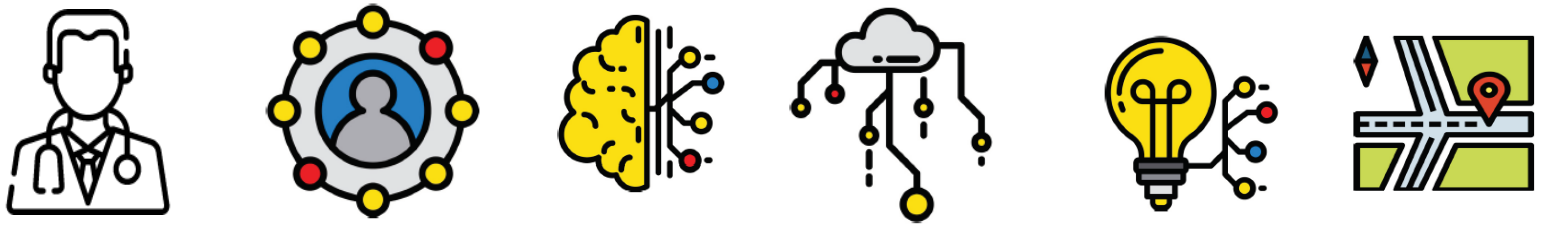
Implementation of AI & Digital Innovations in Healthcare **Reflections and Pearls in Management**



Professor Wong Tien Yin

Professor & Medical Director, Singapore National Eye Centre

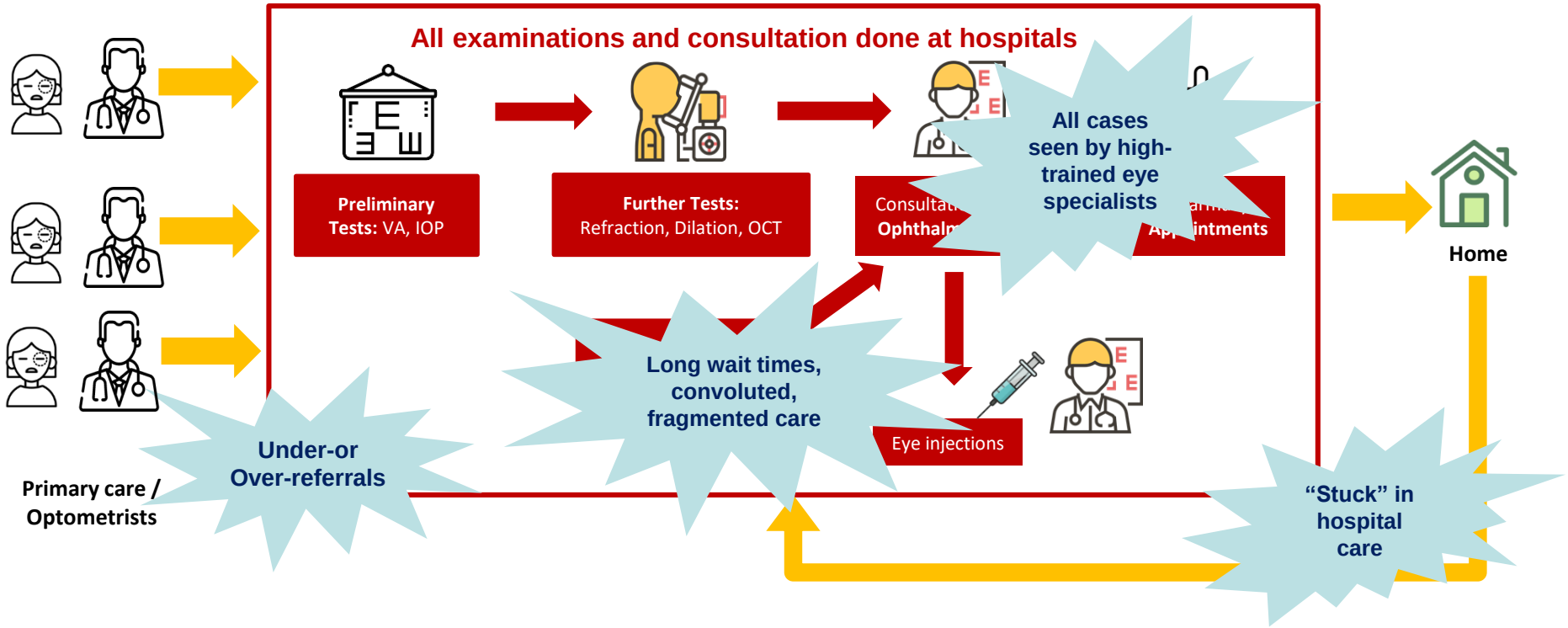
Deputy Group CEO, Research and Education, SingHealth

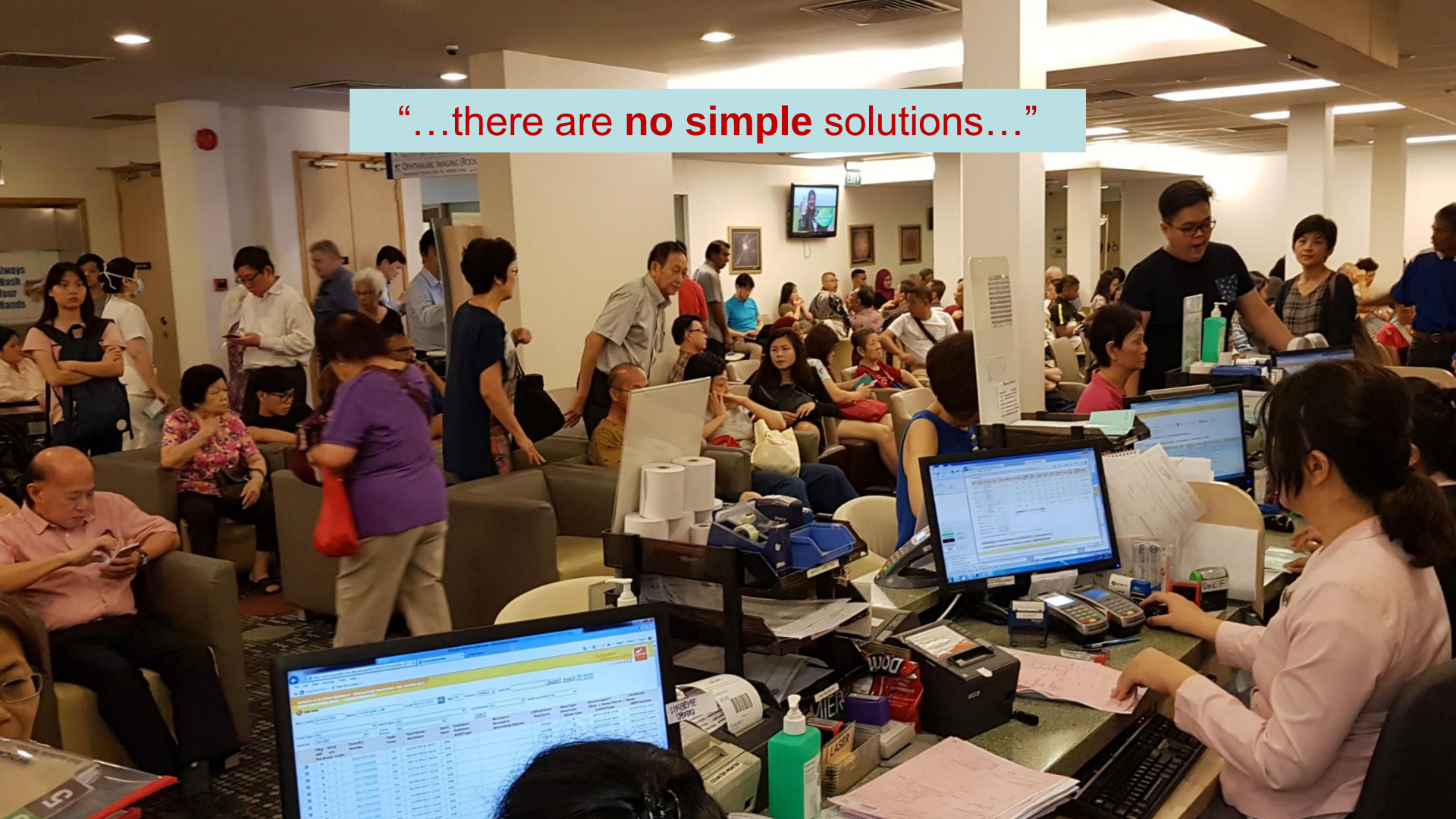
Vice-Dean, Duke-NUS Medical School, National University of Singapore

Disclosure: Holds patents on SELENA+ and co-founder of EyRiS

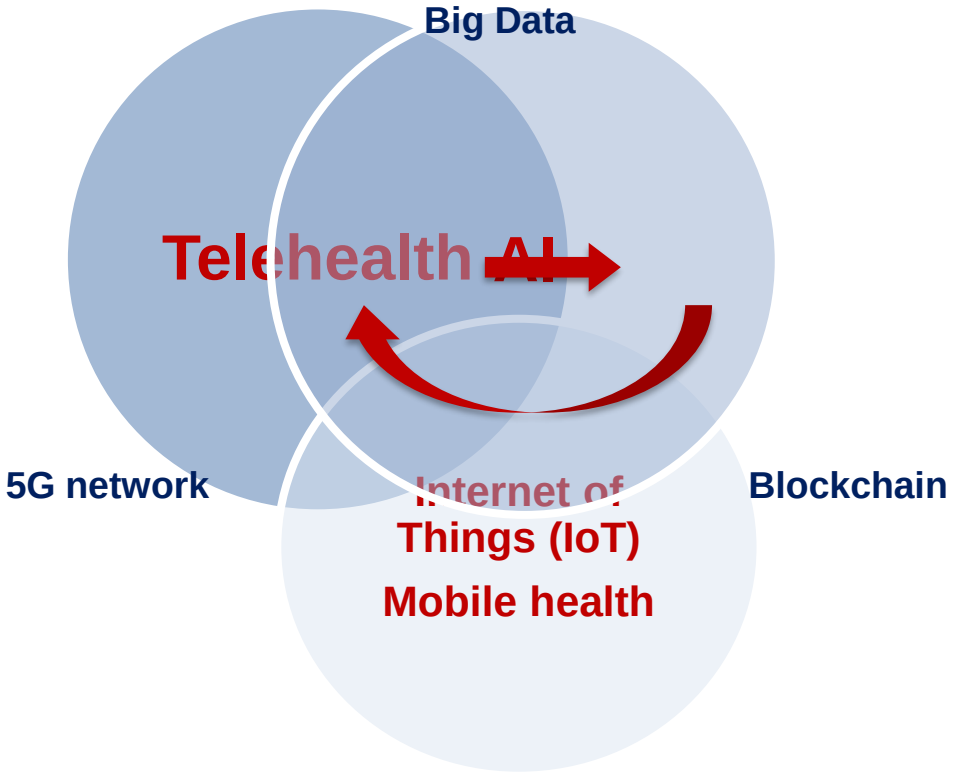

Vision without execution
is just hallucination.
Henry Ford
quotefancy

Current model of healthcare (e.g., eye-care)




"…there are **no simple** solutions…"

What are major digital healthcare technologies?



…telehealth…

The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

Edward W. Campion, M.D., *Editor*

State of Telehealth

E. Ray Dorsey, M.D., M.B.A., and Eric J. Topol, M.D.

TELEHEALTH IS THE PROVISION OF HEALTH CARE REMOTELY BY MEANS OF a variety of telecommunication tools, including telephones, smartphones, and mobile wireless devices, with or without a video connection. Telehealth is growing rapidly and has the potential to transform the delivery of health care for millions of persons. Although several reviews have examined the historical use and effects of telehealth,[1-3] few articles have characterized its current status. Here we examine the trends of telehealth, its limitations, and the possibilities for future adoption.

CURRENT TRENDS

Three trends, all linked, are currently shaping telehealth. The first is the transformation of the application of telehealth from increasing access to health care to providing convenience and eventually reducing cost. The second is the expansion of telehealth from addressing acute conditions to also addressing episodic and chronic conditions. The third is the migration of telehealth from hospitals and satellite clinics to the home and mobile devices.

From the perspective of patients, the fundamental aim of telehealth is to increase access to care,[4] and as such, it has historically increased access to health care for conditions[5] and populations for which care was otherwise not available. Among the early and enduring applications of telehealth have been programs to provide care to persons in the military, prisons, and rural locations.[6] In addition to increasing access, the Internet is enabling the convenient delivery of health care,[7-9] as it has done for travel, retail, and finance. Numerous organizations, from academic health centers to startups, now offer low-cost virtual visits (less than $50 per visit) around the clock

Three Trends

#1. Access to expertise and care → improve **efficiency** and reduce **cost**

#2. **Acute** and episodic → **chronic** conditions

#3. Patient and hospitals → **Patient and technology/AI**

Modified from Dorsey & Topol 2016

difficult history…non-technical barriers

Journal of Internal Medicine 2000; **247**: 615–628

INTERNAL MEDICINE IN THE 21ST CENTURY

Telemedicine: barriers and opportunities in the 21st century

B. STANBERRY
From the Centre for Law Ethics and Risk in Telemedicine, Cardiff, Wales, UK

Abstract. Stanberry B (Centre for Law Ethics and Risk in Telemedicine, Cardiff, Wales, UK). Telemedicine: barriers and opportunities in the 21st century (Internal Medicine in the 21st Century). *J Intern Med* 2000; **247:** 615–628.

This paper aims to examine how health telematics will develop in the first 10 years of the new millennium and, in particular, to assess what operational, ethical and legal barriers may lie in the way of this development. A description of the key principles and concepts involved in telemedicine and a short historical overview of telemedicine's evolution over the past century are followed by consideration of why empirical research into 'info-ethics' and other transmission of visual media in disciplines such as teleradiology, teledermatology, telepathology and teleophthalmology; telesurgery and robotics and the use of call centres and decision-support software. These are discussed in the light of their moral, ethical and cultural implications for clinicians, patients and society at large.

The author argues that telemedicine presents unique opportunities for both patients and clinicians where it is implemented in direct response to clear clinical needs, but warns against excessive reliance upon technology to the detriment of traditional clinician–patient relationships and against complacency regarding the risks and responsibilities – many of

"…people are rarely neutral about it; either **enthusiastic proponents** or **vehement opponents…**

…proponents believe that telemedicine represents the **future**. It will lead to **higher standards** of medical care as well as **reduced costs**…

…opponents believe that it represents a **threat to the traditional doctor-patient relationship** and is an intrinsically **unsafe** way to practice medicine. The potential **legal** and **ethical** problems…it **could not be used to form the basis of a clinical service**…"

Stanberry 2000

…what about AI?

2018 Google Makes A.I. History By Beating World 'Go' Champion

"…by far the **greatest danger** of AI is that people conclude too early that they understand it…the field of AI has a reputation for **making huge promises** and then failing to deliver on them…"

Eliezer Yudkowsky 2008

…decades of unmet expectations

Medicine and the Computer — The Promise and Problems of Change

William B. Schwartz, M.D.

The NEW ENGLAND JOURNAL of MEDICINE

December 3, 1970
N Engl J Med 1970; 283:1257-1264
DOI: 10.1056/NEJM197012032832305

Abstract

Rapid advances in the information sciences, coupled with the political commitment to broad extensions of health care, promise to bring about basic changes in the structure of medical practice. Computing science will probably exert its major effects by augmenting and, in some cases, largely replacing the intellectual functions of the physician. As the "intellectual" use of the computer influences in a fundamental fashion the problems of both physician manpower and quality of medical care, it will also inevitably exact important social costs — psychologic, organizational, legal, economic

"…[computing would be] augmenting and, in some cases, **largely replacing the intellectual functions of the physician**…" Schwartz NEJM 1970

Artificial Intelligence in Medicine

William B. Schwartz, M.D., Ramesh S. Patil, Ph.D., and Peter Szolovits, Ph.D.

March 12, 1987
N Engl J Med 1987; 316:685-688

This article has no abstract; the first 100 words appear below.

After hearing for several decades that computers will soon be able to assist with difficult diagnoses, the practicing physician may well wonder why the revolution has not occurred. Skepticism at this point is understandable. Few, if any, programs currently have active roles as consultants to physicians. The story behind these unfulfilled expectations is instructive and, we believe, offers hope for the future.Research

"After hearing for decades that computers will soon be able to assist with difficult diagnoses, the practicing physician may well wonder **why the revolution has not occurred**" Schwartz NEJM 1987

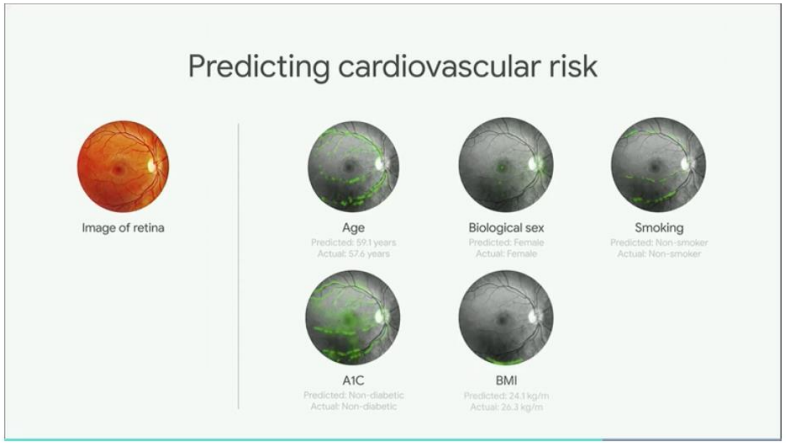
…significant “hype” and media attention!

Google’s new AI algorithm predicts heart disease by looking at your eyes

Experts say it could provide a simpler way to predict cardiovascular risk

By James Vincent | Feb 19, 2018, 12:04pm EST

SHARE



The Economist

Today Weekly edition Menu

Science & technology

Dec 18th 2019 edition ›

A new idea for diagnosis

A system based on AI will scan the retina for signs of Alzheimer’s

And, after that, of stroke susceptibility and heart disease

pore National Eye Centre
SingHealth

…beyond peak of inflated expectations

PERSPECTIVE

The NEW ENGLAND JOURNAL of MEDICINE

Machine Learning and Prediction in Medicine — Beyond the Peak of Inflated Expectations

Jonathan H. Chen, M.D., Ph.D., and Steven M. Asch, M.D., M.P.H.

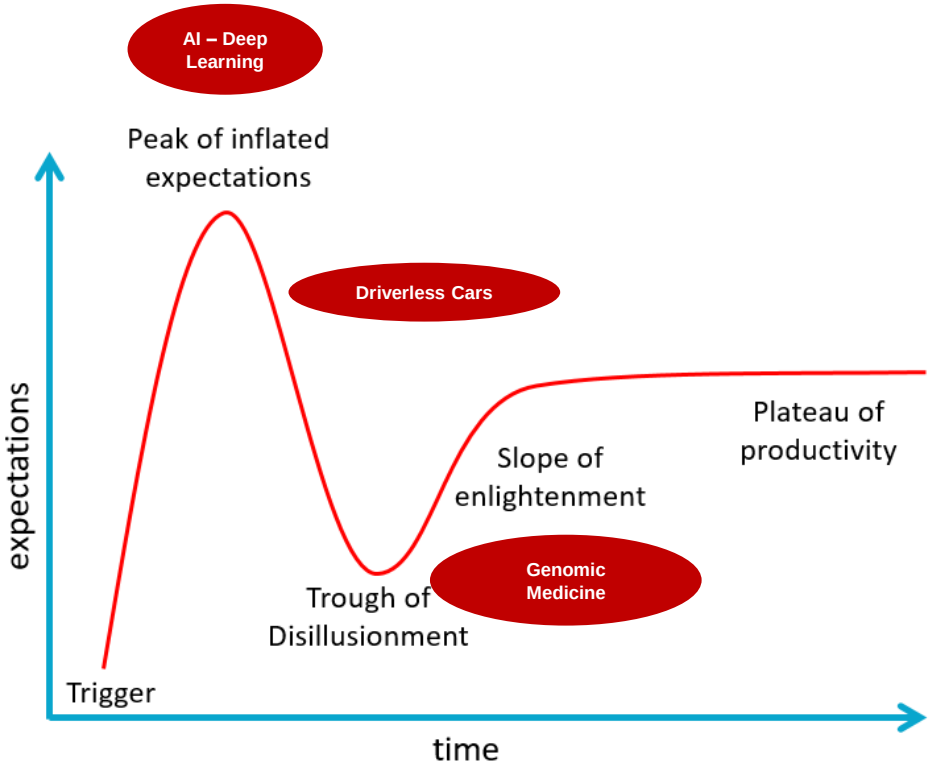
Big data, we have all heard, promise to transform health care with the widespread capture of electronic health records and high-volume data streams from sources ranging from insurance claims and registries to personal genomics and biosensors.[1] Artificial-intelligence and machine-learning predictive algorithms, which can already automatically drive cars, recognize spoken language, and detect credit card fraud, are the keys to unlocking the data that can precisely inform real-time decisions. But in the "hype cycle" of emerging technologies, machine learning now rides atop the "peak of inflated expectations."[2]

gate bias, emerging data sources are typically less structured, since they were designed to serve a different purpose (e.g., clinical care and billing). Issues ranging from patient self-selection to confounding by indication to inconsistent availability of outcome data can result in inadvertent bias, and even racial profiling, in machine predictions. Awareness of such challenges may keep the hype from outpacing the hope for how data analytics can improve medical decision making.

