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REVIEW ARTICLE: TELE-OPHTHALMOLOGY

By

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Teleophthalmology is a branch of telemedicine that delivers eye care through digital medical equipment and telecommunications technology. Applications of teleophthalmology encompass access to eye specialists for patients in remote areas for ophthalmic disease screening, diagnosis and monitoring as well as distant learning **(Kanagasingam et al., 2012)**.

Teleophthalmology enables health professionals to take ocular images and attend to patients who have limited access to ocular health care. These images allow the ophthalmologist, health care professionals and researchers to carry out the aforementioned applications **(Marie et al., 2005)**.

Current teleophthalmological solutions are generally focused on a particular eye problem such as diabetic retinopathy, retinopathy of prematurity, macular degeneration, strabismus, and adnexal eye diseases. Less common conditions that can be revealed using retinal images are arterial and vein occlusions, and congenital anomalies **(Richter et al., 2009)**.

Several population-based studies have used retinal imaging to relate ophthalmic abnormalities to general conditions including hypertension, renal dysfunction, cardiovascular mortality, subclinical and clinical stroke, and cognitive impairment **(Pérez et al., 2012)**.

TELEOPHTHALMOLOGY SYSTEM

Telemedicine systems are essentially categorized into two different technical approaches :

a) On-line systems which provide real-time consultation in terms of sampling medical data and consultation.

b) Off-line store-and-forward systems which capture medical data and then forward them to doctors via e-mail delivery or file transfer **(Jingli et al., 2002)**.

Description of the system

A. System Architecture: Fig. (1) Illustrates the infrastructure of the present Teleophthalmology system which includes two kinds of sites. Without loss of generality, one site is called clinic and another is called hospital. The patient's medical data will be captured by instruments (e.g. Camera and Ophthalmoscope) in the clinic. At the other end, the ophthalmologist will receive the patient's medical data and provide consultation advice in the hospital **(Shengsheng et al., 2008)**.

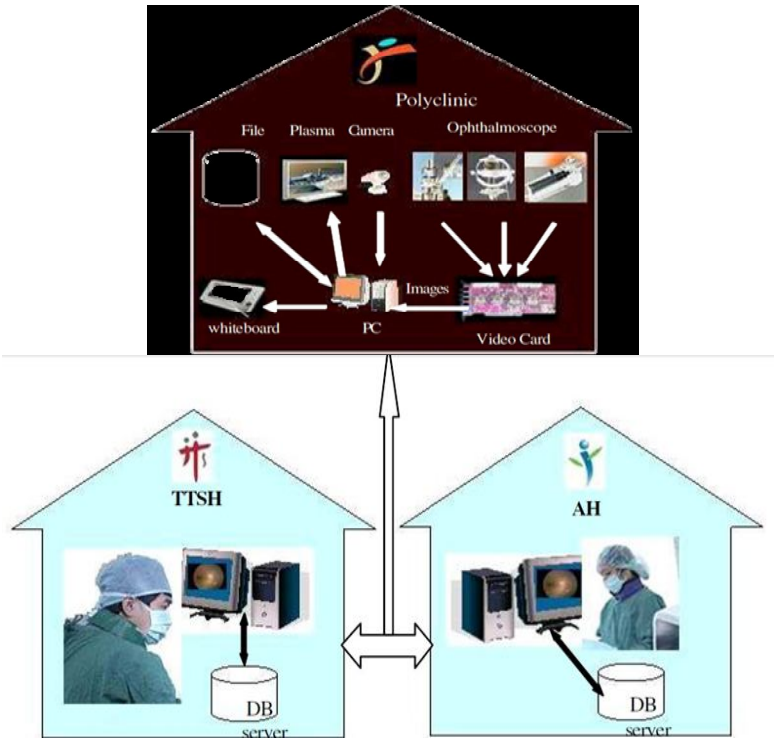

Figure (1): A simple system configuration **(Shengsheng et al., 2008)**.

B. System Workflow: Fig. (2) Illustrates Teleophthalmology which consists of Tele-Clinic, Tele-Hospital and Stream Server. The Tele-Clinic sub-system is used for patient registration and patient consultation. The Tele-Hospital sub-system includes hospital local patient registration, previewing, consultation, and specialist to specialist joint-consultation .

Stream Server, installed at both hospital and clinic, receives video stream data from video encoder, encrypts the video, sends encrypted video, and decrypts the received video **(Robert et al., 2006)**.

