Content Design and System Implementation of a Teleophthalmology System for Eye Disease Diagnosis and Treatment and Its Preliminary Practice in Guangdong, China

Original Research

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Abstract

Background: *We have developed a new telemedicine system for comprehensive eye examination, diabetic retinopathy (DR) screening, and eye disease diagnosis and treatment. The novel points of the system include a tablet application for facilitating doctor's examination and diagnosis process, a comprehensive eye examination component, and integrated treatment planning and recording.*
Methods: *The system provided a new service model through one ophthalmological center linking with multiple remote and rural hospitals for eye care in Guangdong province, China.*
Results: *The early stage of the project study also undertook the responsibility of educations for remote-area doctors and image graders for DR grading and glaucoma grading and research on the effectiveness of short message service (SMS) reminder for patient revisit. Some other research, such as the comparison of the accuracy of graders' DR grading with the gold standard, and doctor's tentative diagnosis with final diagnosis and related statistical information, has been implemented in the system. In the preliminary practice, we summarized the outcomes related to presenting system performance and made an initial analysis.*
Conclusion: *From the practice, the project has shown the telemedicine system and associated contents have satisfied our initial goal and demonstrated their effectiveness and efficiency.*

Keywords: *teleophthalmology, diabetic retinopathy, glaucoma, comprehensive eye examination*

Introduction

Diabetic retinopathy (DR), is one of the major and long-term microvascular complications of diabetes. It is the most common cause of vision loss and blindness in working-age adults. According to the International Diabetes Federation, 415 million adults had diabetes in the world in 2015. If without effective actions, the number would rise to 642 million by 2040.[1] With the high prevalence of diabetes, the American Diabetes Association (ADA) and American Academy of Ophthalmology (AAO) recommended annual eye examination for Type I and Type II diabetes patients. Some early DR screening programs were developed and practiced in developed countries.[2–5]

In the past decade, the combination of telemedicine and digital retinal imaging technology was gradually applied in DR screening programs.[6–11] In the U.S., there have been several long-term and large-scale DR screening programs, which screened millions of people and achieved success, such as the U.S. Veterans Administration VistA program, EyePACS (University of California Berkley),[12,13] UPMC DR screening project (University of Pittsburgh Medical Center),[14] Joslin Vision Network Diabetes Eye Care Program (JVN),[7] and Innovative Network for Sight (INSIGHT).[15]

In France, "Ophdiat" diabetes telemedicine network created in the Île-de-France area in 2004[16] was a successful one.[17,18] In The Netherlands, EyeCheck program was developed in 2000 for primary care offices.[19,20] The United Kingdom is one of the earliest countries starting DR screening programs nationwide.[21,22] The National Health Service (NHS) Diabetic Eye Screening Program (NDESP) has been providing to serve Scotland, Wales, England, and North Ireland in the past decades and achieved a nationwide uptake of 79%.[23,24] Literature reviews about the teleophthalmology projects, which focused on DR and/or other eye diseases, can be referred in the literature.[25–27]

In the past decades, China became one of the regions with highly increased DR populations. It is estimated that in 2030, the number of diabetes patients would be 42 million.[28] Early DR screening for the populations is increasingly required in China. A first DR screening system in 2009 in China and its preliminary practice in community-based clinics had been reported.[29]

In this article, we present a new telemedicine system for comprehensive eye examination, DR and glaucoma grading, and other eye disease diagnosis and related treatment management. This project has been supported by the World Diabetes Foundation (WDF) and ORBIS. The project aimed at providing a telemedicine-based service model for rural and remote patients' eye care based on local hospital settings. The project also aimed at training remote doctors and DR image graders for the improvement of DR image grading and conducting some related research. This article presents the content design and implementation of the telemedicine system for meeting the above goals.

