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An Overview: The Roles Of, Laboratory Testing and Imaging Technicians in Diagnosis and Management of Tuberculosis

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ABSTRACT

Tuberculosis (TB) is a serious infectious disease that continues to be a significant cause of mortality and morbidity globally. Consequently, clinicians and radiologists must utilize all available diagnostic tools in disease assessment to deliver accurate recommendations for initiating anti-tubercular treatment, thereby mitigating the risk of TB transmission and complications, particularly in developing countries where the disease remains endemic. Thoracic ultrasonography (TUS) is a portable, non-invasive, radiation-free, and cost-effective technology that can be readily accessible in resource-constrained environments. This perspective essay examines the possible role of TUS in diagnosing and managing patients with pulmonary tuberculosis. Regrettably, there remains inadequate evidence and conflicting data to evaluate TUS as a suitable diagnostic technology for disease screening. Laboratories and laboratory networks are essential for tuberculosis (TB) control, offering diagnostic testing, surveillance, and treatment monitoring throughout all tiers of the health-

care system. New initiatives and resources aimed at enhancing laboratory capacity and executing rapid and innovative diagnostic tests for tuberculosis necessitate the acknowledgment that laboratories function as systems requiring quality standards, suitable human resources, and a focus on safety, alongside necessary supplies and equipment.

KEYWORDS: Tuberculosis, imaging, technicians.

1. Introduction

Tuberculosis is a bacterial infection caused by Mycobacterium tuberculosis. Tuberculosis is considered a public health issue and a top cause of death worldwide [1]. In 2020, the COVID-19 pandemic generated enormous health issues and displaced tuberculosis as the top lethal infectious illness, affecting TB health services, particularly in high-burden countries [2]. It is estimated that 30% of the global population has tuberculosis [3]. Infection is typically caused by prolonged or recurrent exposure to Mycobacterium tuberculosis, which is spread via airborne droplets from an actively infected person's coughs or sneezes. The lung is the most common site of tuberculosis infection, but it can affect every organ in the body [1, 3]. Approximately 90% of those who have been exposed to the germs carry the bacteria but have no clinical, radiological, or microbiological signs, resulting in latent infection. Approximately 5% of infected patients develop active illness during the first two years; this is known as primary tuberculosis. The remaining 5% of infected persons with good immunity can control the primary infection, but viable mycobacteria remain latent and reactivate, a condition known as post-primary or reactivated tuberculosis [3,4].

The laboratory has always been crucial in diagnosing tuberculosis (TB) and monitoring treatment. In the new millennium, the strength of the laboratory network frequently reflects the efficacy of tuberculosis control programs. Developed countries have taken advantage of modern technology that allow for rapid detection, identification, and medication susceptibility testing of Mycobacterium TB, hastening the disease's decline when combined with effective treatment programs. In contrast, many impoverished nations have high rates of tuberculosis and struggle to deliver high-quality microscopy, with access to culture and drug susceptibility testing (DST) limited to non-existent. Countries have long demonstrated excellent tuberculosis control through microscopy-based diagnosis and monitoring, along with well-managed treatment programmes [5,6]. However, insufficient administration and support for TB programmes and laboratory networks stymies disease control efforts. Furthermore, problems from the HIV epidemic and multidrug-resistant tuberculosis (MDR-TB), particularly in Africa and Eastern Europe, impede efficient tuberculosis control that depends solely on microscopy-based case diagnosis and management. Effective control requires access to laboratory services at all levels, which necessitates maintaining and sustaining laboratory networks that deliver dependable and consistent dispersed services. Although laboratory strengthening is becoming a higher priority on the TB agenda, as seen by the current Stop TB Strategy, additional efforts are required to increase access to and utilization of existing diagnostics, as well as to develop and adopt new technologies [7,8].

2. Review:

TB symptoms include night sweats and fever, unexplained weight loss, loss of appetite, and lethargy. Additional indications of highly contagious pulmonary tuberculosis include a chronic cough with or without hematemesis, dyspnea, and chest pain while breathing. However, clinical signs of extrapulmonary tuberculosis vary depending on the infected organs; thus, extrapulmonary tuberculosis requires a high index of suspicion as well as further laboratory and radiographic examinations [4,5]. Several tests are required to diagnose tuberculosis (TB). The gold standard tests are Mycobacterium tuberculosis smears and cultures. However, they are costly and result in a delayed diagnosis. A tuberculin skin test or an interferon-gamma release assay can be used to diagnose latent tuberculosis, but these tests do not play a role in the diagnosis of active TB. In active tuberculosis, nucleic acid amplification tests (NAATs) include DNA extraction and polymerase chain reaction (PCR) amplification; the new molecular diagnostic test Xpert mycobacterium tuberculosis/rifampicin resistance (Xpert MTB/RIF) assay, which can detect the Mycobacterium tuberculosis complex within two hours; histopathological examination of biopsy samples; and medical imaging are required for evaluation. Recently, Lipoarabinomannan (LAM) has been proposed as a biomarker for diagnosing tuberculosis based on its detection in urine [9,10]. Extrapulmonary tuberculosis, in particular, is a significant cause of nonspecific clinical symptoms in TB-endemic areas, such as fever of unknown origin (FUO). However, medical imaging tests are critical in detecting tissue abnormalities and making an early diagnosis of tuberculosis in many regions of the body [11].

