Screening for Diabetic Retinopathy in Rural Area Using Single-Field, Digital Fundus Images

Paisan Ruamviboonsuk, MD*,
Nattapon Wongcumchang, MD*, Pattamaporn Surawongsin, MD**,
Ekchai Panyawatananukul, MD***, Montip Tiensuwan, PhD****

** Department of Ophthalmology, Rajavithi Hospital*
*** Department of Ophthalmology, Lerdsin Hospital*
**** Director of Kabcheang Community Hospital, Surin*
***** Department of Mathematics, Faculty of Science, Mahidol University*

Objective: *To evaluate the practicability of using single-field, 2.3 million-pixel, digital fundus images for screening of diabetic retinopathy in rural areas.*
Material and Method: *All diabetic patients who regularly attended the diabetic clinic at Kabcheang Community Hospital, located at 15 kilometers from the Thailand-Cambodia border, were appointed to the hospital for a 3-day diabetic retinopathy screening programme. The fundi of all patients were captured in single-field, 45 , 2.3 million-pixel images using nonmydriatic digital fundus camera and then sent to a reading center in Bangkok. The fundi were also examined through dilated pupils by a retinal specialist at this hospital. The grading of diabetic retinopathy from two methods was compared for an exact agreement.*
Results: *The average duration of single digital fundus image capture was 2 minutes. The average file size of each image was 750 kilobytes. The average duration of single image transmission to a reading center in Bangkok via satellite was 3 minutes; via a conventional telephone line was 8 minutes. Of all 150 patients, 130 were assessed for an agreement between dilated fundus examination and digital fundus images in diagnosis of diabetic retinopathy. The exact agreement was 0.87, the weighted kappa statistics was 0.74. The sensitivity of digital fundus images in detecting diabetic retinopathy was 80%, the specificity was 96%. For diabetic macular edema the exact agreement was 0.97, the weighted kappa was 0.43, the sensitivity was 43%, and the specificity was 100%.*
Conclusion: *The image capture of the nonmydriatic digital fundus camera is suitable for screening of diabetic retinopathy and single-field digital fundus images are potentially acceptable tools for the screening. The real-time image transmission via telephone lines to remote reading center, however, may not be practical for routine diabetic retinopathy screening in rural areas.*

Keywords: *Diabetic retinopathy screening, Digital screening, Nonmydriatic fundus camera*

J Med Assoc Thai 2005; 88(2): 176-80
Full text. e-Journal: *http://www.medassocthai.org/journal*

Diabetic retinopathy remains the most common cause of blindness in working adults around the world. Several cost-effectiveness analyses of screening for diabetic retinopathy have pointed out that screening for diabetic retinopathy can save vision at a relatively low cost, compared to the disability payments provided to people who would go blind without a screening[1-4]. Recently a number of studies have introduced the usage of digital fundus images, either stereoscopic[5-7] or non-stereoscopic[8-11], multiple-field[5,7,8] or single-field[9,11-13], as an alternative to stereoscopic film-based fundus photography or clinical examination for diabetic retinopathy screening. Advantages of the system include electronic capturing, archiving and transmission to a remote reading center

Correspondence to : Ruamviboonsuk P, Department of Ophthalmology, Rajavithi Hospital, Bangkok 10400, Thailand. E-mail: paisan_ru@rcopt.org

where experienced ophthalmologists can review the images to detect the presence and severity of diabetic retinopathy[14-17]. It would be very helpful if the digital system could be accessed by diabetic patients who live in rural areas where ophthalmologists cannot provide adequate retinopathy screening.

The present study evaluates practical aspects of the digital image system for screening of diabetic retinopathy at a primary care unit in a rural area. An agreement between interpretation of digital fundus images and dilated fundus examination in the diagnosis of diabetic retinopathy is also evaluated. The main outcome measures include the duration of single digital fundus image capture, the file size of each image, the duration of image transmission to remote reading center in Bangkok, and the weighted kappa statistics for evaluating an agreement between digital fundus images and dilated fundus examination for diabetic retinopathy screening.

