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Maribel Gamon - Multidrug-Resistant Tuberculosis in India: Solving a Problem by Reconstructing the Public Health Infrastructure

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ABSTRACT

Mycobacterium tuberculosis, commonly referred to as TB, is responsible for causing about 630,000 cases per year of infectious diseases worldwide. Recently, multidrug resistant tuberculosis (MDR-TB) has become an alarming public health concern. In addition, many developing countries lack effective treatment programs. India is one of those countries with a high prevalence of TB, seemingly affected by disconnectedness in their public health infrastructure. India, although a developing country, is still burdened with both chronic and infectious diseases, and there is a reactive public health system that must place focus on long-term effects of emerging resistant strains of TB. It is important to develop rapid drug susceptibility testing for quick diagnosis and treatment of monitored TB levels. According to a 2013 article published by *Lancet*, countries with well-run public health programs, supported by early diagnosis and access to quality drugs, have better treatment outcomes and compliance. Compliance must be maximized in developing countries to prevent the continuing emergence of MDR-TB. India's public health infrastructure must be reshaped and empowered with implementation of treatment programs and surveillance frameworks similar to those seen in countries with low rates of MDR-TB levels. It is important that India strengthen their framework for combating MDR-TB, with emphasis on increasing health literacy among community leaders, informing government agencies of the necessity of research and surveillance, strengthening rapid TB diagnostic systems, and providing culturally-appropriate TB treatment programs. Using intervention strategies from other communities may help India develop an appropriate solution for decreasing the prevalence of MDR-TB.

INTRODUCTION

Infectious diseases are at the dawn of a new era where strains are becoming resistant to medications that have been used for decades. However, emerging strains with resistance to medications may be prevented through public health measures. Specifically, multidrug resistant tuberculosis (MDR-TB) is of particular concern to public health officials throughout the world. Surveillance of MDR-TB is especially important in the four major economically developing countries, referred to as BRIC: Brazil, Russia, India, and China (*Lancet*, 2013). An evaluation of the current TB epidemic will be specifically completed in relation to India. Importantly, as India develops into a booming economy, there is a need for more investment and government funds to build the public health infrastructure, in order to decrease the rapidly increasing rates of MDR-TB. Another important factor in combating the current TB epidemic in India is a commitment to MDR-TB treatment programs.

Tuberculosis is an aerosol transmitted infectious disease. That is to say, a person suffering from TB may easily transmit the bacterium through air droplets or a hacking cough. The transmission of the bacterium is particularly problematic in areas with dense populations, such as the overpopulated areas of India. According to the Centers for Disease Control and Prevention (CDC), TB usually affects the lungs; however, there can be metastasis to the brain, kidneys, or the spine. The adverse effects of TB are exacerbated most when the wrong treatment is given. If an inappropriate course of treatment is given, that is either too short or missing an active ingredient, the strain of bacterium develops resistance, and this form is regarded as multidrug-resistant tuberculosis.

In the same way that TB is transmitted through the air, so are MDR-TB pathogens (Drlica, 2011). During outbreaks of tuberculosis there is an increased risk for the transmission of

antibiotic resistant pathogens. Consequently, "when a strain of TB acquires resistance to the two main antituberculosis drugs, currently rifampin and isoniazid, the strain [becomes MDR-TB]" (Drlica, 2011, p. 111). Without a doubt, MDR-TB is a global threat due to its aerosol transmission and aggressive nature when treated improperly. At the point of antibiotic resistance, there are limited agents for treatment. In addition, "accumulation of additional resistance mutations leads to extensively resistant (XDR-[TB])" (Drlica, 2011, p. 111), which is rendered almost untreatable. Unquestionably, high prevalence rates of TB and MDR-TB in developing countries must be addressed with the primary goal of avoiding a high percentage of their population being resistant to any type of treatment.

There is a specific focus on appropriate and effective treatments for tuberculosis (TB) due to the pathological nature of this infectious disease. As referenced earlier, an individual infected with TB and inadequately treated will develop resistance to first-line antibiotics. Unfortunately, due to the lack of communication between private and healthcare institutions in India, there exist some of the highest worldwide percentages for MDR-TB because first-line drugs are being distributed but TB treatments are not being monitored, with the result being MDR-TB. The problem with the high rates of MDR-TB, aside from being a communicable infectious disease, is the need for expensive, lengthy, and aggressive treatments.

Among the risk factors for acquiring MDR-TB are overpopulation, poverty, low health literacy, and inadequate courses of treatment for already infected TB patients. Also, outside of the United States, TB is the number one opportunistic infection for patients who are HIV positive. Mortality rates therefore increase due to co-infections of TB and HIV. Particularly alarming are the statistics that demonstrate that TB in the United States is increasingly found in foreign-born persons (National TB Surveillance System, 2012). Most of the cases of TB that

have caused panic in the U.S. have been imported from other countries but have been rapidly treated. The reason that the U.S. TB rates have remained low among the general population is due to the strong public health infrastructure and more significant funds contributing to surveillance and monitoring of emerging diseases. However, with increased globalization and tourism, strains of MDR-TB are increasing at rates that may not be as quickly diagnosed and treated. The World Health Organization (WHO) estimates there are roughly 630,000 cases per year of tuberculosis worldwide, with prevalence of multi-drug resistant tuberculosis rising.

