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The Impact of Genexpert MTB/RIF Technology on the Minimization of Tuberculosis: A Review of Literature

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The molecular revolution in tuberculosis (TB) diagnosis has ushered in a new era of patient treatment that is quicker, more accurate, and clinically appropriate. In cases where treatment resistance is suspected or if tuberculosis (TB) is present, the most cutting-edge molecular diagnostic tool available is the Xpert test developed by Cepheid in Sunnyvale, California. In December 2010, it was swiftly recognized as the main technique for TB diagnosis by the World

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Health Organization. This comprehensive review provides an in-depth understanding of TB and GeneXpert technology and its impact on the minimization of TB. The leading infectious disease killer in 2019 was tuberculosis (TB). Worldwide, tuberculosis (TB) killed an estimated 1.2 million people in 2019, with an additional 208,000 lost to the disease among HIV-positive individuals. almost the world, the sickness affected almost 10.0 million people. Of all tuberculosis cases, 88% were in adults, while 12% were in children less than 15 years old. The 2019 tuberculosis case rates were lower in the East Mediterranean (8.2%), the Americas (2.9%), and Europe (2.5%), compared to the World Health Organization (WHO) zones of South-East Asia (44%), Africa (25%), and the Western Pacific (18%). This study will provide an in-depth understanding of GeneXpert technology and its impact on the healthcare system.

Keywords: Tuberculosis; genexpert; diagnosis; health; patients.

1. INTRODUCTION

The global public health community is deeply concerned about tuberculosis (TB) due to the high number of new cases (10.0 million) and deaths (1.4 million) documented so far (WHO, 2019). The increasing prevalence of drug-resistant microorganisms is a serious problem that affects healthcare costs, illness, and mortality rates on a worldwide, regional, and national level [1]. Only prompt and accurate diagnosis of this illness will result in the eradication of drug-resistant tuberculosis (TB) and a subsequent decrease in illness and death rates. Mycobacterium tuberculosis (TB), which is resistant to more than two drugs, is known as "multi-drug-resistant tuberculosis," or "MDR-TB." Starting second-line drug (SLD) treatment is the second line of protection against TB. According to the data, using GeneXpert MTB/RIF® (Xpert) technology for diagnostics rather than the old-fashioned way and using sputum smear microscopy may save both time and money. Additionally, it speeds up the start of SLD therapy for MDR-TB and significantly shortens the time it takes to diagnose patients in clinical settings [2,3]. A recent meta-analysis by Horne et al. (2019) using 95 trials found that Xpert MTB/RIF identifies pulmonary tuberculosis and rifampicin resistance quite sensitively [4]. The World Health Organization recommends Xpert for all individuals who may have tuberculosis (TB) that has shown resistance to several treatments [2]. Because drug-resistant tuberculosis (TB) is on the rise, this is a particularly pressing issue in countries like Ghana. As the impact of Xpert testing on patient outcomes varies greatly by country and circumstance, it is crucial to conduct a place-by-place evaluation of its implementation [1].

The leading infectious disease killer in 2019 was tuberculosis (TB). Worldwide, tuberculosis (TB) killed an estimated 1.2 million people in 2019, with an additional 208,000 lost to the disease among HIV-positive individuals. almost the world, the sickness affected almost 10.0 million people. Of all tuberculosis cases, 88% were in adults, while 12% were in children less than 15 years old. The 2019 tuberculosis case rates were lower in the East Mediterranean (8.2%), the Americas (2.9%), and Europe (2.5%), compared to the World Health Organization (WHO) zones of South-East Asia (44%), Africa (25%), and the Western Pacific (18%) [5].

2. TUBERCULOSIS EPIDEMIC

Tuberculosis (TB) is a major public health concern worldwide because of its status as a leading infectious disease. 1.5 million people died from tuberculosis in 2014, which affected 9.6 million people [6]. The mycobacterium was also found in one out of 10 people who caught it. The incidence rate has been declining globally since 2000, with an average annual decline of 1.5%; however, it varies slightly among countries. Despite accounting for about 80% of all cases, just 22 countries are deemed to have a high incidence of TB. Many cases of TB, especially drug-resistant strains, go undiagnosed or unreported, which is a major cause for worry [7].

