

Automated Post-Trabeculectomy Bleb Assessment by Using Image Processing

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Abstract—Glaucoma is a second leading cause of blindness after cataract. Glaucoma caused by unbalance absorption of aqueous humour so it increase intraocular pressure. As a result, it surpresses nerve cells so that nerve cells can not get enough blood flow as nutrition intake and can lead to permanent blindness. One of the treatment for glaucoma is by surgical procedure, called trabeculectomy. After the surgery a slightly lifted tissue due to passing fluid, called bleb, should appears. Bleb assesment is necessary to examine the successful of trabeculectomy surgery. One of standard assesment is Indiana Bleb Appearance Grading Scale (IBAGS). Ophthalmologist used this standard to grade the bleb images manually so the result is subjective. This work offered a new approach to standardize the system of bleb assesment by computer software. Features related to bleb height, width and vascularity were extracted from the bleb image by using image processing algorithm. The KNN algorithm then used to classify the image according the IBAGS. The proposed method has successfully increased the Cohen's kappa coefficient from 0.56 to 0.63. Therefore, it potentially reduced the subjectivity of the bleb grading.

Keywords—glaucoma; trabeculectomy; bleb; Indiana Bleb Appearance Grading Scale, parallel thinning.

I. INTRODUCTION

Glaucoma is second leading cause of blindness after cataract. According to the WHO, in 2010 as many as 3.2 million of people worldwide have suffered visually impaired caused by glaucoma. Glaucoma caused when intraocular fluid called aqueous humour can not be absorbed properly so it increase intraocular pressure (IOP) of the eye. As a result, it surpresses nerve cells so nerve cells do not get blood flow as nutrition intake. Dying nerve cells will cause vision impairment and permanent blindness.

One of the treatment for glaucoma is by surgical procedure commonly called trabeculectomy. This procedure was introduced by Sugar [1] and improved by Cairns [2]. Trabeculectomy performed by creating a new channel under the sclera so that aqueous humour can be absorbed back into the body to lower the IOP. After the surgery a slightly lifted tissue due to passing fluid called a bleb will appear. The succes rate of trabeculectomy related to the successful formation of the bleb and the final decrease of IOP [3, 4]. Bleb assesment is necessary to examine post-trabeculectomy surgery. The bleb image taken from the slit lamp observation is graded by its morphology [5, 6, 7]. Popular bleb grading system called The Indiana Bleb Appearance Grading Scale (IBAGS) use 4 parameters to grade the bleb image [5]. The 4 parameters include bleb height, extend,

vascularity and leakage. The leakage evaluated by using fluorescein dye (Seidel test) and not included in this study.

Bleb assesment is usually done by an ophthalmologist using slit lamp. Ophthalmologist graded the appearance of the bleb based on IBAGS so it is subjective. Bleb height examined from slit light image while bleb extent and vascularity examined from normal light image. The leakage graded by observing the dynamic of the dye inside the bleb (Seidel test) therefore it can not be graded from a single image. Different ophthalmologist tends to grade differently. This study offered a new approach to standardize the system of bleb assesment that can potentially reduce the differences among ophthalmologist by using computer software.

II. BLEB MEASUREMENT

There are 4 parameters of assesment by IBAGS, where 3 assessments uses bleb image and 1 assesment which is Seidel test assessed directly by ophthalmologist. The assessment parameters that use eye image are bleb height, bleb extent, and bleb vascularity. Fig. 1 showed a typical eye images with bleb. The first image was captured under normal light condition while the second image was using slit light from 20-30° angle to show the curvature of the bleb for bleb height assessment. Eye image with normal light used to assess the bleb extend and vascularity parameters.

Bleb height represents the elevation of conjunctival above the scleral surface and it is divided into 4 classes: H0 (flat bleb), H1 (low bleb elevation), H2 (moderate elevation), and H3 (high bleb). Bleb extent represents the horizontal dimension of filtering bleb, or it can be called by bleb area. The bleb extent is divided into 4 classes: E1 (no visible bleb or less than 1 clock hour), E2 (extent equal to or greater than 1 clock hour but less than 2 clock hour), E2 (extent equal to or greater than 2 clock hours but less than 4 clock hour), and E3 (greater than 4 clock hour). Bleb vascularity represents the vesselness in bleb area and is divided into 5 classes: V0 (avascular/ white), V1 (cystic), V2 (mild vascularity), V3 (moderate vascularity), and V4 (extensive vascularity).