THE PROBLEM

Although ranked "the fifth largest economy in the 21st century" (John, 2011, p. 252), India is facing the threat of an uncontrolled MDR-TB outbreak among their rural and urban populations. There is a lack of data regarding the exact percentage of persons in India affected with MDR-TB due to poor diagnostic and surveillance systems. Despite the lack of data, the prevalence of TB itself cannot be denied, and India's public health infrastructure must be reshaped in order to best serve the emerging diseases sector. According to an annual emerging diseases series published by *Lancet*, "the cause of this deficiency is the health system…[lacking] an adequately functional public health infrastructure that is essential for prevention of disease in all communities" (John, 2011, p. 252). In effect, a lack of surveillance in all communities leads to skewed data, presenting numbers that consider only parts of a threatening TB outbreak. Furthermore, India's current surveillance system for infectious diseases must be updated and integrated to create communication between all states and the federal health department. Reshaping an integrated surveillance system for infectious diseases will allow more prompt diagnostic services and minimize the amount of time between diagnosis and treatment. In order to accomplish an effective surveillance system, policy makers must be informed about the

threatening health results of MDR-TB. In order to adapt a more effective framework for the public health issue of MDR-TB in India, their current TB intervention programs must be reevaluated. Proliferating intervention programs of other countries, with similar demographics and risk factors, should be assessed for guidance in reconstruction. The objective of evaluating example intervention programs is to build an integrated surveillance system that would allow for prompt diagnosis and appropriate TB courses of treatment, with regulation of pharmaceuticals. Furthermore, based on evaluated programs, there is a need to increase the health literacy among communities in order to minimize the relapse of first-line TB treatments.

REVIEW OF LITERATURE

Infectious diseases worldwide

The challenge for the current global health agenda is dealing with an epidemic of infectious diseases worldwide. Furthermore, disease outbreaks become difficult to control in countries that do not properly diagnose and report these outbreaks (Christian et al., 2013). As a result, the inability to contain such diseases threatens to cause an inception of newly antibiotic resistant pathogens. Pathogens that become resistant to typical courses of treatment are equally as infectious as their counterparts and spread in a similar manner (Drilca, 2011). Eventually, all available antibiotics become ineffective in treating dangerous pathogens. In a 2013 article, in *Emerging Health Threats*, the Centers for Disease Control and Prevention's (CDC) Global Disease Detection (GDD) Operations Center identified five of the emerging pathogen threats as avian influenza A (H5N1), cholera, wild poliovirus, enterovirus-71, and extensively drug-resistant tuberculosis (Christian et al., 2013). The infectious diseases were identified according to the following factors: "high transmissibility, disease burden and severity; established or pandemic potential; disease eradication; and lack of available preventative or treatment

interventions" (Christian et al., 2013). Lack of available intervention programs is of particular importance for low-socioeconomic regions where there are insufficient clinics, hospitals, and laboratory resources. Also, transmissibility of diseases is of important concern in current society where global mobility is allowing for pathogen translocation from one area to another (Hartley et al., 2010). For this reason, the goal of surveillance, diagnosis, and treatment programs is to contain diseases at their local origin, with the purpose of preventing a global threat of disease.

Global program initiatives for infectious diseases

Consequently, global health initiatives have implemented various prevention programs in countries that are most burdened by infectious diseases. According to Dr. Margaret Chan, director general of the World Health Organization (WHO), "When the world is collectively at risk, defense becomes a shared responsibility of all nations" (World Health Day, 2007). Indeed, WHOs integrated network is part of formulating important tasks for its representative countries. Furthermore, responsibilities of countries are outlined in places such as the annual United Nations Millennium Development Goals (MDGs) Report, where obstacles, expectations, and great visions are established for combating global inequities. The MDGs were established during a 2000 conference where 191 United Nations' member states declared to bring a taskforce against the following eight global disparities: poverty, hunger, disease, illiteracy, environment sustainability, and women's rights (United Nations, 2013). The forthcoming targets are to be met by 2015. Furthermore, enforcing and regulating health care measures is greatly affected by a country's already established health institutions. Gathered data results in either further action or a reconstruction and review of both the MDGs as well as the country's health institution programs that may seem to struggle with combating the problem.

Global Tuberculosis Warning

Currently, one third of the world's population is infected with *Mycobacterium tuberculosis* (*M.tuberculosis*) (Tille, 2014). Tuberculosis (TB) is currently an infectious disease of global concern because its "incidence rate is falling at less than 1% per year," and nearly 9 million cases are being reported each year (Lönnroth et al., 2010, p. 1814). The fight against the global TB epidemic has led to many established global health programs. Some examples of well-known TB prevention, diagnosis, and treatment programs are as follows: WHO's Stop TB Strategy and Global Plan; Center for Disease Control and Prevention (CDC) National TB Performance Targets for 2015; basic National TB Programs (NTPs); and most importantly the Directly observed Treatment Short-course (DOTS) strategy (World Health Organization, 2012). In addition, the MDGs for 2050- established as post-2015 goals- present an overarching goal of decreasing TB incidence rates to less than one case per million (Lönnroth et al., 2010, p. 1814). In order to meet the target, WHO recommends that all of the member states assess their current TB programs with the objective of building the most effective healthcare intervention programs.

Directly Observed Treatment Short-course (DOTS) Strategy Defined

DOTS is the core component of WHOs Stop TB Strategy. The vision of WHO is to eliminate TB as a public health problem by 2050 (WHO, 2013). Achieving WHOs target requires proper treatment of TB. Treatment for TB is complicated and DOTS was developed for ensuring that diagnosed patients take the correct medications in proper doses (WHO, 2012). Primarily, a healthcare worker visits the patient at their home or workplace, for the purpose of ensuring complete adherence. Furthermore, each visit is documented until the TB treatment course is completed. Also, it is important to recognize that DOTS is used for treating patients

with diagnosed TB and DOTS-Plus is the program used for treating multidrug-resistant TB. DOTS-Plus was established for ensuring reduced fees on second-line treatment drugs, which are often very costly and disproportionately affect populations of lower socioeconomic status (Stop TB Partnership, 2006). Every location implements DOTS and DOTS-Plus according to their demographics and treatment completion rates. Recently, barriers have risen for treating MDR-TB due to lack in laboratory technology, quick drug susceptibility testing (DST), and inception of second-line drug resistance (XDR-TB). In effect, countries must assess their healthcare facilities to ensure that qualifying diagnosed TB/MDR-TB patients are receiving adequate treatment courses from DOTS/DOTS-Plus. Also, WHO must ensure that its partners are creating community consciousness regarding the availability of DOTS TB treatments.