Material and Method

This study was approved by the Ethical Committee on Researches Involving Human Subjects, Rajavithi Hospital and was conducted at Kabcheang Community Hospital located 15 kilometers from Thailand-Cambodia border. All diabetic patients who regularly attended the diabetic clinic at the hospital were appointed for a 3-day diabetic retinopathy screening programme. All patients were required to give informed consent. The fundi of all patients were captured using nonmydriatic digital fundus camera (Topcon TRC-NW100, Tokyo, Japan). The single-field, 45 , 2.3 million-pixel, digital fundus images including optic nerve and macular area were then sent via either satellite with uploading rate at 256 kilobytes per second or conventional telephone line with uploading rate at 56 kilobytes per second to a reading center in Bangkok where a retina specialist interpreted the images. After digital image capture 1% tropicamide and 10% phenylephrine eye drops were instilled to the patients for indirect ophthalmoscopy by another retina specialist. The retina specialist could also use a slit lamp with contact lens for detailed fundus examination in some cases. The diagnosis of diabetic retinopathy level for each patient was made upon the eye with more severity on the basis of clinical examination. The diabetic retinopathy level interpreted from digital images of the same eye was then used for assessing agreement between each method. The levels of diabetic retinopathy were classified according to a standard text book[1].

Results

The demographic characteristics of the patients are shown in Table 1. The majority of the participants were between 41-60 years old and had had diabetes for 1-5 years. Of all 150 patients, 130 had digital fundus images clear enough to assess an agreement with dilated fundus examination. Of 20 patients whose digital fundus images could not be used for evaluating the agreement with dilated fudus examination, 11 patients could be diagnosed by the examination as no diabetic retinopathy, 2 patients could be diagnosed as mild and another as moderate nonproliferative diabetic retinopathy. There were 6 patients in whom either screening method could not diagnose the diabetic retinopathy levels due to dense cataracts, corneal scars, and glaucoma.

The modal value of the duration of a single digital fundus image capture was 50 seconds, the mean value was 2 minutes ranging from 20 seconds to 4 minutes. The mean file size of each 2.3 million-pixel image was 750 kilobytes (ranging 620-905). The mean duration of single image transmission to a reading center in Bangkok via satellite was 3 minutes (ranging 1-4), and via a conventional telephone line was 8 minutes (ranging 3-15). Some images could not be uploaded via telephone line at all due to timeout error.

The exact agreement of diagnosis of diabetic retinopathy level between digital fundus images and dilated fundus examination was 0.87, the weighted kappa statistics was 0.74. The sensitivity of digital fundus images in detecting diabetic retinopathy was 0.8, the specificity was 0.96 (Table 2). The agreement for diabetic macular edema is shown in Table 3. There were 7 cases of macular edema from stereoscopic clinical examination using contact lens with slit lamp but there were only 3 cases from single-field digital fun-

Table 1. Demographic Characteristics of Patients

	Number (%)
Age	
20-40 years old	9 (0.06)
41-60 years old	82 (54.7)
> 60 years old	59 (45.2)
Gender	
Male	38 (25)
Female	112 (75)
Duration of diabetes	
< 1 year	8 (0.05)
1-5 years	68 (45.3)
6-10 years	52 (34.7)
> 10 years	22 (19.95)

Table 2. Agreement between Dilated Fundus Examination and Digital Fundus Images for Diabetic Retinopathy Level

	Dilated Fundus Examination					
	No DR	Mild	Mod	Severe	PDR	HR
Digital Images						
No DR	91	7				
Mild	4	20	4			
Mod		1	2			
Severe						
PDR						1
HR						

Exact agreement: 0.87, Weighted kappa: 0.74, Sensitivity: 80%, Specificity: 96%
DR = diabetic retinopathy, Mild = mild nonproliferative diabetic retinopathy, Mod = moderate nonproliferative diabetic retinopathy, Severe = severe nonproliferative diabetic retinopathy, PDR = proliferative diabetic retinopathy, HR = high-risk proliferative diabetic retinopathy

Table 3. Agreement between Dilated Fundus Examination and Digital Fundus Images for Clinically Significant Macular Edema

	Dilated Fundus Examination	
	No CSME	CSME
Digital Images		
No CSME	123	4
CSME	0	3

Exact agreement: 0.97, Weighted kappa: 0.43, Sensitivity: 43%, Specificity: 100%
CSME = clinically significant macular edema

dus images. Although the exact agreement was 0.97 the weighted kappa statistics was only 0.43, the sensitivity was 43%, and the specificity was 100%. There were 5 patients whose digital images could detect retinopathy in more severity than clinical examination and there were 12 patients whose images could detect retinopathy in less severity than clinical examination.

