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A Pediatric TB Diagnosis Recommendation System for the Barangay Health Centers

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Abstract: Tuberculosis (TB) remains a formidable health challenge, especially for children under 15 years. Pediatric Tuberculosis, characterized by a higher risk of life-threatening disease, demands precision in diagnosis and treatment decisions. At the Barangay level, especially in remote rural communities where TB Experts are not prevalent, diagnosis needs to be supported with a technological solution to make a diagnosis recommendation based on the Department of Health Manual of Procedures (DOH-MOP) and Experts' diagnosis experiences in every Barangay Health Center. At the time of the project's conceptualization, no software solutions for pediatric TB in the Philippines exist to help physicians render clinical diagnoses and determine eligibility for TB preventive treatment. This project focused on empowering barangay healthcare professionals to make informed, data-driven diagnoses in response to these situations. The solution comprises several module components; this paper focuses on the Diagnosis Recommendation and Diagnosis Likelihood sub-modules, essential to support the early diagnosis of TB amongst children below 15 years. The resulting disparities in actual diagnosis and the diagnosis recommendation have revealed during validation interviews with barangay health workers that some attending medical doctor may have their own diagnosis style. This has led to several recommendations for improving the diagnosis recommendation system to allow it to collect essential data for both DLHSI-CTR and the DOH in their efforts to improve the diagnosis protocols.

Key Words: Pediatric Tuberculosis, Diagnosis Recommendation, Health Informatics

1. INTRODUCTION

Tuberculosis (TB) is an airborne disease that can be spread from person to person. TB disease for children under 15 years of age (also called Pediatric TB) is more likely to develop life-threatening disease (The END TB Strategy, 2014). 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 (World Health Organization, 2022).

Contributing to controlling and maintaining the disease, the project involved developing a solution to help doctors, nurses, and other healthcare professionals at the barangay health make a TB diagnosis and determine the eligibility for TB preventive treatment (TPT). The solution includes a diagnosis recommendation and likelihood module that uses rules based on the Department of Health Manual of Procedures (DOH-MOP) and the Experts' diagnosis experiences.

2. PROBLEM BEING ADDRESSED

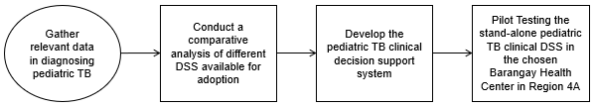
Pediatric TB, a tuberculosis disease in children under 15 years of age, is a public health problem because it is a marker of the recent transmission of TB (United Nations, 2019). Even with increased emphasis on national health programs, pediatric TB remains a significant problem worldwide since, according to Aldaba et al. (2018), 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 (Snow et al., 2018). 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 (Aldaba et al.., 2018). Barriers 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: one for use in settings with CXR and one for use in settings without CXR. The practical guidance on their services and development is included in the operational handbook (World Health Organization, 2022).

Pediatric TB and its spread within the community can be controlled by early detection, resulting in immediate treatment. The Barangay level situation, especially in remote rural communities where TB Experts are not prevalent, needed a technological solution to make a diagnosis recommendation based on the Department of Health Manual of Procedures (DOH-MOP) and Experts' diagnosis experiences in every Barangay Health Center. At the time of the project's conceptualization, no software solutions for pediatric TB in the Philippines exist that can help physicians render clinical diagnoses and determine eligibility for TB preventive treatment.

3. METHODOLOGY OF THE PROJECT

The United States Agency for International Development (USAID) funded the project through the University Research Co (URC) organization. In order to develop the solution, several major activities were identified and approved by the URC, as shown in Figure 1. This paper focuses on the results of performing Activities 3 and 4 of the methodology.

Figure 1. Methodology



Activity 1: Evaluate the DOH-MOP and De La Salle Health Science Institute-Center for Tuberculosis Research (DLSHSI-CTR)'s current TB clinical diagnostic protocol and its criteria for systematic eligibility assessment and TB preventive treatment (TPT) provision. This activity will enable the design of the diagnosis recommendation

Activity 2: Perform a comparative assessment of DSSs available for adoption.

Activity 3: Develop a stand-alone pediatric TB decision support system based on the targeted DSS. In this activity, an agile applications development methodology will be used. In this activity, modules and features to be developed were identified and organized into an architecture, internal testing conducted (unit and integration), and the technical requirements to deploy the solution as a stand-alone system (not connected to the internet or online or cloud).

Activity 4: Pilot-test the developed stand-alone pediatric TB decision support system

4. ARCHITECTURE OF THE SOLUTION

The solution is made up of an interrelated set of components organized in an architecture (figure 2) made up of three (3) main modules (highlighted in Red and Orange in Figure 2), two (2) support modules (highlighted in purple in Figure 2), and (2) reference data management modules (highlighted in green in Figure 2). The modules provide

a. medical record management capabilities,
b. diagnosis recommendations,
c. health institution recommendations for needed diagnostic tests
d. treatment eligibility, and
e. contract tracing management, where users can efficiently upgrade close contact to a TB patient whenever initial symptoms are suggestive of TB, an essential component to the early detection of TB cases.

