Glaucoma Diagnosis by Measuring Spatial Parameters in Ultrasound Bio-Microscopy Images

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Abstract - Glaucoma is a chronic eye disease, in which the optic nerve is progressively damaged. It is second leading cause of blindness. Glaucoma cannot be cured, but its progression can be slowed down by treatment. As symptoms only occur when the disease is quite advanced, glaucoma is called silent thief of sight. Therefore, detecting glaucoma in time is critical. Anterior segment assessment of eye can be done by using Ultrasound Bio-Microscopy (UBM) images of eye. It is a high-frequency ultrasound technology that provides exceptionally detailed two-dimensional gray-scale images of anterior segment structures of eye. Initially the UBM image is converted to a binary image, so that traversing different geometric regions would be easy. In this image various approved spatial parameters like Pavlin's parameter are measured. Clinically, standard threshold levels to differentiate between normal and abnormal patients using these parameters are unavailable. So measurement is done for many patients and from that data the range of values for normal and abnormal cases is identified.

Keywords - Ultrasound Bio-Microscopy image.

I. INTRODUCTION

Medical image analysis and processing has great significance in the field of medicine, especially in non-invasive treatment and clinical study. Due to increasing number of medical images the use of computers in facilitating their processing and analysis has become necessary. Glaucoma is an eye disease causing blindness. Its symptoms occur only in advanced stage hence detecting it in-time is critical. The eye continuously produces fluid called aqueous, that must be drained out to maintain a healthy eye. In glaucoma, aqueous fluid's drainage path gets blocked due to trauma or infections, resulting in accumulation of aqueous fluid. This accumulation of aqueous fluid increases the intra-ocular pressure of eye damaging the optic nerve. High frequency Ultrasound Bio-Microscopy (UBM) provides high-resolution imaging of anterior segment of eye. It provides detailed two dimensional gray-scale images of anterior segment structures of an eye. By analysing the UBM image, any deformity in the anterior chamber can be identified.

Tanuj Dada et al. [1] have discussed about the impact caused by Ultrasound bio-microscopy in evaluation of the anterior segment of the eye. It gives an excellent view of the pathology occurring in the anterior and posterior chamber of the eye and allows objective documentation of the anterior chamber angle and the ciliary body, thereby providing clear insight into the cause for aqueous obstruction. Hiroshi Ishikawa et al. [2] Schuman discusses the role of UBM in imaging of anterior segment of the eye in qualitatively and quantitatively analysis point of view. It stresses the importance of the need for a semi-automated tool to measure the anterior segment structures. It deals about various possibility of deformity that can occur in eye with angle-closure glaucoma, open-angle glaucoma, pupillary block, plateau iris and so on. Saurabh Patwardhan el al. [5] discuss about the usefulness of Ultrasound bio-microscopy images for identifying various anterior chamber deformities, especially relating to Glaucoma. Chiranjeevi et al. [3] briefs about the steps in processing UBM image and to calculate the parameter Angle of Departure (AOD 500). The measurement is compared with results obtained from other measurement techniques such as tonometry, perimetry, gonioscopy, direct view of image and found out that computerised measurement in more precise [3]. All the above mentioned papers gives no account about the algorithms used for manipulating the UBM image for finding desired parameters.

In this paper, various techniques to measure the parameters for diagnosing Glaucoma are discussed. Chapter 2 gives the various parameters used to diagnose Glaucoma and chapter 3 explains the techniques to measure the parameters. Chapter 4 discuss about simulation results and chapter 5 concludes the work.

II. PARAMETERS MEASURED

Blockage of aqueous fluid can be caused by alter in size or positions of anterior segment structures. By measuring the spatial parameters in anterior segment of eye, any undesirable variations in the anterior segment structures that possibly obstruct the aqueous fluid flow can be found out. Pavlin and Potash parameters are the standard parameters taken for measurement for an UBM image.