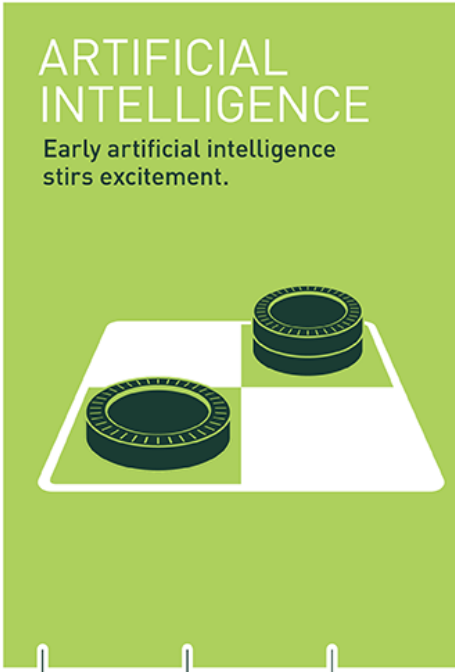
Machine-learning methods are particularly suited to predictions based on existing data, but precise predictions about the distant future are often fundamentally

Research into decision-support algorithms that automatically learn inpatient medical practice patterns from electronic health records reveals that accumulating multiple years of historical data is worse than simply using the most recent year of data. When our goal is learning how medicine should be practiced in the future, the relevance of clinical data decays with an effective "half-life" of about 4 months.[4] To assess the usefulness of prediction models, we must evaluate them not on their ability to recapitulate historical trends, but instead on their accuracy in predicting future events.

Although machine-learning al-

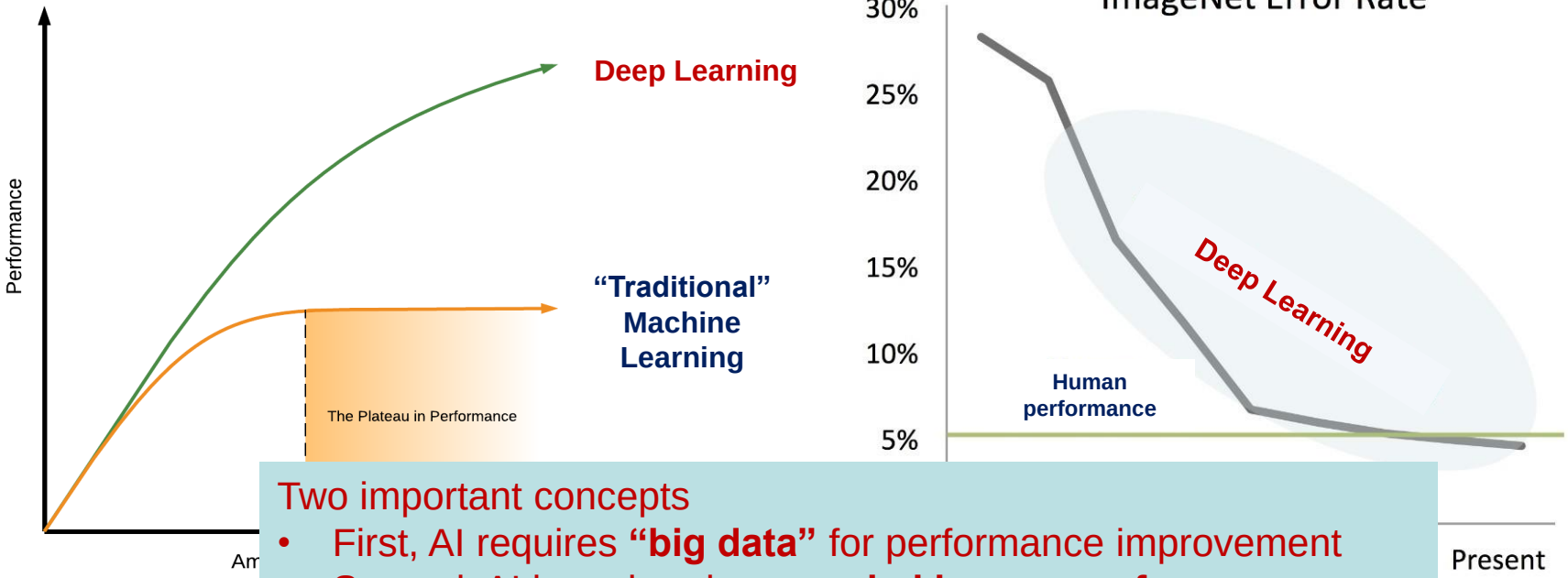


Brief history of AI…deep learning



1950's 1960's 1970's 1980's 1990's 2000's 2010's

“traditional” machine learning vs deep learning



Two important concepts

- First, AI requires **“big data”** for performance improvement
- Second, AI has already **exceeded human performance**…so **why** is it not “acceptable”?

Singapore National Eye Centre
SingHealth

Telehealth & AI…unique opportunity in COVID-19?

COVID-19 Pandemic Will Propel US Telehealth Market To Grow At A CAGR of Over 29% During 2019-25

By **Cathy Russey** - 27. April 2020

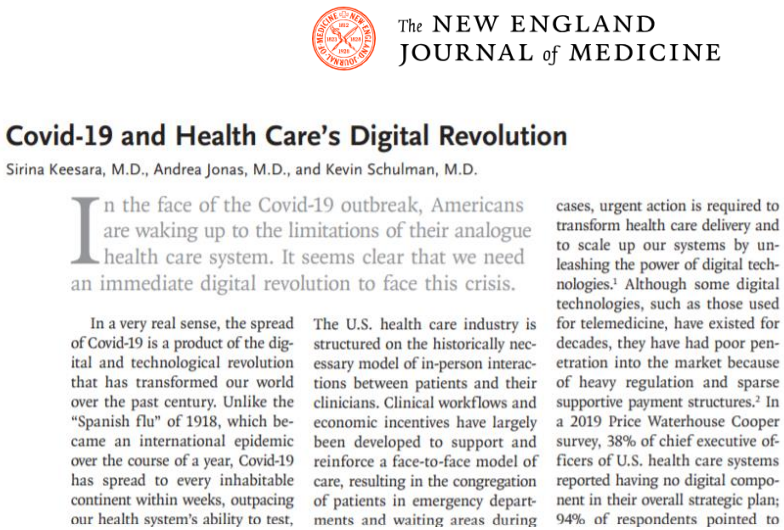
MIT Technology Review

Artificial intelligence / Machine learning

Doctors are using AI to triage covid-19 patients. The tools may be here to stay

Faced with staff shortages and overwhelming patient loads, a growing number of hospitals are turning to automated tools to help them manage the pandemic.

…reflection of “bricks & mortar” healthcare system



The NEW ENGLAND JOURNAL of MEDICINE

Covid-19 and Health Care’s Digital Revolution

Sirina Keesara, M.D., Andrea Jonas, M.D., and Kevin Schulman, M.D.

In the face of the Covid-19 outbreak, Americans are waking up to the limitations of their analogue health care system. It seems clear that we need an immediate digital revolution to face this crisis.

In a very real sense, the spread of Covid-19 is a product of the digital and technological revolution that has transformed our world over the past century. Unlike the “Spanish flu” of 1918, which became an international epidemic over the course of a year, Covid-19 has spread to every inhabitable continent within weeks, outpacing our health system’s ability to test,

The U.S. health care industry is structured on the historically necessary model of in-person interactions between patients and their clinicians. Clinical workflows and economic incentives have largely been developed to support and reinforce a face-to-face model of care, resulting in the congregation of patients in emergency departments and waiting areas during

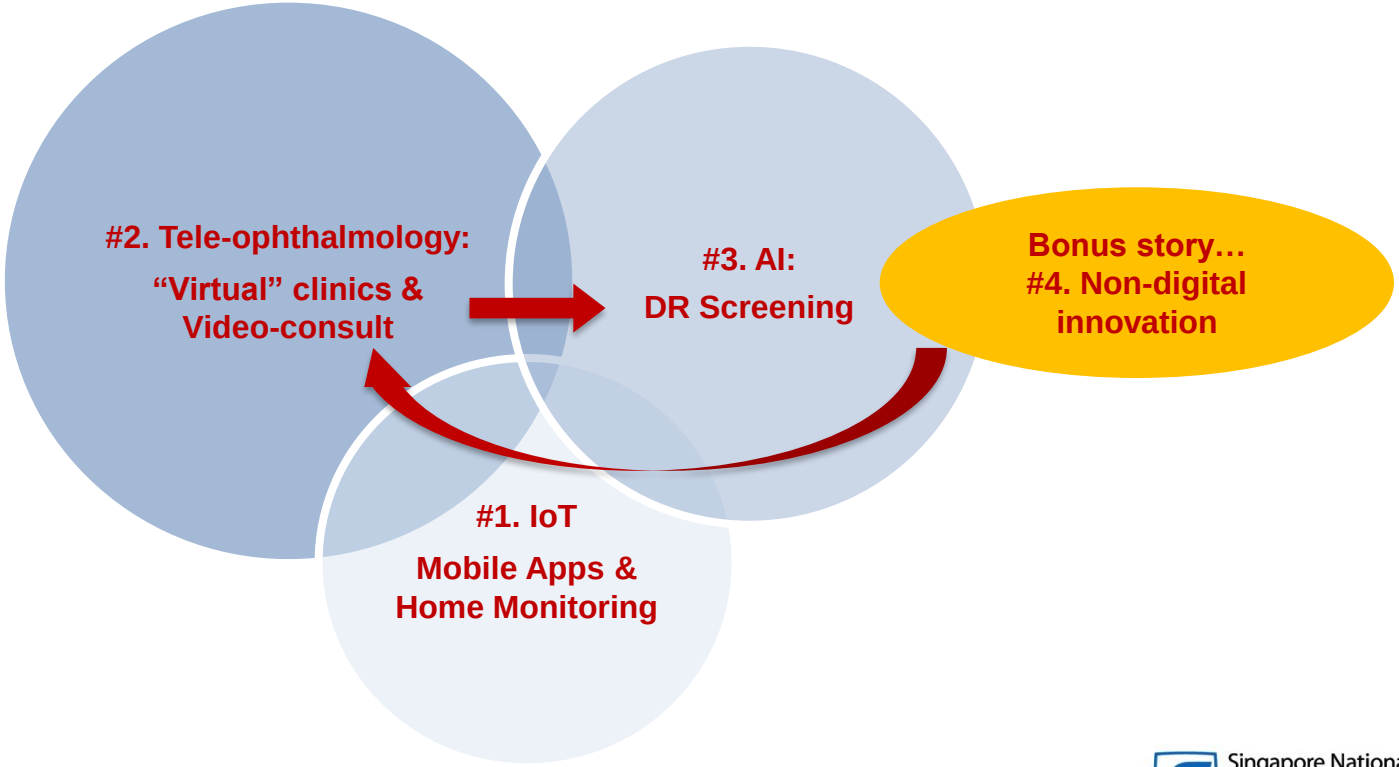
cases, urgent action is required to transform health care delivery and to scale up our systems by unleashing the power of digital technologies.[1] Although some digital technologies, such as those used for telemedicine, have existed for decades, they have had poor penetration into the market because of heavy regulation and sparse supportive payment structures.[2] In a 2019 Price Waterhouse Cooper survey, 38% of chief executive officers of U.S. health care systems reported having no digital component in their overall strategic plan; 94% of respondents pointed to

“In the face of the Covid-19 outbreak, [we] are waking up to the limitations of [our] **analogue health care system**. It seems clear we need **immediate digital revolution**”

…**private** companies and institutions of **higher education** have made an abrupt transition to remote videoconferencing and other digital solutions…while the health care system is still managing through risky **brick-and-mortar visits**….

…health care industry is structured on the historically necessary model of **in-person interactions between patients and their clinicians**…resulting in the congregation of patients in ER and waiting areas during this crisis.”

3 stories on implementing digital models of care



#1. Mobile Apps & Home Monitoring

Mobile apps & home monitoring

Traditional retinal care

Primary care /GPs

All examinations and consultation done at hospital (SNEC)

Home

Home

Home VA check

Further Tests: Refraction, Dilation, OCT

Consultation with **Ophthalmologist**

IVT

Home

Home delivery medications

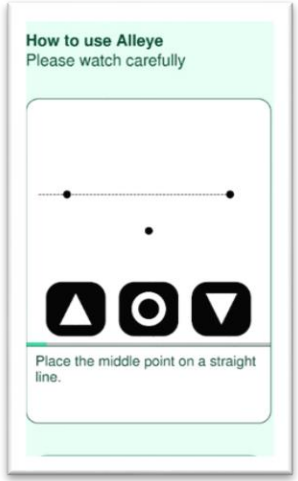
Home monitoring

Mobile apps & home monitoring

1

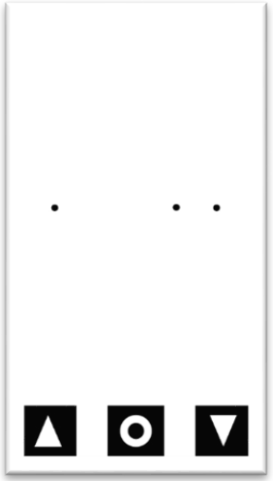
Patients register upon clicking a link on a SMS notification. Only Phone number is collected

2



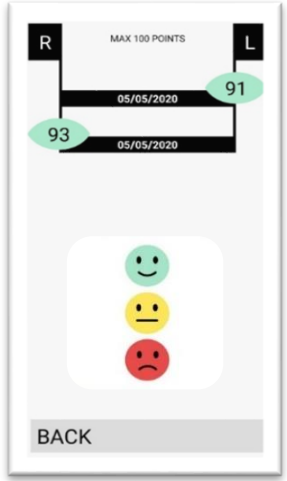
Patients download the app and learn how to use the app for optimal results via short demo

3



Patients perform self-monitoring test 2-3x per week. Test results are monitored by Dr

4



Results displayed and color coded. Patients with Red indicators will be contacted for appt with eye Dr.

…shorten patient journey in clinic

…**empower** patients to self-monitor their vision

ngapore National
e Centre
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Mobile apps & home monitoring

AMERICAN ACADEMY OF OPHTHALMOLOGY®

Patterns and Characteristics of a Clinical Implementation of a Self-Monitoring Program for Retina Diseases during the COVID-19 Pandemic

Kelvin Yi Chong Teo, MBBS,[1,2] Lucas M. Bachmann, PhD,[3] Dawn Sim, PhD,[4,5] Shu Yen Lee, FRCS(Ed),[1,2] Anna Tan, MBBS,[1,2] Tien Y. Wong, PhD,[1,2] Chui Ming Gemmy Cheung, FRCOphth,[1,2] Gavin Siew Wei Tan, PhD[1,2]

Purpose: We describe the large-scale self-initiated recruitment of patients to a self-monitoring initiative for macular pathologic features during the coronavirus disease 2019 (COVID-19) pandemic.

Design: Observational study with retrospective analysis.

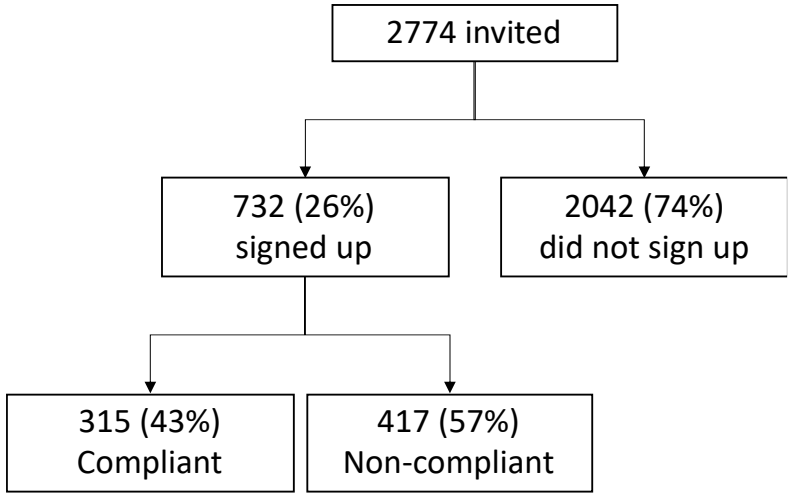
Participants: A total of 2272 patients from the Singapore National Eye Centre (SNEC) whose visits were rescheduled over lockdown (April 13–June 1, 2020) were offered participation in a self-monitoring initiative administered by SNEC with the Alleye application (Switzerland) as the testing instrument.

Methods: This was an observational study with retrospective analysis. Demographics and characteristics were compared between those who signed up and those who did not. Similar comparisons were made between patients who complied with the initiative versus those who did not. Outcomes were tracked for 6 months starting from the commencement of lockdown.

Main Outcome Measures: Participation and compliance rates and characteristics of patients who were more likely to participate and comply with the initiative.

Results: Seven hundred thirty-two patients (32%) participated in this self-monitoring initiative. Those who participated were younger (62 years of age vs. 68 years of age; $P < 0.001$), men, and living with family. Patients not receiving treatment and those with poorer vision in the worse-seeing eye were more likely to participate. When grouped according to diagnosis, the proportion who participated was highest for diabetic macular edema (52%), nonneovascular age-related macular degeneration (AMD; 42%), diabetic retinopathy (35%), retinal vein occlusions (18%), and neovascular AMD (15%; $P < 0.001$). Testing compliance rate was 43% (315/732). Patients who complied with the initiative were older, were receiving treatment, and had poorer vision in the worse-seeing eye. Trigger events occurred in 33 patients, with 5 patients having clinically verified disease progression (1.6%).

Conclusions: We
offered, participated in,
standardized clinical s
Despite this, self-monit
scaling such programs
American Academy of



...25% did **not sign-up**
…60% were **non-compliant**

So a 100% free Mobile App during COVID-19,
≈10% eligible patients participated fully…**why?**

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SingHealth

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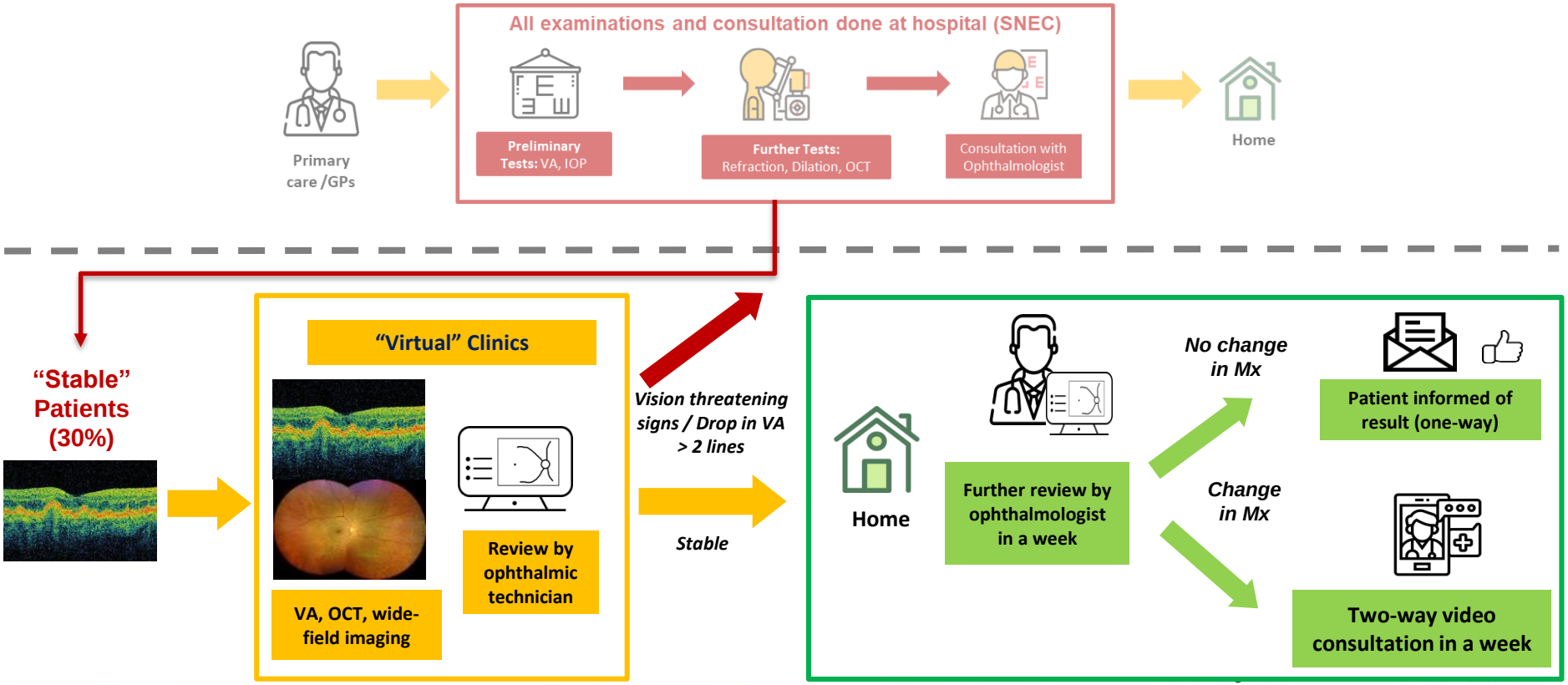
#2. Tele-ophthalmology: “Virtual” clinics & Video-consult

Tele-ophthalmology: “virtual” clinics & video-consults



What is the experience of “virtual” clinics in UK?

