Australia's National Science Agency

Establishing eye screening services to prevent avoidable blindness in remote Northern Australian communities

CRCNA Project H.5.1718035

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Foreword

Achieving equality in health outcomes for Australia's Indigenous people is a national challenge. While it is impossible with one project to do more than scratch the surface of a complex issue, the activities described in this report provide a pathway towards closing the gap in providing specialist eye care for several northern Australian rural and remote communities.

[Pedestrian walkway on Thursday Island. Text attributed to the Late Mr Ephraim Bani, renowned cultural advisor and linguist for the Torres Strait region and traditional chief]

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Acknowledgments

This research is funded by the CRC for Developing Northern Australia (CRCNA) which is supported by the Cooperative Research Centres Program, an Australian Government initiative. The CRCNA also acknowledges the support of its investment partners: the Western Australian, Northern Territory and Queensland Governments.

We also acknowledge the support of our project partners, Queensland Health, Laynhapuy Homelands Aboriginal Corporation, Marthakal Homeland and Resource Centre Aboriginal Corporation, Gidgee Healing and NT Eye Specialists.

We are grateful for the participation of staff from these organisations, specialist ophthalmologists involved in the review of retinal images and most importantly the patients screened to date who consented to participating in this project.

We pay respect to the traditional custodians, past, present and future, of the lands where this project was carried out.

Executive summary

In July 2018, CSIRO along with its project partners Queensland Health, Laynhapuy Homelands Aboriginal Corporation, Marthakal Homeland and Resource Centre Aboriginal Corporation, Gidgee Healing and NT Eye Specialists commenced a multi-year project to establish telehealth-based eye screening services to prevent avoidable blindness in remote northern Australian communities. This project is funded by CSIRO and the Commonwealth Department of Industry, Innovation and Science acting through the Cooperative Research Centre for Developing Northern Australia (CRCNA), and additional in-kind contributions from project partners. This document represents the Final Report of the project describing project activities, outcomes and lessons learnt.

The primary outcome sought from this project was a working sustainable teleophthalmology service, to continue serving the communities after project completion. This outcome has been achieved, and a secure telehealth service now connects metropolitan-based ophthalmologists to patients in several regional and remote communities in Northern Territory and Queensland. The telehealth platform incorporates AI-based image quality and disease detection algorithms to complement and support decisions of eye health assessment teams. This service helps in closing the gap in access to eye care services for people living in under-served rural and remote communities, preventing needless blindness.

The project was delivered via new partnerships between researchers from CSIRO, Queensland Health, Laynhapuy Homelands Aboriginal Corporation, Marthakal Homeland and Resource Centre Aboriginal Corporation, Gidgee Healing and NT Eye Specialists. The sites selected for undertaking remote screening are in the main, remote, regional areas of northern Australia. Retinal cameras and laptops were procured and tested at all sites, and healthcare workers were trained in capturing high quality images of the eye, entering data, uploading information to a secure telehealth portal, and reviewing of diagnostic advice. Expanding the skills of the Northern Australian workforce can lead to increased opportunities for employment as well as bringing eye care to the community with the help of trained community health workers.

Over the course of the project, there were screening records from 378 patients uploaded to a comprehensive telehealth system developed by CSIRO ('Remote-I') and diagnosed by ophthalmologists, exceeding the project target of 350. Patients were recruited for participation based on the assessment of need by eye screening nurses and health workers as well as opportunistic recruitment.

Almost all cases of sight-threatening diabetic eye disease can be avoided by having regular eye checks, thus patient recruitment included those with pre-existing eye conditions as well as those without. Regular eye checks are essential to monitor the early stages of the disease so that risk factors for worsening retinopathy can be tackled and treatment can be delivered at the most appropriate time. Analysis of diagnosis data indicates 64 cases of diabetic retinopathy (DR) were picked up (16 in NT and 48 in Queensland). Critically, two patients were diagnosed with proliferative DR and four patients with severe non-proliferative DR. Diabetic macular oedema (a frequent manifestation of DR) was noted in 18 patients (6 in NT, 12 in Queensland). The majority of participants screened had no eye problems, which enables the removal of these patients from the queues of overwhelmed specialist lists, improving service efficiency. Initial analysis estimated the cost of screening and diagnosis using Remote-I at approximately $540 per patient for NT and Queensland. This compares favourably with the Independent Hospital Pricing Authority (IHPA) efficient cost for similar consultations. Moreover, the fact that access to specialist services is deficient in remote areas indicates travel costs are likely with the traditional approach to service delivery, making it more expensive and inefficient when compared to the innovative approach assessed in this project.

Health workers and patients reported being satisfied with the Remote-I system and the overall service offered.

The project involved obtaining ethics, cybersecurity and privacy approvals from the relevant jurisdictions, cultural awareness training and education for project staff, technical training of staff at all sites covering image capture and local storage, generation of user documentation, and regular planning meetings with key stakeholders. An 'offline' mode of the Remote-I system was implemented to enable screening records to be documented in the event of no internet connection.

A valuable screening service has been established in the target areas, evidenced by the following outcomes realised by the project:

- improved access to ophthalmic health services for residents of the project screening locations, thereby closing the gap in providing specialist eye care to the rural and remote communities;
- demonstration that routine eye examination (instead of opportunistic eye examination) is feasible for early detection of some eye diseases for remote and rural patients;
- cost savings relating to reduced patient travel to metropolitan areas and/or prioritising patients by need for a consultant's visit to their locality, hence increasing efficiency and maximising resource use;
- improved health outcomes by earlier identification of diseases, enabling not only vision saving treatment but reduced consumption of scarce health resources;
- capacity building of Northern Australian healthcare workers to perform eye screening and obtain new knowledge about eye diseases; and
- improved patient health awareness where the retinal camera is used as an educational tool.

In summary, all aims and anticipated deliverables for the project have been achieved.

The remainder of this report is structured as follows.

Section 1 provides an introduction to the problems targeted through this project: diabetic retinopathy, avoidable blindness and the long waiting list for ophthalmology consultations. The focus on northern Australia and Indigenous health is also described.

An outline of the project is presented in **Section 2**, describing its overall objective, project milestones and the activities carried out.

Section 3 provides analysis of selected project outcomes, primarily earlier detection of diabetic retinopathy to prevent blindness as well as improving access to specialist eye care for rural and remote communities. This section also contains commentary on the cost effectiveness of the program.

Recommendations and issues relating to scaling and sustaining the service are presented in **Section 4**. Activities conducted within the project can be scaled into a standard service offering at a national level and this section includes guidelines for program expansion.

The lessons learnt from undertaking this project are documented in **Section 5** with the belief that many of the insights are applicable to broader health initiatives in remote communities.

Section 6 presents prediction performance of artificial intelligence components that have been embedded into the telehealth platform underlying this project for the purposes of improving the quality of captured images and detecting disease to provide clinical decision support to a health service.

Finally several appendices provide further detail of the telehealth platform, the stakeholder consultations carried out and broadening the application beyond retinopathy to other eye diseases and settings.

Flags at the end of the Thursday Island jetty QLD

Marthakal Health clinic on Elcho Island NT

1 Introduction

The main eye condition targeted through this project was diabetic retinopathy, which remains the leading cause of preventable blindness in working-aged people. It is identified in a third of people with diabetes and associated with increased risk of life-threatening systemic vascular complications, including stroke, coronary heart disease, and heart failure[1]. One of the major issues the public health system faces to overcome this problem is the increasing waiting list for ophthalmology consultations.[2] The project also has a focus on eye health for people living in rural and remote communities in northern Australia, where there are challenges in recruiting and retaining a trained medical and health workforce. Health systems and their funding remains oriented to treatment and curative care services, while many of the upstream determinants of Indigenous, rural and remote health are poorly addressed.[3] Ophthalmic public service models often demand that a patient travel to where the provider is located (metropolitan area) or that a consultant travel to rural and remote localities at a selected time during the year: a costly, time consuming and inefficient effort. Tele-ophthalmology programs similar to this project offer new opportunities to improve access and quality of care for people with diabetic retinopathy. Specifically, by screening potentially at-risk populations, where access to specialist health care services is not available, one can target a consultant's visit and time to a selected identified group of patients.

The focus on northern Australia aligns with the Australian Government's agenda for developing the north of Australia[4], which is being facilitated through research and development ventures funded through the Cooperative Research Centre for Developing Northern Australia (CRCNA) which was established in 2017. This project demonstrates alignment with the CRCNA's priority of northern Australia health service delivery in the area of improving the early detection of diseases. Specifically, the project demonstrates the development of new technologies which assist with the flow of information, support timely decision-making and treatment options, improve access and connectivity to existing technologies, and enhance workforce skills and capability to use new technologies.

Higher diabetes prevalence rates in Aboriginal and Torres Strait Islander communities have been documented previously (between 2-and 4-fold overall higher diabetes prevalence in aboriginal than in non-aboriginal communities)[5]. The epidemiology of this disease along with geographical and cultural differences pose challenges relating to screening, treatment and follow-up in the Aboriginal and Torres Strait Islander communities. The screening undertaken in this project is increasing the likelihood of early detection of sight threatening conditions among these patients.

[1] Cheung N1, Mitchell P, Wong TY. Diabetic retinopathy. Lancet. 2010 Jul 10;376(9735):124-36.

[2] Siciliani L, Borowitz M, Moran V (eds.), Waiting Time Policies in the Health Sector: What Works?, OECD Health Policy Studies, OECD Publishing, 2013

[3] Humphreys J, Wakerman J. Primary health care in rural and remote Australia: achieving equity of access and outcomes through national reform: a discussion paper, National Health and Hospitals Reform Commission, Canberra, 2008

[4] Australian Government Department of Industry, Science, Energy and Resources. Our North, Our Future: White Paper on Developing Northern Australia, June 2015, Available online (accessed Jun 2022): https://www.infrastructure.gov.au/territories-regions-cities/regional-australia/office-northern-australia/northern-australia-agenda

[5] Guidelines for the Management of Diabetic Retinopathy, Prepared by the Australian Diabetes Society for the Department of Health and Ageing, Commonwealth of Australia 2008

2 Project Outline

2.1 Aims and Objectives

The primary objective for this project was to establish an innovative model of service delivery for diabetic retinopathy management in remote communities in Northern Australia using telehealth technologies and identify factors around successful implementation of service delivery.

The overall aim of these activities was to close the gap in access to specialist eye care for adult Australians living in rural and remote areas, where the lack of access to specialist health care is well documented, by providing direct access to expert diagnostic services based in metropolitan areas through a tele-ophthalmology system (‘Remote-I’). Further details of this system including screenshots of the secure Remote-I portal are presented in Appendix A .

This aim has been accomplished, with the main outcome of the project being the establishment of a tele-eye care service linking the resources of remote health providers and metropolitan ophthalmologists to enable regular eye examination and disease diagnosis services for remote and rural adult Australians.

2.2 Milestones, Tasks and Deliverables

The project milestones outlined in the Agreement between CSIRO and CRCNA are presented below.

Table 1 - Key Project Milestones

MILESTONE NO.	KEY RESEARCH ACTIVITY	OUTPUTS – KEY OUTPUT	DUE DATE	STATUS
M1.	All parties have signed contract	All head agreements fully executed All participant declarations fully executed All participants members of CRCNA All co-contributions paid	30 June-19	Completed
M2.	Ethics approval	CRCNA provided with Ethics approval documentation	30-Sep-18	Completed
M3.	Establishment & planning	Screening Protocol finalised	30-Sep-18	Completed
M4.	Quarterly report due	2018/19 Q1 report to CRCNA	14-Oct-18	Completed
M5.	Establishment & Planning	Referral Pathways and Workflow finalised	31-Dec-18	Completed
M6.	Quarterly report due	2018/19 Q2 report to CRCNA	14-Jan-19	Completed
M7.	Establishment & Planning	Hardware procurement complete	31-Mar-19	Completed
M8.	Quarterly report due	2018/19 Q3 report to CRCNA	14-Apr-19	Completed
M9.	Establishment & Planning	Screening sites confirmed	30-Jun-19	Completed
M10.	Service Installation	Hardware and software deployed and tested	30-Jun-19	Completed
M11.	Quarterly report due	2018/19 Q4 report to CRCNA	14-Jul-19	Completed
M12.	Annual report due	2018/19 Financial Year Annual Report to CRCNA	31-Aug-19	Completed
M13.	Service Installation	Workforce training complete	30-Sep-19	Completed
M14.	Quarterly report due	2019/20 Q1 report to CRCNA	14-Oct-19	Completed
M15.	Quarterly report due	2019/20 Q2 report to CRCNA	14 Jan-20	Completed
M16.	Quarterly report due	2019/20 Q3 report to CRCNA	14-Apr-20	Completed
M17.	Quarterly report due	2019/20 Q4 report to CRCNA	14-Jul-20	Completed

MILESTONE NO.	KEY RESEARCH ACTIVITY	OUTPUTS – KEY OUTPUT	DUE DATE	STATUS
M18.	Annual report due	2019/20 Financial Year Annual Report to CRCNA including audited financials	31-Aug-20	Completed
M19.	Interim Research Report	Written report outlining the lessons learnt from the project	30-Sep-20	Completed
M20.	Quarterly report due	2020/21 Q1 report to CRCNA	14-Oct-20	Completed
M21.	Clinical Services Stage 1	+50 patients screened (50 cumulative)	31-Dec-20	Completed
M22.	Quarterly report due	2020/21 Q2 report to CRCNA	14-Jan-21	Completed
M23.	Clinical Services Stage 2	+50 patients screened (100 cumulative)	31-Mar-21	Completed
M24.	Quarterly report due	2020/21 Q3 report to CRCNA	14-Apr-21	Completed
M25.	Clinical Services Stage 3	+50 patients screened (150 cumulative)	30-Jun-21	Completed
M26.	Quarterly report due	2020/21 Q4 report to CRCNA	14-Jul-21	Completed
M27.	Annual report due	2020/21 Financial Year Annual Report to CRCNA including audited financials	31-Aug-21	Completed
M28.	Clinical Services Stage 4	+50 patients screened (200 cumulative)	30-Sep-21	Completed
M29.	Quarterly report due	2021/22 Q1 report to CRCNA	14-Oct-21	Completed
M30.	Clinical Services Stage 5	+50 patients screened (250 cumulative)	31-Dec-21	Completed
M31.	Quarterly report due	2021/22 Q2 report to CRCNA	14-Jan-22	Completed
M32.	Clinical Services Stage 6	+50 patients screened (300 cumulative)	31-Mar-22	Completed
M33.	Quarterly report due	2021/22 Q3 report to CRCNA	14-Apr-22	Completed
M34.	Clinical Services Stage 7	+50 patients screened (350 cumulative)	30-Jun-22	Completed
M35	Final Research Report	Final report delivered to CRCNA	30-Jun-22	Completed
M36.	Final end of project report	Final end of project report delivered to CRCNA including audited financials.	31-Aug-22	In preparation

It can be observed that milestones related to clinical service delivery in the latter stages of the project were based on a quota of 50 patients being screened each quarter with a cumulative requirement of 350 patients to be screened via the telehealth platform. All milestones for this project were successfully delivered on time in accordance with this schedule.

2.3 Project Activities

Project activities defined in the initial project documentation were as follows:

- Identify and establish relationships with remote communities that have limited or no access to eye screening services.
- Develop a sustainable model of service delivery and referral pathways to ensure that patients identified with eye issues receive appropriate treatment.
- Develop collaborative data governance and custodial frameworks between project participants.
- Apply for ethics clearance from appropriate service providers
- Procurement and implementation of cameras, telemedicine system and training to use the technology.
- Commence screening service as a sustainable model to continue beyond the life of the project, refining patient referral pathways as required.
- Evaluate the service.

2.3.1 Establishing relationships with remote communities

One of the initial activities of the project was to identify and establish relationships with remote communities that previously had limited or no access to eye screening services.

Following approval from CSIRO's Human Research Ethics Committee, project activities in Queensland were reviewed by the Far North Queensland HREC and governance team and activities involving participating NT Health Services were reviewed by the research committee associated with AMSANT (Aboriginal Medical Services Alliance Northern Territory). The AMSANT research committee who reviewed the research proforma indicated they were happy for the CSIRO personnel to approach individual Aboriginal and Community Controlled Health Organisations (ACCHOs) about participating directly. This endorsement from AMSANT assisted in building relationships with community-level organisations.

A monumental effort was expended in respectfully approaching organisations to participate, for example Sunrise Health Service, Katherine West Health Board, Miwatj Health Aboriginal Corporation, Urapuntja Health Service, Wuchopperen Health Service, and Apunipima Cape York Health Council to name a few. For securing the involvement of the clinics that are participating, the team worked out what the clinics needed and ensured we addressed specific concerns of their executive. These concerns included reassurance of how CSIRO personnel would respect and recognise the values of Aboriginal and Torres Strait Islander peoples with regard to health research in its design and conduct.

The team endeavoured to create respectful relationships from project commencement and made clear how and who will be conducting the research. To demonstrate respect and build trust, the research team visited the communities prior to commencement, thereby informing themselves about local structures and seeking to engage with these in a spirit of respect and integrity. In those meetings, health clinic managers indicated they were satisfied with the way the research would be carried out. Where required, aspects of the research (e.g. Patient Information and Consent processes) were modified in accordance with participating community values and aspirations.

2.3.2 Developing a sustainable model of service delivery and referral pathways

Referral pathways were identified by consultation with ophthalmologists, optometrists, clinic managers and agencies with long histories in providing eye health services in Northern Australia to ensure that patients identified with eye issues receive appropriate treatment. Some further description of these stakeholder consultations are presented in Appendix B . It is extremely important that any new model of service delivery includes referral pathways to ensure patients get treatment if required, and it had been stressed to the team that surveying (screening) without service provision is almost unethical. The ophthalmologists that were involved in this project have some involvement with the public health system, and the referral process is that as a metropolitan-based specialist reviews the images, if anything is detected that requires follow up, this is relayed back to the site that performed the screening. At this point the patient is referred to the nearest public eye clinic or to a private ophthalmologist if they prefer.

For this project, NT-based ophthalmologists were reimbursed for their time from project funds whereas Queensland-based ophthalmologists provided diagnoses as part of Visiting Medical Officer contracts with the health department. In Queensland, the review of clinical images and provision of advice attracts a state-wide Telehealth Store and Forward incentive payment, provided the medical officer reviewing the image is employed by Queensland Health at least in a VMO capacity. The business model is that a Hospital and Health service can claim the store and forward incentive payment and negotiate VMO contracts as required.

2.3.3 Data governance and custodial frameworks between project participants

This involved defining where and how the digital data collected in the project was to be physically stored, who should have access to it, definition of important roles such as "screener", "specialist grader", and "administrator", the required data fields to collect within clinics to assist in grading, and the workflow of data after initial collection. This shaped the evolution of the screening workflow presented in in Appendix Section A.3, and ultimately the steps that a Worker/Nurse screener and Specialist/ophthalmologist would need to follow. It also informed the design of the Remote-I dashboard into work stages: 'Drafts' (still working on adding in all the details), 'Pending Assessments' (submitted to the ophthalmologist), 'Completed' (diagnosis has come back from the ophthalmologist) and 'Archived' (user has noted the results and potentially saved the diagnosis in the patient's record).

In this project, the store-and-forward workflow adopted a structure where one ophthalmologist read images from potentially more than one screening clinic. Thus, custodial principles were established such that clinic staff could only access patient data that had been uploaded from that clinic. However a generic username and login was often provided to a screening clinic to enable multiple health workers to upload patient exams.

The CSIRO project team consulted with other project participants as well as CSIRO's Privacy Office and Information Management & Technology teams with regards to information storage and data retention policies. The consultation process resulted in adding further strict record viewing rules (e.g. another user accessing a patient record via a link is restricted based on the site from where they upload; allowing a user to submit a record only if the patient had agreed to the consent process via a check box; and database retention periods).

2.3.4 Ethics, privacy, and cybersecurity clearance

Ethical approval for this project was obtained from the CSIRO Health and Medical Human Research Ethics Committee (CHM HREC Ref HREC 10/2018), project activities in Queensland were reviewed by the Far North Queensland Human Research Ethics Committee (Ref HREC/2020/QCH/59956 – 1410) and governance team and activities involving participating NT Health Services were reviewed by the research committee associated with AMSANT (Aboriginal Medical Services Alliance Northern Territory). A Privacy Threshold Assessment was also undertaken to assess the impact that the project may have on the privacy of individuals. The project was found to comply with all relevant Australian Privacy Principles, with no risk to individuals' personal information.

Other preparatory steps prior to using this service included obtaining Queensland Health cybersecurity approval for use of the planned telehealth platform (where a security assessment was completed against the Queensland Health Cloud Services Security Standard) and additional assessment undertaken by Queensland Health's Biomedical Technology Services regarding connection of the retinal cameras to the Queensland Health network. CSIRO also undertook its own penetration and vulnerability tests as well as completing an Amazon Web Services (AWS) Well Architected review (providing architectural best practices for reliable, secure, efficient, and cost-effective systems in the cloud). The team worked through the recommendations from AWS for the test and production AWS accounts and undertook minor tweaks and further automation. This testing resulted in hardened infrastructure which guarantees the security of information uploaded into the system.

In order to get the service embedded within Hospital and Health Services in Queensland, the team were not approved to use the system until we provided Queensland Health with extensive documentation on the cybersecurity testing and privacy impact statement that has been undertaken on this system. This included penetration tests, vulnerability assessments and the AWS Well Architected review facilitated by an AWS cloud architect. Queensland Health's cybersecurity team advised their organisation recently moved from a compliance-based cybersecurity process to a risk based one following ISO 2701 standard. For the platform we proposed, patient identifying information is sent to the cloud (hosted in AWS's Sydney Data Centre), hence there was a need to provide reassurance that all information was encrypted, in transit and at rest, and everything remains encrypted. Documentation and elaborate clarifications eventually demonstrated this and further information about the security architecture and security protocols used is presented in Appendix A .

2.3.5 Procurement and implementation of cameras, telemedicine system and training

Based on the need for portability, handheld cameras were initially procured and delivered to NT sites (Marthakal and Laynhapuy Health Services). Despite persevering for several months, health workers found the handheld cameras were too finicky so larger desktop cameras were procured to improve the quality of captured images, and the team were able to also provide a 'Pelican' padded case for one clinic who wished to transport the camera around by little plane and troop carrier. Additional equipment was procured and delivered to screening clinics to facilitate project progress. This includes purchase and delivery of two retinal cameras funded from CSIRO internal funding (CAPEX) for Marthakal and Laynhapuy clinics to overcome hurdles staff were facing in trying to capture a good retinal image using the handheld portable cameras that had been supplied. The team also delivered new Canon CR-2 desktop cameras to Marthakal Health Service (NT) and Thursday Island Hospital (Qld). We also recommissioned three used (second hand) DRS cameras from the Torres Strait to supplement the new Canon camera. These were brought to Brisbane for servicing which involved upgrading software and firmware, replacement of internal y-axis springs, lubrication of worm gears, and re-calibration of the cameras with Centre-Vue Italy. These refurbished cameras were then delivered to clinics at Thursday Island Primary Health Centre, Bamaga Primary Health Centre and Badu Island Primary Health Centre (Qld).

At all sites, the team conducted training with health worker staff and specialist ophthalmologists. Additional walk-throughs and demonstrations of the platform covering correct image capture and synchronising clinical data and dashboard operations were held with staff from Thursday Island, Bamaga, Gidgee Healing, Mt Isa Hospital, Qld and NT Eye Specialists, Weipa, Laynhapuy and Marthakal clinics.

Health workers were trained in correct image capture – patient seating, pupil dilation, recording of patient details, focusing of camera, docking of equipment, and website overview. Proper operation of the camera, patient cooperation during the imaging, and the condition of the equipment (keeping the lens clean) are very important for obtaining images with good quality. High image quality is crucial for correct Diabetic Retinopathy grading, as well as evaluating algorithms for automated grading. This training and eye health familiarisation is assisting in the development of the northern Australian workforce, and equipping health workers with transferable skills.

Although training had been provided for these handheld cameras, in order to address their challenges in use, new desktop retinal cameras were procured and delivered to sites and staff trained in their use. After receiving concerns about the tricky operation of one brand of desktop camera (Canon), we procured alternative cameras (DRS) that are fully automatic. For another clinic that could not acquire an image with the fully automatic DRS camera, we sought advice from screening personnel at other sites who shared their experiences and arranged for the health worker to have a go at using an alternative Canon camera. The end result is shared delivery of the project goals to establish a viable service that can raise awareness of diabetic eye risks and serve as a useful educational tool to help patients seek help for their own health issues which can be a cultural barrier for the uptake of the service. Further comments about staff training are presented in Section 3.4.

2.3.6 Screening commencement

Clinical services using the telehealth platform commenced in October 2019, accomplishing the goal of using telehealth to link remote health providers and metropolitan ophthalmologists to enable regular eye examination and disease diagnosis services for remote and rural communities. However it took the team over a year before this point to establish comfort levels and trust because we wanted to ask enough people for input and ideas before we started doing anything.

From the commencement of this project, we have been trying to speak to as many people as we can that may inform the research, and throughout the project, have been on the look out to discuss and seek the opinions of more stakeholders (refer Appendix B for a summary of these consultations). In these discussions we have ensured that there is a clear understanding of what is hoped the project achieves, what success looks like, and offering the opportunity for the stakeholder to contribute to and influence the project.

The team have endeavored to maintain two-way open communication, listen to individuals and groups that have an interest in eye screening and service provision, keep them informed via update emails, and being clear about the role of the project in related activities.

Key success factors have been the comfort levels of participating ACCHOs, balancing realistic goals for this project with comprehensive delivery of treatment, as well as the diplomacy required for telehealth to form a component of future state- and territory-based health service delivery by supplementing (not replacing) the services of visiting eye specialists. The team has been gaining an awareness of challenges and issues associated with eye screening and identifying how to add clinical value and complement existing workflows rather than "tread on toes". Through these stakeholder engagements, we reinforced the goal of this project to offer better decision-making tools rather than replacing current care teams, and that telehealth (and the artificial intelligence we are embedding) should integrate with the human element of the service, and not replace it altogether.

The team have worked extremely hard to achieve the project's target regarding the number of patients screened by the project completion at the end of June 2022. This is remarkable given that in 2020 all eye screening activity stopped and specialist clinics were cancelled at all study sites due to COVID-19 concerns. The health clinics remain extremely wary about the potential introduction of the virus into the communities which needed to remain isolated.

Despite the obvious continued presence of the pandemic, health workers have been safely assessing the use of the secure platform to obtain diagnoses for patients from late September 2020 onwards. As of mid-2020, nine patients had undergone a retinal examination uploaded via the secure telehealth platform and a diagnosis provided by a specialist ophthalmologist. A year later, this had increased to 163 patients and the team achieved the project's target of 350 patients by its completion date in mid-2022.

A snapshot of the project summarising the outcomes and benefits arising from the above-mentioned project activities is presented over.

