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Original askiatic imaging used in Chinese medicine eye-feature diagnosis of visceral diseases

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Eye-feature diagnosis is a time-honored method for studying many diseases in traditional Chinese medicine. There is a close relationship between eye-feature and viscera, and eye-feature is a reflection of visceral health status. Commercially used ophthalmology diagnosis instruments have disadvantages and cannot satisfy the requirements of eye-feature diagnosis. In this paper, we proposed a novel askiatic imaging method that removes the interference of an illumination source's reflection shadow and is free from image splicing. We developed a novel imaging system to implement this method, and some eye-feature characteristics to analyze visceral diseases were obtained.

Keywords: *In vivo*; eye-feature diagnosis; askiatic imaging; image processing.

1. Introduction

Eye-feature diagnosis is a traditional Chinese medicine method for many diseases. It includes observing the color and shape of each part of the eye, and the number and color of eye secretions.[1] This diagnosis method was recorded in the magnum opus "The Inner Canon of Huangdi" thousands of years ago. Eye-feature refers to items in the white of the eye, such as blood vessels, fog, and spots. There is a close relationship between human eyes and viscera, and the health status of viscera will be reflected in the health of the eyes. In other words, if there are lesions in some viscera, some eye-feature characteristics will show variations.[2] Based on the "five-round and eight-character" theory of traditional Chinese medicine, doctors of traditional

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Chinese medicine divide the eye into sections of meridians and organs to observe the color changes of the blood vessels in each subarea, and diagnose diseases of different organs in each subarea.[3] Zheng *et al.* created a model of eye diagnosis. The sclera of the eye was divided into 14 regions corresponding to different organs.[4] Diseases were diagnosed by observing changes of the eye in each region. This is also a reflection of the "holistic view" of Chinese medicine.

One of the ophthalmology diagnosis method mostly used nowadays is iris diagnostics.[5] It has a history of more than one hundred years and is one of the Western eye diagnostic theories. This method is to diagnose the damage and function of the viscera by examining the iris of the eye. In the 1980s, Jensen proposed iris positioning method, and it was verified with high accuracy in the clinics.[6] Fragnay *et al.* diagnosed over 3000 patients with iris diagnostics, and wrote the book "Iris Diagnostic".[7] However, such method mainly focuses on characteristic of iris, and it lacks the information of the white of the eye.

The other ophthalmology diagnosis method usually used is eyeball wide-field imaging.[8] In this method, physiological information of the eyeball can be quickly acquired. However, because the eyeball is spheroidal and strongly reflects the illumination source, the reflection shadow of the illumination source will overlap on the white of the eye, which will interfere with detection. To solve this problem, Gullstrand invented the slit-lamp microscope in 1911, with which doctors can observe the structure of the eyeball in a narrow zone using a slit light produced by the slit lamp, free from illumination source's reflection shadow. The slit-lamp microscope has been commonly used in ophthalmological diagnosis,[9] and does not have the drawbacks of the wide-field imaging method. However, it brings a new problem: it requires an additional scan of slit light to acquire an overall image of the eyeball. Moreover, the images taken with a slit light scan must be spliced.

Other commercially used ophthalmology diagnosis instruments also have problems such as high cost, radiation, and invasiveness. Thus, a novel askiatic imaging method is urgently needed. In this paper, we developed a novel askiatic imaging system for eye-feature diagnosis to visceral diseases *in vivo*.

2. Method

2.1. *Novel askiatic imaging method*

We proposed a novel askiatic imaging method free from an illumination source's reflection shadow and complex manipulations such as image splicing. As shown in Fig. 1, for example, the light of the illumination source slants into the eye from the right with an angle of incidence 60°, guiding the iris to reach the right of the eye frame, with the left portion of the white of the eye fully exposed to the field of view, which can be free from the illumination source's reflection shadow overlapping the left portion of the white of the eye. Using the same method, when the light illuminates from the top, bottom and left, the bottom (or top or right) of the white of the eye will be detected. Following this procedure, all items in the white of the eye will be acquired, and the health status of viscera can be analyzed.

In order to perform the askiatic imaging method, a novel askiatic imaging system was developed. As shown in Fig. 2(a), the system is composed of four components: a location hole, an illumination source, an imaging device, computer and a processing software. The location hole is used to guide the location of the eye frame and to broaden the eyelids using fingers. The illumination source consists of four 1 W white lighting LEDs located at the top, bottom, left, and right. It provides illumination from four directions to illuminate aslant into the eye with the angle of incidence 60°. We have done a series of experiments with different angles of incidence, because the light illuminates through the location hole to the eye from the side. In order to acquire a full view of eye-feature image, there must be a specific angle of incidence so that the light can illuminate the entire eye. According to the experiment results, the angle of 60° satisfies our needs.