Tuberculosis: Symptoms and Progression

To further illustrate the threat of TB, there is a necessity to understand and describe the epidemiology of such a communicable disease. Tuberculosis is caused by a pathogenic bacterium called *Mycobacterium tuberculosis* (*M. tuberculosis*), and it has the ability to contaminate individuals through airborne means when someone coughs or sneezes and transmits infected nuclei droplets (Tille, 2014). Usually, a person with a healthy immune system is able to fight minimal exposure to a TB germ, but continual exposure poses a serious threat by compromising a healthy system and lungs. Once someone becomes infected with TB, the infection may become either latent or active. Usually, latent TB remains inactive and the individual poses no symptoms or threat to others unless their immune system becomes compromised and the TB pathogen becomes activated. In the active form, TB infects the human host in a progression of weeks or months, depending on the person, and presents itself in the

form of an infectious tubercle. A TB tubercle infects its host by releasing the bacterium into the lungs, which causes a progression of inflammation, scarring, granulation, and necrosis of normally sterile lung tissue. Delayed diagnosis of TB results in the debilitating progression of TB. Some general symptoms identified in pulmonary TB are as follows: unexplained weight loss, loss of appetite, night sweats, fever, and fatigue. Generally, a more conclusive diagnosis of TB is reached with more advanced symptoms, where the patient presents with a 3-week prolonged cough having sputum discharge, possibly with blood, and having chest pain with shortness of breath (Tille, 2014). Regardless of identifiable symptoms, a TB diagnosis is not certain unless laboratory analysis is done to test for the bacteria, hence the delay between diagnosis and treatment in low socioeconomic regions that lack quick diagnostic technology.

Tuberculosis: Diagnosis

It is estimated that in developing or underdeveloped countries "fewer than half of patients are correctly diagnosed with TB the first time they seek help" (Dyer, 2010, p. 16). In more developed countries such as the United States, screening for TB is accomplished with the Mantoux skin test, a test that most people are required to get every two-years due to school or employment regulations. The typical results from the Mantoux test are noticeable within 48 to 72 hours, and health care providers identify the presence of TB depending on spot diameter and skin inflammation or elevation. A positive TB-skin test results in further laboratory diagnostic testing of the patient's sputum to confirm a diagnosis. In contrast to the U.S., developing countries actually vaccinate babies at birth with the Bacillus Calmette-Guérin (BCG) vaccine (Reichman & Tanne, 2002). The BCG vaccine is not used in the U.S. because TB is not endemic there and the effectiveness of the vaccine is questionable. Moreover, other diagnostic measures used for

identifying TB are a blood test, QuantiFeron-TB Gold (QFT-G) or a chest X-ray (Tille, 2014). However, neither of these gives a definite TB diagnosis, nor do they completely quantify the extent to which the TB bacterium has progressed. The only definitive diagnosis for TB is done in labs equipped for the microbiologic procedure of acid-fast bacteria staining and culture (Dyer, 2010). Sputum samples are collected from identified patients, and laboratory professionals use specialized biohazard-containment environments to best incubate the slow growing TB bacteria (Chiang, Van Weezenbeek, Mori, & Enarson, 2013). However the methods for definitive identification, diagnosis, and antimicrobial susceptibility testing are lengthy, which affects timely treatment.

Tuberculosis: Treatment

Delays in treatment can result in less effective opportunities for cure as well as higher TB risk for the patient's surrounding community. Overall, diagnosis and immediate treatment rely on access to adequate healthcare in order to prevent the progression of TB infection. In treating TB, it is the cellular structure of the bacteria that poses difficulty due to a cell wall that acts as a barrier to antibiotic drugs. Additionally, the TB bacterium quickly adapts and develops resistance to virtually all effective drugs (Tille, 2014). Treatments for promptly diagnosed TB consist of a combination of first-line antibiotics, namely isoniazid and rifampicin (Vassal et al., 2011). The length of an effective treatment for a TB treatment course lasts around six to nine months (Dyer, 2010). Treatments given for too short of a time period or with the wrong combination of antibiotics will indeed result in TB known as multidrug-resistant tuberculosis (MDR-TB). The length of an effective treatment for MDR-TB is an estimated two years of multiple drug combinations (Farmer, 2003). Additionally, what are known as second-line drugs for treating

MDR-TB are more toxic, expensive, and less effective in curing the patient (Dyer, 2010). Unfortunately, MDR-TB has become a worldwide problem and WHO reports that from 2008 to 2010 there was an increase in the number of cases from 29,000 to 53,000, respectively (Raviglione et al., 2012). However, due to a dearth in available drug susceptibility, it is believed that these numbers represent just one-fifth of the world's actual MDR-TB cases (Raviglione et al., 2012). Globally, certain locations suffer more disproportionately from MDR-TB than others. As is expected, these areas are those also affected by their large TB prevalence and in need of intervention strategies that will allow for reliable diagnostic tests, prompt treatments, and well-constructed health programs for infection control.

