of negative pressure, number of air changes per hour and presence of external vents.

These observations will be conducted by personal observation, and if any aspects are not visible, the facility engineer will be contacted to determine compliance.

2.5.4 Measurements:

The measurement of air velocities will be performed by making use of the Lutron Anemometer (Model AM-4203). The device is factory-calibrated and does not allow any manual calibration. Measurements are accurate enough for the purposes of this study. Further information on this device is available at <http://gonewtech.co.kr/123image/lut/AM-4203.pdf>. The number of air changes in the room per hour will be calculated as follows:

Step 1: Calculate the volume of fresh air supplied:

- a. Calculate the surface area of the supply duct (or window, if natural ventilation is used)
- b. Multiply this by the measured air flow rate in front of the duct (or window)
- c. Multiply this by 3600 to obtain the fresh air supply in m³/hour

Step 2: Calculation of the volume of the room or facility. A normal builder's measuring tape will be used which is accurate to the nearest millimeter. The measuring technique is consistent with the methodology described in Annexure B of the Draft National Infection Prevention and Control Policy for TB, MDR-TB and XDR-TB⁸

- a. Multiply the width, length and height of each room (to obtain the volume in m³)
- b. Add the volume of all rooms that are supplied by a single fresh air source

Step 3: Calculate the air exchange rate by dividing the fresh air supply by the volume of the room or facility (which yields the number of air changes per hour).

Example air exchange rate calculation⁸:

| | |
|---|---|
| Window opening: high x 0,5m wide | 0.5m |
| Window area = 0,5m x 0,5m = 0,25m ² | 0,5m x 0,5m = 0,25m ² |
| Average air velocity through window: | 0,5m/s |
| Room dimensions: 3m wide, 5m deep, and 3m high | |
| Room Volume = | 3m x 5m x 3m = 45m ³ |
| Average flow rate = | Area of window times average air velocity 0,25m ² x 0,5m/s x 3600s/hour = 450m ³ /hour |
| Air exchange rate = | Average flow rate divided by room volume 450 m ³ /hour ÷ 45m ³ = 10 air exchanges per hour |

Smoke testing will be done to determine if a room is under negative pressure. The smoke will be generated by adding water to dry ice about 5cm in front of the door close to the bottom. Care will be taken to release the smoke slowly as to not overpower the air velocity. If the room is under negative pressure, the smoke will travel inwards towards the room. If the room is not under negative pressure, the smoke will be blown away or stay stationary.

If the facility relies on windows (natural ventilation) as the primary ventilation source and these are closed at the time of the audit, then this will be captured as such on the day, and thus reflect as a lack of compliance to ventilation standards.

Since this study represents an audit of the ventilation systems, the evaluation will follow the normal practice for an audit; in that, when a room is not functional at the time of evaluation, it will be recorded as such. No facility will be revisited. The same argument will be applied to facilities that are fully compliant at the time of the audit – these will also not be revisited, although it is conceivable that such a unit may be rendered non-functional the next day.

2.5.5 Data management and analysis:

Data collected at each facility will be captured on the data capture sheet and transcribed onto a Microsoft Excel spreadsheet. Accuracy of the data will be confirmed by verification checks performed by the supervisor. After the accuracy of data entry is verified, the original data capture sheets will be scanned and saved electronically in a password-

protected file that is only accessible to the study team. The hard (paper) copies of the data capture sheets will be shredded.

Data will be analyzed and presented using tables, graphs and descriptive statistics (as appropriate). Numerical data will be described as means (with standard deviations) or medians (with interquartile ranges) if the data is skewed. Categorical data will be described using proportions (or percentages). Population estimates will be described using 95% confidence intervals.

If considered appropriate, associations will be measured by means of odds ratios (using contingency tables), with 95% confidence intervals. While this is not primarily planned, hypothesis testing may be performed if deemed appropriate (dependent on the data found during the study). This will be done using the Chi-squared test (or the Fishers Exact test if individual cell frequencies are too low). A significance level of 0.05 will be used for all hypothesis tests.

All the abovementioned procedures will be performed using a combination of the PhStat add-in for Microsoft Excel (version 2.5), and Stata/IC (Statacorp) for Windows, version 12.1.

2.6 Ethical and Legal considerations

The general ethical concerns related to health research do not apply directly to this study, since no human study participants are involved. We will therefore request an expedited Human Research Ethics Committee review if exemption from review is not permitted.

The study team takes cognisance of the principles enshrined in the Declaration of Helsinki (2013), as well as those in the “Good Clinical Practice” documents and other relevant legislative and ethical guidance texts and will adopt the principles and apply these to this study scenario:

Beneficence: The individual units may not directly benefit as a result of the study, although it will be useful for these units to know the functionality of the ventilation systems that are installed. If problems are identified and addressed, it would ultimately result in increased patient and HCW safety.

