Abstract: Ophthalmology departments face intensifying pressure to expedite sight-saving treatments and reduce the global burden of disease. The use of electronic communication systems, digital imaging, and redesigned service care models is imperative for addressing such demands. The recently developed Scottish Eyecare Integration Project involves an electronic referral system from community optometry to the hospital ophthalmology department using National Health Service (NHS) email with digital ophthalmic images attached, via a virtual private network connection. The benefits over the previous system include reduced waiting times, improved triage, e-diagnosis in 20% without the need for hospital attendance, and rapid electronic feedback to referrers. We draw on the experience of the Scottish Eyecare Integration Project and discuss the global applications of this and other advances in teleophthalmology. We focus particularly on the implications for management and screening of chronic disease, such as glaucoma and diabetic eye disease, and ophthalmic disease, such as retinopathy of prematurity where diagnosis is almost entirely and critically dependent on fundus appearance. Currently in Scotland, approximately 75% of all referrals are electronic from community to hospital. The Scottish Eyecare Integration Project is globally the first of its kind and unique in a national health service. Such speedy, safe, and efficient models of communication are geographically sensitive to service provision, especially in remote and rural regions. Along with advances in teleophthalmology, such systems promote the earlier detection of sight-threatening disease and safe follow-up of non-sight-threatening disease in the community.

Key Words: electronic referrals, digital imaging, teleophthalmology, screening, teledmedicine, Scottish Eyecare Integration Project

Perspective

Electronic Referrals and Digital Imaging Systems in Ophthalmology: A Global Perspective

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Ophthalmology in the 21st century faces many challenges. The burden of chronic disease management is augmented by factors including an aging population, financial constraints, earlier detection of disease and, in many countries, increasing rates of diabetic retinopathy (DR). Developing community-based services to maximize access and streamline the use of the hospital eye service is key to coping with this rising demand. This strategy is absolutely dependent on high-quality communication between hospital and community-based ophthalmic services such as local optometrists. Electronic referral systems allow for the safe and effective sharing of clinical information between the two, enabling better triage, diagnosis, and management. Furthermore, the enhancement of referral quality with digital imaging is well documented.1 Our experience, recent evidence in this area, and the global applications are the focus of this article.

ADVANCES IN REFERRAL AND COMMUNICATION SYSTEMS: THE SCOTTISH EXPERIENCE

The paper-based referral system (as shown in Fig. 1) is still the principal pathway in the majority of United Kingdom (UK) ophthalmology departments and in many parts of the world. In this setting, an optometrist sends a letter to a general practitioner (GP), who then has to make a decision whether to refer the patient to the hospital eye service (HES). A consultant of the HES then reviews the combined referral and decides whether an appointment is required.

The current technological possibilities make this indirect referral approach via the GPs and handwritten report by an optometrist very limited. Many clinicians and scientists have noticed that electronic referrals would be more efficient, more accurate, faster, and more resource sparing.2 Electronic optometric referrals (Fig. 2) can include images (Fig. 3), are legible, and encourage the inclusion of a minimum dataset of clinical information. Further, they facilitate direct referral to the hospital but can concomitantly request that the GP send a summary of the patient’s medical record. According to recent evidence, there is a need to make an effective triage amid conditions that could safely be managed in the community with the aid of electronic referral/digital images to HES.3 Some of these include DR, retinopathy of prematurity (ROP), and glaucoma. This model of electronic referral retains the crucial involvement of the GP but does not require him/her to triage and forward the referral onto the HES, and is thus beneficial in terms of time and resources.

In 2005, the Scottish government funded a pilot study in Fife to assess the feasibility of a new electronic-based referral system with attached digital images, directly from optometrists to HES. The results of our pilot study at NHS Fife showed superiority of the electronic referral system over the old paper-based approach. We compared the number of necessary appointments determined by using the new electronic-based system with 2 control groups dealing with the old paper-based system.3 The results were astonishing, with the electronic system marking 37% of cases as not requiring a hospital eye appointment, as opposed to the control groups in which an appointment was not needed in 15% and 8.4% of cases (Fig. 4). This large reduction in the number of clinic appointments required stems from better efficacy of the direct approach, and although some limitations were granted, the
Figure 1. The old paper referral form, in existence throughout Scotland for decades, possibly since the inception of the NHS.