India's Prevalence of Tuberculosis

Presently, the country of India is of particular concern for their prevalence of MDR-TB. Overall, infectious diseases continue to be an urgent subject matter for the healthy outcomes of their citizens. Despite India's economic development, infectious diseases still contribute 30% of the disease burden in India (John, 2011, p. 252). Some preventable infectious diseases currently threatening India's public health are malaria, filariasis, visceral leishmaniasis, leprosy, HIV, and last, but not least, tuberculosis (John, 2011, p. 252). In 2011, WHO estimated 12 million prevalent cases worldwide, with 40% of TB cases being from India and China (Porwal, et al. 2013). These two countries are also responsible for roughly 50% of all global MDR-TB reported cases (Maurya et al., 2013). Furthermore, although there is not enough accurate data regarding the total number of MDR-TB cases, hospitals of India have reported some TB cases that have included both MDR-TB and XDR-TB. Tuberculosis and the other preventable infectious diseases may be decreased in prevalence with more suitable and updated disease control

programs. The challenge, however, is India's health system, where disease control programs are not integrated nor do they function as a system. Rather, selected diseases are prioritized and special programs are autonomously implemented in burdened districts (John, 2011). The gap in communication between programs may limit accessibility regarding important disease outbreaks or innovative diagnostic services and treatment solutions. In effect, undertaking the challenge of constructing an effective infection control program for India will require reevaluation of current risk factors for prevalent diseases such as TB. An effective TB program should be implemented for India, in order to lessen the possibility of an uncontrollable MDR-TB outbreak.

India's TB Program

Currently, India's more recognized TB intervention program is the Revised National Tuberculosis Control Program (RNTCP). This program is considered a National TB Program (NTP) and is partnered with WHO with the objective of delivering the DOTS strategy to TB infected individuals (Goodchild et al., 2011). The program reached geographical coverage of India in 2006 (Goodchild et al., 2011). Importantly, RNTCP treatment programs are provided free of cost by health facilities and follow the DOTS program dosage three times a week under the supervision of a healthcare worker (Satyanarayana et al., 2011). However, many patients further seek cure from private healthcare facilities, believing the treatment is lengthy and not as personalized as private care. Compliance often fails with RNTCP alone, hence the reason that health literacy about TB and MDR-TB should be increased in TB affected areas. This is evidence that RNTCP drug treatment alone is not sufficient in treating TB in locations where diseases are exacerbated by socio-environmental factors. Furthermore, there is minimal data regarding the prevalence of TB-infected individuals outside of the RNTCP program, because those individuals

are seen by private sectors of India's healthcare system. Some recently published reports consider the emergence of MDR-TB to be roughly 110,000 cases spread across the country but an actual national report has not been completed (Maurya et al., 2013). Having reviewed the prevalence of TB in India and the program working to combat this disease, recognition of underlying socio-environmental factors is necessary.

Tuberculosis: A "social disease"?

In 1952, René Jules Dubos (1901-1982), a microbiologist, published *The White Plague: Tuberculosis*, and described tuberculosis as a "social disease" (Dyer, 2010). Dubos claimed that the solution for understanding tuberculosis was beyond the scope of traditional medicine. As referenced previously, factors that magnify the communicability of these bacteria are socioeconomic factors such as poverty, leading to poor sanitation, overcrowding, unhealthy living conditions, and malnourishment (Lönnroth et al., 2013). In addition, TB is the primary opportunistic infection in HIV patients in many developed and underdeveloped countries, where co-infection forms a significant population percentage (Swaminathan & Narendran, 2008). Globally, HIV and TB are the two more common causes of population mortality, with HIV being the most common. Furthermore, HIV/AIDS compromises the immune system, which makes a TB-infected individual more susceptible to the debilitating factors from the disease. Thus, developing intervention programs that control both medical and socio-environmental risk factors can allow for more substantial progress in the fight against TB.

India's Healthcare System

In addressing disease and social inequalities in India, it is important to recall the interconnectedness between a communicable pathogen, susceptible host, and incubating environment (Atre & Mistry, 2005). The conducive environment, in India's case, is the current healthcare system. Although India is economically prospering, the healthcare sector is receiving an expenditure of 4.13% from the gross domestic product (GDP) (Balarajan, Selvaraj, & Subramanian, 2011). Comparing this GDP to other developing countries, the percentage is not importantly critical, but its allocation is certainly an issue of urgent assessment. From the 4.13% there is an allotment of just 1.10% to public health in rural and urban areas, and from this 1.10%, the funding disproportionately affects rural healthcare resources (Balarajan, Selvaraj, & Subramanian, 2011). These insufficient funds in the public health sector result in low-quality diagnostic and treatment services from healthcare facilities. This is especially detrimental for individuals of low-socioeconomic status who rely on low-cost services from the publicly run federal clinics. Also, rural areas are many times inadequately treated because physicians are not appropriately trained for the influx of infectious disease cases (Rao, Rao, Kumar, Chatterjee, & Sundararaman, 2011). In addition, individuals are made more vulnerable in the context of an unregulated pharmaceutical market put in use by both the public and private sector (Balarajan et al., 2011). Certainly, the private sector of India's healthcare is also in need of reform and implementation of regulations, considering 70% of health workers are employed by it (Balarjan, et al. 2011). Considering the healthcare environment, it is evident that TB is transmitting to the vulnerable populations because of a need for framework reconstruction. Both India's state and federal governments are essential in increasing funding, staffing rural clinics with trained professionals, assessing private physician qualifications, and regulating the unregulated drug

companies. India should be driven to invest in reconstructing a healthcare framework due to the increasing number of cases for MDR-TB, induced by the lack of diagnostic services and physicians with unpracticed skills in providing treatment.

