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Decision Support System and Health Analytics for Pediatric Tuberculosis Clinical Diagnosis

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Abstract. Tuberculosis (TB) is an airborne disease that can be spread from person to person. Children that are below 15 years old (also known as Pediatric Tuberculosis) have high probability to develop life threatening disease and the most substantial number of TB cases are observed in children younger than five years of age and adolescents older than ten years of age. The focus of this research is how the technology innovation was designed and developed to help doctors, nurses, and other healthcare professionals make better data driven decisions, optimize its current TB clinical diagnostic practices, and improve its process on determining the eligibility for TB Preventive Treatment (TPT).

Keywords: Clinical Decision Support System, Health Analytics, Pediatric Tuberculosis

1. Introduction

The United Nations Sustainable Development Goals (UN SDGs) and the World Health Organization (WHO) End TB Strategy have included targets to reduce TB incidence by 80% and reduce TB deaths by 90% by 2030, relative to baseline levels in 2015 [1]. The latter has developed two treatment decision algorithms in the operational handbook accompanying the 2022 consolidated guidelines on managing pediatric TB based on a large and geographically diverse cohort of commissioned children evaluated for childhood TB [2]. The U.S. Agency for International Development's (USAID) TB Platforms for Sustainable Detection, Care, and Treatment (TB Platforms), on the other hand, aims to strengthen essential supportive and cross-cutting TB interventions at the provincial, municipal, and community levels in the country to increase TB and drug-resistant and TB case detection and treatment success rates [3]. Together with Stop TB Partnership, the two have recently teamed up with the iconic character Hello Kitty on the urgent need to address and end pediatric TB in the country [4]. Recently, the DOH National TB Control Program (DOH-NTP) issued revised guidelines for implementing Tuberculosis Control Program in Children in February 2022 while the COVID-19 response is still in effect [5].

Pediatric TB, a tuberculosis disease in children under 15 years of age, is a public health problem because it is a marker of the recent transmission of TB [6]. Even with increased emphasis on national health programs, pediatric TB remains a significant problem worldwide [7] since infants and young children are more likely than older children and adults to develop life-threatening TB disease (e.g., disseminated TB, TB meningitis). Among children, the most substantial number of TB cases are observed in children younger than five years of age and adolescents older than ten years of age. As suggested by Snow et al., one of the keys to improving TB control is understanding the disease's epidemiology and implementing evidence-based interventions for at-risk groups [8].

A prospective, community-based surveillance study in rural public clinics was conducted in the Philippines to describe how TB in children is identified and managed in a routine TB program [9]. Barriers

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in the diagnosis, low IPT completion, and problems in contact tracing were among the issues identified hindering the successful implementation of TB programs for children in the country. The WHO guidance that standardizes clinical approaches to support rapid and uniform treatment decision-making for presumptive TB cases has developed two treatment decision algorithms included in the operational handbook accompanying the consolidated guidelines on the management of TB in children and adolescents [10]: one for use in settings with Chest Radiograph (CXR) and one for use in settings without CXR. The practical guidance on their services and development is included in the operational handbook [10], while the algorithm for use in settings with CXR is shown in Fig. 1.

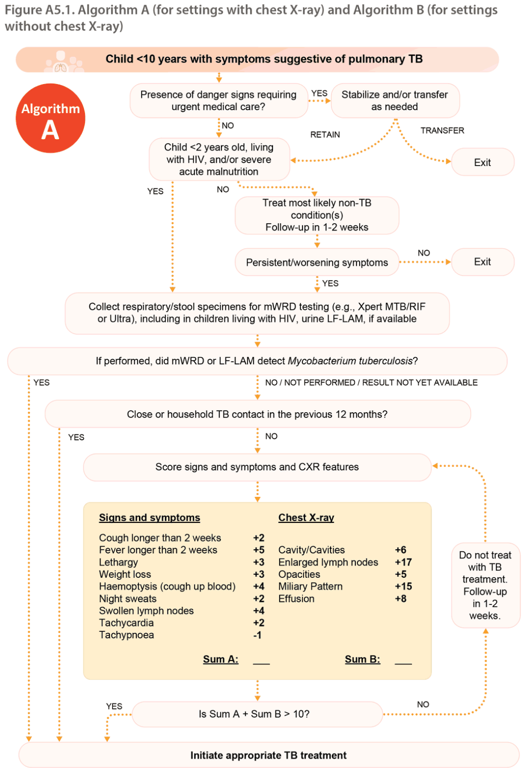

Fig. 1: TB Treatment Decision Algorithm in Children Less Than 10 Years of Age

1.1. Literature Review

Tuberculosis (TB) is referred to as a potentially threatening infectious disease that mostly affects the lungs [11]. People can contract TB from one another by coughing, sneezing, or speaking, which releases microscopic droplets of germs into the air. According to the World Health Organization, this disease, caused by a bacteria that attacks the lungs, is treatable and preventable [12]. This disease is a significant public health problem in the Philippines, as about 1 million Filipinos are affected by active TB [13]. The Department of Health (DOH) is the main government agency tasked with preventing and controlling TB in the country. The DOH carries out the National Tuberculosis Control Program (est. 1978), which aims to reduce the incidence of TB and the number of deaths caused by the disease. DOH Undersecretary Vergeire also emphasized the necessity of strengthening the country's dedication to eliminating TB [12].

