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Most laboratory tests used in the diagnosis of tuberculosis in Ethiopia are based on direct microscopy: A systematic review

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Abstract
Background: Laboratories and laboratory tests are fundamental components of tuberculosis control programme; providing testing for diagnosis, surveillance and treatment monitoring at every level of health care system. This review is, therefore, aimed at comparing and summarizing data on these laboratory systems used in the diagnosis of tuberculosis in Ethiopia. *Methods*: A systematic review of literature addressing the diagnosis of tuberculosis in Ethiopia was carried out. Literature search was done in MEDLINE and EMBASE for articles published from 2000 to 2013. We used the following search terms: *Laboratory, tuberculosis, diagnosis, Ethiopia.* Only studies addressing diagnostic systems of tuberculosis and English language publications were included. *Results:* A total of 267 potential studies were identified by the search. Thirty-three studies qualified for the review. The reported diagnostic systems used to diagnose TB in Ethiopia included Symptom screening, Physical examination, Chest X-ray, Histology, Histopathology, Cytology, Smear microscopy, Tuberculin skin test (TST), QuantiFERON TB Gold In Tube and Culture. Ten (30.3%) studies utilized culture as the reference standard and only one study employed polymerase chain reaction (PCR) as a standardized test. Most studies have used more than one diagnostic system. Four (12.5%) studies reported the use of sample processing methods (liquefaction and concentration of sputum using either sodium hypochlorite or sodium hydroxide followed by centrifugation) before actual tests, twenty seven (81.8%) studies used direct smear microscopy, three (9.4%) studies used TST and QFTGIT together and two (6.3%) studies employed cytological techniques. Chest X-ray was employed in the majority of smear negative results with symptomatic patients suggestive of tuberculosis. *Conclusions*: The results of this review suggest that there is a need for revising the diagnostic systems. Most of the laboratory tests employed was based on direct smear microscopy, which is insensitive and can only detect 36 % of tuberculosis cases in Ethiopia. This may result in misdiagnosis of the disease and further transmission of the disease especially in children and populations with high HIV co-infection. Therefore, there is a need for laboratories to find a rapid and efficient method for TB diagnosis as a complement to the smear microscopy.

1. Introduction

Tuberculosis (TB) is one of the world's most important causes of morbidity and mortality among adults. It is caused by the bacterium Mycobacterium tuberculosis and most commonly affects the lungs (pulmonary TB), but may affect any organ or tissue outside of the lungs (extra pulmonary TB). When TB is detected and effectively treated, the disease is largely curable. One of the largest challenges in preventing morbidity and mortality from TB is the difficulty in making a timely diagnosis. Diagnostic approaches relying on symptoms, chest radiographs, tuberculin skin tests, microscopy or cultures, all have particular challenges [1, 2].

Early, accurate and rapid diagnosis of TB is critical for reducing TB transmission and incidence. Even though WHO has endorsed a novel, rapid and automated diagnostic systems that are simple enough to be run in basic laboratories and clinics, outside of a reference laboratory setting in 2010, smear microscopy is the sole method used for TB diagnosis in most laboratories in developing countries, where over 95% of TB-related deaths occur. In patients with active pulmonary TB, only an estimated 45% of infections are detected by sputum microscopy. In most cases, mycobacterial culture is considered to be the best available reference diagnostic test for TB diagnosis and is the most important method in detecting drug resistance [2].

TB remains the leading cause of morbidity and mortality in developing countries including Ethiopia, despite the availability of short-course therapy that can be both inexpensive and effective. Early and proper diagnoses are essential for effective tuberculosis control programs; to improve treatment, to reduce transmission and to control development of drug resistance. Laboratories and laboratory networks are fundamental components of tuberculosis control, providing testing for diagnosis, surveillance and treatment monitoring at every level of the health-care system [3, 4].

Care of patients with tuberculosis starts with a quality assured diagnosis. Arguably, the weakest component of health systems is laboratory services, which have been grossly neglected, understaffed and underfunded over time. Low-income and middle-income countries, which bear most of the global burden of tuberculosis, rely heavily on outdated tuberculosis diagnostic tests; including sputum smear microscopy, solid culture, and chest radiography [2].