More cases of drug-resistant tuberculosis (DR-TB) and extensively drug-resistant tuberculosis (XDR-TB) are likely to be reported as more patients are found and treated and adherence is either not checked or fails. This is because infection control methods are not very good. The prevalence of drug-resistant tuberculosis strains is alarming, accounting for almost 500,000 new cases annually, or around 25% of all infections [7]. There has to be a concerted effort to better detect drug-resistant TB and connect patients with the right treatment.

Since tuberculosis (TB) is so hard to eliminate once it has spread, multidisciplinary teams are necessary for controlling the illness. Traditional TB prevention methods include early detection improvements, new ways to get patients outside of hospitals, more focused prevention, better treatment plans for both drug-susceptible and drug-resistant tuberculosis (TB), and steps to lower the number of cases and deaths in both adults and children.

In regions where HIV co-infection is common, it is essential to increase access to antiretroviral medication (ART) and closely follow patients who have not yet received treatment. The Millennium Development Goals for TB and HIV infections were reached in 2015, while progress varied across states. The Sustainable Development Goals have replaced the Millennium Development Goals. The World Health Organization (WHO) developed and made public the End-TB Strategy as a result of this process. We aim to eliminate tuberculosis (TB) and all related diseases, deaths, and suffering by the year 2035 [8].

Crucial elements of this strategy include stringent regulations, enhanced health support systems, integrated patient-centered management, and, most significantly for the purposes of our study, ongoing research and development into new diagnostics, vaccinations, and treatments [9]. Although these tactics are not new, they face many obstacles in achieving their aims, such as the ineffectiveness of vaccines, the likelihood of HIV latency throughout life, the growing complexity of the virus, and the lack of information about the pathogenic pathways that cause infection. Several research organizations have used advanced models to determine which methods are more effective in achieving the intended objectives within the allotted time. The World Health Organization (WHO) recommends that all people living with HIV undertake baseline and enhanced screening [10], but the effectiveness of this case-finding approach varies by setting, region, and screening method.

3. PATHOGENESIS

The likelihood of disease development from infection to tuberculosis depends on the number of infecting bacilli and the host's immune system. Swelling of the lymph nodes, effusion into the pleura, infiltrates and lesions in the lung tissue, or disease spreading to other areas of the body are all symptoms of a more severe infection. A localized pathological lesion that the patient's immune system causes frequently involves significant tissue destruction and cavitation. Cavitating lesions comprising several actively dividing bacilli most often occur in the lungs. Patients with these lesions often get positive results on sputum smears. Scar tissue may harbor latent tuberculosis bacilli for a long period after the acute illness has passed. The chance of developing post-primary tuberculosis increases if a tuberculosis bacilli infection occurs during the main infection and reactivates in any organ system. Multiple factors, such as primary infection, secondary infection, or external reinfection, might trigger the activation of a dormant infection in an infected individual.

Even when co-infection with HIV was not present, a study by Comstock, Livesay, and Woolpert found that infected people had a 5 to 10% chance of developing tuberculosis (TB), with the highest risk occurring in the first five years of infection [11]. As individuals age, their risk of complications from tuberculosis (TB) changes. Young children, especially those under the age of five, are more likely to get tuberculosis, especially the more severe kinds like miliary TB and TB meningitis, since their immune systems are still maturing. Tuberculosis resistance is very low in children and adolescents (five to fifteen years old). During adolescence, the risk is highest; during middle age, it is lowest; and in old age, it is highest again [11,48].

Multiple diseases, including HIV, undernourishment, toxins (such as alcohol, tobacco, corticosteroids, and immunosuppressive medications), and silicosis, all increase the likelihood of tuberculosis (TB) infection [12,13]. On average, an unidentified or delayed diagnosed TB person who remains untreated could infect at least ten new persons within a year [10,49]. The introduction and use of molecular platforms such as the GeneXpert that provide cutting-edge results similar to the gold standard; TB culture within 2 hours and also can identify drug resistance using rifampicin as a proxy for first-line TB drugs is revolutionary and indeed a game changer [2,3]. The technology has time, specificity, and sensitivity as its added advantages thus making it a significant tool in the mitigation of TB in the End TB strategy [4].

4. HISTORY OF TUBERCULOSIS

The ancient civilizations of Babylon, Egypt, Rome, and the Incas all had significant health-

promoting and illness-prevention policies in place. These techniques were designed to prevent disease and promote health. A significant number of individuals were working toward the goal of reducing the incidence of infectious diseases such as TB during that particular period in history.