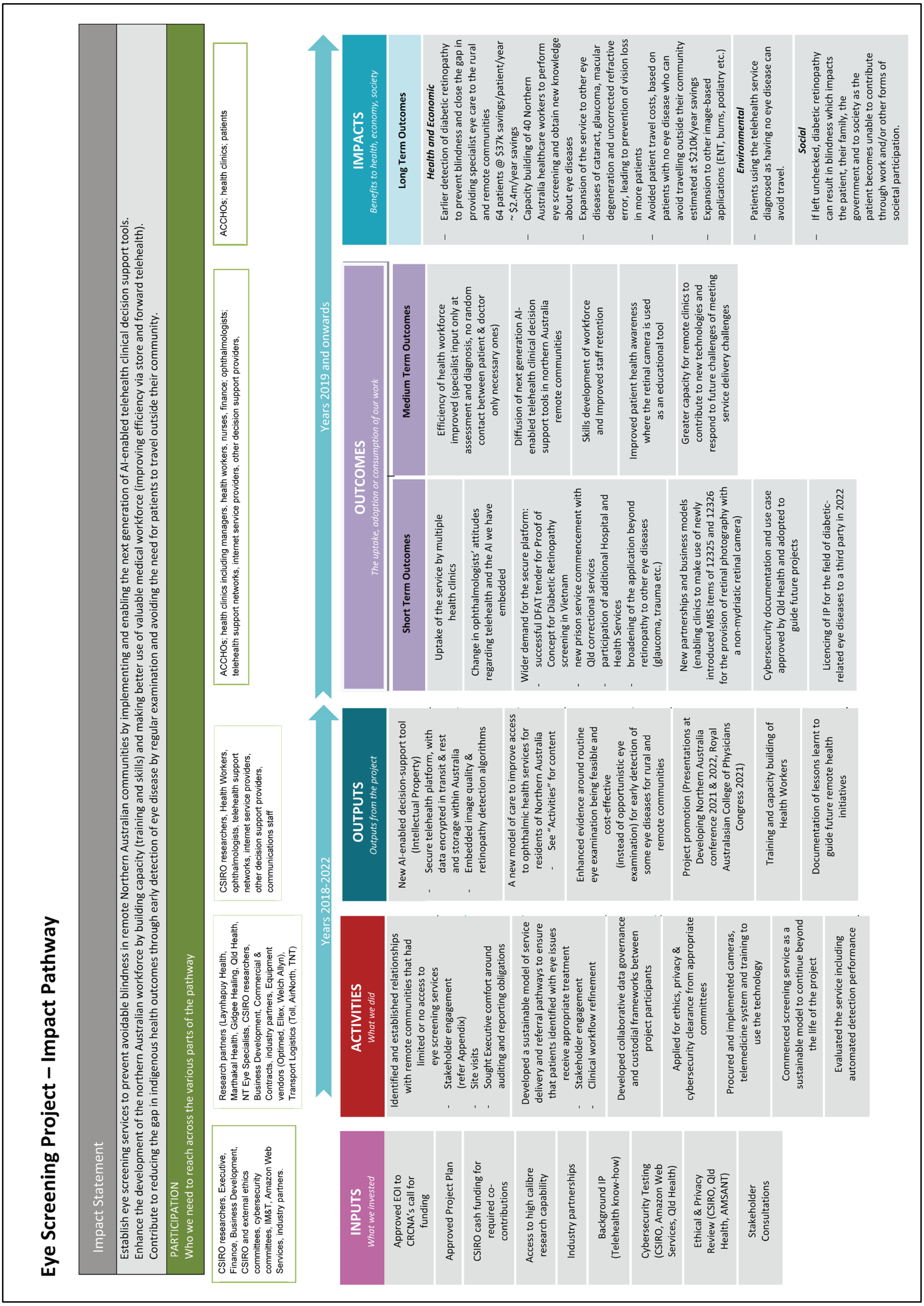


Figure 1 – The Impact Pathway for this project

3 Outcomes and Benefits

This section provides further analysis of the following selected project outcomes:

- closing the gap in providing specialist eye care to the rural and remote communities;
- reducing the number of patients that have to travel outside their community;
- earlier detection of diabetic retinopathy to prevent blindness;
- training and capacity building of health workers;
- evidence for the service being feasible and cost-effective for early detection of eye diseases.

3.1 Closing the gap in providing specialist eye care to the rural and remote communities

The main outcome of the project has been the establishment of a new tele-eye care service linking the resources of remote health providers and metropolitan ophthalmologists to enable regular eye examination and disease diagnosis services. Clinical teleophthalmology service delivery was undertaken at the locations tabled below.

Table 2 - Screening Site Locations

SITE NAME	LOCATIONS PHONE NUMBER	ADDRESS	AGENCY
Laynhapuy Health Clinic	(08) 8939 1861	86 Galpu Road Yirrkala, 0880, NT	Laynhapuy Homelands Aboriginal Corporation
Marthakal Homelands Health Service	(08) 8970 5511	PMB 62 Elcho Island, 0822, NT	Marthakal Homeland & Resource Centre Aboriginal Corporation
Gidgee Healing Mount Isa Primary Health Care Services	1800 GIDGEE-1	121 Marian St, Mount Isa, 4825, QLD	Gidgee Healing
Gidgee Healing Normanton Primary Health Care Services	1800 GIDGEE-2	32 Brown St, Normanton QLD 4890	Gidgee Healing
Thursday Island Hospital	(07) 4069 0200	163 Douglas St, Thursday Island 4875 QLD	Queensland Health
Badu Island Health Centre	(07) 4069 4127	Tamwoy Street, Badu Island 4875 QLD	Queensland Health
Saibai Island Primary Health Care Centre	(07) 4069 4252	School Road, Saibai Island 4875 QLD	Queensland Health
Murray Island Primary Health Centre	(07) 4069 4089	Murray Island, 4875 QLD	Queensland Health
Bamaga Primary Healthcare Centre	(07) 4069 3166	Sagaukaz Street, Bamaga 4876 QLD	Queensland Health
Injinoo Primary Health Care Centre	(07) 4212 2000	55 Pablo Street, Injinoo 4876 QLD	NPA Family & Community Services ATSI Corporation
Weipa Integrated Health Service	(07) 4082 3654	Lot 407 John Evans Drive, Weipa 4874 QLD	Vanguard Health & Queensland Health
Rockhampton	(07) 4927 6111	119 Bolsover St, Rockhampton QLD 4700	Moore Eyes & Queensland Health
Emerald	(07) 4982 4450	144 Egerton St, Emerald QLD 4720	Sankey Fraser Eyecare & Queensland Health

The new service improves access to ophthalmic health services for patients residing in the areas surrounding the above sites. As of 30 June 2022, there have been 246 residents in Queensland and 132 residents of the Northern Territory who have received a tele-ophthalmology service (eye screen examination and diagnosis via Remote-I).

This total (378) exceeds the number of participants targeted in this project (350). A breakdown by site and month of the project is tabled below.

Table 3 - Telehealth service delivery by site and quarter

	NUMBER OF PATIENTS SCREENED AND DIAGNOSED WITH THE SERVICE AS OF:										
Site	31/12/19	31/3/20	30/6/20	30/9/20	31/12/20	31/3/21	30/6/21	30/9/21	31/12/21	31/3/22	30/6/20
Laynhapuy (NT)	4	4	4	4	31	45	65	75	95	115	121
Marthakal (NT)	5	5	5	5	5	9	11	11	11	11	11
Thursday Island (Torres Strait QLD)				7	28	52	67	91	115	144	148
Injinoo (Torres Strait QLD)					14	14	14	14	14	14	14
Badu Island (Torres Strait QLD)						1	1	3	3	3	3
Bamaga (Torres Strait QLD)						2	2	2	2	2	2
Gidgee Healing - Normanton (NW QLD)							3	7	11	11	11
Murray Island (Torres Strait QLD)									1	1	1
Saibai Island (Torres Strait QLD)									3	3	3
Weipa (Far North QLD)											27
Gidgee Healing – Mt Isa (NW QLD)											35
Rockhampton (Central QLD)											1
Emerald QLD (Central QLD)											1
TOTAL:	9	9	9	20	78	123	163	203	255	304	378

Average exams diagnosed per quarter between October 2020 – June 2022 = 52 patients/quarter.

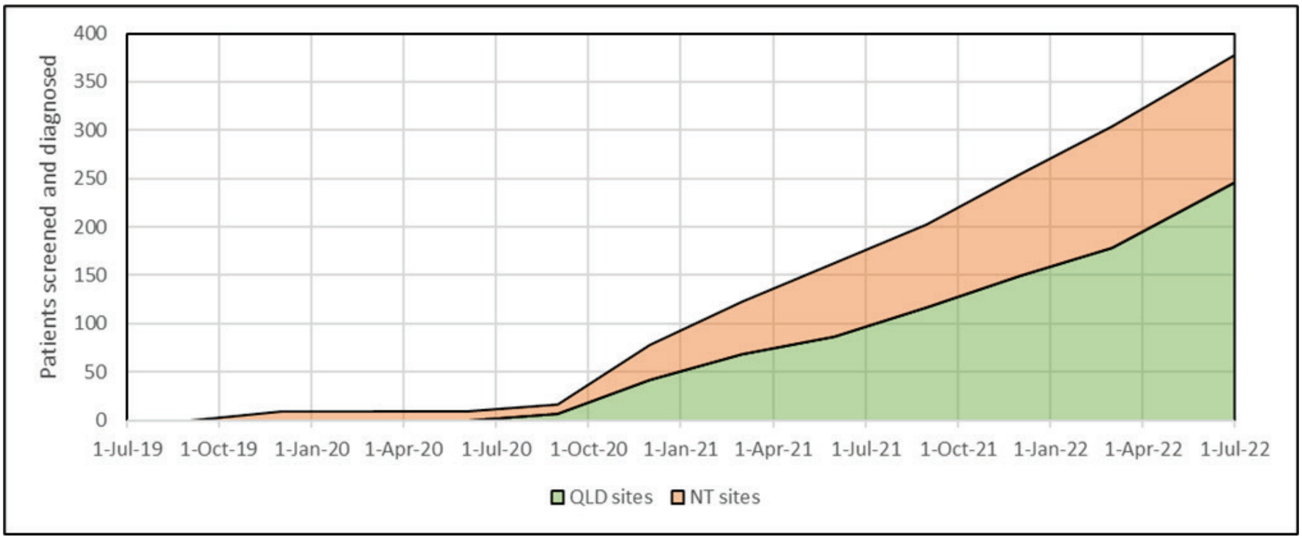


Figure 2 - Patient participation in the project

At the commencement of the project, two health clinics in East Arnhem (Laynhapuy and Marthakal), and three clinics in the Torres Strait (Thursday Island, Bamaga and Badu Island) were the focus of the team's engagement. Capitalising on where there was additional enthusiasm, investigations into screening at other locations were explored, which included additional sites such as the outer Torres Strait islands of Saibai and Murray Island, the southern area of Cape York (Weipa, Cooktown, Pormpuraaw, Kowanyama), central Queensland (Rockhampton, Yeppoon and Emerald) and north-west Queensland (Mt Isa, Doomadgee, Normanton and Mornington Island). At each site, there is extensive planning around referral pathways and workflow components that are required, and it can be seen from Table 3 that there has been uptake of the service by multiple health clinics beyond the initial targeted sites. Also the number of patients screened and diagnosed with the service is in accordance with the milestones shown in Table 1.

Observing the figures in Table 3, it is also evident that some sites have achieved higher screening counts than others. Factors contributing to where counts are highest (Laynhapuy Health, Thursday Island, Weipa and Gidgee Healing sites) include staff enthusiasm, higher technical literacy, and a dedicated eye health coordinator or screening nurse who has taken ownership and driven the program locally. These screening locations also enjoy the advantage of relatively more amenities to attract and retain staff.

Conversely sites where screening counts are low (Marthakal Health and the outer Torres Strait islands) have faced resourcing staff shortages, where despite best intentions and high commitment to improving outcomes for patients, there is simply not the time for staff to embrace additional activities. In the outer Torres Strait islands, it has been relayed that low screening volume in these areas are not due to lack of patient engagement, but severely understaffed clinics who have no time and see screening as a low priority. Gidgee Healing had good success with training health workers in their Normanton and Mt Isa primary health care centres who are now good at using the retinal cameras, but continue to be severely understaffed at Mornington Island and Doomadgee despite advertising for staff. Marthakal Health has faced the challenges of severe workforce shortages including at the clinic manager level, where staff absences and the need to wear multiple hats (e.g. being the plumber) can make managing a remote health service particularly chaotic.

Table 4 compares selected characteristics of the screening locations that impact screening volumes to illustrate the diversity among health services involved in this project.

Table 4 – Characteristics of screening locations that impact clinical service delivery

	Previous eye health experience	Dedicated eye health nurse/coord.	High Technical Literacy	Amenities of surrounds	Executive support	Dry community	Serviced by visiting optoms	Health worker patient rapport	Experience of clinic manager	Payment made to agency from this project	Cameras supplied via this project	Multiple hats worn by staff	Trained staff
Laynhapuy		●	●	●	●	●	●	●	●	●	●		●
Marthakal					●	●	●	●		●	●	●	●
Thurs. Island	●	●	●	●	●		●	●	●		●		●
Injinoo						●	●					●	●
Badu Island					●		●		●		●	●	●
Bamaga					●	●	●				●	●	●
Normanton		●	●		●		●	●	●				●
Murray Island					●		●				●	●	●
Saibai Island					●		●				●	●	●
Weipa		●		●	●		●	●		●			●
Mt Isa		●	●	●	●		●	●	●				●
Rockhampton	●	●	●	●			●		●				●
Emerald	●	●	●	●			●		●				●

On the whole, the successful use of advanced technology combined with cost savings (estimates are presented in the next section) demonstrate that a model for a sustainable tele-health model has been established for Australians living in regional and rural northern Australian locations. Following the restart of eye clinics after the first wave of COVID-19, the service has achieved an average use of 52 patients per quarter.

Feedback has indicated that patients were very appreciative of having access to this service. Comments relayed by health workers included the following:

- *Patients were very relieved that they were not having their pupils dilated. They accept the fact that a visiting optometrist or ophthalmologist may dilate, but building rapport with no drops was very successful.*
- *Patients were very keen to see the back of their eyes. This also allowed for education and questions related to risk factors for eye disease.*
- *Patients didn't really care who was reading the photos, just that if something was found they would get referred straight away to the next clinic to see the ophthalmologist.*
- *Patients liked the interaction with staff about their eyes and talk was done the usual way of yarning about every- thing under the sun until the discussion got to the bit about what happening with their eyes. e.g. The fact that kids are on the media platform all the time and their "long way vision" is disappearing and the old people can see the dugong/turtle before the young people.*
- *Patients were not interested where the photos were being stored or that there was a permanent record of their eyes*.

Health workers and ophthalmologists stated that they liked the web-based telehealth system, that it was easy to use, easy to find photos that have been archived, easy to download reports, and the system was well developed. When asked whether ophthalmologists perceived any changes in earlier detection of sight threatening conditions i.e. diabetic retinopathy, macular degeneration, cataract or glaucoma, as a result of using Remote-I, they indicated that it had on a few occasions. Specific comments received from health workers included the following:

- *Remote-I is a great tool that definitely helps us provide early intervention. The system has created smoother health journeys for our patients and prevented blindness in some cases.*
- *As a result of using Remote-I, earlier detection will and has occurred. Even though the system has only been used for a short time we have already picked up cases that needed medical attention. Feedback was received promptly from the Specialists at the hospital as to urgency of review. Two diabetics and a retinal bleed.*
- *The store and forward is secure in relation to patient confidentiality of data and in the permanent archiving of clinical information. It is also auditable. Previous methods of image transfer and information have been in some cases less reliable or secure. As we also rely heavily on imaging of the eye, many other methods do not allow colour photography to be sent to the hospital.*
- *Much of what we need is achieved by Remote-I and it is invaluable as an asynchronous system for the two clinical situations we have planned: 1. Prison Health diabetics, red eye and trauma. 2. Central Qld for review of cases by local optometrists that will then avoid travel to Outpatient appointments in Brisbane.*
- *Due to many staff shortages across our service region we have experienced a delay in our ability to fully implement the process of doing the retinal images and uploading to the Remote-I portal. It is our target within the next 6 months to fully implement retinal imaging into all health checks and images be uploaded to the portal daily.*
- *Our service area covers the Northwest and lower gulf regions of QLD. The visiting Ophthalmology service visits Mount Isa 2 days each month – more than half of our patients reside outside Mount Isa and are required to travel over 600kms to attend. If Telehealth appointments can be offered for some Ophthalmology services this will alleviate issues related to transport, accommodation and cost.*
- *The ophthalmologist is completing the assessments very quickly, typically within 24 hours.*
- *Very simple to use, the log in is secure & the portal itself is very easy to navigate.*
- *Advantages are Early intervention, Direct line of contact to Ophthalmologist, Quicker access to health care, Smoother health care journeys. Disadvantages are NIL.*
- *There are no perceived barriers to its use. It [Remote-I] had very good acceptance with the users, who have found it straightforward. Nursing staff have been very enthusiastic.*

- *Remote-I has allowed review of diabetic, trauma or red eye cases by nursing staff. Nurses can then relay this to the hospital for opinion. As the visiting Optometrist I can also log in remotely to assess patents that nursing has alerted me to review. The remote review of patients will allow local review of patients who may be more reliable with attendance, as they do not have to travel to Brisbane for these reviews.*

Early detection of eye disease through improved access to ophthalmic screening can reduce the devastating impacts on the lives of those people affected by the disease. Even the threat of reduced vision and the need for ongoing examinations and treatment can have negative emotional, social and economic effects.

Although the milestones for this project had been set up based on patient screening quotas, higher screening volumes should not necessarily be the target nor measure of ultimate success, as highlighted in a recent situational analysis of northern Australia health service delivery[6] funded by the CRCNA:

> *"Some studies offered critiques of current funding schema that reward volume over value (activity throughput rather than high quality care, which disadvantages smaller population centres with higher health needs) and highlighted a need for financing models to reflect not only disease burden and cost but also the notion of a "minimum equitable viable service". This is particularly relevant in small rural and remote communities where Medicare funding is inadequate to sustain services."* [pg. 23]

A stronger indication of the success of project activities is positive feedback from health workers as indicated above and case studies that focus on value rather than volume (high quality care rather than activity throughput). Case studies documenting some of the benefits realised from this project are presented in Box 1, 2 and 3 in the following pages.

Case Study 1, based on a family of diabetics in the Torres Strait, demonstrates that by screening children by just taking a photo every year without dilating, develops trust and education right from the beginning. The camera was described as a valuable screening and diagnostic tool especially in remote areas where visits to the ophthalmologist are logistically difficult and it enabled opportunistic, diagnostic proof of screening findings, was non-invasive and incredibly easy for the operator to use.

Case Study 2 describes the benefit in motivating behaviour change in a diabetic patient. The role of patient self-help (taking medicine in time, not missing doctor's appointments, monitoring blood sugar levels regularly) and improved awareness about diabetes in controlling sight-threatening complications of diabetic retinopathy is not well documented in the literature.[7] Case Study 2 contributes to the evidence in this area to suggest that improving diabetic self-help, or knowledge/awareness about diabetes and its risk factors, plays an important role in the control of diabetes and diabetic retinopathy.

Case Study 3 is an example of where the Remote-I platform has been directly attributable to preventing blindness.

Further details of cases of eye disease picked up through this project are given in Section 3.3.

[6] Edelman A, Grundy J, Moodley N, Larkins S, Topp SM, Atkinson D, Patel B, Strivens E, and Whittaker M. 2020. Northern Australia Health Service Delivery Situational Analysis. Cooperative Research Centre for Developing Northern Australia, Townsville.

[7] Sapkota R, Chen Z, Zheng D, Pardhan S. The profile of sight-threatening diabetic retinopathy in patients attending a specialist eye clinic in Hangzhou, China. BMJ Open Ophthalmol. 2019 Apr 11;4(1):e000236.

Figure 3 - A patient undergoing an eye test in the Torres Strait, QLD

BOX 1

Case Study 1 – Altering health outcomes for the next generation

A Family Affair (Shared with permission)

Mother was diagnosed as a young woman at the age of approx. 22yrs. She has had 5 children since then. On diagnosis she received regular diabetic checks, was prescribed oral hypoglycemics and had yearly Ophthalmology review. As time went by, she was prescribed Insulin along with oral medications. In 2013 she was diagnosed with NPDR and continued with regular Ophthalmology checks which identified her Diabetic Eye Disease increasing to PDR and vitreous bleeds. For this she received laser and regular Eylea Injections on a 3monthly basis. Due to the mothers need for other medical reasons to go to the city, she at times has missed the Ophthalmology visits. Due to the high waitlist for Ophthalmology appointments in the City, the opportunity for early review was at times missed and hence the need for more invasive action to try and preserve her sight.

Father was diagnosed with diabetes from 2014 at the age of 42 yrs. He was prescribed Insulin and Oral Hypoglycemics on diagnosis. He had received no Ophthalmology care up to this stage and on his first visit was diagnosed with NPDR. For this he received laser but over time this progressed to both laser and Eylea Injections due to PDR and Macular Odema. Due to other medical needs, father has had to spend time in the City. With the high waitlist for Ophthalmology appointments, he as well as his wife has missed very important reviews. Due to having a Non Mydriatic camera we have been able to take photos which are sent to the Visiting Ophthalmologist who has been able to activate an urgent Cat 1 referral for treatment in the City to try and preserve his sight.

Daughter 1 was diagnosed at 16 years. She was prescribed Insulin and oral hypoglycemics. She has received regular Ophthalmology review since diagnoses (5 yrs) which has been via Ophthalmology visits and the Non mydriatic camera. The use of the camera has allowed her to present for regular photos, the visit being for a short duration and without dilating drops in complete confidentiality. At this stage she has not been diagnosed with Diabetic Eye Disease. The importance for a young person to receive screening, without invasive procedures, at a time of their wishes that does not impact on their need to be part of their peer group is incredibly important. The camera is also an excellent teaching platform where the person can own their eyes and can ask questions.

Daughter 2 was diagnosed at 9 yrs. She was prescribed Insulin and Oral Hypoglycemics. She had received no Ophthalmology care until she had Diabetic Retinal Photos in 2020 and by 2021 has developed mild NPDR. She is now watch and wait with regular Diabetic Retinal Photos. She is now 8yrs since diagnosis.
The reluctance for regular Ophthalmology review was "dilating drops".

The **Non Mydriatic Camera** is a valuable screening and diagnostic tool especially in remote areas where visits to the Ophthalmologist is logistically difficult, invasive with Dilating drops and can be felt as "big shame" for young people. This has also a great importance to the older folk who also struggle with a family to care for (moving from outer islands / communities to central areas) age immobility and disruption to life needs. The camera is opportunistic, diagnostic proof of screening findings, non- invasive and incredibly easy for the operator to use.

Queensland Government

BOX 2

<u>Case Study 2</u> – Demonstrating behaviour change as a result of the team's work

Shared with patient's permission – a photo of one of our "Diabetes Champions".

The patient has had a diagnosis of Type 2 Diabetes since 2018 and a HbA1C of 10% -11% since diagnosis.

In July 2021 she came to the clinic and we were able to persuade her to have an eye screening. During her visit we used the retinal screening camera and we were able to show the patient photos of her eyes. It looked like she had some myopic shift and we used the images on the retinal camera to help explain this. It was around this time that she started taking her medications, she came back the following month for another check-up for her eyes and her following HbA1C in July came down to 7.1%.

I believe that part of the reason for her improved diabetes control was due to myopic shift and the ability to be able to explain this with real photos.

LAYNHAPUY HOMELANDS ABORIGINAL CORPORATION

BOX 3

<u>Case Study 3</u> – Remote-I: Preventing Avoidable blindness with early intervention!

The patient has been type 2 diabetic for a little over 5 years, she is also temporarily living away from her remote home community to be able to receive full time dialysis treatment. This patient presented to our clinic for her annual health check as well as retinal imaging apart of her diabetes management.

The health check was performed & retinal images done, from this it was identified the patients unaided visual acuity was 6/30 RE, 6/18 LE and needed an optometry review as it had been over 14 months since she had a full comprehensive eye test. It was also noted the patient was already on the waitlist for Cataract surgery which could have been the reasoning behind the poor visual acuity. The appointment was booked for the next available Optometrist visit to our clinic (two weeks away) and the images were uploaded to the Remote-I portal to be assessed by the ophthalmologist.

Within 24 hours the ophthalmologist had reviewed the images/information submitted on the Remote-I platform and determined the patient had a possible retinal detachment in her LE. The ophthalmologist advised urgent VR injections would be required and the patient would need to go to Brisbane urgently for this procedure.

From here we submitted an urgent referral to Royal Brisbane Hospital and the patient was booked to go ASAP for specialist review.

By intervening early:

- The patient received much needed specialist care quicker preventing further vision loss
- While flights/accommodation were being sorted, we were able to arrange for the patient to have dialysis treatment while in Brisbane and allowed us to quickly arrange a family member from the patients home town to escort the patient to their appointment.

Without early intervention:

- If we didn't have access to the Remote-I platform, the poor vision could've been ruled down to cataracts, a new referral would've been submitted to the hospital however it could've been days/weeks before the referral/images were reviewed.
- If we had waited another 10 days for the Optometrist appointment, the outcome could have been much worse, the patient could have potentially lost all vision.

Overall, by utilising the Remote-I portal we were able to prevent this patient from losing her vision.

<u>Our Plan:</u>

Our optometrist currently visits each of our 5 communities every 5-6 weeks this works out to about 7 visits to each community within a 12-month period. The service is regulated which is great however, between these visits we need a continuing screening process to help identify any eye conditions needing early intervention.

The Remote-I programme is efficient and effective and the portal is easy to navigate. The support we receive from CSIRO is beyond so our focus within the next 6 months is to utilize the programme as part of our everyday health checks. Basically, this will be implemented by upskilling all Aboriginal Health Workers to use the Retinal Camera when performing health checks and at the end of each day uploading images to the Remote-I portal for Ophthal assessment.

With type 2 diabetes being one of our prevailing chronic diseases among our communities, integrating Retinal images into all health checks and uploading to the portal for assessment will inevitably prevent vision loss in many cases. Overall, utilising the Remote-I resource in our remote communities will help with early intervention and lead to vital improvement to our patient's health care journey. We look forward to the progress of this process and are happy to provide further case studies.

Gidgee Healing

3.2 Reducing the number of patients that have to travel outside their community by ensuring patients receive treatment as close to their place of residence as possible

The premise of many telehealth programs is reducing unnecessary patient travel. An assessment of this benefit is made by assuming that patients using the telehealth service diagnosed as having no eye disease could avoid travelling outside their home health service district and hence avoid costs associated with that travel.

In Queensland, DR grading was possible for 206 patients, of which 158 (77%) showed no signs of diabetic retinopathy. In NT, DR grading was possible for 100 patients, of which 84 (84%) showed no signs of diabetic retinopathy. If a patient has to travel for these outpatient appointments, an extra cost is incurred for travel subsidy schemes (state government-funded travel and accommodation payments to eligible patients and approved escorts who are required to travel to access specialist medical services), which are estimated at $1000 for NT patients and $800 for those in the Queensland areas. The basic eligibility requirement for NT patients is that they must be more than 200 km one way to the nearest approved medical specialist.[8,9] For Queensland, patients must be more than 50 km one way from the closest public hospital or health facility to the nearest eligible medical specialist, and be unable to use telehealth.[8,10] NT Health is also supportive of promoting telehealth as the option of first choice for people wishing to access travel subsidy schemes.[11] It’s been contended that demand for patient travel subsidy schemes will continue to increase over time as services in regional, rural and remote areas continue to decline, the population ages and other issues such as more sophisticated and more expensive medical technologies are introduced.[12]

A quick calculation of cost savings through not using travel subsidies for screening is shown below. For the number of patients screened and at the calculated average cost per trip, the screening program would save the health system close to $210,000 per year in unnecessary travels alone.