Clinical science

OPEN ACCESS

Implementation of a cloud-based referral platform in ophthalmology: making telemedicine services a reality in eye care

Christoph Kern ,[1,2] Dun Jack Fu,[1] Karsten Kortuem ,[1,2] Josef Huemer,[1,3] David Barker,[4] Alison Davis,[1] Konstantinos Balaskas,[1] Pearse A Keane,[1,5,6] Tom McKinnon,[7] Dawn A Sim[1,5,6]

► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/bjophthalmol-2019-314161).

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[6]Institute of Ophthalmology, University College of London, London, United Kingdom
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Revised 24 April 2019
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Published Online First 18 July 2019

ABSTRACT

Background Hospital Eye Services (HES) in the UK face an increasing number of optometric referrals driven by progress in retinal imaging. The National Health Service (NHS) published a 10-year strategy (NHS Long-Term Plan) to transform services to meet this challenge. In this study, we implemented a cloud-based referral platform to improve communication between optometrists and ophthalmologists.

Methods Retrospective cohort study conducted at Moorfields Eye Hospital, Croydon (NHS Foundation Trust, London, UK). Patients classified into the HES referral pathway by contributing optometrists have been included into this study. Main outcome measures was the reduction of unnecessary referrals.

Results After reviewing the patient's data in a web-based interface 54 (52%) out of 103 attending patients initially classified into the referral pathway did not need a specialist referral. Fourteen (14%) patients needing urgent treatment were identified. Usability was measured in duration for data input and reviewing which was an average of 9.2 min (median: 5.4; IQR: 3.4–8.7) for optometrists and 3.0 min (median: 3.0; IQR: 1.7–3.9) min for ophthalmologists. A variety of diagnosis was covered by this tool with dry age-related macular degeneration (n=34) being most common.

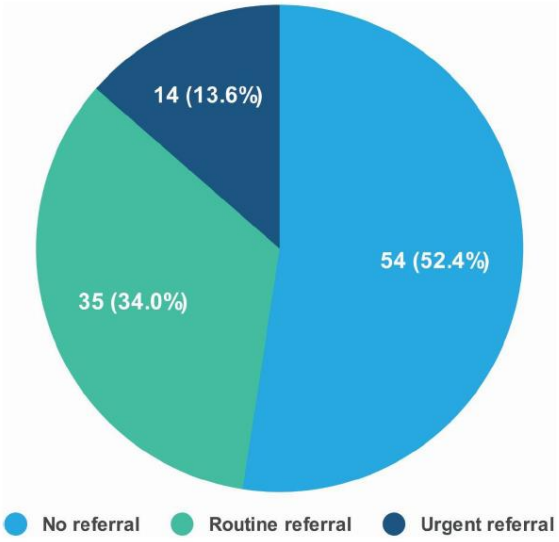
Conclusion After implementation more than half of the HES referrals have been avoided. This platform offers a digital-first solution that enables rapid-access eye care for patients in community optometrists, facilitates communication between healthcare providers and may serve as a foundation for implementation of artificial intelligence.

by an expected growth of the population over 60 years at twice the rate of the profession.[2]

People aged below 16 or above 60, with diabetes or a family history of glaucoma are eligible for a free eye test within the NHS every 2 years.[6] The Opticians Act 1989 obligates UK optometrists to refer any incidental eye abnormality detected during an NHS eye test to a Hospital Eye Services (HES) unless they provide a sufficient disease description including medical advice to the patient.[7] With the introduction of advanced imaging devices as optical coherence tomography (OCT) and ultra-wide field imaging (UWFI), detection rates of asymptomatic retinal conditions and therefore specialist referrals have drastically increased.[8]

Cameron *et al*[9] demonstrated that that more than a third of optometric referrals within the NHS did not need specialist consultancy.[9] They also reported a reduction in these unnecessary referrals following introduction of an electronic referral system containing images sent as email attachments. This accentuates the importance of communication between optometrists and HES within the NHS, especially addressing imaging data as reported by the British Broadcasting Corporation (BBC) in 2016.[10] Improved communication and data sharing could counteract the increasing pressure on HES by reducing unnecessary referrals.

The aim of this pilot study is to report the implementation and initial results of a cloud-based referral platform to medical retina HES, which was developed to overcome the increasing demand on scarce ophthalmologist services by improving communica-



>50% did **not** require referral to eye hospital

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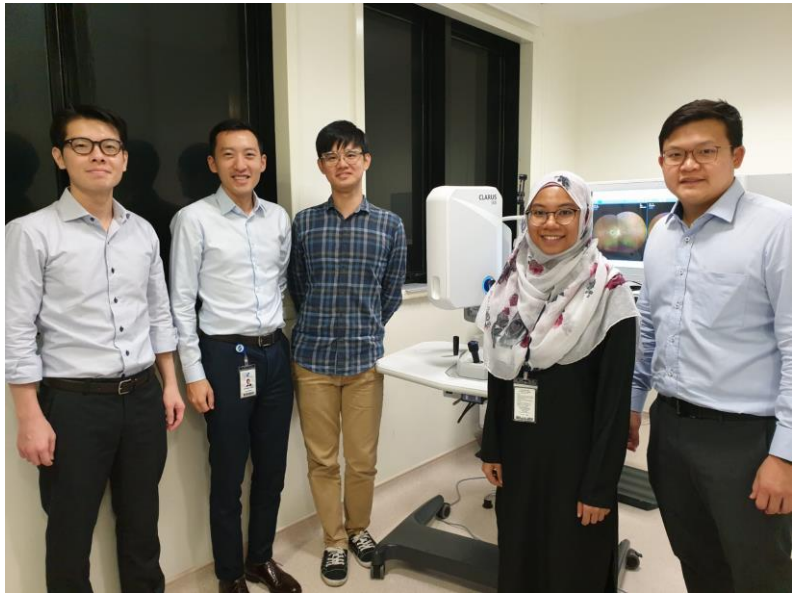
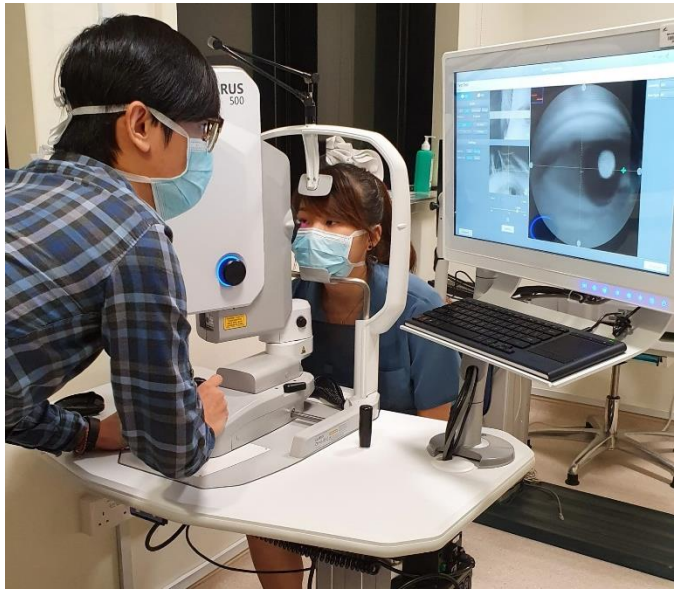
Tele-ophthalmology: “virtual” clinics



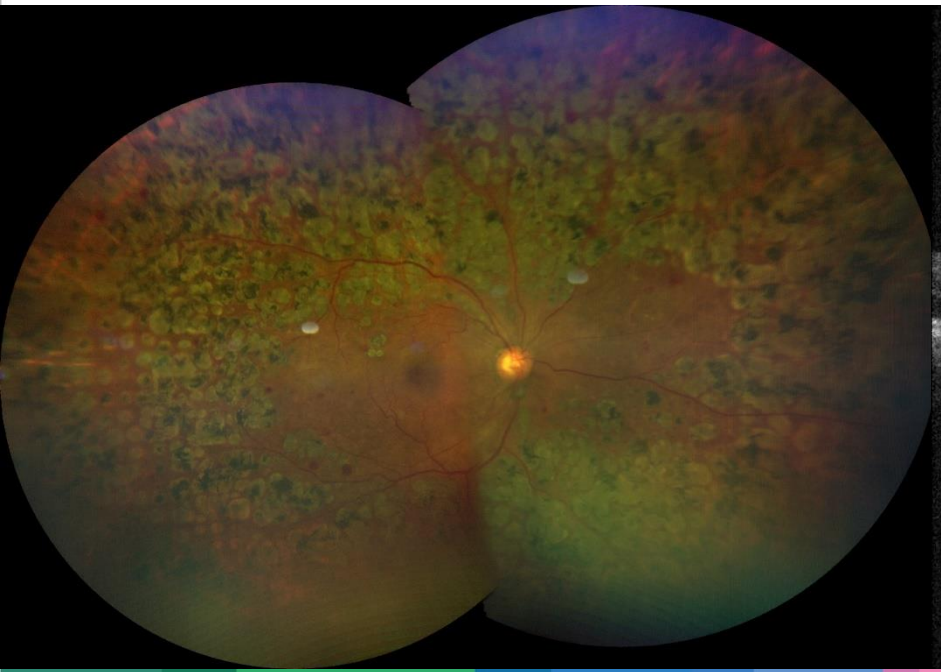


Glaucoma & Retina Observation Clinics (GLOC & ROC)

- **Stable** glaucoma & retinal patients with ≥6 months follow-up
- **Impact:** Shorter waiting time, better patient experience, >20,000 patients (5%) annually

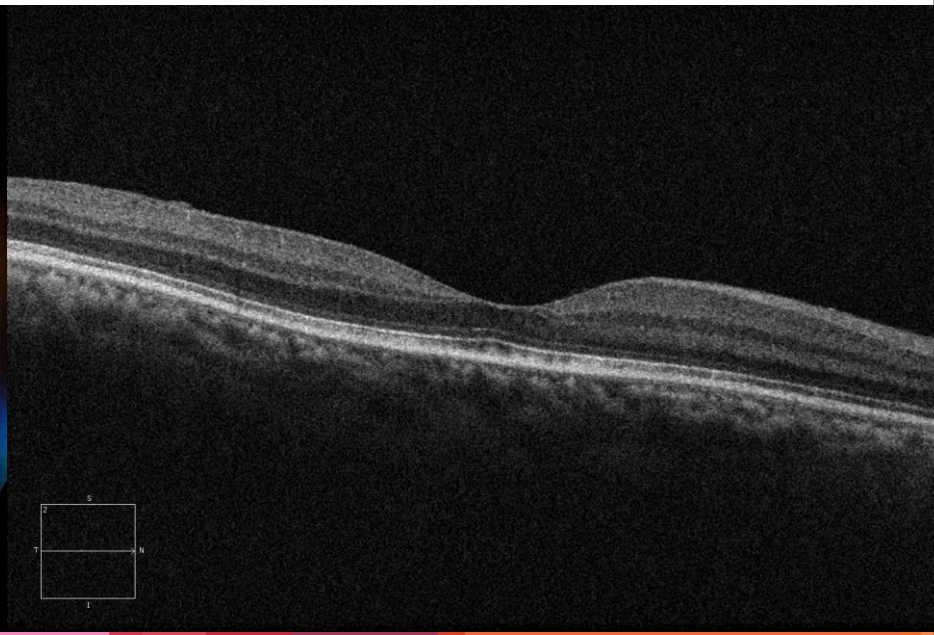
Retinal observation clinic (ROC)

64 yr old female, **stable diabetic retinopathy with previous laser**
RE VA: 6/9.5
Outcome: **Continue ROC** in 1 year



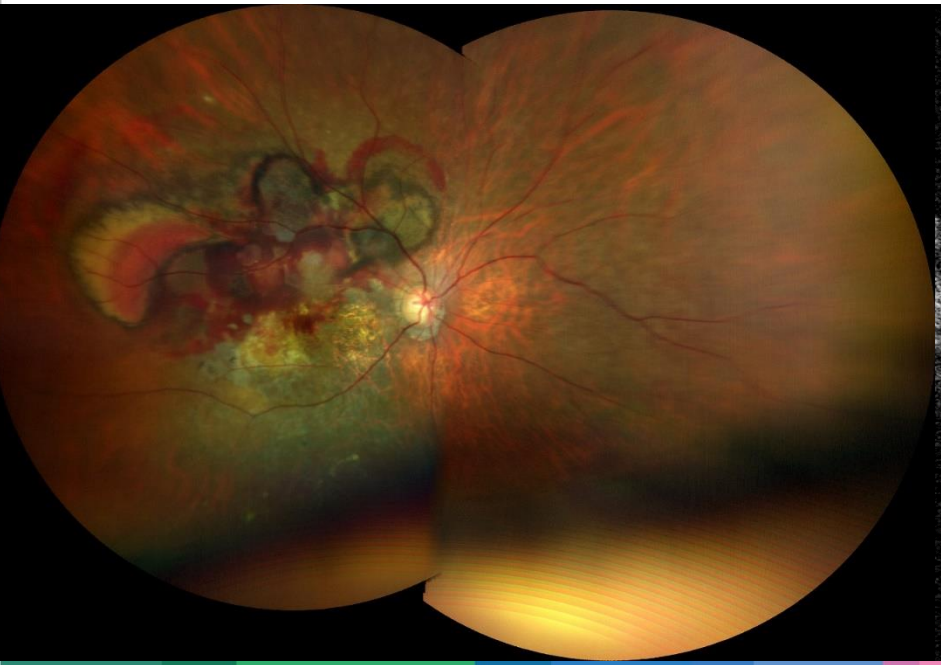
Retinal observation clinic (ROC)

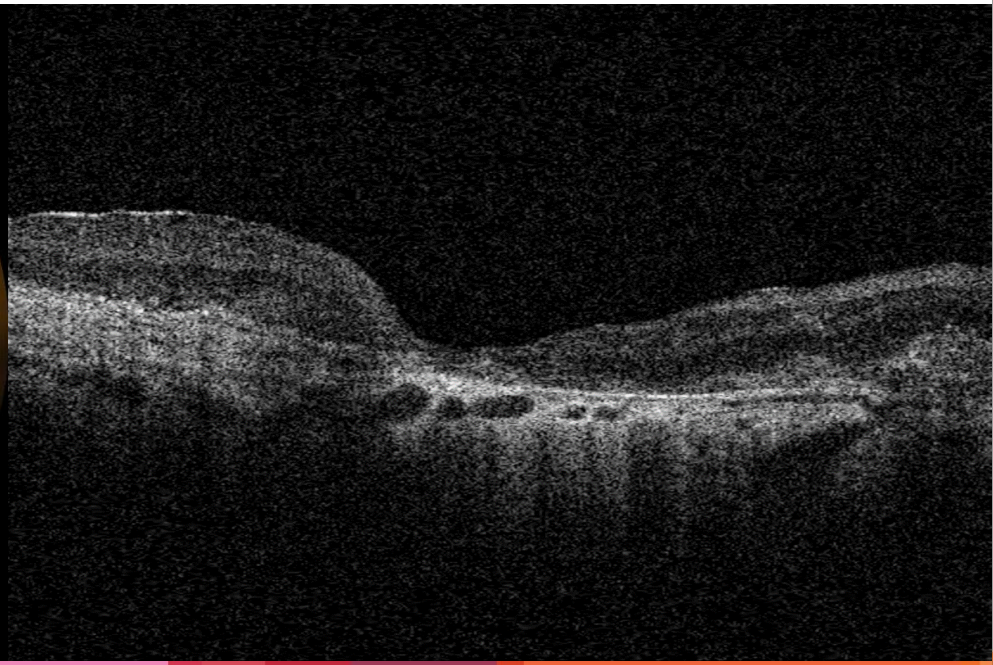
68 yr old female, **history of retinal detachment with surgery**
RE VA: 6/15
Outcome: **Continue ROC** in 18 months



Retinal observation clinic (ROC)

73 yr old female, **advanced age-related macular degeneration**
RE VA: CF
Outcome: **Referred back to SNEC Retinal Clinic in 6 months** due to **new hemorrhage**





Tele-ophthalmology: video-consults

National eye centre launches telemedicine for glaucoma patients

Joyce Teo
Senior Health Correspondent

"Doctor, my right eye is a little red," said Mr Tan, 70, a glaucoma patient at the Singapore National Eye Centre (SNEC).

"Come closer," Professor Tina Wong, head and senior consultant at the centre's glaucoma department, instructed, leaning forward.

This sounds like a typical consultation, except it isn't. Mr Tan and Prof Wong are on a video call – a new mode of care that SNEC has started for its growing pool of glaucoma patients whose conditions are stable.

The redness is a side effect of eye drops, Prof Wong told Mr Tan, who did not want to reveal his full name. After reviewing some previously taken eye images, she said she would order more checks for him at the centre in about two months.

Telemedicine became a necessity at the SNEC and other healthcare institutions during the circuit breaker beginning on April 7, when face-to-face consultations were minimised to urgent cases.

Now, it may become a normal part of business. The SNEC aims to offer video consultations to 500 stable glaucoma patients by the end of the year, and another 3,600 next year.

About 15,000 stable glaucoma patients who typically make two visits a year, forming 60 per cent of all SNEC glaucoma patients, will eventually be able to access this service, if they are willing.

Glaucoma is one of the leading causes of blindness in people aged above 60 and is brought on when high fluid pressure within the eye damages the delicate fibres of the optic nerve.

Patients will still need routine tests, such as visual field exams and eye imaging, to be done at the SNEC and future satellite clinics. But follow-ups can be done via telemedicine, saving them the commute to the centre and waits to see the doctor and collect their medicines, which can be delivered to their homes.

The SNEC handles nearly three quarters of the glaucoma patients in Singapore. There are more patients now as the population ages.

"We have over 55,000 to 60,000 patient visits a year. From 2015 to 2019, we saw a 40 per cent increase in the number of visits to the SNEC for glaucoma. So, the load is growing, but the space is the same," said Prof Wong.

Care can be stratified according to disease severity, she said.

Telemedicine will allow the centre to better serve patients whose conditions are more serious and need to be seen in person, she said.

Prof Wong said telemedicine works well for glaucoma. "We do a lot of imaging for glaucoma to monitor the disease and its progression," she said. "Having good photographs of the front of the eye is as good as if I were to examine a patient physically here."

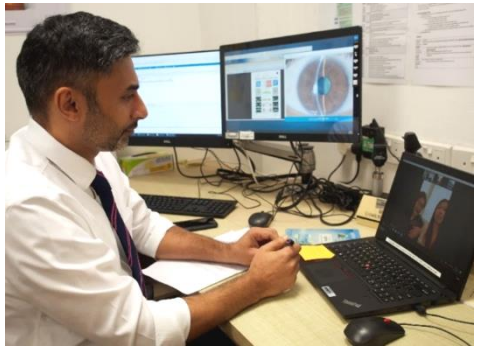
For now, like other specialist centres and hospitals, the SNEC is handling only urgent cases.

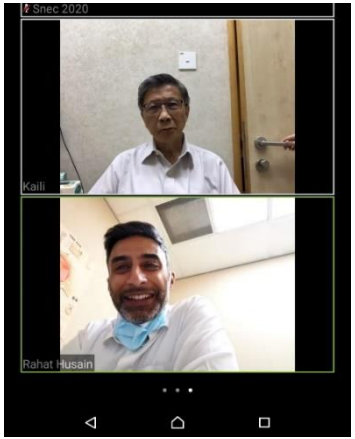
"We had 28 patients in the morning, when we normally see over 100," said Prof Wong. The SNEC expects to see a reduced number of patients going forward as safe distancing measures will still need to be observed.

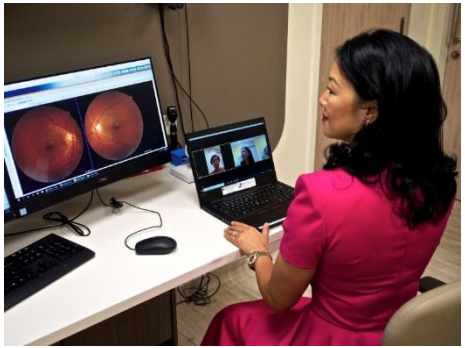
In the near future, the SNEC also plans to offer telemedicine to selected patients with myopia, and corneal, retinal as well as neuro-opthalmology conditions.