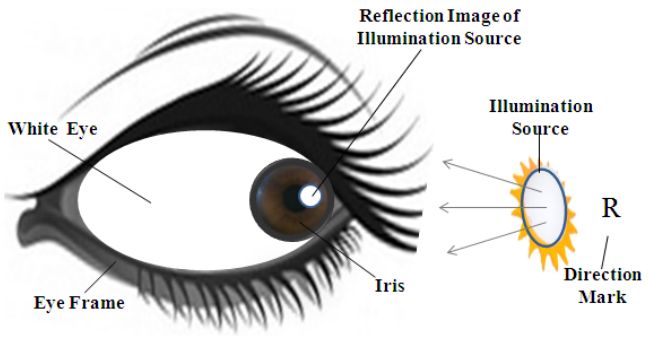

Fig. 1. Schematic diagram of the askiatic imaging method.

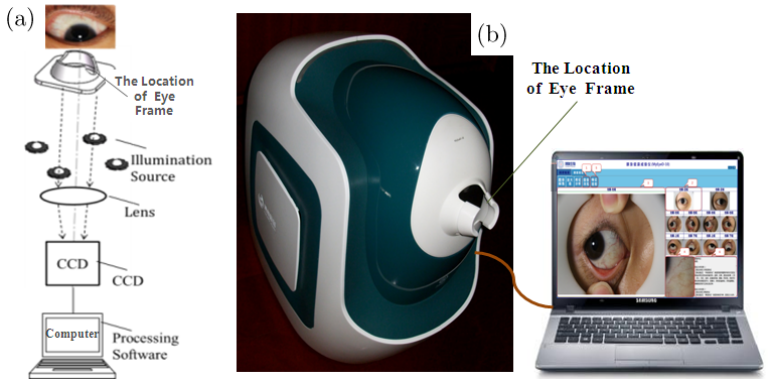

Fig. 2. (a) Schematic diagram and (b) photo of the askiatic imaging system.

Besides, with such angle of incidence, the reflection shadow of the light source will only overlap on the iris, which will not interfere the analysis of the characteristic on the white eye. In addition, we have done experiments of light sources with different powers, and we finally choose four 1 W white LEDs, because they can provide sufficient illumination intensity. What's more, such power will not make patients feel uncomfortable. The imaging device is composed of a lens with the focal length of 100 mm and a charge-coupled device (CCD, the resolution of 28 mega pixels) to capture the eye-feature image. Computer and processing software is used to control the illumination source and imaging device to store eye-feature images taken by the imaging device, and to analyze the eye-feature characteristics. Figure 2(b) is a photo of the askiatic imaging system.

The image acquisition process is as follows: First, the patients make their one eye frame (for example, the left eye) fit with the location hole and broaden the eye with fingers. Second, the light illuminates from left, right, top and bottom, respectively, which guides the iris of patients to reach the respective direction, so the opposite side sclera of the eye can be illuminated and detected, respectively, at the same time, the imaging system captures the eye-feature images, extract features and process the images. Then, following the above process, the detection of the other eye (for example, the right eye) could be carried out.

Compared with commonly used ophthalmology diagnosis instruments, the novel askiatic imaging system we developed has the following advantages: First, the reflection shadow of the illumination source overlaps on the iris but not the white of the eye to be diagnosed, and without the interference of a shadow. Second, after capturing eye-feature images in four directions, we analyze the items in the eye-feature image to judge the health status of viscera without image splicing, thus saving a lot of time and manipulation.

2.2. *Description of eye-feature in Chinese medicine*

As shown in Fig. 3(a), in the contemporary theory of Chinese medicine, the white of the eye is divided into 17 different sections that correspond to different viscera.

The items on such sections can reflect the health status of corresponding viscera. For example, the color of the white of the eye (off-white, blue, pale yellow, etc.), morphological items (point, bar, spot, fog and so on), and blood vessels on the surface of the white of the eye (color, shape, orientation, and so on) contain health information. One's health status can be learned by analyzing such features.

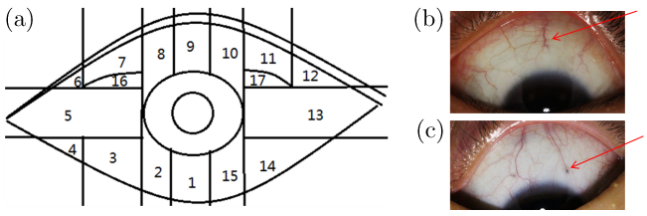

Fig. 3. Schematic diagram of eye-feature and eye-feature images of normal people and patient with kidney deficiency. (a) Schematic diagram of eye-feature diagnosis in Chinese medicine for left eye: (1) stomach; (2, 15) spleen; (3) large intestine; (4) small intestine; (5) heart; (6) breast; (7) lung; (8, 10) kidney; (9) bladder; (11) ovary (testis); (12, 14) liver; (13) gallbladder; (16) brain; (17) lumbosacral. (b) Eye-feature image of normal people. (c) Eye-feature image of people with kidney deficiency.