In high-incidence countries, TB control relies on passive case finding among individuals self-presenting to health care facilities, followed by either diagnosis based on clinical symptoms or laboratory diagnosis using sputum smear microscopy. Serial sputum specimens are required (one taken on the spot and the second brought in the following morning), which asked patients to make repeated visits to the health care centers for specimen delivery and collection of results. For many patients, the costs of repeated visits to health care facilities are prohibitive, and patient dropout is a significant problem [4].

Many smear microscopy laboratories are single room and understaffed with poorly maintained microscopes, and some of these laboratories lack consistent sources of electricity and clean water. There are few opportunities for the training of staff and little staff capacity to handle high-volume workloads. Quality assurance programs including quality control and external quality assessments are often lacking. Thus, there is a critical need for new, sensitive, easy, and rapid point-of-care diagnostics and also for investments in laboratory infrastructure, quality assurance programs, and well-trained staff [5].

Ethiopia is ranked 7th among the 22 countries with a high-burden of TB and third in Africa [6] but almost all TB laboratories in Ethiopia have only equipped with the acid-fast staining and lack resources for culture, identification and drug susceptibility testing of mycobacteria, which present a huge hindrance for tuberculosis control in the country. Culture and drug susceptibility testing for *M. tuberculosis* are not performed routinely in clinical microbiology laboratories. Smear microscopy contributes little to the diagnosis of pediatric TB and does not identify smear-negative TB which may account for 24% to 61% of all pulmonary cases in people living with HIV [7, 8].

Sputum smear microscopy remains the cornerstone of TB diagnosis in developing countries. The method depends upon the quality and bacterial load of the sputum specimen and the training and motivation of laboratory technicians. Although highly specific in most countries, smear microscopy is insensitive - it detects roughly 50% of all the active cases of TB. Sensitivity can be as low as 20% in children and HIV infected people. In addition, smear microscopy cannot detect bacterial resistance to anti-microbial drugs [1].

Sputum smear examination for acid-fast bacilli (AFB) can diagnose up to 50–80% of cases of pulmonary tuberculosis in well-equipped laboratories [9]. In low-income countries, poor access to high-quality microscopy services contributes to even lower rates of AFB detection. Furthermore, in countries with high prevalence of both pulmonary tuberculosis and HIV infection, the detection rate is even lower owing to the paucibacillary nature of pulmonary tuberculosis in patients with HIV infection. In the absence of positive sputum smears for AFB, at primary care level, most cases of pulmonary tuberculosis are diagnosed on the basis of clinical and radiological indicators [7].

Culture is a more sensitive method for TB diagnosis than smear microscopy and it permits testing for drug resistance but it has limitations and requires biosafety facilities that are expensive to build and maintain and specially trained laboratory technicians to perform the procedure. Some national TB programmes in developing countries have no functioning TB culture facility at all. In others, TB culture

is performed only at national reference laboratories or in hospital laboratories in large cities. Even where capacity exists, diagnosing TB with culture can take weeks because of the slow growth rate of TB bacilli. In most countries TB culture is reserved for retreatment cases. Specimens are often sent to distant laboratories. This can delay processing of specimens and lead to inaccurate results. Furthermore, test results must travel long distances back to reach the clinic and the patient [1].

2. Methodology

A systematic search of studies addressing the diagnosis of tuberculosis in Ethiopia was performed. All returned titles were reviewed and articles that obviously did not involve diagnosis or isolation of tuberculosis were excluded. The authors then reviewed abstracts of remaining articles to determine which studies examined diagnostic systems used in the diagnosis of tuberculosis. Bibliographies of relevant articles were also reviewed for potential articles. The two investigators independently reviewed the remaining articles, independently deciding on inclusion in the review using a predetermined eligibility criterion. Disagreements were resolved by consensus. For inclusion, the articles needed to describe a study involving the use of diagnostic system to diagnose tuberculosis. Only English language articles were included. Each article was analyzed to determine the study setting, study design, sample characteristics, type of diagnostic system used, reference or gold standard used for comparison, and findings of the diagnostic system. Duplicate publications of the same findings were excluded. Studies analyzing the diagnosis of tuberculosis without actually performing the diagnosis or isolating tuberculosis from study subjects were also excluded from the review.