Risk Factors Affecting India's Population

Furthermore, the population of India is made vulnerable by the underlying risk factors influenced by their social environments. Poverty has been recently recognized as an important feature in recognizing TB susceptible populations. Currently, India is ranked 119 out of 169 countries based on human development and 41.8% of their population is living below the international poverty line (Kamineni, et al., 2012). Also, using the multidimensional poverty index (MPI), 8 Indian states, with a total population of 421 million, were comparable to 26 of the poorest African countries with a population of 410 million people (Alkire & Santos). According to Kamineni (et al., 2012), the five Indian states with highest proportion of their population living below the poverty line are Bihar, Jharkhand, Madhya Pradesh, Chattisgarh, and Uttarakhand. Based on the high incidence of poverty in India, it can be expected that being poor is a risk factor for acquiring TB and MDR-TB due to lack of finances for appropriate healthcare. Consequently, a recent survey done in Delhi revealed that the "poor were two times more likely to have TB, three times less likely to access TB care, four times less likely to complete treatment and many times more likely to incur impoverishing payments for TB care" (Goodchild et al., 2010). The co-relation between poverty and health exemplifies the need for constructing a public health system that serves such vulnerable populations. A diseased individual who is poor has lack of access for healthcare because their socioeconomic status directly influences their nutritional status, living conditions, and their residing districts.

When clinicians analyze the nutritional status of a patient, they must consider poverty as an important risk factor for TB and MDR-TB. Mainly, malnutrition increases the susceptibility of an individual because the immune system is weakened by lack of vital nutrients. In effect, acquiring TB is dependent on the strength of the host's macrophages, cytokines and T-lymphocytes, all part of a responsive healthy immune system. Studies done on TB-infected lab animals have reported that lack in protein calorie intake will result in enhanced bacterial growth (Gupta, Gupta, Atreja, Verma, & Vishkarma, 2009). There has also been linkage of protein deficiency leading to a dearth in the immune system's natural process of generating antigen-specific-immune lymphocytes when infected with disease (Gupta et al, 2009). Consequently, in receiving the BCG vaccine, protein deficient systems do not have the strength of acquiring reactive T-lymphocytes following vaccination (Gupta et al., 2009). Although it is true that tuberculosis alone is a debilitating disease, causing patients to waste away from the reduction in appetite and nutrient malabsorption, food shortages should still be considered when reconstructing a public health infrastructure for regions of India. Perhaps addressing malnutrition can prevent secondary immunodeficiency disorders that lead to the higher mortality rates of TB and MDR-TB.

Another factor arising from poverty is the overcrowded living conditions that breed transmission of communicable diseases like TB. Other than China, India is known to be one of the most overpopulated countries in the world. However, unlike China, there is no limit placed on the number of family members allowed per household. Nevertheless, the implementation of such measures is less necessary with improvement of infection control measures. Community-based programs on infection control may prove useful for overpopulated and TB prevalent areas of India. Moreover, because TB is an aerosol transmitted disease, strict implementations should

be placed on healthcare facilities, academic facilities, and any other common areas in which individuals are more likely to become infected. Perhaps implementation of annual TB screening and DST testing should be required from healthcare professionals and other healthcare stakeholders. Government regulations are an important factor in keeping their populations free from disease through infection control and assuring effective access to qualified healthcare professionals.

Lack of access to physicians experienced in treating TB is another risk factor for the poor and even the middle-class populations of India. Although programs such as RNTCP provide free care to populations of lower socioeconomic status, there is still a necessity for government officials to intervene regarding qualified primary care providers. Specialized training in TB risk factors, diagnosis, and appropriate treatment should be implemented for medical schools, private and public institutions. Training programs for combating TB can minimize the lack of knowledge between multiple providers that see TB patients outside of the RNTCP program. However, increasing physician knowledge about TB is only a minor step in minimizing the deliverance of poor healthcare. Campaigns about TB risk factors and availability of public health treatment programs should be delivered to all regions of India.

India's health programs, for combating TB, should have the objective of increasing health literacy nationwide. Health literacy is an important risk factor for the impoverished because these are populations more rooted in traditional medications that are not keen on accepting drug therapy from programs such as RNTCP. In a cross-sectional community survey based on 30 districts of India, Satyanarayana (et al., 2011) found that the reasons people sought treatment outside of RNTCP were due to "poor knowledge about the disease and the services available." The study also found 43% of the 30 districts to be illiterate, therefore instructions on

taking medication or pamphlets with information about healthcare options may have proved difficult for them to research and accept (Satyanarayana et al., 2011). Another study by Pinto and Udwadia (2010) interviewed patients from P.D. Hinduja Hospital and Research Centre in Mumbai, India, and found that "only 30 of 200 patients (15%) were aware of the DOTS [RNTCP] program." Surprisingly, after a brief explanation of the RNTCP agenda, 91.5% of the patients admitted that they would rather buy treatment drugs themselves before accepting this type of therapy (Pinto & Udwadia, 2010). The time inconvenience, intrusion of privacy, and the public nature of the program were commonly cited reasons for patient disinterest in RNTCP. Unfortunate for RNTCP, there is a "stigma" attached to public health care in India, and many individuals, both literate and illiterate, believe the private sector to be best at serving their purpose. The private sector is believed to offer more patient privacy and more prompt as well as flexible services. The lack of trust of public health care in India is a "stigma" that must be resolved with support both from public health campaigns and the private health sector, who should recommend RNTCP programs to its TB-infected patients.

Another campaign of interest for increasing health literacy and combating infectious diseases in India is one regarding HIV/TB co-infection. In addition to the vulnerable populations from low-socioeconomic backgrounds, there is also a vast amount of individuals diseased both by HIV and TB. The HIV/TB co-epidemic is significantly relevant for India, because TB takes a fast disease course in patients with HIV with more probability of acquiring MDR-TB in a shorter period of time. Unfortunately, the treatment for an HIV/TB infected patient is complex, expensive and involves a burden of many pills with varying toxicities (Swaminathan & Narendran, 2008). Generally, HIV-patients infected by TB suffer from higher mortality rates during and after treatment (Swaminathan & Narendran, 2008). The higher mortality rate among

HIV/TB co-infected patients is due to the overwhelming workload being placed on an already vulnerable immune system. By definition, HIV is associated with a general loss of T-lymphocytes and the immune system is less effective in maintenance of intruding pathogens (Swaminathan & Narendran, 2008). Consequently, a co-diseased immune system takes a quickly aggressive and depleting course.