Medical imaging is critical for detecting tissue changes and making the first diagnosis of tuberculosis. All conventional radiography, computed tomography (CT), ultrasonography, magnetic resonance imaging (MRI), and positron emission tomography CT (PET-CT) methods play a role in the diagnosis of tuberculosis and can help physicians diagnose a variety of diseases throughout the body. A variety of medical imaging modalities can be used to diagnosis different forms of tuberculosis, including pulmonary, abdominal, scrotal, brain and spine, and musculoskeletal (MSK) [12,13].

Although tuberculosis can affect every organ in the body, the pulmonary parenchyma is typically the first site of infection with TB mycobacteria. As a result, chest imaging is an important first-line diagnostic tool for early illness detection. Chest X-rays are still the first line of defense for detecting suspected tuberculosis, albeit the exam may be benign or show only moderate or non-specific abnormalities in individuals with active disease. Chest CT, with or without contrast enhancement, may aid in the better characterization of radiographic results by distinguishing between past inactive and active disease or detecting changes that cannot be seen on normal radiographs. Centrilobular nodules, tree-in-bud pattern, thick-walled cavities, consolidations, miliary nodules, pleural effusions, or necrotic lymphadenopathy are all indicators of "active" illness [14]. "Inactive" tuberculosis is defined by 6-month stable changes, such as scarring (peri-bronchial fibrosis, bronchiectasis, and architectural distortion) and nodular opacities (calcified granulomas and lymph

nodes) [15]. In any case, because clinical and radiological indications of tuberculosis can mimic those of many other diseases (for example, lymphoma and other neoplasms, granulomatous disorders, and sarcoidosis), making a precise diagnosis can be difficult [16]. Furthermore, fibronodular alterations are typical in patients with latent tuberculosis, particularly in the lung apices, making it difficult to distinguish between active and inactive illness.

Thoracic ultrasonography (TUS) has recently acquired popularity among doctors and radiologists as a useful diagnostic tool for the investigation of a variety of pleuro-pulmonary diseases [17]. Although TUS examination does not yet have a standardized role in the diagnosis and management of pulmonary tuberculosis in international guidelines, this imaging technology is advantageous in terms of non-invasiveness and cost-effectiveness, is suitable for a quick real-time evaluation, and is a portable technology available to all clinicians in all hospital wards. This makes TUS a potentially valuable diagnostic technique for pulmonary tuberculosis, especially in places with limited access to radiographic or laboratory investigations. Furthermore, TUS has the advantage of not exposing children and pregnant women to ionizing radiation, while simultaneously serving as a diagnostic tool that allows for significant safety improvements for patients who require regular follow-ups [17].

If the data on the use of TUS are contradictory and do not allow for clear conclusions, endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) is an established minimally invasive method for the assessment of mediastinal/hilar lymphadenopathy in adult TB patients. The diagnostic accuracy of the method ranges between 68 and 94% in various investigations [18]. There is more limited data on the use of EBUS-TBNA in children, with diagnostic accuracy ranging from 36 to 100%. Some authors found that a heterogeneous echotexture at EBUS or the presence of coagulation necrosis on a granulomatous biopsy could aid in the differential diagnosis of tuberculosis against other lymph node diseases such as sarcoidosis or lymphoma [19]. The combination of TB cultures and a nucleic acid amplification (NAA) test, such as the Xpert MTB/RIF assay, can improve the specificity for diagnosing mediastinal tuberculous lymphadenopathy and its drug-resistant variant [20].

Bronchogenic spread could be a problem. In such circumstances, chest CT reveals many micronodules with a centrilobular distribution and sharply margined linear branching opacities in the small airways ("tree-in-bud" sign). Centrilobular nodules are histopathologically associated with granulomatous inflammation and caseous necrosis within and surrounding terminal and respiratory bronchioles, whereas peripheral linear branching opacities correspond to tuberculous bronchitis of the small airways (21). These findings are symptomatic of active TB. The "tree-in-bud" pattern typically affects the lower lung lobes because centrilobular nodules are peripheral but do not affect the subpleural lung. Clearly, TUS cannot be used to diagnose small airway disease since it may only show abnormal interface indications, such as pinching and irregularities of the pleural line, as well as non-specific artifacts such as comet tails and ring down (B-lines) [22,23]. A CT is more successful than a chest X-ray (CXR) for detecting LNs, which are distinguished by a low density center and peripheral augmentation after contrast injection, resulting in the "rim sign" [23]. Bilateral hilar lymphadenopathy is a key differential diagnosis

for several benign and malignant illnesses, including sarcoidosis and lymphoma [23].