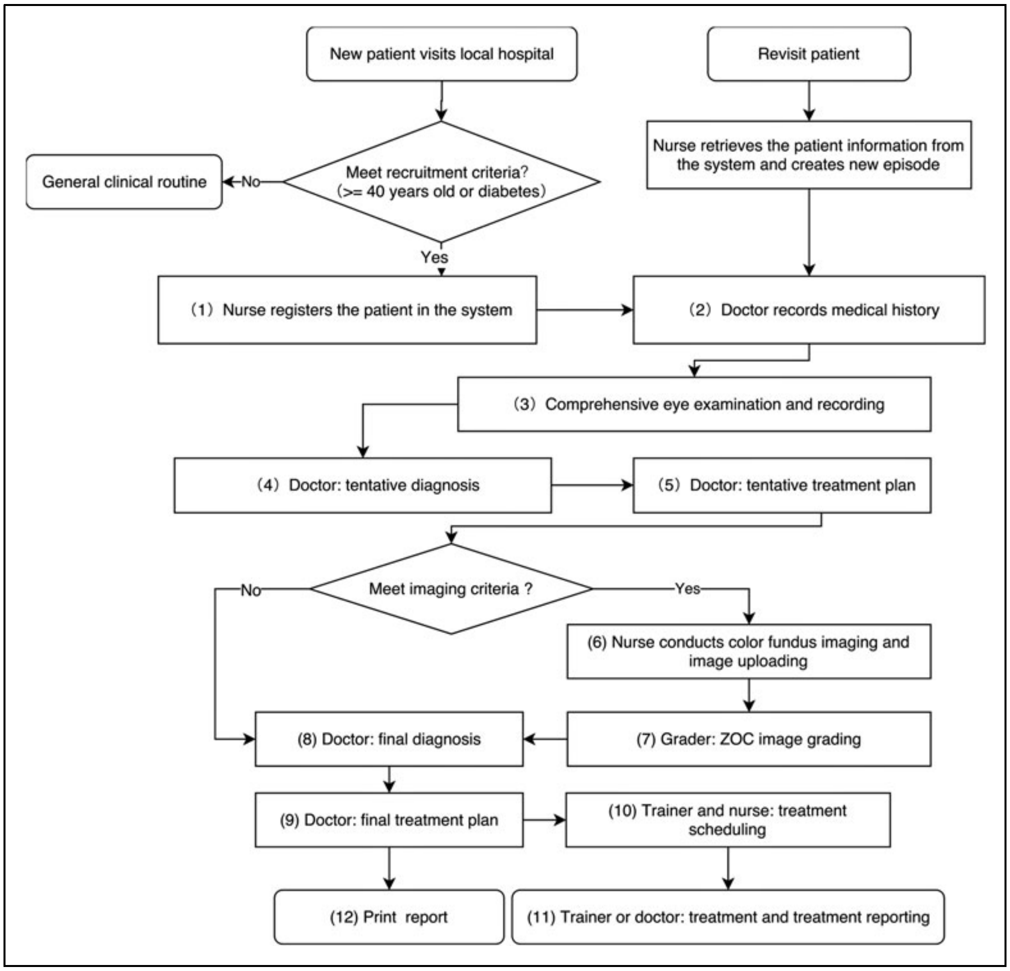

Fig. 1. System's main workflow.

Materials and Methods

The goal of the project was to develop a teleophthalmology system centered at Zhongshan Ophthalmic Center (ZOC) and linking with 10 remote or rural hospitals in Guangdong province for providing DR and glaucoma grading (at ZOC), comprehensive eye examination, and eye disease diagnosis and treatment at local hospitals.

MAIN WORKFLOW

A main teleophthalmology workflow for conducting the procedure from patient registration to the diagnosis or treatment was designed according to the goal of the project (*Fig. 1*). When a patient visits a local hospital at his/her first time, he/she would be registered in the system if meeting the project's recruitment criteria. A registration nurse would input the patient's demographics in a new patient episode in the teleophthalmology system (main workflow [MW]-step [1]). After the registration, the patient's name would be displayed in a waiting list page. Once a doctor selected the patient from the system, the doctor first needs to query and record the patient's medical symptoms (MW-step [2]). Then the doctor could instruct the patient to complete some necessary examining items listed in the comprehensive eye examination and record the results (MW-step [3]). Based on them, the doctor could make tentative diagnosis and treatment plan for the patient (MW-steps [4] and [5]). If the patient meets the project's imaging selection criteria, he/she would be sent for retinal image scan (MW-step [6]). The system would automatically transmit the patient's images to the ZOC grading center for image grading (MW-step [7]). After the grading result is sent back, the doctor could view the image grading result and use it as a reference to make the final diagnosis and treatment plan (MW-steps [8] and [9]). If the patient is scheduled for laser photocoagulation or eye surgery, the registration nurse would coordinate with the doctor and ZOC trainers for making a treatment schedule (MW-step [10]). A scheduled treatment would be performed and a treatment record would be filed and signed (MW-step [11]).

IMAGE GRADING AND WORKFLOW

A ZOC DR grading workflow was designed and implemented in the system (*Fig. 2*) by referring to the DR grading standard from the United Kingdom National Screening Committee (UK NSC). The workflow used two image graders (grader 1 and grader 2, according to back-to-back grading

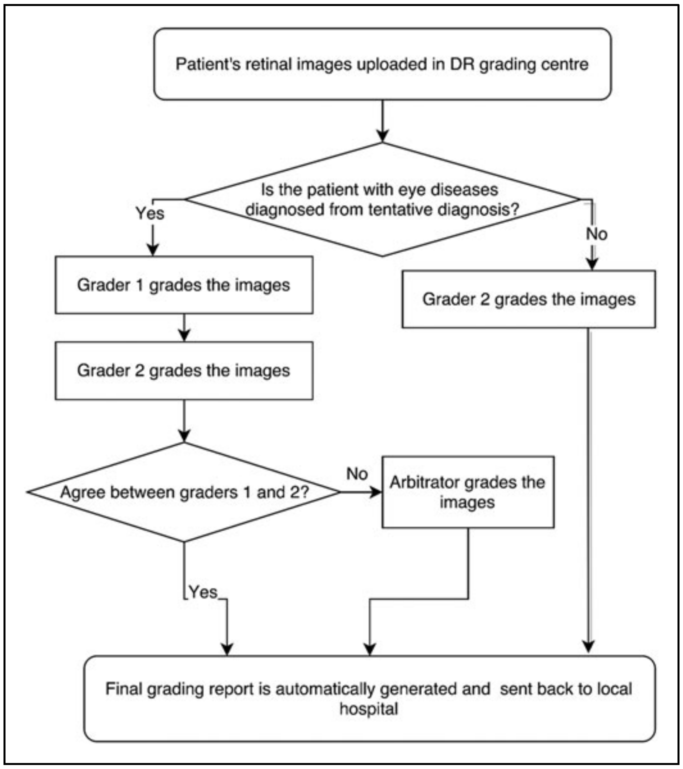

Fig. 2. Image grading workflow.