Non-maleficence: No individual will be harmed as a result of this study. Due care will be taken that the study procedures do not interfere with patient care provided at the facilities. Data will be de-identified during the analysis phase of the study, so that individual facilities

cannot be recognized when aggregate data is reported (although detailed feedback will be given to each facility regarding their own systems).

Autonomy and consent: No unit will be evaluated if permission to collect data on their premises is denied. Permission to perform the study will first be obtained from the Departmental Research Committee; the institutional Human Research Ethics Committee; and then the protocol will be submitted to the National Health Research Database (<http://nhrd.hst.org.za/>) to obtain access to facilities under the authority of Provincial Health.

Confidentiality: Only the principle investigator and direct supervisors would know individual unit details. No institution will be singled out or mentioned by name in the aggregate reports/ publications. The individual institutions will be allocated a letter of the alphabet in the final database used for analysis.

Actions related to gross abnormalities: If any gross abnormalities are noted, it will be directed to the responsible person of that specific unit (highlighting the legislative requirements), without publicly stating any collected data. Infection Prevention and Control information will also be made available to such a unit, in order to allow them to prioritize administrative control measures and personal protective equipment in order to mitigate the risk.

2.7 Reporting and dissemination of results:

The results will be written up and reported in the form of a research report that meets the requirements of the MMed (Emergency Medicine) degree program.

The research team will also publish the findings of this study in a locally relevant peer-reviewed scientific journal.

Individual units, institutions and their staff will be informed about the findings of this study by means of a meeting scheduled with the responsible person. Feedback will be given to the Provincial Department of Health as required by the Provincial Research Committee.

2.8 Logistics and Time Schedule

Responsibilities of investigators

The principle investigator will collect the data and organize it, with appropriate oversight from the student's supervisors. Venues will be contacted prior to evaluation in the 3-month data collection period and personal transport will be used to visit the locations in order to capture the data.

Project Timeline

| 2015 | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Jan |
|-------------------------------|-------|-------|-----|------|------|-----|------|-----|-----|-----|-----|
| EM DRC | X | X | | | | | | | | | |
| Sx DRC | | X | X | | | | | | | | |
| Ethics | | | | X | | | | | | | |
| Provincial Research Committee | | | | | X | | | | | | |
| Data collection | | | | | | X | X | | | | |
| Data analysis | | | | | | | | X | | | |
| Final write-up | | | | | | | | | X | X | |
| Thesis submission | | | | | | | | | | | X |

Budget:

| Item | Description | Cost per item | Number of items | Total cost |
|--------------------|-----------------------|---------------|--|------------|
| Consumables | | | | |
| Paper and printing | Data collection forms | 50c /page | 5 pages / institution (9 insitutions) | R22.50 |
| Dry Ice | For smoke testing | R 626 | 1 container of 3mm pellets. 20 kg in container | R626 |

| | | | | |
|---|---------------------------------|-------|-----------------------|------------|
| | | | | |
| Research-related travel | | | | |
| Transport to sites | Investigator's personal vehicle | R3/km | Approximately 1000 km | R3000 |
| Transport to sites (Supervisors private vehicle) | Supervisor's private vehicle | R3/km | Approximately 1000 km | R3000 |
| Research equipment | | | | |
| Anemometer | | R4500 | 1 | R4500 |
| Total | | | | R 11148,50 |

Sources of funding:

The anemometer will be made available via the Unit for Infection Prevention and Control (the main study supervisor is the head of this unit). The other expenses will be borne by the student investigator

2.9 References:

1. World Health Organization. TB Report 2013.
2. Claassens M, van Schalkwyk C, den Haan L, et al. High prevalence of tuberculosis and insufficient case detection in two communities in the Western Cape, South Africa. *PLoS One*. 2013;8(4):e58689.
3. O'Donnell MR, Jarand J, Loveday M, et al. High incidence of hospital admissions with multidrug-resistant and extensively drug-resistant tuberculosis among South African health care workers. *Ann Intern Med*. 2010; 153(8): 516-522.
4. Joshi R, Reingold AL, Menzies D, Pai M. Tuberculosis among health-care workers in low- and middle-income countries: A systematic review. *PLoS Med*. 2006;3(12):e494.
5. Republic of South Africa. Circular instruction no. 178: circular instruction regarding compensation for pulmonary tuberculosis in health care workers. Published under Government Notice 81 in Government Gazette 24231. 2003.
6. National Department of Health. Occupational Health and Safety Act, 1993. Regulations for hazardous biological agents. 2001.
7. National Department of Health. National core standards for health establishments in South Africa. . 2011.
8. Republic of South Africa Department of Health. The national infection prevention and control policy for TB, MDRTB and XDRTB http://Www.who.int/hiv/pub/guidelines/south_africa.pdf. 2007.
9. World Health Organization. WHO policy on TB infection control in health-care facilities. 2009.