"One of the things we will remember from Covid-19 is that it has made us all go into the digital transformation era because we have had to adapt in times of adversity," said Prof Wong.

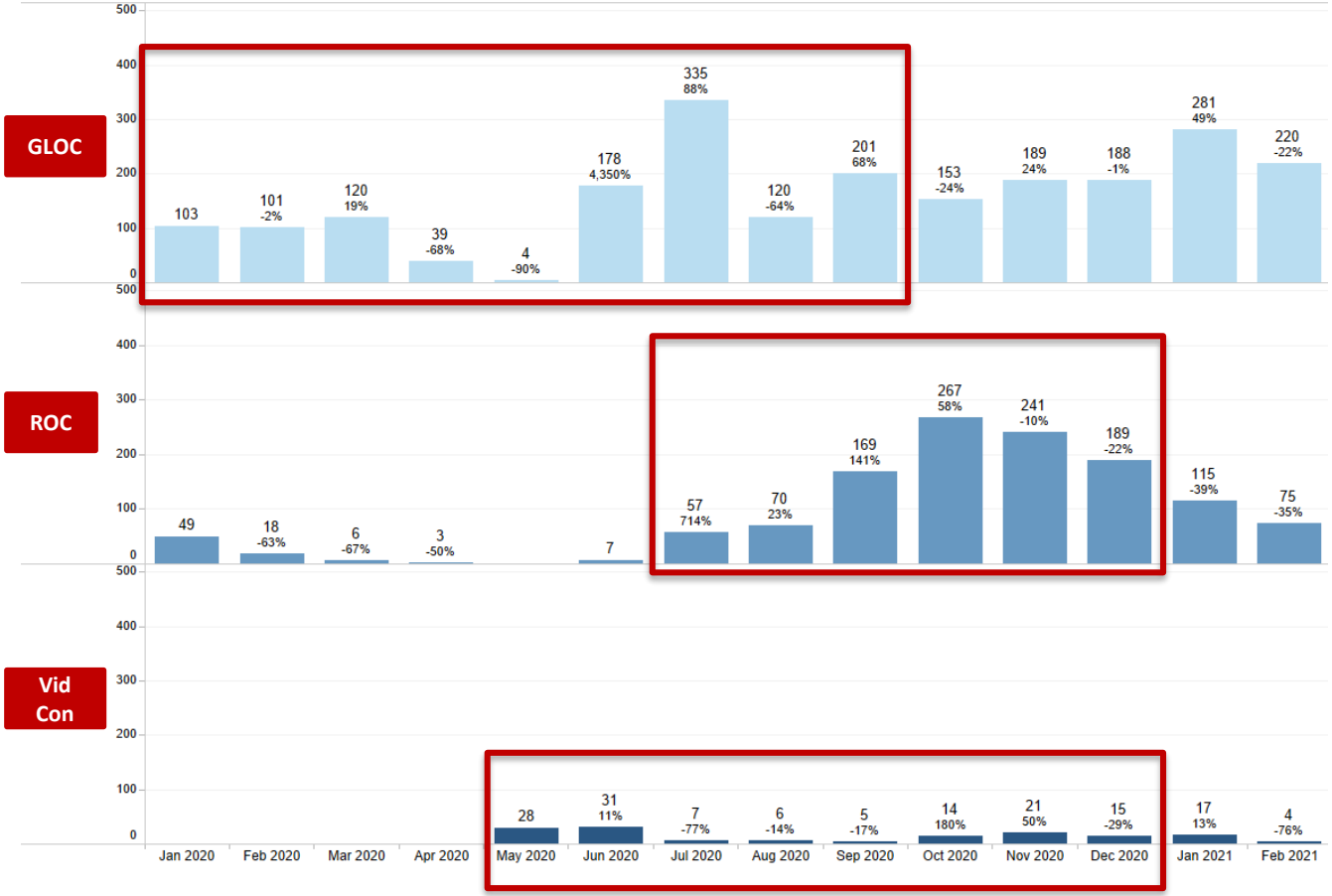
joyceteo@sph.com.sg







“Virtual” clinics & video-consults



- Difficult to sustain **initial excitement & momentum**
- **Resourcing:** Limited manpower to support
- **Doctors**: Unable to have clarity on **pay**
- **Patients** preferred F2F

Singapore National Eye Centre
SingHealth

SINGAPORE EYE RESEARCH INSTITUTE

…pushback from patients…

Forum: Telemedicine for glaucoma patients not a good idea

PUBLISHED MAY 30, 2020, 2:45 AM SGT

I read with some concern that the Singapore National Eye Centre (SNEC) aims to offer video consultations to more of its stable glaucoma patients (National eye centre launches telemedicine for glaucoma patients, May 27).

But based on my personal experience as a glaucoma patient over 20 years, my condition can fluctuate within four to six months from stable to unstable, with unacceptable high eye pressure leading to a need for urgent surgery.

The SNEC should build up its glaucoma services in its satellite clinics to cope with the increase in patient load, and not simply reduce patient visits by using telemedicine.

It should also be aware that most glaucoma patients are elderly, and may not have access to computers or know how to do video calls.

…introducing new indication for ROC…

Eye (2021) 35:1532–1537
https://doi.org/10.1038/s41433-020-01380-2

The ROYAL COLLEGE of OPHTHALMOLOGISTS

EDITORIAL

The Royal College of Ophthalmologists recommendations on monitoring for hydroxychloroquine and chloroquine users in the United Kingdom (2020 revision): executive summary

Imran H. Yusuf[1,2] · Barny Foot[3] · Andrew J. Lotery[4]

Received: 14 December 2020 / Revised: 17 December 2020 / Accepted: 17 December 2020 / Published online: 9 January 2021

Introduction

The Royal College of Ophthalmologists (RCOphth) published recommendations for monitoring in users of hydroxychloroquine and chloroquine in the United Kingdom in 2018 in order to reduce the risk of irreversible sight loss from toxic retinopathy in this group [1]. The 2018 recommendations have been replaced by the recently published clinical guideline: "Hydroxychloroquine and Chloroquine Retinopathy: Recommendations on Monitoring" (RCOphth, 14 Dec 2020)" [2]. This executive summary describes the new recommendations, and highlights the key changes from the previous clinical guideline with their justification. A review of the previous recommendations was prompted by the availability of high-quality published audit data based on the real-world outcomes of monitoring according to the 2018 recommendations [3, 4], feedback from UK retinal specialists and other key stakeholders, and the availability of supporting data from new clinical research studies judged to be of sufficient quality and relevance.

The case for monitoring was originally supported by the finding of an overall prevalence of retinopathy of 7.5% in long-term (>5 years) hydroxychloroquine users using modern retinal imaging techniques in the USA [5]. A real-world, UK-based audit identified a prevalence of retinopathy of 6.3% according to the same diagnostic criteria, validating the case for monitoring services in the UK for patients at risk [3].

The full guideline can be found online at: https://www.rcophth.ac.uk/standards-publications-research/clinical-guidelines/. An updated patient information leaflet written by the authors in collaboration with the Macular Society is available and should be distributed to patients. The criteria used for grading evidence is specified in Table 1. The recommendations and grade of evidence supporting them are detailed in Table 2a–h. Figure 1 presents a flow diagram summarising the monitoring algorithm—the recommended order of diagnostic tests for all patients.

Executive summary

After careful review of the existing peer-reviewed literature, we recommend that all patients be referred for annual monitoring after five years of therapy and be reviewed annually thereafter whilst on therapy. At each monitoring

Hydroxychloroquine (HCQ) screening

"…Monitoring for hydroxychloroquine retinopathy may **most effectively take place in virtual clinics** where visual field testing and dilated retinal imaging is undertaken before later being interpreted by an ophthalmologist…"

…pushback from doctors

"Dear MD

HCQ screening would be **the ideal con** for the relevant tests, be asked question

telemedicine the default model….

"…there are **subtleties** with HCQ examination that make it not suitable for virtual clinic..,

…may be the beginning of the **"dilution" of XXX** as a sub-speciality…

HoD, Department XXX

"Dear MD,

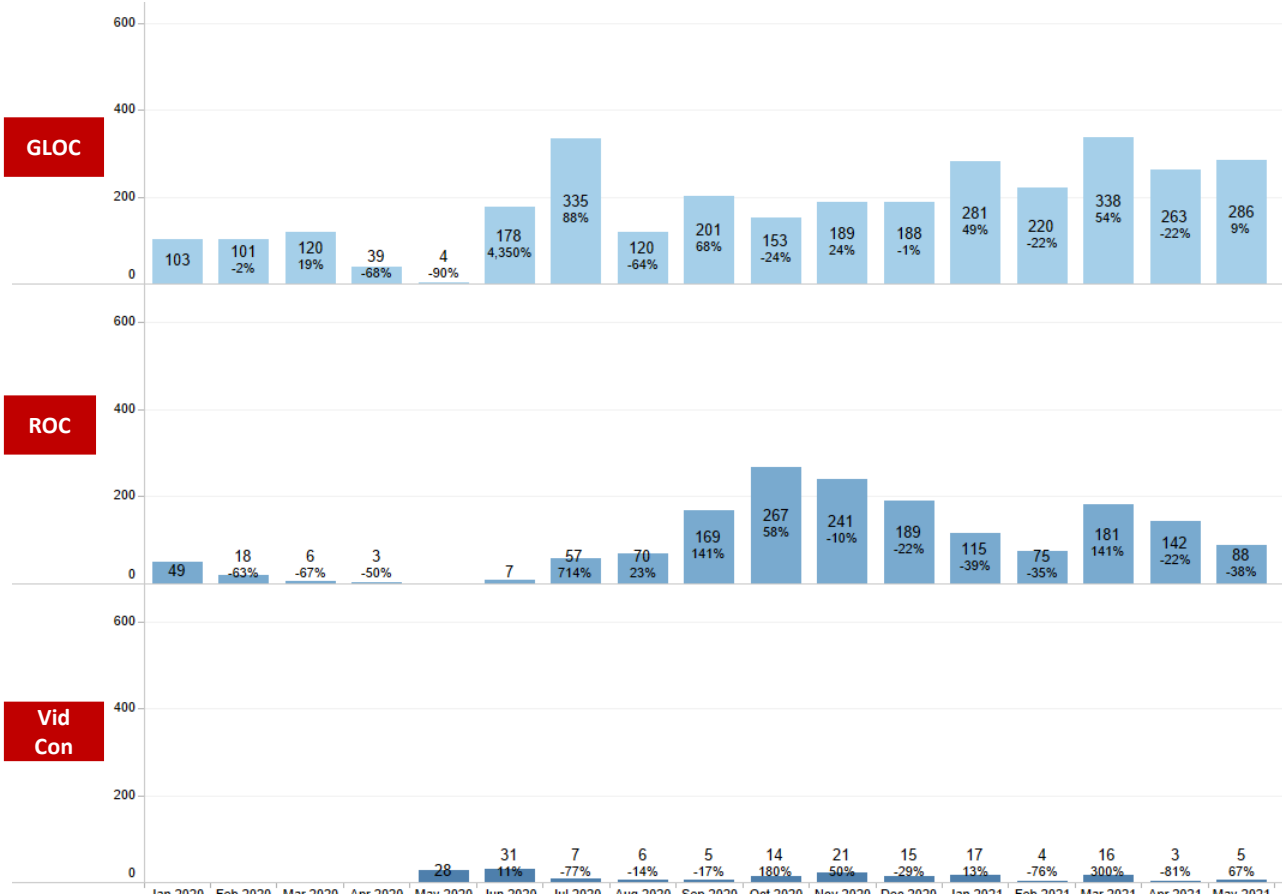
I was disappointed with emails regarding HCQ screening for telemedicine. To me it's an ideal condition for virtual clinic.

…I emailed one of my colleagues at **Moorfield's** to ask what they did for HCQ and he told me they are doing virtual clinics for screening.

I'm just frustrated by the **lack of enthusiasm for telemedicine** at SNEC. If the leaders cannot see that this condition is suitable for telemedicine, **what hope do we have for the rest of faculty**?"

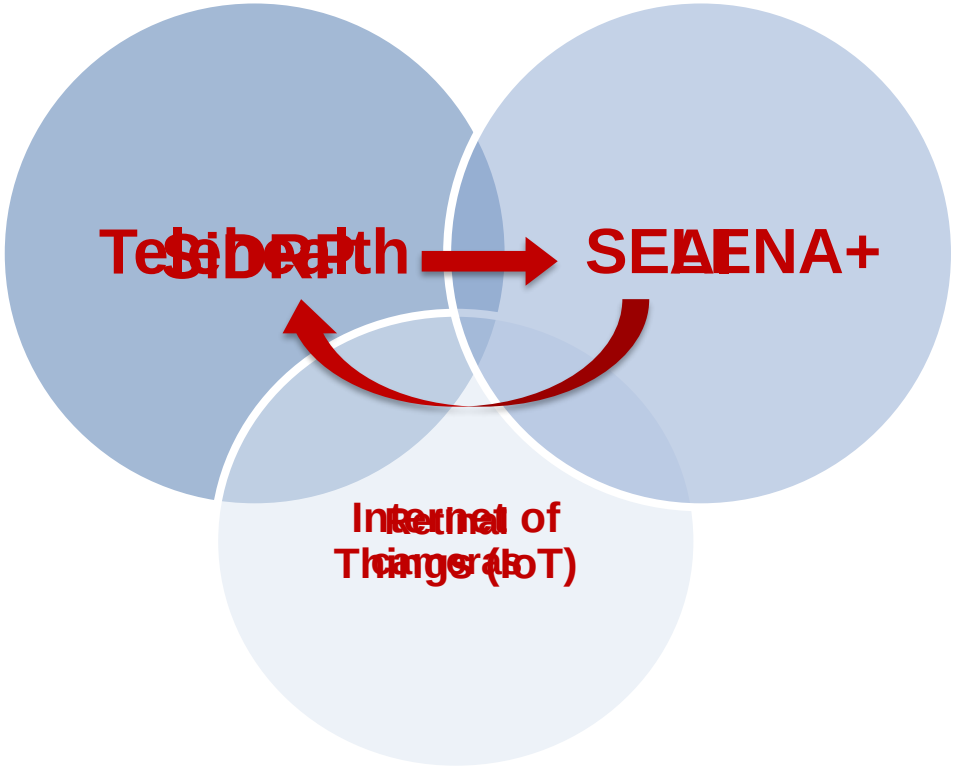
HoD, Vid-Con Program, SNEC

…Digital innovation: resilience…we push on!



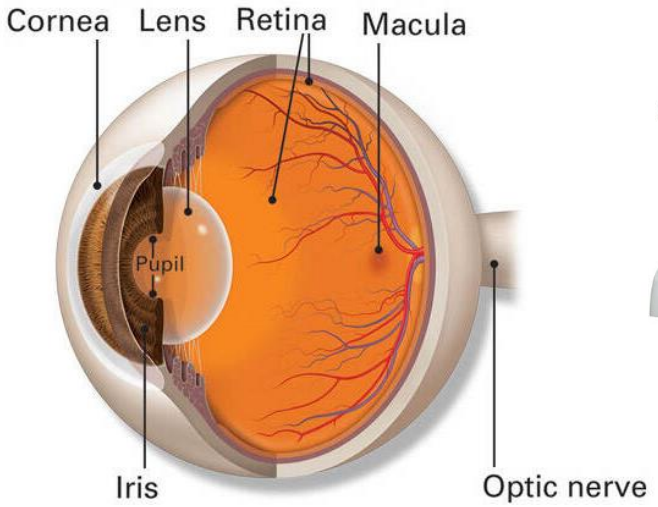
#3. AI: DR Screening

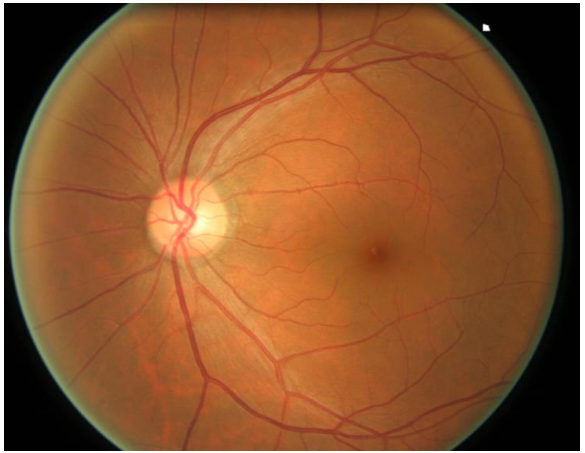
The story of SELENA+



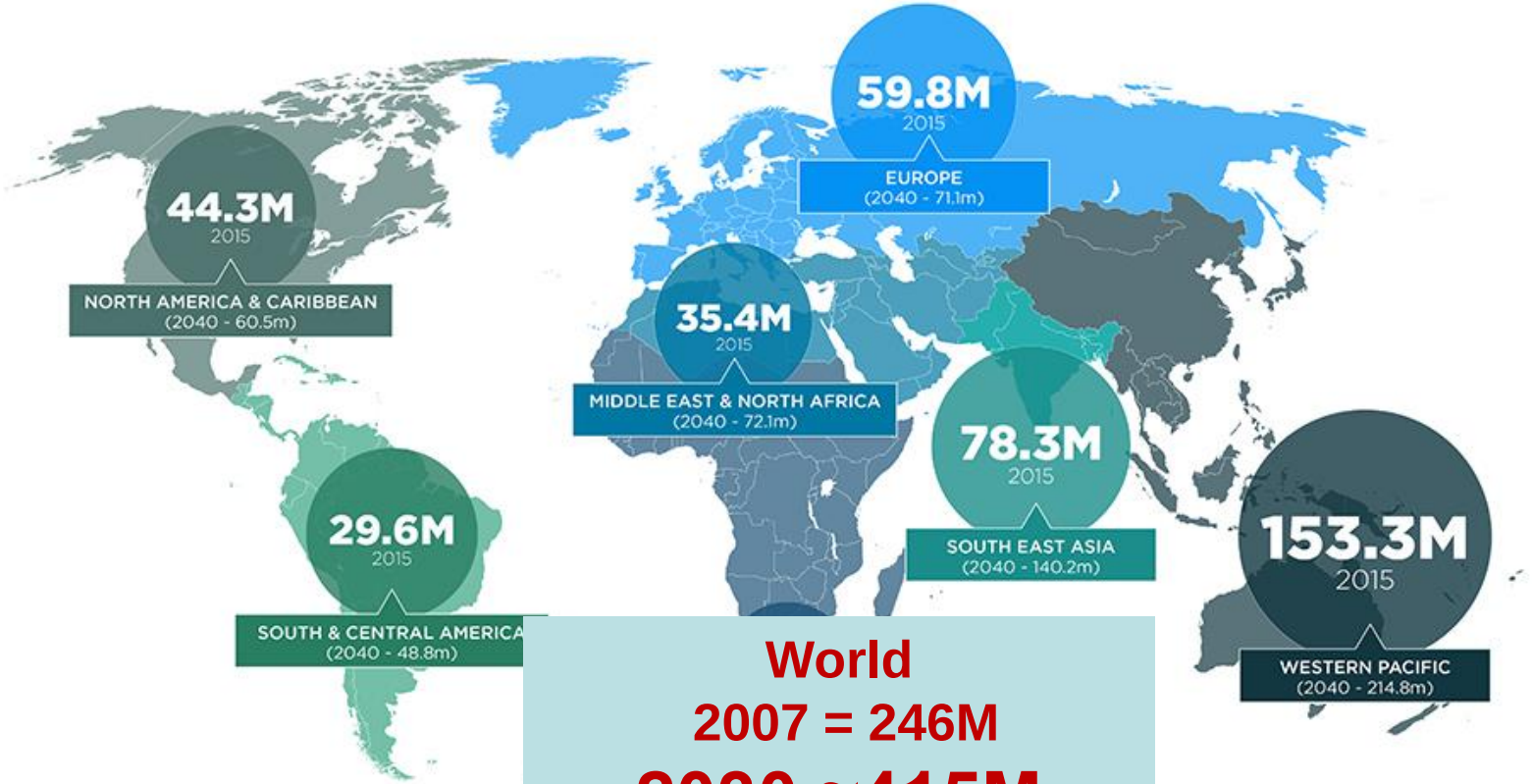
The retina is the “nerve layer” of the eyeball

