

Detection of Streptococcus Pyogenes to Combat Rheumatic Heart Disease

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Abstract — Rheumatic Heart Disease (RHD) is a nonsuppurative complication of group A Streptococcal pharyngitis, Streptococcus pyogenes in particular. RHD is a significant cause for cardiovascular disorder in the world today. Despite a documented decrease in the prevalence of the disease, it continues to pose medical and public health problems in both industrialized and industrializing countries.

For at least five decades Rheumatic Heart Disease has been a concern of the World Health Organization and its member countries. Sentinel studies conducted under the auspices of the WHO clearly documented that the control of the preceding infections and their sequel is both cost effective and inexpensive. The project aims to provide a three way approach to the diagnosis of Rheumatic heart disease: identification of Streptococcus pyogenes, Allele analysis and Jones's criteria. The initial identification is corroborated by a positive throat culture through a swab test. Allele analysis based on three ethnicities: Black, White and Indian, is directed toward determination of odds ratio. Jones's criterion is divided into a set of major and minor criteria. The major criteria and the minor criteria together with a preceding instance of infection caused by Streptococcus pyogenes indicate the stage of the disease. However, till RHD remains to be conquered, optimal methods of prevention and management are required.

Index Terms—Jones criteria, Rheumatic Fever, Rheumatic Heart Disease, Streptococcus Pyogenes

I. INTRODUCTION

1.1 Rheumatic Heart Disease

Rheumatic heart disease (RHD) is the most common acquired heart disease in children in many countries of the world, especially in developing countries. The global burden of disease caused by rheumatic fever currently falls disproportionately on children living in the developing world, especially where poverty is widespread. RHD is a chronic heart condition caused by rheumatic fever that can be prevented and controlled. Rheumatic fever is caused by a preceding group A streptococcal (strep) infection. Treating strep throat with antibiotics can prevent rheumatic fever. Moreover, regular antibiotics (usually monthly injections) can prevent patients with rheumatic fever from contracting further strep infections and causing progression of valve damage.

1.2 Streptococcus Pyogenes

Streptococcus pyogenes (Group A streptococcus) is a Gram-positive, non-motile, non-spore forming coccus that occurs in chains or in pairs of cells. Individual cells are round-to-ovoid cocci, 0.6-1.0 micrometer in diameter. Streptococci divide in one plane and thus occur in pairs or in chains of varying lengths. The metabolism of S. pyogenes is fermentative; the organism is a catalase-negative aero

tolerant anaerobe and requires enriched medium containing blood in order to grow.

Streptococcus pyogenes is one of the most frequent pathogens of humans. It is estimated that between 5-15% of normal individuals harbor the bacterium, usually in the respiratory tract, without signs of disease. S. Pyogenes can infect when defenses are compromised or when the organisms are able to penetrate the constitutive defenses. When the bacteria are introduced or transmitted to vulnerable tissues, a variety of types of suppurative infections can occur.

1.3 Diagnosis of Rheumatic Fever

Jones Criteria for the Diagnosis of Rheumatic Fever

The Jones criteria were introduced in 1944 as a set of clinical guidelines for the diagnosis of rheumatic fever (RF) and carditis. The clinical features of RF were divided into major and minor categories, based on the prevalence and specificity of manifestations. Major manifestations were least likely to lead to an improper diagnosis and included carditis, joint symptoms and chorea. A history of RF or preexisting rheumatic heart disease (RHD) was considered to be a major criterion since RF tends to recur. Minor manifestations were considered to be suggestive, but not sufficient, for a diagnosis of RF.

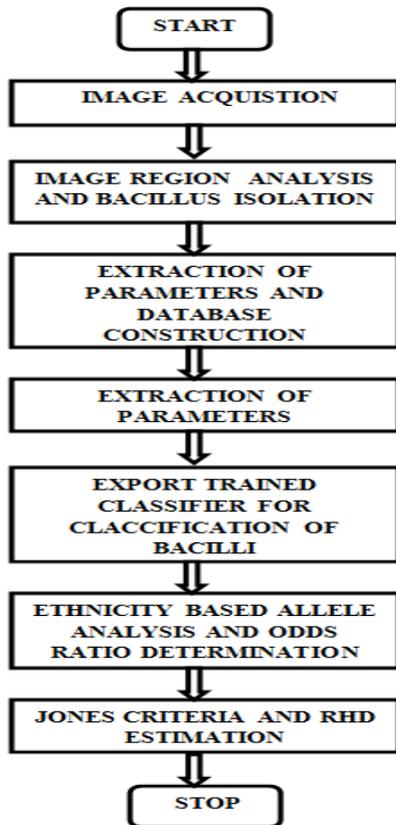


Fig 1. Flow Chart depicting sequence of detection mechanisms

II. IMAGE ACQUISITION AND ISOLATION PROCEDURE

The Streptococcal chain is analyzed and based on the row and column selection, a single bacillus is isolated from the chain. This can be adopted when the bacillus chain does not take the form of complex clusters. Alternative method for analysis of clusters can be done using Image region Analysis.