Tuberculosis treatment decision algorithms are clinical tools that provide guidance for healthcare professionals in managing patients with tuberculosis. It helps clinicians determine the appropriate treatment course for TB patients based on various factors such as clinical presentation, age, and laboratory results, using evidence-based guidelines and recommendations [6]. Supported by the World Health Organization, treatment decision algorithms use a flowchart or decision tree that outlines the steps to follow in assessing and managing TB patients, which includes diagnostic workup and treatment recommendations [14]. The first algorithm for adult TB treatment was published in 2007 [13].

Meanwhile, the first TB treatment algorithm for children was published in 2014 and revised recently in 2022 [14]. These decision algorithms aim to assist healthcare professionals in making informed decisions regarding the diagnosis and management of TB in both adults and children based on the best available evidence and guidelines. Based on the research of Gunasekera et al., treatment decision algorithms were shown to be effective in improving the detection and treatment of TB in primary healthcare centers in high-incidence settings [6]. The algorithms were able to assess the risk of TB, provide guidance to healthcare workers, and enable them to make the appropriate treatment decisions.

Tuberculosis treatment decision algorithms have evolved throughout time as medical technology and the understanding of TB diagnosis and therapy have advanced. In recent years, there has been more research on Pediatric TB using this technology. In the research of Gunasekera et al., they used various algorithms and scoring systems to diagnose TB in children, following the updated guidance on TB management [6]. Evaluation of individual patient data from 12 countries, involving 4,718 children, was done to test the accuracy of existing treatment decision algorithms for detecting pulmonary tuberculosis in children. Based on their findings, they were able to detect TB in children with 38.4% diagnosed with pulmonary TB. However, it was not as accurate as their new prediction model, which follows the accepted practice for diagnosing pediatric TB. Their algorithm demonstrated a sensitivity of 86% and specificity of 37% compared to the various algorithms with 70% of unconfirmed bacteria. The WHO advises using treatment decision algorithms to diagnose TB in children because it can evaluate the risk of TB and equip medical professionals to choose the best course of action. Research shows that the application of algorithms improved the identification of pediatric TB and the start of treatment in primary healthcare settings with a high incidence of tuberculosis.

In specific research by Gunasekera et al., they developed a treatment decision algorithm that comprises clinical data, chest radiographic (CR) findings, Xpert Mycobacterium tuberculosis (MTB), and Xpert rifampin (RIF) laboratory results from baseline respiratory specimens to inform medical practitioners of existing TB and its classification in patients [14].

1.2. Objective of the Study

Following UN SDGs and WHO's End TB Strategy in ensuring sustained TB services aimed by DOH-NTP, the primary goal of this research is to develop a Pediatric TB Clinical Decision Support System (PedTB-CDSS) that can collect, store, and analyze data to aid in rendering clinical diagnosis and determining eligibility for TB Preventive Treatment (TPT).

1.3. Significance of the Study

The Academic Community will have a basis on how Artificial Intelligence can be adopted in Clinical Diagnosis. This research can serve as the leapfrog for semantic AI-enabled user interfaces. This could involve feeding datasets into a machine to create self-learning patterns, thus enabling the proposed system to perform cognitive functions such as thinking, perceiving, learning, problem-solving, and decision-making tasks that historically required human intelligence. Furthermore, the proponents are considering applying blockchain technology in PedTB-CDSS to enhance its security, accountability, and transparency toward trustful TB data. The same proponents also plan to establish more solid system requirements for PedTB-CDSS to increase collaboration with other potential health service users, including health professionals and managers. Finally, in-depth negotiations with governmental and non-governmental entities to institutionalize the use of PedTB-CDSS will be pursued.

PedTB-CDSS will provide Physicians and Health Institutions valuable guidance for decision-making in resource-limited settings, to optimize its current TB clinical diagnostic practices, and to improve process on determining the eligibility for TB Preventive Treatment (TPT).