can be imaged by retinal fundus camera





Diabetes is a global public health **problem**

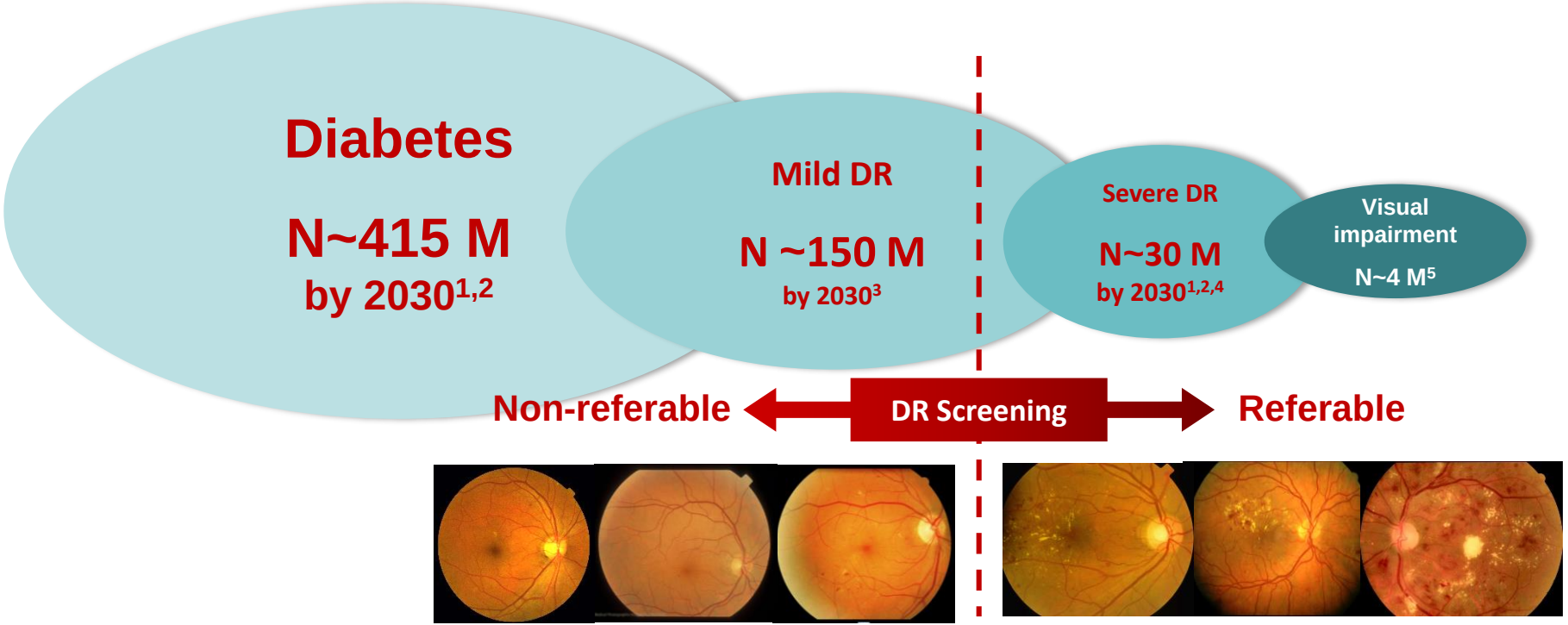


World

2007 = 246M

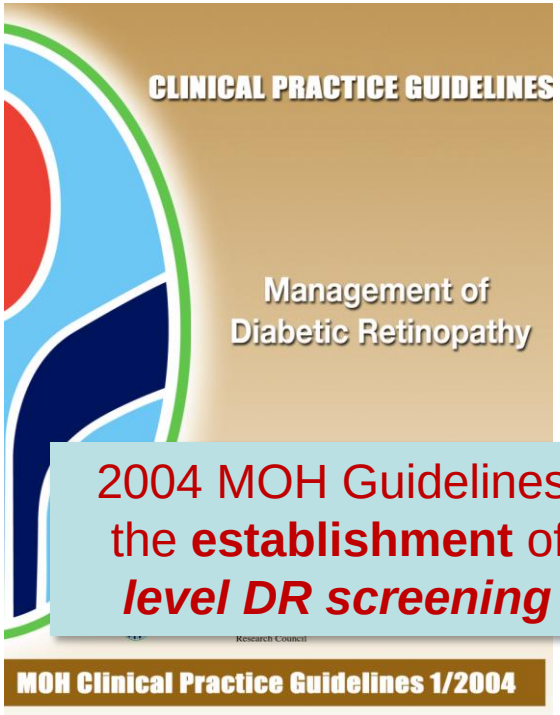
2030 ≈415M

Diabetic retinopathy (DR) is a major cause of blindness

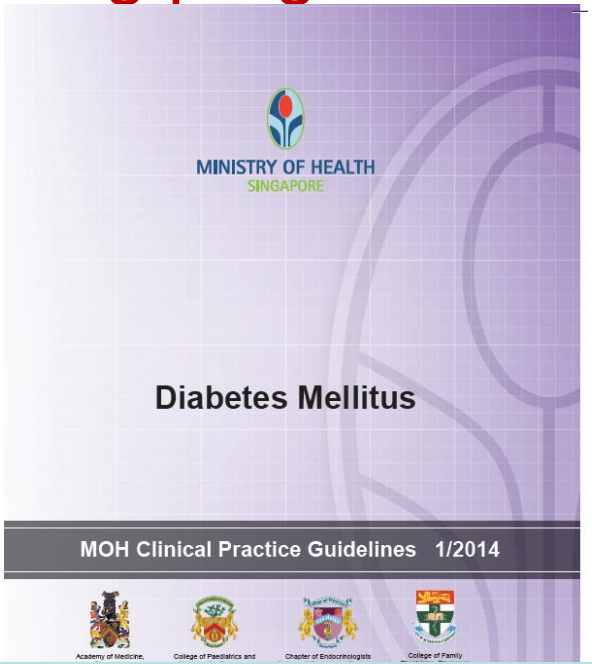


1. Shaw JE, et al. Diabetes Res Clin Pract. 2010;87(1):4–14; 2. Wild S, et al. Diabetes Care. 2004;27(5):1047–53; 3. Ting DSW, et al. Clin Exp Ophthalmol. 2016;44(4):260–77; 4. Yau JW, et al. Diabetes Care. 2012;35:556–64; 5. Leasher JL, et al. Diabetes Care. 2016;39:1643–49x

Singapore's DR screening program



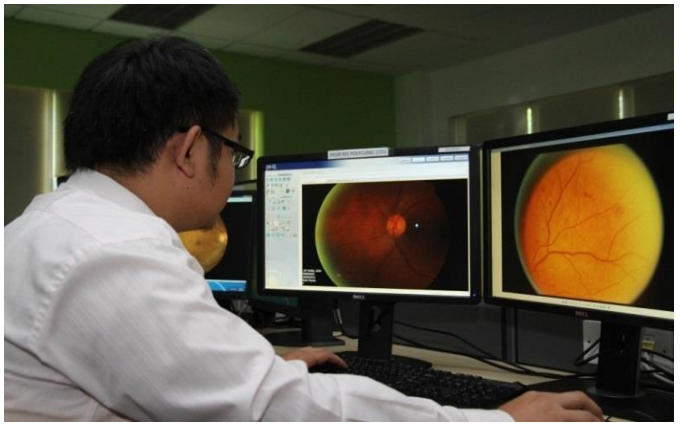
2004 MOH Guidelines recommend the **establishment** of a ***national-level DR screening program***…



2014…support for ***national-level DR screening program***…

SiDRP
SINGAPORE INTEGRATED DIABETIC RETINOPATHY PROGRAMME

Singapore's Integrated DR Program



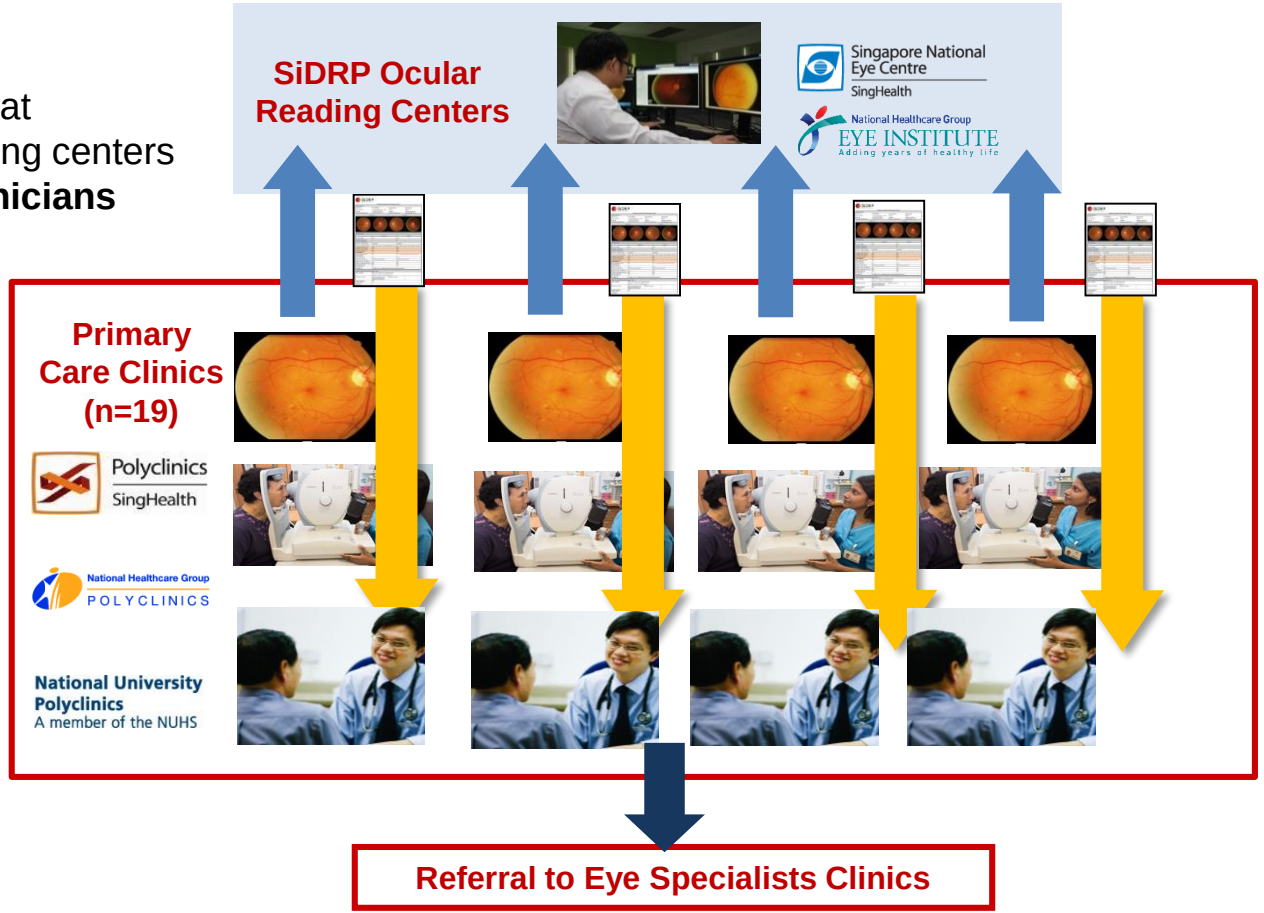
- National **tele-ophthalmology** based DR screening program, covering **120-150,000 persons** with diabetes (50%) in **19 primary care clinics** across Singapore

SiDRP
SINGAPORE INTEGRATED DIABETIC RETINOPATHY PROGRAMME

#2. DR grading at centralized reading centers by **trained technicians**

#1. Digital retinal photos taken by nurses at primary care clinics → uploaded to **secured server**

#3. Report transmitted back to primary care clinics → **Standardized & uniform** referral criteria



#4. Clear reporting outcomes

- No/Mild DR → Re-screen in 1 yr
- ≥Moderate NPDR → Refer

SiDRP
SINGAPORE INTEGRATED DIABETIC RETINOPATHY PROGRAMME

AMERICAN ACADEMY OF OPHTHALMOLOGY

Cost-effectiveness of a National Telemedicine Diabetic Retinopathy Screening Program in Singapore

Hai V. Nguyen, PhD,[1] Gavin Siew Wei Tan, MMed(Ophth), FAMS,[2] Robyn Jennifer Tapp, PhD,[3,4] Shweta Mital, MSc,[5] Daniel Shu Wei Ting, MD, PhD,[2] Hon Tym Wong, FRCSEd(Ophth), MMed(Ophth),[6] Colin S. Tan, FRCSEd(Ophth), MMed(Ophth),[6] Augustinus Laude, FRCSEd(Ophth), FAMS(Ophth),[7] E. Shyong Tai, FRCP, PhD,[8] Ngiap Chuan Tan, MMed(FM), MCI,[9] Eric A. Finkelstein, PhD, MHA,[5] Tien Yin Wong, MMed(Ophth), PhD,[2,10,*] Ecosse L. Lamoureux, MSc, PhD[2,10,*]

Purpose: To determine the incremental cost-effectiveness of a new telemedicine technician-based assessment relative to an existing model of family physician (FP)–based assessment of diabetic retinopathy (DR) in Singapore from the health system and societal perspectives.

Design: Model-based, cost-effectiveness analysis of the Singapore Integrated Diabetic Retinopathy Program (SiDRP).

Participants: A hypothetical cohort of patients aged 55 years with type 2 diabetes previously not screened for DR.

Methods: The SiDRP is a new telemedicine-based DR screening program using trained technicians to assess retinal photographs. We compared the cost-effectiveness of SiDRP with the existing model in which FPs assess photographs. We developed a hybrid decision tree/Markov model to simulate the costs, effectiveness, and incremental cost-effectiveness ratio (ICER) of SiDRP relative to FP-based DR screening over a lifetime horizon. We estimated the costs from the health system and societal perspectives. Effectiveness was measured in terms of quality-adjusted life-years (QALYs). Result robustness was calculated using probabilistic sensitivity analyses.

Main Outcome Measures: The ICER.

Results: From the societal perspective that takes into account all costs and effects, the telemedicine DR screening model had significantly lower costs (total cost savings of S$173 per person) while generating similar QALYs compared with the physician-based model (i.e., 13.1 QALYs). From the health system perspective that includes only direct medical costs, the cost savings are S$144 per person. By extrapolating the results to approximately 170 000 patients with diabetes currently being screened yearly for DR in Singapore's primary care polyclinics, the present value of future cost savings associated with the telemedicine-based model is estimated to be S$29.4 million over a lifetime horizon.

Conclusions: While generating similar health outcomes, the telemedicine-based DR screening using technicians in the primary care setting saves costs from a societal perspective. Our data provide a strong economic rationale to expand the telemedicine program in Singapore and elsewhere. *Ophthalmology 2016;■:1–10 © 2016 American Academy of Ophthalmology*

Original Article — Singapore Med J 2012; 53(11): 715

Accuracy of diabetic retinopathy screening by trained non-physician graders using non-mydriatic fundus camera

Mayuri Bhargava[1,§], MD, Carol Yim-Lui Cheung[1], PhD, Charumathi Sabanayagam[2], MD, PhD, Ryo Kawasaki[2], MD, PhD, C Alex Harper[3], MD, Ecosse L Lamoureux[1,2], MSc, PhD, Wai Leng Chow[4], MBBS, Adrian Ee[4], MBBS, Haslina Hamzah[1], BSc, Maisie Ho[1], BSc, Wanling Wong[1], MBiostat, Tien Yin Wong[1,2,§], PhD, FRCSE

INTRODUCTION We compared the agreement of diabetic retinopathy (DR) assessment between trained non-physician graders (NPGs) and family physicians (FPs) in a primary healthcare setting.

METHODS This was a cross-sectional study conducted retrospectively over a period of one month. The participants were diabetic patients from two primary healthcare clinics (polyclinics) in Singapore. Single-field digital retinal images were obtained using a non-mydriatic 45-degree fundus camera. Retinal images were graded for the presence or absence of DR by FPs at the polyclinics and by NPGs at a central ocular grading centre. The FPs' and NPGs' assessments of DR were compared with readings by a single retinal specialist (reference standard).

RESULTS A total of 367 diabetic patients (706 eyes) were included in the study. The mean age of the patients was 63 years, and the majority were Chinese (83.8%). For DR assessment, the agreement between NPGs and the retinal specialist was substantial (κ = 0.66), while the agreement between FPs and the retinal specialist was only fair (κ = 0.40). NPGs' assessment showed higher sensitivity (70% vs. 45%) and comparable specificity (94% vs. 92%) as compared to FPs' assessment. The area under the receiver operating characteristic curve of NPGs' assessment of DR was greater than that of the FPs' (0.82 vs. 0.69, p < 0.001).

CONCLUSION This study has demonstrated that trained NPGs are able to provide good detection of DR and maculopathy from fundus photographs. Our findings suggest that DR screening by trained NPGs may provide a cost-effective alternative to FPs.

Keywords: diabetic retinopathy, family physicians, screening, single-field digital retinal images, trained graders
Singapore Med J 2012; 53(11): 715–719