2.1. Search Strategy

We searched MEDLINE and EMBASE database for reports published in English up to the end of July 2013. The first search was done on 20th April 2013 and repeated on 7th July 2013. The searches yielded 267 citations of which 38 were duplicate papers, 229 were subject to title and abstract review, 76 were subject to full text review and 33 articles were included in the final review. An over inclusive search strategy was used to ensure that no papers were missed. The key search words used were: *"Tuberculosis OR TB, "Mycobacterium tuberculosis OR MTB", "diagnosis OR screening OR isolation OR tests OR assays", "AND Ethiopia"*. We also reviewed references of the selected papers to ensure that no papers were missed. We have also searched the website of the STOP TB Partnership's New Diagnostic Working Group. We reviewed studies cited by articles identified by this search strategy and selected those we identified as relevant. The researcher reviewed titles and abstract in duplicate to exclude ineligible articles. Papers meting the inclusion criteria were subject to full-text review (Figure 1).

2.2. Inclusion and Exclusion Criteria

To be eligible, articles needed to: peer-reviewed publications, published in English, conducted in Ethiopia, conducted after 2000, focused on diagnosis or isolation of tuberculosis, use of clear screening and diagnostic methods and algorithms in the diagnosis of TB and applied a survey methodology for data collection.

2.3. Data Extraction and Classification

The following data was extracted and summarized in evidence tables: Citation, year of publication, Settings, study design, study population, type of diagnosis and outcomes.

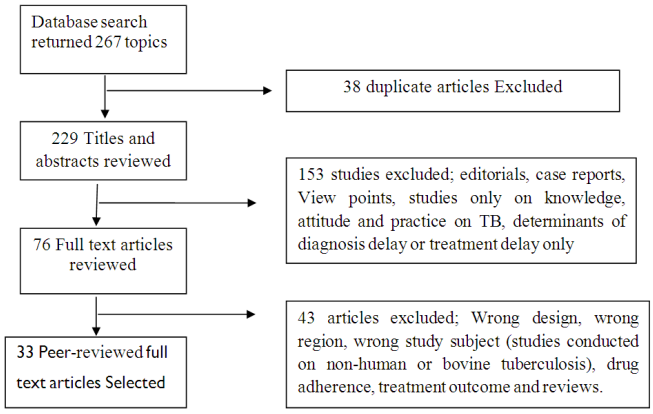

Figure 1. *Search strategy and paper selection flowchart.*

3. Results

The online search of MEDLINE and EMBASE yielded 267 articles. Additional potential studies were identified through searches of bibliographies. After articles that did not address the diagnosis of tuberculosis in Ethiopia were excluded, 229 articles remained. Further, 153 articles were excluded upon closer review because they did not include a diagnosis system or focused on screening of drug resistant tuberculosis. We retrieved full text articles for 76 citations, of which 43 studies were excluded based on a review of title and abstract. Articles that briefly mentioned a diagnosis system but did not give details or include how it was used in the study were also excluded. Thirty-two published peer-reviewed articles and one country wide survey from Ethiopia met the general study criteria and included in the review (Table 1).

We have also performed an updated search on 7 July 2013 that yielded 62 titles, all of which had been identified during the previous search or were ineligible based on title or abstract. Repeated searches using the same search strategies were employed until the end of July 2013 to ensure that no new publications were missed. Thus, we included 33 relevant studies in this review (Figure 1). Of the total 33 studies, one was population based country study [10] carried out at three (urban, rural and pastoralists) study setting.