Electronic-based referrals were recognized as safe and clinically accurate. Limitations were shown in 4 cases that were deemed not requiring a HES appointment and were subsequently found to have pathology, such as a peripheral retinal tear.3

In 2011, the Scottish government committed £6.6 million to electronic connections between community and HES. The Scottish Eyecare Integration Project was launched in 2013, with plans for Scottish-wide connection of 14 healthcare boards and 900 optometry practices using a bespoke virtual private network connection.4 Over 50 local referral forms were amalgamated into 5 standardized electronic forms, tailored to the type of referral. The implementation of teleophthalmology in Scotland has become an important goal, with a target of 90% electronic referrals by the end of 2016. One of the most important conclusions of the Scottish Eyecare Integration Project was that the extension of this practice to the rest of the UK would reduce the burden on the NHS, whose resources are stretched at a time of an increasing aging population.5

**Technological Advances**

Owing to recent technological advances, rural areas with limited access to healthcare can now promote better screening and ophthalmic care by using smartphone technology. A broad range of iPhone app-based testing tools is available, including near vision cards, accommodation targets, a fluorescein light, color vision plates, Amsler grids, and optokinetic nystagmus drum simulation.6 These can be particularly useful in emergency settings, complementing and facilitating traditional clinical examination.

Furthermore, specially designed camera attachments and software systems are being developed, such as the PEEK (Portable Eye Examination Kit) vision system.7 The main specialized function of these small kits attached to smartphones is taking fundus photographs, so called smartphone fundoscopy.8 This makes the technology required for diagnostically useful fundus imaging far more compact and affordable and has implications globally for triaging in the community many ophthalmic conditions (including DR) and those that require hospital consultation.9

**Significance of Electronic Referrals for Glaucoma**

A recent meta-analysis addressing the global burden of glaucoma found a global prevalence of 3.54% (95% credible interval, 2.09–5.82) in 40–80 year olds.10 With 64.3 million people worldwide affected in 2013, they project an increase to 111.8 million in 2040, with a disproportionate effect on Asia and Africa. Much of the clinical information required for decision making in glaucoma referral and management is captured electronically: optic disc photography, optical coherence tomography (OCT) of nerve fiber layer, visual fields. Stereoscopic images are increasingly used. Thus, the availability of electronic referral systems (Fig. 5) and advances in digital imaging are reshaping glaucoma services worldwide.

Imaging or grading of the iridocorneal angle is not yet widely incorporated into teleglaucoma or electronic referral systems. This is particularly an issue in Asia, where 80% of the world’s primary angle-closure glaucoma (PACG) cases are found. We now...
know that PACG affects over 1% of the adult population in China and Japan. There are further controversies regarding glaucoma’s suitability for remote diagnosis. Some studies point out that the problem lies in the inability to make the diagnosis of glaucoma with 1 single portable device and in the suspicion that some of the devices claiming their accuracy are still not ready to be used widely. On the other hand, some systematic studies have come to the conclusion that teleophthalmology produced even better results in diagnosing glaucoma than in-person contact, not to mention its benefit for persons from rural areas and significant cost reduction.

**SIGNIFICANCE OF ELECTRONIC REFERRALS FOR DIABETES**

A recent systematic review and meta-analysis confirmed the high diagnostic accuracy of telemedicine in DR. Subgroup analysis examined the effect of different digital imaging techniques, with mydriatic wide-field (100–200 degree angle) imaging giving the best results. In addition to ultra-widefield imaging, OCT can be used to greatly enhance DR screening. The potential incorporation of OCT into DR referrals is arguably the most useful in reducing the burden on the hospital eye service. Along with reducing unnecessary appointments, the earlier detection of center-involving macular edema facilitates prompt intravitreal treatment.

To our knowledge, the only universal DR screening program (DRS) at this moment exists in the UK. This is despite clear evidence of its benefit: the prevalence of sight-threatening diabetic eye diseases and of all grades of retinopathy is significantly lower in diabetic patients who undergo screening with the DRS. However, DRS in the UK is not flawless, sometimes involving compromise between the existing infrastructure, the educated professionals conducting it, and the efficacy of the method. On rare occasions DRS can miss changes that could be sight threatening, although every effort is made to reduce the risk of this happening. Furthermore, screening does not replace regular eye examinations and patients should attend both.