The eye-feature diagnosis is mainly used to judge the state of viscera, for example, whether the functions of the lung, kidney, or heart are normal. In Fig. 3(b), the red arrow denotes blood vessels on the region corresponding to the kidneys of normal people, but in Fig. 3(c), there is a gray spot on the blood vessels of people with kidney deficiencies, which implies a deficiency of the viscera.[10]

3. Results

With the askiatic imaging method and analytical system, when the light of the illumination source illuminates aslant into the eye from the left, right, top, or bottom, guiding the iris to reach the left, right, top, or bottom of the eye frame in turn. The right, left, bottom, or top of the white of the eye is fully exposed, respectively, as shown in Fig. 4(a). The letters "*R*," "*L*," "*B*," and "*T*" denote, respectively, the right, left, bottom, and top of the askiatic images for the white of the eye. The research was approved by The Institutional Review Board, Tsinghua University, and informed consent was obtained from all human subjects. The sample collection was carried out in Shanghai Sixth People's Hospital and China Meitan General Hospital, and the subjects were the patients of these hospitals with spleen deficiency, kidney deficiency, liver deficiency, gallbladder diseases and so on.

Figure 4(b) shows an eye-feature image taken with a wide-field imaging method, where the reflection shadow of the illumination source overlaps the white of the eye and interferes analysis to the items on the white of the eye. Figure 4(c) shows an image using a slit lamp, in which only a narrow band can be viewed. Although the reflection shadow of the illumination source does not overlap the viewable section, an additional scan of slit light is required to acquire all items in the white of the eye.

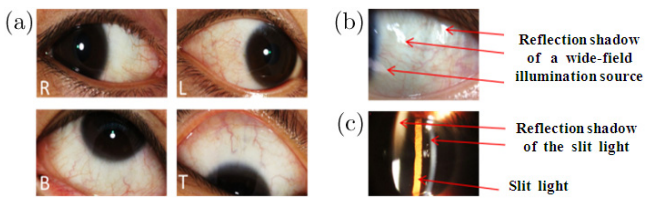

Fig. 4. Eye-feature images taken by different imaging methods: (a) askiatic imaging, (b) eyeball wide-field imaging, and (c) slit-lamp imaging.

Comparing the images of Fig. 4(a) to those of Figs. 4(b) and 4(c), the advantage of the askiatic imaging method is its freedom from reflection shadows of the illumination source. All eye-feature characteristics can be analyzed using the images from four directions without complex manipulation such as image splicing.

Figure 5 shows the eye-feature images taken by askiatic imaging, where the red frames denote the eye-feature in regions corresponding to different viscera. Figure 5(a) is the eye-feature image of normal people, where the white of the eye is clean, and the blood vessels are clear.

If there is some lesion in the spleen resulting in blood oxygen concentration decreased, the blood vessels will be dark red, because there is a close relationship between eye-feature and viscera, the blood vessels on the white of the eye will be dark red. Figure 5(b) is the eye-feature image of spleen deficiency patients who have clinical symptoms such as asthenic fever and malaise, and the condition of patients deteriorates from left to right. It is obvious that the blood vessels on the region of the white of the eye corresponding to spleen are dark