Discussion

The image capture of nonmydriatic digital fundus camera is practical with less than 1 minute duration of taking a single fundus image in most patients and the process is easy to learn. The image file saved in JPEG format is not too large for high-speed electronic transmission. However, it takes 3 minutes to upload a 750-kilobyte JPEG file although it should theoretically take only a few seconds to upload at 256 kilobytes per second rate as in the present study. This happened because of relay signals of satellite transmission. The duration of image transmission via conventional telephone line is too long and should not be acceptable for real-time transmission on a routine basis.

The mode of remote digital data transmission may be divided into "real-time" and "store-and-forward" categories [2]. Each mode may also be divided into "wire" and "wireless" mode. The "wire" mode includes transmission via conventional telephone lines or high-speed Asymmetrical Digital Subscription Line which is easier to set up but the line must be fixed to a location. The "wireless" mode can transmit data via wireless computer servers or satellites. Although using a satellite makes the operated location flexible a technician is required to set up equipment and find satellite signals in every new location.

In fact, real-time tele-screening for diabetic retinopathy may not be necessary. All the images can be saved in a CD-ROM then the disc can be sent to an ophthalmologist by any means. The ophthalmologist can review the images and results can be sent back to the rural area shortly thereafter.

The high agreement, high sensitivity and specificity of digital fundus images in detecting diabetic retinopathy could be reached in the present study even though the retina specialists who made a diagnosis of diabetic retinopathy levels by clinical examination and by interpreting digital fundus images were different. The rate of agreement is comparable to other studies[9,11-13]. In the present study dilated fundus examination was chosen to compare with digital images instead of standard 7-field stereoscopic fundus photography[19] because clinical examination, not the 7-field photography, is routinely employed in screening of diabetic retinopathy. The 7-field photography is not practical and may not be necessary for classification of diabetic retinopathy[20].

The agreement and sensitivity for digital images in detecting diabetic macular edema was poor. This probably occurred because of too small sample size of diabetic macular edema in the present study. The detection of diabetic macular edema using digital fundus images was also poor in another study[8] unless stereoscopic application was employed[6]. Therefore, all patients showing hard exudate in the macular region of digital fundus images should be referred to an ophthalmologist if confirmation with stereoscopic methods are not available. Due to the chance of having under-diagnosed diabetic retinopathy level (there were 12 patients whose digital images

were interpreted as retinopathy in less severity than clinical examination) referring all moderate nonproliferative or higher level of diabetic retinopathy to ophthalmologists is also recommended.

Since the present study was conducted in only one district of a rural province with limited sample size, a larger-scale study is needed and health economics analysis is also required before implementing this method as a model for national eye screening for diabetic retinopathy.

In conclusion, the image capture of the nonmydriatic digital fundus camera is suitable for screening of diabetic retinopathy. Digital fundus images are potentially acceptable tools for the screening, however, the real-time image transmission via telephone lines to a reading center may not be practical for screening of diabetic retinopathy in rural areas.

Acknowledgement

This study was supported by a research fund of Rajavithi Hospital grant number 38/2546. The authors have no financial interest in any products mentioned in this study.