Table 5 – Assumed travel cost savings associated with the project

	QLD	NT	TOTAL
Patients screened	246	132	378
Valid exams diagnosed	238	126	364
Unique patients	220	116	336
Unique patients where DR grading was possible	206	100	306
Patients found to have no symptoms of DR	158	84	242
Average cost per trip	$800	$1000	
Estimated total travel cost savings	**$126,400**	**$84,000**	**$210,000**

[8] National Rural Health Alliance, A guide to Patient Assisted Travel Schemes, Nov 2019, available online (accessed June 2022): https://www.ruralhealth.org.au/sites/default/files/publications/nrha-guide-pats-2019.pdf

[9] Northern Territory Government, Patient Assistance Travel Scheme, available online (accessed June 2022): https://nt.gov.au/wellbeing/health-subsidies-support-and-home-visits/patient-assistance-travel-scheme

[10] Queensland Government, The Patient Travel Subsidy Scheme (PTSS), available online (accessed June 2022): https://www.qld.gov.au/health/services/travel/subsidies

[11] Department of Health, Northern Territory 2013, Review of the Patient Assistance Travel Scheme July 2013, available online (accessed June 2022): https://digitallibrary.health.nt.gov.au/prodjspui/bitstream/10137/570/1/Review%20of%20the%20PATS%20September%202013.pdf

[12] Parliament of Australia. Report - Highway to health: better access for rural, regional and remote patients, 2007, available online (accessed June 2022): https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Community_Affairs/Completed_inquiries/2004-07/pats/report/index

3.3 Earlier detection of diabetic retinopathy to prevent blindness

The screening undertaken in this project has increased the likelihood of early detection of sight threatening conditions among patients. Diagnosis data from Remote-I is shown in Figure 4.

Diabetic retinopathy is typically divided into two stages. Key features in the early stage known as non-proliferative diabetic retinopathy (NPDR), include haemorrhages within the retina and the leakage of fluid into the retina. The later stage of diabetic retinopathy involves the growth of new abnormal blood vessels on the retinal surface that may lead to severe vision threatening eye complications. Diabetic macular oedema (DMO) occurs when the leakage of fluid from small retinal blood vessels affects the macula. Diabetic macular oedema is the leading cause of vision loss in diabetes.

In the initial stage of the disease, people do not have visual impairment and may not notice any visual symptoms. However, in its advanced form of complication, the disease progress into proliferative phase which is characterised by formation of new blood vessels and macular oedema owing to accumulation of fluid within the retina producing severe and often irreversible vision loss.[13] In addition, the new blood vessels may bleed, adding further complication of preretinal or vitreous haemorrhage. Also neovascular glaucoma associated with the new vessels can be a cause of visual loss.[13]

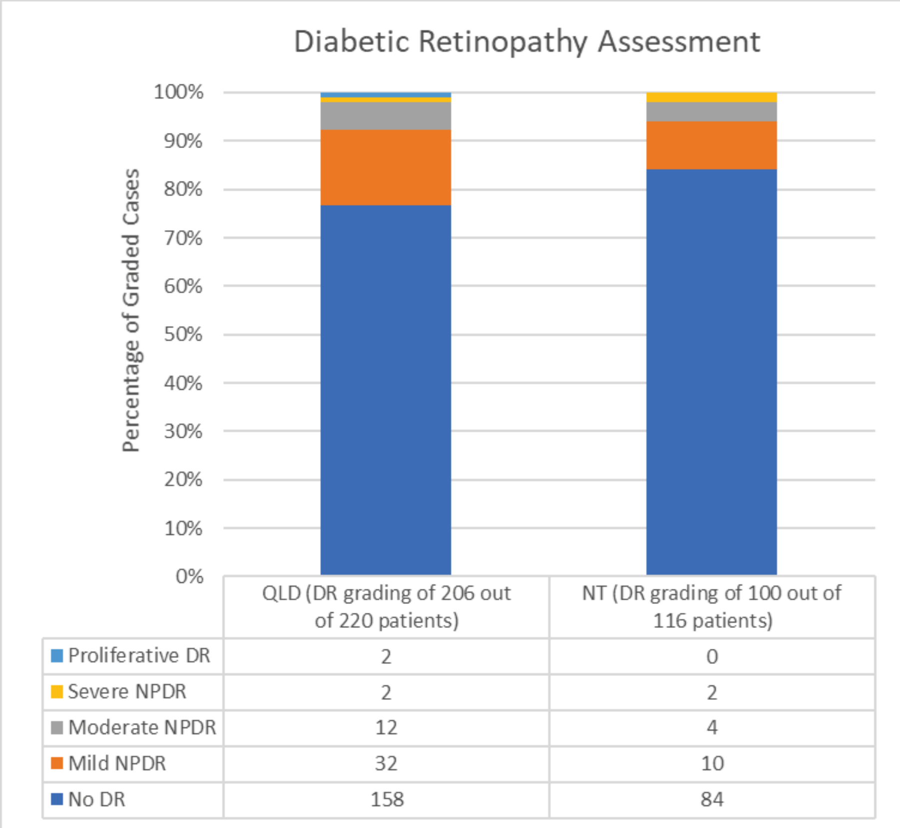
For the classification of diabetic abnormalities, aneurysms and small retinal haemorrhages may progress to mild, non-proliferative diabetic retinopathy or to moderate and severe non-proliferative diabetic retinopathy and ultimately to proliferative diabetic retinopathy. It is estimated that this progressive pattern takes on average ~17 years.[14] However regression from mild non-proliferative diabetic retinopathy to no visible retinopathy can occur and this regression is reinforced by effective treatment of hypertension and hyperglycaemia.[14]

Mild and moderate NPDR cases may be argued to be not immediately sight-threatening. However given the disease can progress to proliferative DR, the earlier detection of DR of *any* severity is reported within this project.

As shown in Figure 4, two critical cases of proliferative diabetic retinopathy, four cases of severe non-proliferative diabetic retinopathy, 16 cases of moderate non-proliferative diabetic retinopathy and 18 cases of macula oedema have been picked up, allowing for early intervention which has potentially prevented blindness in these patients. All uploaded participant records received diagnoses and recommended treatment plans to follow (eg. rescreen in 12 months).

[13] Alemu Mersha G, Tsegaw Woredekal A, Tilahun Tesfaw M. Sight-threatening Diabetic Retinopathy and Associated Risk Factors Among Adult Diabetes Patients at Debre Tabor General Hospital, Northwest Ethiopia. Clin Ophthalmol. 2020 Dec 30;14:4561-4569.

[14] Groeneveld Y, Tavenier D, Blom JW, Polak BCP. Incidence of sight-threatening diabetic retinopathy in people with Type 2 diabetes mellitus and numbers needed to screen: a systematic review. Diabet Med. 2019 Oct;36(10):1199-1208.



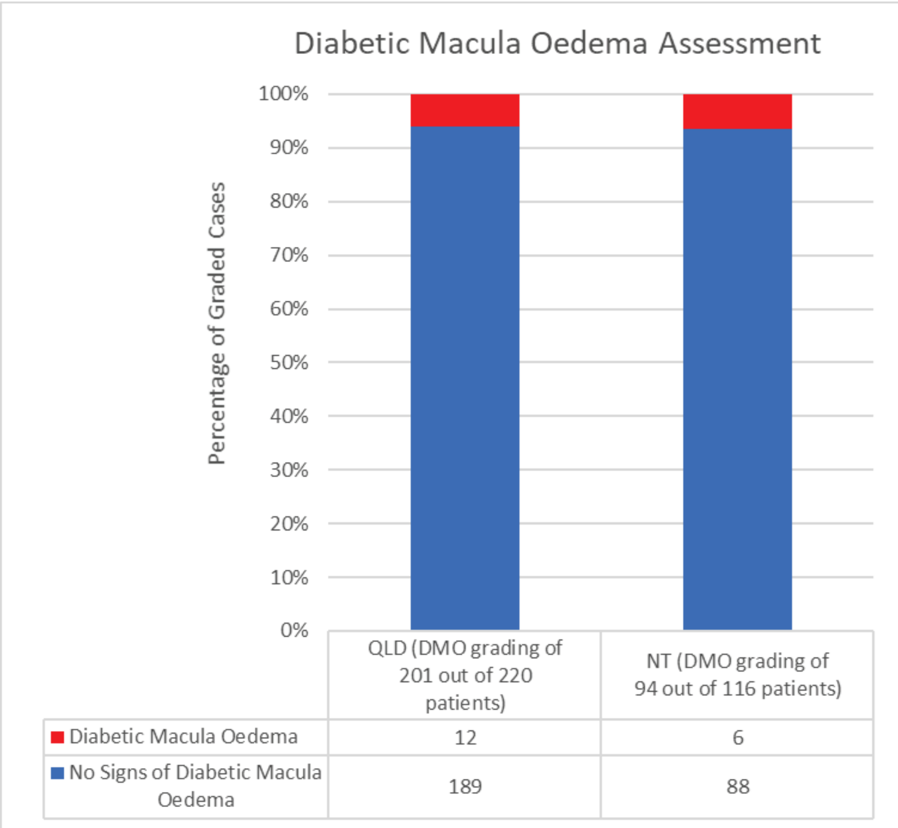


Figure 4 - Remote-I – Diagnosis Data

Grading results from this project are presented below.

Table 6 – Diagnoses assigned for patients

	NONE	NORMAL	NA	MILD NPDR	MODERATE NPDR	SEVERE NPDR	PDR	UNABLE TO GRADE	DR DIAGNOSIS	NO DR	TOTAL	INCIDENCE	QUALITY
Badu Is	2	0	0	0	0	0	0	0	0	2	2	0%	100%
Bamaga	0	0	0	2	0	0	0	0	2	0	2	100%	100%
Gidgee	19	0	0	12	7	2	1	3	22	19	44	50%	93%
Injinoo	12	0	0	2	0	0	0	0	2	12	14	14%	100%
Laynhapuy	76	1	1	6	4	2	0	15	12	78	105	11%	86%
Marthakal	2	3	1	4	0	0	0	1	4	6	11	36%	91%
Murray Is	1	0	0	0	0	0	0	0	0	1	1	0%	100%
Saibai Is	2	0	0	0	0	0	0	1	0	2	3	0%	67%
Thurs Is	100	0	0	16	5	0	1	5	22	100	127	17%	96%
Weipa	21	0	1	0	0	0	0	5	0	22	27	0%	81%
TOTAL	**235**	**4**	**3**	**42**	**16**	**4**	**2**	**30**	**64**	**242**	**336**		

The 2nd last column in the table above headed 'Incidence' reflects how many DR cases were picked up as a proportion of total exams. We observe Bamaga, Gidgee sites, and Marthakal had relatively high numbers of DR cases as a proportion of patients screened.

The last column headed 'Quality' reflects how well the images were captured at each site, and measures the percentage of gradable images. This measure was based on the reviewing specialist's point of view (which is different to automatic Image Quality Assessment discussed in Section 6). While quality was generally pretty good, ungradable exams affect the success of the program in detecting early signs of diabetic retinopathy.

The overall results from this project in the early detection of diabetic retinopathy are as follows:

- Total patients screened = 378
- Patients with valid diagnoses = 364
- Unique patients diagnosed (removing multiple visits by the same patient: 24 patients were seen twice across the study, and 2 patients were seen 3 times) = 336
- Unique Patients with DR = 64
- Unique Patients with DR who also have DMO = 17 (27%)
- Unique Patients with Mild NPDR = 42
- Total unique patients with potential sight threatening conditions = 64 (including mild NPDR cases)
- Total unique patients with severe sight threatening conditions = 22 (excluding mild NPDR cases)
- No DR = 242
- Unable to grade = 30

There is a broad range of positive impacts that occur as a result of improving eye health for patients. These include benefits such as improved physical health; improved wellbeing; and greater participation in employment or education.[15]

[15] The Value of Indigenous Sight PwC report, commissioned by University of Melbourne Indigenous Eye Health, Sept 2015, available online (accessed June 2022): https://mspgh.unimelb.edu.au/__data/assets/pdf_file/0011/2260865/value-of-indigenous-sight-sep2015.pdf

For Indigenous Australians, health also has a greater meaning than the physical or mental health and wellbeing of the individual. For Indigenous Australians, 'health' has a holistic definition as defined in the Constitution of NACCHO[16]:

> *"Aboriginal health" means not just the physical well-being of an individual but refers to the social, emotional and cultural well-being of the whole Community in which each individual is able to achieve their full potential as a human being thereby bringing about the total well-being of their Community."*

Therefore, the positive impact of improved Indigenous eye health is felt not just by the individual, it is also felt by their community more broadly.

Vision loss has an associated economic impact, and vision disorders in Australia are estimated to cost well over $10 billion, half of which is the loss of wellbeing (years of life lost as a result of disability and premature mortality).[17] The relative reduction in employment for people with vision loss for Australasia is estimated to be 32%.[18] Health system costs for vision disorders are claimed to be higher than for coronary heart disease, diabetes, depression, and stroke and the Centre for Eye Research Australia has advocated that even a developed economy such as Australia's cannot afford avoidable vision loss.[17]

The cost of vision loss per patient has been estimated[19] to be as follows:

- $5,200 Health system costs
- $4,000 Productivity losses
- $440 Carer opportunity costs
- $1,463 Other indirect (aids/modifications/other carer)
- $1,515 Deadweight Loss
- $16,400 Loss of wellbeing
- TOTAL $29,000 / patient / year (expressed in 2009 dollars).

These costs are adjusted to 2021 dollars based on changes in the Consumer Price Index published by the Australian Bureau of Statistics (ABS) using the average of the CPI in the four quarters of the calendar year:

$$\text{Inflation between calendar year 2009 and 2021} = \left(\frac{\text{Average of CPI level in Mar2009, Jun2009, Sep2009, Dec2009}}{\text{Average of CPI level in Mar2021, Jun2021, Sep2021, Dec2021}} - 1\right) \times 100\% = 27.9\%$$

This adjustment means a basket of goods and services valued at $100 in calendar year 2009, would in calendar year 2021 cost $127.90. Thus the cost of vision loss per patient in 2021 dollars (12 years at an average annual inflation rate of 2.1%) is estimated to be $37,000 / year.

Considering all 64 unique patients that were picked up as having sight threatening conditions, the annual health system and other cost savings associated with avoided vision loss is estimated to be:

64 patients x $37,000/year = $2.4m annual savings.

Adopting a more conservative view of applying this saving only for the 22 unique patients with *severe* sight threatening conditions (i.e. excluding mild NPDR cases) would equate to ~ $814,000/year savings. It can be appreciated how substantial economic impacts could be realised if screening were to be deployed at additional locations.

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[16] National Aboriginal Community Controlled Health Organisation, available online (accessed June 2022): https://www.naccho.org.au/acchos/

[17] Taylor H, Pezzullo M, Keeffe J. The economic impact and cost of visual impairment in Australia. Br J Ophthalmol. 2006 Mar;90(3):272-5.

[18] Marques AP, Ramke J, Cairns J, et al. Global economic productivity losses from vision impairment and blindness. EClinicalMedicine. 2021 Apr 26;35:100852.

[19] Clear Focus, The Economic Impact of Vision Loss in Australia in 2009, A report prepared for Vision 2020 Australia by Access Economics Pty Limited, June 2010, available online (accessed June 2022): https://www.vision2020australia.org.au/wp-content/uploads/2019/06/Access_Economics_Clear_Focus_Full_Report.pdf

3.4 Training and capacity building of health workers

The project included a component of ground-up workforce development (often starting from zero knowledge of ocular health) in the community-controlled sector for remote communities by upskilling Aboriginal and Torres Strait Islander health workers in diagnostic skills and data management and governance. Remote health workers have been trained to capture high quality images of the eye, data entry, uploading information to a secure telehealth portal, and reviewing of diagnostic advice. Expanding the skills of the Northern Australia workforce can lead to increased opportunities for employment as well as bringing eye care to the community with the help of trained community health workers. A breakdown of staff training undertaken by site is presented in Table 7.

Table 7 - Breakdown of staff training by site

REGION	SITE	# HEALTH WORKERS	TRAINING LEVEL (REFER BELOW)	# OF REVIEWING SPECIALISTS	TRAINING LEVEL (REFER BELOW)
NW QLD	Mt Isa (Gidgee Healing)	1	2	2	4
	Normanton (Gidgee Healing)	2	3		
	Doomadgee (Gidgee Healing)	6	1		
	Mornington Island (Gidgee Healing)	2	1		
TORRES STRAIT QLD	Thursday Island (Queensland Health)	2	3	3	4
	Badu Island (Queensland Health)	4	2		
	Murray Island (Queensland Health)	2	2		
	Saibai Island (Queensland Health)	2	2		
NORTHERN CAPE YORK QLD	Bamaga (Queensland Health)	4	1		
	Injinoo (NPA Family and Community Services ATSI Corporation)	1	2		
SOUTHERN CAPE YORK QLD	Weipa, Kowanyama, Pormpuraaw (Queensland Health and Vanguard Health)	2	2	1	4
EAST ARNHEM NT	Yirrkala, Nhulunbuy (Laynhapuy Health)	3	3	2	4
	Galiwinku (Marthakal Health)	9	3		
TOTAL		**40**		**8**	

<u>Training Levels:</u>
Level 1: Overview of the telehealth workflow.
Level 2: Level 1 + How to transfer images from the camera, how to upload images, and add visual acuity and diabetic history to the telehealth portal, how to review diagnosis reports received from ophthalmologists. (Staff have previously been trained in use of retinal cameras).
Level 3: Level 2 + Ocular anatomy and vision basics, Detailed training on use of the Welch Allyn RetinaVue portable handheld camera, Canon CR-2 camera and DRS retinal cameras.
Level 4: How to access images and clinical data, how to provide a diagnosis and recommendations for follow-up including timeframe.

Training videos (uploaded to YouTube) and a clinical protocol were developed to assist healthcare workers with the new workflow and allow them to watch it repeatedly at leisure. This process was informed by previous projects in the area and refined based on feedback from health workers. A similar protocol was also developed for specialist ophthalmologists (not based in community) who have been trained to use the system for reading the data and providing diagnoses. The purpose of these protocol documents is to educate the end users in steps that they need to follow, and the team walked through the workflow and steps with end users to ensure they understand the process. Valuable feedback was received from healthcare workers during this process which was used to improve the workflow.

These training activities develop the capacity and empower health workers and contribute to the ongoing benefit of the program by the fact that services are being provided in the local community on an ongoing basis, rather than requiring patients to travel to metropolitan areas, or waiting months for an ophthalmologist to visit the region. Also rather than an ophthalmologist conducting a face-to-face examination, local health workers have been acquiring the skills necessary to perform basic vision testing and recording of relevant medical information. Health workforce training and support needs to be unrelentless as it is an ever-present requirement and one of the priority actions arising from a recent CRCNA-funded situational analysis of northern Australia health service delivery.[6] In particular, supporting the participation of Aboriginal and/or Torres Strait Islanders and supporting the broader health workforce with improved retention (reducing staff turnover) could result in significant financial savings for northern Australian health services.

Figure 5 - Health workforce training and skills development at Marthakal Homeland and Resource Centre Aboriginal Corporation with a desktop retinal camera

3.5 Service cost effectiveness

The assessment of service cost effectiveness is based on the premise that patients using the telehealth service diagnosed as having no eye disease could avoid travelling outside their home health service district and hence avoid costs associated with that travel.

There were 246 patients screened in Queensland and 132 patients screened in NT, comprising a total of 378 patients seen of which 364 exams had valid diagnoses provided by ophthalmologists (96%). Discounting multiple visits by the same patient, there was a total of 336 unique patients assessed. Of those, 242 (72%) were found to have no symptoms of diabetic retinopathy (DR) and 42 (13%) were diagnosed with Mild Non-proliferative DR (NPDR) and 30 patients (9%) had images that were deemed unable to be graded.

On the other hand, 22 patients were diagnosed with Proliferative DR and/or Severe and Moderate NPDR and if left unattended would most likely lose their eyesight. These patients were saved by opportunistic and inexpensive eye screening and can be referred to a hospital for admission and possible management of their condition.

The average day stay at a hospital for eye conditions is calculated at around $3000 (refer Table 8) using the National Hospital Cost Data Collection maintained by the Independent Hospital Pricing Authority (IHPA), based on cost weights for AR_DRG version 10.0, Round 23 (2018-19)[20]. Costs are considered to be even higher considering that Indigenous patients have an additional 3% cost loaded into their episodes and a great part of patients screened are of Indigenous background. Moreover, because of their location of residence, a remoteness cost factor applies, which can vary from 24% (remote) to 32% (very remote), thereby increasing even further the costs (and/or cost savings) associated with these patients[21].

Some conditions have very long stays (Average LOS column in Table 8) and most likely the 22 patients with severe conditions would have had to be admitted to a public hospital at the extreme end of the cohort of patients under this condition. Early detection can potentially save thousands of dollars to the health system if a patient can be discharged at the average length of stay or even earlier. Further, early discharge frees up beds for other patients to be admitted, increasing hospital efficiency and hence benefiting the population as a whole.

Finally, if those patients were not seen and their condition not detected, they may go blind, hence imposing a massive cost to their family and the government, which would have to maintain their wellbeing through disability allowances in place for these conditions. This is an immense cost to the government as well as to society as the person becomes unable to contribute through work and/or other forms of societal participation.

[20] Independent Hospital Pricing Authority, National Hospital Cost Data Collection (NHCDC) for the public sector, Round 23 (financial year 2018–19), available online (accessed June 2022): https://www.ihpa.gov.au/what-we-do/nhcdc/public-sector

[21] Independent Hospital Pricing Authority, National Efficient Price Determination 2022–23 – March 2022, available online (accessed June 2022): https://www.ihpa.gov.au/sites/default/files/publications/national_efficient_price_determination_2022-23.pdf

Table 8 – Eye condition hospital stay costs

DRG V10	DRG DESCRIPTION	COST WEIGHT	NO. OF SEPERATIONS	AVERAGE LOS (DAYS)	DIRECT COST	OVERHEAD COST	TOTAL COST	TOTAL COST PER DAY
C01Z	Interventions for Penetrating Eye Injury	1.95	375	2.6	7395	2415	9810	3759
C02A	Enucleations and Orbital Interventions, Major Complexity	3.76	253	6.3	14414	4498	18912	2997
C02B	Enucleations and Orbital Interventions, Minor Complexity	1.52	441	1.5	5766	1877	7643	5095
C03A	Retinal Interventions, Major Complexity	1.11	5,815	1.4	4168	1401	5569	4006
C03B	Retinal Interventions, Minor Complexity	0.33	14,979	1.0	1306	362	1667	1651
C04A	Major Corneal, Scleral and Conjunctival Interventions, Major Complexity	3.16	343	5.5	11685	4196	15881	2872
C04B	Major Corneal, Scleral and Conjunctival Interventions, Minor Complexity	1.50	906	1.3	5790	1733	7523	5743
C05Z	Dacryocystorhinostomy	1.12	809	1.1	4238	1376	5614	5013
C10Z	Strabismus Interventions	1.04	1,795	1.0	3935	1271	5206	5155
C11Z	Eyelid Interventions	0.81	4,633	1.1	3097	979	4077	3576
C12A	Other Corneal, Scleral and Conjunctival Interventions, Major Complexity	1.89	504	4.1	6817	2696	9513	2326
C12B	Other Corneal, Scleral and Conjunctival Interventions, Minor Complexity	0.69	3,127	1.0	2619	848	3468	3367
C13Z	Lacrimal Interventions	0.58	522	1.1	2219	703	2922	2632
C14A	Other Eye Interventions, Major Complexity	1.99	316	5.5	7078	2938	10016	1828
C14B	Other Eye Interventions, Minor Complexity	0.59	1,478	1.3	2216	764	2980	2346
C15A	Glaucoma and Complex Cataract Interventions, Major Complexity	2.56	415	5.1	9517	3370	12887	2522
C15B	Glaucoma and Complex Cataract Interventions, Minor Complexity	0.85	4,969	1.2	3267	1006	4273	3684
C16Z	Lens Interventions	0.60	73,378	1.0	2393	637	3030	3000
C60A	Acute and Major Eye Infections, Major Complexity	2.42	462	7.0	8952	3195	12147	1733
C60B	Acute and Major Eye Infections, Minor Complexity	0.98	1,012	2.9	3690	1258	4948	1694
C61A	Neurological and Vascular Disorders of the Eye, Major Complexity	1.06	1,466	3.0	4055	1297	5352	1761
C61B	Neurological and Vascular Disorders of the Eye, Minor Complexity	0.53	1,778	1.7	2031	646	2677	1566
C62A	Hyphaema and Medically Managed Trauma to the Eye, Major Complexity	0.94	915	3.1	3507	1220	4728	1530
C62B	Hyphaema and Medically Managed Trauma to the Eye, Minor Complexity	0.23	4,990	1.1	889	290	1179	1034
C63A	Other Disorders of the Eye, Major Complexity	1.06	1,850	2.9	3945	1387	5332	1820
C63B	Other Disorders of the Eye, Minor Complexity	0.35	5,765	1.3	1307	441	1747	1304
	Average of eye-related DRGs			**2.6**	**$4,858**	**$,1646**	**$6,504**	**$2,847**

Screening for DR and other eye diseases applicable to this eye screening process has many benefits. It is inexpensive, it can be done without a medical consultant presence, it is quick and therefore it can be done to a large number of patients. Initial calculations (refer Table 9) estimate the cost of screening and diagnostic imaging at around $540/patient. The table includes costs for six retinal cameras that were procured for this project , but excludes initial outlays of cameras that were purchased either before this project or via other sources (for example the Canon desktop cameras deployed at Gidgee Healing and the DRS camera in Weipa). Workforce resource time has been provided as time estimates as opposed to the dollar value of project subcontracts that covered image capture and diagnosis activities. An allowance has been included for an extra 20 minutes per patient for clerical activity not associated with the work already being done by the nurse in charge, even though in most cases in the project this was not necessary.

Table 9 – Cost of Eye Screening

ITEM	DESCRIPTION	COST
Welch Allyn RetinaVue100 handheld portable camera	2 x $9995: 1 unit Laynhapuy Jan '19 1 unit Marthakal Mar'19	$19,990
DRS package including stand and column	2 x $25,300: 1 unit Laynhapuy (relocated to Thursday Island PHC at clinic request) 1 unit Marthakal	$50,600
Canon CR-2AF Colour fundus Cameras including electric table and PC	2 x $29,337: (purchased from CSIRO CAPEX to improve experience for screeners) 1 unit Laynhapuy 1 unit Thursday Island	$58,674
Laptops and peripherals	$2650 Oct'20 $1451 May'19	$4,101
Custom Aluminium Flight Case to Suite CR-2 Retinal Camera	1 unit Laynhapuy	$2,915
AWS cloud platform costs (cloud compute, load balancing and security)	Mar'19-June'22 (40 months @ $291/month average)	$11,638
DRS Camera Servicing and Reconditioning	3 units Badu Is, Bamaga, TI PHC	$5,687
Postage and Freight costs	Camera freight and relocation costs	$5,292
Phonecalls	Additional VoIP/Call charges	$200
Teamviewer licence for remote support	May'19-Jun'22 (38 months @ $58/month average)	$2,206
Image reading and diagnostic	364 exams @ 10mins*/exam = 60hours @$300/hr = $18,000	$18,000
Nursing time (screening + clerical)	378 patients @$50/hr (Registered Nurse rate) * 1 hr/patient = $22,680	$18,900
Other admin /clerical	378 patients @$50/hr (Registered Nurse rate) * 20mins/patient = $7560	$6,300
Total Running Costs		$204,543
Costs per patient	**@ 378 patients**	**$541/patient**

*DR grading time is about 1 to 10 minutes for each patient with DM even by a well-trained reader (grading time varies with DR severity and image quality).[22]

[22] Goh JK, Cheung CY, Sim SS, et al. Retinal Imaging Techniques for Diabetic Retinopathy Screening. J Diabetes Sci Technol. 2016 Feb 1;10(2):282-94.

Note the costs outlined in above table has not been offset by existing incentives applicable through Medicare (MBS items for DR screening 12325 and 12316 introduced in 2016) nor the Queensland Health Incentive funding where the applicable Hospital and Health Service is eligible to receive of payment of $100 for each image that is clinically reported on.