In light of the results of the physical examinations, the following tactics were found to be less preventative and more reactive [14]. "The science and art of preventing disease, prolonging life, and promoting optimal health and productivity through organized community efforts for cleanliness of the environment, the control of community infections, the education of the individual in principles of personal hygiene, the structuring of medical and nursing services for early diagnosis and preventive management of disease, and the development of social machinery that will ensure that every individual in the community has a standard of living adequate for the maintenance of health" [14]. To the rest of the globe, the concept of public health was first presented for the first time at the beginning of the nineteenth century.

According to Schneier et al., the interpretation of public health issues was primarily a political process in which a huge number of parties strove to impose their interests on the situation [15]. The results of this study have not only shed light on the method by which politics and public health interact with one another, but they have also shown how political acts may have an influence on public health. When evaluated from an interpretive viewpoint, medical models aimed to cure illnesses before they reached their terminal stages and to prevent them from arising (by mass screening and selection, vaccination, and other treatments). Health education and the adoption of healthy habits were two things that social scientists advocated for on both an individual and a societal level. Social scientists worked to promote these two things. According to Schneier et al., individuals who advocated for the political economics of health believed that it was the responsibility of the government to influence the economic, social, and environmental circumstances in such a way that would either make it easier or more difficult for people to obtain high-quality medical care [15]. This conviction was based on the belief that the government should have the ability to influence these circumstances.

The idea of mortality transition has been and continues to be focused on the effects that declines in communicable diseases have on health transitions in industrialized countries. This is because communicable diseases have been decreasing. Throughout the years, this concentration has remained consistent. Three of the illnesses that have been effectively eradicated from the world include scarlet fever, smallpox, and TB. Without a shadow of a doubt, the prevalence of each of these illnesses has reduced during the last several decades. Debates concerning successful tactics for the treatment of TB have taken place in a number of industrialized nations, and these debates have taken on a variety of forms. This is due to the fact that there are a wide variety of topics that are capable of capturing the attention of social, economic, and medical political organizations.

Publications, including those authored by Thomas McKeown, are examples of publications that have often been cited as jumping-off points for talks on how to reduce the occurrence of infectious diseases. McKeown, who spent twenty years studying death rates in Britain starting in the 17th century, claims that the industrial revolution's effects on rising income and nutritional changes were the main causes of the decline in mortality rates [16]. The study that McKeown looked at was carried out in the United Kingdom. McKeown's thesis caused a paradigm shift in medical history and medical theory [17]. This shift occurred as a result of McKeown's thesis casting doubt on a long-established general orthodoxy regarding the contribution of medical science and the medical profession to the decline in death rates that followed industrialization in Britain. It was McKeown's argument that brought about this change in perspective. According to Szreter, this research provided incontestable evidence that immunotherapies and chemotherapy, which are the cornerstones of contemporary conventional clinical and hospital practice, had a significantly less significant impact on the precipitous decline in death rates that was seen in earlier periods [17].

Changes in socioeconomic conditions have an impact on infectious diseases like the flu, dysentery, typhoid, and fever. Other infectious diseases include tuberculosis and influenza. Much of his argument was directed at this point. Up until 1935, research conducted by McKeown and record suggested that the reduction in the number of deaths brought on by infectious illnesses might be attributed to the development of new dietary practices [18]. McKeown, Brown,

and Record state that infectious illnesses were the leading cause of the 3027 fatalities that occurred for every 100,000 inhabitants in Britain between the years 1901 and 1910 [19]. These deaths happened throughout the period under consideration. When the year 1947 rolled around, infectious diseases were the cause of death for 730 people out of every million people who were still alive. In spite of the fact that medical control methods and bacillus virulence levels were unable to explain this finding, McKeown, Brown, and Record came to the conclusion that the mortality rates, which were caused by TB, started to decrease significantly beginning in the year 1838 [19]. A concurrent improvement in living circumstances and nutritional standards occurred at the same time that this process unfolded. Improvements in the nutritional and dietary status of potential victims would increase their resistance to the illness, which would ultimately result in a decrease in the number of deaths brought on by airborne diseases like tuberculosis (TB). According to McKeown, who stated that this would improve the situation, On the other hand, preventive measures for public health do not have the ability to influence the likelihood of a person being exposed to the sickness for the very first time [16].