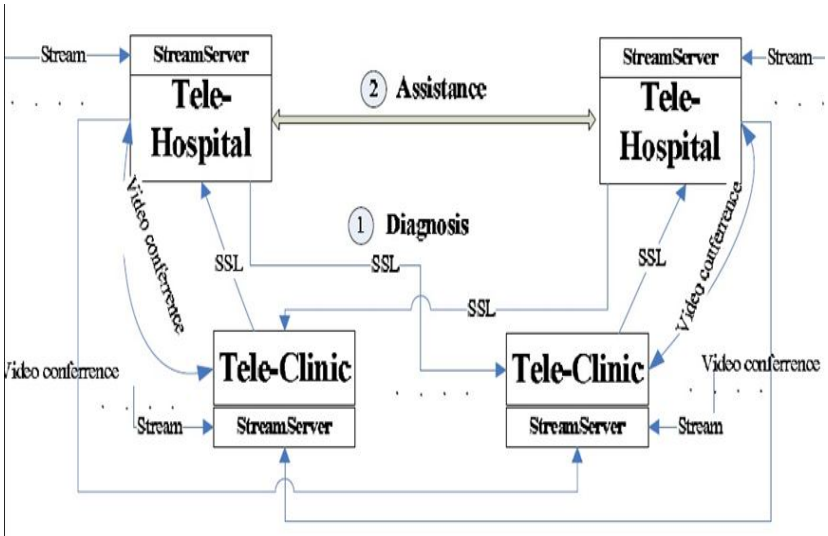

Figure (2): System workflow **(Robert et al., 2006).**

In the Tele-clinic sub-system, registration module includes recording patient particulars, sampling patient's eye image and video data, and selecting an appropriate hospital for the purpose of Tele-consultation. Consultation allows a patient to communicate with a remote ophthalmologist. The patient can also view the data which is loaded by the ophthalmologist on the shared white-board **(Zhe et al., 2001)**.

In the Tele-Hospital sub-system, the preview module helps the ophthalmologist to view the patient's images and video data. A consultation session with the patient can begin when an ophthalmologist completes his/her diagnosis. White board and video conference are used for communication. During consultation, there may be further online sampling and off-line supplement data required by the ophthalmologist. Optionally, a joint consultation may be carried out if an ophthalmologist may decide to ask for advice from other ophthalmologist. In addition, Tele-Hospital module enables local registration which is similar to the Tele-Clinic registration in order to support walk-in consultation at the hospital **(Bengisu et al., 2003)**.

C. System Properties: Teleophthalmology enables a new practice of ophthalmology medical care on the basis of modern communication technologies. It takes advantage of multimedia, network, and information security technologies to provide a flexible and reliable consultation platform for patients and healthcare providers **(Harnett, 2006)**.

In comparison with the prior work, Teleophthalmology has the following properties:

a) Flexible medical resolution: Many existing telemedicine systems manage only low-resolution images as the diagnosis result is often not satisfactory. In contrast, Teleophthalmology provides not only images, but also video data for consultation so as to improve the accuracy of diagnosis.

b) Secure communication: Teleophthalmology uses Secure Socket Layer (SSL) channel for transmitting medical data so that medical data is always protected during transmission .

c) Shared Electronic White board: Synchronous white board with highlighting tools is a flexible tool in consultation. Hence, white board provides the patient friendly way of medical consultation.

d) Joint consultation: Teleophthalmology provides the joint consultation module between ophthalmologists so as to increase the consultation accuracy.

e) Interactive sampling: Ophthalmologists can preview and sample patient data during consultation .

f) Uniform structure: In addition to remote consultation, an integrated Tele-Hospital provides local registration by which the walk-in patients at the hospital are handled in the same way as the remote clinic's patients, such as registering, sampling, and consultation with white board.

g) Timely prescription: When ophthalmologists finish the session of diagnosis with a patient, he will make use of standard prescription document templates for recording, these data

will be sent back to clinic for follow-up **(Harnett, 2006)**.

Teleophthalmology in practice

I. Teleophthalmology for Diabetic Retinopathy (DR) Screening and Management: In a general teleophthalmology program for DR screening, retinal images are obtained with digital retinal cameras (mydriatic or non-mydriatic) by a previously trained non-specialist in a remote place. The data is then securely transferred to a reading center for evaluation, in which ocular assessment is performed by an eye specialist or a certified reader. Specifications regarding image compression, bandwidth, encryption and error checking mechanisms are tailored according to each screening program. Finally, findings are reported back to the primary care physician with the recommendation regarding the need for referral **(Bursell et al., 2012)**.

In some cases, images may be of poor quality due to presence of media opacities, small pupil size or technical difficulties. In Telescreening for DR, unreadable images are considered positive findings and patients must be referred for a comprehensive evaluation. To overcome this issue, the use of pharmacologic agents for pupil dilation may be incorporated in the screening protocol **(Li et al., 2012)**.

According to the American Telemedicine Association (ATA), the main goals of a teleophthalmology program for DR are to reduce the incidence of vision loss due to DR, improve access to diagnosis and management of DR, and decrease the cost of identifying patients with DR **(Cavallerano et al., 2004)**.