10. Sheno SV, Escombe AR, Friedland G. Transmission of drug-susceptible and drug-resistant tuberculosis and the critical importance of airborne infection control in the era of HIV infection and highly active antiretroviral therapy rollouts. *Clin Infect Dis.* 2010; 50 Suppl 3:S231-7.

11. National Department of Health. National Health Act 61 of 2003.

2.10 Appendices:

Appendix A.

Data Capture Form

Hospital Name:

Date of evaluation:

| | | | |
|--|--|-------------------------------------|-----------------------------|
| | Number | | |
| Total number of emergency unit bed complement actually available | | | |
| Number of intensive care beds available in emergency units | | | |
| Number of high care beds available in emergency units | | | |
| Number of side rooms (Single bed rooms) in emergency units | | | |
| Number of side rooms designed to have negative pressure ventilation | | | |
| Number of side rooms with en-suite toilet facilities | | | |
| Can staff indicate (provide a written report) when the last test of the ventilation unit was performed to confirm correct airflow? | YES (date) | NO | |
| What is the location of the isolation room/s in the unit? | FRONT | MIDDLE | BACK |
| If present, the isolation room/s are fitted with (tick all applicable) | En-suite bathroom | En-suite shower | En-suite toilet |
| Is an anteroom present (Y/N) | | | |
| Does the isolation facility have a | Isolation facility has negative pressure | No pressure difference was detected | Irregular air flow detected |

| | | | | | | |
|---|---|---|---|---|---|-----------|
| negative pressure compared to the rest of the unit upon smoke-testing? ** | | | | | | |
| The type of ventilation/air conditioning system designed for the isolation facility (tick all that apply) | Central extraction | Central provision | Local Extraction | Local Provision | Natural ventilation (open windows) | Uncertain |
| If single room facility, what is the number of air changes per hour with | Door open: | | | Door closed: | | |
| Is air coming from the isolation room: | Recirculated yes/ no / uncertain | | Filtered yes/ no / uncertain Does the staff (responsible person) know of the date when the filter was last checked? Yes / no / uncertain Is it within the last month? Yes / no / uncertain | | Directly vented to the outside yes/ no / uncertain | |
| What is the location of the exhaust vent? | To an outside wall or window yes/ no/ unsure | | | Considered safe in terms of contamination of other areas? i.e. close to an intake/open window? yes/ no/ unsure | | |
| What type of door is fitted to the isolation room/facility? | Regular/Sliding | Automatic/Manual (foot) or Manual (hand) with automatic close | Wooden/ Metal/ Glass/ Other | Providing an effective seal yes / no | | |

**Evaluation of airflow with all different combinations and permutations of doors of the isolation room being open and/or closed.

For each combination state that the airflow in the doorway indicates that the isolation room is under negative pressure

| Permutations and combinations of door positions | | |
|---|----------|----------|
| HALLWAY | BATHROOM | ANTEROOM |
| Isolation rooms with bathrooms and anterooms | | |
| Open | Open | Open |
| Closed | Closed | Closed |
| Closed | Closed | Open |
| Closed | Open | Closed |
| Open | Closed | Closed |
| Closed | Open | Open |

| | | |
|--|--------|--------|
| Open | Closed | Open |
| Open | Open | Closed |
| Isolation rooms with bathrooms, but without anterooms | | |
| Closed | Closed | |
| Open | Open | |
| Closed | Open | |
| Open | Closed | |
| Isolation rooms without anterooms or bathrooms | | |
| Closed | | |
| Open | | |

Appendix 3: Measurements per room

| | |
|---|--|
| Measurements per Room: | |
| Hospital: | |
| Room identification/Name: | |
| Room Volume: | |
| Central Prov Parameters: | |
| Central Prov Flow: | |
| Central Extract Parameters: | |
| Central Extract Flow: | |
| Local Extract Parameters: | |
| Local Extract Flow: | |
| Local Provide Parameters: | |
| Local Provide Flow: | |
| Natrural Vent (window) Measurements: | |
| Natural Vent Flow: | |
| Air Changes / Hour | |
| Pressure door closed: | |
| Pressure door open: | |

4.4. Instructions to Authors

The Instructions to Authors for The Journal of Hospital Infection is multi-page document available in PDF format and the link is attached below:

https://www.elsevier.com/wps/find/journaldescription.cws_home/623052?generatepdf=true