This paper focuses on the Diagnosis module of the solution composed of the Diagnosis Recommendation and the Diagnosis Likelihood sub-modules. The diagnostic test recommendation sub-module aims to guide users on what diagnostic tests patients must undertake to improve the diagnosis recommendation. This sub-module is not the focus of this paper.

The diagnosis module uses a rules repository based on the DOH-MOP Diagnosis Protocol. The diagnostic test recommendation sub-module also uses the same DOH-MOP. The medical expert from the DLSHSI-CTR validated the translation of the DOH-MOP to the rules repository. The translation resulted in 11,376 rules in the repository handling the different combinations of medical factors used in diagnosing pediatric TB. Rules fire depending on the medical data provided (see Figure 3). In order to guide diagnosis, the solution also offered a diagnosis likelihood to the user, given the patient's medical data. The solution scans similar historical medical records, and a likelihood computation for every diagnosis made is performed (see Figure 4)

Figure 3. Diagnosis Recommendation Processing Logic

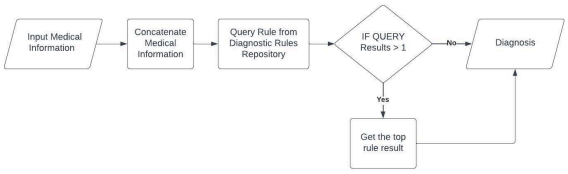
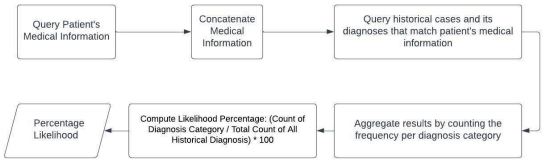
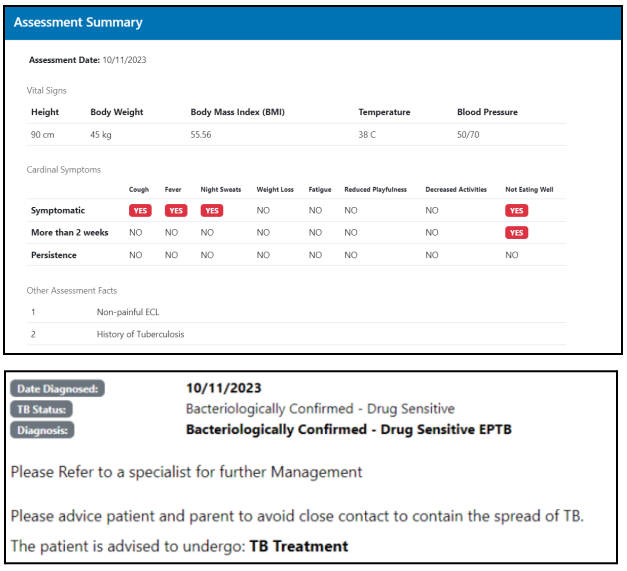


Figure 4. Diagnosis Likelihood Logic
Count of the Diagnosis / Total Count of All Diagnosis



A sample diagnosis recommendation that the solution is provided based on patient medical data is shown in Figure 5.

Figure 5. Sample screenshot of the Diagnosis Recommendation



Assessment Summary

Assessment Date: 10/11/2023

Vital Signs

Height	Body Weight	Body Mass Index (BMI)	Temperature	Blood Pressure
90 cm	45 kg	55.56	38 C	50/70

Cardinal Symptoms

	Cough	Fever	Night Sweats	Weight Loss	Fatigue	Reduced Playfulness	Decreased Activities	Not Eating Well
Symptomatic	YES	YES	YES	NO	NO	NO	NO	YES
More than 2 weeks	NO	NO	NO	NO	NO	NO	NO	YES
Persistence	NO	NO	NO	NO	NO	NO	NO	NO

Other Assessment Facts

1	Non-painful ECL
2	History of Tuberculosis

Date Diagnosed: **10/11/2023**
TB Status: Bacteriologically Confirmed - Drug Sensitive
Diagnosis: **Bacteriologically Confirmed - Drug Sensitive EPTB**

Please Refer to a specialist for further Management

Please advice patient and parent to avoid close contact to contain the spread of TB.

The patient is advised to undergo: **TB Treatment**

5. RESULTS AND DISCUSSION

To assess the reliability of the diagnosis recommendation sub-module, a formal testing session was conducted with the target users, who entered the patient data from historical medical records in either face-to-face or online guided use of the system. The resulting diagnosis recommendation was recorded and compared to the actual diagnosis made by the attending physician in the medical records. Users from the DLSHI-CTR, Barangay Health Center of Naic, and Trece Martires were among those identified in the project as test sites for the project.