It can be observed from the table that the highest costs were associated with retinal cameras. A recent study[23] into barriers and facilitators to DR screening in Australian primary care reports that although the MBS items are positive developments, the rebates ($50) do not justify the cost of retinal cameras and ongoing expenses including training and time spent on DR screening and their capital cost was a major barrier especially for small or rural GP practices.

It also should be considered that unit costs will decrease as more patients are seen when the program is deployed further. As noted by others, telehealth entails upfront investments in technology, program design, staffing and training[24] – and following this initial investment, operating costs will come down. As a comparison, outpatient costs in Queensland are estimated to range from $325 to $399 depending if there are allied health or medical appointments, while NT outpatient costs are estimated between $305 to $598 (IHPA Round 24 National Hospital Cost Data Collection for the 2019–20 financial year[25]).

Further, if a patient has to travel for these outpatient appointments, an extra cost is incurred for travel subsidy schemes, which are estimated at $1000 for NT patients and $800 for those in the Queensland areas studied. Hence, each patient would potentially cost in the range of $1,125 to $1,598 per appointment. These costs do not include accommodation and other necessary expenses while away from home and also time away from work and/or family.

Finally, the inefficiency of bringing all patients for outpatient appointments and/or sending a travelling medical consultant to see those patients is significant. For a doctor to travel and see patients for screening it is estimated to cost a minimum of $10,000 per week for salary and travel and accommodation/meals. If a doctor can screen and diagnose 30 patients per day it would take around 7 weeks of work, which would also include nursing and clerical time. Clearly inefficient, overly expensive and also, it would take the doctor away from his/her metropolitan position thereby affecting the services in the area.

The calculation of cost savings through not using travel subsidies for screening was presented in Table 5. For the number of patients screened and at the calculated average cost per trip, the screening program would save the health system close to $210,000 per year in unnecessary travel alone.

In summary, the above assessment provides evidence that routine eye examination is feasible and cost-effective for early detection of diabetic retinopathy for rural and remote communities.

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[23] Watson MJG, McCluskey PJ, Grigg JR, Kanagasingam Y, Daire J, Estai M. Barriers and facilitators to diabetic retinopathy screening within Australian primary care. BMC Fam Pract. 2021 Nov 30;22(1):239.

[24] Marks J, Augenstein J, Brown A, A Framework for Evaluating the Return on Investment of Telehealth, Manatt Health Strategies, Sept 2019

[25] Independent Hospital Pricing Authority, e Round 24 National Hospital Cost Data Collection (NHCDC), Non-admitted care tables, vailable online (accessed June 2022); https://www.ihpa.gov.au/sites/default/files/publications/nhcdc_round_24_infographic_financial_year_2019-20.pdf

4 Recommendations for scaling and sustaining the service

This section describes recommendations and issues relating to scaling and sustaining the Remote-I service.

4.1 Scaling the service

During this project, Health Professionals indicated the Remote-I system is useful for detecting eye disease (particularly in diabetics) and there is potential for earlier detection of sight threatening conditions as a result of using Remote-I. High patient satisfaction also indicates there is a readiness to embrace the technology and grow the service beyond ophthalmology and the pilot sites.

At the commencement of the project, two health clinics in East Arnhem (Laynhapuy and Marthakal), and three clinics in the Torres Strait (Thursday Island, Bamaga and Badu Island) were the focus of the team's engagement. Capitalising on where there was additional enthusiasm, investigations into screening at other locations were explored, which included additional outer Torres Strait islands of Saibai and Murray Island, the southern area of the Cape (Weipa, Cooktown, Pormpuraaw, Kowanyama), central Queensland (Rockhampton, Yeppoon and Emerald) and north-west Queensland (Mt Isa, Doomadgee, Normanton and Mornington Island). At each site, there is a requirement to work out referral pathways and workflow components that integrate with existing health service delivery, and Table 3 indicates that clinical teleophthalmology services commenced at most of these additional sites.

Activities conducted within the project can be scaled into a standard service offering at a national level to collect eye disease data from remote and regional areas, and compare planned service use by individual patients to actual service use. Without such information, it is difficult to determine the efficacy of or gaps in eye care service provision and coordination, thereby severely limiting policy formation and response to the local needs of adult Australians.

From an equipment perspective, the system can be readily expanded in response to uptake of the service. Remote-I can easily be scaled by adding new locations on the web interface, and the service can simply be scaled to a multi-site service. Additional workloads are handled by the server efficiently. Remote-I functions are modularised: this enables successful delivery of services to a specific group of users without the need of modifying the entire system. The system can easily be extended to other health care services by adding new modules.

One example of this modularised service is work done throughout 2022 at the request of Queensland Health where at no additional cost, the team incorporated new features in the platform to target other eye health issues, including glaucoma and trauma. This broadens the service beyond diabetic retinopathy and enables metropolitan-level eye care to be delivered to new Hospital and Health Services as well as prisoners within Queensland's correctional system. In June 2022, five new health clinics in central Queensland (two in Rockhampton, two in Yeppoon and one in Emerald) were provided access to this broader platform to enable regional central Queensland patients to receive diagnoses provided via telehealth by specialists at the Royal Brisbane and Women's Hospital. In June 2022, access to this broader eye care platform was also given to the Queensland correctional system with exams from Wolston Park Correction Centre diagnosed by Queensland Health's Metro South PAH Eye Casualty. The software design of this modification was not trivial such that the changes could be pushed to the live system where new users could get access to the additional fields without affecting existing users. Screenings and analysis of outcomes from the prison screenings are not counted towards the quotas required for this project, since the sites are not within the definition of northern Australia maintained by the CRCNA project (north of the Tropic of Capricorn). Nevertheless, this expansion demonstrates an outcome from the project valued by an end user (Queensland Health) which they are very happy about. It also positions the technology as a preferred platform that has undergone extensive cybersecurity system and suitable for additional national telehealth requirements. A screenshot of the broader telehealth platform is presented in Appendix C .

After the capital outlay required for purchasing retinal cameras, the highest costs in relation to maintaining and scaling the service relate to specialist fees for diagnoses. Software engineering requirements for scaling the activity is minimal. Local screeners will require IT support but the system can be readily incorporated into clinical workflows to improve the efficiency of existing services. The high costs will be for grader/specialist time. For this project, NT-based ophthalmologists were reimbursed for their time from project funds whereas Queensland-based ophthalmologists provided diagnoses as part of Visiting Medical Officer contracts. In Queensland, the review of clinical images and provision of advice attracts a state-wide Telehealth Store and Forward incentive payment, provided the medical officer reviewing the image is employed by Queensland Health at least in a VMO capacity. The business model is that a Hospital and Health service can claim the store and forward incentive payment and negotiate VMO contracts as required. It is also noted that most ophthalmologists are busy with their routine clinics, often preferring to focus on treatment and surgery, and for ongoing sustainable service delivery, there is potential to use ophthalmology fellows and registrars to read the images. In 2016, two new Medicare Benefits Schedule items (MBS items 12325 'for Aboriginal and Torres Strait Islander population' and MBS items 12326 'for general population') were introduced. These MBS items support retinal photography and image reporting by general practitioners rather than ophthalmologists or optometrists.

On completion of this project, the platform will be maintained to support the existing user base, and the project partners are in a position to maintain a presence on the ground, increasing patient awareness even if patients are not diabetic. An identified opportunity to keep the screening happening and grow the service may be through relationships with sporting associations, for example, rugby league which has a large following in north Queensland.

Another advantage for long term sustainability is the potential integration with electronic medical record systems used by health providers. At present, Remote-I is hosted as a standalone application on CSIRO-managed Amazon Web Services in AWS's Sydney data centre, and in the long term, it may be an advantage to have this system either integrated or made interoperable with the electronic medical record systems being developed at the state level (which may be several years away) or with PACS systems used for ophthalmic care. If the Remote-I application is hosted within a Hospital and Health Service, or corporate state or territory health department, all patient details could be stored and a patient would be identifiable through their hospital ID, although external access from outside the hospital environment could be challenging. Another approach is to host the Remote-I application within the state or territory health department's managed cloud infrastructure (e.g. Microsoft Cloud infrastructure of Queensland Health). In such scenarios, a patient's hospital bar code (ID) could be used to populate patient details and then images could be attached for that patient. This is presuming the Department / individual health workers prefer that approach for continuity of care, archiving and administrative follow-up (workflow), but is not essential.

4.2 Interoperability

The central component of the Remote-I system is the server, which uses Python server architecture and an industry standard web framework (Django) for building service-oriented applications and creating web services and web service clients. Patient medical records and the data transmitted by the web services is stored within a database based on a PostgreSQL database. The server system provides a mail notification service to screeners and specialists when a new request is received. Both screeners and specialists use a unique web-based application, which is built on HTML5 and JavaScript technologies.

At the specialist side, ophthalmologists can use a desktop computer to login to the Remote-I system in order to read images. Standard broadband connectivity is adequate for ophthalmologists to read images.

From a technology scaling perspective, Remote-I can export HL7 messages when required, which is highly beneficial when transferring patient medical records and outcomes to other hospital patient record management systems.

Remote-I stores data in a structured database which could easily be mapped to SNOMED CT clinical reference terminology to enable future interoperability with other clinical information systems. The system also is capable of interoperating with medical devices to download retinal images with minimal user input. The project team has built a specific Windows based application (Sync-App) which streamlines the process of getting images out from retinal cameras automatically. Feedback from optometrists collected during this project indicated that it would be helpful if Remote-I could upload directly into local GP software and work has commenced within CSIRO to make Remote-I compliant with the personally controlled My Health Record system, an eHealth initiative of the federal government. This allows doctors, hospitals and certain other healthcare providers (such as an optometrist) involved in the individual's care to view their health information. An individual can also access their My Health Record online. This encourages providers to understand the ability of technology to facilitate new ways to bring specialist eye care to the underserved and manage the patients in their familiar local environment.

4.3 Guidelines for program expansion

In any consideration of expansion, it is recommended to follow established guidelines and standards. The development of guidelines and standards for telemedicine is an important and valuable process to help ensure effective and safe delivery of quality healthcare.[26] Some organisations, such as the American Telemedicine Association (ATA), have made the development of standards and guidelines a priority. The practice guidelines developed so far have been well received by the telemedicine community and are being adopted in numerous practices, as well as being used in research to support the practice and growth of telemedicine.[26]

Specifically for tele-ophthalmology programs, the team concur with the findings of the American Telemedicine Association, Ocular Telehealth Special Interest Group[27], particularly around recommendations for personnel. For example, an ophthalmologist with expertise in evaluation and management of DR should assume ultimate responsibility for any program oversight of image interpretation and patient wellbeing. A licensed eye care professional may not be physically available at all times during a telehealth session, but imagers should possess knowledge and skills for independent imaging or with assistance and consultation by telephone, including understanding basic ocular telehealth technology and principles.

A recent study[23] informed by the viewpoints of urban and rural general practices in NSW and WA advocates that for broader implementation of DR screening, the following enabling strategies should be adopted:

- Increase GPs' access to training and Continuing Professional Development on DR grading and detection;
- Launch nationwide awareness campaigns to increase the rollout of DR screening in primary care similar to other successful Australian screening programs (e.g. National bowel cancer screening program);
- Subsidise the cost of retinal cameras, particularly for small or rural general practices;
- Identify a champion ace to ensure the integration and continuity of eye screening service within a clinic e.g., delegating a nurse or health educator to organise appointments/follow-ups and acquire images;
- Uncouple the need to perform both retinal photography and reporting by GPs. e.g., letting GPs grade the images while nurses organise appointments and capture images;
- Establish a diabetes registry to identify eligible individuals for screening, recall system and effective referral pathways; and
- Establish auditing and quality assurance schemes to be integrated into the service.

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[26] Krupinski EA, Bernard J. Standards and Guidelines in Telemedicine and Telehealth. Healthcare. 2014; 2(1):74-93

[27] Li HK1, Horton M, Bursell SE, et al. Telehealth practice recommendations for diabetic retinopathy . Telemed J E Health. 2011 Dec;17(10):814-37

These enablers are consistent with other successful international DR screening models, such as the English NHS Diabetic Eye Screening Programme[28]. This NHS program is delivered and supported by suitably trained, competent, and qualified, clinical and non-clinical staff who participate in recognised ongoing Continuous Professional Development and Quality Assurance schemes, and there is an appropriate referral route for those with screen-positive disease for ophthalmology treatment. The program commenced in 2003 and reached population coverage across the whole of England by 2008, where in 2015-16, 2.6 million people with diabetes were offered screening and 2.1 million were actually screened. The benefit of the program is that in England, diabetic retinopathy/maculopathy is no longer the leading cause of blindness in the working age group.

4.4 Preparing for the future: efficiency improvements

Australia's preparedness for the economic and social consequences of population ageing will be greatly enhanced by forward planning around infrastructure and workforce needs likely to emerge over the coming years.[29] This planning should include telehealth models to improve access to care. This is especially important for diabetic patients: in a study looking at projected health expenditure from 2002-03 to 2032-33, diabetes shows the greatest expected proportional increase in cost to the economy out of all diseases assessed.[29]

One of the major issues the public health system faces to overcome this problem is the increasing wait list for ophthalmology consultations.[2] Waiting lists for ophthalmology consultations continue to increase, specifically referrals without appointments.

Tele-ophthalmology makes better use of valuable medical workforce as doctors are considerably more productive in their use of time to assess and diagnose patients using digitally stored eye-images. It allows medical specialists more time to be used in other functions such as eye-surgery, teaching, training and research. Having medical input only at assessment and diagnosis stage makes the use of medical workforce much more efficient as there is no random contact between patient and doctor, only necessary ones. Health professionals working on this project reported many occasions of patients not showing up, which hampers the efficiency of the medical workforce. The expansion of teleophthalmology services is recommended as a way to reduce waiting lists and control scarce health resource consumption. The model is complementary to several other medical specialties such as dermatology, ENT, speech pathology, etc.

4.5 Reducing the disease burden

In addition to improving service efficiency, a primary business driver for tele-ophthalmology services is reducing the burden of eye disease by regular examination (preventing blindness and impaired vision from retinopathy). Diabetic retinopathy is a major cause of blindness in Australia, and early detection of eye disease by regular examination is vital in attempting to reduce preventable blindness and impaired vision from retinopathy. The ability to perform the daily tasks that most people take for granted can become extremely challenging, if not impossible, by eye diseases, particularly proliferative retinopathy and clinically significant macular oedema[30].

It is now well recognised that advanced diabetic eye disease, may be associated with depression, loss of confidence, anger as well as strains on social and work commitments[31]. A study from the Centre for Eye Research Australia (CERA) has provided valuable insights into patient perspectives on the impact of diabetic

[28] Scanlon PH. The English National Screening Programme for diabetic retinopathy 2003-2016. Acta Diabetol. 2017 Jun;54(6):515-525.

[29] Begg S, Vos T, Goss J, Mann N. An alternative approach to projecting health expenditure in Australia. Aust Health Rev, 2008. 32(1): p. 148-55

[30] Lamoureux E, Hassell J, Keeffe J. The impact of diabetic retinopathy on participation in daily living. Arch Ophthalmol, 2004. 122(1): 84-8.

[31] Fenwick E, et al. Social and emotional impact of diabetic retinopathy: a review. Clin Experiment Ophthalmol, 2012. 40(1): 27-38

eye disease on quality of life. Patient concerns ranged from the frustrations caused by driving restrictions, to wide ranging impacts on social and work lives, emotional states, and financial situations[32].

A joint report from Access Economics and CERA estimated that vision disorders, including diabetic eye disease, comprise nearly 3% of the total disability burden of all diseases. The disability burden of vision disorders was estimated to be greater than that of prostate cancer, melanoma and oral diseases[33]. The report also found that only one in three people with vision disorders in the 40 to 65 year age group were employed – less than half the rate for those in the same age group in the general population. It is clear that the optimal management of diabetic eye disease extends well beyond the eyes.

Eye diseases and vision problems are the most common long-term health conditions reported by Aboriginal and Torres Strait Islander Australians, with over a third of Indigenous Australians self-reporting eye or sight problems.[34] According to the National Eye Health Survey 2016 report[35], 90% of vision impairment or blindness among both Indigenous and non-Indigenous Australians is preventable or treatable. This was calculated by combining the five major conditions responsible for the majority of vision impairment and blindness in Australia (age-related macular degeneration, cataract, diabetic retinopathy, glaucoma and uncorrected refractive error) as a percentage of all vision impairment and blindness. However in 2019–20, only 12% of Indigenous Australians had an eye examination undertaken by an optometrist or ophthalmologist in the preceding 12 months, and the proportion was lowest in Western Australia and the Northern Territory (8%) and was highest in Tasmania (15%).[36]

In order to encourage early detection and treatment of common conditions that cause ill health and early death, all Aboriginal and Torres Strait Islander people are eligible for an annual Indigenous-specific health check, subsidised through Medicare. These checks can be received for free at Aboriginal Medical Services and bulk billing clinics. Agencies such as University of Melbourne Indigenous Eye Health Unit have developed a range of useful resources[37] including flyers and posters to promote patient awareness and eye check cards for GPs and other health professionals which include eye charts to check near and distance vision. The Indigenous-specific health checks were introduced in recognition that Indigenous Australians, as a group, experience some particular health risks and comprise the following MBS Item numbers:

- MBS item 715: provided by general practitioners (GPs)
- MBS item 228: provided by non-vocationally recognised medical practitioners
- MBS item 92004: videoconference (in response to the COVID-19 pandemic) provided by GPs
- MBS item 92011: videoconference provided by non-vocationally recognised medical practitioners
- MBS item 92016 : teleconference (when videoconferencing is not available) provided by GPs
- MBS item 92023: teleconference provided by non-vocationally recognised medical practitioners.

Although all Aboriginal and Torres Strait Islander Australians are eligible for an Indigenous-specific health assessment which includes an eye health check, in 2020–21, just under a third of Indigenous Australians had such a health assessment (including via telehealth).[38]

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[32] Fenwick E, et al. The impact of diabetic retinopathy on quality of life: qualitative findings from an item bank development project. Qual Life Res, 2012. 21(10): 1771-82

[33] The Economic Impact and Cost of Vision Loss in Australia, August 2004, Access Economics: Melbourne

[34] Australian Bureau of Statistics (2013). Australian Aboriginal and Torres Strait Islander health survey: first results, Australia, 2012-13. Canberra: Australian Bureau of Statistics.

[35] Foreman J, Keel S, Xie J, van Wijngaarden P, Crowston J, Taylor H, Dirani M. The National Eye Health Survey 2016: Full report of the first national survey to determine the prevalence and major causes of vision impairment and blindness in Australia prepared by the Centre for Eye Research Australia and Vision 2020 Australia, 2016

[36] Australian Institute of Health and Welfare 2021. Indigenous eye health measures 2021. IHW 261. Canberra: AIHW.

[37] University of Melbourne Indigenous Eye Health, Download Diabetes Eye Care Resources, available online (accessed June 2022): https://mspgh.unimelb.edu.au/centres-institutes/centre-for-health-equity/research-group/ieh/diabetes/downloads

[38] AIHW Australian Institute of Health and Welfare (2021) Tracking progress against the Implementation Plan goals for the Aboriginal and Torres Strait Islander Health Plan 2013–2023, AIHW, Australian Government, last updated 13/12/2021

The Australian Government adopted an Implementation Plan for its National Aboriginal and Torres Strait Islander Health Plan 2013-2023 which outlines the actions to be taken by the government, community-controlled health sector, and other key stakeholders for 20 indicators with a focus on prevention and early intervention across the life course.[39] An update by AIHW in Dec 2021 stated that for these 20 goals, 11 were on track to be met, 6 were not on track to be met and the remaining 3 were not able to be assessed due to the impact of COVID-19. The 6 that were not on track mostly relate to Indigenous-specific health checks.[38] While the existing plan is not due to expire until 2023, a new National Aboriginal and Torres Strait Islander Health Plan 2021–2031 has been released to continue the focus on closing the gap in Indigenous health outcomes.[40]

Specifically in relation to comprehensive DR screening, studies have shown that only 50–77% of non-Indigenous Australians and 20–44% of Indigenous Australians receive appropriate retinal screening.[23] In 2019–20, an estimated 1,213 (1.4 per 1,000 Indigenous population) Indigenous Australians diagnosed with diabetes, were screened for diabetic retinopathy with a retinal camera.[36] This is despite incentives through Medicare to facilitate screening via MBS items 12325 and 12326 to cover retinal photography and image reporting by general practitioners rather than ophthalmologists or optometrists. The gap between the recommended NHMRC retinal examination guidelines and actual DR screening rates relates to several factors, including patients' knowledge of both the condition and the need for retinal screening, doctor-patient's communications, travel, operating costs, infrastructure, and time constraints within general practice.[23] Further commentary on the barriers to DR screening is presented in the next section.

4.6 Barriers to the uptake of the service

Specific to this project, health professionals working at the remote project sites identified that scheduled clinics were cancelled due to COVID-19, the weather, festivals and other local celebrations. There were barriers identified in relation to obtaining high quality images and full eye examination history, suggesting future effort is required in ensuring adequate screening coverage. There were significant challenges in recruiting accredited staff to undertake the screening which was suggested by clinic managers to have been exacerbated by the COVID-19 pandemic. The following section expands on specific issues associated with implementing and running a telehealth service, many of which were faced by the project team and collaboratively addressed through close liaison with health workers and remaining vigilant to the needs of end users.

Barriers to wider uptake and adoption of telemedicine have been assessed by many researchers. A review[41] commissioned by the Australian Government identified the following barriers which were noted to be often inter-related:

- Regulatory
- Innovation Capture
- Supply/value chain
- Health systems
- Pervasive access
- Interoperability
- Usability.

[39] Australian Institute of Health and Welfare 2015. Implementation Plan goals for the Aboriginal and Torres Strait Islander Health Plan 2013–2023: technical companion document 2015. Cat. no. IHW 158. Canberra: AIHW.

[40] Department of Health, National Aboriginal and Torres Strait Islander Health Plan 2021–2031, Publications Number: DT0002195, 2021

[41] Telemedicine in the context of the National Broadband Network, Report by National ICT Australia Limited for Department of Broadband, Communications and the Digital Economy. June 2010. Available online (accessed June 2022): http://ict-industry-reports.com.au/wp-content/uploads/sites/4/2010/10/2010-Telemedicine-and-the-NBN-NICTA-June-2010.pdf

The analysts noted that the most advanced telehealth implementations (e.g. UK National Health, Kaiser Permanente in the US) were the result of government strategy, whole-system payment and either pre-existing or self-deployed network technology. The 2016 introduction of MBS items 12325 'for Aboriginal and Torres Strait Islander population' and MBS items 12326 'for general population') to support retinal photography and image reporting by general practitioners rather than ophthalmologists or optometrists is a reflection of national strategy to alleviate regulatory and financial barriers, and could supplement the state-based incentives or direct payments that were made to specialists within this project to read captured images.

The COVID-19 pandemic caused significant problems to deliver medicine traditionally, but created an environment that limited face-to-face medical encounters and fostered legislation to reimburse the telemedicine modality for the broad and rapid adoption of telehealth.[42] From 2022, MBS telehealth items that had been temporarily been made available to help reduce the risk of community transmission of COVID-19 and provide protection for patients and health care providers transitioned to ongoing permanent arrangements.[43] The permanent arrangements also consolidate previous MBS telehealth items – such as MBS telehealth items introduced in 2011 to encourage uptake of video telehealth in rural and remote areas and specific settings - into a single, national MBS telehealth program. This pandemic-induced change has helped expand the access of care beyond the physical walls of the clinic.

A large number of articles were published in the first year of the COVID-19 pandemic on the rapid implementation efforts of telehealth to enable clinics and hospitals to continue to see patients and care for their needs. A systematic review of these studies found that telehealth increased self-management, patient satisfaction, adherence, access, and social support, and was an effective modality of treatment at a decreased cost. The review concluded that health policymakers should focus on remaining barriers of technical literacy, availability of technology, and connectivity to further increase the adoption of telemedicine.

The project team concur with these findings and note that others[44] have also identified regulatory, financial, cultural, technological, and workforce barriers. An example of cultural barriers is that patients and communities in regional and remote areas often have very limited time and motivation to seek medical help. They are often not aware that they have health problems. Furthermore, seeking help sometimes seen as a personal weakness and is not encouraged by family members.

In a review of barriers for delivering telehealth in rural Australia[45], usability, internet and server connectivity, and privacy were raised as additional key issues for the uptake and adoption of telehealth. Usability means designing interfaces that are intuitive to use and effective (i.e., it takes less time to accomplish a particular task). Ophthalmologists and optometrists involved in this CRCNA project indicated that the output from Remote-I was presented in a useful format; information was clear; the system was user friendly, easy to use, and provided up to date information; they could get the information they needed in time; and the information content met their needs. To improve useability in undertaking patient screening activities, there were numerous refinements to the workflow design (e.g. recruitment, screening, review, follow-up) to ensure a sustainable service is established to continue after project completion. Also during initial screening, various content of the Remote-I pages (collected data fields) were modified and customised to suit the preferences of the ophthalmologists and screeners. In this project, all patient liaison was done through the health workers who have knowledge of what works well in their community. For example, the practice of putting a towel over a patient's head, or asking patients to shut their eyes for

[42] Kruse C, Heinemann K. Facilitators and Barriers to the Adoption of Telemedicine During the First Year of COVID-19: Systematic Review. J Med Internet Res. 2022 Jan 4;24(1):e31752.

[43] Australian Government Department of Health, Medicare Benefits Schedule, MBS Telehealth Services from 1 January 2022, Last updated – 18 February 2022

[44] Nepal S, Li J, Jang-Jaccard J, Alem L. A Framework for Telehealth Program Evaluation Telemedicine and e-Health. April 2014: 393-404

[45] Jang-Jaccard J, Nepal S, Alem L, Li J. Barriers for delivering telehealth in rural australia: a review based on Australian trials and studies. Telemed J E Health. 2014 May;20(5):496-504

extended periods to improve pupil dilation is known to occur in one health provider in East Arnhem but unlikely to be tolerated at all sites.

The review noted that many previous telehealth services fail miserably because users cannot access services owing to an unreliable internet connection or an unstable server. The service needs to be operational 24/7 to avoid frustrated end users. Privacy and the leakage of sensitive medical information through the exploitation of unencrypted data has also been mentioned as an important issue that needs to be addressed to make telehealth more acceptable and widely used.[45] The investment that the team put into the design and testing of the web platform not only ensures patient details are secure but that multiple users can access the system without performance issues and it can be relied upon to not have access issues. Similarly, internet connectivity was found to be adequate and stable within the main health clinic sites which reflects the large investment that the Australian government and telecommunication agencies have made in the last decade. However many of the sites undertake screening in outreach communities which do not have internet coverage and it is common to perform a screening without internet. To cater for this, an offline version of the Remote-I platform was introduced, allowing images that were acquired at a remote community to be uploaded at a later time when adequate connectivity exists. Moving computing infrastructure into the cloud also offers a great cost saving and convenience for deploying telehealth services in rural communities.[45]

Another example of a cultural barrier is that at the start of this project, the team learnt that telehealth faced a mixed reception amongst ophthalmologists regarding its ability to transform the way services are delivered, as face-to-face visits have been traditionally regarded as the ‘gold standard’. However, in some regions, we were informed of the high prevalence of diabetes and that despite twice-yearly optometrists visits to most communities, there are still many people who don't get seen (due to factors such as cray season, celebrations, sorry business, weather, working away) and the health workforce were looking forward to wider telehealth availability. In these regions, the ophthalmologist regards screening via telehealth as vital to help prioritise their caseload and pick up cases requiring urgent attention.