Studies on tuberculosis (TB) that were conducted in a number of locales around the world have given some support for the conclusions that McKeown and his colleagues came to during their study [19]. These studies were carried out over the course of their investigation. According to Johnston, who conducted research on the history of tuberculosis (TB) in Japan, the dietary idea was brought up at several points over the course of the examination [20]. He made the observation that "nutrition is one of the most powerful of all socially and environmentally determined influences on the development or retardation of active TB... neither medicine nor public health measures had a significant impact on mortality from the disease until after World War II" [20].

Fairchild and Oppenheimer, who argued that increasing socioeconomic indicators is essential to reducing tuberculosis (TB) epidemics, noted the recent spike in TB cases in many Eastern European republics whose economic circumstances have worsened [21]. They believed that decreasing TB epidemics would be possible if socioeconomic indicators were improved. According to Fairchild and Oppenheimer, this line of thinking received some support from their findings [21]. Among the persons who have expressed their disagreement with McKeown's idea, two of the individuals who have done so are Szreter and Elwood [17,22]. On the other hand, they claim that the theory does not take into consideration larger social activities that are targeted at improving nutrition and instead places an excessive amount of attention just on nutrition.

They were developed in Germany in the middle of the 18th century as a component of a larger public health effort that was aimed at preventing TB. The earliest institutions of this sort were institutions known as sanatoria. According to Bryder [23], the British sanatoria system placed importance on treating patients in their early stages rather than chronic "incurables" when it came to making judgments on therapeutic interventions. This was the case when it came to determining patient treatment. The basic notion of the sanatoria was characterized by Bates [24] as being "spartan, austere, and sometimes punitive... prison-like to be hospitals and too hospital-like to be prisons." According to these authors, the practice of keeping patients in a sanatorium was ineffective.

According to Fairchild and Oppenheimer [21], the primary objective of constructing such sanatoria was to encourage the use of outdoor tuberculosis (TB) treatments. These treatments comprised progressive work, exercise, and diet. The creation of such sanatoria facilities was done with the main intention of accomplishing this goal. Even though there was no treatment available for tuberculosis (TB), the number of infections that occurred during the course of the illness was reduced by isolating consumptives rather than providing home care. This was done in order to prevent the spread of the disease throughout the population.

Furthermore, there is evidence for the idea that widespread social interventions have an effect on TB in Western nations, which takes us to the third reason. According to Szreter [17], some of the social programs that are well known include restrictions on housing and industrial activities, inspection and processing of meat (in order to battle bovine TB), and other programs that are quite similar to these. Numerous academics have suggested that the poor ventilation present during the early stages of the industrial period contributed to the rapid spread of TB. This comment was made in connection with tuberculosis and was included in the article by

Dubos and Dubos [25]. They said that "TB was, in effect, the first penalty that capitalistic society had to pay for the ruthless exploitation of labor." According to Pradana [26], this reduction in tuberculosis (TB) rates among urban workers in industrialized countries happened throughout the first half of the 1900s. This decline occurred in the United States. One possible explanation for this is that the working conditions have improved.

The imposition of rigorous constraints on the consumption of milk and meat from cattle has been shown to be one social action that has been proven to have an impact on the development of TB, particularly bovine traits. The results of other studies have demonstrated that there are some clear connections between human TB and bovine tuberculosis. Because of this, laws that apply to cow products, such as those that require meat to be inspected and pasteurized, were regarded as effective in the fight against the sickness. It was found that there was a decrease in the frequency of cases of TB in children in regions of the United States where pasteurization was strongly enforced. This was in contrast to countries like Britain, where it was not used in such a stringent manner. According to Fairchild and Oppenheimer [21], the Meat Inspection Act of 1906 in the United States of America was responsible for a significant decrease in the number of cases of human TB. In order to do this, tests were performed on each and every cow corpse in order to ascertain whether or not the cows tested positive for bovine TB before they were consumed.

As a result of the fact that different writers emphasize different areas of public health, nutrition, and wide social changes as possible ways of lowering tuberculosis (TB), it is considered that the varying political and philosophical viewpoints among scientists are responsible for this phenomenon [21]. The degree of support that the authors had for the political system that was already in existence and the policies that it utilized to solve social problems was closely proportional to the amount of political power that they had. From a philosophical point of view, researchers have a responsibility to demonstrate their support for fields of study such as social medicine, public health, or biological and clinical science. Szreter [17], for instance, says that McKeown resigned from his position as a physician because he had lost trust in clinical science as a consequence of his personal experiences in clinical practice. McKeown's resignation was a result of his personal experiences. There seems to be a wide range of political and philosophical viewpoints that have had an impact on the issues that have led to the development of concepts that are in conflict with one another. Although the effects on tuberculosis [TB] patterns and levels differed from one activity to the next, they did serve to complement one another. This was the case, despite the fact that the intensity of the effects varied.