Scleral spur (SS) is the only anatomical landmark that is used as reference point in most of the parameter. Parameters considered for measurement to in this work for diagnosing glaucoma are,

- Anterior Chamber Area (ACA) is area of entire anterior chamber of the eye.
- Angle of Departure (AOD) is the length of the perpendicular line from cornea to iris (0.5 or 0.75mm from SS)
- Tubercular Iris Angle (TIA) is the angle formed at the apex of the eye.
- Tubercular Iris Space Area (TISA) is the trapezoidal area formed between AOD and perpendicular line from scleral spur to iris.
- Angle Recess Area (ARA) is the triangular area formed between AOD and apex point
- Iris Area

III. TECHNIQUE for MEASURING the PARAMETER

A. Anterior Chamber Area

The UBM image of entire anterior chamber of eye, contain many discontinuities. So it is hard to trace the boundaries of anterior chamber. The inner boundary region of the anterior segment is manually marked as shown in Fig. 1(a). Based on the boundary marked, the image gets cropped. Number of white pixel in the cropped image gives the area of anterior chamber. The cropped output is shown in Fig. 1(b).To get more accuracy of the cropped anterior chamber number of points marked on the boundary region is increased.
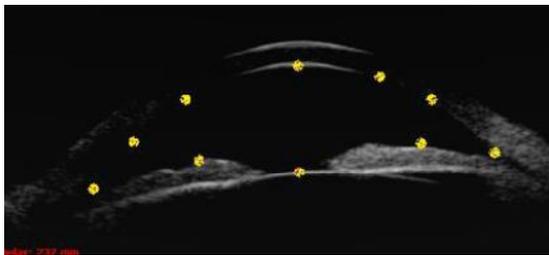

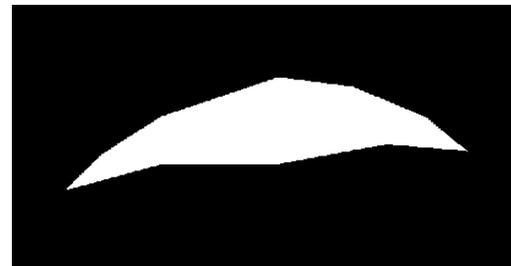Fig.1(a) Anterior Chamber Marking Boundary

Fig. 1(b) Cropped Anterior Chamber

B. Tubercular Iris Angle (TIA)

The UBM image used for measuring Tubercular Iris Angle (TIA) should have visually distinct able scleral spur, because the angle measurement is dependent on the position of scleral spur. In the input image, the position of scleral spur and convergence point of cornea & iris (apex point) is marked as shown in Fig. 2(a). Circle is drawn with scleral spur as centre and radius of 0.5mm and the intersection point of this circle with cornea, gives the top point of AOD (Fig. 2(b)). Then a line perpendicular to cornea is drawn from top of AOD until it meets iris, to get the lower end of AOD (Fig. 2(c)).Angle formed at apex by the line from apex to two ends of AOD gives the Tubercular Iris Angle (TIA), which is shown in Fig. 2(d). If ends of two lines are known the angle formed by them is found out using [1]. For image with right orientation mirror inversion is performed same steps are repeated.

$$TIA = \tan^{-1}\left(\frac{m_1 - m_2}{1 + m_1 m_2}\right) \tag{1}$$

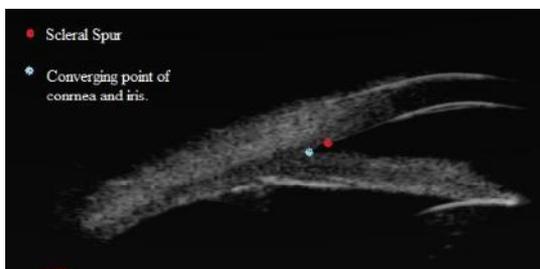where, m1 and m2 are slope of two lines between which angle is to be found

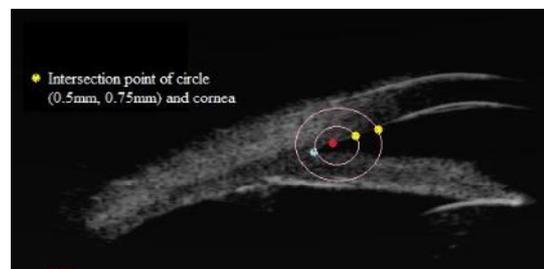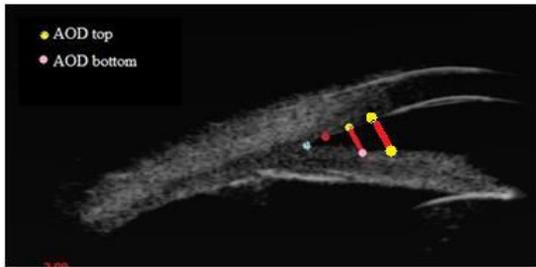Fig. 2(a) TIA (Apex and SS marked)