From the identified risk factors and system disparities, it is a fact that the delivery of TB services cannot be an autonomous effort by existing organizations. Intervention strategies for combating TB must include collaborations between NTPs like RNTCP and foreign nonprofits or NGOs. Funding must be sought both from the national government as well as partnering programs interested in eliminating infectious diseases like MDR-TB. As of 2009, the treatment success for MDR-TB failed to reach the global target of 75% success rate (Chiang et al., 2013). The reported success rate was 48% (Chiang et al., 2013). Therefore, the next decade should seek to unite nations, foreign organizations, and nonprofits in an alliance towards establishing strong public health structures for all countries. The focus of the study is specific guidelines for India's reconstruction and possible intervention strategies for bridging the gap in disparities among their TB-infected populations.

RESEARCH DESIGN/METHODS

The objective of the study was to identify effective TB treatment programs in countries with similar risk factors to that of India. The study used qualitative and comparative methods to examine the current treatment programs being used in locations with high prevalence of TB and MDR-TB, such as the vulnerable populations of Bangladesh, Peru, Russia, and Thailand. All of these countries have established TB programs because they experience prevalent TB rates and

have identified cases of MDR-TB. However, they have taken aggressive measures to reduce the burden of TB and MDR-TB. Also, with the objective of making the study more complete, it was necessary to assess programs not just from TB prevalent areas, but also from a country with record low rates for the debilitating disease. Therefore, U.S. TB programs will be analyzed for insight into their framework of keeping TB at less alarming percentages.

The populations that were chosen for the comparative study was based on their similarities to India's demographics and risk factors for TB. The risk factors similar to those of India also arise from high percentages of poverty among their rural populations. Evidently, poverty influences living conditions, infection control, health literacy, and access to effective healthcare facilities with appropriate laboratory equipment to mitigate the time between diagnosis and treatment. Most effective healthcare facilities arise from strong government regulations and surveillance systems. Among the populations that will be studied, laboratory technology ranges from best to most minimal access. The U.S. is the known to have some of the best laboratory diagnostics available to them, whereas Bangladesh, Peru, Russia, and Thailand are steadily recognizing the importance of healthcare expenditure on quick diagnostic procedures for TB/MDR-TB.

The research conducted was based on mainly primary and secondary sources. Primary sources were gathered from studies that were previously conducted to gather statistics about the effectiveness of the programs mentioned. Generally, databases such as ProQuest were used to identify scientific journals such as *The Lancet's Infectious Diseases*, PLoS ONE and reports from WHO as well as CDC. The keywords used in searching for relevant and up-to-date information were as follow: "tuberculosis AND intervention AND programs," "tuberculosis AND Bangladesh," "tuberculosis AND Peru AND initiatives," "tuberculosis AND Russia AND

prisons," "tuberculosis AND Thailand AND programs," "tuberculosis AND global AND programs," "tuberculosis AND U.S. AND epidemic," "U.S. AND public health," "tuberculosis AND partners in health," and other searches using keyword variations. Articles of interest were those with valuable statistics or discussions of outcomes from effective TB/MDR-TB programs in any of the locations of interest.

In analyzing the gathered information, statistics were partially important for measuring the effectiveness of a program by quantitative measures and examining whether or not the program achieved their target goal and was effective. However, findings and discussion sections were more importantly analyzed for the followings: community intervention programs, adequate access to healthcare facilities, and deliverance of appropriate treatment programs, strengthening of surveillance systems, and government agency initiatives. Evaluation of the gathered qualitative results should give insight to India's current lack of unity among their deliverance of healthcare diagnosis, treatment, and prevention to TB infected individuals. The purpose is to provide India with examples of intervention programs that can possibly strengthen their current public health system.

FINDINGS/RESULTS

Bangladesh's TB Campaigns

Bangladesh is a country in South Asia and is bordered by part of India. There is a large rural population that lives in villages accustomed to traditional lifestyles and their urban population is recognized as the 7th largest population in the world (Global Health Initiative). In 2005, Bangladesh was one of the most burdened TB countries in the world and launched a community-based TB campaign for delivering public health awareness (Rifat et al., 2008). As a

collaborative effort between a nongovernmental organization (NGO) and Bangladesh's NTP, known as Fund for Innovative DOTS Expansion through Local Initiatives to Stop Tuberculosis (FIDELIS), the program delivered TB information to 27.56 million people in 10 rural districts of Bangladesh (Rifat et al., 2008). Information about TB was reported through theater performances, in classroom settings of primary schools, in mosques, at small group meetings, and through television messages (Rifat et al., 2008). The mobilizing campaign increased TB case detection by 36%, compared to the 29% from other districts that did not implement the same measures (Rifat et al., 2008). Certainly, conveyance of cumbersome TB information was made more amusing by the animated activities from the campaign. These types of public health awareness campaigns are vitally important for all low-income countries in need of infection control. Programs must be structured in a manner that appeals to the community culture and they must not be threatening in any way. Community-based initiatives such as this communicate TB risk factors, forms of transmission, and importance of receiving medical check-ups in a more effective manner because the community engages. Also, health literacy is drastically increased when community leaders are able to translate information to adequate dialogues in the simplest manner. As mentioned before, India's government must invest in a nationwide campaign regarding TB. Leaders from high TB burdened communities must receive proper training in how to best deliver TB information regarding prevention, diagnosis and treatment. The cost-effectiveness of this program is not known, but preventing cases of MDR-TB from surfacing saves funds on second-line medical treatments. A TB campaign to increase health literacy in India is especially important for its disadvantaged communities that are unaware of NTPs or the dangers of being diseased with MDR-TB.