In response, the team have been careful not to tread on toes and identified where telehealth offers clinical value and complement existing workflows. We have reassured all stakeholders that the goal isn’t to replace physicians or healthcare professionals, but give them better decision-making tools. This is aligned with the CRCNA-funded situational analysis of Northern Australia health service delivery[6], which noted [pg. 79] that while telehealth was widely used in some locations and was as an important and evolving service component, there was a need to consider it as a complement to patient-focused local service models rather than a model of care in itself. We have worked out how to complement a specialist’s workload and have demonstrated that telehealth offers clinical value to a point where now at the completion of this project there is a willingness to embrace the Remote-I platform. Telehealth (and the artificial intelligence we are embedding) has been integrated with the human element of the service, rather than replacing it altogether.

5 Lessons learnt

This section documents the lessons learnt in this project along with the changes made by the team in response. While the project activities have focused on eye health and improving access to ophthalmic health services for people residing near the project screening locations, the lessons learnt and insights are applicable to broader health initiatives in remote communities.

The lessons learnt have been grouped into the following areas:

1. Establishing relationships;
2. Developing a sustainable model of service delivery and referral pathways;
3. Implementing new processes;
4. Technical Implementation;
5. Project Management;
6. Cultural Preferences and Approaches.

5.1 Establishing relationships

<u>Learning</u>: Relationships are key to the success of this program and any health initiatives in remote communities.

<u>Response</u>: Face-to-face visits with clinics were incorporated into early project activities which have done wonders for building trust and rapport.

<u>Learning</u>: Who knows who is very important – meet with experts and seek their advice.

<u>Response</u>: The team identified experts and made appointments to meet with these early on in the project. These included optometrists and ophthalmologists who have been providing eye health services to northern remote communities for many years as well as a myriad of other relevant organisations such as Brien Holden Vision Institute, Fred Hollows Innovation team, Vision Eye Institute, The Royal Australian and New Zealand College of Ophthalmologists (RANZCO) and Aboriginal Medical Services Alliance Northern Territory (AMSANT). Advice from these experts helped shaped the project ethics protocols and screening workflow.

In addition, the relationship with health workers is key. They are at the coal-face, the technology has to work, and they have to build the trust and rapport with patients (who were the most important stakeholders in this project). An effective bi-directional telehealth service requires engaged health workers and ophthalmologists embracing the system and being satisfied that it adds clinical value for their practice.

<u>Learning</u>: Obtaining signed agreements with partners and subcontractors is very challenging – be unrelenting in the pursuit of signed agreements.

<u>Response</u>: The team overcame a number of false starts and run arounds – for example while NT Health initially indicated their willingness to participate, they referred the team on to AMSANT. Following submission of a research proforma, the AMSANT research committee who reviewed the research proforma indicated that it would be better for the team to approach individual health services directly about participating. For securing the involvement of the clinics that are participating, the team worked out what the clinics needed and ensured we addressed specific concerns of their executive.

5.2 Developing a sustainable model of service delivery and referral pathways

Learning: Telehealth faces a mixed reception amongst ophthalmologists regarding its ability to transform the way services are delivered. This was mentioned in Section 4.6 as an example of a cultural barrier, where telehealth was described as a third-world solution when compared with the gold standard of a visiting optometrist and ophthalmologist.

Response: The team identified where telehealth offered clinical value and complements existing workflows by integrating with the human element of the service rather than replacing physicians or healthcare professionals. Qualitative studies have found that GPs are enthusiastic about the use of AI and its potential to improve DR detection and save GPs' time without the need for eye experts' opinions.[23] It is acknowledged that in some areas of regional Australia, the role of decision support may complement primary care better than ophthalmic service (a telephone in the hand of a well-trained nurse is currently adequate telehealth).

Learning: Screening is nowhere near as difficult as service provision and there should be no screening undertaken without clear service provision. It is imperative that any activity is symbiotically integrated with existing processes, and that service delivery should come first.

Response: To provide service, the ophthalmologists that agreed to be involved in this project have some involvement with the public health system. Most patients requiring ophthalmic review fall into the public system and ophthalmologists who are outside the public system can play no part in service provision. NT Health have indicated that the Ophthalmology Department at Royal Darwin Hospital can handle urgent referrals from our screening. This is a reassuring outcome as there is already a long wait-list for ophthalmology service in the NT, but if the referral is urgent, the Head of Ophthalmology is happy to handle this quickly and accept the patient. Similarly, Queensland Health have committed to handle any referrals coming from the screening. A Screening Protocol has been developed by the team and the referral process is that as a metropolitan-based specialist reviews the images, if anything is detected that requires follow up, this is relayed back to the site that performed the screening. At this point the patient is referred to their nearest public eye clinic or to a private ophthalmologist if they prefer. The clinic is responsible for initiating the referral, notifying and following up with patients and adding the ophthalmologists report to the patient record within the practice management software.

Learning: Much of the population that is screened believe screening is the treatment, and fail to show for actual treatment (e.g. lasering, anti-VEGF drug injections etc). The referral pathway has been described as a leaky pipe with a blockage at its end such that many people drop out.[46] Successful eye health outcomes involve co-ordination of both eye care services and the patient journey.

Response: The team ensured that the Patient Information Sheet contained information about the process and the fact that future treatment may be required which was requested to be conveyed at the time of examination. Patient information sheets were reviewed by the CSIRO Health and Medical Human Research Ethics Committee and the Far North Qld HREC and modified based on their comments. There were many occasions in this project where showing a patient a picture of their eye during an examination helped with the patient's understanding of an underlying health issue. The team are mindful that really difficult-to-access populations may not continue on to access treatment even if they are diagnosed, but there's at least some evidence to suggest that they do, and health workers continue to consult with specialists in order to

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[46] Taylor HR, Jatkar U, Anjou MD, The Roadmap to Close the Gap for Vision Indigenous Eye Health, Melbourne School of Population and Global Health, The University of Melbourne, Sept 2015, Available online (accessed June 2022): https://mspgh.unimelb.edu.au/__data/assets/pdf_file/0006/1984173/roadmap-summary-september-2015.pdf

maximise the chance that patients detected to have diabetic retinopathy do go on to receive the treatment that they need.

Learning: In diabetes and with choroidal neovascular membranes, when blood vessels leak, they leak blood (red), fat/lipids (yellow) and water/fluid (crystal clear). Although new retinal blood vessels in diabetic patients can be successfully photographed, another threat to sight is the appearance of clear fluid (macula edema). This clear fluid can't be seen on Red/Yellow retinal photography; it can only be seen with a hand held lens using a slit lamp (hence the use of a trained optometrist and ophthalmologist to see this) or Ocular Coherence Topography (not easily transportable) or fluorescein angiography (not readily available).

Response: The devices for our project were selected based on prior use, guidance from the UK's Diabetic Retinopathy eye screening program[47] (who operate the largest DR screening program worldwide, screening > 2million patients/year that stipulates that acceptable methods of systematic screening for diabetic eye disease includes retinal photography) and we also consulted ophthalmologists about the cameras prior to purchase. Most ophthalmologists indicated they didn't have a preference for camera as long as the images were of good quality. Although mobile OCT would offer advantages for outreach teams, purchase of a mobile OCT device was beyond the means of this project (~$100k), but like all technology, the price will come down. However the team have made provision in the web-based software platform to allow clinics to upload any image files, be they retinal photography images, clinical notes, or OCT images if they have such a device (Torres Strait Hospital and Health Service have an OCT device).

Learning: There is debate about the best method for treating diabetic retinopathy. For example, one ophthalmologist has stated that lasering is on the way out and injections of anti-VEGF (Vascular Endothelial Growth Factor) drugs are on the way in as the global standard of ophthalmic and optometric care for all diabetic retinopathy and other retinal and choroidal diseases affecting 60-100 year olds. However other specialists disagree that anti-VEGF drugs are the treatment of the future as it is too challenging to recall patients for periodic injections compared to on-the-spot lasering.

Response: Differences between treatment methods are outside the expertise of the team and beyond the scope of the project. We assume that specialists will select the best treatment option based on the patient. It appears a combination of lasering and anti VEGF-injections could be optimal for delivering long term outcomes, overcoming the challenge with patient attendance that injections-only require.

5.3 Implementing new processes

Learning: Make workflow simple (or simpler than current practices).

Response: This was a primary goal during training and familiarisation sessions held with the specialist ophthalmologists and screening nurses. Once the screening workforce and ophthalmologists using the telehealth platform get accustomed to this change they never want to return to the previous methods. This also ensures that equipment that may have been provided with the best intentions gets used and doesn't become a doorstop.

Learning: Identify shortcomings of competing products and ensure technology that is offered is superior.

Response: In this project we learnt the views held by one of the ophthalmologists that a competing cloud-based system offered by Welch Allyn was slow, had poor resolution, and did not readily capture the fields

[47] Public Health England Guidance Document. Diabetic eye screening: guidance on camera approval. April 2022, available online (accessed June 2022): https://www.gov.uk/government/publications/diabetic-eye-screening-approved-cameras-and-settings/diabetic-eye-screening-guidance-on-camera-approval

necessary for making an accurate clinical diagnosis (diabetic history and visual acuity). We made sure the Remote-I platform addressed all the limitations raised about this alternative system. We received feedback from one of the participating ophthalmologists about the Remote-I system:

> *"Your site is better than retinavue in that it is:*
> *- More responsive (in loading/changing fields) and easier to use*
> *- More specifically diabetes (other pathologies can be noted in comments)*
> *Advantages of retinavue:*
> *- Offers a "chromic" (red free) view of the image also*
> *- Has a "minimal" DR (ie microaneurysms only) category*
> *Overall, I would expect that your site proves better."*

We have since added a minimal DR category and the chromic feature to the system.

Learning: The team consulted with other researchers who were implementing web-based eye screening in central Australia who made the observation that there is not a huge appetite for eye screening in primary care, where they have found that GPs aren't overly interested as the screening doesn't treat the condition. However machine learning, particularly around detecting very early symptoms (ie. minimal or mild diabetic retinopathy) would be incredibly valuable in determining a referral/treatable pathway, and having a system do a first pass at finding lesions would assist GPs to do grading.

Response: The team have developed an AI-based decision support for the Remote-I platform, comprising a module that performs quality assessment of the captured image (Good vs Bad) and a Diabetic Retinopathy deep learning module which detects adverse pathology (Healthy vs Disease). The performance of these AI-based components on images collected in this project is presented in Section 6.

In terms of understanding barriers better, the staff and health clinics have been clear they want improved access to eye health for their patients. They can't advise on nuances relating to camera preferences without first trying and attempting to see what works. For example, we first procured portable hand-held cameras for the clinics, based on the preference by the clinic for portability, as screening numbers might be reduced with less mobile equipment which may lead to those most at need of screening not accessing services. A handheld camera was thought to be probably best if a small number of staff perform photography, and the camera could go to multiple centres / offer more accessible screening to patients. However after trying this, health clinics reported that it was tricky to get the camera positioned properly and they were getting blurry images and we then went down the path of providing desktop cameras. This is just one example which is only identifiable by delivering a practical service.

The project has provided a solution in direct response to the lesson learnt here: that machine learning, particularly around detecting very early symptoms (ie. minimal or mild diabetic retinopathy) would be incredibly valuable in determining a referral/treatable pathway, and having a system do a first pass at finding lesions would assist GPs to do grading.

Learning: Change is hard so embrace enthusiasm where it exists.

Response: The clinics differ based on organisational culture, attitudes of health workers, experience of health workers, differences in bedside manner and the ability to earn trust and rapport with patients, management support and prioritisation, available time, and technology literacy. At several clinics there was a genuine willingness to screen patients' eyes which shouldn't be hampered by technology. The team provided extensive troubleshooting assistance in such situations and endeavoured to provide these go-getting personnel with equipment that enables them to provide this service.

Learning: It is very challenging to acquire a good quality retinal image. Handheld cameras (which offer the advantage of being portable) have turned out to be too finicky, and even trained optometrists could not get a picture without dilating the patient's pupils and thought that it was impossible to acquire images from both eyes as the other eye would react as reflex from the flash. One clinic reported that the Canon desktop camera requires too much dexterity, requiring delicate and precise hand movements.

A related issue is the problem of pupils not dilating enough in darkened rooms. One vendor was advocating that 5 minutes in a darkened room was all that is needed for a 90% success rate. However this was found to be too short and ~15 minutes at least is needed. Another vendor suggested to get the patient to close their eyes for a while first (as well as being in a darkened room), then do the Right eye first, then close for at least a minute then do the Left eye. This was trialled but it was found that a patient needed to open their eyes again before taking the picture which takes at least 10 seconds if not longer, by which time the pupils have readjusted. A towel over the camera and over the patient's head was also tried in one clinic. Other clinics advised they don't like putting a cloth/bag etc. over a patient's head and instead used a black-out curtain which would be hung at the window wherever screening takes place which was found to help. Other suggestions were a cloth over the front (screen) of the camera and to make sure no laptops etc. were lit up as every bit of dark helps.

It is possible to dilate a patient's pupils via use of mydriatics (eye drops). However eye drops are contraindicated in patients that have narrow angle glaucoma (high pressure in the eye) as they can further increase the pressure in the eye. One option before dilating pupils is to first measure the intra ocular pressure using a tonometer; however that in itself is tricky and requires training.

Response: Training has been provided for all provided equipment. Notwithstanding, in order to address challenges of handheld cameras, new desktop retinal cameras were procured and delivered to sites and staff trained in their use. After receiving concerns about the tricky operation of the Canon desktop camera, the team procured an alternative DRS camera that is fully automatic. It seems there are some organisations where the DRS camera is effective and works and some where it is not a success and does not take good enough pictures. For another clinic that could not acquire an image with the fully automatic DRS camera, we sought advice from screening personnel at other sites who shared their experiences and allowed the health worker to have a go at using an alternative Canon camera. Due to the risks for glaucoma patients, the screening protocol for the project doesn't insist on use of dilation drops, which shouldn't be given by non-optometrically trained staff.

The DRS camera system used in the project is highly automated when scanning both eyes. However proper operation of the camera, patient cooperation during the imaging, and the condition of the equipment (keeping the lens clean) are important for obtaining images with good quality. The team have educated screeners to show them which images are good and which ones are bad in relation to image quality. Algorithms to automatically check image quality were developed in this project and their performance is presented in Section 6. High image quality is crucial for correct diabetic retinopathy grading, especially for evaluating algorithms for automated DR grading. Although the quality of captured images improved over the course of the project, numerous captured images were assessed as unable to be graded due to insufficient quality or insufficient retinal coverage which was conveyed back to the clinics.

Learning: Eye screening in regional communities is more effective if run as part of, and alongside, other services. If run in isolation it is more difficult to attract patients and convey the potential health benefits of screening.

Response: The team promoted that eye screening could be included in the Indigenous-specific health check (MBS item 715 and associated tests), Men's Health check, Diabetes checks, Home and Community Care (HACC) services etc. This allows many opportunities for screening throughout the year and raises awareness of lifestyle impacts on eye health. People are more likely to come to a fixed date drop in clinic and it reduces pressure on health workers.

Clinics have also stated that it would be great to have the resourcing for opportunistic care when a patient appears, and better staff resourcing could also help strengthen the link between optometric outreach visits with the eye team.

Learning: Ongoing technical support is essential. When there are IT problems or equipment issues, eye screening often gets placed in the "too hard" basket. Consequently there is a clear need to provide technical support for regional communities.

Response: The way that technical support was to be provided to system users was planned from the start of this project. Where possible, we enabled remote access of computers to provide support where support personnel can remotely take over a user's mouse.

Technical stakeholders have been clearly identified and clear communication pathways established (eg: with camera manufacturers, laptop vendors, additional software vendors, screening equipment and device distributors).

When the system does not behave as it should, users may get irritated, be reluctant to use the system, and there is a risk of losing the user. In any project involving a new process or workflow, user relationships are key, and where possible the team have tried to specify in advance if there is any likelihood the system could operate not as planned.

Learning: The team also learnt that video conferencing is not necessary for tele-ophthalmology, particularly diabetic retinopathy screening.

Response: In this project, store-and-forward capability was found to work well, as consultations did not require specialists and patients to be available simultaneously, and consequently, the need for coordinating schedules was removed, and the efficiency of the health care services increased.

5.4 Technical Implementation

Learning: It is essential to ensure that any cloud-based system is aligned with a client's IT and cybersecurity policy policies. A mapped network drive may disappear if the local system is updated to a new policy, restricting user access to images. This requires close relationships with a client's IT department at the planning level of the project. Even though system testing may have been comprehensively undertaken in-house, the security of health systems often needs to be independently verified and sufficient project schedule time should be allowed to factor this in.

Response: Exhaustive cybersecurity testing was undertaken on the Remote-I server, including Vulnerability Assessment and Penetration Testing, to ensure the security of the system was watertight and patient privacy could not be compromised. Privacy Impact Assessments were undertaken to ensure privacy legislation was not breached (for example, no information was sent to an offshore server). This applies for all sites. In addition to this testing, the security of the system was also independently tested and accepted by Queensland Health's cyber security committee. By allowing images to be uploaded via a web-based platform, the project enabled users to directly upload images from the camera computer connected to the internet increasing the flexibility of operations and eliminating the need for complicated Virtual Private Network (VPN) connections.

Learning: Most of the sites undertake screening in outreach communities which do not have internet coverage and it is common to perform a screening without internet.

Response: An offline version of the Remote-I platform was introduced, allowing images that were acquired at a remote community to be uploaded at a later time when adequate connectivity exists. At all locations, the retinal cameras are set up to work independently. This is an advantage, as otherwise, if the connection from the camera is lost, then users cannot access the images of the patients and will require to call IT support.

Learning: The system access needs to encompass all modalities of the system usage. At present, the Remote-I system is mainly supported under Windows, but as many specialists prefer Mac books, additional web pages needed to be added in the system to accommodate Mac users.

Response: We have ensured the software is platform and browser independent and have tested this on Windows and Macbooks with a range of browsers. The software works best with Google Chrome though Firefox or Microsoft Edge is OK (not Internet Explorer).

Learning: The project involves a range of cameras and the platform needs to be camera-agnostic.

Response: In this project the platform was successfully used to support Canon CR2, Welch Allyn RetinaVue Pro and DRS cameras. The team ensured interoperability between different camera types and additionally on uploading a file, there is the ability to perform real time quality detection to see if images are ungradable and protocol detection. Images are uploaded to the auto grading server for quality assessment. It takes a few seconds to do the quality check and approximately another minute to do the auto-grading.

Learning: The costing model for using managed cloud services is an ongoing operation (Amazon Web Services have charged approx $300 per month).

Response: The team have a better understanding of cloud-based infrastructure costs. Full secure monitoring of a cloud environment requires an enterprise-level managed cloud infrastructure program and this is a consideration for any governing health jurisdiction moving forward. The project team is continually working with the CSIRO Information, Management & Technology team in monitoring of such costs and improving cloud-based efficiency.

Learning: In the early stages of any software deployment, it is preferable to talk to end users in person or via phone instead of emails.

Response: Though email communications serve a purpose and form a trail of recorded conversations, the team noticed that we get quicker and personal response over the phone especially when interacting with remote clinics.

Learning: Remote computer access works well for configuration of software deployment.

Response: During the initial setup of the system, it was very crucial to have remote access to a client's computer. During our visits at the remote sites, due to limited allocated time, we were able to install the software application and train the users. Since then, retinal camera hardware and staff members have changed. We used TeamViewer remote control software which allowed us to remotely login to the remote user's computer and provide support and set up the system.

Learning: The DICOM (Digital Imaging and Communications in Medicine) file format is still widely supported by most of the camera manufacturers.

Response: The Remote-I Sync App associated with the telehealth platform now supports reading DICOM files and the team continue to monitor the medical imaging space and work with hospital systems regarding standard image storage solutions.

Learning: During the initial engagement with clinical end users, video demonstration of the proposed system is ideal.

Response: A YouTube video of the system usage with timed video description was created and distributed which helped a lot in communicating the intention of the project and workflow.

5.5 Project Management

Learning: Have project milestones that are not linked to quotas. In this project, project milestones (and hence billing milestones) were linked to the numbers of patients screened using the telehealth platform. The numbers of patients screened were affected by delays (most acutely the COVID-19 pandemic), and the team was unable to claim completion of the milestones despite significant project work and effort expended.

Response: Future projects should be setup to focus on value rather than volume and define a minimum equitable viable service for demonstrating the value of investment. This point was mentioned in Section 3.1 (page 13 of this report) in relation to recommendations flowing from the CRCNA-funded situational analysis of northern Australia health service delivery.[6]

The most important stakeholder in this project was the patient, and from their perspective, the number of patients screened is irrelevant. Hence we sought to identify case studies (refer to Section 3.1) that additionally focus on value rather than volume (high quality care rather than activity throughput) which is particularly relevant in small rural and remote communities.

Learning: Have a flexible approach to time. While a project may have an overarching schedule it runs to, this is not necessarily shared.

Response: At commencement, the team allowed for some float within the project schedule. However efforts to adhere to a schedule and the concept of delivering a project on time were misconstrued by one project stakeholder as undue pressure. While feedback from an Indigenous liaison personnel suggested that such a flexible attitude is a copout and excuse for being lazy, the preferred approach is to sell the benefits and adopt a shared desire to deliver the project.

Learning: All possible users of the system should be identified. If the system makes this data available then there is a reduced need for implementing additional interfaces.

Response: Along with the targeted end users of the system (screeners and graders/ophthalmologists), project administrators and coordinators have been considered users of the system as there was a need to obtain statistics and data related to management of the service.

Learning: Screening programs like this one should plan for workforce attrition and retraining staff and factor in leave periods where staff will be on leave and screening won't be undertaken.

Response: The team accept this workforce factor associated with remote health care delivery. The team developed a set of offline training materials (user guides, workflow documents and YouTube videos) to assist with remote training of new staff.

5.6 Cultural Preferences and Approaches

Learning: The value of having an Indigenous health worker speaking the local dialect with patients cannot be overstated. It immediately builds rapport, trust and acceptance by the patient to participate in what can be an uncomfortable process to acquire a good retinal image

Response: We recommend all clinics adopt this if possible after observing the benefits of this approach. There is substantial evidence that the cultural preferences and approaches to health and wellbeing among Aboriginal peoples and Torres Strait Islanders in many instances are not being reflected in dominant, biomedical models of health care.[6]

Learning: Make the patient information sheet culturally appropriate. Feedback from ethics committees recommended that the information sheet given to patients about the screening shouldn't require them to sign it and also shouldn't be too complex.

Response: The team ensure material provided to patients could be easily understood and stripped out unnecessary jargon.

Learning: When consulting with ophthalmologists it was learnt that in some regional areas (Central Australia) a large barrier to eye health wasn't access to services, but uptake of services related to cultural issues, staff turnover, and attendance fatigue. Trust and cultural issues are ever present challenges with some patients denying they have eye problems only overcome by establishing long term relationships and trust.

Response: From the outset of this project the team attempted to demonstrate trust and have an awareness that in some places, people are sick and tired of being a captive survey population, and that they lose faith in the service provider when they turn up, something is done to them, and then nothing happens. The project was shaped by first approaching The Fred Hollows Foundation and ophthalmologists that have worked for many years delivering services in these communities. The team also shared material with the screening clinics that could be used for media advertisements to raise awareness in communities regarding the importance of getting eyes tested.

In summary, these learnings are an important part of identifying factors around successful implementation of telehealth service delivery in remote communities in northern Australia. The insights are applicable to similar health initiatives that may be undertaken in remote communities in the future.

6 Automated Diagnosis Performance Assessment

6.1 Automated Diagnosis for improved image capture and clinical decision support

The Remote-I telehealth platform incorporates artificial intelligence for the purposes of improving the quality of captured images and detecting disease to provide clinical decision support to a health service. The AI-based decision support comprises a module that performs quality assessment of the captured image (Good vs Bad) and a Diabetic Retinopathy deep learning module which detects adverse pathology (Healthy vs Disease). This section of the report evaluates the performance of these AI-based components on images collected in this project. Note the algorithm was developed on a different image database and here we are not fine-tuning algorithm performance based on these new images but reporting performance of the algorithms applied to this new image dataset.

The image quality assessment algorithm can process one image within 2 seconds and give immediate feedback on its quality (GOOD vs BAD) for diagnostic purposes. This function can benefit the camera operator to get instant feedback of the image quality and decide whether an image rescan is needed. This not only reduces screener workload and patient inconvenience associated with rescreening at a later date, but ensures that specialist graders have access to the best quality images, to reduce the chance of missing important image features.

The Diabetic Retinopathy detection module[48] was deployed in two separate sub-modules. The first module is based on a deep learning-based AI algorithm which categorises the non-DR and Mild NPDR cases as 'Healthy' and Moderate and Severe NPDR and Proliferative DR as 'Disease'. This sub-module performs its operation within 2 seconds. The second sub-module is based on a rule-based approach which goes through the whole retinal image pixel by pixel and using advanced machine learning techniques, determines the severity of the image (eg. Moderate/Severe DR).

In this project, ophthalmologists were tasked with grading each and every image uploaded by a health clinic and their diagnoses form the 'gold' standard' against which the automated algorithms were assessed. Eight different specialists were involved in grading images over the period October 2019 – June 2022. Therefore a limitation of this exercise is variation introduced by different grading specialists and also consistency over time by the same specialist. In this analysis, we did not assess inter-rater and intra-rater reliability to assess how well the specialist agree amongst each other about the same image or the consistency of their diagnoses via repeated reading of the same image. Instead the specialist's diagnosis was accepted as the 'gold standard' or official rating of a given image.

The use of artificial intelligence in diagnostic medical imaging has shown impressive accuracy and sensitivity in the identification of imaging abnormalities.[49] There is a plethora of studies[50,51,52,53] using retinal images

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[48] Kanagasingam Y, Xiao D, Vignarajan J, Preetham A, Tay-Kearney ML, Mehrotra A. Evaluation of Artificial Intelligence-Based Grading of Diabetic Retinopathy in Primary Care. JAMA Netw Open. 2018 Sep 7;1(5):e182665.

[49] Oren O, Gersh BJ, Bhatt DL. Artificial intelligence in medical imaging: switching from radiographic pathological data to clinically meaningful endpoints. Lancet Digit Health. 2020 Sep;2(9):e486-e488.

[50] Grzybowski A, Brona P, Lim G, Artificial intelligence for diabetic retinopathy screening: a review. Eye (Lond). 2020 Mar;34(3):451-460.

[51] Padhy SK, Takkar B, Chawla R, Artificial intelligence in diabetic retinopathy: A natural step to the future. Indian J Ophthalmol. 2019 Jul;67(7):1004-1009.

[52] Wang YL, Yang JY, Yang JY, Progress of artificial intelligence in diabetic retinopathy screening. Diabetes Metab Res Rev. 2021 Jul;37(5):e3414.

[53] Gulshan V, Peng L, Coram M, Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs. JAMA. 2016 Dec 13;316(22):2402-2410.

to test the performance of AI grading systems for detecting DR and even a Kaggle machine-learning competition[54]. Automated DR detection algorithms have several advantages over human-based screening: they do not get tired and can grade thousands of images a day; they are often able to provide results very quickly; and scaling automated DR screening is largely just a matter of acquiring more hardware.[50] In some reports, performance of AI systems has been noted to be either on par or better than ophthalmologists and to have exceeded that of clinicians with less experience.[55] Also it has been noted that an adequate balance between high sensitivity and specificity is key to establishing cost effective screening programs.[50] With lower sensitivity, more cases of DR are missed, which goes against the main aim of a DR screening programme—the early detection of DR. With lower specificity, a relatively large number of false positives that warrant further examination are returned, which wastes the resources that automated DR screening is trying to spare.

In this section of the report, the performance of the AI algorithms against images collected within this CRCNA project is assessed. Grading analysis is first presented at an 'eye' level then at a 'patient' level. The 'gold-standard' is the grading assessment given by the specialist.