The users entered eight (8) medical records to test the diagnosis recommendation, and the testing results are shown in Table 1. Before these eight (8) medical records, several medical cases were used during every sprint cycle with the Expert Medical Doctor from the DLSHSI-CTR as part of the system's internal testing (unit and integration testing).

For both formal and internal testing, whenever there are disparities between the actual diagnosis and the recommended diagnosis, the following are conducted:

a. The rules that fired on the medical case were investigated
b. The rules were adjusted based on the user's explanation of the diagnosis
c. The rules were counter-checked with the DOH-MOP to ensure that the protocol they should follow is preserved. Whenever the recorded diagnosis violates the protocol, the rule based on the protocol should persist.

Further testing was initially planned in order to assess (in an actual diagnosis scenario) the reliability of the diagnosis recommendation further but was impeded due to the needed City/Municipal Sangunian resolution for clearance to use and test the system in actual TB Case Diagnosis in Barangay Health Centers.

From the results, both the users and the funding agency accepted the reliability of the diagnosis recommendation. With the possible disparity in actual diagnosis, where the attending medical doctor may not follow the recommendation, the system was recommended to provide a mechanism to record the doctor's disagreement with the diagnosis recommendation. This will provide essential data for both DLHSI-CTR and the DOH in their efforts to improve the diagnosis protocols.

The rules repository is a mechanism intentionally decided by the team due to the limited development time needed to produce the solution and translate DOH-MOP to rules. The proponents acknowledged that this is not the most efficient way to translate the DOH-MOP for diagnosis recommendations. The lack of access to medical records at the start of the development of the solution makes the project unable to maximize machine learning techniques to develop a decision tree from the medical cases leading to diagnosis recommendations.

Since the diagnosis recommendation sub-module is limited to using the first-rule-to-fire method whenever multiple rules actually fire on a medical case, integrating this with the diagnosis likelihood will enhance the selection of the appropriate rule to use when multiple rules are fired on a medical case.

6. CONCLUSIONS

Pediatric TB and its spread within the community can be controlled by early detection, resulting in immediate treatment. The situation at the Barangay level, most especially in remote rural communities where TB Experts are not prevalent, needed a technological solution to make a diagnosis recommendation based on the DOH-MOP. The project was conceptualized in order to provide the initial attempt to digitize the DOH-MOP and the diagnosis experience of experts into a system that can provide diagnosis recommendations. Within three (3) months, the team assembled this solution and successfully tested its reliability, given the project's limitations.

7. ACKNOWLEDGMENTS

This project was funded by the United States Agency for International Aid through the TB Platforms project under the University Research Co (URC). The proponents would like to acknowledge the support of Dr. Karen Dalawangbayan of URC, Dr. Maria Golla of the DLSHSI-CTR, and the different Barangay Health Workers from General Trias and Trece Martires, who provided valuable inputs critical to the development of the system and the improvements that were undertaken in order to reach the project's targets and goals.

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Figure 2. Overall Architecture of the Solution

