Section A-Research paper
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Correlation and Association Mapping for Assessing the Open Angle and Normal Tension Glaucoma using Visual Field Test Cases

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Abstract

To figure out different areas in visual field test with satisfactory designs for medication is a pertinent issue in the domain of ophthalmology. In the current research, A procedure has been designed for the prediction of Open Angle Glaucoma (OPAG) and Normal Tension Glaucoma (NTG) in it's early stages or the possibility of getting affected with it in the near future. The presence of the disease can be detected using a novel method called Associative Correlated Mapping with different variables of interest ranging 10-2,24-2 and 30-2 visual field patterns. These variables are linear in nature and the test patterns will have different range fields. The levels are compared with a statistical technique using correlation on range values for generating the output. Later, this knowledge can be used for assessing the left and right eye independently for the presence of the disease. The decision making by the physicians can be made by examining the results generated in the analysis.

Keywords: Open Angle Glaucoma, Normal Tension Glaucoma, Visual Field Defects and Correlation Analysis

1. Introduction

Glaucoma is a chronic and progressive disorder and is caused by the damage of the optic nerve. Millions of people are suffering from this problem due to the macular degeneration. This macular degeneration generates vision loss affecting many lives of the people all over the globe and this number is more than the people got affected with cataract and glaucoma taken together[1]. In the current scenario, it is observed that, Macular Degeneration is not curable [2] and it usually happens with the deteriation of central portion of retina. The brain receives the images through optic nerve from the recording of the images in the back layer of the eye. The macula being the central portion of the retina plays a vital role for the vision and to see the objects in detail.

It is observed that, Initially, Glaucoma is a major cause of concern especially in African and American counties considering the old aged people in those regions. Slowly, It has been spreading to other parts of the world[4]. In the current scenario, prevalence of this disease is becoming rapid especially with the middle aged persons. This is due to the over straining of optic nerve of the eye by using long hours of different electronic gadgets [2,5]. In order to get correct medication of the disease, visual field defects should be identified by patients in the initial stages and this becomes a cardinal factor for correct diagnosis of the disease.

When we identify the visual field defects, basing on the result we can assess the patient is suffering from Glaucoma or not. Glaucoma or non-glaucoma can be detected with visual field defects [6-7]. The motive behind this paper is to know the possibility of existence of Glaucoma in future or the disease is in its early stages. It requires a proper testing by the physician for the visual patterns with different tool to identify the stage of the disease in its early stages.

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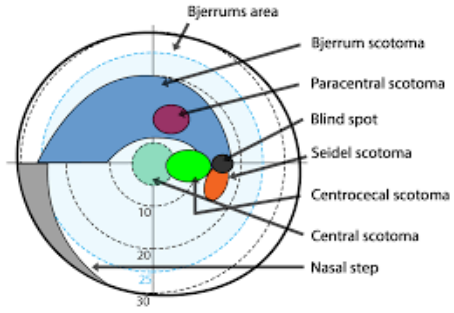
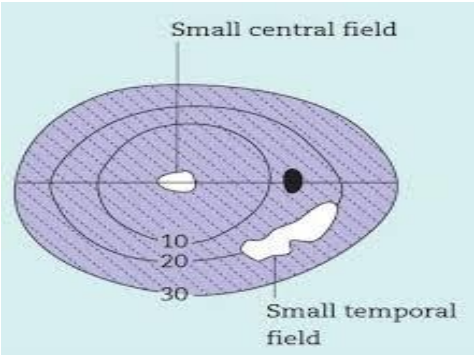


(a) Basic structure of isopter and scotoma in different visual fields



(b) Locations of blind spot and temporal fields and covered field areas

Examining the visual field is imperative as it being the first phase for determining the Glaucoma in its early stages[10]. If it is detected early, there is high probability to get cured the disease with 100% accuracy. The result of which leads to reducing the expenses for medication and aggravation of the disease can be cured to the maximum possible extent. Optic nerve and cup segmentation can be considered later for further diagnosis [11]

Predicting the Occurrence of the disease in the early stages by analyzing the Open angle and Normal Tension Glaucoma is important [12]. Predicting the early stage glaucoma can be done using variable delta-VF or VF tests. These contain basically 10-2(10),24-2(24), 30-2(30) ranges and have been termed as central, medium and wide ranges.