2. Methodology

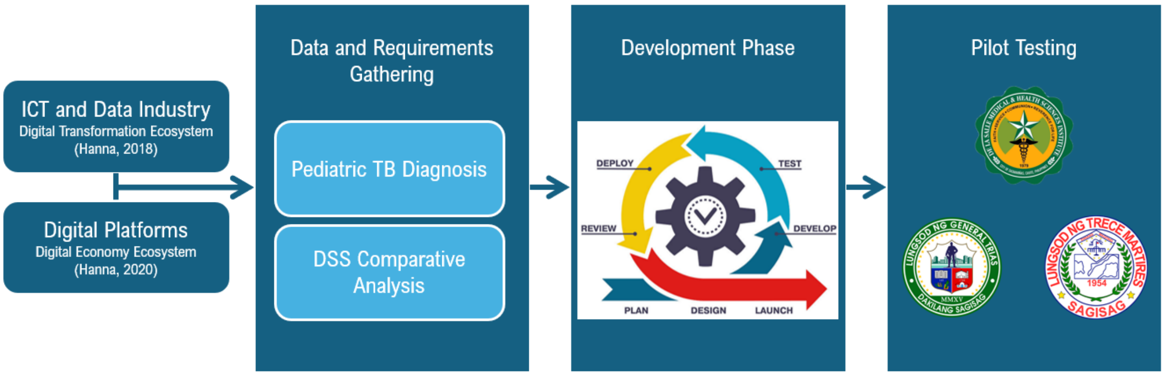

Fig. 2: Conceptual Framework

As shown in Fig. 2, this research is anchored on Digital Transformation and it utilized the Digital Transformation Ecosystem [15], with a focus on the Information and Communication Technology (ICT) and Data Industry components, as well as the Platforms within the Digital Economy Ecosystem [16] as the foundation for solving the UN SDG Good Health and Well-Being. Continuous data gathering and analysis were conducted over 12 weeks to evaluate pediatric TB diagnosis methods, analyze current health system processes, and address diagnostic challenges to enhance the CDSS. During the development phase, an agile methodology is utilized, splitting development into sprints to allow flexibility in prioritizing milestones and enabling concurrent development and testing once the CDSS is deployed. Finally, an on-site pilot test of the CDSS was conducted at DLSMHSI and two health facilities in General Trias, and Trece Martires, utilizing a local machine to enable health workers to access the web application via a desktop computer.

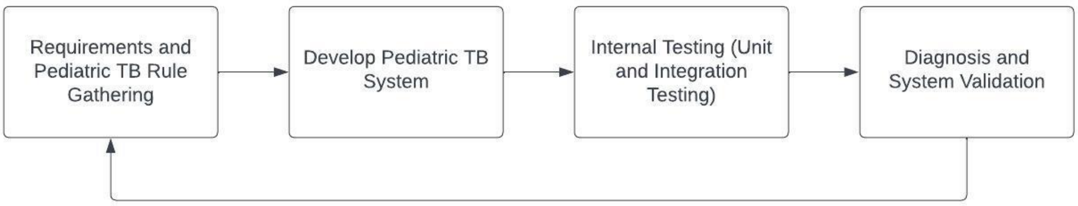

Fig. 3: System Development Methodology

As shown in Fig. 3, the research follows an agile methodology with iterative refinement. It begins with gathering requirements for system features, UI/UX, and diagnostic rules based on data from DOH-MOP and DLSMHSI TB diagnostic protocols. Developers then build the application modules and conduct internal unit and integration testing to ensure functionality. Health professionals from the pilot test health facilities validated the application, including diagnosis accuracy. Their feedback initiates a new cycle of requirement-gathering.

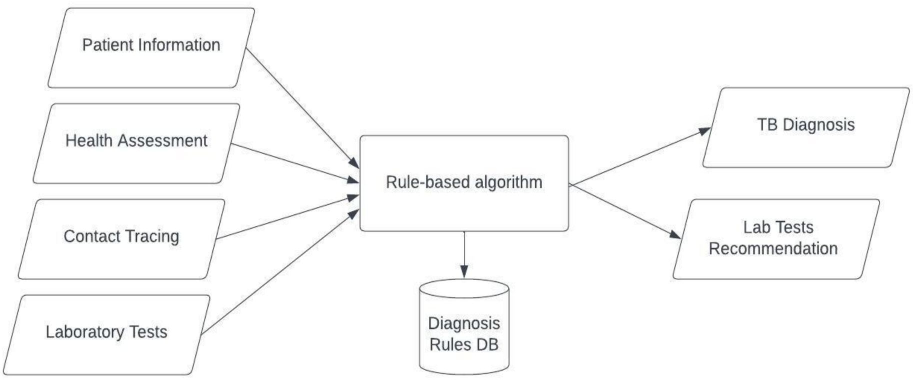

Fig. 4: Rule-based TB Diagnosis Algorithm

To generate a TB diagnosis, the system uses a rule-based algorithm grounded on DOH-MOP and DLSMHSI TB diagnostic protocols, as depicted in Fig. 4. The algorithm takes input from multiple data points from the patients such as patient information, health assessments, contact tracing, and laboratory tests. After taking inputs, the algorithm goes through the diagnosis rules table in the MySQL database and retrieves the most relevant results. These results are then finally interpreted as the TB diagnosis as well as the recommended laboratory tests to administer.