2,245 2010

8,395 2011

11,779 2012

16,958 2013

21,805 2014

30,726 2015

>120,000 2019-2020

Started in Pasir Ris polyclinic

Started in Hougang polyclinic

Started in Woodlands polyclinic

Started in Clementi & Geylang East Polyclinics

11 out of 18 polyclinics

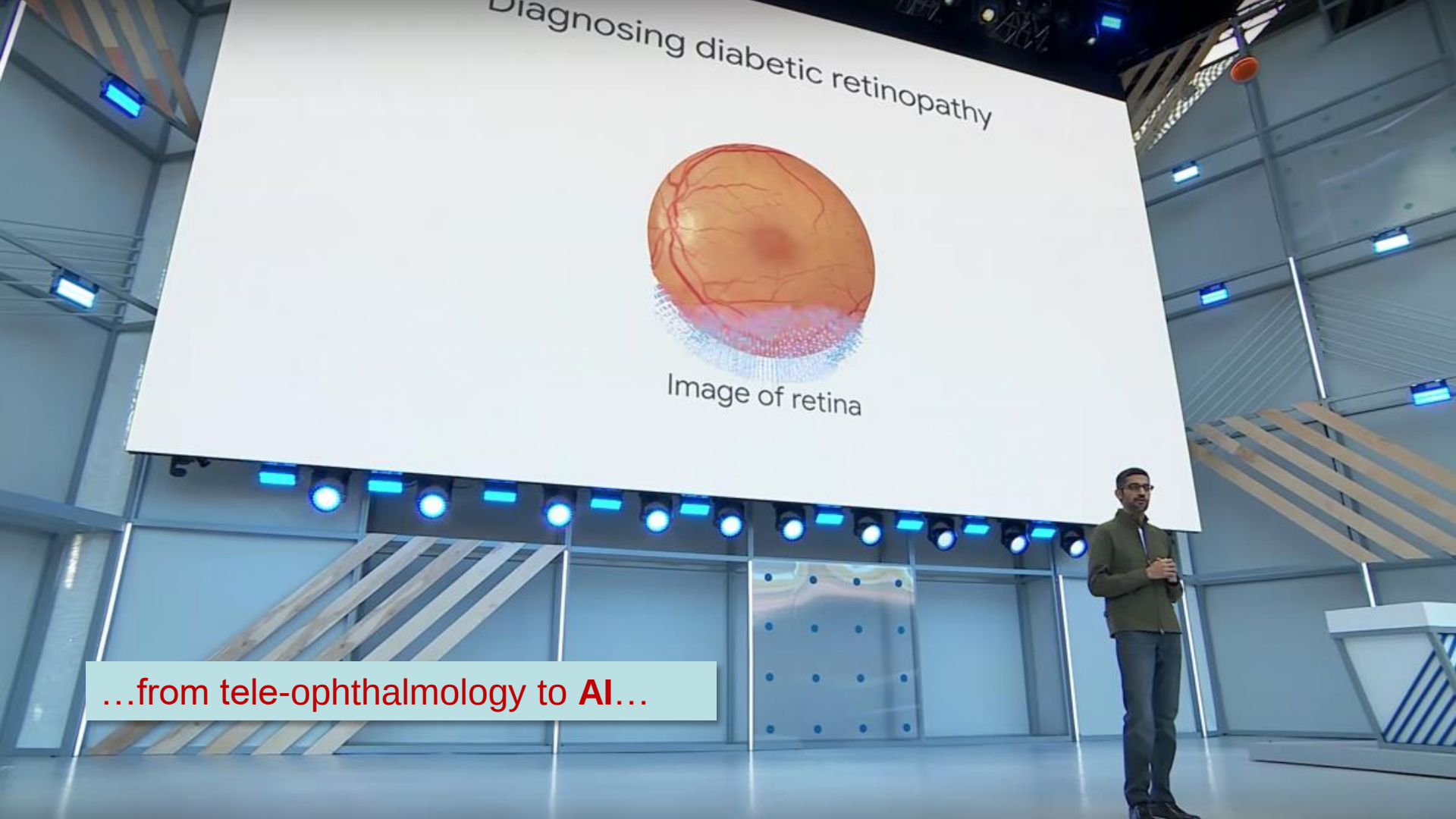
All 19 polyclinics

Singapore National Eye Centre
SingHealth

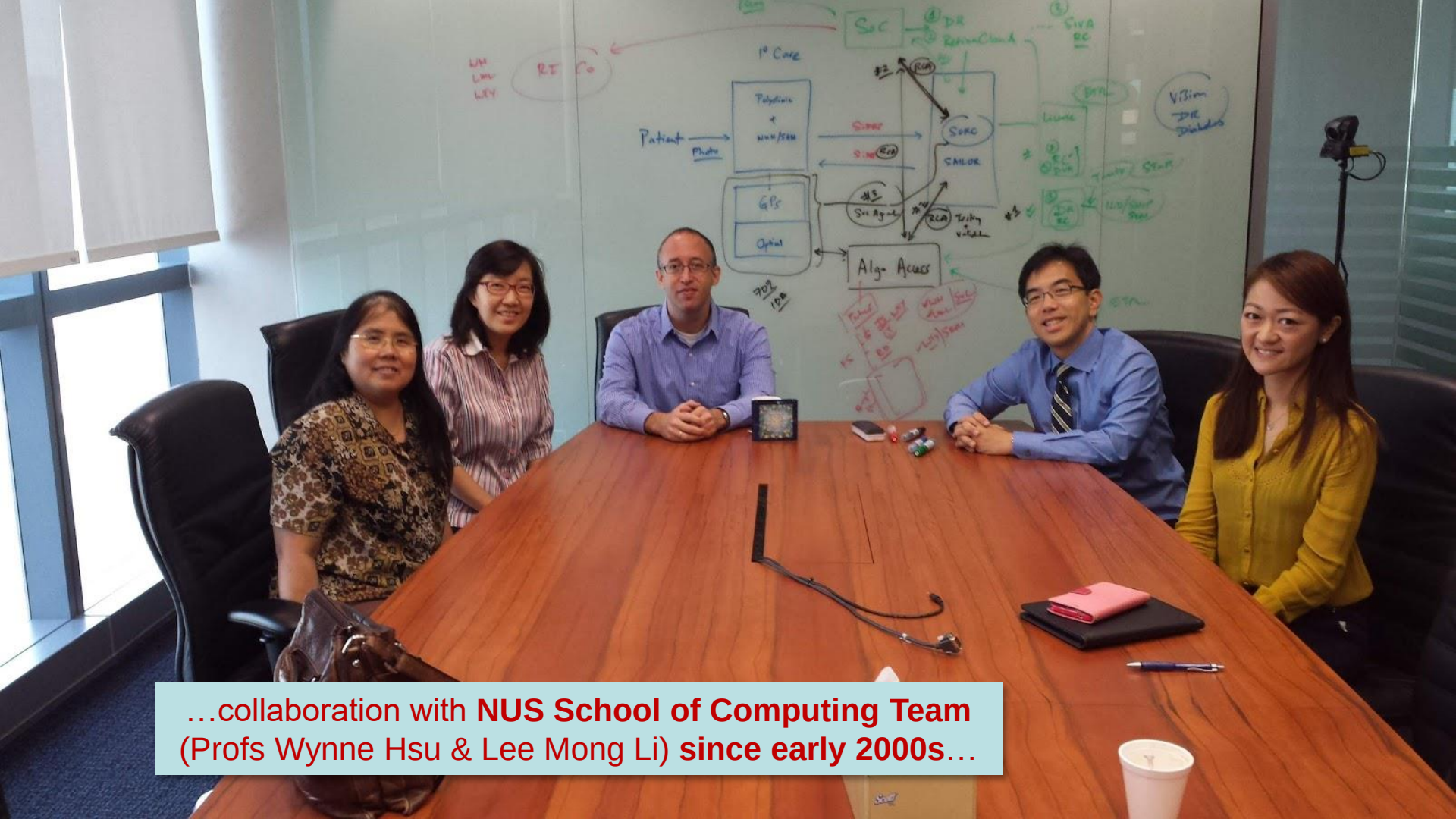
PATIENTS. AT THE HEART OF ALL WE DO.

…2019 **MOH's National Medical Excellence Team Award**…

Question…how to improve **sustainability** of SiDRP?



…from tele-ophthalmology to **AI**…



…collaboration with **NUS School of Computing Team** (Profs Wynne Hsu & Lee Mong Li) **since early 2000s**…

…from SiDRP (telehealth) to SELENA+ (AI)

SiDRP: Tele-ophthalmology platform

IHiS

procures and manages all external vendors for SIDRP i.e. vendor and software maintenance for OphthLive system by
(i) Topcon
(ii) Pellucid

Singapore National Eye Centre
SingHealth

National Healthcare Group EYE INSTITUTE
Adding years of healthy life

Established

supports → SiDRP
SINGAPORE INTEGRATED DIABETIC RETINOPATHY PROGRAMME

Polyclinics SingHealth

National Healthcare Group POLYCLINICS

National University Polyclinics
A member of the NUHS

SELENA+: AI program

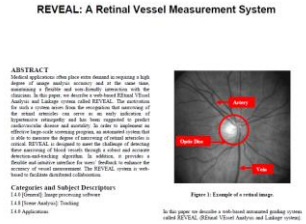
SINGAPORE EYE RESEARCH INSTITUTE

NUS National University of Singapore

Co-developed

Early 2000s → **REVEAL**

2015-present → **SELENA+**


REVEAL: A Retinal Vessel Measurement System

ABSTRACT

Categories and Subject Descriptors

National Healthcare Group EYE INSTITUTE
Adding years of healthy life

Singapore National Eye Centre
SingHealth

SELENA+

Ting et al. JAMA 2017

Research

JAMA | Original Investigation

Development and Validation of a Deep Learning System for Diabetic Retinopathy and Related Eye Diseases Using Retinal Images From Multiethnic Populations With Diabetes

Daniel Shu Wei Ting, MD, PhD; Carol Yim-Lui Cheung, PhD; Gilbert Lim, PhD; Gavin Siew Wei Tan, FRCSEd; Nguyen D. Quang, BEng; Alfred Gan, MSc; Haslina Hamzah, BSc; Renata Garcia-Franco, MD; Ian Yew San Yeo, FRCSEd; Shu Yen Lee, FRCSEd; Edmund Yick Mun Wong, FRCSEd; Charumathi Sabanayagam, MD, PhD; Mani Baskaran, MD, PhD; Farah Ibrahim, MB, BCh, BAO; Ngiap Chuan Tan, MCI, FAMS; Eric A. Finkelstein, MHA, PhD; Ecosse L. Lamoureux, PhD; Ian Y. Wong, FRCOph; Neil M. Bressler, MD; Sobha Sivaprasad, FRCOph; Rohit Varma, MD, MPH; Jost B. Jonas, MD, PhD; Ming Guang He, MD, PhD; Ching-Yu Cheng, MD, PhD; Gemmy Chui Ming Cheung, FRCOph; Tin Aung, MD, PhD; Wynne Hsu, PhD; Mong Li Lee, PhD; Tien Yin Wong, MD, PhD

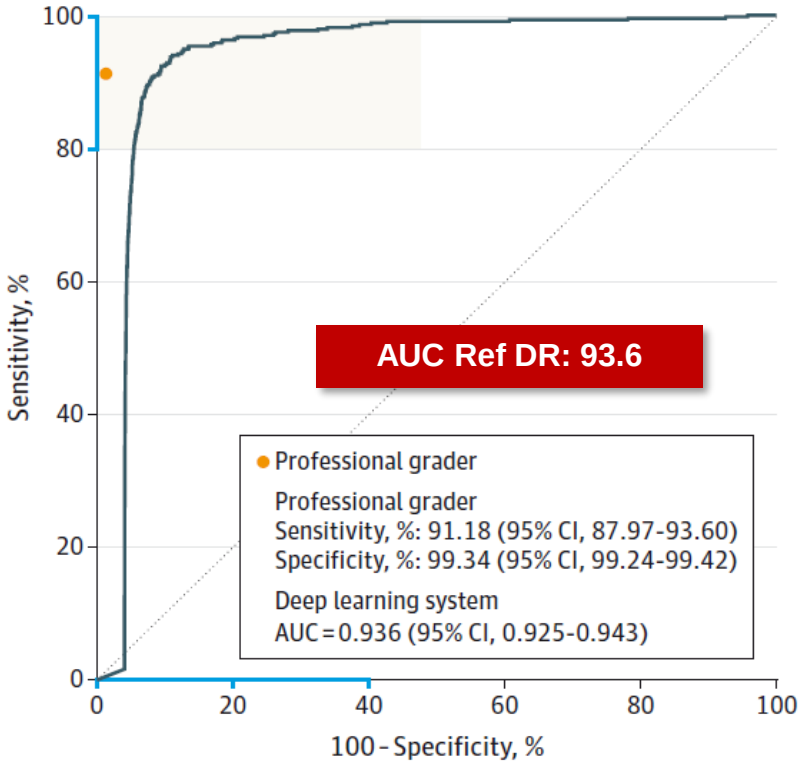
IMPORTANCE A deep learning system (DLS) is a machine learning technology with potential for screening diabetic retinopathy and related eye diseases.

Related article page 2199

Supplemental content

Total retinal images : **493,667**

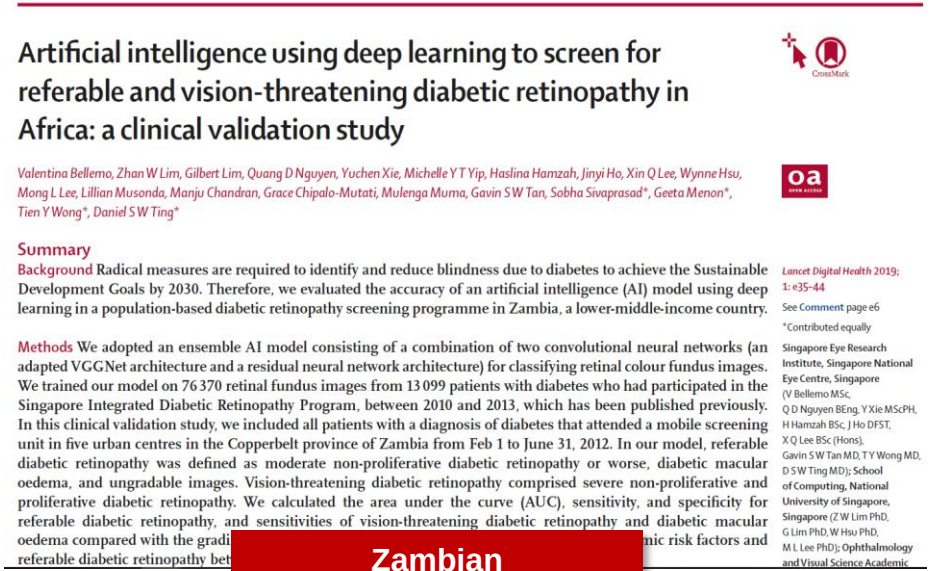
	Training	Testing
DR	76,370	112,648
Glaucoma	125,189	71,896
AMD	71,616	35,948



SELENA+

…testing in extreme real-world setting

Bellemo et al. Lancet Digital Health 2019



Artificial intelligence using deep learning to screen for referable and vision-threatening diabetic retinopathy in Africa: a clinical validation study

Valentina Bellemo, Zhan W Lim, Gilbert Lim, Quang D Nguyen, Yuchen Xie, Michelle Y T Yip, Haslina Hamzah, Jinyi Ho, Xin Q Lee, Wynne Hsu, Mong L Lee, Lillian Musonda, Manju Chandran, Grace Chipalo-Mutati, Mulenga Muma, Gavin S W Tan, Sobha Sivaprasad*, Geeta Menon*, Tien Y Wong*, Daniel S W Ting*

Summary

Background Radical measures are required to identify and reduce blindness due to diabetes to achieve the Sustainable Development Goals by 2030. Therefore, we evaluated the accuracy of an artificial intelligence (AI) model using deep learning in a population-based diabetic retinopathy screening programme in Zambia, a lower-middle-income country.

Methods We adopted an ensemble AI model consisting of a combination of two convolutional neural networks (an adapted VGGNet architecture and a residual neural network architecture) for classifying retinal colour fundus images. We trained our model on 76 370 retinal fundus images from 13 099 patients with diabetes who had participated in the Singapore Integrated Diabetic Retinopathy Program, between 2010 and 2013, which has been published previously. In this clinical validation study, we included all patients with a diagnosis of diabetes that attended a mobile screening unit in five urban centres in the Copperbelt province of Zambia from Feb 1 to June 31, 2012. In our model, referable diabetic retinopathy was defined as moderate non-proliferative diabetic retinopathy or worse, diabetic macular oedema, and ungradable images. Vision-threatening diabetic retinopathy comprised severe non-proliferative and proliferative diabetic retinopathy. We calculated the area under the curve (AUC), sensitivity, and specificity for referable diabetic retinopathy, and sensitivities of vision-threatening diabetic retinopathy and diabetic macular oedema compared with the gradi… …mic risk factors and referable diabetic retinopathy bet…

Lancet Digital Health 2019; 1: e35–44

See Comment page e6

*Contributed equally

Singapore Eye Research Institute, Singapore National Eye Centre, Singapore (V Bellemo MSc, Q D Nguyen BEng, Y Xie MScPH, H Hamzah BSc, J Ho DFST, X Q Lee BSc (Hons), Gavin S W Tan MD, T Y Wong MD, D S W Ting MD); School of Computing, National University of Singapore, Singapore (Z W Lim PhD, G Lim PhD, W Hsu PhD, M L Lee PhD); Ophthalmology and Visual Science Academic

Zambian DR screening program AUC Ref DR: 97.3

"Although tele-ophthalmology has been attempted in Africa, screening programs that provide instant feedback have **involved taking an individual who normally provides key services at eye departments**…

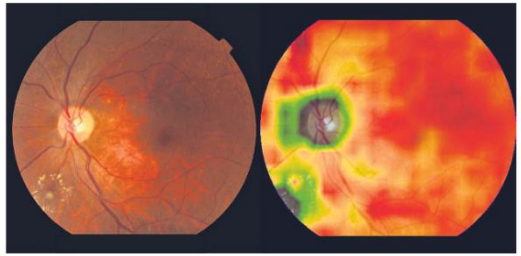
…taking skilled individual from a setup already struggling with shortages of trained eye workers adds further strain to system."

Editorial, *Lancet Digital Heath 2019*

Singapore National Eye Centre
SingHealth

SELENA+…significant publicity

AI system promises faster tests for 3 eye diseases



(Far left) A retinal image with diabetic retinopathy (DR) next to a heat map generated by the AI system which highlights where the DR lesions are.
PHOTO: SINGAPORE NATIONAL EYE CENTRE OCULAR READING CENTRE

PREVENTIVE USE

The next step is to train the AI system to predict which patients will have eye diseases in the future, simply by looking at their retinal images before they develop any diseases.

PROFESSOR WONG TIEN YIN medical director of the Singapore National Eye Centre and the study's senior author

Singapore's artificial intelligence strategy

Applying AI to help – not replace – people

Singapore's national artificial intelligence strategy has kicked off with five projects in various sectors. Will the new technology make workers irrelevant? The Straits Times examines the issues.

Jolene Ang and Timothy Goh

Human teachers and healthcare workers will still play an important role, even though some have embarked on an aggressive plan to use artificial intelligence (AI) technologies in both the education and healthcare sectors.

Education

For one thing, there are no plans to use automated marking systems in exams including the Primary School Leaving Examination, the Ministry of Education (MOE) told The Straits Times.

Automated systems, to be rolled out to mark primary and secondary English language assignments by 2022, will be applied in limited areas such as open-ended, short-answer questions and essays.

"Our plan is to use an AI-enabled automated marking system to focus on language errors such as in grammar, spelling and syntax, with the teacher marking for ideas, structure and content," said an MOE spokesman. "It is likely that teachers will spend less time on routine assessment tasks, which will free up time for designing effective lessons... and building strong teacher-student relationships."

The national AI strategy was unveiled by Deputy Prime Minister Heng Swee Keat last month. Education is one of five AI projects identified. The others are in healthcare, transport and logistics, smart cities and estates, and border security.

On the sidelines of the Smart City Expo World Congress in Barcelona last month, Minister-in-charge of the Smart Nation initiative Vivian Balakrishnan said: "At the heart of education is interaction... I do not believe that AI will ever replace teachers. But there are some things that AI does well, for instance, in the identification of plagiarism and the customisation of curriculum."

An "adaptive learning" system for mathematics at the primary and lower secondary levels will be launched in 2021.

It will use machine learning to tell how each student responds to various learning materials and activities, and customise learning.

The automated marking system for English will collect data on common grammar mistakes so that teachers can focus on problematic areas.

The MOE will expand both systems to include more subjects in 2030.

Parents believe this is a prudent move. Parent and former teacher Shirlen Soo, 37, said: "This system has to be piloted and tried out in a few schools first, before such a drastic overhaul can be made."

A former General Paper (GP) teacher in a junior college, who declined to be named, said the human touch is irreplaceable in marking.

Citing GP as an example, he said: "The truly exceptional scripts that blow my mind let me feel the personality of the writer as well as his or her conviction."

Singapore Polytechnic lecturer Dora Chua, who teaches streaming analytics and the Internet of Things, said the AI programme will have to be exposed to many English assignments, in all kinds of variants, to have an idea of what constitutes an A or B grade.

Mr Jia Junhua, chief executive of education technology company ProQed, said the real challenge to adaptive learning could be in designing and developing material to work with the new AI tool. For instance, content creators will have to think of the "dynamic routes" that different students may take and plan alternative content.

Dr Gavin Tan, director of the Singapore National Eye Centre's ocular reading centre, said AI does not remove the human from the screening process. For instance, only primary grading – which is the first of three levels of checks and consists of the bulk of the grunt work – will be done by the machine, he noted. Senior graders will conduct the other levels of checks, which involve more detailed inspection of images flagged to have problems.

A mock screening session with artificial intelligence system Selena+. The system will be deployed across Singapore by 2022 to help detect eye conditions.
ST FILE PHOTO

Healthcare

In healthcare, a new system dubbed Selena+ will be deployed across Singapore by 2022 to help detect eye conditions, including diabetic eye disease.

Before Selena+, images were processed by human graders staring at retinal images on a screen.

The system was first tested for a few months from November last year in a few polyclinics and it has since processed over half a million images. A second trial will start this month in all polyclinics.

Dr Gavin Tan, director of the Singapore National Eye Centre's (SNEC) ocular reading centre, said AI does not remove the human from the screening process.

For instance, only primary grading – which is the first of three levels of checks and consists of the bulk of the grunt work – will be done by the machine, he noted. Senior graders will conduct the other levels of checks, which involve more detailed inspection of images flagged to have problems.

"Preliminary data shows that if we allow our most senior graders to review a certain category of the images, we can improve the overall accuracy of the programme," he said.

Selena+ was developed by the SNEC's Singapore Eye Research Institute and the National University of Singapore's School of Computing. It is licensed to local start-up Eyris.

Tests have shown that with Selena+, a patient with normal results could receive a report in just three minutes, instead of one hour.

The system has also proven itself to be as good as, if not better than, a trained grader.

Dr Tan said: "We expect to need less manpower, and anticipate that our overall sensitivity of the programme might increase... (Unlike human graders), there is no fatigue or concentration lapses."

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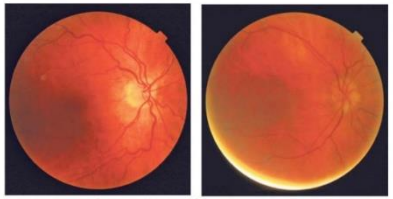
Using AI to interpret eye images for major health risks

It can screen for life-threatening conditions like brain tumours

Joyce Teo
Senior Health Correspondent



Images of the ocular fundus (inside, back surface of the eye) showing the optic nerve head – the region where the blood vessels converge – in a normal patient (left) and in a patient with subtle abnormalities associated with a brain tumour.
PHOTOS: SINGAPORE NATIONAL EYE CENTRE

An artificial intelligence (AI) system can look at photographs of the back of the eye and accurately detect if there is an eye condition that points to a brain tumour or other life- or vision-threatening conditions.

It sounds almost too good to be true, but Professor Dan Milea, a neuro-ophthalmologist and a senior consultant at the Singapore National Eye Centre (SNEC), said this game-changing concept has recently been proven.

AI has recently been used to detect various ophthalmic diseases, such as diabetic retinopathy.

SNEC's deep-learning AI software system Selena+, which can detect whether someone has diabetic retinopathy, glaucoma or age-related macular degeneration from a photo of the person's eye, was approved for use in Singapore only last October.

Now, AI has been shown to be able to make inferences about rare but serious conditions, not in the eye, but in the brain, by interpreting photographs.

A global study has shown that an AI system can look at images of the back of your eye and rapidly identify various optic abnormalities.

Importantly, it can accurately detect a specific type of optic nerve abnormality known as papilledema, which is linked to life- or vision-threatening diseases of the brain, such as brain tumours.

Papilledema is the swelling of the optic disc (or optic nerve head) due to pressure build-up in or around the brain.

The AI system has a 96 per cent sensitivity, meaning that it can pick up 96 out of 100 images with papilledema, said Prof Milea, who is also head of the visual neuroscience group at the Singapore Eye Research Institute (Seri).

While rare, papilledema can lead to blindness or even death, he said.

"Thus, the appropriate identification (of papilledema) on a simple photograph can alert doctors who do not have expertise in ophthalmology to the possibility of a severe brain condition that may otherwise get overlooked," he said.

"If further validated, this method may improve detection of brain and optic nerve abnormalities in patients who do not have other obvious signs of the disease."

The study, Artificial Intelligence To Detect Papilledema From Ocular Fundus Photographs, was published in the prestigious New England Journal of Medicine in April.