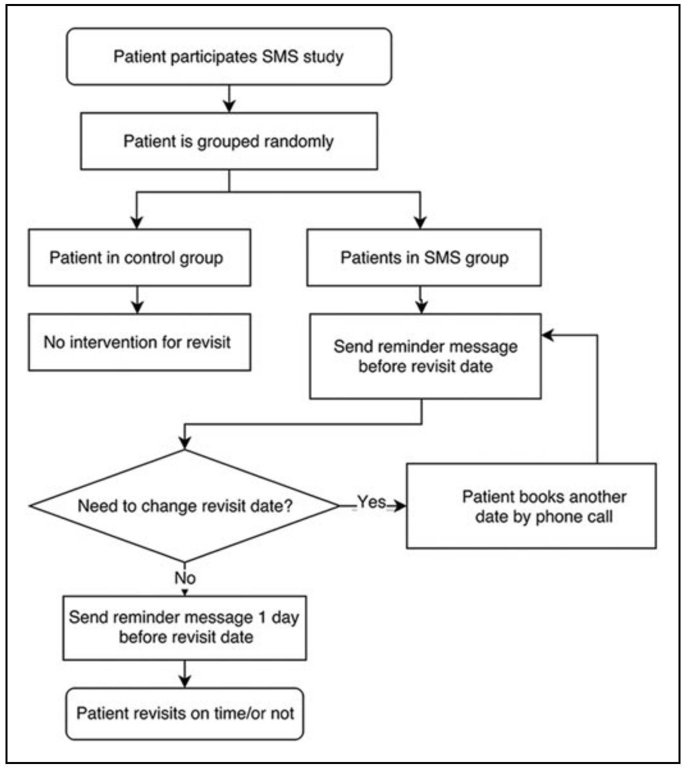

Fig. 3. Patient SMS reminder workflow. SMS, short message service.

rule) and one arbitrator (ophthalmologist) in the process of image grading on each patient.

SMS STUDY AND WORKFLOW

A SMS study component was implemented to aim at evaluating the efficiency of SMS function for reminding patient revisit (*Fig. 3*). After completing a tentative treatment plan (MW-step [5]), the doctor should answer several questions (related to SMS selection criteria) promoted by the system to decide if the patient would be eligible for joining the project's SMS study. In each hospital, the patients joining the study would be automatically assigned into a control group or a SMS group based on an independent randomization table. The patients in the SMS group would be sent mobile message reminders.

TREATMENT SCHEDULING AND TREATMENT WORKFLOW

A treatment scheduling and treatment workflow was designed (*Fig. 4*). The workflow needs collaboration between the ZOC trainers and local hospital doctors. The treatment schedule would be displayed in the system's calendar component, which could be scheduled and viewed by the corresponding nurses, doctors, and trainers. After finishing the treatment, the trainers or doctors in charge of the treatment need to complete an online treatment report.

SELECTION CRITERIA

Key selection criteria and rules were designed in the project:

1. Selection criteria for recruiting patients in the project: patients need to meet either: (1) with age equal and greater than 40 years; or (2) with diabetes.
2. Selection criteria for patient retinal imaging: patients need to be: (1) diagnosed with eye diseases and the doctors decide the patient's need for retinal imaging; or (2) if diagnosed without eye diseases but selected randomly by the system (10% chance) for retinal imaging; and (3) patients should agree to participate in retinal imaging.
3. Selection criteria for revisit SMS study: patients need to meet: (1) with diabetes; or (2) be found with DR signs by tentative diagnosis; and (3) patients and his/her caregivers should have mobile contact numbers.
4. Rule of sending SMS reminder: (1) a reminder SMS is sent 3 days before a revisit; (2) a second reminder SMS is sent one day before the revisit; (3) the messages will be sent to both the patient and his/her caregiver registered in the system.

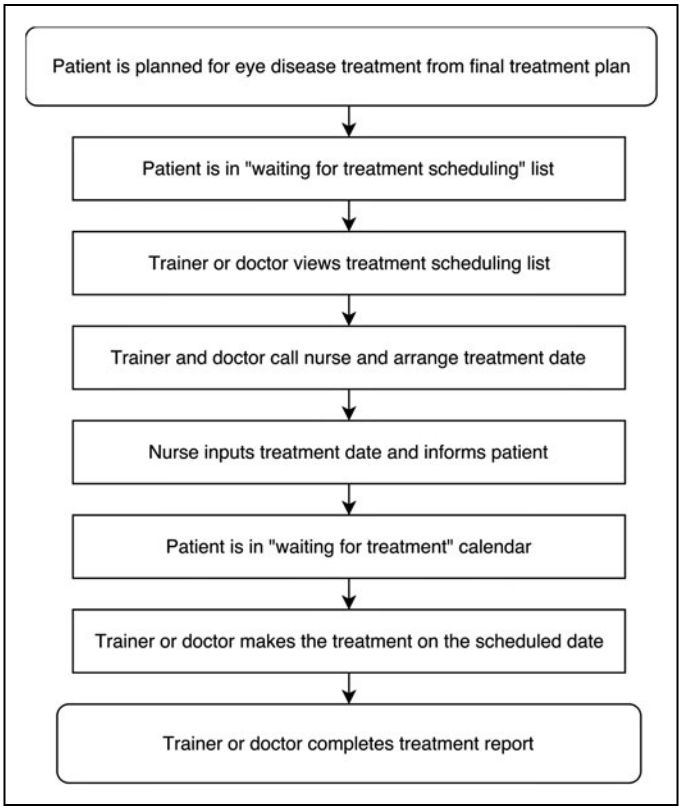

Fig. 4. Treatment scheduling and treatment workflow.

Table 1. Patient Medial History

Main symptoms	Visual symptoms (25 items: decreased vision, distorted vision, etc.)
	Sensory symptoms (19 items: eye pain, headache, etc.)
	Self-discovered symptoms (13 items: yellow–white discharge, etc.)
Associated symptoms	Nervous system (4 items: dizziness, etc.)
	Fever (1 item: fever.)
	Eye-nose-throat (ENT) (7 items: earache, tinnitus, etc.)
	Digestive system (3 items: vomit, etc.)
	Immune system (2 items: arthralgia, etc.)
	Skin (7 items: itchy skin, etc.)
Causes	Eleven items (Electrical injury etc.)
Intraocular laser	Nine items (Glaucoma:YAG Laser peripheral iridotomy, etc.)
Eye surgery history	Glaucoma (4 items: glaucoma surgery, etc.)
	Cataract (3 items: cataract surgery, etc.)
	Ocular fundus disease (6 items: vitrectomy, etc.)
	Strabismus surgery (1 item: strabismus surgery.)
	Orbital tumors and ocular surface surgery (10 items: eyelid surgery, etc.)
	Ocular trauma surgery (9 items: keratoplasty, etc.)
Ophthalmic history	Four items (Cataract, DR, etc.)
Systemic history	Seven items (diabetes, hypertension, etc.)
Family history	Eleven items (diabetes, heart disease, etc.)