5. DISCOVERY OF TUBERCULOSIS

Until Dr. Robert Koch in March 1882 announced the discovery the mycobacterium tuberculosis, the disease had killed several thousands. The disease accounted for the life of one out of every seven people in the United States and Europe. This discovery was very significant and formed the foundation to the elimination of the deadly disease [21,52]. Until Johann Schonlein coined the term tuberculosis for the disease, it was known as “phthisis: in Ancient Greece. In Ancient Hebrew it was known as “tabes” while in other jurisdictions it was referred to as the “white plague” due to the paleness that was associated with the disease. Prior to the discovery in 1882, Jean-Antoine Villemin had actually demonstrated how mycobacteria tuberculosis was transmitted [17,52]. Subsequently, Clemens von Pirquet developed the tuberculin skin test (TST) which he later used to demonstrate that latent TB was asymptomatic in children. After World War 1, the use of Bacillus Calmette-Guerin (BCG) vaccination became population even though it had been used in humans much earlier in the 1920s. The modern day tuberculosis treatment and control is largely linked to the discovery of Streptomycin and Isoniazid in 1944 and 1952 respectively [20,53].

6. MANAGEMENT OF TUBERCULOSIS IN GHANA

Because it is the infectious illness that is responsible for the greatest number of deaths and the greatest number of impairments, tuberculosis (TB) is a significant cause for worry in the field of public health all over the globe. This is because it is the infectious disease that causes the most deaths. According to the World Health Organization [27], the disease went from being considered a worldwide emergency to being recognized as one in 1993. Because tuberculosis is becoming an increasingly important issue in terms of public health, this categorization was created. It has been reported

by the World Health Organization [28] that TB is accountable for more than 25 percent of fatalities that might have been prevented in nations that are afflicted by poverty. In addition, the illness is responsible for nearly 1.5 million instances of the disease each year in sub-Saharan Africa, and it infects more than one-third of the population of the whole globe by itself. As a consequence of the financing that was supplied by the Danish government, Ghana has made remarkable improvements in the treatment of tuberculosis (TB) since 2004. During the year 2004, there were 206 documented incidences of tuberculosis (TB) for every 100,000 people present. Two hundred and twenty-two of the cases were determined to be new smear-positive cases. In light of the discoveries that Utami and Ariyanti [29] have uncovered, the National Tuberculosis Control Programme (NTP) has been tasked with the responsibility of bringing the death rate associated with tuberculosis (TB), as well as treatment resistance and transmission rates, down to a more manageable level.

The National Tuberculosis Programme (NTP) has made the choice to use directly observed treatment strategy (DOTS) as a therapeutic mechanism as a result of the significant recognition that it has garnered. Providing patients with the most effective medicine, checking in with them to ensure that they are taking their prescription as directed, and finally evaluating their progress are the three essential components that comprise the DOTS strategy for the treatment of tuberculosis (TB). The United States Department of Health and Human Services is responsible for the development of this method. The Ghana Health Service (GHS) implemented the Stop TB strategy and the wider DOTS framework throughout all of Ghana's health institutions in order to battle the pandemic of tuberculosis [30]. This was done in order to combat the epidemic. This course of action was adopted with the intention of doing something about the issue.

In order to achieve the objective of detecting TB cases among patients who are reporting symptoms, the DOTS policy of the World Health Organization (WHO) is constructed on the basis of three pillars: political will, well-managed short-course chemotherapy, and sputum smear microscopy. The primary objective is to identify at least seventy percent of cases that have a positive smear while concurrently treating eighty-five percent of patients who have recently been identified. This is the primary objective.

In spite of the fact that the DOTS strategy is primarily concerned with enhancing the identification, treatment, and monitoring of the condition rather than educating the general population about the medications that are available for tuberculosis, the objective of the strategy is to decrease the morbidity rates that are associated with tuberculosis in Ghana.