References

1. American Diabetes Association. Diabetic retinopathy. Diabetes Care 2002; 25 (Suppl 1): S90-3.
2. Rubin RJ, Altman WM, Mendelson DN. Health care expenditures for people with diabetes millitus, 1992. J Clin Endocrinol Metab 1992; 78: 809A-809F.
3. Javitt JC, Canner JK, Sommer A. Cost effectiveness of current approaches to the control of retinopathy in type 1 diabetics. Ophthalmology 1989; 96: 255-64.
4. Javitt JC, Ferris FL III, Aiello LP, et al. Preventive eye care in people with diabetes is cost-saving to the federal government. Diabetes Care 1994; 17: 909-17.
5. Cavallerano AA, Cavallerano JD, Katalinic P, et al. Use of joslin vision network digital-video nonmydriatic retinal imaging to assess diabetic retinopathy in a clinical program. Retina 2003; 23: 215-23.
6. Rudnisky CJ, Hinz BJ, Tennant MTS, et al. High-resolution stereoscopic digital fundus photography versus contact lens biomicroscopy for the detection of clinically significant macular edema. Ophthalmology 2002; 109: 267-74.
7. Buresell SE, Cavallerano JD, Cavallerano AA, et al. Stereo nonmydriatic digital-video color retinal imaging compared with early treatment diabetic retinopathy study seven standard field 35-mm stereo color photos for determining level of diabetic retinopathy. Ophthalmology 2001; 108: 572-85.
8. Lim JI, LaBree L, Nichols T, et al. A comparison of digital nonmydriatic fundus imaging with standard 35-millimeter slides for diabetic retinopathy. Ophthalmology 2000; 107: 866-70.
9. George LD, Halliwell M, Hill R, et al. A comparison of digital retinal images and 35 mm colour transparencies in detecting and grading diabetic retinopathy. Diabet Med 1998; 15: 250-3.
10. Ryder REJ, Kong N, Bates AS, et al. Instant electronic imaging systems are superior to polaroid at detecting sight-threatening diabetic retinopathy. Diabet Med 1998; 15: 254-8.
11. Lin DY, Blumenkranz MS, Brothers R.J, et al. The sensitivity and specificity of single-field nonmydriatic monochromatic digital fundus photography with remote image interpretation for diabetic retinopathy screening: a comparison with ophthalmoscopy and standardized mydriatic color photography. Am J Ophthalmol 2002; 134: 204-13.
12. Maberley D CA, Barile G, Slakter J,. Digital photographic screening for dibetic retinopathy in the James Bay Cree. Ophthalmic Epidemiol 2002; 9: 169-78.
13. Herbert HM, Jordan K, Flanagan DW. Is screening with digital imaging using one retinal view adequate? Eye 2003; 17: 497-500.
14. Gomez-Ulla F, Fernandez Maria I, Gonzalez F, et al. Digital retinal images and teleophthamology for detecting and grading diabetic retinopathy. Diabetes Care 2002; 25: 1384-9.
15. Marcus DM, Brooks SE, Ulrich LD, et al. Telemedicine diagnosis of eye disorders by direct ophthalmoscopy a pilot study. Ophthalmology 1998; 105: 1907-14.
16. Shanit D, Lifshitz T, Giladi R, et al. A pilot study of tele-ophthalmology outreach services to primaey care. J Telemed Telecare 1998; 4(Suppl 1): 1-2.
17. Li HK. Telemedicine and ophthalmology. Surv Ophthalmol 1999; 44: 61-72.
18. Chew EY, Ferris FL III. Nonproliferative diabetic retinopathy. In: Ryan SJ, ed. Retina, 3rd ed. St Louis: Mosby Inc., 2001; 2: 1295-308.
19. Early Treatment Diabetic Retinopathy Study Research Group. Grading diabetic retinopathy from steroscopic color fundus photographs-an extension of the modified Airlie House classification ETDRS report no. 10. Ophthalmology 1991; 98(Suppl 5): 786-806.
20. Moss SE, Meuer SM, Klein R, et al. Are seven standard photographic fields necessary for classification of diabetic retinopathy? Invest Ophthalmol Vis Sci 1989; 30: 823-8.