DR, diabetic retinopathy.

CONTENT DESIGN

All contents in the phases of patient medical history, eye examination, disease diagnosis, image grading, and treatment were carefully designed and implemented in the telemedicine system. Under each phase, the contents were divided into different categories with concrete items.

The following tables give a summary of the contents and categories. *Table 1* lists the categories and subcategories contained in patient medical history. In this phase, the system enables the doctors to record a patient's medical information. *Table 2* lists all the categories for eye examination and related comprehensive symptom items. In this phase, the system enables the doctors to record a patient's eye examination results by easily selecting specific items. The phases of tentative and final diagnoses provide diagnostic result recordings. *Table 3* lists the contents. The phase of ZOC grading provides grading result recordings for DR, diabetic macular edema, history of photocoagulation, glaucoma probability (refer to the DR grading section in *Table 3*), and image quality evaluation. *Table 4* lists the contents in the treatment plan phase. If a patient needs laser or surgery treatment, the ZOC trainers or local hospital doctors can record the laser photocoagulation and eye surgery settings in the treatment phase. *Table 5* gives the contents. *Table 6* lists the contents of statistical report component, designed for research purpose.

EDUCATION FUNCTION

In the system, there were several components designed for educational purpose. The first one was the structure of two separate diagnostic steps—tentative diagnosis and treatment plan and subsequent final ones. During the process (MW steps [4], [5], [8], and [9]), the doctors could learn DR grading approach on color fundus images by referring to the ZOC's grading results and the standard DR images provided in the system. Another educational module was in the ZOC grading process. The two graders from ZOC needed to grade the images by a back-to-back rule. The arbitrator would then take the responsibility for guiding the graders reviewing the

Table 2. Comprehensive Eye Examination

Vision and IOP	Uncorrected visual acuity
	Pinhole vision
	Corrected visual acuity
	Intraocular pressure
Pupil examination	Seven items (Pupil shift, etc.)
Eye movement	Text input
Slit lamp examination	External eye (25 items: eyelid edema, etc.)
	Conjunctiva Sclera (24 items: conjunctival hyperemia, etc.)
	Cornea (29 items: corneal edema, etc.)
	Anterior chamber (8 items: Anterior chamber opacity, etc.)
	Iris (6 items: iris atrophy, etc.)
	Lens (8 items: transparent, etc.)
Gonioscopy	Static: 90° above pigmented trabecular meshwork
	Dynamic
	Angle neovascularization
Fundus examination	Mydriasis (Yes/no)
	Vitreous body (7 items: vitreous organization, etc.)
	C/D Optic disc and cup (12 items: edema, notch, etc.)
	C/D Ratio
	Macula (8 items: edema, etc.)
	Retinal vascular (32 items: retinal neovascularization, etc.)
Others	Text input

C/D, cup/disc; IOP, intraocular pressure.

Table 3. Diagnostic Results

Cataract	Twelve items (age-related cataract, etc.)
Glaucoma probability	Three single options
	Unlikely to be glaucoma
	Probably to be glaucoma
	Most likely to be glaucoma
Glaucoma	Primary open-angle glaucoma (1 item: Primary open-angle glaucoma)
	Primary angle-closure glaucoma (2 items: Acute angle-closure glaucoma, Chronic angle-closure glaucoma)
	Secondary glaucoma (15 items: traumatic open-angle glaucoma, etc.)
	Others (6 items: Physiologic large cup, etc.)
DR	DR (Single option)
	R0: no DR
	R1: DR (background)
	R2: DR (NPRD)
	R3a: active PDR
	R3s: stable PDR
	Diabetic macular edema (single option)
	M0: no diabetic macular edema
	M1: diabetic macular edema
Photocoagulation history	Yes/no
Ametropia	Five items (myopia, hyperopia, etc.)
Eye injury	(Text input)
Inflammation	Four items (Conjunctivitis, uveitis, etc.)

DR, diabetic retinopathy; NPDR, non-proliferative diabetic retinopathy; PDR, proliferative diabetic retinopathy.

inconsistent grading results and educating them on the correct DR levels. In the treatment process, the ZOC trainers could provide treatment support and guide the local hospital doctors for laser treatment and eye surgery.

SYSTEM ARCHITECTURE AND SOFTWARE DEVELOPMENT

Based on the above workflows and contents, a system architecture was implemented to meet the project's requirements. The architecture consisted of several main components: imaging camera, server system, web-based application, and tablet app.

The server system adopted distributed server model. In each local hospital, an independent work station with local web server and database server was built for storing all medical records and providing internet service, web-page service and web service. In the ZOC grading center, a central database server and web server were set up. The ZOC server system consisted of two synchronization frameworks for synchronizing all medical records and retinal images respectively, with 10 hospitals. Microsoft technology was used for the servers. Nonmydriatic fundus cameras were set up for image capturing and uploading in the hospitals.