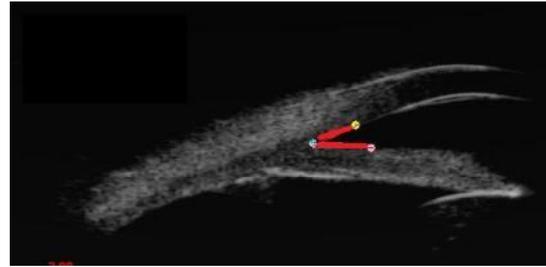Fig. 2(b) TIA

Fig. 2(c) TIA (AOD ends)

Fig. 2(d) Tubercular Iris Angle

C. Angle of Departure (AOD)

The orientation of images for each patient varies based on the part of anterior chamber focused while imaging. Images with different orientations are operated separately. Image with left orientation is shown in Fig. 2(a). Scleral spur and apex points are the input parameters for measuring AOD. In reference to those parameters, circles of radius 0.5mm and 0.75mm are drawn with scleral spur as center. The junction made by these circles in cornea gives the top point of AOD. A perpendicular line is dropped to iris from the AOD top point to get the other end of AOD (Fig. 3).
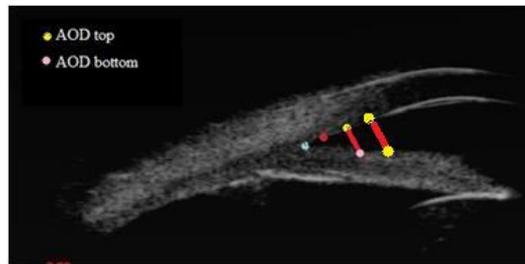

Fig. 3 Angle of Departure

D. Tubercular Iris Space Area (TISA)

Initially AOD line (0.5mm) is found out and then a perpendicular line is dropped from scleral spur to iris. From fig. 4, the area found between AOD and the perpendicular line from SS to iris is TISA (at 0.5mm).Once these two lines are known the area between them is calculated using area of trapezium formula. In the same way, TISA is also calculated for 0.75mm.

$$Area\ of\ Trapezium = \frac{h(a+b)}{2} \tag{2}$$

where, a is the length of one parallel slide, b is the length of other parallel side and h is the height of trapezium
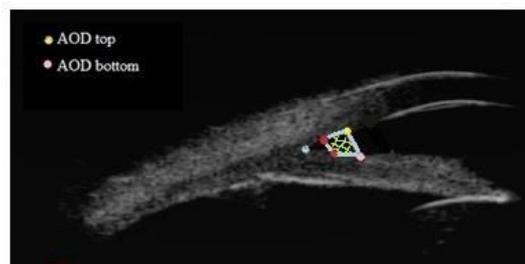

Fig. 4 Tubercular Iris Space

E. Angle Recess Area (ARA)

The calculation of TISA is explained in the above paragraph. Angle Recess Area is the total area lying in between AOD and apex point. Mathematically it is calculated as TISA plus the left out triangular area as shown in Fig. 5. The apex point and Scleral Spur are obtained and the perpendicular line from SS reaching iris is found out. Since these three points are known the area is calculated using,

$$Area\ of\ Triangle = \sqrt{s(s-a)(s-b)(s-c)} \tag{3}$$

Where a, b, c are length of side of triangle, and
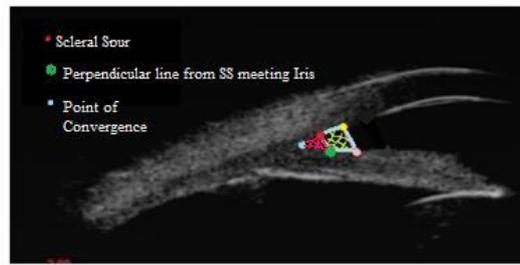
$$s = \frac{a+b+c}{2} \tag{4}$$