การคัดกรองผู้ป่วยเบาหวานเข้าจอตาในเขตชนบทโดยใช้ภาพดิจิตอลที่ถ่ายจากบริเวณเดียวของจอตา

ไพศาล ร่วมวิบูลย์สุข, ณัฐพล วงษ์คำช้าง, ปัฐมาภรณ์ สุรวงษ์สิน, เอกชัย ปัญญาวัฒนานุกูล, มนต์ทิพย์ เทียนสุวรรณ

วัตถุประสงค์: *เพื่อประเมินความเป็นไปได้ในเชิงปฏิบัติ ของการใช้ภาพดิจิตอลขนาด 2.3 ล้านพิกเซล ถ่ายจากบริเวณเดียวของจอตา ในการคัดกรองภาวะเบาหวานเข้าจอตาในพื้นที่ชนบท*

วัสดุและวิธีการ: *ทำการศึกษาในกลุ่มผู้ป่วยเบาหวานจากคลินิกเบาหวานของโรงพยาบาลกาบเชิง จังหวัดสุรินทร์ ซึ่งตั้งอยู่ห่างจากชายแดนไทย-กัมพูชา 15 กิโลเมตร ผู้ป่วยทั้งหมดจะได้รับการถ่ายภาพจอตาด้วยกล้องถ่ายภาพระบบดิจิตอลแบบไม่ต้องขยายม่านตา ซึ่งให้ภาพขนาด 2.3 ล้านพิกเซล ภาพดิจิตอลทั้งหมดจะถูกส่งต่อเพื่ออ่านผลทันทีในกรุงเทพมหานคร จากนั้นผู้ป่วยจะได้รับการขยายรูม่านตาและการตรวจจอตาโดยจักษุแพทย์ผู้เชี่ยวชาญด้านจอตา ทำการศึกษาเปรียบเทียบผลการวินิจฉัยภาวะเบาหวานเข้าจอตาจากทั้ง 2 วิธีเพื่อประเมินความเห็นพ้องกัน*

ผลการศึกษา: *การถ่ายภาพจอตาระบบดิจิตอลใช้เวลาเฉลี่ย 2 นาทีต่อภาพ ภาพดิจิตอลของจอตาหนึ่งภาพมีขนาดเฉลี่ย 750 กิโลไบต์ การส่งภาพดิจิตอลหนึ่งภาพเข้ามาที่ศูนย์อ่านภาพในกรุงเทพฯ ผ่านระบบดาวเทียมใช้เวลาเฉลี่ย 3 นาที ผ่านระบบสายโทรศัพท์ใช้เวลา 8 นาที มีผู้ป่วยเบาหวาน 130 คนจากผู้ป่วยเบาหวานในคลินิกทั้งหมด 150 คน สามารถได้รับการประเมินความเห็นพ้องกัน ระหว่างการใช้ภาพดิจิตอลของจอตา กับการตรวจจอตาด้วยการขยายม่านตาในการวินิจฉัยภาวะเบาหวานเข้าจอตา พบว่าค่า exact agreement เท่ากับ 0.87 ค่า weighted kappa เท่ากับ 0.74 มีความไว (sensitivity) เท่ากับ 80% ความจำเพาะ (specificity) เท่ากับ 96% สำหรับการวินิจฉัยจุดรับภาพบวมจากเบาหวาน (diabetic macular edema) พบว่าค่า exact agreement เท่ากับ 0.97 ค่า weighted kappa เท่ากับ 0.43 มีความไว เท่ากับ 43% ความจำเพาะ เท่ากับ 100%*

สรุป: *การถ่ายภาพจอตาระบบดิจิตอล จากกล้องที่ถ่ายได้โดยไม่ต้องขยายรูม่านตา เป็นวิธีที่ยอมรับได้ในการใช้คัดกรองภาวะเบาหวานเข้าจอตา การถ่ายภาพจอตาเพียงภาพเดียว จากตำแหน่งเดียว ก็อาจเพียงพอที่จะใช้ในการคัดกรอง การส่งภาพผ่านสายโทรศัพท์เพื่อให้การวินิจฉัยทันที ที่ศูนย์อ่านภาพที่อยู่ไกลออกไป อาจไม่เหมาะสมกับการคัดกรองภาวะนี้อย่างสม่ำเสมอในเขตชนบท*