III. METHODS

This work offers bleb assesment system from bleb images by using image processing algorithm. In this paper, we focused on grading based on data from the bleb images as showed in Fig. 1. The slit image (b) contains bleb height information. The bleb extent was extracted from image with

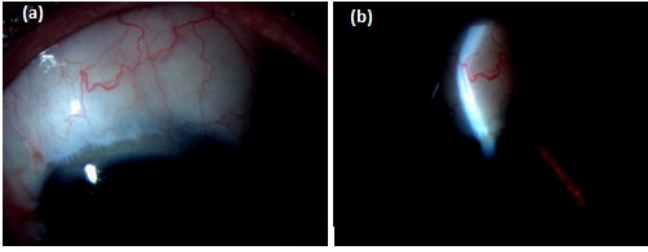


Fig. 1. Eye image for bleb assesment. (a) normal light, (b) slit light.

normal light (b). The bleb vascularity was then evaluated for area under the bleb extent.

Eye images were taken by using a slit lamp camera from Zeiss S1 type. The images resolution is 1296 x 972. Eye image taken from the front and facing down to target the bleb area according to the standard of photography of IBAGS assesment. Image was taken twice, first with normal light and second with slit light.

The image processing algorithm is shown in Fig. 2.

A. Pre-processing

Pre-processing was used to change the position of image with slit light so that it align with the image with normal light. The process of this reposition was done semi-manually by selecting two correspond points from both images. The software then automatically positioned the slit image align with normal light as a reference.

B. Slit Segmentation using K-Means

The slit light image was filtered by low pass Gaussian filter to reduce the noise and to flatten the intensity value. The sigma value was set to eight. The green channel was selected from RGB color image for further processing because it has a better contrast. The image was then segmented by using K-means

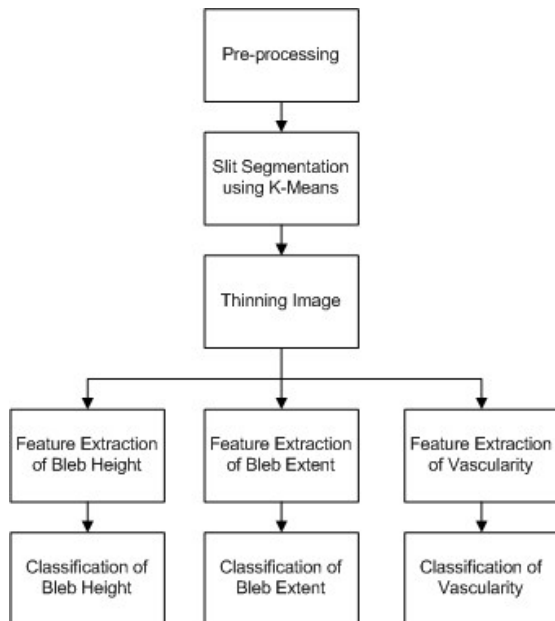


Fig. 2. Image processing algorithm for bleb assesment.

where K was set to four. The threshold value was set to separate the slit image from the background.

C. Thinning Image

The thinning method was used to convert slit image into one pixel size structure that represent its centerline. This method is often used in pattern recognition features [8]. We used the paraller thinning method in this work [9]. The algorithm examined any neighbors in 3x3 window starting from top left of image to determine which point to be deleted. Iteration was repeated until the image stops changing which means the image has changed in to the thinnest form.

D. Feature Extraction

The centerline of the slit resulted from the thinning process was rotated by 90°. Fig. 3 showed a sketch on the bleb image analysis.

- 1) The highest point determined the peak point. The start and the end of the bleb determined by change in curvature. This change can be located from the first derivative of the plot. The maximum distance from the peak and valleys determined the bleb height below:

$$Bleb\ Height = \max[peak - valley] \text{ (pixel)} \quad (1)$$

- 2) The extent of bleb was determined by the distance between two valley points (start and end point of the bleb) as given below:

$$Bleb\ Extent = [valley\ 1 - valley\ 2] \text{ (pixel)} \quad (2)$$

- 3) Bleb vascularity evaluated only below bleb area. In this work we approximated the bleb area by bleb extent information (formula 2). The bleb extent was used as diameter to create a circle in normal light image.