As of 30/6/22, 1039 raw records had been uploaded to Remote-I. Test records that had been made by sites were removed along with records uploaded from West Moreton Wolston Prison Health which demonstrate impact and broader applicability of the project output but the sites are not located within northern Australia and hence outside the project scope (refer Appendix C for further details).

Within the Remote-I platform, Image Laterality is a database field to specify if images are suitable for further image processing routines. If they are, then they are allocated Left / Right values which then get passed on to automated processing algorithms. 'NA' values were added when the image laterality could not be obtained by visual inspection (e.g. Anterior Eye Photos, Retinal Photo Report from an OCT device). Following removal of these records, 751 records were retained (375 Left eye records and 376 Right eye records). The diagnoses assigned by specialists to these records are tabled below. Note the counts relate to the images assessed by the specialists as opposed to the counts of patients with DR reported earlier in Section 3.3 that have been picked up via this project.

Table 10 - Ophthalmologist grading outcome data for 'Left' eyes

	NO DR	NORMAL	NA	MILD NPDR	MODERATE NPDR	SEVERE NPDR	PDR	UNABLE TO GRADE	DR DIAGNOSIS	NO DR	TOTAL	INCIDENCE	QUALITY
Badu Is	2	0	0	0	0	0	0	0	0	2	2	0%	100%
Bamaga	0	0	0	2	0	0	0	0	2	0	2	100%	100%
Gidgee	21	0	0	7	5	2	1	0	15	21	36	42%	100%
Injinoo	11	0	0	2	0	0	0	1	2	11	14	14%	93%
Laynhapuy	92	2	1	4	3	3	0	30	10	95	135	7%	78%
Marthakal	2	7	0	7	0	0	0	2	7	9	18	39%	89%
Murray Is	1	0	0	0	0	0	0	0	0	1	1	0%	100%
Saibai Is	2	0	0	0	0	0	0	1	0	2	3	0%	67%
Thurs Is	111	0	0	16	3	0	1	8	20	111	139	14%	94%
Weipa	24	0	0	0	0	0	0	1	0	24	25	0%	96%
TOTAL								**43**	**56**	**276**	**375**		

[54] Kaggle Diabetic Retinopathy Detection competition. https://www.kaggle.com/c/diabetic-retinopathy-detection (accessed June 2022).

[55] Long E, Lin H, Liu Z, et al. An artificial intelligence platform for the multihospital collaborative management of congenital cataracts. Nature biomedical engineering. 2017 Jan 30;1(2):1-8.

Table 11 - Ophthalmologist grading outcome data for 'Right' eyes

	NO DR	NORMAL	NA	MILD NPDR	MODERATE NPDR	SEVERE NPDR	PDR	UNABLE TO GRADE	DR DIAGNOSIS	NO DR	TOTAL	INCIDENCE	QUALITY
Badu Is	2	0	0	0	0	0	0	0	0	2	2	0%	100%
Bamaga	0	0	0	2	0	0	0	0	2	0	2	100%	100%
Gidgee	20	0	0	7	5	0	0	0	12	20	32	38%	100%
Injinoo	11	0	0	2	0	0	0	0	2	11	13	15%	100%
Laynhapuy	90	3	1	8	4	0	0	37	12	94	143	8%	74%
Marthakal	1	2	2	6	0	0	0	5	6	5	16	38%	69%
Murray Is	1	0	0	0	0	0	0	0	0	1	1	0%	100%
Saibai Is	3	0	0	0	0	0	0	0	0	3	3	0%	100%
Thurs Is	114	0	0	15	4	0	1	6	20	114	140	14%	96%
Weipa	24	0	0	0	0	0	0	0	0	24	24	0%	100%
TOTAL								**48**	**54**	**274**	**376**		

As with the patient-level prevalence data shown in Table 6, the 2nd last column of the above tables headed 'Incidence' reflects how many DR cases were picked up as a proportion of total exams. We observe Bamaga, Gidgee sites, and Marthakal had relatively high numbers of DR cases as a proportion of exams undertaken.

The last column headed 'Quality' reflects how well the images were captured at each site, and measures the percentage of gradable images. This measure was based on the reviewing specialist's point of view (which is different to Image Quality Assessment by AI discussed below). While quality was generally pretty good, ungradable images affect the success of the program in detecting early signs of diabetic retinopathy.

Of note, Thursday Island only had 8 Left Eye images 6 Right Eye images which couldn't be graded by an ophthalmologist, which reflects the presence of a dedicated eye nurse with prior experience in eye health. Laynhapuy had 30 Left Eye images and 37 Right Eye images which couldn't be graded; Marthakal had 2 Left Eye and 5 Right Eye images which couldn't be graded, suggesting that further training may be required in capturing high quality images at these sites.

In the performance tables that follow, we report:

- overall accuracy
- the number of true positives "hits" (T_p)
- the number of false positives "misses" (F_p)
- the number of true negatives "correct rejections" (T_n)
- the number of false negatives "false alarms" (F_n).
- sensitivity and specificity defined as:

$$Sensitivity = \frac{T_p}{T_p + F_n}$$

$$Specificity = \frac{T_n}{T_n + F_p}$$

6.2 Image Quality Alert Algorithm Performance

This section assesses the ability of the image quality alert algorithm to correctly identify images that the ophthalmologist (the gold standard) identified as 'Unable to be graded'. Prediction performance is tabled below.

Table 12 – Performance of Image Quality Alert Algorithm on raw eye images

	LEFT EYE	RIGHT EYE	BOTH EYES
Total Eyes	375	376	751
overall correct	272	270	542
overall wrong	103	106	209
% correct	**73%**	**72%**	**72%**
Total images assessed by ophthalmologist as *unable* to be graded	43	48	91
True Positives (Hits)	40	43	83
False Negatives (Misses)	3	5	8
Sensitivity	**93%**	**90%**	**91%**
Total images assessed by ophthalmologist as *able* to be graded	332	328	660
True Negatives (Correct rejections)	232	227	459
False positives (false alarms)	100	101	201
Specificity	**70%**	**69%**	**70%**

At an individual image level, the image quality detection algorithm was correct 72% of the time. The algorithm was reasonable at detecting images that the ophthalmologists deemed unable to be graded (high sensitivity: 91%). However it raised a high number of false alarms where the images were actually able to be graded (low specificity: 70%).

Many of the uploaded images are not macular centred images. Some images were optic disc-centred images, and some images were not aligned correctly due to patient positioning. Some images were completely missing the optic disc area but the macular area was still visible. These images were gradable by the ophthalmologists, however, the automated quality assessment may have detected them as bad quality ones due to the positioning of the optic disc.

Some examples of images that were correctly detected as Unsatisfactory-Image-Quality are presented in Figure 6.

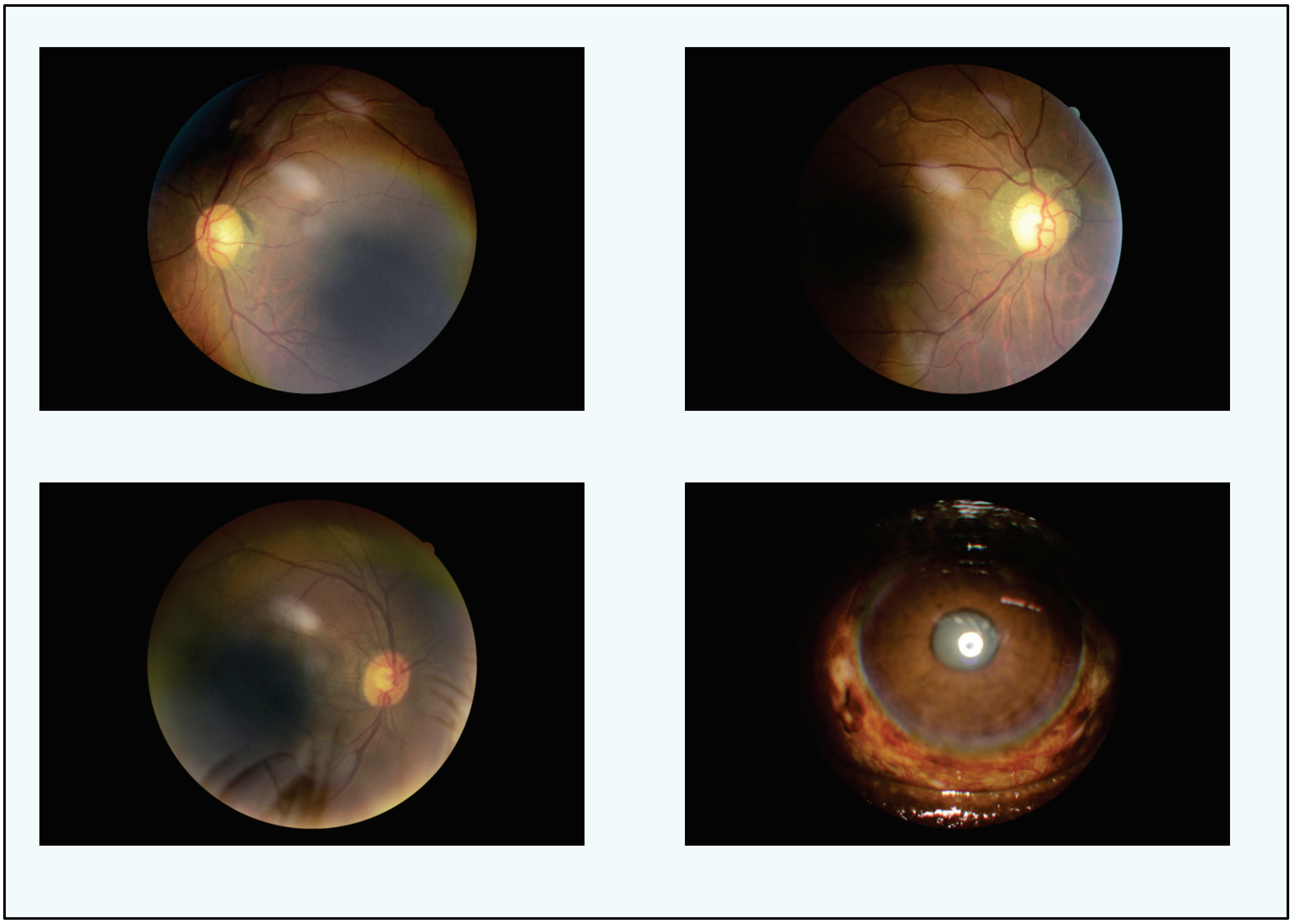


Figure 6 - Examples of images correctly detected as Unsatisfactory-Image-Quality by the Image Quality Alert algorithm

6.3 DR Detection Algorithm Performance

The output of the deep learning algorithm is a binary classification of 'Disease' or 'Healthy'. There is a subsequent rule-based assessment that can be used for classifying the severity (mild, moderate, severe etc.) of images but here we assess the performance in detecting the binary outcome of DR disease. The automatic grading is only performed on images that are assessed as satisfactory quality. Thus the performance tabled below exclude cases where the ophthalmologist still graded the eye but the auto-grading system rated images as unsatisfactory quality and therefore an automated diagnosis was not provided.

Note that results are initially presented here on the basis that Mild NPDR cases are considered 'Disease'. This is aligned with the inclusion of mild NPDR cases in the prevalence tables presented earlier in this report. We repeat this analysis in Section 6.6 considering an alternative definition where "Mild NPDR" cases are considered 'Healthy' to quantify any differences in predictive performance.

DR detection performance at the individual eye level is tabled below.

Table 13- Disease Detection Analysis - (where "Mild NPDR" cases are considered 'Disease')

	LEFT EYE	RIGHT EYE	BOTH EYES
Total Eyes	232	227	459
overall correct	200	190	390
overall wrong	32	37	69
% correct	**86%**	**84%**	**85%**
True Positives (Hits)	25	21	46
False Negatives (Misses)	12 (all Mild DR)	18 (17 mild DR, 1 moderate)	30 (29 mild DR, 1 moderate)
Total eyes diagnosed with DR	37	39	76
Sensitivity	**68%**	**54%**	**61%**
True Negatives (Correct rejections)	175	169	344
False positives (false alarms)	20 (all auto-diagnosed as moderate DR)	19 (all auto-diagnosed as moderate DR)	39 (All auto-diagnosed as moderate DR)
Total eyes diagnosed with no DR	195	188	383
Specificity	**90%**	**90%**	**90%**

The overall accuracy for detecting DR is 85% at the level of individual image grading. The specificity for detecting DR (the ability to correct identify healthy images with no disease and simultaneously minimise false alarms) is higher than the sensitivity (the ability to correct identify images with disease and minimise missed cases). The algorithm missed 30 images depicting diabetic retinopathy (according to the 'gold standard' grading by ophthalmologists) which were all mild DR, except 1 moderate case. The algorithm also raised false alarms for 39 images, which were all automatically diagnosed to have moderate DR.

For detecting DR, it can be argued that higher sensitivity is more important than specificity as it's important to not miss patients whereas false alarms will just cause inconvenience. Consequently there is scope to fine-tune and further develop these algorithms to ensure predictive performance – particularly sensitivity - is as high as possible. Examples of images that were correctly graded by the DR detection algorithm are presented in Figure 7.

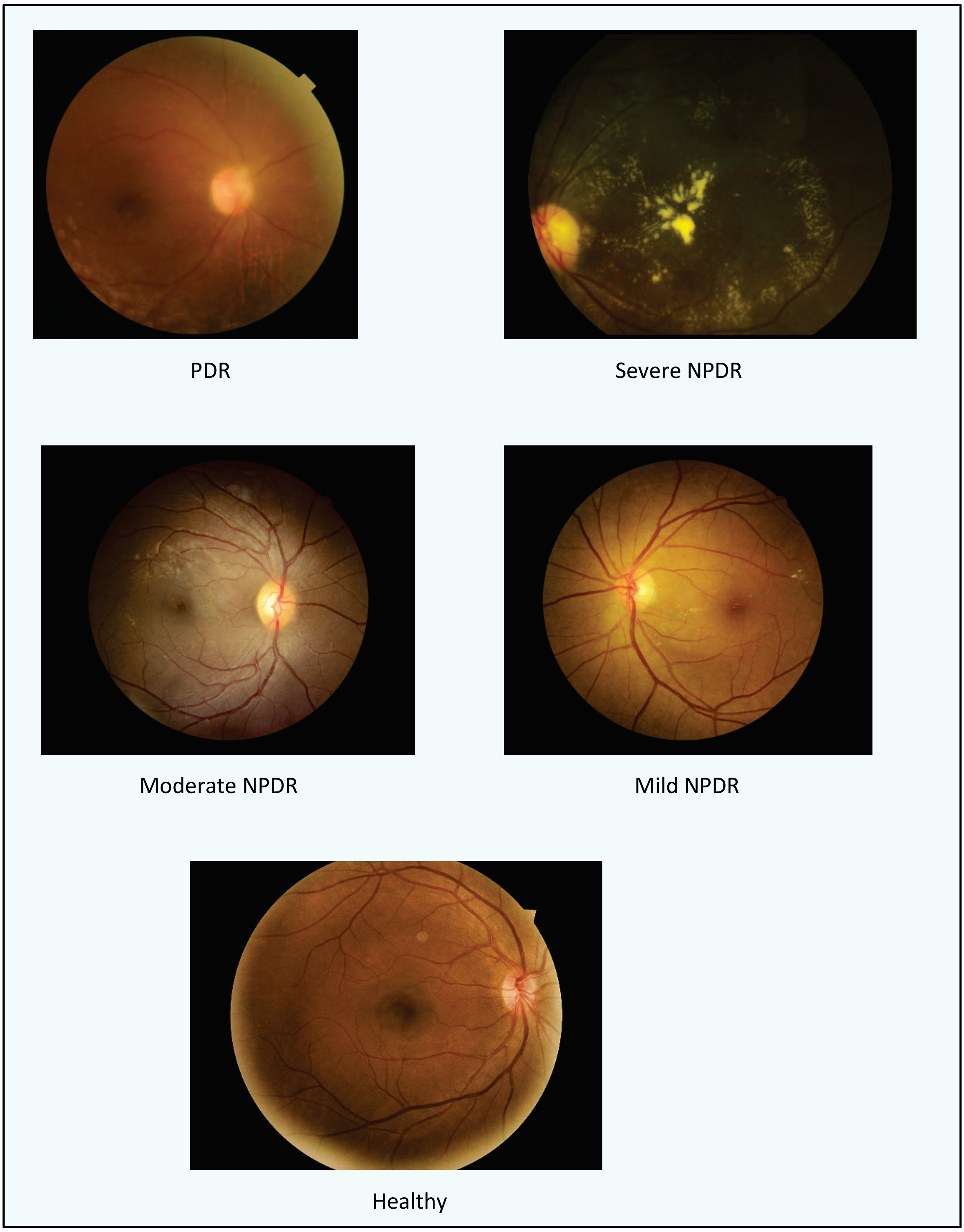


Figure 7 - Examples of images correctly graded by the DR detection algorithm

6.4 Patient-level grading analysis

The 751 Left and Right eye records were combined and records were collapsed to a patient-level by ignoring similar records from the same patient with identical diagnoses. Multiple visits by the same patient were collapsed to a single record, preserving the most severe pathology. This left 328 unique patient visits that had laterality, quality and DR diagnosis fields completed. Note this number of cases doesn't match the prevalence data presented earlier in this report (Table 6 which depicted 364 unique patients) as the automated grading requires these fields to be filled in. Of the 328 unique patients, the auto-grading system rated images as unsatisfactory quality for 74 patients and therefore an automated diagnosis was not provided for those 74 patients. This left 254 unique patients for patient-level DR grading assessment.

Detection performance at the patient level is tabled below.

Table 14 – Patient level detection performance

	IMAGE QUALITY ALERTS	DR DETECTION
Total unique Patients	328	254
overall correct	279	228
overall wrong	49	26
% correct	**85%**	**90%**
True Positives (Hits)	25	32
False Negatives (Misses)	2	12 (12 mild DR cases missed)
Sub-total patients	27 patients assessed by ophthalmologist as unable to be graded	44 patients diagnosed with DR
Sensitivity	**93%**	**73%**
True Negatives (Correct rejections)	254	196
False positives (false alarms)	47	14 (All auto-diagnosed as moderate DR)
Sub-total patients	301 patients assessed by specialist as able to be graded	210 patients diagnosed with no DR
Specificity	**84%**	**93%**

We observe higher predictive performance at a patient level in all areas: accuracy, sensitivity and specificity. Predictive performance at a patient level is higher than at an eye level as there is more chance for the algorithm to make a correct diagnosis (according to the gold standard ophthalmologist) with often more than one image available per patient.

6.5 Eye-level and patient-level performance comparison

The tables below combine eye-level and patient-level performance for easier comparison.

Table 15 - Image Quality Alert Detection Performance summary

	LEFT EYE	RIGHT EYE	BOTH EYES	PATIENTS
Total Eyes	375	376	751	328
overall correct	272	270	542	279
overall wrong	103	106	209	49
% correct	**73%**	**72%**	**72%**	**85%**
Total images assessed by ophthalmologist as *unable* to be graded	43	48	91	27
True Positives (Hits)	40	43	83	25
False Negatives (Misses)	3	5	8	2
Sensitivity	**93%**	**90%**	**91%**	**93%**
Total images assessed by ophthalmologist as *able* to be graded	332	328	660	301
True Negatives (Correct rejections)	232	227	459	254
False positives (false alarms)	100	101	201	47
Specificity	**70%**	**69%**	**70%**	**84%**

Table 16 - DR Detection Performance Summary (where “Mild NPDR” cases are considered ‘Disease’)

	LEFT EYES	RIGHT EYES	BOTH EYES	PATIENTS
Total	232	227	459	254
overall correct	200	190	390	228
overall wrong	32	37	69	26
% correct	**86%**	**84%**	**85%**	**90%**
True Positives (Hits)	25	21	46	32 patients
False Negatives (Misses)	12 (all Mild DR)	18 (17 mild DR 1 moderate)	30 (29 mild DR 1 moderate)	12 patients (12 mild DR cases missed)
Total diagnosed with DR	37	39	76	44 patients
Sensitivity	**68%**	**54%**	**61%**	**73%**
True Negatives (Correct rejections)	175	169	344	196
False positives (false alarms)	20 (all auto-diagnosed as moderate DR)	19 (all auto-diagnosed as moderate DR)	39 (all auto-diagnosed as moderate DR)	14 (all auto-diagnosed as moderate DR)
Total diagnosed with no DR	195	188	383	210 patients
Specificity	**90%**	**90%**	**90%**	**93%**

6.6 Performance considering alternative definitions of DR severity

In this project, cases of Mild NPDR have been included as potentially sight threatening cases that have been picked up through screening activities i.e. all severity levels of DR are reported due to possible progression of mild DR cases (albeit slowly) to more severe cases unless underlying conditions are actively managed. However as noted in Section 3.3, regression from mild non-proliferative diabetic retinopathy to no visible retinopathy can occur and is reinforced by effective treatment of hypertension and hyperglycaemia.[14]

Thus the DR grading analysis was repeated using an alternative definition of Mild NPDR patients being considered as 'healthy'. This classification also aligns with the definition used when developing the deep learning algorithms applied here.

DR grading performance where 'Mild NPDR' cases were considered as 'healthy' by the deep learning algorithm is tabled below.

Table 17 - DR Detection Performance Summary (where "Mild NPDR" cases are considered 'Healthy')

	LEFT EYES	RIGHT EYES	BOTH EYES	PATIENTS
Total	232	227	459	254
overall correct	197	192	389	220
overall wrong	35	35	70	34
% correct	**85%**	**85%**	**85%**	**87%**
True Positives (Hits)	10	6	16	12 patients
False Negatives (Misses)	0	1 (moderate)	1	0
Total diagnosed with DR	10	7	17	12 patients
Sensitivity	**100%**	**86%**	**94%**	**100%**
True Negatives (Correct rejections)	187	186	373	208
False positives (false alarms)	35	34	69	34
Total diagnosed with no DR	222	220	442	242 patients
Specificity	**84%**	**85%**	**84%**	**86%**

Comparing this table with Table 16, it can be observed that the overall accuracy is similar. However by considering "Mild NPDR" cases as 'Healthy':

- Sensitivity is now higher than specificity - but only 17 images with DR were assessed (12 unique patients) compared to 76 images with DR previously (44 unique patients);
- The algorithm only missed 1 image depicting diabetic retinopathy (according to the 'gold standard' grading by ophthalmologists) which was graded as a moderate case;
- The algorithm also raised a lot more false alarms (69 images or 34 patients compared to 39 images or 14 patients).

DR detection performance is plotted below showing performance for both classifications of Mild NPDR cases. The target performance level is high sensitivity and simultaneous high specificity (i.e. the upper left corner of the plot below).

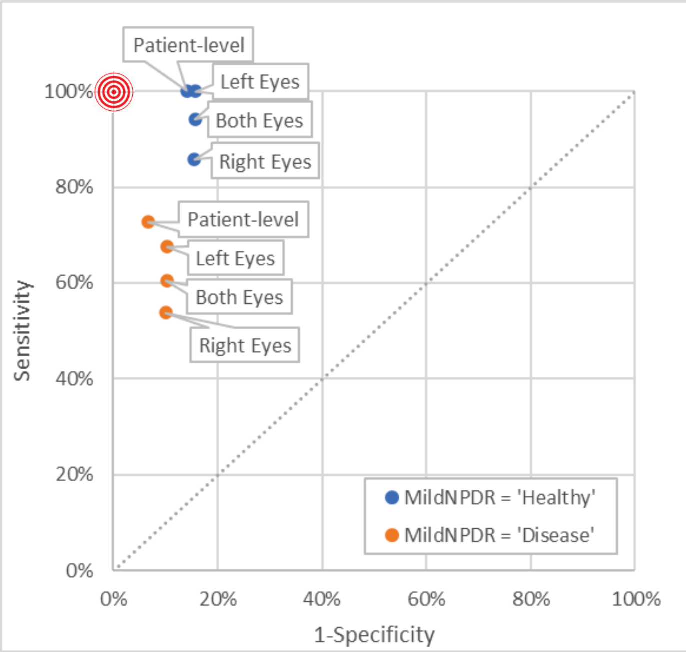


Figure 8 - Target DR detection performance target is high sensitivity and high specificity

The DR detection algorithm was developed and validated on retinal images collected outside this project from other sources (and classifying Mild NPDR cases as 'Healthy'), and as part of that development, detection performance was optimised using the area under the Receiver Operating Characteristic curve. We highlight that the performance assessment presented here is not an optimised performance and revalidation of that algorithm, but an evaluation of a previously established algorithm on the retinal images collected through this CRCNA project.

In summary, two AI-based components that have been embedded into the Remote-I platform were evaluated on images collected for this project: an image quality alert system and DR disease detection system. Predictive performance at a patient level was found to be higher than at an eye level as there is more chance for the algorithm to make a correct diagnosis (according to the gold standard ophthalmologist) with often more than one image available per patient.

At an individual image level, the image quality detection algorithm was correct 72% of the time, and 85% accurate at a patient level. The algorithm was reasonable at detecting images that the ophthalmologists deemed were unable to be graded (sensitivity ≥ 90%). However, it raised a high number of false alarms corresponding to situations where the images were gradable by the ophthalmologists, but the automated quality assessment detected them as bad quality, possibly due to the positioning of the optic disc.

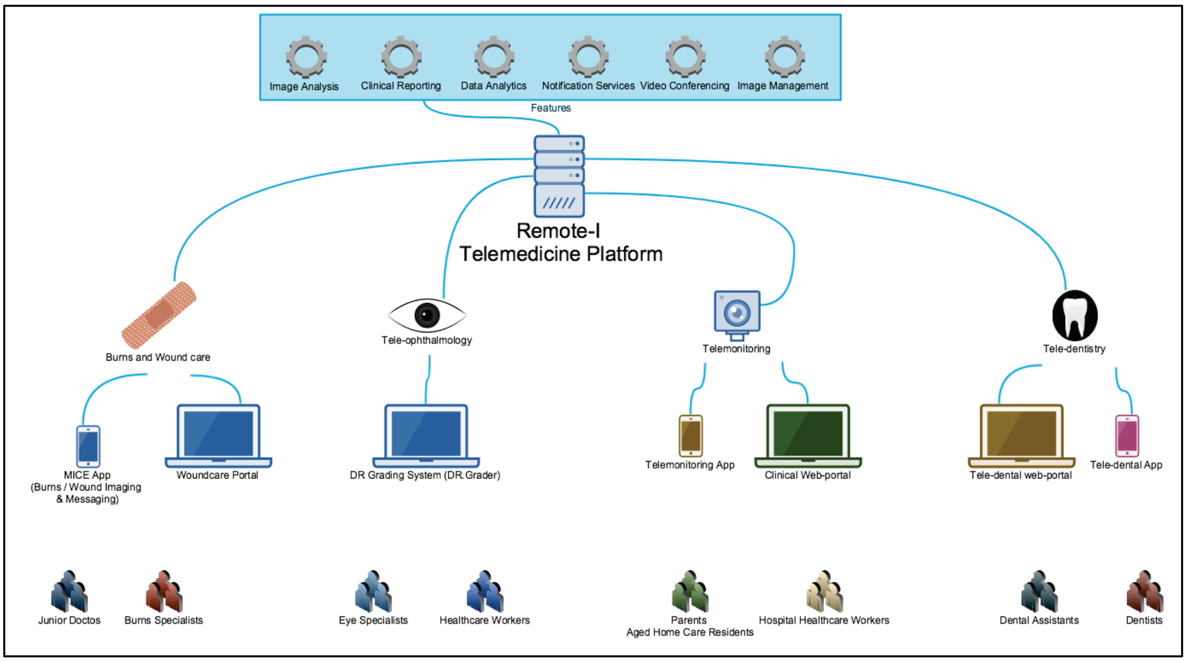
The DR detection algorithm was correct 85% accurate at an individual image level, and 90% accurate at a patient level. While the specificity for detecting DR (the ability to correct identify healthy images with no disease and simultaneously minimise false alarms) was high (≥ 90%) its sensitivity (ability to correct identify images with disease and minimise missed cases) was lower (73% at the patient level). The algorithm missed 12 patients with DR (according to the 'gold standard' grading by ophthalmologists) which were all mild DR and raised false alarms for 14 patients. Adopting a different classification for Mild NPDR cases resulted in similar overall accuracy, but sensitivity increased to 100% (i.e. no Moderate NPDR, Severe NPDR or PDR patients were missed by the algorithm) but at the expense of more false alarms (34 patients). The team will continue efforts to refine these algorithms to ensure predictive performance is as high as possible.