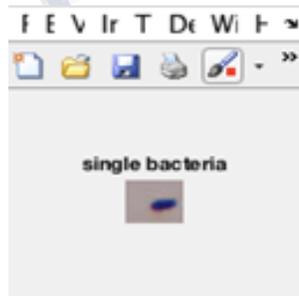


Fig 2. Isolated Bacillus

III. DATABASE CREATION

II. MATLAB Toolboxes Used

❖ *Image Region Analyzer*

The Image Region Analyzer app measures a set of properties for each connected component (also called an object or region) in a binary image and displays this information in a table. You can also use this app to create other binary images by filtering the image on region properties.

❖ *Classification Learner*

The Classification Learner app trains models to classify data. Using this app, you can explore supervised machine learning using various classifiers. You use the data to train a model that generates predictions for the response to new data. To use the model with new data, or to learn about programmatic classification, you can export the model to the workspace or generate MATLAB code to recreate the trained model.

III. ECG Database

To evaluate the possibility of a preceding or recent occurrence of infection by Streptococcus Pyogenes, it is essential to determine the PR-interval. To ensure no cardiac dysfunction, this PR-Interval must lie within 0.12 to 0.20ms.

Input Images Used For Extraction of Parameters

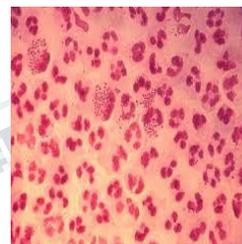


Fig 3. Diplococcus

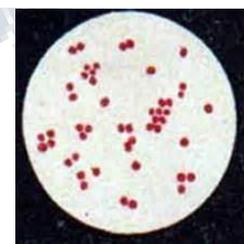


Fig 4. Monococcus

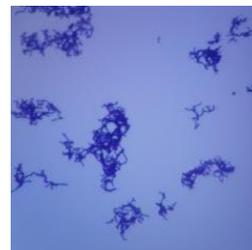


Fig 5. Streptococcal Cluster

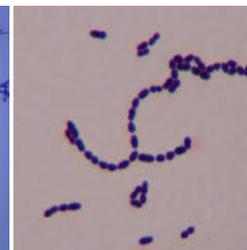


Fig 6. Streptococcal Chain

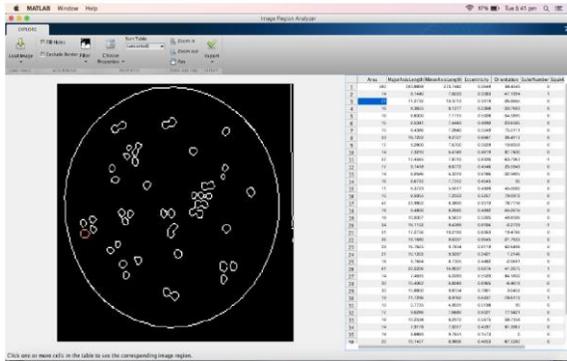


Fig 7. Extraction of Parameters From a Monococcal Image

IV. TRAINED CLASSIFIER

The Training Data is created based on the parameter values extracted from the image region analysis of all the four input images. The created training data is loaded in the Classification learner for training, using the complex tree model. The trained model is then exported for further prediction with the test data.

Table 1. Training Data

Table 2. Test Data

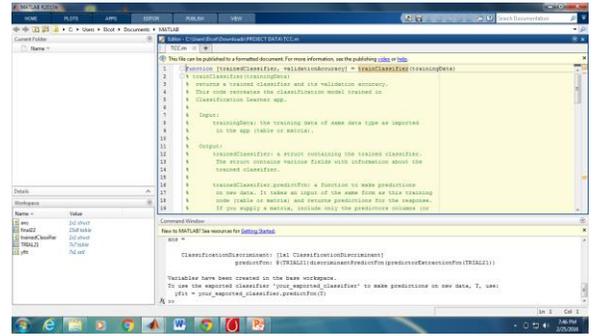


Fig 8. Generated Code for Trained Classifier

V. ALLELE ANALYSIS AND JONES CRITERIA

Allele analysis is the second stage of analysis that is adopted based on the ethnicity and corresponding DR allele. It computes an Odds ratio that is a specific indicator that points towards the presence of Rheumatic Heart Disease. This factor in the range from 2 to 3 affirms the existence of the disease, while a range from 0.3 to 0.5 indicates a negative association.