7. GENEXPERT TECHNOLOGY

In order to provide demonstration results to the WHO in September 2010, the Xpert MTB/RIF test, which was established in 2004, was validated and used with the GeneXpert analyzer. In December of that year [31], endorsements were granted at a record pace. In 2010, the World Health Organization (WHO) prescribed Xpert MTB/RIF as the initial diagnostic tool for HIV-associated tuberculosis and cases where there was suspicion of high rates of medication resistance [31]. The assay was first in class for a number of reasons: (i) improved sensitivity over prior attempts at using nucleic acid amplification testing (NAAT) strategies, (ii) the simultaneous detection of rifampin resistance, (iii) a modular format allowing testing across a spectrum of volume needs, (iv) the possibility of automation (Infinity group of analyzers), (v) simplicity, (vi) speed, and (vii) safety (single room, no biohazard hoods required, and testing available even to the clinic setting) [32,33]. There was also no need for a cold chain, and the mat platform is sometimes called a "lab-in-a-cartridge." Because of its modular design, the analyzer may integrate with various lab management systems and provide a platform for remote communication, allowing for centralized monitoring of instrument performance [34]. It was likewise random-access in nature [35]. This test has set a new bar for fast followers to follow. Following this, in 2013, the FDA authorized the assay, classifying it as a medium-complexity test [36]. The same year that the test gained widespread acceptance as a viable alternative to smears, its use was expanded to include pediatrics and EPTB [36]. In March 2011, Ghana took a bold step to replace smears with the Xpert MTB/RIF test nationwide. This allowed for early identification and treatment of tuberculosis (TB), which was a growing concern. The high rates of HIV co-infection (65 to 70% of HIV-positive people are TB coinfected) [37], the high prevalence of undiagnosed drug-resistant tuberculosis cases, and the high smear-negative rate of light-emitting diode microscopy (8 to 10% of referred cases positive nationally) (National Health Laboratory Service [NHLS]; W.

Stevens, personal communication) led us to this decision. Also, for pediatric patients, the diagnosis of EPTB was challenging and accounted for roughly 15% of all cases [38]. Many patients were never followed up on, and the time it took to receive a culture result ceased to be a clinically important concern. The essential molecular paradigm and knowledge were already well regarded in the nation as a result of its effective application in HIV for the nationwide expansion of PCR for HIV viral load testing and early newborn diagnosis of HIV [39].

8. HISTORY OF GENEXPERT TECHNOLOGY

The World Health Organization (WHO) authorized the Xpert test in 2010, but few people were eager to use it right away because there were no useful implementation models or recommendations. Despite this, a number of nations' tuberculosis (TB) programs are utilizing or will use it. The absence of instructions on how to incorporate the test into the existing, sophisticated tuberculosis clinical algorithms casts more doubt on the initiative's total cost and field success. Operating strategies, which are now easier to adopt than previously, are recommended in these publications. Following the rules and processes for training, upkeep, and purchasing, these items follow [28].

9. IMPACT OF GENEXPERT IN TB DETECTION AND MANAGEMENT

After the initial demonstration trials, the assay's performance was assessed, verified, and researched in almost every country's clinical setting. New research on how point mutations can change results [40,41] and huge amounts of data from countries with low and high loads, each with their own unique epidemiological patterns [33], support the test's pros and cons.

You may not be able to tell right away how the Xpert programme changed certain parts of the national TB control programme. This became clear when the test was implemented on a massive scale over the whole country of Ghana. The data collected from this initiative has enhanced the processes needed to administer more tests and create models for the rollout of similar programs in Ghana and other countries. More people are paying attention to implementation science now, which is great news for the diagnostics sector, in our opinion. People in the area were naturally apprehensive about the new test since they had depended on traditional microbiological diagnostic procedures for so long. This necessitated that the assay work in tandem with other molecular tests and the standard cultural model. The test has a history of user or clinician misunderstanding owing to its complex algorithms, which prevents it from being utilized to its full potential. Programs should include clinical diagnostics and any applicable clinical treatment criteria prior to launch.

In areas where co-infection is prevalent, this should be included in HIV treatment regimens. It seems that the Xpert test is less useful in high-burden HIV settings when it comes to the presentation of critically ill patients receiving empiric treatment. The platform's polyvalency, however, makes further integration of HIV and TB therapy feasible. Screening tests, including digital X-rays and urine lipoarabi nomannan, should also be considered for future use. The sensitivity of the Xpert assay in paucibacillary HIV-infected individuals has been the subject of several investigations; these issues may be addressed in future iterations of the test, such as the Ultra cartridge, or in other tests, including the Abbott MTB assay (Abbott Molecular) [42].

