Automated Detection of Arteriovenous Crossing Phenomenon on Retinal Images

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***ABSTRACT:** Arteriolosclerosis is one cause of acquired blindness. Retinal fundus image examination is useful for early detection of arteriolosclerosis. In order to diagnose the presence of arteriolosclerosis, the physicians find the silver-wire arteries, the copper-wire arteries and arteriovenous crossing phenomenon on retinal fundus images. The focus of this study was to develop the automated detection method of the arteriovenous crossing phenomenon on the retinal images. The blood vessel regions were detected by using a double ring filter, and the cross sections of artery and vein were detected by using a ring filter. The center of that ring was an interest point, and that point was determined as a cross section when there were over four blood vessel segments on that ring. And two blood vessels gone through on the ring were classified into artery and vein by using the pixel values on red and blue component image. Finally, V_2-to-V_1 ratio was measured for recognition of abnormalities. V_1 was the venous diameter far from the blood vessel cross section, and V_2 was the venous diameter near from the blood vessel cross section. The cross section with V_2-to-V_1 ratio over 0.8 was experimentally determined as abnormality. Twenty four images, including 27 abnormalities and 54 normal cross sections, were used for preliminary evaluation of the proposed method. The proposed method was detected 73% of cross sections when the 2.8 sections per image were mis-detected. And, 59% of abnormalities were detected by measurement of V_1-to-V_2 ratio when the 1.7 sections per image were mis-detected.*

***KEYWORDS:** Arteriolosclerosis, Hypertensive retinopathy, Retinal Fundus image, Arteriovenous crossing phenomenon, Image analysis, Computer-aided diagnosis*

I. INTRODUCTION

The fundus is examined selectively in the diagnosis performed by physicians as part of a specific health checkup scheme initiated in Japan in April 2008. Thus, the numbers of retinal examinations have been increased. Computer-aided diagnosis (CAD) systems, developed for analyzing retinal fundus images, can assist in reducing the workload of ophthalmologists and improving the screening accuracy. Thus, we have been developing a CAD system for analyzing retinal fundus images [1-13]. Our CAD system was targeted for three diseases, hypertensive retinopathy [1-5], diabetic retinopathy [6-8] and glaucoma [9-13]. Using Scheie classification, hypertensive retinopathy is divided into two main categories, retinopathy and arteriolosclerosis. Arteriolosclerosis was graded by silver-wire artery, copper-wire artery and arteriovenous crossing phenomenon (AVCP) [14]. If the venous diameter V_2 near the cross section of the artery and the vein was narrow than the venous diameter V_1 far from the cross section, the section was determined as AVCP (as shown in Figure 1). But, to detect AVCP automatically was very difficult, and automatic AVCP detection was no reported. Thus, this study was designed to develop an automated method for detecting AVCP on retinal fundus images.

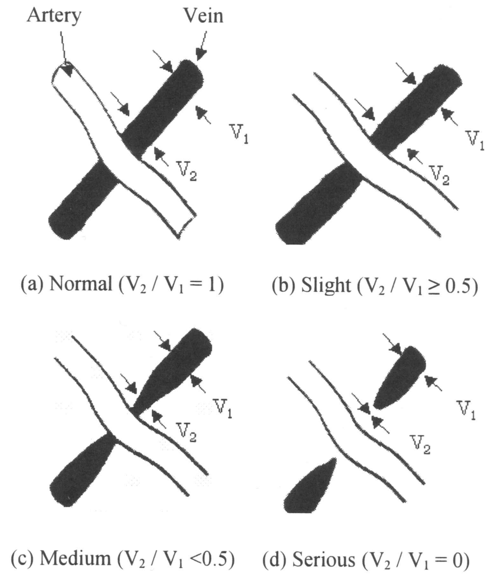

Figure 1. Grades of arteriovenous crossing point.

II. METHODS

Retinal fundus images were captured using a fundus camera (the nonmyd 7, Kowa Company, Ltd., Tokyo, Japan). The photographic angle of the fundus camera was set to 45 degrees. The retinal fundus images were obtained with an array size of 3008 × 2000 pixels and 24-bit color.