Lima, Peru's New Database

Like India, Peru experiences a high incidence of TB globally and is the highest TB-infected country of South America (Fraser et al., 2012). During 1995, Lima identified 12 cases of MDR-TB and began a reform in healthcare (Fraser et al., 2011). In attempts to combat their grave MDR-TB problem, Partner in Health (PIH) partnered with a sister organization by the name of Socios En Salud and delivered home-based DOT treatment to the diseased community (Fraser et al., 2011). Resulting from these first initiatives were further partnerships with other stakeholders, such as Ministry of Health (MOH) and The Massachusetts State Laboratory Institute (MSLI) (Fraser et al., 2011). Recently, another partnership with the National Institutes of Health (NIH) has resulted in great technological advances for Lima. The NIH provided funding to Lima for establishing an electronic medical record system with the objective of tracking patterns of the disease (Fraser et al., 2011). The program is cost-effective for countries with low-resources and has an encoding application for the implementation of foreign languages (Fraser et al., 2011). The system is called OpenMRS, and with the training of three Peruvian programmers, the system could be implemented and launched in September of 2009 (Fraser et al., 2011). OpenMRS was established with the objective of tracking the patterns of TB on one database that would allow for accurate documentation of disease outbreaks in households and other research data collection (Fraser et al., 2011). Information has not been well researched in regards to the engineering technicalities underlying the implementation of such a database. However, India's programmers are innovative and with sufficient funding, a database that would track TB-case reports can deliver an accurate nationally based record on disease patterns and areas to implement intervention programs.

Tomsk, Russia's 'Sputnik' TB Program

Similar to India, Russia forms part of BRIC, the quickly developing global economies, and is also combating a TB epidemic. Tuberculosis risk factors similar to those of India are poverty and a minimally integrated public health system with a dearth in healthcare professionals to access all regions. Also, Russia experiences a high-burden of mortality due to drug-abuse and crime as well as high TB-rates among their prisoners (Gelmanova, 2011). The disintegration of the public health in Russia occurred following the collapse of the Soviet Union and an overcrowding in their prisons cultured the overwhelming TB epidemic (Pickett, 2012). However, through much delegation with the political agenda of Russia, Partners In Health (PIH) became a key foundation for the establishment of national tuberculosis initiatives. Partners in Health assisted in establishing TB control procedures in the prison systems of Russia and provided training to laboratory as well as medical professionals. Also, the integration of Partners in Health, a nonprofit, has recently partnered with Russia's Health Ministry to launch a program by the name of 'Sputnik.'

The 'Sputnik' program was established in December of 2006 in Tomsk, Russia, with the objective of increasing the adherence of MDR-TB infected patients (Partners in Health, 2011). Sputnik uses a home-based therapy approach with healthcare professionals who visit MDR-TB identified patients who are at high risk for non-adherence and provide treatment (Gelmanova et al., 2011). After analyzing treatment adherence, Gelmanova (et al., 2011) found the "cure rate [to be] 71.1% for patients with MDR-TB, 60% for all others, and 68% in the program overall" (p. 1373). The study also found the cost of treating a Sputnik patient to be "U.S. $6.50 per day, where the cost of the alternative- in-patient care for the duration of treatment- ranges from U.S. $9.30 per day to as high as U.S.$35.00 per day" (Gelmanova et al., 2011, p. 1377). Furthermore,

replication of Sputnik in other cities would require funding for ambulatory vehicles, training of professionals, and purchase of both first as well as second line MDR-TB treatment regimens. For India, a study needs to be done to calculate the cost-effectiveness for the possibility of implementing such a program. The program could prove beneficial for treating MDR-TB patients in rural areas of India who are at higher risk for non-adherence. Also, before implementation of a Sputnik-style approach, India needs to increase awareness about the risks of TB to populations who may be illiterate or need more information on why compliance to treatment can save their life and the lives of those around them. India could also benefit from partnering with nonprofit organizations seeking to make an effective change in the TB-infected communities.

Thailand's Surveillance Network

During 2006, Thailand ranked as the 18th most TB burdened country in the world (Varma et al., 2007). Some risk factors for Thailand's population that are similar to India's are socioeconomic factors as well as the HIV/TB co-infection epidemic. Following WHO's Global Plan to Stop TB 2006- 2015, Thailand mobilized their TB Active Surveillance Network in October of 2004 with the target of drastically reducing the percentage of TB burden (Varma et al., 2007). According to the study by Varma (et al., 2007), the Thailand TB Active Surveillance Network collaborates with "Thailand's Ministry of Health of Public Health, the Bangkok Metropolitan Administration, the United States Centers for Disease Control and Prevention, and the Research Institute of Tuberculosis Japan." Similarly to the countries previously described, the TB program in Thailand is also dependent on collaborations with national and foreign stakeholders. The program focuses on collecting all reported TB cases from both public and

private healthcare facilities in order to best measure the effects of programs such as DOTS. The staff from Thailand's healthcare facilities of selected districts uses an electronic database and securely delivers information to the national TB program (Varma et al., 2007). Overall, the TB program of Thailand is successful in reporting TB cases in Thai citizens, but the limitation of the reporting system is that it has minimal reports for non-Thai migrants who migrate from TB endemic places like Cambodia and Myanmar (Varma et al., 2007). Regardless, Thailand's surveillance system for TB is another example of technology able to record epidemiological significant data. As referenced previously, India must establish a surveillance system with a public-private collaboration effort, in order to accurately identify disease outbreaks such as TB and MDR-TB.