A journal editorial on the study had concluded that "the breadth of this study makes it likely that some versions of these automated systems will make their way through regulatory approval and into the clinic".

The AI system was developed in Singapore by a collaborative group including researchers from Seri, Duke-NUS Medical School and the Agency for Science, Technology and Research.

Prof Milea said the system would be particularly helpful in emergency departments, in neurology practices and even in general practitioner clinics.

He offered the following scenario: Someone walks into the emergency room at 2am, complaining of a very bad headache but otherwise having no symptoms of visual impairment, such as blurred vision.

The patient would not get to see an ophthalmologist at that time, and may instead be sent for brain scans to rule out the small chance of a stroke or bleeding in the brain.

The AI system would be able to give an answer in a few seconds at minimal cost, he said.

"Detecting this, I can say: This guy goes to the top of the queue for a scan. This guy has high brain pressure. There is bleeding or something growing in the brain and that can cause death."

Professor Wong Tien Yin, SNEC's medical director and one of the study's authors, said the power of AI in this area is unmistakable.

"At the E.D (emergency department), sometimes the doctors should look at the optic nerve but don't for lack of experience and expertise," he said.

However, if there is swelling of the optic disc, you would be prioritised for a scan, he said.

Prof Milea said it is just as important to rule things out. "If there's nothing wrong with the eye, the doctor can confidently send the patient back home," he said.

That is a big deal, as expensive, unnecessary and sometimes dangerous investigations like a lumbar puncture can be avoided.

The study involved more than 7,000 patients from 25 centres around the world, and the AI system was fed with 15,846 ocular fundus photographs from individuals of multiple ethnicities.

It was a major undertaking to collect so many images and Prof Milea, who is originally from France and has worked in other countries, said he tapped his contacts to do so over a period of about two years.

"Papilledema is rare... In this study, the machine was trained by being exposed to more pictures of papilledema and other optic disc abnormalities than what one specialist can see in a normal practice over a long career," he said.

"Transferring such skills to AI-based medical devices may contribute to evolving new ways of practising medicine at a distance, in order to better protect patients and a very bad headache but otherwise having no symptoms of visual impairment, such as blurred vision.

The patient would not get to see an ophthalmologist at that time, and may instead be sent for brain scans to rule out the small chance of a stroke or bleeding in the brain.

The AI system would be able to give an answer in a few seconds at minimal cost, he said.

"We are currently conducting a pilot prospective, real-life study at SNEC. The next step is to extend this pilot by including other international centres for another large international study in the very near future."

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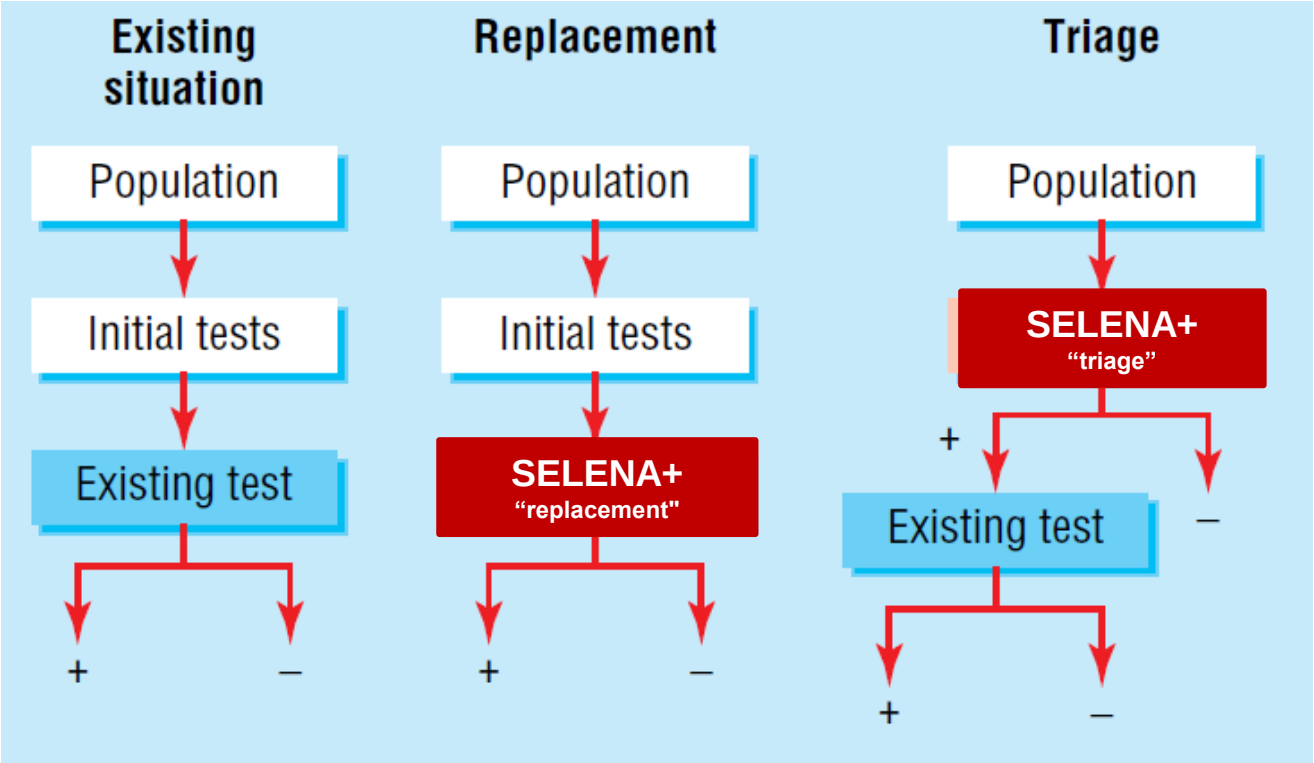
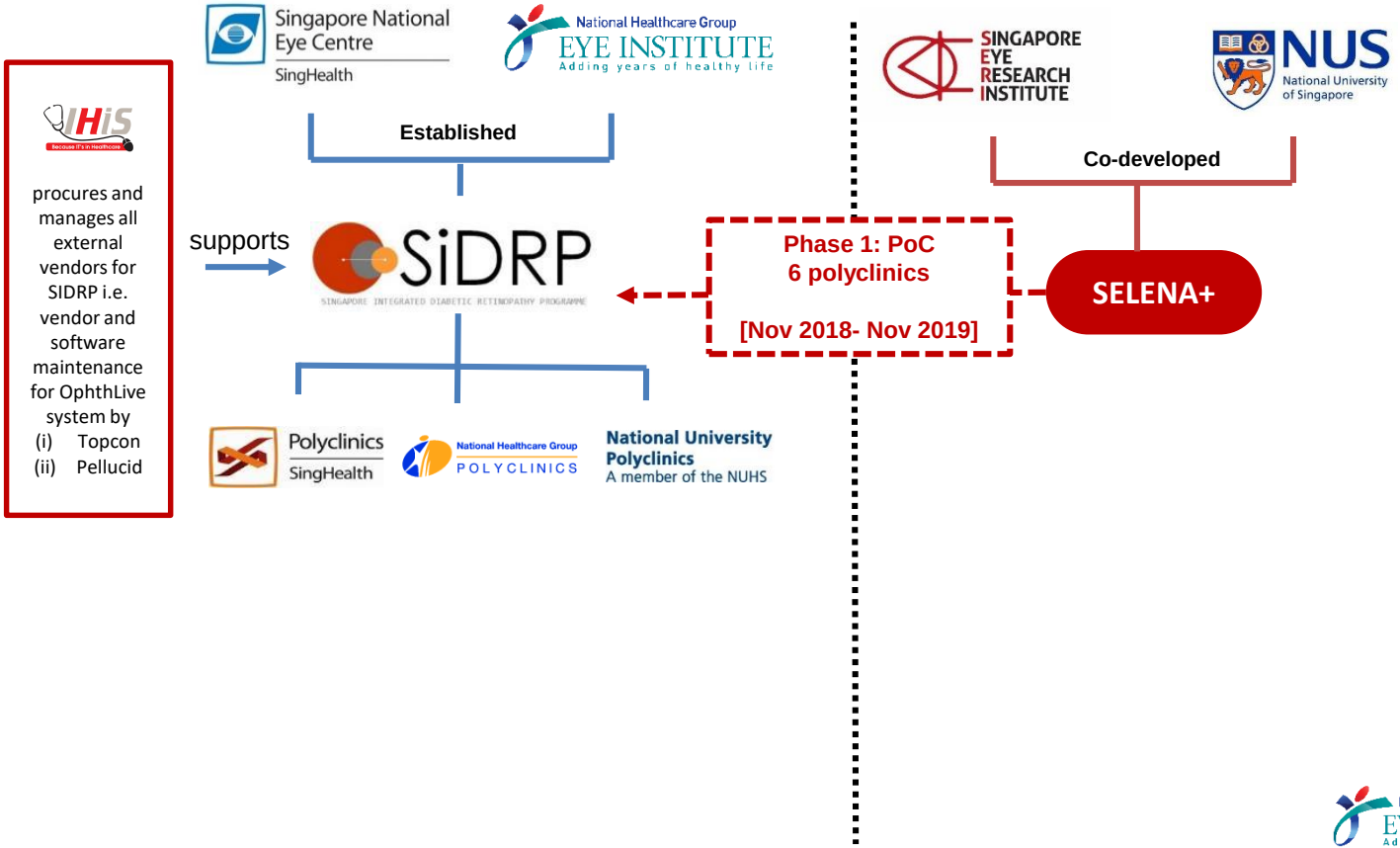
…after the media hype died down, **what next?**

Singapore National Eye Centre
SingHealth

first, where does the AI fit in clinical workflow?



…second, develop a phased implementation plan



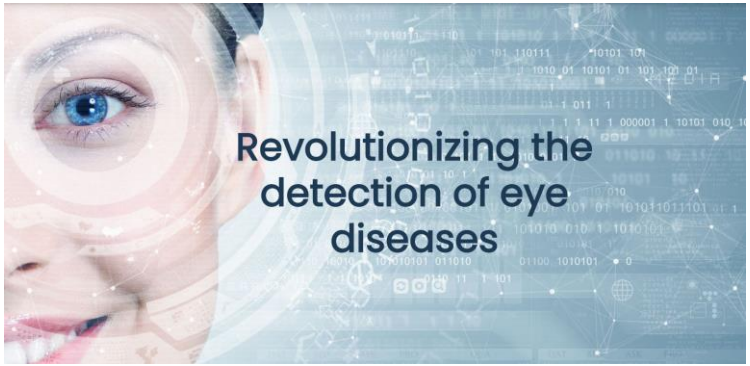
Phase 1: Proof of Concept

Comparing **humans (graders)** & **AI (SELENA+)** vs gold standard (retinal specialist)

n=1,619 patients	Referable DR			VTDR (Key outcome)	DME
Primary Outcome	**AUC (95% CI)**	**Sensitivity (95% CI)**	**Specificity (95% CI)**	**Sensitivity (95% CI)**	**Sensitivity (95% CI)**
Graders vs Retinal Specialist	0.981 (0.969, 0.992)	98.89 (93.96,99.97)	97.23 (96.58,97.79)	91.67 (73.9, 97.0)	92.86 (66.13,99.82)
SELENA+ vs Retinal Specialist	0.962 (0.950, 0.974)	94.68 (88.02,98.25)	82.19 (80.77, 83.53)	100 (85.75, 100)	100 (78.2, 100)
SELENA+ vs Graders	0.961 (0.952, 0.969)	97.19 (93.57,99.08)	84.28 (82.91, 85.57)	100 (91.78, 100)	98.04 (93.1,99.76)

finally…collaborate with private entity

EyRIS
TRANSFORMING AI VISION INTO REALITY



#1. TECHNICAL/OPERATIONAL

- **License** & manage **"day to day"** operational issues
- **Regulatory** registrations and compliances

#2. COMMERCIAL

- **Commercialization and global marketing** (e.g., Malaysia, Brunei, China, Middle-East)
- **Business & financials**
- **Local customisation**

SiDRP

SELENA+

Singapore National Eye Centre, SingHealth

National Healthcare Group Eye Institute, Adding years of healthy life

Established

supports

SiDRP — Singapore Integrated Diabetic Retinopathy Programme

Polyclinics, SingHealth

National Healthcare Group Polyclinics

National University Polyclinics, A member of the NUHS

IHiS

procures and manages all external vendors for SIDRP i.e. vendor and software maintenance for OphthLive system by
(i) Topcon
(ii) Pellucid

EyRIS

Software and maintenance of SELENA+

Singapore Eye Research Institute

NUS National University of Singapore

Co-developed

SELENA+

EyRIS

Licensed to EyRIS (Sept 2018)

Phase 1: PoC
6 polyclinics

[Nov 2018- Nov 2019]

- ✓ **HSA approval for Class B Medical Device (Oct 2019)**
- ✓ **CE certification (March 2020)**
- ✓ **Malaysia MDA certification (April 2020)**
- ✓ **Indonesia RAMS approval (Jan 2021)**

Phase 2: Implementation [on-going in 12 out of 20 polyclinics] [Dec 2020 – Dec 2021]*

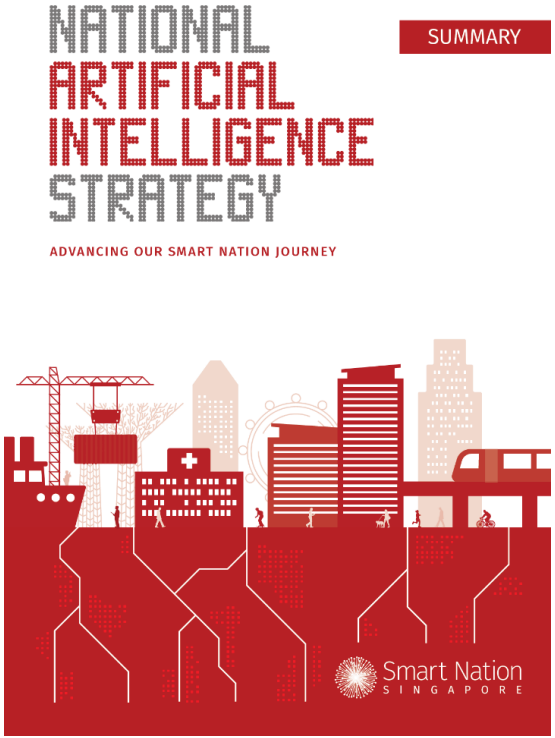
Phase 3: Full Deployment [>Dec 2021]

Commercialization with private providers

Singapore National Eye Centre, SingHealth


EyRIS
SINGAPORE OPTOMETRIC ASSOCIATION

SELENA+ is now part of National AI Strategy



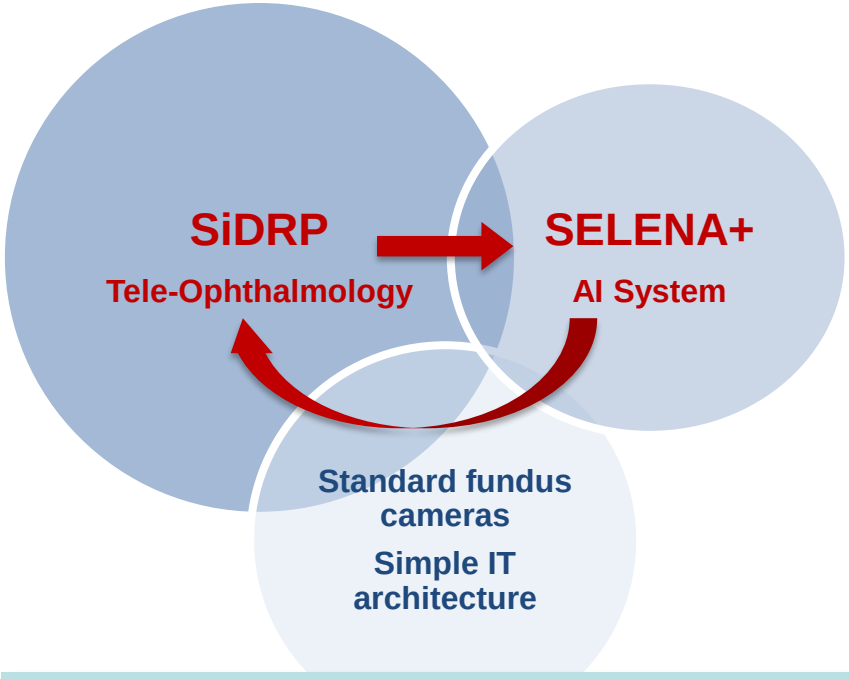
One such project relates to healthcare – one of the common challenges for many countries. There is great potential for AI to be applied to the prediction, detection and management of chronic diseases. Many seniors suffer from chronic diseases, such as diabetes and hypertension. Many might be unaware of their conditions, which, if left untreated, can lead to serious medical complications. AI can be used to analyse clinical and genomic data, medical images, and health behaviours to better assess the risk profile of individual patients – for better prevention and care management. Our first step is to deploy SELENA+, an AI system that is able to detect three major eye conditions – including diabetic eye disease – from retinal photographs accurately and quickly. These solutions can be applied beyond Singapore, to the region and the world.

Singapore National Eye Centre
SingHealth

SINGAPORE EYE RESEARCH INSTITUTE

SiDRP (tele-health) & SELENA+ (AI)

1. Clearly defined **clinical problem** and **gap**
2. Single modality **fundus image** → Standard **fundus camera** & simple **IT platform**
3. Diagnosis of DR requires **no additional data**
4. Impact of change: **Primary care GPs**



1. Impact of AI: **incremental** (***vs*** disruptive)…
2. Impact of change: **Technicians**

…no impact on **ophthalmologists**!

…but the story continues for SELENA+

FW: Queries on SELENA+

I would like to take this opportunity to introduce myself as the Medical Officer who will be taking over Patricia's role in MOH PCC. I would also like to include our MOH Healthcare Finance and Data Analytics Division in this thread to sync our discussions related to SELENA+ between MOH and RCs.

2 Resurfacing this email thread for your inputs if any to the minutes from the last discussion with PCC on 10 May. As part of the follow-up from the last discussion on the clinical implications of transiting to SELENA+, we would like to highlight that with the introduction of an AI screening tool, as with any significant changes in care models, MOH will need to seek approval from Senior Management before SELENA+ can be rolled out to all polyclinics, i.e. prior to Phase III. The approval process will involve an assessment of clinical and cost effectiveness of the AI tool to ensure that desired standards of care will continue to be delivered at reasonable cost.

3 We would thus like to better understand from the RCs on the latest status of Phase II of SELENA+ prior to full transition in Phase III:

a. Are there any issues to highlight arising from Phase II of implementation?
b. What would be the rough timeline to transit to Phase III?

4 Additionally, MOH would like to work with SNEC on the cost-effectiveness analysis based on the Lancet Digital Health 2020 economic analysis modelling study published by your team (please see file attached below):

a. We understand from the last discussion that SNEC was planning to update the Lancet Digital Health 2020 study, as that was done some time back. Could MOH partner SNEC on this and work together to update the study? We will be interested to learn more about the details of the model and the assumptions used, and have access to the model, if possible. For example, one thing we noticed was that the estimated cost of SiDRP was $49USD, which is relatively far off from the cost estimate of ~$25SGD that has been computed for the recent assessment of continuation of SiDRP funding. We would also like to understand how the equivalent costs (i.e. image grading, IT support and admin) for SELENA+ were derived.
b. In addition, could we check if there are updated figures on accuracy of SELENA+ (i.e. sensitivity and specificity) based on latest Phase 2 data? We understand from slide 24 of the communications deck for SELENA+ deployment (see attached) that we will prioritise higher sensitivity at compromise of specificity and deploy 2nd level human read to reduce false positive. What are the sensitivity and specificity figures of the programme as a whole (after incorporating SELENA+ and second level grader) using this approach?

"…from the last discussion on the clinical implications of transiting to SELENA+, we would like to highlight that with **the introduction of an AI screening tool, as with any significant changes in care models**, MOH will need to seek approval before SELENA+ can be rolled out to all polyclinics, i.e. prior to Phase III….