There were two key software systems. A web-based application based on Microsoft .NET was developed for the nurses to complete all their tasks for patient registration and arrangement, etc. The same web-based application in ZOC server was used by image graders and arbitrators, ZOC trainers, researchers, and system administrators based on their roles in the system. Patient's medical records could be viewed or

Table 4. Treatment Plan

Medication	Text input
Optometry	Automatic refractometer
	Small pupil optometry
	Mydriasis optometry
Referral to mobile van	Reasons for mobile van (multiple options): (9 items: panretinal photocoagulation, etc.)
Surgery	Location of surgery:
	Doctors at local hospital for surgery
	ZOC trainers going to local hospital for surgery
	Referral to ZOC for surgery
	Type of surgery (43 items: Peripheral iridotomy, etc.)
Revisit	Revisit in 2–4 months
	Revisit in 6–12 months

ZOC, Zhongshan Ophthalmic Center.

Table 6. Statistical Report Component

CATEGORY	STATISTICAL DATA (NUMBER AND RATIO)
Usage of EMR system	Number of patients, archived patients, etc.
Comprehensive eye examination	Number of patients under each eye examination item.
Fundus imaging	Number of patients meeting imaging criteria; number of patients not participating in fundus imaging.
Diagnosis	Data reflecting the agreement/disagreement between tentative diagnosis and final diagnosis under each diagnostic item.
Image grading	Data reflecting the agreement/disagreement between grader 1 and 2 under each grading item.
Treatment plan	Number of patients for each treatment item.
SMS study	Number of patients for SMS group and control group.

SMS, short message service.

edited by the users according to the different diagnostic phases and the users' access roles. The main page of the web application was designed to contain all main functional components that facilitated the users to go through all states of a patient's diagnosis procedure and also easily access some specific function components.

A native android tablet app was developed targeting at only the doctors as users. The android app aimed at facilitating the doctors to record patient's symptoms and make diagnosis and treatment plan. The principle of the app development was to provide an easy graphical user interface (GUI) for the doctors accessing each diagnostic phase intuitively and provide fully listed optional items under each medical symptom and disease type for the convenience of user selection, rather than manual input. *Figure 5* illustrates the structure of the app, including three levels of functional pages and specific categories under each page.

Table 5. Treatment Records

Patient information	Patient id, name, contact number, hospital name, etc.
Diagnosis	Same content as in Table 3.
Type of treatment	1. Referral to mobile van
	• Treatment approach of laser photocoagulations
	• Photocoagulation parameter settings
	2. Surgery by local hospital doctor
	3. ZOC trainers at local hospital for surgery
	4. Referral to ZOC for surgery
	Under 2, 3, 4, multiple options for surgery type (42 items: glaucoma surgery, cataract surgery, etc.)

Doctor name: Signature: Date:

Results

LOCAL HOSPITAL CLINICAL ENVIRONMENT

Figure 6a shows a clinical environment in a hospital in Shaoguan, Guangdong province, where a nurse is registering a patient by using the web-based application in a desktop computer and a doctor is making his clinical diagnosis by using his tablet. *Figure 6b* shows a retinal imaging room, where an imaging nurse is scanning a patient's eyes for color fundus imaging.

WEB-BASED APPLICATION

Figure 7 illustrates the homepage of the teleophthalmology system (CREST EMR system). All functional components of the system are arranged in the homepage area. At the top right, there are six functional buttons for reporting, creating new patient, etc. Once a registration nurse clicks the "creating new patient" button for a new recruited patient, a pop-up window comes out and allows the nurse input the patient's personal information. After the new patient episode is created, the patient's name will be listed and displayed in the first tab

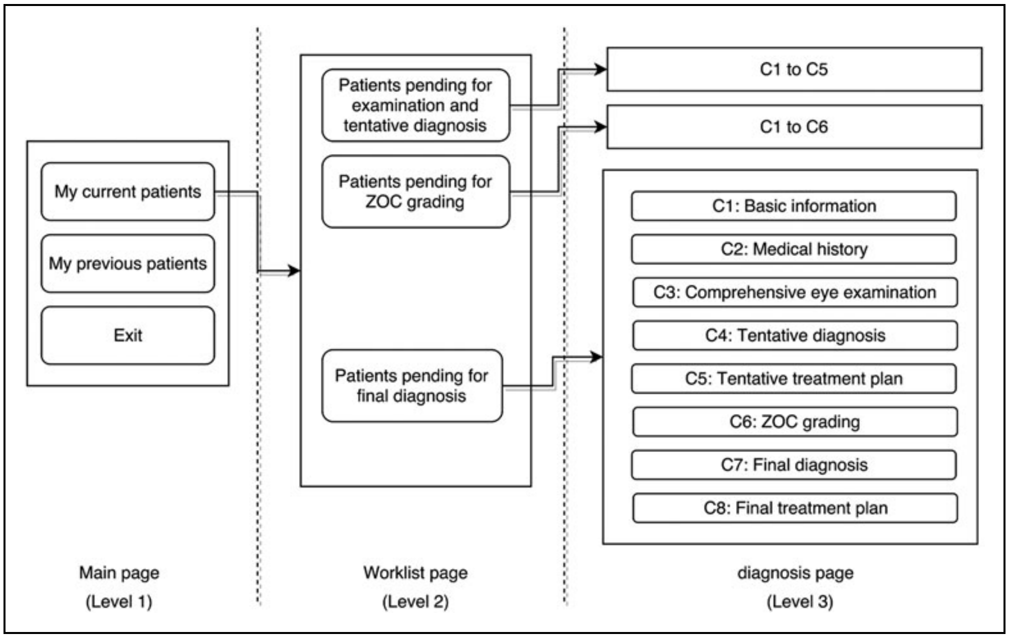

Fig. 5. Structure of tablet app.

(T1) "Waiting for examination," representing the current medical state of the patient (*Fig. 7*). Tabs T1–T7 (top left portion of the homepage) in sequence represent the different states of the patients in the EMR system. The nurse can access each tab and view the patient list (lower portion of the homepage). The nurse can also view a patient's full information, including personal contact, examination result, diagnosis result, and treatment plan etc. in a pop-up window. *Figure 8* illustrates an image grading result window. Other users can access and use different functional components according to their roles authorized by the system.