As clearly stated by the American Telemedicine Association (ATA) and the American Academy of Ophthalmology (AAO), retinal telemedicine examination is currently not intended to replace a comprehensive eye examination by an experienced ophthalmologist. To act as a first-line screening tool for DR that will filter and reduce the volume of unnecessarily referred patients **(Li et al., 2011)**.

II. Age Related Macular Degeneration (ARMD): The potential application of evolving Tele-medical screening paradigms to the diagnosis and management of other blinding retinal diseases, like AMD, through image management in the primary care space and subjective data collected from the patient-centered “home,” is rapidly becoming a reality **(Ulrich et al., 2009)**.

Established Tele-medical infrastructure that is currently being used to acquire retinal images for the purpose of DR screening can similarly be applied to the acquisition of fundus photographs from patients with AMD, for the remote assessment of disease features by qualified readers. However, similar to the use of two-dimensional color images for the photographic assessment of DR, there are some inherent limitations to methods from which 3D features can be difficult to discern and which must be inferred. These limitations are particularly relevant to the diagnosis and stratification of disease in patients with AMD **(Karnowskiet al., 2011)**.

III. Teleglaucoma: It is the application of electronic technologies to detect and manage patients with or at risk of glaucoma. Important parameters in this

type of delivery of health care include timeliness, quality, efficiency, and patient and provider acceptability. An ongoing concern of incorporating teleophthalmology into clinical care has been maintenance of proper standards and quality control. Thus, it has become particularly important to be able to rigorously validate protocols similar to the model of diabetic retinopathy **(Quigley and Broman, 2010)**.

Teleglaucoma is a relatively new screening and diagnostic tool for targeting remote or under-serviced communities. It uses stereoscopic digital imaging to take ocular images which are transmitted electronically to an ocular specialist. The ocular specialist will assess the images and identify risk factors and diagnose for glaucoma. If necessary, the ocular specialist will refer identified glaucoma cases for medical consultations or to ophthalmologists for follow-up treatment

Unlike other teleophthalmology tools, Teleglaucoma requires more sophisticated diagnostic tests. The main tests are optic nerve photographs, Optical Coherence Tomography (OCT), Intraocular Pressure (IOP) measurements, central corneal thickness (CCT) measurements, and visual field tests **(Kassam et al., 2012)**.

The combination of examinations and equipment required can vary based on organizational resources, target goals and populations. However, the more diagnostic tools used during screening for glaucoma, the greater the accuracy and effectiveness of the screening process **(Kassam et al., 2012)**.

Another area where telehealth may be useful is in postsurgical management. Crowston et al. (2004) assessed the inter observer agreement for clinical signs in post-trabeculectomy eyes when evaluated by real-time video images compared with face-to-face consultation. Remote assessment provided high levels of agreement for bleb vascularity, anterior chamber depth, and the existence of a bleb leak. It was much more variable for bleb height and bleb wall thickness. A Japanese group has similarly shown images acquired using a remote controlled slit lamp to be of use in postoperative management **(Kashiwagi et al., 2013)**.

IV. Smartphone Teleophthalmology: The availability of smartphones has been increasing worldwide over the last decade. It is estimated that approximately 60% of adults have a smartphone. On a daily basis, most ophthalmologists will have access to these devices which provide a platform for capturing and sharing ophthalmic clinical images **(Bastawrous, 2012)**.

Fundus photography is an essential part of an ophthalmic practice because it allows for photo documentation of intraocular pathologies and for diagnosis and sharing of encrypted information with colleagues and patients. Acquisition of high-quality fundus images requires a combination of appropriate optics and illumination, usually with a condensing lens and a coaxial light source **(Bastawrous, 2012).**

The first report of the use of the smartphones for this purpose was by Lord et al. (2010) who showed that these devices could be used for many clinical and educational tools, including capturing images of the eye, such as external photos, slit-lamp photos and fundus photos. Since then, newer techniques and modifications

have resulted in the acquisition of high-quality images that compare to images obtained with more expensive ophthalmic imaging devices **(Russo et al., 2015)**.

Traditional fundus cameras are expensive and have problems with convenience, compatibility and portability. In contrast, smartphones are readily available, relatively inexpensive, easy to operate and compatible across various platforms and systems, making them ideal for use outside traditional office settings and in remote areas of the world **(Maamari et al., 2014)**.

The availability of smartphones and their extensive mobile-phone networks make these devices ideal for telemedicine. The transfer of images to these devices is readily available through existing ophthalmic digital software. These images can then be easily sent for remote expert consultation, to be reviewed in a traditional office workstation or on another smartphone **(Lord et al., 2010)**.

Teleophthalmology has the potential to improve access to screening and early treatment for a number of ocular conditions. It serves to identify patients who are at risk of various types of retinopathy and allows further evaluation and early management resulting in considerable economic benefit **(Kumar et al., 2012)**.