3.1. Description of Included Studies

Of the 267 citations identified by literature searches, a total of 33 English-language publications (32 articles, and 1 population based survey) met the eligibility criteria (Figure 1). Of the 33 studies, ten (30.3%) studies utilized culture [10,11,12,13,14,15,16,17,18,19] and one study employed polymerase chain reaction (PCR) as the reference standard [20]. Eighteen (54.5 %) studies used a cross sectional study design, three (9.1 %) used comparative, two (6.1%) used a retrospective design, two (6.1%) randomized trial and one (3%) did not describe the study design employed. Missing data were treated as "not reported" (indicated in the table as not reported) (Table 1). Three studies presented the data based on two separate microscopy methods (Ziehl-Neelsen [ZN] and Light Emitting Diode Fluorescence Microscopy [LED-FM]) [10, 21, 22]. Twenty five (75.8%) studies were published after 2008 and few studies included information about patients infected with HIV.

Descriptive information on population characteristics, such as sex and age category, was often reported. Most studies have used more than one diagnostic system. Twenty-four (72.73 %) of the 33 studies utilized ZN stained microscopy and three (9.4%) studies used LED-FM. Four (12.1%) reported the use of some processing methods [13, 23], three (9.1%) studies used TST and QFTGIT together and two (6.1%) studies employed cytological techniques. Chest X-ray was employed in the majority of studies especially for smear negative results with symptomatic patients suggestive of tuberculosis. For the majority of studies, information about timing, manner of sputum collection, mycobacterial culture methods and quality assurance for microscopy was reported while sputum characteristics (macroscopic appearance of sputum samples) and appropriate instructions how to produce quality sputum was not described except one study [24]. Eighteen (54.5 %) of the 33 studies reported about PTB alone, seven (21.2 %) studies reported EPTB alone, four (12.1%) studies reported both PTB and EPTB, three (9.1 %) studies reported LTBI alone and one study reported both PTB and LTBI (Table 1).

Table 1. *Diagnostic systems used in the diagnosis of Tuberculosis and characteristics of selected studies in Ethiopia.*

Author, Year, Ref.	Study Settings	Study subjects	Study design	Diagnosis type	Form of TB
Cambanis et al, 2006, [25]	Health Center	PTB suspects	Cross sectional	Smear microscopy	PTB
Legesse et al , 2011, [17]	Community	Adults	Cross sectional	QFTGIT TST	LTBI
Aderaye et al, 2007, [13]	Hospital	HIV patients	Comparative	Chest X-Ray Smear microscopy* Culture	PTB
Dagnew et al, 2012, [26]	University	Young adults	Exploratory	QFTGIT TST	LTBI
Beyene et al, 2008, [18]	Rural	Patients	Cross sectional	Histology Cytology Smear microscopy Culture	EPTB
Alebachew et al, 2011, [10]	Urban/rural/ pastoralist	Persons ≥ 15 years	Cross sectional	Chest X-Ray LED-FM Culture	PTB EPTB
Yimer et al, 2009, [27]	Rural	Adults	Cross sectional	Smear microscopy	PTB
McNerney et al, 2010, [28]	Hospital	Adults	Comparative	Chest X-Ray Smear microscopy	PTB
Datiko et al, 2009, [29]	Rural	PTB suspects	Randomized Trial	Smear microscopy	PTB
Beyene et al, 2009, [20]	Hospital	Lymphadenopathy patients	Cross sectional	Histology Culture PCR	EPTB
Alene et al, 2013, [30]	Hospital	Adult HIV patients	Retrospective	Chest X-Ray Smear microscopy Cytology	PTB EPTB
Yassin et al, 2013, [22]	Community	PTB suspects	Implementation	LED-FM	PTB, EPTB
Deribew et al, 2011, [31]	Health Center	TB suspects	Cross sectional	Chest X-Ray Smear microscopy Symptom screening	PTB EPTB
Shah et al, 2009, [14]	Hospital	HIV patients	Prospective	Physical examination Chest X-Ray Smear microscopy**	PTB
Eshete et al, 2011, [32]	Hospital	Suspected patients	Cross sectional	Culture Histopathology Smear microscopy	EPTB
Bruchfeld et al, 2002 [11]	Hospital	Adult TB suspects	Analytical	Smear microscopy** Culture	PTB
Aderaye et al, 2003, [12]	Hospital	HIV patients	Investigative	Chest X-Ray Smear microscopy**	PTB