Integrating analyzers globally with laboratory information systems is crucial for producing actionable results. New channels of contact between patients and healthcare providers may emerge as a result of these technological developments. The Xpert assay's straightforward result reporting (no more than 160 characters) opens the door to several mHealth tactics, including the utilization of cellphones and SMS printers. A centralized data warehouse now stores the outcomes from all analyzers, allowing for accountability at every level of the healthcare system. Facilities like laboratories allow for the tracking of data like locations, equipment modules, and turnaround times.

The geo-referenced nature of all labs allows for the establishment of accountability on several levels, including the national, regional, facility, and individual patient levels, from a clinical standpoint. In particular, rifampin resistance monitoring stands out as a telltale sign of multidrug-resistant microorganisms. This statistic may also be used to measure how well programs and therapies are working, which allows for more focused interventions. Using unique identifiers also makes it possible to verify adherence to clinical practice. For instance, in the absence of a

follow-up sample to validate MDR and XDR, further verification of compliance with clinical practice might be performed [35,43].

It is quite a challenge to monitor 314 analyzers across all programs using the Xpert assay because of its modular design; this is the same as monitoring 4,180 individual devices. As a result, a method for continuous internal quality monitoring has been developed, and an interface is required for real-time analyzer performance monitoring. Part of the enormous task of defining the requirements for a comprehensive quality assurance program was the ability to continuously monitor quality indicators on the analyzer and an external quality assurance program (EQA). Other aspects of the program included making sure that samples were collected and processed in a simple and appropriate manner [44,45].

The Xpert analyzer now uses a new quality assurance product called a dried culture spot (DCS) instead since it is safer to do so, as transporting entire TB germs is biohazardous [45]. Thus, it is quite evident that the test must demonstrate the shortcomings of these technologies in a way that is compatible with the procedures currently used for EQA and laboratory quality control.

10. EVALUATION OF GENEXPERT TECHNOLOGY

An understanding of the primary causes of tuberculosis is required prior to assessing the potential effects of GeneXpert MTB/RIF on disease burden and tuberculosis control. Among the many variables that increase the likelihood of tuberculosis or predisposes one to the infection, some of the most common include: HIV positivity (11% of cases), exposure to biomass fuels (22% of cases), smoking (16%), alcohol abuse (10%), diabetes (8% of cases), and many more [46]. Overcrowding, poverty, and poor nutrition (as a result of drug misuse and transmission) predisposes a person to tuberculosis; however, there are also problems with the healthcare system and no effective vaccine. Because programming methods prioritize passive rather than active case discovery, it is well established that most transmission happens weeks or months before diagnosis. Misdiagnosis accounts for 30–40% of tuberculosis cases in community settings, which is another well-known fact [6].

Even if their symptoms are mild or unusual, many of these individuals may put off seeing a doctor until they get much worse. A significant percentage of this cohort may have tested positive for smears. Xpert does not seem to be going to significantly affect disease burden, tuberculosis control, or transmission. Supporting this view are factors like GeneXpert's late-stage diagnosis of tuberculosis and the fact that diagnostic tests have no effect on the underlying causes of the disease.

In countries where tuberculosis (TB) is common, it is especially important to enhance the overall functioning of the health system, particularly in terms of improved diagnosis, in order to improve TB outcomes. Therefore, all patients should have access to TB diagnosis and treatment. Active case-finding strategies, improved service accessibility, and other measures are among those that might close the tuberculosis care cascade gap [47-53].

11. CONCLUSION

To get the most out of GeneXpert testing, it's important to stress the importance of improving health systems. Before any new instrument can make a difference and meet the aims of the WHO END-TB plan, there must be health system change, poverty reduction, and political resolve. Therefore, for the program to achieve greater success, more funds should be dedicated to healthcare worker education, pharmaceutical accessibility, patient retention, laboratory facility expansion, and similar initiatives. When the healthcare system runs well, accurate diagnoses are possible. Although diagnosis technologies alone will not be sufficient to combat tuberculosis (TB), especially considering the equal importance of political will and initiatives to relieve global poverty and overpopulation, the introduction of GeneXpert technology in healthcare facilities has sped up the rate of diagnosis and also enabled health professionals to have the ability to do early detection and treatment before its increase and/or spread.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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