E. Bleb Vascularity Extraction

After the bleb area was roughly segmented, then vessel extraction was performed by using Frangi filter [10]. This filter is commonly used to detect tubular-like structures, such as a blood vessel.

In this work we used parameter $\sigma = 4$; $\alpha = 0.5$; $\beta = 15$. The final response of the Frangi filter as shown in Fig. 3. After that, the threshold was used to get the binary image. The vascularity parameter was calculated as percentage of white pixels (vascular) as given below:

$$Bleb\ vascularity = \frac{white\ pixels}{all\ pixels} \times 100\% \quad (3)$$

IV. RESULT AND DISCUSSION

The bleb assesment using IBAGS was performed on 41 datasets of eye images taked at Cicendo eye hospital, Bandung. Two ophthalmologists (OP 1 and OP 2) have assessed the overall bleb image. From these results then the Cohen's kappa coefficient of assesment of the two ophthalmologist were

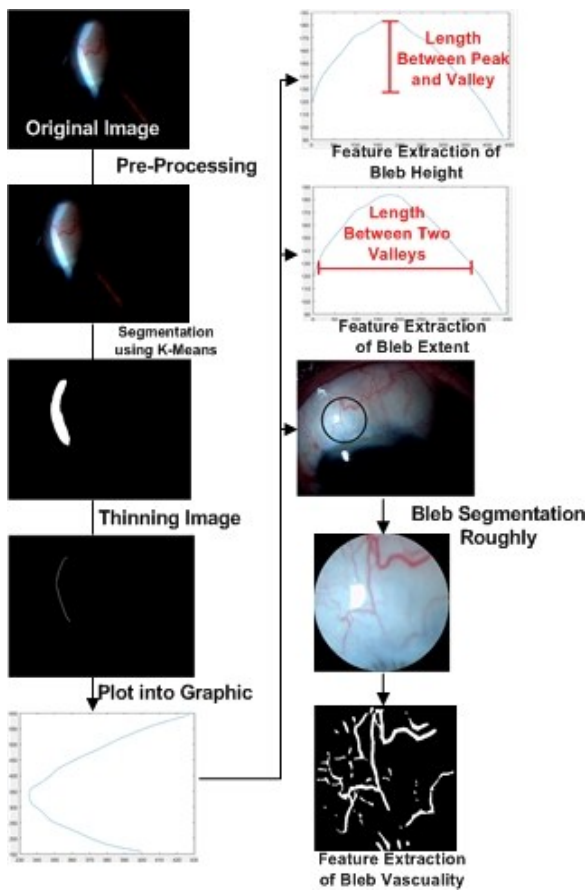


Fig.3. The proposed method of bleb assesment using image processing

calculated. Cohen's kappa was used to measure inter observer agreement between two ophthalmologist. The results of the experiment are shown in Table I. The Cohen's kappa coefficient were relatively low (0.56) indicated that the standard bleb assessment method was not easy to follow by different ophthalmologist.

Data that gave similar assesment by both ophthalmologists were used for training the bleb classification by using K-NN algorithm. The remaining data were used for the test. There are 25 training data and 16 testing data used for height bleb classification, 24 training data and 17 testing data for extent bleb classification, and 20 training data and 21 testing data. As shown in Table I the result of the proposed method increase the kappa coefficient. The inter-observer agreement of both ophthalmologist at 0.56, has increased to 0.61 and 0.63 using KNN classification, respectively.

TABLE I. The Result Of The Bleb Assesment Using Image Processing

Bleb Parameters	Cohen's Kappa Coefficient		
	<i>OP 1 vs OP 2</i>	<i>Software vs OP 1</i>	<i>Software vs OP 2</i>
Bleb Height	0.48	0.51	0.63
Bleb Extent	0.59	0.68	0.73
Vascularity	0.62	0.64	0.52
Average	0.56	0.61	0.63

V. CONCLUSION

This work offered a new approach by computer software to standardize the system of bleb assessment. Features related to bleb height, extent and vascularity were extracted from the bleb image by using image processing algorithm. The KNN algorithm then used to classify the image according the IBAGS. The proposed method has successfully increased the Cohen's kappa coefficient from 0.56 to 0.61 and 0.63. Therefore, it potentially used to help the bleb grading.

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