Despite ongoing research and advancement in digital photography, digital imaging techniques still face certain barriers including low sensitivity and specificity, as well as lack of stereopsis (impression of depth). As such, teleophthalmology cannot be a true substitute for comprehensive eye examinations using traditional binocular observation **(Chew, 2006)**.

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مناجزة أمراض العيون عن بعد

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يعتبر مجال تشخيص وعلاج ومتابعة أمراض العيون عن بعد هو تقديم الخدمة الطبية عن طريق إستخدام الأجهزة الطبية الرقمية وتقنية الاتصالات .و يتم اليوم إستخدام هذه المنظومة في تشخيص ومتابعة أمراض العيون للمرضي الذين يعيشون في أماكن بعيدة عن الأطباء المتخصصين في علاج هذه الأمراض ، وكذلك تستخدم في التعليم عن بعد . وتمكن هذه المنظومة مقدمي الخدمة الطبية من إلتقاط صور للمرضي وإرسالها للأطباء المتخصصين في متابعة هذه الأنواع من الأمراض.

وعلي الرغم أنه تم التوسع في الأبحاث المخصصة لدراسة هذه المنظومة علي مدار العقود الماضية ، فإنه مازال هناك اختلاف في تقيم طرق تبادل المعلومات ودرجة أمان هذه المنظومة و إمكانية إتاحة مثل هذه المنظومة في المراكز الصحية وتكاليف الأجهزة اللازمة لممارستها .

والآن يتم توجيه هذه المنظومة لعلاج أمراض مثل تغيرات الشبكية السكرية وأمراض مركز الإبصار الإنتكاسية والحول ،وأيضا الأمراض الأقل شيوعا مثل الأمراض التي تعتمد تشخصيها ومتابعتها علي تصوير الشبكية مثل إنسداد اوردة الشبكية و إلتهاب الشبكية وأمراض الشبكية الخلقية . وقد تم عمل أبحاث علي مرضي تم فيها إستعمال هذه المنظومة في تسجيل صور الشبكية أثناء دراسة بعض الأمراض العامة التي تؤثر علي الشبكية مثل مرض إرتفاع ضغط الدم ،وأمراض قصور الكلي، وأبحاث دراسة نسب وفيات المرضى من أمراض القلب والدورة الدموية وأبحاث جلطات المخ .

وما نحتاجه في هذه المنظومة هو كاميرا رقمية لتصوير العين ،وأجهزة حاسوب تتصل بشبكة لنقل الصور . ويوجد الآن برامج للتليفون المحمول تستعمل في تقيم أمراض العيون مثل برامج تحديد حدة الأبصار وقدرة المريض علي تمييز الألوان، ويمكن أيضا أن تستخدم في التعليم .

ومع تطور تصنيع وتطوير الكاميرا الرقميه ،وفي مقدمتها التقدم الهائل في مجال التصوير المقطعي للشبكية ،أصبح لدينا كاميرا تعطي تفاصيل دقيقة للشبكية والتي يمكن أن تستغل في تشخيص الأمراض . ومثل هذا التطور كان دافعا للتفكير في إنشاء مراكز تعمل بهذه المنظومة.

ولم يقتصر التطور فقط علي الكاميرات ،ولكن حدث تطوراً في برامج الحاسوب بحيث أصبحت قادرة علي التعرف علي الصور وتحليلها وإعطاء تشخيص لهذه الأمراض ،وقدرتها علي

التفريق بين الأمراض و تحديد درجة الإصابة بالرجوع إلي معلومات مسجلة مسبقه لديها عن كل مرض . ويتم إستخدام الأبحاث المخصصة للذكاء الإصطناعي في تحديث وتطوير قدرة البرامج في التعرف علي الصور وتحليلها .

وهذه المنظومة تتبع معايير في التعامل مع الصور ونقلها وتحليلها ومنها ما هي معايير عالمية مثل معاير منظمة (التصوير الرقمي والإتصالات في الطب) ومنها ما هو محلي تضعها الدول بما يناسب طبيعة ممارسة الطب فيها وبما يناسب قانون الدولة وأولوياتها.

وتمر الشبكات الطبية التي تعمل بهذه المنظومة بمرحلة نمو كبير وتطور خاصة في مجال التشخيص الآلي وخاصة التغيرات السكرية للشبكية. ويتم تحديث هذه المنظومة لتكون أكثر فاعلية في الإكتشاف والعلاج المبكر للأمراض وجعل إستخدامها أقل تكلفة . وعلي الرغم من تقدم طرق وآلات التصوير الرقمي ،إلا أن هناك بعض العوائق مثل حساسية ودقة التصوير وعوائق تقنية أخري تخص تجسيم الصور .

لذلك ،حتي الآن لا يمكن إستبدال هذه المنظومة بالطرق التقليدية للكشف علي العين .