Appendix A The Telehealth System

This Appendix contains details of the password-protected web-based Remote-I application.

A.1 Remote-I

The implemented telehealth platform 'Remote-I' is a hybrid tele-health system developed by CSIRO which supports healthcare delivery across multiple modalities using imaging, video conferencing, store-and-forward transmission and mobile phones. Incorporating the latest imaging techniques and artificial intelligence, Remote-I comprises several modules to cater for different health care applications such as automated disease detection using retinal photographs and burns / wound imaging (refer below). The security of the system was extensively tested for this project and accepted by Queensland Health's cyber security committee, CSIRO's cybersecurity testing team and an Amazon Web Services 'Well Architected' review team.



Telehealth platform 'Remote-I'

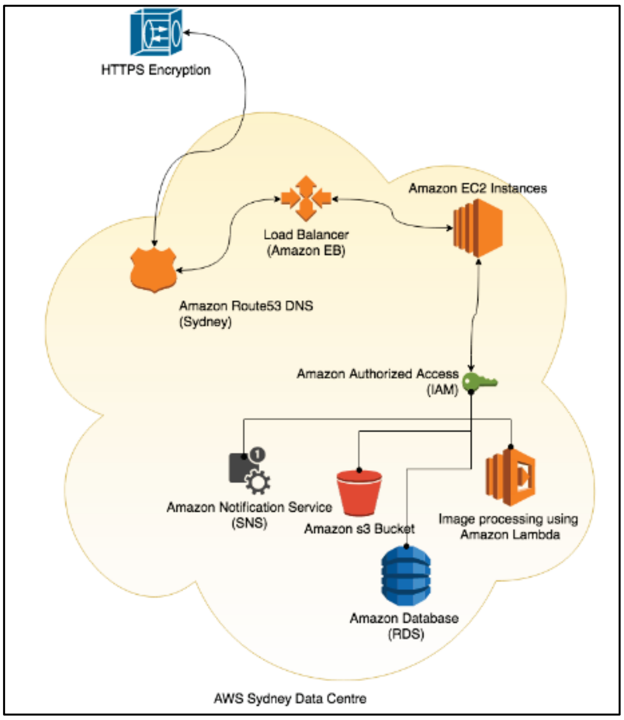
Features of the system include the following:

- Store and Forward solution for documents and images
- Video Conferencing via web-browser with scheduling and booking functions
- Accessible throughout mobile browsers
- Image capture using USB Plug & Play cameras within web-browser
- Detailed reporting
- Data monitoring
- Support for FHIR standard (in progress)
- Real-time information updates
- SNOMED CT codes for medical fields
- Searchable Australian Medicines Terminology
- Automatic Diabetic Retinopathy Disease Grading
- Utilises Cloud Web Services.

A.2 System Installation

The system is a cloud deployment using server infrastructure from Amazon Web Services (AWS). The following factors are relevant to system security:

- Communication is through a HTTPS tunnel.
- Users are registered and controlled using two-factor authentication.
- The database is encrypted at rest.
- Images are stored securely with controlled access through AWS S3. A dynamic URL is generated on every image every time a request is made.
- Load balancing and availability is managed by AWS which is proven to be very efficient.
- Data storage is in Sydney.
- A simple cloud infrastructure is shown below.

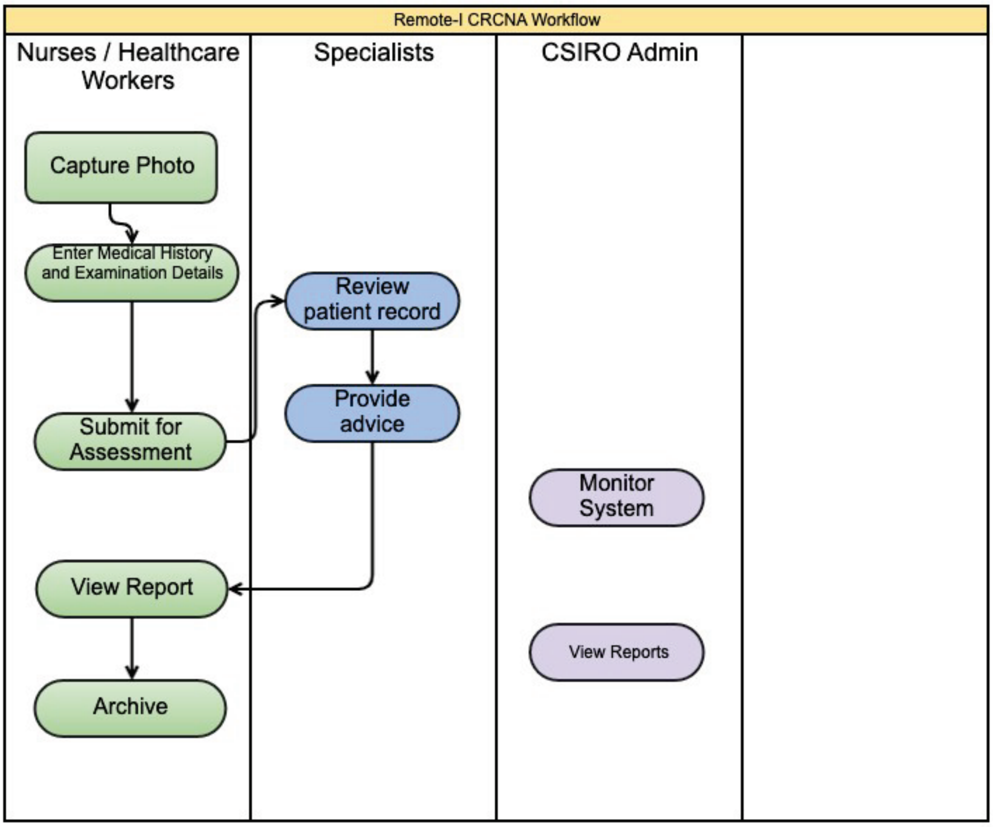


A.3 Screening workflow

The following section illustrates a basic workflow for the diabetic retinopathy screening service using the tele-ophthalmology system. The workflow describes the role of screeners (GPs, health workers and nurses) who undertake patient information input, preliminary grading result interpretation and final result notification and patient referral arrangement. Image reviewers (ophthalmologists / image graders) use the system to complete the image grading online. There is an automated DR grading feature in the workflow which is used for research purposes. The results from the automatic DR grading system compared with the 'gold standard' assessment from ophthalmologist reviewers were presented in Section 6.

There are 3 types of users in the system.

1. Nurse or Healthcare workers
2. Specialists/Ophthalmologists
3. Admin or Researchers from CSIRO



The method of service delivery is as follows. Patient participants are typically interviewed by a local Health Worker/Nurse screener who will establish the consent of the patient to participate, enter the participant's medical history and upload retinal photographs and other investigation results onto the secure Remote-I website. The Specialist/ophthalmologist will receive an e-mail about the referred patient. He/ She has to login to the Remote-I system to assess the data, indicate their diagnosis and a recommended time for follow-up. At the specialist side, the ophthalmologist uses a desktop computer to login to the Remote-I system in order to read images. Standard internet connectivity is adequate for ophthalmologists to read images.

A training video (uploaded to YouTube) and a clinical protocol were developed to assist healthcare workers with the new workflow and allow them to watch it repeatedly at leisure. This process was informed by previous projects in the area and refined based on feedback from health workers. A similar protocol was also developed for specialist ophthalmologists (not based in community) who was trained to use the system for reading the data and providing diagnoses. The purpose of these protocol documents is to educate the end users in steps that they need to follow, and the team walked through the workflow and steps with end users to ensure they understand the process. Valuable feedback was received from healthcare workers during this process which was used to improve the workflow.

A link to the training video describing the workflow is here: https://www.youtube.com/watch?v=KWzO47vTgBg.

Note the first part of this video provides description for the screening clinic, whereas the last part of the workflow from 3mins, 20s is more relevant for the reviewing specialist.

In a nutshell, the screening workflow is:

a) Obtain consent from patient. Gather details of name, date of birth, diabetic history, and visual acuity.

b) Take photos with the retinal camera.

c) Depending on the camera type, export images from the camera to a connected computer.

d) Upload to the Remote-I server.

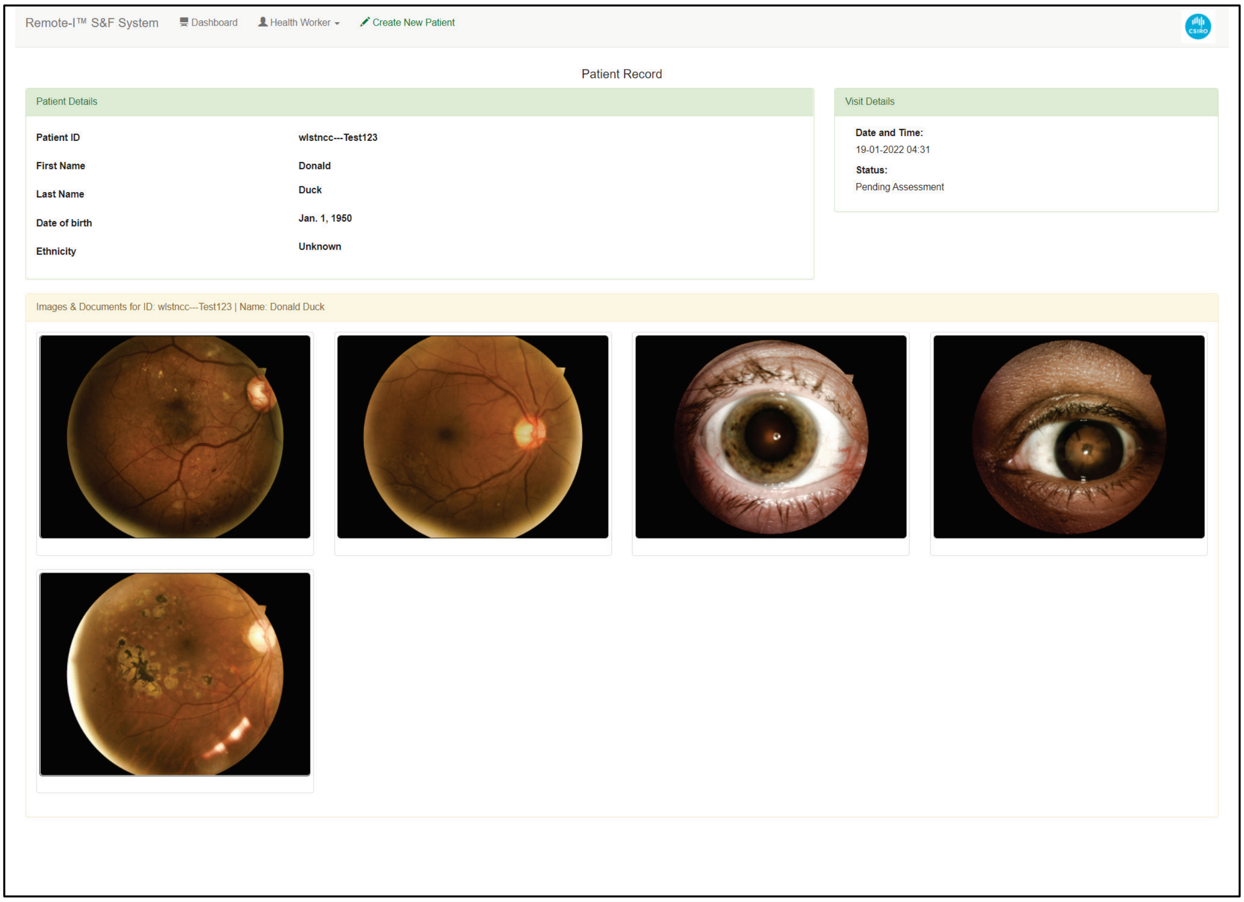
- Using any laptop or PC in the clinic with an internet connection, access the Remote-I site using a web browser (ideally Google Chrome, but Edge should work): https://live.remotei-crcna.com/remotei/dashboard/
This website was bookmarked on a shortcut saved to the user's desktop for easy access.
- There are 4 areas on the Dashboard: 'Drafts' (still working on adding in all the details), 'Pending Assessments' (submitted to the ophthalmologist), 'Completed' (diagnosis has come back from the ophthalmologist) and 'Archived' (user has noted the results and potentially saved the diagnosis in the patient's record).
- When a user logs in, the dashboard puts them automatically into the 'Drafts' area. Choose 'Create New Patient' – add patient ID which is a reference used in the clinic, name, date of birth.
- Edit Medical History section (normally the reviewing specialist the ophthalmologist has asked for any relevant diabetic history (e.g. Hba1c result and date, anything else that might be relevant e.g diabetic foot issues, poor diet control).
- Edit Examinations section to add visual acuities for right and left eye (don't need to complete all options, just one will do either: uncorrected, pin hole or corrected).
- Add New image file, adding all images for that patient, noting each time whether it was left or right eye.
- Confirm that the patient has consented.
- Hit submit for assessment.

e) At a later stage, log back in to review the diagnoses provided by the ophthalmologist, 'archive' the completed cases and follow local practices for saving the information. For example, one clinic saves a copy of the report as a pdf file and uploads this to the patient's record within the GP software (e.g. 'Best Practice') and a diabetic spreadsheet, then sends the report to the visiting optometrist for referrals.

The workflow of the reviewing specialist is as follows:

a) Login.
b) View dashboard for pending assessment patients and completed patients.
c) Open pending patient record.
d) View the images. Sometimes a user may need to click on the thumbnail images on the right-hand side of the screen which will bring the image up as a large image in the centre of the screen.
e) Zoom in and pan retinal images. A user can zoom in easily on the centrally displayed main image using a mouse scroll wheel and pan the image using the mouse.
f) View patient demographics, medical history, and acuity examinations by hovering over the bubble in the corner.
g) Enter diabetic retinopathy grading
h) Diabetic retinopathy level for each eye
i) Diabetic macular oedema for each eye
j) Enter recommendation
k) Enter next diabetic screening time period
l) Enter additional signs and comments
m) Submit record for completion
n) Logout.

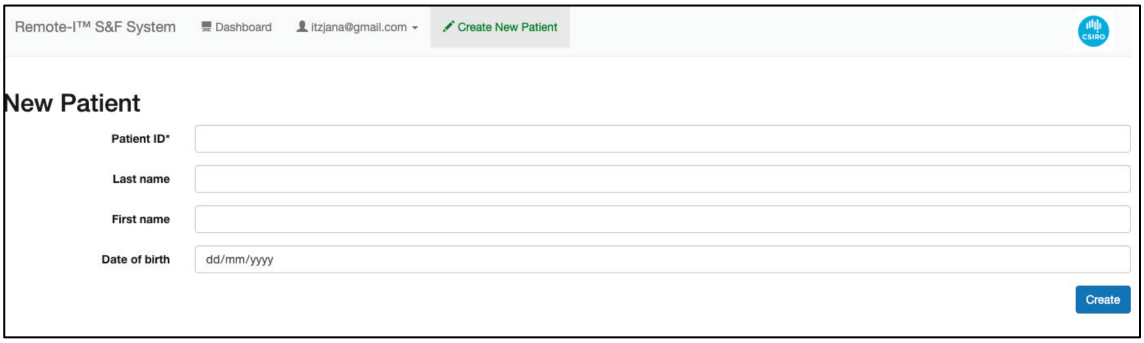
A.4 Screenshot of Remote-I Platform



A.5 Screenshots of Remote-I Data Entry Fields

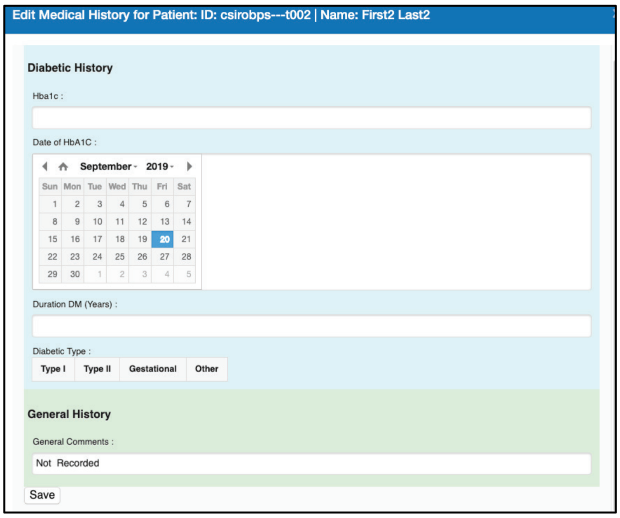
A.5.1 Patient Demographics – input by Health Worker

Create Patient Screen

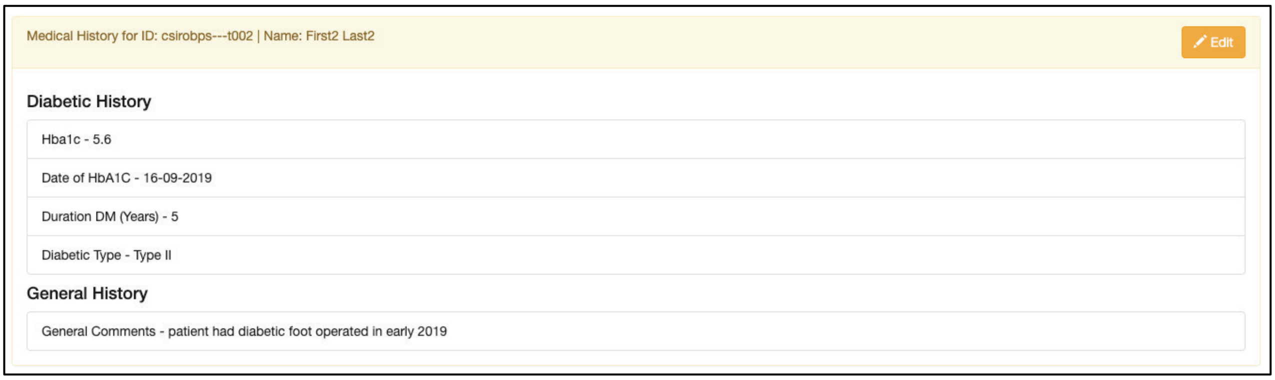


A.5.2 Medical History – input by Health Worker

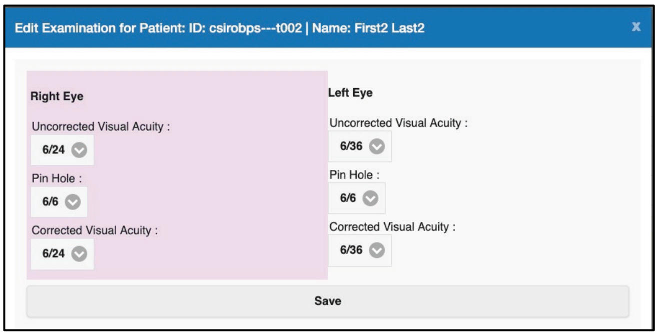
Edit medical History Screen:



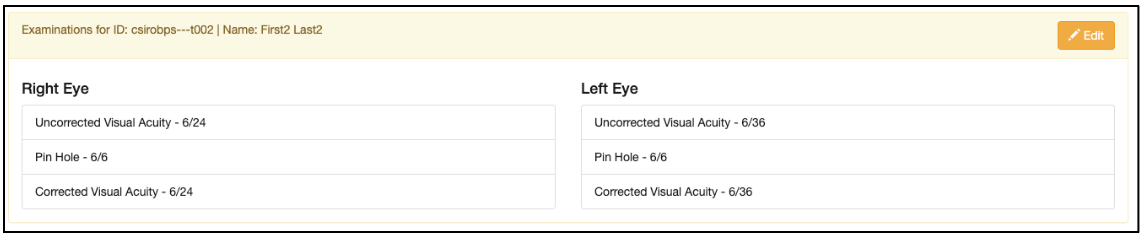
View Medical History Screen:



Edit Visual Acuity Examinations Screen:

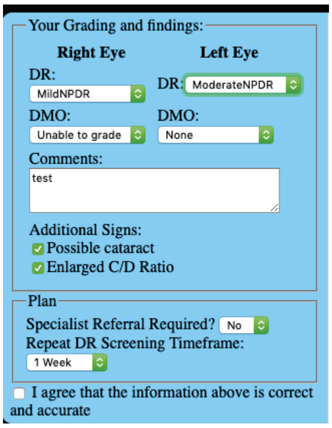


View Visual Acuity Examinations Screen:

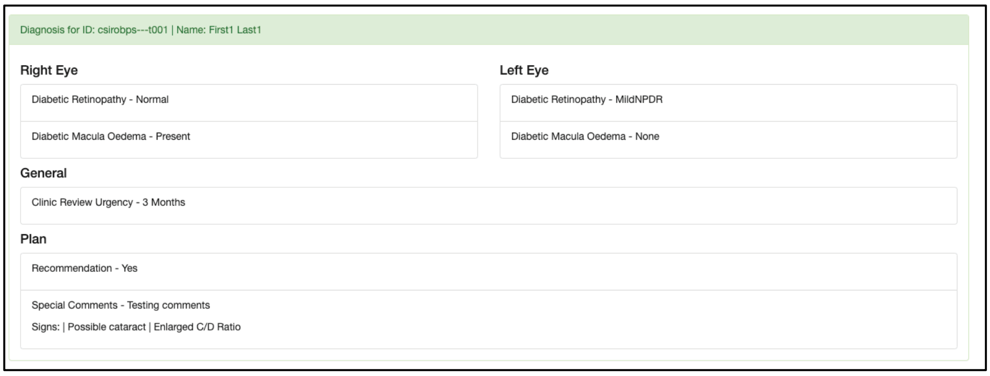


A.5.3 Diagnosis – input by Specialist

Edit Diagnosis:



View Diagnosis on screen:

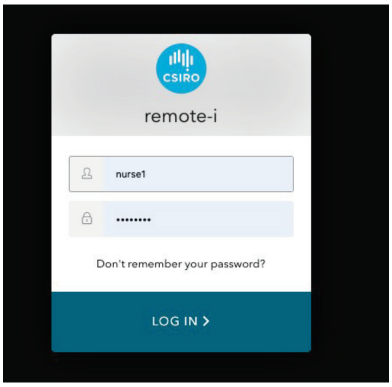


A.6 General Workflow

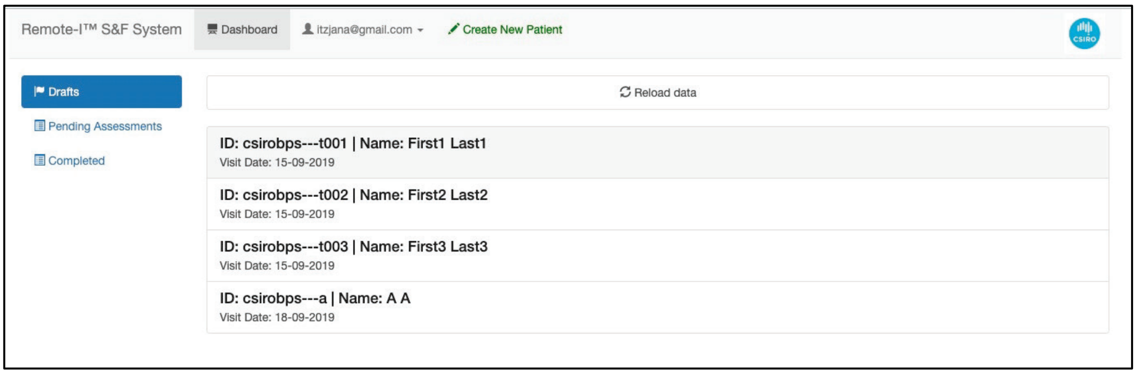
A.6.1 Uploading patient exams by the screener

After retinal imaging process is complete the following steps shall be taken to successfully send the report to the ophthalmologists for review and receive feedback.