TABLET APP

Figure 9 illustrates one of the third level pages—a patient's tentative diagnosis page (in the following, we will use Chinese version for illustrating the GUI's original Chinese style). A doctor can follow the categories in sequence in the left panel to complete the patient's tentative diagnostic process. *Figure 10* shows the ZOC grading result page in a final diagnostic process. By clicking the two buttons at the bottom of the page (*Fig. 10a*), the doctor can view the patient's color fundus images and also standard DR images for reference (*Fig. 10b*). *Figure 11* shows the contents in a final treatment plan page. In this process, the doctor can view his/her previous tentative diagnosis, refer to the ZOC DR grading result and make his/her final diagnosis, and finalize the final treatment plan for the patient.

IMAGING AND IMAGE UPLOADING

The imaging camera adopted in the system was 3nethra classic nonmydriatic fundus camera with 45 degrees angle of field view (Forus Health Pvt. Ltd., Bengaluru, India). After completing retinal imaging by the camera system, an imaging nurse can use the web application from the camera computer to select the scanned images and upload.

Fig. 6. A clinical environment for registration, diagnosis, and imaging. **(A)** clinical environment; **(B)** retinal imaging room.

Fig. 7. Upper panel: Homepage of CREST EMR system (web app). Comments with red text: all tabs: T1-Waiting for examination; T2-Waiting for imaging; T3-Waiting for grading; T4-Waiting for final diagnosis; T5-Waiting for treatment scheduling; T6-Waiting for treatment; T7-Archived. All functional buttons: B1-Reporting; B2-Refreshing; B3-Calendar; B4-Searching; B5-Creating new patient. In the patient list area, each patient tag contains the patient's name, visit date, and project ID. B6-Exit. Lower panel: Zoomed in tab labels with patient list. Note: all the patients displayed are test data rather than the real patient data.

Fig. 8. Window for ZOC DR grading. (The items under each eye are: DR level, DME level, other comment, photocoagulation history, glaucoma probability, image quality). DR, diabetic retinopathy; ZOC, Zhongshan Ophthalmic Center; DME, diabetic macular edema.

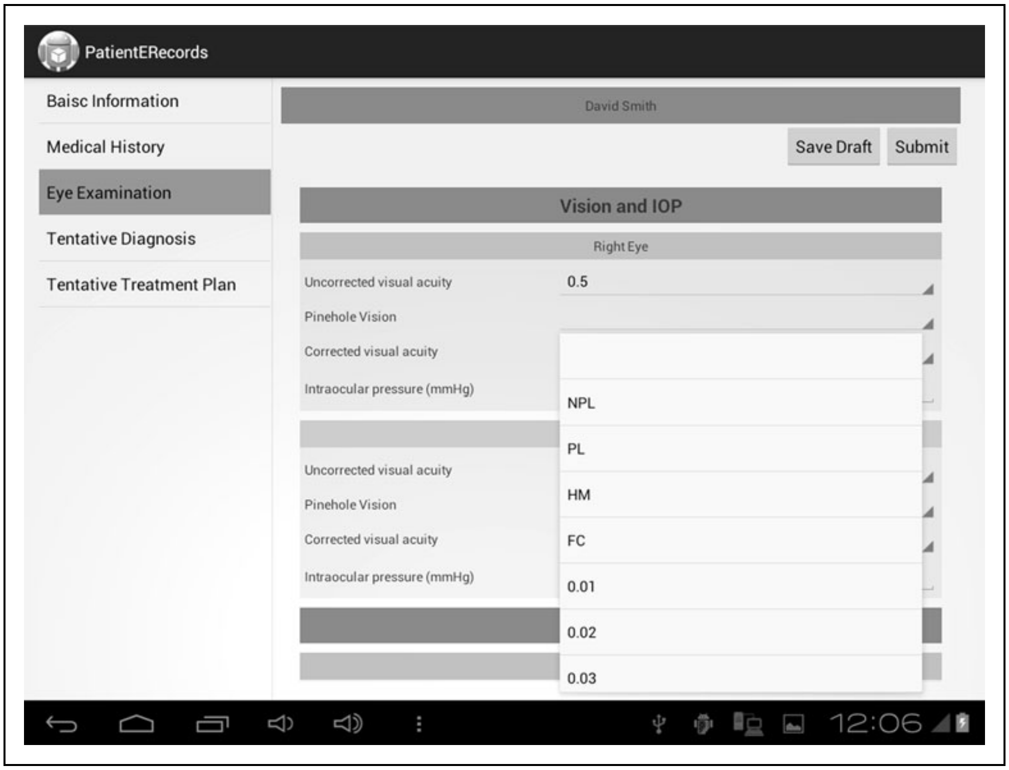

Fig. 9. Tentative diagnosis page.

PRELIMINARY PRACTICE OF THE TELEOPHTHALMOLOGY SYSTEM

In China, patients living in remote small- or medium-size cities with concern that they may have ophthalmic problems usually choose directly going to see a doctor in the department of eye-nose-throat (ENT). The ENT departments of the hospitals need to face a lot of patients with eye diseases daily. This project targeted at the situation. We, therefore, combined the two, DR grading and comprehensive eye examination, in one telemedicine system for increasing the rate of patient access, eye disease assessment, and DR screening in the remote hospitals in the small- or medium-size cities in China.

The first prototype version of the system with basic functions was completed in June 2013 and installed in one hospital at Shaoguan, Guangdong province, for initial system test and evaluation by our working group. In the following half year, more functional components were added and system improvement was made, according to the feedbacks from our working group and clinical staff. At the end of the year, an improved version was installed in 10 hospitals from 10 cities distributing in the remote areas of Guangdong province. After completing the system evaluation in the 10 hospitals, a new version (version 3) was installed in March 2014. In June 2014, we started to work on a statistical report function component. Since April 2016, a full statistical report component has been installing and under test.