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Fig. 5 Angle Recess Area

F. Iris Area

Iris in an UBM image appears as a region of grey pixel surrounded by black pixel (Fig. 6). Initially the grey image is converted to a binary image, hence the iris will be white region bounded by black pixels. The area of iris is found out using region growing algorithm. The iris region grouped is shown in the Fig. 7. The steps in the region growing algorithm is,

Step1: Seed point is selected (left starting point of iris).
Step2: Iris area is white region surrounded by black pixels.
Step3: Seed point grows by grouping the white pixels.
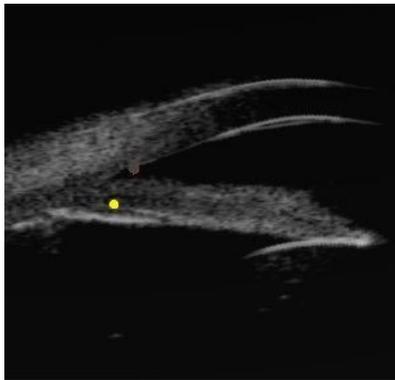Step4: Stop until black boundary is reached
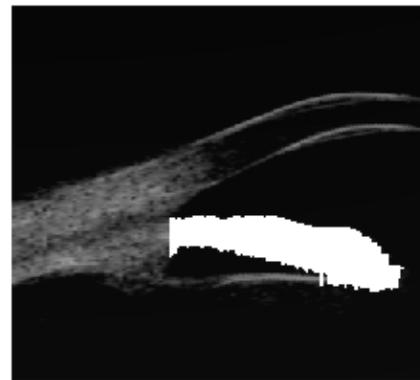

Fig. 6 Iris with marked Seed Point

Fig. 7 Iris

G. Metric Conversion:

Parameters which have been measured above are in pixels. Transforming them to standard distance unit is important, only then it could serve wide range clinical analysis. The size of UBM image is restricted to the machine configurations and image capture settings. So careful considerations should be done while taking down the image specifications. The specification of image taken for this experiment and consequently pixel-mm relation are given in the Table 1. It is clear from the table that the resolution is 0.0195mm.

TABLE I
RELATIONSHIP BETWEEN PIXEL & MM

Size of Image	13.1x13.1 mm
Size in Pixels	672x672
Size of Single pixel	0.0195 mm
1 mm	51 pixels

IV. SIMULATION RESULTS

The choice of image plays a vital role while measuring each parameter. For example, in order to measure TIA the image need to have visually distinct able scleral spur. Similarly measuring chamber area is not possible with a quadrant image. This semi-automated algorithm is applied for a set of 20 images for each parameter. From the measured results the boundary range for normal and abnormal cases are tabulated, as shown in table 2. In each image it is ensured that unchanged system settings are used for image capture, so that the metric conversion is unaffected. There is no distinction in values of iris area for normal and abnormal cases; hence it is been left out in the table 2.

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TABLE II
PARAMETERS FOR NORMAL AND ABNORMAL IMAGES

Parameters	Normal	Abnormal
TIA	37 to 58 degree	24 to 38 degree
Chamber Area	11.15 to 18.42 mm^2	7.83 to 9.95 mm^2
AOD_500	0.39 to 0.96 mm	0.22 to 0.37 mm
ARA_500	0.26 to 0.51 mm^2	0.04 to 0.17 mm^2
AOD_750	0.53 to 1.44 mm	0.32 to 0.51 mm
ARA_750	0.17 to 0.78 mm^2	0.11 to 0.24 mm^2

V. CONCLUSION

In this paper, screening glaucoma from UBM images is explained by considering various parameters. The main advantage of automated measurement over clinical instruments is resolution and here it is about 0.0195mm. Since no clinical threshold is available, repeated set of readings are taken to find distinction between normal and abnormal cases. As shown in results, those set of parameters has shown a distinction in value for normal and abnormal cases. The combined result of all these parameters will give more clear insight about the eye condition. With these set of values only open angle glaucoma can be diagnosed. No clear distinction has been obtained for the parameter, iris area. So, in future iris measurements are done in light and dark conditions so that clear distinction can be obtained. Furthermore parameters like ILCD (Iris Lens Contact Distance), ILA (Iris Lens Angle), iris volume, and chamber volume can be considered so that distinction between different types of glaucoma can be analysed. Furthermore some pre-processing technique need to be employed so that discontinuities in cornea region can be removed and overall quality of image can be improved resulting in more precise results.

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