…approval process will involve an assessment of **clinical and cost effectiveness of the AI tool** to ensure that desired standards of care will continue to be delivered at reasonable cost…"

Singapore National Eye Centre
SingHealth

SINGAPORE EYE RESEARCH INSTITUTE

#4. Nurse-led IVT Program

Nurse-led IVT Program

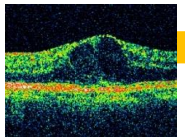
Traditional retinal care

Primary care /GPs

All examinations and consultation done at hospital (SNEC)

Home

"Active" retinal cases



Preliminary Tests: VA, IOP

Further Tests: Refraction, Dilation, OCT

Consultation with **Ophthalmologist**

IVT

Home

Nurse-led IVT Program

Nurse-led IVT Program

Transforming the delivery of nursing care

By Suki Lor

21 July 2021| Singapore Health

"This has never been done by any nurse at SNEC so I thought it would be quite interesting to be the one to start. I wanted to expose myself to more challenges"

Staff Nurse Becky

Nurse-led IVT Program

Eye (2020) 34:2123–2130
https://doi.org/10.1038/s41433-020-0920-2

The ROYAL COLLEGE of OPHTHALMOLOGISTS

ARTICLE

Design, implementation, and evaluation of a nurse-led intravitreal injection programme for retinal diseases in Singapore

Alvin Wei Jun Teo[1] · Tyler Hyungtaek Rim[1,2] · Chee Wai Wong[1] · Andrew Shih Hsiang Tsai[1] · Nazurah Loh[1] · Thiyagarajan Jayabaskar[1] · Tien Yin Wong[1,2] · Chui Ming Gemmy Cheung[1,2] · Ian Yew San Yeo[1,2]

Received: 11 November 2019 / Revised: 16 April 2020 / Accepted: 21 April 2020 / Published online: 7 May 2020

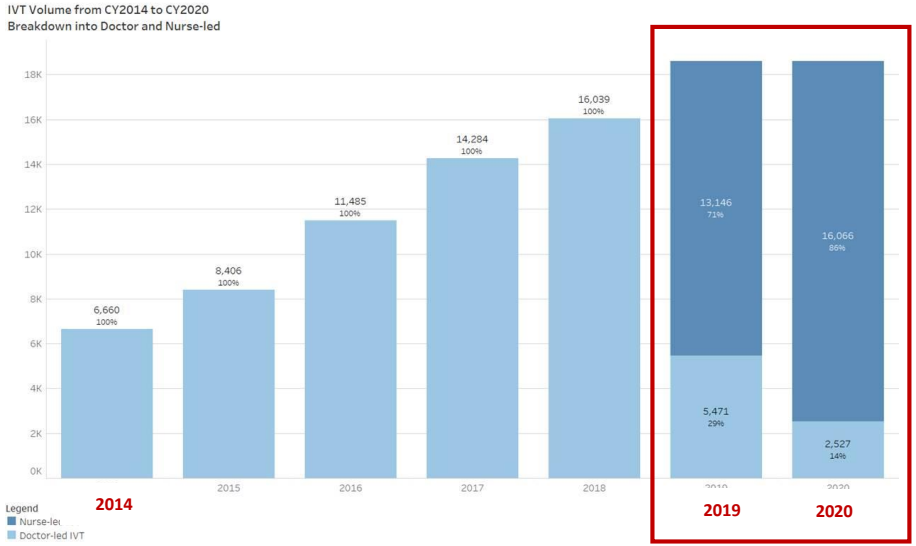
Abstract

Background To describe the design, implementation, and evaluation of a nurse-led intravitreal injection (NL-IVT) programme in a Singapore tertiary eye hospital.

Methods Patients requiring anti-vascular endothelial growth factor (VEGF) IVT were recruited. Implementation and evaluation were done in the Singapore National Eye Centre, a tertiary centre. To assess safety, nurse injectors recorded details of procedures performed and complications for an 8-month period from February 2019. To evaluate patient experience, we used a modified patient questionnaire and recorded both patients' waiting time and IVT procedure duration. A retrospective audit of IVTs before and after the introduction of NL-IVT was performed from January 2017 to September 2019. Cost difference between NL-IVT and standard doctor-led (DL) IVT was evaluated.

Results A total of 8599 NL-IVTs were performed. No cases of severe complication were detected in the follow-up. A total of 135 patients who received NL-IVT and DL-IVT were surveyed. General satisfaction, interpersonal manner, financial aspect, time spent with injector, and staff competence were higher in NL-IVTs than in DL-IVTs ($p < 0.05$). There were no differences in terms of technical quality and communication. For 934 patients, waiting time was significantly shorter in NL-IVT (3.6 ± 10.3 min) compared with DL-IVTs (35.3 ± 32.3 min); on average, 19.7 min were saved through NL-IVT ($p < 0.01$). The cost difference per IVT between NL-IVT and DL-IVT is estimated at 286 SGD (163 GBP).

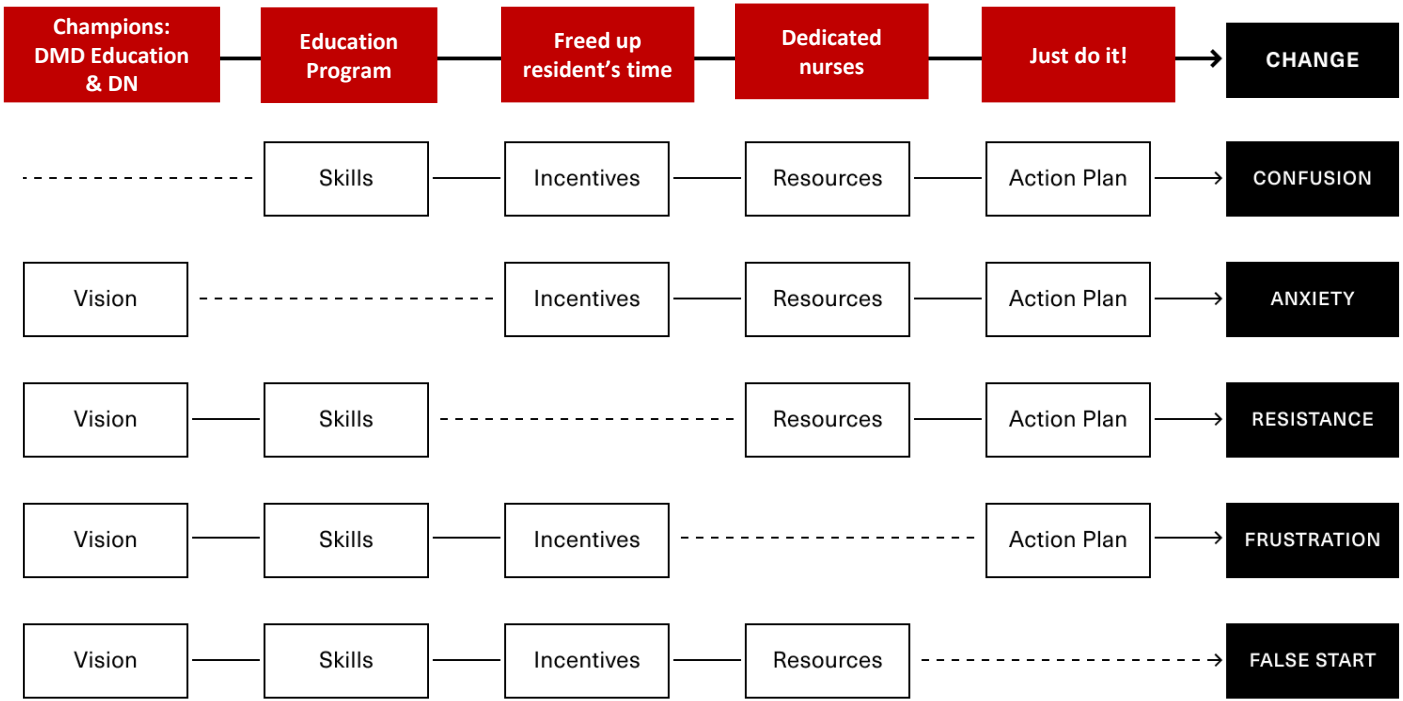
Conclusion With a well-designed training programme, NL-IVT is a safe, acceptable, and cost savings procedure. With increasing demand for IVT, NL-IVT provides an alternative model of care for healthcare systems globally.



…**85%** of >18,000 IVTs in SNEC

AMEI Programme Excellence Award

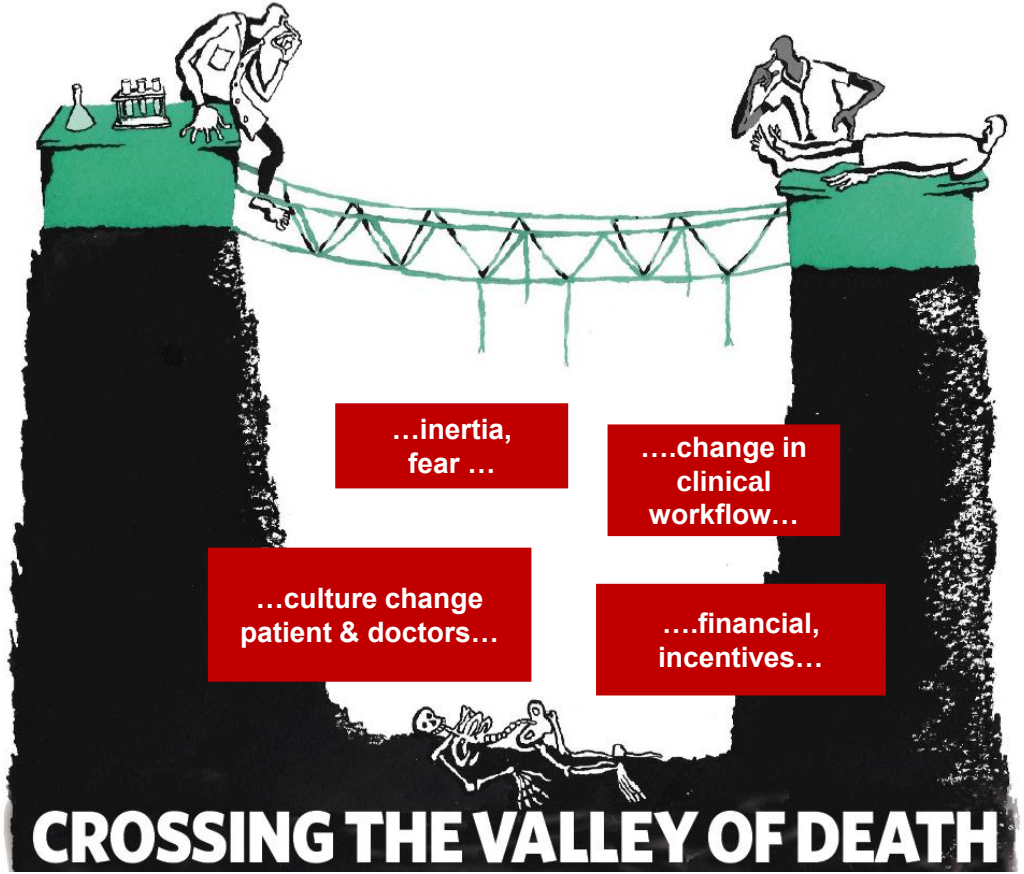
Nurse-led IVT Program



Reflections & Pearls

Digital innovation: crossing the “valley of death”

Digital technology



Clinical care transformation

#1. First, need significant engagement & education

…patients & public…

AI Can Outperform Doctors. So Why Don't Patients Trust It?

by Chiara Longoni and Carey K. Morewedge

October 30, 2019

Annals of Internal Medicine IDEAS AND OPINIONS

Should Health Care Demand Interpretable Artificial Intelligence or Accept "Black Box" Medicine?

Fei Wang, PhD; Rainu Kaushal, MD, MPH; and Dhruv Khullar, MD, MPP

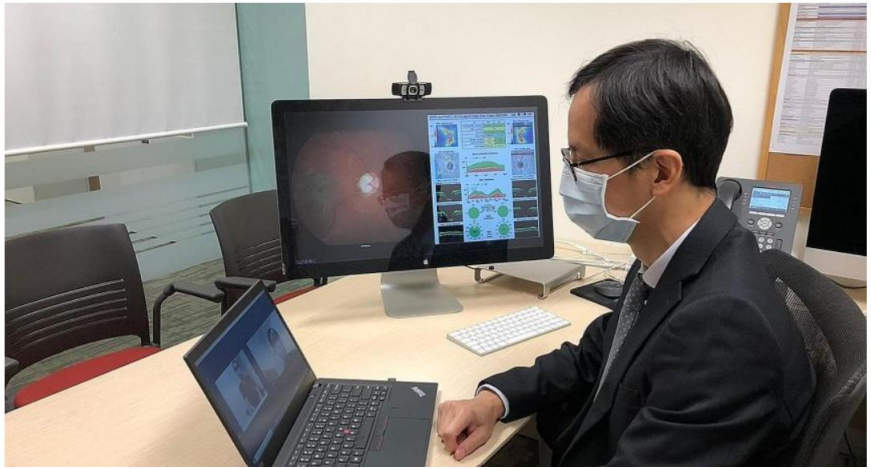
In recent years, health care applications of artificial intelligence (AI), such as detection of atrial fibrillation from electrocardiography, retinopathy from optical coherence tomography, and in-hospital mortality risk from electronic health records, have emerged (1–3). Artificial intelligence is also capable of assisting with more abstract clinical situations, such as predicting the onset of sepsis before clinician recognition (4). Artificial intelligence approaches, such as deep learning, rely on vast amounts of data and complex model structures with millions of parameters. For example, the Inception v3 model (Google), which is more accurate than physicians at identifying diabetic retinopathy from fundus photographs and skin cancer from dermoscopic images, has 23 million parameters (5). This complexity makes it difficult to understand how models make a given decision or prediction. Thus, they are often called post hoc interpretability (7). The Inception v3 model uses raw image pixels as inputs, transforms them through a series of computations into a set of complex predictor variables, and then feeds this final set of variables into a logistic regression for classification of the likelihood that a skin lesion is cancerous. The model's predictive ability hinges on the final learned set of variables that, although not themselves readily interpretable, offer the opportunity for knowledge distillation (9). This process constructs a more transparent secondary model, like a decision tree or random forest, through which inputs can be connected to the final predictor variables, and the features most important to prediction can be elucidated (10).

Although clinicians are likely to prefer intrinsically interpretable models to those understood only through post hoc interpretation, we believe black box models will play an important role in medicine and, in many

…significant engagement & education

…patients & public…

Seniors less receptive to telemedicine and uncomfortable with AI interpreting medical results: S'pore survey



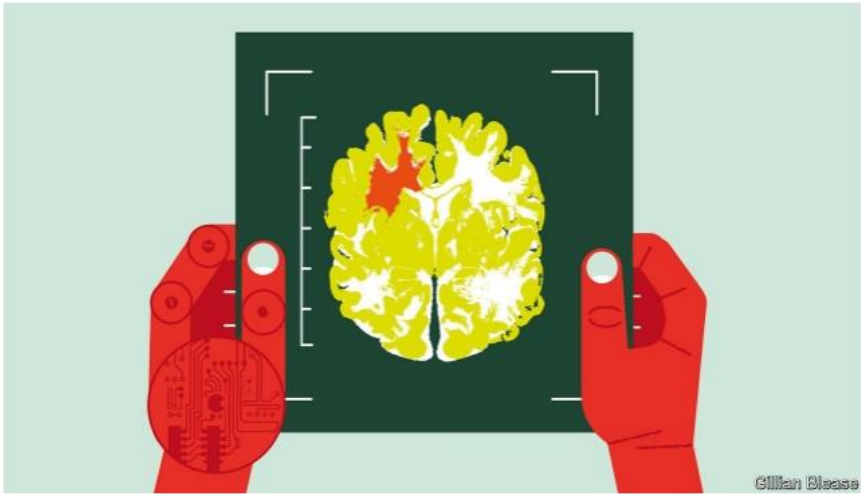
"…suddenly switching to telemedicine, videoconference and Zoom is **very new** to me, and I'm **not ready** for it," said Mr Mathew. Although the 59-year-old has attended meetings on Zoom, he finds it **tough**. "There are certain things the doctor has to examine in person... And **I'm not very tech-savvy**," he added. He is not the only one who feels that way….

#2. Need physician-champions & buy-in

Images aren't everything

AI, radiology and the future of work

Clever machines will make workers more productive more often than they will replace them



"Unhelpful" comments from key thinkers of AI

"It's quite obvious that we should stop training radiologists"

Geoffrey Hinton

"Radiologists should be worried about their jobs"

Andrew Ng

#3. Integrate innovation into clinical workstreams

Forbes

609 views | Jun 9, 2020, 09:20am EDT

Three Insights From Google's 'Failed' Field Test To Use AI For Medical Diagnosis

David Talby Forbes Councils Member
Forbes Technology Council COUNCIL POST | Paid Program

Innovation

AI = Computer Science + Engineer

+ Clinical process change

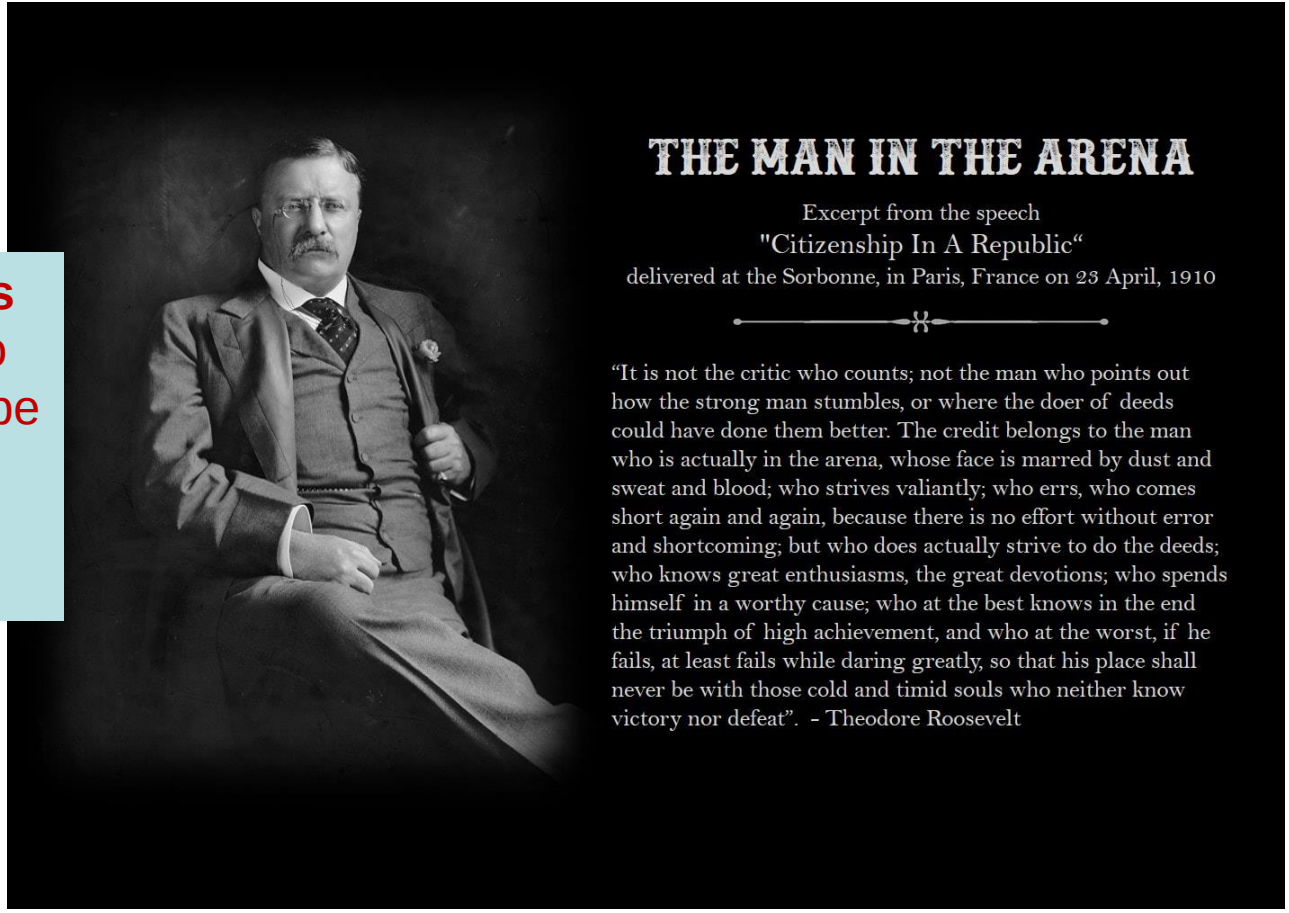
1. Science: We need to develop highly accurate data science algorithms for specific problems, as Google did with its original deep learning models for detecting diabetic retinopathy. In the analogy to cars, this would be like the invention of the internal combustion engine.

2. Engineering: We need to develop ways to productize these inventions at high quality, high scale, safely and cheaply. In the analogy to cars, we need to invent the equivalents of the mass production line, hand brakes, electric starters, air conditioners, airbags and headrests. In the AI space, think MLOps, explainability, bias detection and model governance (as a start). This is the area of the ecosystem where I personally work and specialize.

3. Process change: We need to develop the human-centered processes that enable people to use these innovations effectively and safely. In the analogy to cars, think splitting the public space between roads and sidewalks, establishing driver licensing, public education, safety standards and pollution regulation. In medical AI, we've barely started on this, which makes the recent Google field study an important baby step.

#4. Finally, resilience & equanimity

"…if he fails, at least **fails while daring greatly**, so that his place shall never be with those cold and time souls who neither know victory nor defeat…"



Conclusion

- **Digital innovations** (e.g., AI, telehealth) have potential to transform current healthcare models
- Significant **technology advances**
- However, implementation of such technology into clinical care requires a **careful phased plan**, addressing **non-technical challenges** (i.e., crossing the “valley of death”) with much **patience and resilience**

Singapore National Eye Centre
SingHealth

Thank you