Next, the blood vessels (BV) regions were detected. Much research has been conducted on automated BVs detection on retinal images [1-4, 14-17]. They include the methods using matched filters [14], differential filters [15], region growing [16] and Gabor wavelets [17]. We also developed BVs detection methods using a double ring filter [1, 2] and black top hat transformation [3, 4]. A double ring filter was used for BVs detection in this study. Figure 2 shows a result of BVs detection by using a double ring filter. The optic disc region was then detected by using p-tile

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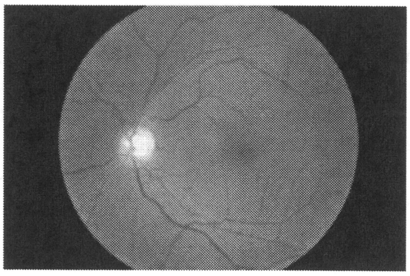
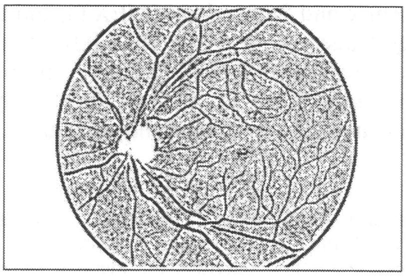
technique of the histogram with green component of color image.

The major BVs used for the AVCP detection usually run from the optic disc to the upper and lower temporal regions. In order to select such BVs, a vessel-range mask was superimposed to the images for including vessels that were inside this mask. The vessel-range mask was created based on the BVs in the 24 cases by centering the optic discs as shown in Figure 3. To detect the cross sections of the artery and the vein, a ring filter was determined (as shown in Figure 4). If over 4 BVs were existed on the ring, the interest point was determined as the cross section. But this ring filter mis-detected many false positives like Figure 5 (b), and they were reduced by using contrasts between the pixel value on interest pixel and pixel value on the position far from there on green and blue components of color image.

The artery and the vein were classified by using pixel values on the ring (as shown in Figure 6). The four pixel values of 4 BV points on the ring were ranked on the red and green components. The ranking values were summed, and that sum and that opposite sum of the ring were summed. The vein was darker than the artery in the color image, thus the BV with smaller sum was classified as the vein. Then, V_1 and V_2 were then determined for detection of the AVCP. The vein on the ring was determined as the center of the ring on the vein was determined as the position P_2 (as shown in Figure 7). V_1 was the average venous diameter between P_1 and P_2, and V_2 was the minimum venous diameter between P_2 and the interest point. Finally, the interesting point was experimentally determined as AVCP when the V_2-to-V_1 (V_2 / V_1) ratio was under 0.8.

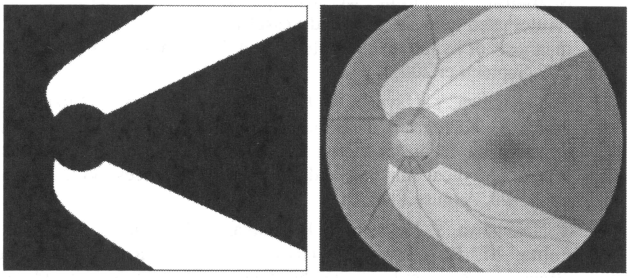


(a) Original retinal fundus image



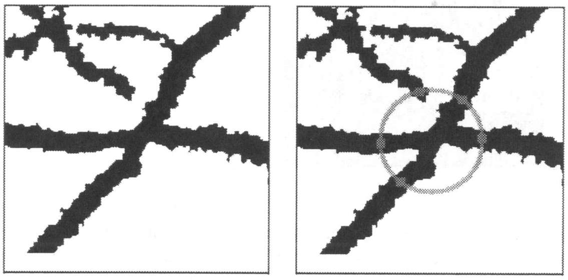
(b) Result of the blood vessels detection.

Figure 2. Detection of blood vessels by using double ring filter.

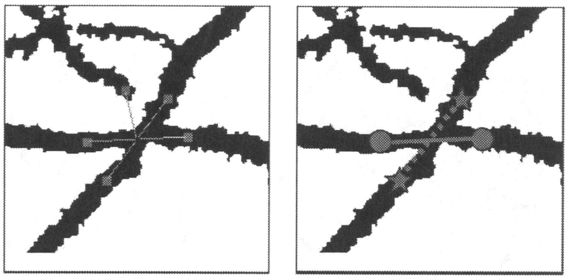


(a) (b)

Figure 3. The vessel-range mask. (a) The range of the arteriovenous crossing phenomenon locations determined by superimposing the optic disc centers of the 24 cases. (b) The searching area was determined by superimposing the range.