In the current research, we talk about the prediction of early stage glaucoma with either of the eye or with the both eyes. Usually, the basic test that need to be performed is VF-test and based on the result of this test, we can assess the individual is suffering from basic eye problem. Of all the Visual Field tests, The central Visual Field test [15] is an important one and the results generated by this test indicate the occurrence of Glaucoma. A standard known as Goldman Perimetry (24-2) test is also used in diagnosing the disease accurately [16]. The wide area test is also used to take decision for generating accurate results[2]. For arriving at proper decision and analysis, The results of these VF tests need to be correlated with Association Mapping mechanism.

2. Related work

Earlier work on the role of Visual field defects in predicting the early stage of Glaucoma need to be considered in this proposed research. Şerife Seda KucurID* et al, have developed a CNN model for predicting the early stage Glaucoma. They have developed OCTOPUS 101 program and Humphry field analyzer to distinguish control and Glaucoma cases. IlanaTraynis et al, have done work related to prevalence and characteristics of visual field defects with Glaucoma suspects and patients with mild Glaucoma [15,17]. Koji Nitta et al have developed a formula for the increase of visual field with primary open angle glaucoma using Normal tension Glaucoma. The formula could distinguish the open and Normal tension Glaucoma with receiver operator characteristic and the area under the curve was found to be nearly 0.75 for different cut-off values [18]. Ananth C Viswanathan et al, have done the early deterioration in the visual field by comparing the performance of the PROGRESSOR and STATPAC2[19]. Ravi Daruka et al, have found the correlation between central index field activity limitation in Glaucoma affected patients. But in all these works, Association Mapping has not been performed in the diagnosis of Glaucoma.

3. Method

Mapping rules have been designed based on the degree of correlation. Certain variables called as straight line variables or linear variables representing the ranges of the visual field have been considered for the purpose. The Degree of correlation has been used to find the intensity of visual field effect. The PSD (Pattern Standard Deviation) values obtained from different locations of 24-2 visual field test have been considered for identifying the abnormalities of Central Visual Field. This is done for those people having suspected of visual field or for those patients already suffering from Glaucoma.

Patients suspected of having Glaucoma or at risk of getting affected with Glaucoma were identified with a technique of masked grading of optic disc stereophotographs using PSD values. It is evident that, Although 10-2 tests are not useful, but these tests form as a basis for future studies for the comparison against 2-2 tests. Afterwards, 30-2 tests have been conducted and compared with earlier outcomes of 10-2 and 24-2 tests.

Following are different test cases and their association with other test regions of interest were depicted in the following table giving the combination of tests with respect to Normality and abnormality.

Normal	Abnormal
10-2	24-2, 30-2
24-2, 30-2	10-2
10-2, 24-2	30-2
10-2, 30-2	24-2
30-2	10-2 and 24-2

Taking into cognizance of the above testcases, we can assess the performance of each of the testcases along with their relationship between them. For instance, 24-2 is abnormal at blindspot and whereas 10-2 region of Central Visual Field showing the normal at isopter[22]. Paracentral defects and Nasal steps need to be considered for examining the eye field. Hence, we need to consider Central, Medium and Wide visual field for analyzing the defect. The Different cases are 10-2, 24-2 and their relationship called P1 (Limit). Different cases arise here. They are

Case1: if 10-2 is normal, 24-2 is Normal then no correlation
Case2: if 10-2 is Normal, 24-2 is Abnormal, Then moderate correlation
Case3: if 10-2 is Abnormal, 24-2 is Normal, then moderate
Case4: if 10-2 is Abnormal, 24-2 is Abnormal , Then moderate

Again by comparing the 24-2 and 30-2 test fields showing the two possible ways of 24-2 and 30-2 compared and prediction can be made using limit $P2_{(limit).}$ Here also, different cases arise.

Case 1: if 30-2 is Normal, 10-2 is Normal, Then there exists no correlation
Case 2: if 30-2 is Normal, 10-2 is Abnormal, Then there exits a moderate relationship
Case 3: if 30-2 is Abnormal, 10-2 is Normal, Then there exists moderate relationship
Case 4: if 30-2 is abnormal, 10-2 is abnormal, Then there exits perfect relationship.

$A \wedge B \rightarrow P_1$: $B \wedge C \rightarrow P_2$: $Z \wedge X \rightarrow P_3$

The correlation of two variables is known with the use of association mapping between correlated value and the value of the new variable.

Explanation for Association Level.:

If A & B are considered then P_1 will be associated and correlated with a_3
If B & C are considered then P_2 will be associated and correlated with a_1
If A & C are considered then P_3 will be associated and correlated with a_2
$\rightarrow (P_1, a_3) V (P_2, a_1) V (P_3, a_2)$ indicating the results of this correlation.