The final stage of analysis is implemented using Jones criteria that provides a result based on various major and minor criteria. Together, the three separate approaches augment the certainty of identifying an individual affected by the disease.

The Jones criteria is performed along with the analysis of an ECG that helps to estimate the value of PR interval and QRS complex. These serve as identification factors to affirm the presence of a streptococcal infection.

Study Population	Allele	Homogeneity (p value)	Association (p value)	OR [95% CI]
White (n = 3)	DR4*	< 0.003	< 0.03	1.74 [1.10-2.74]
	DR1	> 0.09	< 0.004	2.80 [1.40-5.57]
Black (n = 2)	DR6	> 0.15	< 0.003	2.03 [1.27-3.26]
	DR8	> 0.98	< 0.02	0.32 [0.13-0.79]
Indian (n = 2)	DR2	> 0.95	< 0.00001	0.31 [0.20-0.49]
	DR3	> 0.38	< 0.00003	2.44 [1.62-3.69]
	DR5	> 0.11	< 0.05	0.52 [0.29-0.91]

Table 3. Ethnicity Based Allele Values Used For Analysis

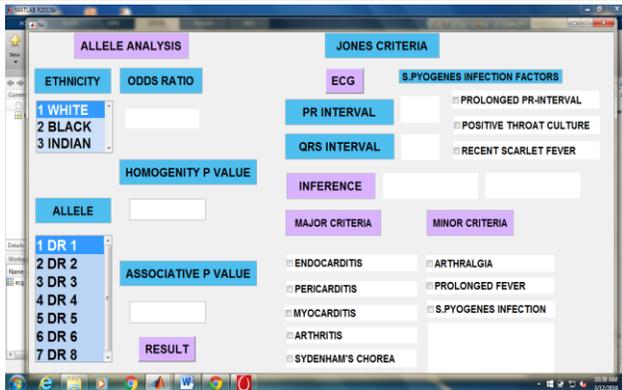


Fig 9. Allele Analysis and Jones Criteria

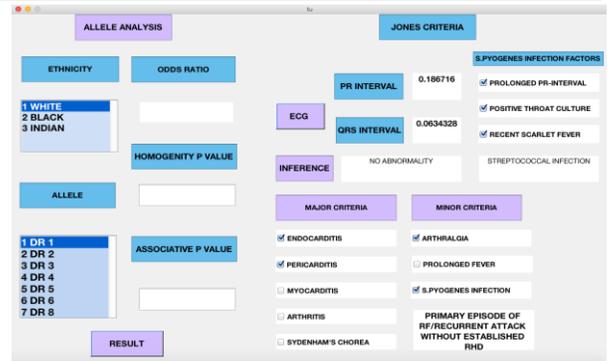


Fig 12. Detection of Rheumatic Heart Disease Based On Selection of Various Criteria

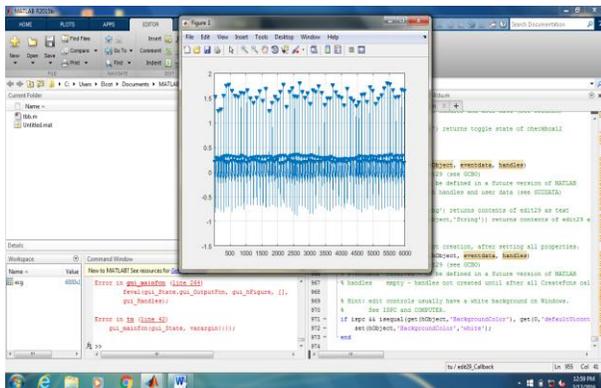


Fig 10. ECG Plot and Detection of Prominent Peaks

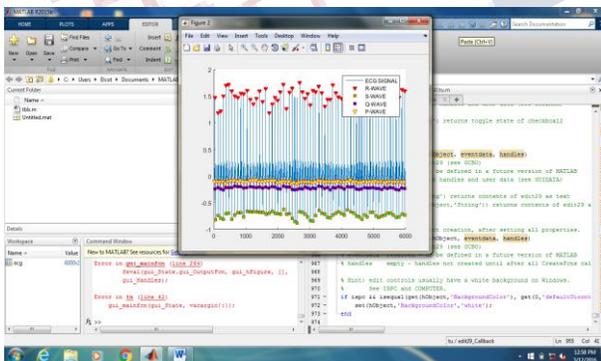


Fig 11. Detection of P, Q, R, S Peaks and Estimation of PR Interval

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