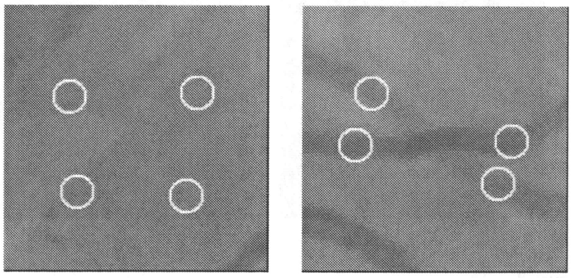


(a) (b)



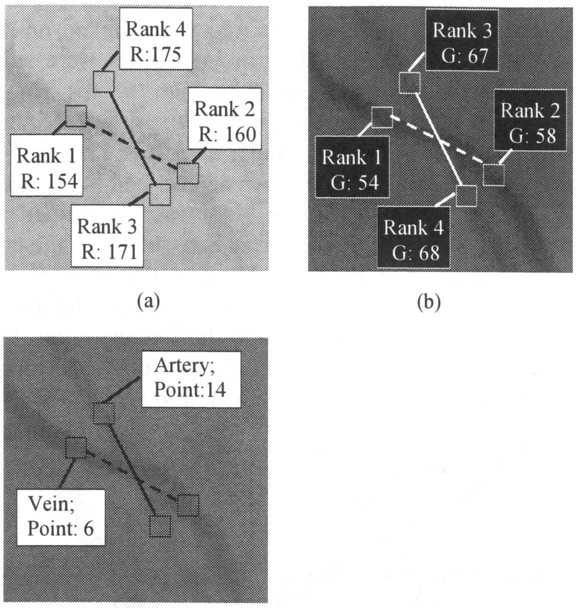
(c) (d)

Figure 4. Using a ring filter, the cross sections of artery and vein was detected. (a) Result of blood vessels detection. (b) The ring filter for searching the cross sections. Green line shows a ring filter, and red points show the positions crossing the blood vessel and a ring. (c) False blood vessels elimination. The blood vessels without the opposite blood vessel candidates of the ring were removed. Top and left blood vessel was removed in this case. (d) The cross section was detected by recognition of artery and vein pair.



(a) True AVCP (b) False AVCP

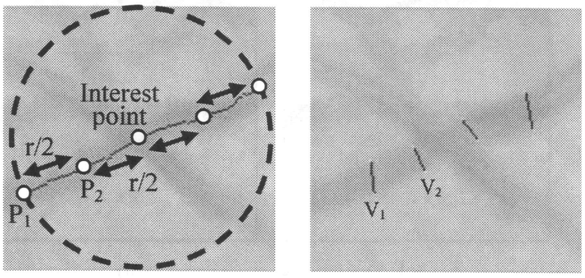
Figure 5. The different pixel value of true AVCP and false one. White circles were misdetected as blood vessels in (b).



(a) (b)

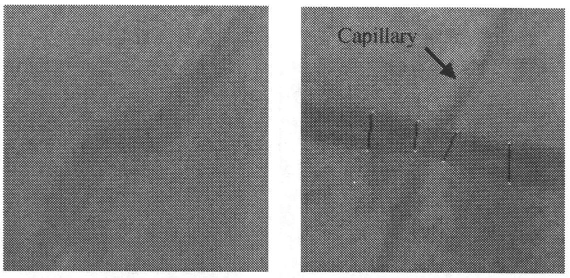
(c)

Figure 6. Classification of artery and vein. (a) The red pixel values on the ring, and their ranks in 4 points. (b) The green pixel values on the ring, and their ranks in 4 points. (c) The distinction points by the sum of the ranks on red and green components.



(a) (b)

Figure 7. Determination of diameter V_1 and V_2. (a) The vein on the ring was determined as the position P1. The venous position on the ring with half radius of the ring filter was determined as the position P2. "r" is a radius of the ring. (b) V_1 was the average venous diameter between P_1 and P_2. V_2 was the minimum venous diameter between P_2 and the interest point.



(a) (b)

Figure 8. These cases are false. (a) The proposed method did not detect this cross section because this included artery wall reflection (which is called silver or cooper wire artery). (b) This cross section was mis-detected because this region includes the capillary crossed the fat main blood vessel.

III. Results and Discussion

Twenty four retinal fundus images, including 27 AVCP and 54 normal cross sections, were used to evaluate the proposed method for detection of AVCP preliminary. The proposed method was detected 73% (59 / 81) of BV cross sections including when the 2.8 (66/24) sections per image were mis-detected. And, 59% (16/27) of the sections with AVCP were detected by measurement of V_2 / V_1 ratio when the 1.7 (41/24) sections per image were mis-detected.

The proposed method could not detect BV cross sections with low contrast of an artery (as shown in Figure 8 (a)) in this evaluation. Their arteriolar walls were reflected, thus detection of such arteries were very difficult. Moreover, proposed method would mis-detect the capillaries like Figure 8 (b), if it detects such arteries. We have been developing a BV tracking method from the optic disc for determination of artery-vein diameter ratio [5], thus the problem (like Figure 8 (b)) may be improved by using such a technique.

IV. Conclusion

We proposed an automated AVCP detection method based on the vein diameter measurement near BV cross section. The preliminary result indicated the potential usefulness of this method for the automated BV crossing sections detection. But, the automated AVCP detection method needs to improve.

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