U.S. Public Health Model

Unlike the developing countries previously described, the U.S. experiences fairly low rates of TB. In 2011, a national TB record low rate was reported to be an incidence of 3.4 cases per 100,000 population (Centers for Diseases Control and Prevention, March 2012). Assessment for an explanation of the low TB rates in the U.S. may be useful for developing countries. Research about U.S. intervention strategies may provide a framework that may help improve their current TB program models. Tuberculosis intervention strategies of the U.S. are dependable, insofar as, historically the U.S. has achieved milestones in combating this infectious disease. During the 17th century and again in 1985, TB accounted for a large percentage of the mortality rates in the U.S. (Schneider, 2004). Therefore, from 1985 to recently, the U.S. advanced from one of the highest to one of the lowest rates of TB worldwide. Many of the advancements that aided the U.S. in their TB struggle were due to strong public health measures

demanding the improvement for living conditions of the poor (Schneider, 2004). Additionally, in the early 1990s, a large outbreak of MDR-TB in New York City resulted in immediate political involvement in terms of funding prevention, diagnostic, and treatment programs (Abubakar et al., 2013). Certainly, intensive public health measures are the explanation for why the U.S. was able to drastically decrease their TB rates. Also, much political involvement and government funding allowed for the implementation of surveillance and monitoring systems with the intent of preventing any further outbreaks. The U.S. public health infrastructure is intrinsic and involves many stakeholders, systems, and organizations all working towards maintaining a healthy population. Currently the CDC provides the U.S. public health infrastructure with infection control guidelines that include surveillance, response, applied research, training, prevention, and control (Schneider, 2004).

Nevertheless, a 2010 report found that foreign-born persons accounted for 60% of all TB cases in the U.S. (Woodruff et al., 2013). The upcoming challenges for the U.S. healthcare system involve more research for "understanding cultural competency in health practice" (Woodruff et al., 2013). In general, developing countries like India should fund research programs that may prove cost-effective for their overall national healthcare system. Funding healthcare initiatives that will increase health literacy through community-based awareness programs will result in prevention and early diagnosis for TB. Investing further funding in a surveillance and monitoring system will allow for rapid recognition of disease outbreaks, rather than the current gap between outbreak and action. Lastly, although RNTCP has proved helpful in treating some TB outbreaks, "NTPs cannot be operated as stand-alone interventions (Chiang et al., 2013). Strengthening of public health systems is fundamental and imperative for the prospective decade of effecting change in TB programs and healthcare facilities.

CONCLUSION/IMPLICATIONS

Resulting from the assessment of India's current difficulty with controlling their TB epidemic, it was necessary to seek TB intervention programs in countries similar to India who are gradually building their public health framework. A thorough review of literature identified the grave social inequities affecting a large percentage of India's TB infected population. The poor are disproportionately affected by malnourishment, overcrowded living conditions, and lack of access to adequate TB diagnostic facilities. Moreover, Indian citizens are affected by a disintegrated healthcare system with gaps in communication between the public and private sectors that produces an ideal environment for the development of MDR-TB. Advantageous to a structure that neglects regulations on pharmaceuticals is a lack of advanced laboratory technology. Monitoring and keeping patient records on a national surveillance system is absent from India's public health infrastructure. Using a surveillance system for detecting outbreaks and developing intervention programs based on disease patterns has proved beneficial to places such as Lima and Thailand. Furthermore, integration of the public-private sectors of India may allow for better control of HIV/TB co-infected patients who consume a toxic level of various treatment drugs and have higher susceptibility for acquiring MDR-TB as well as more prevalent mortality rates.

Having concluded a further examination of other countries, with abundant TB rates and similar risk factors to that of India, it is possible to consider the need for India to establish further collaborations with foreign organizations as well as NGOs. An unfavorable limitation in completing a general cross-analysis between Bangladesh, Peru, Russia, and Thailand with India was the absence of studies examining cost-effectiveness of establishing their TB programs. Also, most studies that were found through the ProQuest database were in regards to individual studies

focusing on collaborations between country NTPs and nonprofits. There was a gap in information concerning the actual public health system of most of the evaluated countries. Furthermore, reviewing for literature about India, RNTCP-DOTS was the only TB program found that paralleled all DOTS programs in the other countries. Principally, studies of other countries suggested the following guidelines: 1) Establishment of a surveillance system; 2) engaging the community with TB awareness campaigns; and 3) Strengthen NTPs with collaborations from foreign establishments such as PIH. In addition, evaluation of the U.S. public health initiative for infection control offers India a guideline for the integration of many departments working towards a single objective.

Future studies should focus on researching cost-effective measures that can be implemented in laboratory settings of all developing and underdeveloped countries. Attempting to replicate the U.S. system for diagnostic purposes would be ineffective for countries combating a much more aggressive outbreak of TB. More specifically, developing countries need to rely more heavily on DST testing services rather than culturing bacteria that would further delay the time between diagnosis and treatment. Innovations such as the recent Xpert MTB/RIF assay may prove to be more reliable for identifying MDR-TB and cost-effective for low as well as middle-income countries. More research should be done regarding the replication of Xpert assay in countries experiencing outbreaks of MDR-TB.

Also, more research must be done for further evidence that community engagement may drastically decrease TB incidence rates. Most of the studies evaluated in this paper involve communicating knowledge to certain regions about their TB diagnosis and treatment. In Bangladesh, for example, TB campaigns were integrated into the daily living activities of its inhabitants. Integration of TB knowledge into the daily day of a child or adult helps increase

health literacy from one generation to the next. According to the CDC, community engagement is defined as, "the process of working collaboratively with and through groups of people affiliated by geographical proximity, special interest, or similar situations to address issues affecting the wellbeing of those people" (Boulanger et al. 2013). Aside from NTPs and NGOs that are more likely to include community engagement activities, combating the MDR-TB epidemic will also require the support from the general public health infrastructure and regulations for ensuring qualified physicians and authenticate treatment TB drugs.

In conclusion, models for combating emerging diseases should be effective innovations worldwide. As mentioned before, the government must increase funding for diagnostic services, community engagement, and further research on how equitable care can be distributed by the public health infrastructure of India. Tuberculosis is a treatable disease and the prevalence of mortality can be changed with dedication and commitment to public health programs against the transmittable bacteria.

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