Recent data in the system presented that 9,100 patients were recorded in the system and 2,275 patients were with different levels of DR. In the section, we will focus on presenting the performance of the system and effectiveness of its clinical practice and management. A comprehensive statistical analysis on the patient data related to patient demographics, disease levels, and grading accuracy etc. is out of the topic of the article and will be our future work.

In the program, a patient pathway followed the path demonstrated in the project's MW (*Fig. 1*) according to the selection criteria presented earlier. We need to stress that some normal patients were recruited for retinal imaging for research purpose.

The nurses in the program underwent a training process for learning imaging protocol, imaging operation, and using related web-based application components. The local hospital doctors were trained to learn the tablet app's functions and operations. The ZOC graders and arbitrators were trained to understand the image grading protocol and how to perform image grading. Our working group and camera supplier went to each hospital for a 1–2 days' training course and more practices were organized by the local hospitals after the courses.

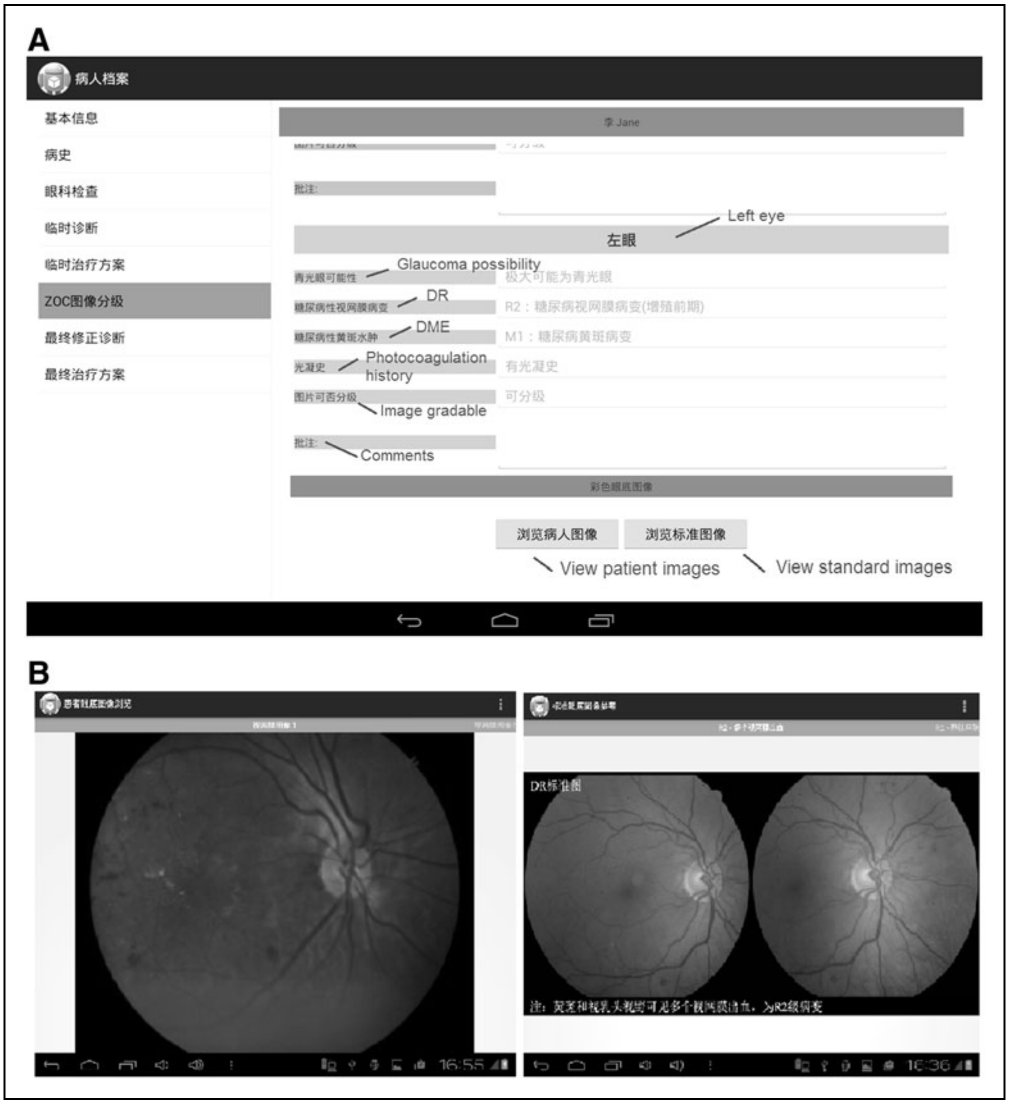

Fig. 10. Final diagnosis page–ZOC grading result category and contents. (**(a)** ZOC grading result. **(b)** Patient image page and standard reference image page).

In the preliminary practice, a total of 10 hospitals' ENT departments linked with the ZOC grading center by the system. Twenty-nine doctors from the 10 hospitals used both the web and tablet systems. Usually 2–3 nurses from each hospital used the imaging system and the web system. According to our statistical data, patient registration needed less than 5 min. The general time of a doctor diagnosing a patient by using the tablet app from starting symptom enquiry to tentative diagnostic result submission was less than 15 min (excluding eye examination time), which is benefited from the portable tablet usage. For comprehensive eye examination, the doctors usually used slit lamp plus handheld 90D lens ophthalmoscopy. Some doctors also used binocular indirect ophthalmoscopy or direct ophthalmoscopy. Visual acuity chart and tonometer were used as well. Most of the time, the local doctors could get ZOC image grading result at the same day as a reference for making final diagnosis (less cases might be in second or third days). At the early stage, we observed that the imaging process might take a longer time. Later, the web-based application was improved to automatically finding the new scanned images under a specific folder for easy file selection; and with the improvement of camera operating skill, the nurses could control an imaging process in 2–5 min.