The range of correlation values lies between -1 and +1 and -1 being No perfect and +1 being Positive. If correlation between two variables is same i.e., from A→B and B→C and hence follows the symmetric property. Basing on the limit property, The prediction can be made whether there is a presence of the visual defect and not having the visual field defect ranging from 10-2, 24-2 and 30-2. These limits are from -1 to +1 everytime. -1 is for negative and NO PERFECT and +1 for positive and PERFECT. If the correlation value is same, it means, Symmetric property is being satisfied. In this proposed research, limit property is being used for prediction with different visual field ranges 10-2, 24-2 and 30-2 respectively. The correlation between the variables X , Y and Z will be calculated and should be in the range -1 and +1. The ranges and degree of correlation between perfect, High and Moderate has been given in different cases given below.

Case 1: If the degree is perfect, Value is +1, Then the correlation is Perfect
Case 2: If the degree is high, Value is in between [±0.50, ±1], Then the correlation is Strong
Case 3: If the degree is moderate and the value lies between [±0.30, ±0.49], then the correlation is medium
Case 4: If the degree is low and the value lies between [±0, ±0.29], then the correlation is small
Case 5: If there is no degree and when the value is 0, Then there exists no correlation.

The table given above gives the correlation values of visual field defect test ranges. Different cases of visual field 10-2(x) and 24-2(y) has been given below by considering the normality and abnormality of the visual field. Let N be the normal value and AB be the Abnormal value of the visual field defect. Then different cases arise. They are

Case I: If the VF defect in 10-2 and 24-2 are both N which implies there exists a normal relation between the two.
Case II: If VF defect in 10-2 is N and VF defect in 24-2 is AB, implying there exists a strong correlation.
Case III: If VF defect in 10-2 is AB and 24-2 is N, implying a strong correlation between the two
Case IV: If VF defect of 10-2 and 24-2 are both AB, indicating a perfect correlation.

10-2(X)	**24-2(Y)**	$P_{1(limit)}$	**Correlation** **Assumption**	Outcome	ω3 Normal ±0.29 to 0 Abnormal +1
Normal	Normal	±2.9 to 0.0	Negative	NoC	
Normal	Ab normal	(-0.30 , +0.30)	Positive	Strong	
Abnormal	Normal	(0.30, -0.30)	Negative	Strong	
Abnormal	Ab normal	+1	+ve	Perfect	

Table 5: : P1(limit)correlation and related association with ω3

It is observed that all three correlations were successfully executed and they are correlated in a systematic manner. The above table will generate the following combinations.

$P11 \rightarrow$ ω3		Outcome
P0.0	ω 0.0	Normal
P0.5	ω 0.0	High Degree
P0.5	ω 0.0	Moderate
P+1	ω 0.0	Strong
P0.0	ω+1	High Degree
P0.5	ω+1	Strong
P0.5	ω+1	Strong
P+1	ω+1	NoC

Table 6: illustration of association from $\wp$ to ω. Level of degree after association.

This method can be generated in such a way if 30-2 and 10-2 techniques are correlated, then it is associated with 24-2 (ie) Z→X and $P_{3_{\rightarrow}}$ ω2. If 24-2 and 30-2 are correlated and associated then, it is associated with 10-2. i.e., Y→Z & P2→ ω1.

VFS range mapping algorithm on Correlation and Association among X→Y→Z:

Step1: let us putin techniques like 10-2, 24-2 to identify the visual Field test patterns. Afterwards, 30-2 technique can be applied for the outcomes P_1, P_2 and P_3 representing the Normal, Abnormal, High Degree and Moderate using the range of correlated values. These results have been generated using the ranges of the correlation.

Step2: The results generated from the step-1 are compared with Karl Pearson Correlation between P_1→z, P_2 →x and P_3 →y and represent by ω1, ω2 and ω3 respectively.

Step3: correlate with (x,y),(y,z) and (z,x) (compute atleast one) using Karl Pearson correlation equation.

Step4: Let P_1, P_2 and P_3 as coefficient variables in an order

Step5: Let ω1, ω2 and ω3 be the end values succeeding correlation with association of rule.

Step6: Generate the results from the conditions below.

Result1→ ω1 implying $\wp_1$→z

Result2→ ω2 implying $\wp_2$ →x

Result3→ ω3 implying $\wp_3$→y

Step7: From the results of Result1,Result2 and Result3, Decide the stage of the disease as Normal(N), Abnormal(AB), Strong (HD) and Moderate (M).

Step8: Replicate the same steps above for right eye as well

Keep the results generated for left eye in E1 and the results generated for the right eye in E2

Results

The Final results of the VF test has been described below using linear variable Correlation. Different Cases have been considered and the corresponding outcome has been given below.