Teleophthalmology could help to solve another issue of DRS, which stems from social deprivation and insufficient attendance of the screening events. This could be particularly important for low-income countries with high incidence of diabetes mellitus and subsequent DR. Sub-Saharan countries, such as Malawi, currently do not have any systematic screening program for DR, even though a real epidemic of diabetes is evident in that country. A total of 5.6% of adults aged from 25 to 64 in Malawi suffer from diabetes, 90% of whom have type 2.

**CAUTIONS AND LIMITATIONS**

Telemedicine has already changed the world of medicine in many positive ways. Long distance testing, self-testing meters, use of smartphones, and communication possibilities between medical institutions and professionals on different levels have made medical administration much easier and created the necessary environment to meet the challenge of an increasing number of patient visits. However, we note several cautions. Despite all the advancements, telemedicine also carries risks, such as communication between the doctor and the patient potentially being jeopardized. Not all aspects of remote ophthalmic care are well suited to remote diagnosis. In the field of glaucoma, for example, gonioscopic assessment is a procedure for which technicians are usually not trained, limiting the remote diagnostic accuracy. Additionally, a degree of caution is always necessary when interpreting 2-dimensional ophthalmic images and there is an acceptance that a full clinical examination is the gold standard for many conditions.

With regards to electronic referrals, bypassing the GP in the referral route may result in patients being pigeon-holed into 1 system or 1 management pathway. For example, they may be directed

**SIGNIFICANCE OF ELECTRONIC REFERRALS FOR ROP**

As with DR, the accurate grading of ROP is possible on the basis of fundus imaging. With technological progress, high-resolution imaging, and increasing use of mobile imaging devices, ROP diagnostics is becoming more and more advanced. In 2015, the American Academies of Pediatrics and of Ophthalmology issued guidelines entitled “Telemedicine for Evaluation of Retinopathy of Prematurity,” which systematically reviewed the literature on the topic and detailed important practical considerations.

Beyond ROP, the concept has been extended to universal neonatal eye screening with fundus imaging, proposed by scientists in India. By conducting the screening at this neonatal level, they have reached the conclusion that 48 (4.7%) of the 1021 examined infants had abnormal findings, and all of them required medical attention, whereas 1% of them required some sort of intervention. They propose serious consideration of the idea of screening all newborns with fundus photography, not just those at risk of ROP.
such systems promote the earlier detection of sight-threatening regions. Along with advances in teleophthalmology and imaging, clinically sensitive to service provision, especially in remote and rural areas may be a result of not yet well established methodology.

...effective in this context by providing improved access and feasible... 

...that might not be set up to detect other pathology, deal with systemic medical issues, detect incidental findings, and discuss psychosocial effects of the condition.  

**GLOBAL APPLICATIONS FOR CHRONIC EYE DISEASE**

The application of teleophthalmology in the management and tracking of chronic eye diseases has developed to a great extent, especially in developed countries. With the use of teleophthalmology, it is now much easier to track relapses, exacerbations, and the response to treatment. For health institutions, teleophthalmology potentially provides a significant reduction in costs and use of resources, as hospital stay in patients with chronic eye diseases is now significantly reduced, with a reduction in the burden of disease. However, controversies still exist, which in some areas may be a result of not yet well established methodology of teleophthalmology research. Nevertheless, where ophthalmic units care for geographically spread-out patients, this innovative initiative is beneficial as unnecessary patient transport to hospital can often be avoided. Teleophthalmology is probably most beneficial in this context by providing improved access and feasible screening/monitoring.

**CONCLUSIONS**

The experience of the unique Scottish Eyecare Integration Project is an example of the benefits to service delivery resulting from electronic communication and digital imaging systems. Such speedy, safe, and efficient models of referral are geographically sensitive to service provision, especially in remote and rural regions. Along with advances in teleophthalmology and imaging, such systems promote the earlier detection of sight-threatening disease and safe follow-up of non–sight-threatening disease in the community. With increasing global ophthalmic disease and new sight-saving treatments with narrow windows of treatment application, teleophthalmology stands to help prioritize the expanding demand for ophthalmic services around the world.

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