The synchronization frameworks synchronized patient records and patient images separately by two different systems. The image synchronization was set for every 10 min for checking any new image scans and synchronizing them. The patient records were synchronized immediately by the synchronous replication function from the Microsoft SQL servers.

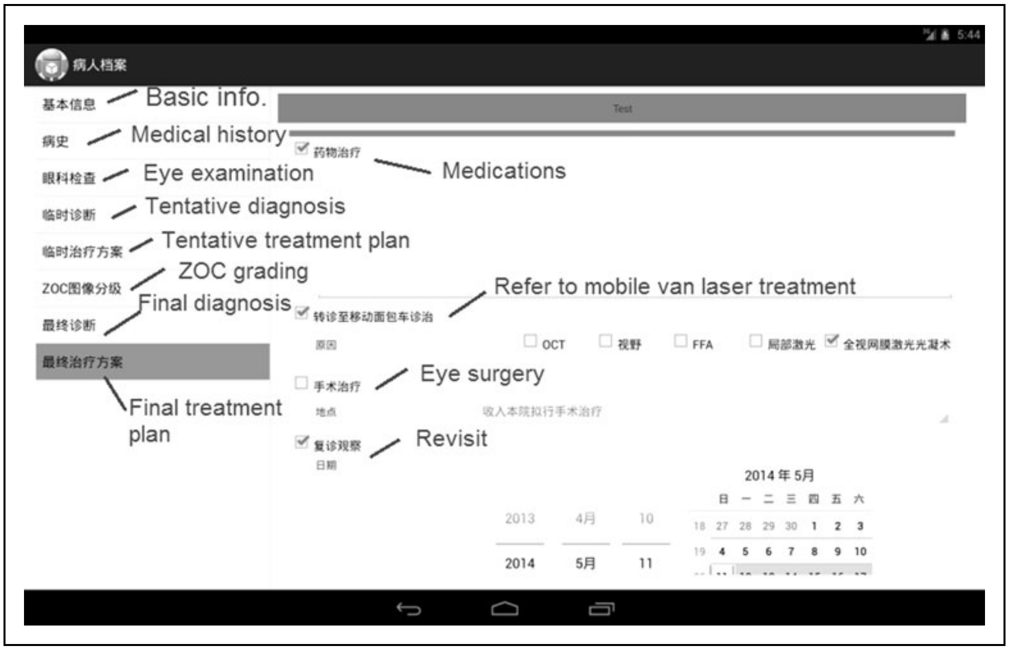

Fig. 11. Final diagnosis page–final treatment plan category and contents.

At the ZOC, there were two image graders and one arbitrator assigned for image grading. Two researchers used the system for monitoring the system running and conducting data analysis research. Three to five trainers used the system for mobile van and surgery scheduling by cooperating with the local hospitals.

In this study, we use the data from 2014 as an example. A total of 393 patients were selected for retinal imaging and grading. According to our statistical data, the image grading process of a single patient was completed on the same day from grader 1 and grader 2 as well as the arbitrator if needed. The corresponding doctors could receive the grading results the same day after the completion of grading. There were 169 patients that the grader 1 and grader 2 achieved the agreement for DR, diabetic macular edema (DME), and glaucoma levels. For the remaining 214 patients, the two graders did not agree with each other and the arbitrator involved for the final grading.

In 2014, the ZOC trainers by using the treatment scheduling component completed 32 times of the local hospital training and patient treatment (once every 2–3 months per hospital). In every ZOC trainer visit, 5–10 patients were treated through the cooperating treatment mode. A total number of patients benefiting from the cooperating and also independent treatments in the year was 366. The web-based scheduling component presents its easy use and efficient patient treatment management, compared with the traditional phone-based scheduling mode.

From the above data, the system has shown its effectiveness for eye disease diagnosis and treatment. Especially, the tablet application, image grading process and treatment scheduling components have presented their great efficiency in the entire diagnostic process.

ADVANTAGES OF THE SYSTEM

The current existing DR telemedicine systems mostly aimed at retinal image transmission, DR grading, and patient referral/no referral recommendation from grading centers to primary care providers, such as early DR system as in,[30] famous EyePACS,[12] INSIGHT,[16] and Chinese DR.[29] Compared with them, our system aimed at the more health services from ophthalmic centers to remote and rural hospitals, which is the major structure of Chinese medical system, thereby providing some distinctive features from others:

- It is an integrated system, which combines color fundus imaging, web-based application, and tablet application for facilitating eye disease diagnosis and treatment. Tablet application is a novel point and provides efficiency for examination recordings.
- The design of the system has involved in the comprehensive contents in the procedure of eye disease examination and diagnosis, especially for DR and glaucoma.
- The system has the function of sending mobile messages to patients to remind their revisits, for the improvement of medical compliance.
- The system has built up the linkage between the tertiary center and the rural hospitals for case discussion, patient referral, and treatment support.
- The education modules have provided the distinctive ability for training the image graders and rural doctors for color fundus image grading on DR and glaucoma.

Conclusion

We have developed a novel telemedicine system for eye disease diagnosis and treatment through our cloud-based web application and tablet application. The teleophthalmology system has provided a new service model to support DR grading by linking multiple remote hospitals and one grading center in Guangdong province, China.

In our early practice of the system, we have shown that the telemedicine system can be used for DR screening and eye disease diagnosis with its usability and scalability. In future, some research and training components can be simplified or switched off once these components have been verified for their functionalities and completed their missions. Then the entire system will be more efficient.

Disclosure Statement

No competing financial interests exist.

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