The World Health Organization advises detecting acid-fast bacilli (AFB) in respiratory specimens as the first step in PTB diagnosis. As a result, laboratories are critical components of all health-care delivery systems. Reliable and quick laboratory examination results are critical in the decision-making process for PTB diagnosis. However, laboratory services are frequently fragmented and given poor priority due to limited resource allocation [24].

Central Java Province utilized the Directly Observed Treatment Short Course method over ten years ago. Training and refreshment programs for TB health practitioners, such as doctors, nurses, and laboratory technicians, were widely used. The implementation included all health facilities, lung clinics, and hospitals in Central Java. Almost all TB health providers received training between 2002 and 2006 [25]. However, a prior study discovered that the performance of TB health providers in many regions was inadequate. Some patients said that health providers appeared hesitant to teach TB patients on how to deliver high-quality sputum.

Many studies have been undertaken to assess the performance of tuberculosis health officers in central Java. Dissatisfaction with their job, particularly their perceived role and workload, has a substantial correlation with their performance. Given that almost all laboratory workers have received adequate training, we hypothesize that the absence of acceptable laboratory performance was due to personal and person-organization relationships. Perceived organizational support (POS) theory suggests that to meet socioemotional needs and determine the organization's readiness to reward increased work effort, employees should develop global beliefs concerning the extent to which the organization values their contributions and cares about their well-being [26.27]. As a result, employees showed a consistent pattern of agreement with various statements concerning the extent to which the organization appreciated.

Modern approaches, such as fluorescence microscopy (FM), the use of liquid cultures for isolation and DST, and amplification for drug resistance detection and/or investigation, are costly, labor-intensive, and sluggish. As a result, there has been a surge of interest in creating new diagnoses and implementing sophisticated diagnostic methods in poor nations. The Foundation for Innovative New Diagnostics (FIND) is now taking a systematic approach to research and development of new diagnostics. However, focusing simply on financing, procedures, and novel diagnostics frequently overlooks the need of well-trained personnel, quality management systems, and other elements that support the standards of practice in industrialized countries [28]. Clinicians will continue to forego existing laboratory testing services in favor of empirical diagnosis and treatment in cases where there is a lack of trust and reliability in the quality of laboratory results [29]. Such failures to meet appropriate quality standards underscore the critical need to work on enhancing the laboratory system alongside efforts to introduce innovative techniques and processes. The issues of MDR-TB, as well as recent occurrences of extensively drug-resistant tuberculosis (XDR-TB), give compelling reasons to increase capacity for culture and DST. As a result, the complexity of offering such services is sparking debate and study on how to establish laboratory capacity that much outweighs the

training, human resources, and networks required for microscopy centres. In countries where TB laboratory services are integrated with general laboratory services or where there is a large private sector, it is also unclear whether national tuberculosis programmes can successfully improve the quality of and access to laboratory services in the absence of coordinated efforts by all health programs to support a general initiative of laboratory capacity-building. Previous efforts to establish a separate and parallel system of TB microscopy procedures, records, and monitoring may have been insufficient to satisfy the demands of improving TB laboratory services in the context of changing health systems. There is growing acknowledgment that the quality of TB laboratory networks can either be a catalyst or a barrier to further progress in TB control [30].

3. Conclusion:

Tuberculosis is a major cause of nonspecific clinical and radiological symptoms, and it can present as any benign or malignant medical condition. Pulmonary tuberculosis can mimic any acute or chronic lung infection, including pulmonary cancer and metastases. Tuberculosis can present as benign or malignant acute or chronic brain and spinal lesions. Tuberculosis can produce equivocal abdominal clinical and radiological symptoms, resulting in catastrophic circumstances and diagnostic problems. Clinical symptoms and conventional laboratory testing have limitations in guiding clinicians to diagnose tuberculosis (TB). It can mimic any acute or chronic renal and genitourinary condition. Tuberculosis is a significant differential diagnosis for the majority of acute and chronic joint and bone diseases. Medical imaging examinations are critical for detecting tissue abnormalities and making an early diagnosis of tuberculosis in various body areas. Radiologists and clinicians should be conversant with and aware of the radiological symptoms of tuberculosis in order to contribute to early TB detection and diagnosis.

Laboratories are more than simply technologies, equipment, and buildings; they are also the people and systems that oversee the processes and standards required to provide accurate and timely outcomes. Successful deployment of novel diagnostic tests will still necessitate functional laboratory networks with qualified and motivated personnel, quality management systems, and safe working conditions. Rather than believing that technology advancements are the sole option to improve tuberculosis detection, international organizations and countries should work together to strengthen laboratory leadership and systems through global direction. The remedies, in the form of technical assistance, effective quality assurance, systems, and capacity building, are all within reach, but they will necessitate a new focus on the laboratory as a whole.

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