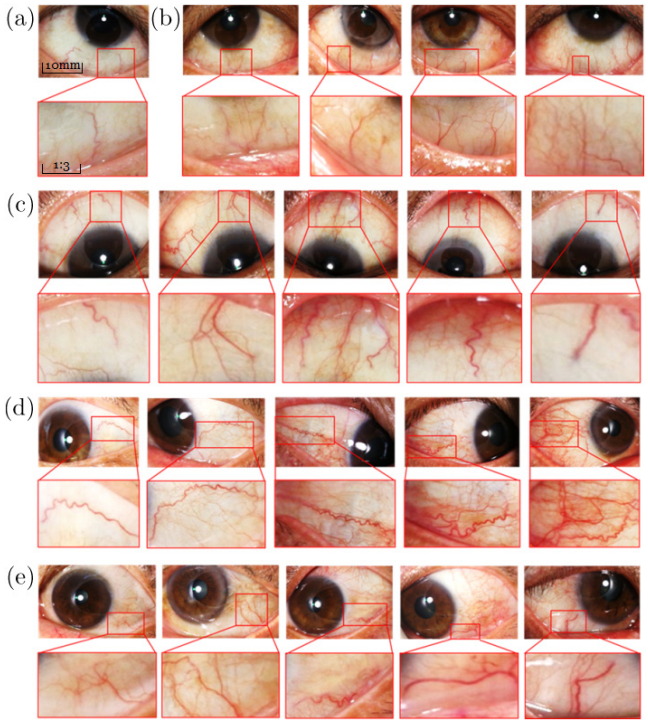

Fig. 5. Eye-feature images of (a) normal people, (b) spleen deficiency patients, (c) kidney deficiency patients, (d) patients with gallbladder diseases, and (e) liver deficiency patients.

red. This is in accordance with the eye-feature diagnosis theory.

If there is some lesion in the kidney which results in blood stasis, the blood vessels will be thick, because there is a close relationship between eye-feature and viscera, the blood vessels on the white of the eye will be thick. Figure 5(c) is the eye-feature of patients with kidney deficiency, who have aching lumbus and knees, and the condition of patients deteriorates from left to right. The blood vessels on the region of the white of the eye corresponding to kidney are thick. The width of the blood vessel in Fig. 5(a) is about 0.132 mm, which is the eye-feature image of normal people, and the width of the blood vessel in Fig. 5(c) from left to right is 0.154 mm, 0.173 mm, 0.198 mm, 0.223 mm and 0.241 mm, respectively, which are the eye-feature images of kidney deficiency patients. The results above were analyzed by image processing software ImageJ.

If there is some lesion in the gallbladder resulting in blood stasis and stagnation, the blood vessels will be curved, because there is a close relationship between eye-feature and viscera, the blood vessels on the white of the eye will be curved. Figure 5(d) displays the eye-feature of patients who have gallbladder diseases, with the clinical symptoms such as dizziness, drowsiness and cephalagra, and the condition of patients deteriorates from left to right. The blood vessels on the section on the white of the eye corresponding to gallbladder are curved.

If there is some lesion in the liver resulting in anemia and deficiency, the blood vessels will be ischemia with no vessel roots, because there is a close relationship between eye-feature and viscera, the blood vessels on the white of the eye will be ischemia with no vessel roots. Figure 5(e) is the eye-feature of liver deficiency patients, who have the clinical symptoms such as nerves and fear, and the condition of patients deteriorates from left to right. The vessel roots of the blood vessels on the section of the white of the eye are insufficiency.

From the results above, it is obvious that there is a close relationship between eye-feature and visceral diseases, for example, the spleen deficiency patients' blood vessels on the spleen region are dark red, the kidney deficiency patients' blood vessels on the kidney region are thick, the blood vessels on the gallbladder region of patients with gallbladder diseases are curved, and the liver deficiency patients' vessel roots on the liver region are insufficient. What's more, as the condition of patients gets worse, the variation of eye-feature will be more serious. So, the health status of patients can be known from their eye-feature, and the condition of diseases could be tracked by observing the eye-feature continuously, which will assist doctors with diagnosis.

4. Conclusion and Discussion

Eye-feature diagnosis is a time-honored method for studying many diseases in traditional Chinese medicine, and there is a close relationship between eye-feature and viscera. The health status of viscera can be reflected on the corresponding regions of the white of the eye. By analyzing the characteristics in the image (such as blood vessels, spots, and fog), we can determine whether there are lesions on the corresponding viscera.

The novel askiatic imaging method used in Chinese medicine eye-feature diagnosis of visceral diseases we proposed creates a paradigm for future studies of ophthalmology, precision eye-feature diagnosis from traditional Chinese medicine and novel instrument development. Because traditional Chinese medicine depends on the doctors' observation and experience, there are usually some accidental errors. Our method can avoid such errors, and it will contribute to telemedicine and personalized medicine.

The novel askiatic imaging system for eye-feature diagnosis *in vivo* that we developed can capture a askiatic image of the white of the eye, and promote the development of automation and precision of the Chinese medicine eye-feature health analysis. The image is free from the interference of the illumination source's reflection shadow and does not require complex manipulations such as image splicing. The system can acquire all characteristics in the white of the eye with high quality, and is time-saving.

For further research, we will focus on capturing an overall image of the white of the eye with fewer procedural steps and making large database for automatic eye-feature diagnosis. This will acquire more information and save more imaging time. We will attempt to track the characteristic variations resulting from viscera diseases to judge the pathology changes of viscera and make precision eye-feature diagnosis for the application of traditional Chinese medicine to health.

Conflict of Interest

No conflicts of interest, financial or otherwise, are declared by the authors.

Acknowledgments

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