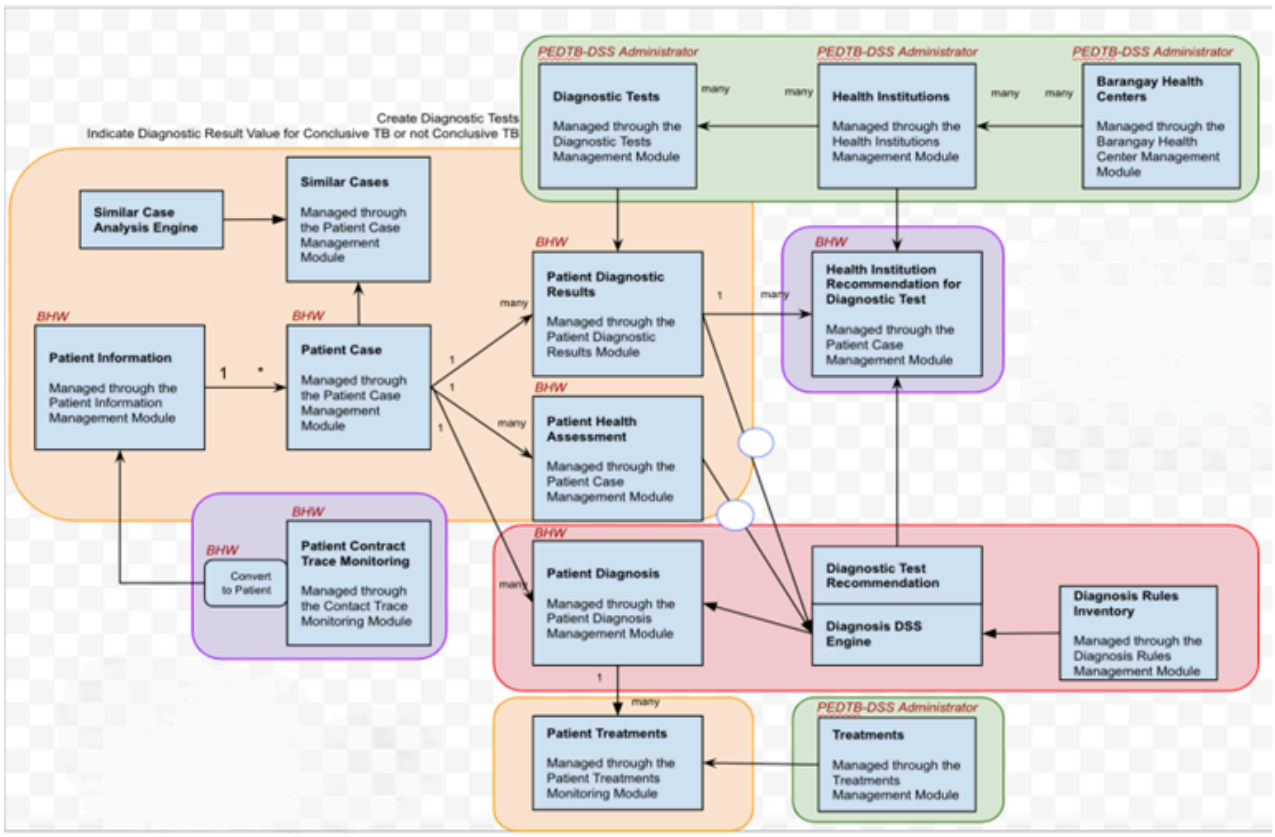

Table 1. Test Cases and Results

Patient Description	Other Health Information	Expected Diagnosis based on Client Medical Record	Actual Diagnosis Recommendation	Initial Result	Result after System Modification
11/M Wt: 23 KG Ht: 120 CM **CASE #1**	[1] Has 2 weeks of persistent coughing [2] MTB detected RIF collection indeterminate [3] Has Non Painful ECL	Bacteriologically Confirmed - EPTB	Bacteriologically Confirmed - EPTB	Passed	Passed
13/F Wt: 27 KG Ht: 140 CM **CASE #2**	[1] Experienced 3 weeks of persistent coughing and fever [2] MTB detected RIF collection indeterminate [3] Experienced drowsiness [4] Has Non Painful ECL	Bacteriologically Confirmed - EPTB	Bacteriologically Confirmed - PTB	Partially Passed. Wrong classification of PTB/EPTB	Bacteriolofically Confirmed - EPTB (Passed)

Patient Description	Other Health Information	Expected Diagnosis based on Client Medical Record	Actual Diagnosis Recommendation	Initial Result	Result after System Modification
5/F Wt: 17 KG Ht: 110 CM **CASE #3**	[1] Experienced 1 month of persistent coughing [2] MTB was not detected and RIF not detected [3] XRAY is suggestive of TB	Clinically Diagnosed	Clinically Diagnosed	Passed	Passed
5/M Wt: 19 KG Ht: 112 CM **CASE #4**	[1] Experienced 2 weeks of persistent fever and night sweats [2] MTB was not detected and RIF not detected [3] XRAY NOT suggestive of TB [4] Father has been diagnosed with DRTB	Clinically Diagnosed	No TB	**Partially Passed.** The system determined a likelihood based on the details of the case.	Clinically Diagnosed (Passed)
7/F Wt: 22 KG Ht: 126 CM **CASE #5**	[1] More than 3 weeks of persistent coughs [2] MTB was not detected and RIF not detected [3] XRAY NOT suggestive of TB [4] No contact with TB [5] TST resulted in > 10mm	Clinically Diagnosed	Presumptive PTB	**Partially Passed.** The system determined a likelihood based on the details of the case.	Clinically Diagnosed (Passed)
9/M Wt: 40 KG Ht: 138 CM **CASE #6**	[1] Experienced a month and half of night sweats and coughing [2] MTB was detected and RIF was NOT detected	Bacteriologically Confirmed - Drug Sensitive PTB	Bacteriologically Confirmed - Drug Sensitive PTB	Passed	Passed
12/M Wt: 28 KG Ht: 145 CM **CASE #7**	[1] Experienced 2 weeks of persistent coughing, night sweats, and fever [2] MTB detected RIF collection indeterminate	Bacteriologically Confirmed	Bacteriologically Confirmed	Passed	Passed
5/F Wt: 22 KG Ht: 112 CM **CASE #8**	[1] Persistent Coughing for 2 weeks [2] XRAY not suggestive of TB [3] MTB was not detected and RIF not detected	No TB	No TB	Passed	Passed