Case 1: if Left Eye is Normal with a value 0.0, and Right eye is Normal with value 0.0, Then the outcome is Pure

Case 2: if Left eye is abnormal with a value +1 and Right eye is Normal with a value 0.0, Then the outcome is Moderate

Case 3: if Left eye is Moderate with a value 0.3 and Right eye is Normal with a value 0.0, Then the outcome is lowdegree

Case 4: if Left eye is high degree with a value 0,5 and Right eye is Normal with a value 0.0, Then the outcome is Lowdegree

Case 5: if Left eye is normal with a value 0.0 and Right eye is Abnormal with a value +1, Then the outcome is Moderate

Case 6: if Left eye is abnormal with a value +1 and Right eye is AbNormal with a value +1, Then the outcome is Perfect

Case 7: if Left eye is moderate with a value 0.3 and Right eye is AbNormal with a value +1, Then the outcome is Strong

Case 8: if Left eye is high degree with a value 0.5 and Right eye is AbNormal with a value +1, Then the outcome is Strong

Case 9: if Left eye is normal with a value 0.0 and Right eye is moderate with a value 0.3, Then the outcome is low degree

Case 10: if Left eye is abnormal with a value +1 and Right eye is moderate with a value 0.3, Then the outcome is Strong

Case 11: if Left eye is moderate with a value 0.3 and Right eye is moderate with a value 0.3, Then the outcome is low degree

Case 12: if Left eye is high degree with a value 0.5 and Right eye is moderate with a value 0.3, Then the outcome is Moderate
Case 13: if Left eye is normal with a value 0.0 and Right eye is high degree with a value 0.5, Then the outcome is Low degree
Case 14: if Left eye is abnormal with a value +1 and Right eye is high degree with a value 0.5, Then the outcome is Strong
Case 15: if Left eye is moderate with a value 0.3 and Right eye is high degree with a value 0.5, Then the outcome is Moderate
Case 16: if Left eye is high degree with a value 0.5 and Right eye is highdegree with a value 0.5, Then the outcome is strong

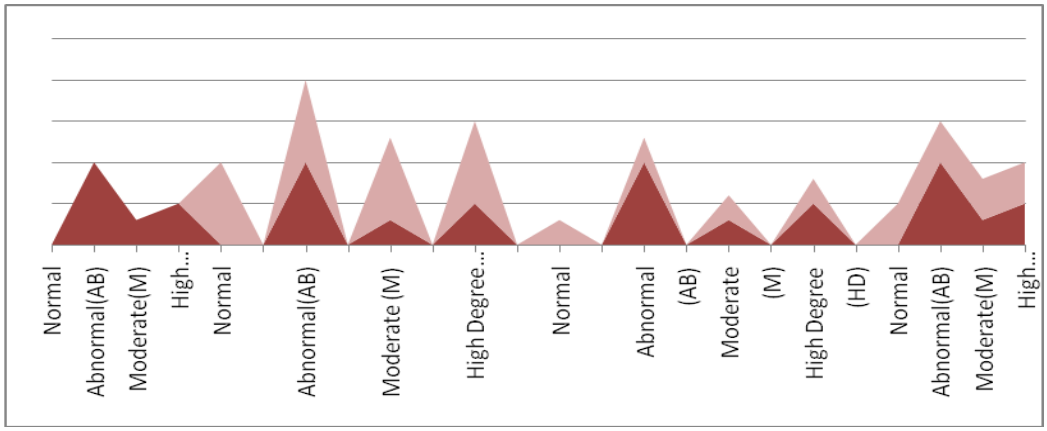


Figure 4: Lefet and Right eye limit range values after association with correlation

Discussion:

It is clear that VF tests certainly gives us some information for examinations which are to be done at a later stage of the diagnosis. The current research discussed in this paper gives us a simplified and easy approach for the physicians to make early detection of the disease. This current research enables the physician to diagnose the POAG, NTG in its nascent stages [10]. This proposed research also gives us a direction that the VF test conducted in this research will give the path to identify other eye related diseases. This research in present form simplify the tests of VFs in different images of the disease[13].

Conclusion:

This proposed research will help the novice clinician in making the apt decision for the diagnosis of the disease. This proposed method in this current research can be implemented in a systematic way so that the advancement of the disease can be prevented during the premature stages of the affliction of the disease. This work further can be enhanced to Optic Disk and Cup segmentation test analysis as the next stage to forecast Open Angle Glaucoma(OAG) in the preliminary stages of the disease.

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