Author, Year, Ref.	Study Settings	Study subjects	Study design	Diagnosis type	Form of TB
Legesse et al, 2010, [33]	Hospital/Health center	Pastoralists	Comparative	Culture Chest X-Ray Smear microscopy QFTGIT	PTB LTBI
Wassie et al, 2013, [34]	Urban	Children	Cohort	Culture QFTGIT, TST	LTBI
Abebe et al, 2011, [19]	Prison	Prisoners	Not reported	Smear microscopy Culture	PTB
Wondimeneh et al, 2013, [35]	Hospital	HIV patients	Cross sectional	Chest X-Ray Smear microscopy	PTB
Abebe et al, 2010, [15]	Rural	Adult TB suspects	Cross sectional	Smear microscopy	PTB
Moges et al, 2012, [21]	Prison	Prisoners	Case finding	LED-FM Cytology	PTB
Shargie et al, 2006, [36]	Rural	Adults	Cross Sectional	Smear microscopy	PTB
Muluye et al, 2013, [37]	Hospital	Lymphadenopathy patients	Retrospective	Cytology	EPTB
Zenebe et al, 2013, [38]	Hospital	EPTB suspects	Cross sectional	Smear microscopy Cytology	EPTB
Amare et al, 2013, [39]	Hospital	Diabetic patients	Cross sectional	Smear microscopy Chest X-Ray	PTB
Ali et al, 2012, [23]	Hospital	PTB suspects	Cross sectional	Smear microscopy*	PTB
Shargeie et al, 2006, [40]	Rural	Adults	Randomized Trial	Smear microscopy	PTB
Biadglegne et al, 2013, [41]	Hospital	Children/adults	Cross sectional	Cytology	EPTB
Abebe et al, 2012, [16]	Rural	Adults	Cross sectional	Smear microscopy Cytology	EPTB
Tadesse et al, 2011, [42]	Urban/rural	Persons $\geq$ 14 years	Cross sectional	Culture Smear microscopy Chest X-Ray	PTB
Deribew et al, 2012, [43]	Rural	Adults $\geq$ 15 years	Cross sectional	Smear microscopy Culture	PTB

QFTGIT = QuantiFERON-TB Gold In-Tube, TST = Tuberculin skin tests
PTB = Pulmonary Tuberculosis, EPTB = Extra-pulmonary Tuberculosis
LTBI = Latent tuberculosis infection, LED-FM = Light Emitting Diodes Fluorescent Microscope
* Primary test was done after concentration ** Re-examined after specimens are concentrated with sodium hypochlorite or sodium hydroxide

4. Discussion

Our systematic review of literature of 33 studies on diagnosis of tuberculosis showed that there is a considerable similarity between diagnosis systems used, study design and the types of TB isolated. However, comparisons of these variables were not significantly different. The diagnostic systems included, the inclusion or exclusion of laboratory testing, and even their diagnostic focus (i.e., pulmonary TB alone, pulmonary and extra pulmonary TB or latent TB infections) were varied. Because publication dates of the articles range over the last thirteen years, some systems were developed and evaluated after the HIV epidemic and focused specifically on co-infected patients.

Smear-positive TB case detection rate is 36% in Ethiopia [24]. Lack of accurate and rapid diagnostics remains a major obstacle to progress in this regard. Health care facilities still heavily rely on sputum smear microscopy for the diagnosis of TB. This technique has low sensitivity and specificity [13]; however, efforts were made to ensure quality AFB diagnosis through appropriate instruction of symptomatic individuals on how to produce quality sputum sample from their lung. In the laboratory the macroscopic appearance of a sputum sample was checked and poor specimens were replaced with an immediate spot collection [42].