3. Discussion of Results

3.1. Diagnosis Accuracy Results

The cases are from the health facilities of DLSMHSI, General Trias, and Trece Martires. The case diagnosis accuracy assessment showed that 5 out of 8 cases met expectations, while 3 out of 8 partially met expectations due to the system not accounting for Gene Xpert testing from different body parts, as per DOH guidelines. Despite these limitations, the system accurately identified the test results but could not specify the tested body part. The positive outcomes highlight the diagnostic system's effectiveness, with potential for further refinement to address a wider range of scenarios.

Table 1: System Version 1.0 Diagnosis Accuracy Results

Patient Description			Expected Diagnosis	Actual Diagnosis	Results
Age/Gender	Wt (kg)	Ht (cm)			
11/M	23	120	Bacteriologically Confirmed - EPTB	Bacteriologically Confirmed - EPTB	Passed
13/F	27	140	Bacteriologically Confirmed - EPTB	Bacteriologically Confirmed - PTB	Partially Passed. Wrong classification of PTB/EPTB
5/F	17	110	Clinically Diagnosed	Clinically Diagnosed	Passed
5/M	19	112	Clinically Diagnosed	No TB	Partially Passed. The system determined a likelihood based on the details of the case.
7/F	22	126	Clinically Diagnosed	Presumptive PTB	Partially Passed. The system determined a likelihood based on the details of the case.
9/M	40	138	Bacteriologically Confirmed - Drug Sensitive PTB	Bacteriologically Confirmed - Drug Sensitive PTB	Passed
12/M	28	145	Bacteriologically Confirmed	Bacteriologically Confirmed	Passed
5/F	22	112	No TB	No TB	Passed

3.2. Treatment Recommendation Accuracy Results

The TPT and TB Treatment Recommendations achieved a high accuracy rate, with 7 out of 8 cases successfully diagnosed and 1 case failing. This result highlights the system's effectiveness in most instances but also indicates room for improvement. It is important to emphasize that while this showcases a perfect outcome in the cases evaluated, the percentage is specific to the limited number of identified cases and should not be extrapolated as the overall accuracy of the entire system.

Table 2: System Version 1.0 Treatment Recommendation Accuracy Results

Patient Description			Expected Recommendation	Actual Recommendation	Results
Age/Gender	Wt (kg)	Ht (cm)			
11/M	23	120	Recommended for TB Treatment	Recommended for TB Treatment	Passed
13/F	27	140	Recommended for TB Treatment	Recommended for TB Treatment	Passed
5/F	17	110	Recommended for TB Treatment	Recommended for TB Treatment	Passed
5/M	19	112	Recommended for TPT	No TPT / TB Treatment	Failed

				Recommendations	
7/F	22	126	Recommended for TPT	Recommended for TPT	Passed
9/M	40	138	Recommended for TB Treatment	Recommended for TB Treatment	Passed
12/M	28	145	Recommended for TB Treatment	Recommended for TB Treatment	Passed
5/F	22	112	No TPT / TB Treatment Recommendations	No TPT / TB Treatment Recommendations	Passed

4. Conclusion

Overall, the development and evaluation of the Pediatric Tuberculosis Clinical Decision Support System (PedTB-CDSS) have shown promising results in aiding healthcare professionals in diagnosing pediatric TB and determining eligibility for TB Preventive Treatment. Through iterative refinement, the system demonstrated improved accuracy in diagnosis and treatment recommendations across its different versions. The successful alignment of cases with expected outcomes underscores the potential of PedTB-CDSS to improve clinical decision-making in remote and resource-limited settings, contributing to the goal of reducing TB incidence and mortality, as outlined in the UN SDGs and WHO End TB Strategy.

5. Recommendation and Future Works

Moving forward, the PedTB-CDSS should undergo a comprehensive validation phase to ensure its reliability across different demographics and clinical contexts. It is imperative to conduct a phase for validation to further assess the performance and robustness of the system. This should involve a larger and more diverse data collection and various demographics to ensure the system's generalizability and reliability across different contexts. To further enhance the system's capabilities, future work could explore the integration of advanced technologies such as Artificial Intelligence (AI), Machine Learning (ML), and Natural Language processing (NLP). These technologies can facilitate more sophisticated data analysis, pattern recognition, and decision-making processes, which could improve the accuracy and efficiency of clinical diagnosis and treatment recommendations. Lastly, as healthcare practices evolve and new evidence-based guidelines emerge, PedTB-CDSS should be regularly updated and expanded to incorporate the latest diagnostic criteria and best practices. Additionally, the system could be expanded to include modules for treatment monitoring to support comprehensive tuberculosis management and able to state the reason for the decision.

6. Acknowledgement

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