The gold standards chosen to evaluate the validity of these diagnostic systems also varied widely. Ten studies used culture as the gold standard [10, 11, 12, 13, 14, 15, 16, 17, 18, 19]; others used TST and QFTGIT [26, 33, 34] or histology, cytology and histopathology [24, 32, 37]. Unfortunately, laboratory diagnosis is likely to depend strongly upon the experience and knowledge base of the laboratory technician; it may be less reliable in settings where technicians have less training. To allow for comparison of diagnostic tests across different studies and settings, future studies need to employ a more consistent and rapid gold standard systems. Ideally, culture would be gold standard, as it is a standard for validation that could be reliably reproduced across settings. However, because cultures are difficult to obtain in resource limited settings and can lead to a delay in treatment, performing studies with culture as the gold standard may be difficult.

In addition to using a variety of gold standards, the various studies often included very different sample populations. Some studies did not clearly describe the characteristics of the patient population or how they were selected. Some were retrospective, often utilizing record review [30, 37]. Prospective studies of diagnostic systems would evaluate a clearly defined sample of participants with a spectrum of disease representative of the study subjects to which the diagnostic systems would be applied

in the study settings. It is essential that researchers should clearly describe the sampling process and inclusion criteria in such studies to allow for more accurate comparison of diagnosis systems across different populations or settings and to promote the utility of these systems.

QFTGIT and TST were also used as part of their diagnostic gold standard to differentiate latent TB from active TB disease [26, 34, 37]. This makes it difficult to interpret the accuracy of a diagnostic system and its ability to predict a diagnosis of TB in a particular patient or patient population. This overlap also causes difficulty in determining the relative importance of particular signs or symptoms within the diagnostic system. The largest shift in the newer diagnostic systems as compared to smear microscopy is the focus on both pulmonary tuberculosis and extra pulmonary tuberculosis including latent tuberculosis. Diagnostic systems focusing simply on pulmonary TB, such as [13, 25] have demonstrated higher sensitivities than those developed to diagnose both extra pulmonary and pulmonary TB. Because children have a higher incidence of extra pulmonary TB, using diagnostic systems targeted at pulmonary TB only addresses part of the diagnostic challenge.

The findings of this review are limited by the study settings and quality of studies included. The lack of consistent and sometimes clearly defined inclusion criteria among the studies makes it difficult to compare sensitivity and specificity across the different diagnostic systems. Most of the various diagnostic systems have only been evaluated in specific geographic locations or single populations; few studies evaluate a particular diagnostic system in multiple geographic regions or patient populations. Fewer studies have compared the diagnostic tests with different specimens (Bronchoalveolar lavage, pre- and post-bronchoscopy sputum for pulmonary tuberculosis) in the same population [13]. There may be probably more TB cases in the surveyed communities or settings than reported in these studies. Furthermore, sputum samples may not be collected and examined in symptomatic individuals that may further aggravate the underestimation of the true TB prevalence.

With a better screening method and diagnostic facility, the prevalence could even be more than what was reported. However, one thing is very certain; the passive case detection approach currently implemented in Ethiopia leaves many (two-thirds of smear-positive TB cases) undetected and untreated TB cases in the community; favoring continuous spread of the disease through maintaining active TB transmission [42].

5. Conclusion

The results of this review suggest that there is a need for revising the diagnostic systems. Most of the laboratory tests employed was based on direct smear microscopy, which is insensitive and can only detect 36 % of tuberculosis cases in Ethiopia. This may result in misdiagnosis of the disease and further transmission of the disease especially in children and populations with high HIV co-infection. Therefore, there is an urgent need for laboratories to find a rapid and efficient method for TB diagnosis as a complement to the smear microscopy. The low case detection rates observed nationally can be improved by introducing enhanced case detection mechanisms and promoting favorable health seeking behaviors

5.1. Weaknesses of the Review

The studies reported varying diagnostic systems. Despite carrying out a comprehensive search, some studies may have been missed to be included in this systematic review. The increase in the prevalence of HIV during the publication range of these studies makes it difficult to compare studies from thirteen years ago to those more recently published. The paper also did not include unpublished data or non-English publications.

Conflict of Interest

None of the authors declare conflict of interest

Contribution of Authors

AMD developed the review protocol. AMD and BZT performed data collection and analysis. AMD wrote the manuscript, and both authors have reviewed and approved it.

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