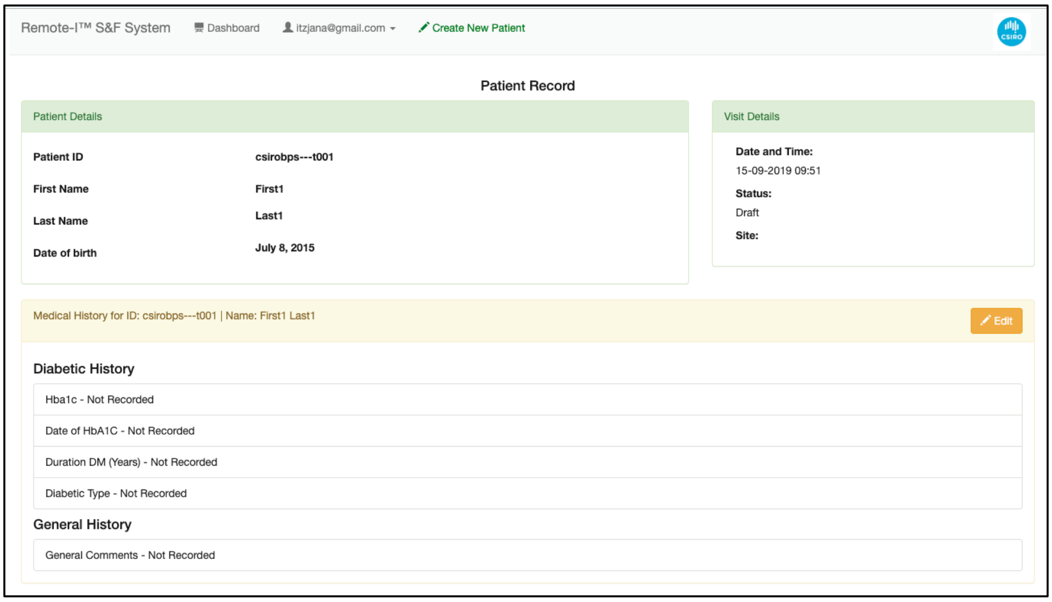
Login to the Remote-I with provided credentials



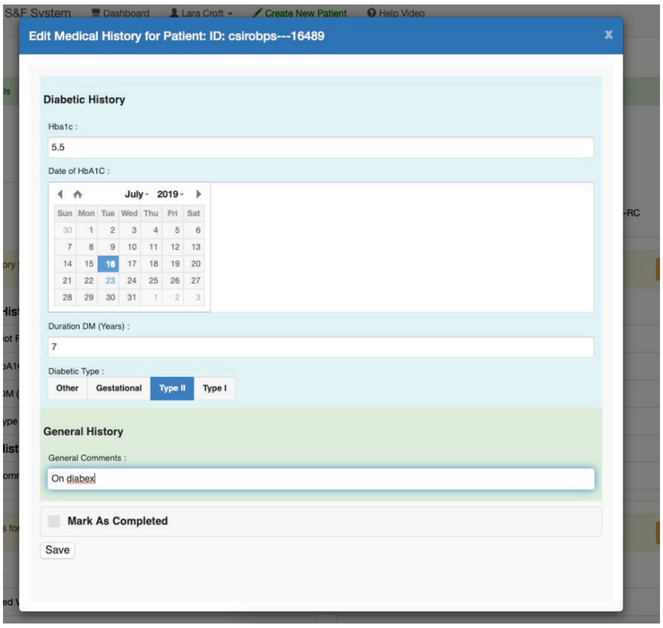
View Dashboard

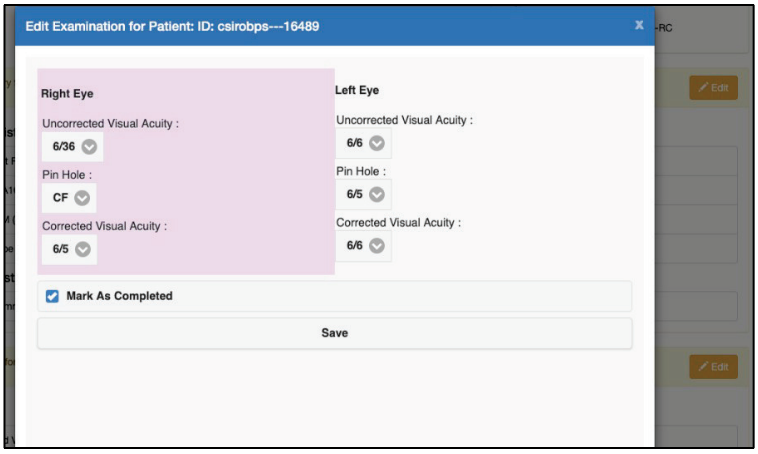


Open patient record

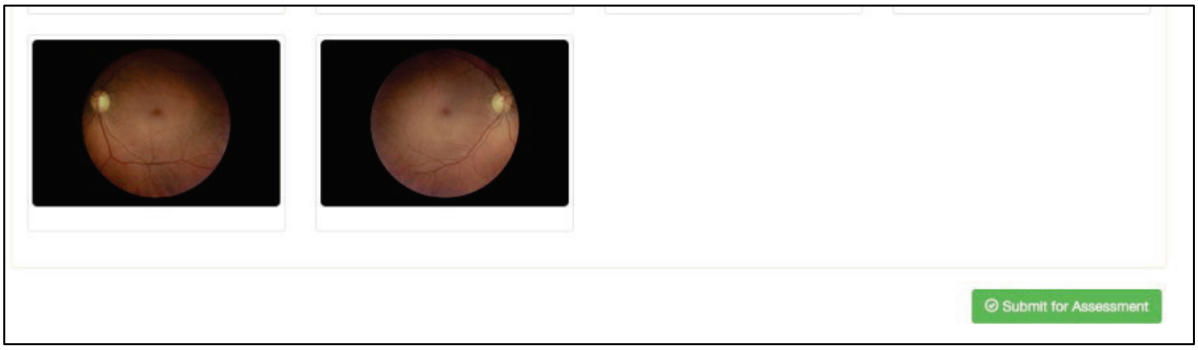


Edit visual acuity and other medical history data related to eye



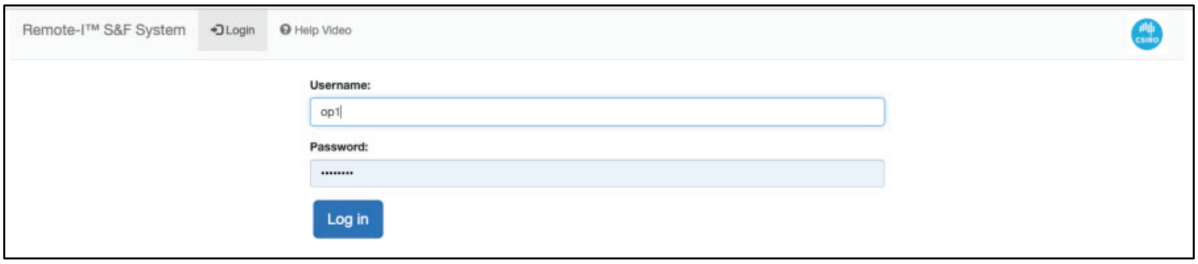


Click "Submit forassessment"

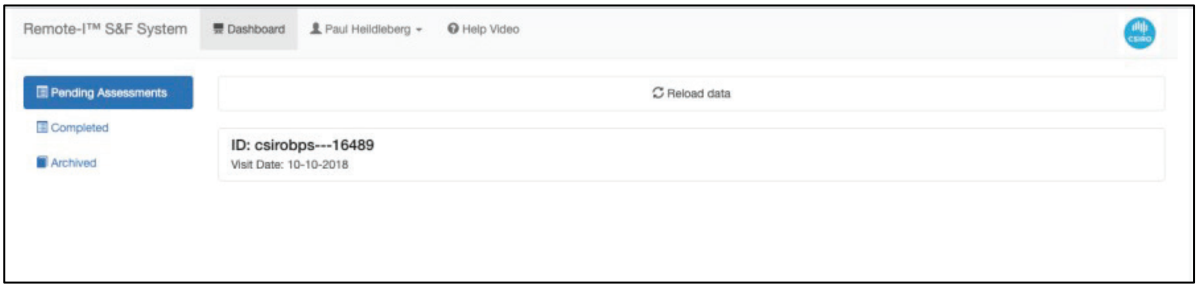


A.6.2 Ophthalmologist Review Process

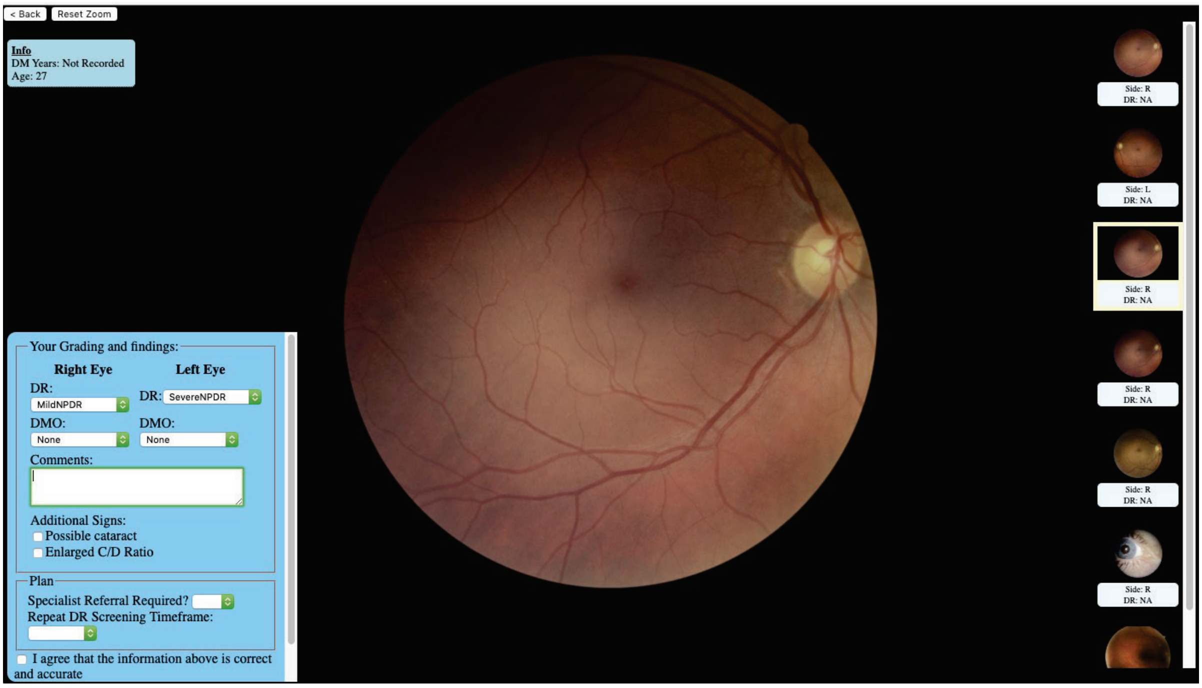
Login



Open Record from Dashboard



Review and grade



A.7 Remote-I Security & Architecture

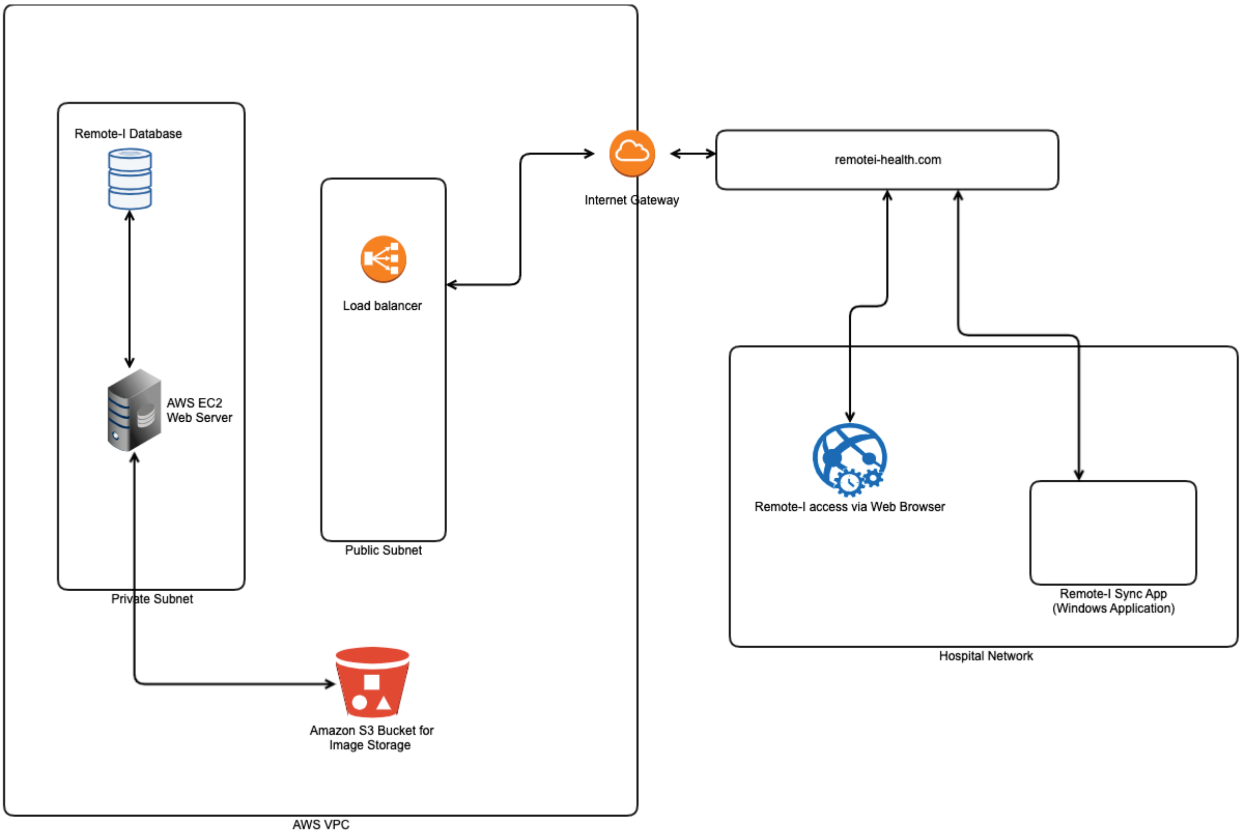
This section of the Appendix covers security and infrastructure aspects of the Remote-I Platform. Description on this documentation is highly simplified. Detailed architectural and security questions can be directed to the project team for further details.

A.7.1 Devices and software applications

- DRS retinal camera (Vendor Supplied);
- Canon CR2 camera (Vendor Supplied);
- Canon CR2 with RICS (Vendor Supplied);
- Retinavue Pro retinal camera (Vendor Supplied);
- CSIRO Remote-I sync app (CSIRO Supplied);
- CSIRO Remote-I web server (CSIRO);
- HealthLink Software Service (Vendor Supplied - Installed within the CSIRO AWS Cloud environment for HL7 communication between Remote-I and GP systems to send reports). Note in this project, we didn't use this, as integration requires individual a health clinic to enter a new service arrangement with HealthLink (https://au.healthlink.net/); however integration has been successfully demonstrated in other implementations.

A.7.2 Overall Architecture (Simplified)

The system is installed within CSIRO-managed AWS infrastructure. All administrative access is restricted to CSIRO specific IP address computers. CSIRO's Cybersecurity team completed an assessment on the system and the project team has mitigated the risks. This is illustrated in below diagram.



A.7.3 Connectivity & Credentials

Users access the Remote-I system using a web browser for any clinical record access. Only HTTPS connections are allowed. All HTTPS connections are encrypted using AWS TLS 1.2. The users are managed by CSIRO staff for the service.

A.7.4 Managed admin access

This is controlled by AWS security group controls. Only CSIRO personnel can access the servers via SSH from the AWS Systems Manager Console. All other access is blocked and not enabled. We use AWS systems manager to remote desktop into the machines when required.

A.7.5 Web Requests

For all client requests, a Web Application Firewall has been implemented to protect against common attacks (a few are listed below):

- Size Restricted web requests
- Detection of bad authentication tokens and block requests
- Detection of SQL injection and block requests
- Detection of RFI-LFI traversal and block requests
- Detect SSI (Server Side Includes) and block requests
- Block requests from Australia only

A.7.6 Remote-I Database

The database is not publicly visible and is secured via AWS cloud management access. The database is encrypted at rest using industry standard AES-256 encryption algorithm. The Remote-I database is setup behind a private subnet and only accepts connections from the web server which also sits inside the private subnet.

Transmission of the database information is handled via the web server using secure HTTP requests using TLS encryption. HTTPS certificates are handled by AWS certificate manager system which itself is a valid certificate authority.

A.7.7 Remote-I Image Storage

Images are stored within AWS S3 buckets which have strict security checks. Only the web server has access to the images and the S3 system creates secure key based access to the authorized users via the web server and is encrypted at rest using AES-256 and is time-based.

A.7.8 Patch Management Process

As we use AWS ecosystems, the system patches are automatically applied to web applications. We use elastic beanstalk as the web application orchestrator and it supports automatic patch management.

A.7.9 Data Backup and Restoration Procedure

The Remote-I web application consists of 2 data sources. The clinical database on AWS RDS and the retinal images on AWS S3. Both of these data sources are protected and backed up regularly.

AWS RDS Backup Procedure:

The Remote-I database is backed up automatically every day using the retention period settings in AWS RDS (35 days) such that in the event of corruption we can go back in time. We also perform monthly database backup and save the database snapshot.

S3 Backup Procedure:

AWS S3 has versioning support which keeps multiple versions of the files which does not delete the data. If in the case of corruption, we can go to a prior version of the s3 images.

A.7.10 Application Level Auditing

Various level of auditing is done through server logs.

We collect various logs within the system

- VPC flow logs enabled
- Elasticbeanstalk requests log and enhanced monitoring
- S3 Access logs
- Web application server logs for auditing
- Cloudwatch
- Auth0 logs for user activity monitoring
- Cloudcheckr monitoring enabled

Furthermore, each action against the record is tagged under the user to ensure operations are authorised.

Appendix B Stakeholder Consultations

As part of this project, the team consulted with many stakeholders including Aboriginal and Community Controlled Health Organisations and agencies with long histories of providing health services in Northern Australia:

- Aboriginal Medical Services Alliance Northern Territory (AMSANT): Public Health Medical Officers, Health clinic liaisons, and Digital Health Advisors
- Sunrise Health Service: CEO
- Katherine West Health Board: Directors of Primary Health Care
- Miwatj Health Aboriginal Corporation: Regional Eye Health Coordinators
- Marthakal Homelands Health Service: CEO, Health Managers and clinic staff
- Laynhapuy Health Service: CEO, Health Manager and clinic staff
- Urapuntja Health Service: Organisational Effectiveness and Program Development Managers
- Wuchopperen Health Service: Director of Medical Services and Research and Evaluation Officers
- Apunipima Cape York Health Council: Research Co-ordinator and Public Health Medical Advisors
- Gidgee Healing: Director of Service Planning and Development, CEO, Eye Health Coordinators, optometrists.
- NPA Family & Community Services ATSI Corporation (Bamaga QLD): Senior Health Worker
- IDEAS (Indigenous Eyes And Screening) van: CEO
- CheckUP Australia (General Practice Queensland): Statewide Indigenous Eye Health Coordinator and Eye Health Consultants
- QAIHC (Queensland Aboriginal and Islander Health Council): Research and Evidence Manager
- NT Eye Specialists: Head of Ophthalmology at Royal Darwin Hospital, Director of Ophthalmology at Alice Springs Hospital, ophthalmologists.
- WA Eye Specialist: ophthalmologist
- Brien Holden Vision Institute: optometrists
- Helen Summers Optometry: optometrists
- Qld Eye Specialists: ophthalmologists and optometrists
- The Royal Australian and New Zealand College of Ophthalmologists (RANZCO): Qld Branch Chair
- The Royal Australasian College of Physicians (RACP): Senior Executive Officers
- NT Department of Health: Digital Health Services Director, General Manager Primary Health Care
- Queensland Health: Information Technology Services Managers, IT technicians, Ophthalmology nurses, Diabetes Educators, Directors of Medical Services, Cairns Human Research Ethics Committee coordinator, Research Governance officers, Executive Directors of Medical Services, Chief Medical Officers, Directors of Endocrinology Dept, endocrinologists, Eye Health Coordinators, Optometry Liaison Officers.
- Qld Health's Biomedical Technology Service: Service managers and Biomedical Engineers
- Vision Eye Institute: General Manager National Projects
- Queensland University of Technology: Head of School of Optometry and Vision Science, QUT Optometry staff.
- Vanguard Health: Surgical Services National Director and optometrists.
- Welch Allyn (Equipment supplier): Marketing Managers and Clinical Educators.
- Ellex Biomedical Services (Equipment supplier): Service Engineers and territory managers
- OptiMed Pty Ltd (Equipment supplier): Services Manager.

B.1 Further Detail on Stakeholder Consultations

The following provides further detail regarding some of the consultations undertaken for this project.

AMSANT - Aboriginal Medical Services Alliance Northern Territory

We met with AMSANT staff in their Darwin office and learnt about their role in liaising with health clinics who are getting eye health equipment via the consortium led by Brien Holden Vision Institute. We also had numerous consultations with AMSANT's Public Health Medical Officer and Digital Health Advisors in relation to remote communities that had limited or no access to eye health and developing referral pathways.

NT Eye Specialists

In the initial stages of the project, we met the Head of Ophthalmology at Royal Darwin Hospital face to face twice at his eye clinic in Darwin and had many subsequent communications to secure their ultimate involvement in the project along with their colleague from NT Eye Specialists. These ophthalmologists have been engaged to provide diagnostic review of collected images in the NT. At other stages of the project we met with the ophthalmologists face to face at their eye clinic in Darwin to walk through the clinical workflow and use of the telehealth platform. NT Eye Specialists provided the first clinical diagnoses for patients through the system and valuable feedback was obtained from her to improve the workflow.

Marthakal Homeland and Resource Centre Aboriginal Corporation

We held many meetings with the CEO of Marthakal Homelands Health Service to secure their ultimate involvement in our project. The CEO provided some advice around legal requirements for Indigenous corporations to meet financial delegation rules and sought some further clarifications around what was being provided and reporting requirements. Following lengthy negotiations and minor amendments, the agreement was executed by their Chairperson and Treasurer. CSIRO personnel travelled to this clinic on Elcho Island to inform themselves of local structures and processes, and later in the project to deliver cameras and train staff on workflow and use of the camera and telehealth platform.

Laynhapuy Homelands Aboriginal Corporation

Numerous meetings were held with staff from Laynhapuy Health Service to secure their ultimate involvement. Their Health Manager was consulted about local processes during a site visit prior to commencement and CSIRO personnel provided training in use of the camera and planned workflow to staff. The team are indebted to one of their eye screening nurses who successfully worked through formidable challenges of commencing service delivery.

Top End Health Services

The team engaged with NT Health (the General Manager of Primary Health Care) at the top level to assist with exploring screening locations in the Northern Territory.

Brien Holden Vision Institute

Brien Holden is part of a consortium that has received federal government funding to provide eye health equipment across Australia. We met with one of their optometrists in her Darwin office who has been undertaking remote optometry bush clinics throughout the NT for many years. We suggested that our project provides the glue in this related work by closing the loop of surveying with service provision. A similar arrangement eventuated in North West Queensland in partnership with Queensland Health (North West Hospital and Health Service) and Gidgee Healing. BHVI had another of their optometrists visit Marthakal Homelands where we had supplied a portable Welch Allyn retinal camera. They provided some additional training with the retinal camera to the clinic's GP and Aboriginal Health Worker. The optometrist reported it was a struggle to get good photos with the portable camera, and that it was relatively tricky to get the camera positioned properly, as the movement required to get the alignment correct was counter-intuitive and would require quite a lot of practice to master. The project subsequently provided Marthakal with a more advanced Canon desktop camera in addition to the Welch Allyn portable camera and provided training on its use.

Gidgee Healing

Gidgee Healing are a primary care provider in North West Queensland who have received cameras from the Brien Holden Consortium but did not have an established pathway for having any collected images assessed. The team met with their Director of Service Planning and Development who was acting as the liaison for solving technical issues with transmitting images and returning reports to Best Practice (clinic practice management software). Meetings were also held with staff from Future Computers who are the technical support company assisting Gidgee Healing. Discussions were around ensuring that the control laptop associated with the cameras have LAN/WLAN connectivity, installing TeamViewer (remote control software) on the devices so that CSIRO could perform testing and local support during testing when input is required locally on the device.

CSIRO and Qld Health telehealth staff also accompanied the previous Eye Health Coordinator for Gidgee Healing on a charter flight to visit several Gidgee Healing communities to determine the level of readiness to commence patient screening: Mt Isa, Doomadgee, Mornington Island, and Normanton (Burketown and Karumba were also visited but only have Queensland Health facilities). The team met with Gidgee Healing clinic managers, Directors of Nursing, nursing staff and health workers at these clinics and discussed the project and that this new diagnostic pathway was available.

Contracts were signed between Queensland Health and Gidgee Healing and the North-West Hospital and Health Service ophthalmologist, and Gidgee Executive and health clinic managers were very keen to commence clinical service delivery. However sensitivity was needed to commence the new service around other players operating in Gidgee Healing sites (the IDEAS van and OneSight). The IDEAS van in Mt Isa is a programme of the Diamond Jubilee which charges for this service, and by its nature, can't be there all the time which makes opportunistic screening difficult and uses a reviewing ophthalmologist from Sydney. OneSight place volunteer optometrists at Mornington Island which results in continuity-of-care issues. The pathway established through this our project does not have these limitations.

One concern expressed by Gidgee Healing was that without sharing the idea and transferring ownership of the idea to commence eye screening into the mind of each individual health manager, the endeavour can backfire. This is so service introduction is undertaken in the best possible manner preserving trust and reputation within the communities. The team met with the Eye Coordinator of Gidgee Healing in their office in Mt Isa and in a subsequent meeting with the specialist ophthalmologist at Mt Isa Hospital in an attempt to make all parties comfortable and kept the Gidgee Healing CEO up to date who was supportive of the model. Working collaboratively through each and every concern has helped realised the eventual goal of getting telehealth-based image reading incorporated into the eye health model for the region. Working through these hurdles is fundamentally part of the project's objective of identifying success factors for implementing diabetic retinopathy screening.

The team subsequently met with the new Eye Health Coordinator at Gidgee Healing and an optometrist who works at Gidgee Healing to encourage their use of the system and uploading images from their retinal cameras. We shared details of the agreement between QH and Gidgee to formalise the model of care and stressed that the agreement doesn't prevent Gidgee Healing from claiming MBS 12325/12326.

IDEAS (Indigenous Eyes And Screening) van

The IDEAS van is a mobile ophthalmic treatment centre that travels to rural and remote communities. Their CEO had heard of our intention to connect other Gidgee Healing clinics via telehealth, was comfortable working together though was a bit uncertain of the eye coordinator's role at Gidgee. They mentioned that the specialist ophthalmologist from NW QLD had asked about connecting the Gidgee cameras to the IDEAS van, so the team subsequently met with this ophthalmologist to clarify the workflow.

Eye Health Consultant with CheckUP

We met with an Eye Health Consultant who was funded by CheckUP and the Medicare rebate for eye examination work in NW Qld, and has used the IDEAS van for telehealth consultations for some of their patients when the need has arisen. The consultant delivered training for all the Canon cameras delivered by the Brien Holden Consortium funded through the federal Department of Health and confirmed that none of them were previously being used. Our project has established a new business-as-usual service to have these cameras used.

General Practice Queensland (trading as CheckUP Australia)

We met with the Statewide Indigenous Eye Health Coordinator at CheckUP to make sure no toes were being stepped on, and to see how to work together. They shared a mapping report for the region done on eye health for the last NW Queensland regional meeting.

Helen Summers Optometry in Darwin

Optometrists from Helen Summers Optometry make visits to the Laynhapuy clinic as part of their outreach work and were interested in using the portable Welch Allyn retinal camera we had supplied. We discussed with them that from the project's perspective, use of the camera should be undertaken in a manner that uses the telehealth system and diagnostic pathway that has been set up. This is to ensure that findings and recommendations for follow-up examinations for Laynhapuy patients are recorded in the practice software system used at Laynhapuy which is the intention of the service and to avoid duplication/gaps in service delivery.

QAIHC - Queensland Aboriginal and Islander Health Council

We met with the Manager of Research and Evidence at QAIHC and provided background on the project and briefed them on our Queensland activities. The Manager accompanied some CSIRO personnel to Gidgee Healing clinics.

Ophthalmology at Alice Springs Hospital

The Director of Ophthalmology at Alice Springs Hospital has been doing rural and remote eye health delivery in NT for many years and the team consulted with them to obtain guidance on ensuring patients use the service. These discussions uncovered that there is currently excellent access to services in Central Australia, and the issue is more uptake of services related to cultural issues, staff turnover, and attendance fatigue. Trust and cultural issues are ever present challenges with some patients denying they have eye problems only overcome by establishing long term relationships and trust. We discussed that the role of decision support may complement primary care better than ophthalmic service (a telephone in the hand of a well-trained nurse is currently adequate telehealth), but may add value if it can be embedded within an image-based regional database that is under development via the NHMRC Centre of Research Excellence for Diabetic Retinopathy (USydney, UMelbourne, FlindersUni). Subsequently the team discussed this with the Telehealth Program Manager at NHMRC Clinical Trials Centre who was also the IT architect of the NHMRC Centre of Research Excellence for Diabetic Retinopathy, in particular new models for automatic grading.

Remote ophthalmologist serving in WA

We held an informal catchup with a remote ophthalmologist serving in WA where we shared approaches and explained what we are doing in our project. They have set up a clinic in Broome and moved there, and the center opened in 2021. They use optometrists for rural screening visits and claimed that model works well as most of the issues are rectified by prescription glasses. They were keen for us to send any updates / achievements and invited us to visit the center.

Cape York Regional Eye Health Program

We consulted with the team of optometrists and ophthalmologists who at the time of project commencement, provided eye health services in the Cape York area. These consultations were focused on how telehealth could offer clinical value and better decision-making tools. The optometrist advised that Wuchopperen Health Service were once running the Cape York Regional Eye Health program, but hadn't been doing that for several years, and also that Apunapima Cape York Health Council (the Aboriginal Community Controlled Health Organisation in Cape York) ended their contract for communities in the Cape in June 2018. Consequently we consulted with the Research Co-ordinator and Public Health Medical Advisor from Apunipima Cape York Health Council and submitted a Research Request Form to Apunapima's research governance committee inviting communities within Apunapima to participate. Ultimately Apunapima advised their position that they didn't have capacity to take on any more research. Discussions were also held with the Director of Medical Services at Wuchopperen Health Service who advised that they already had quite a lot of equipment and felt that our project was better directed to places that are more remote and with more need.

Vanguard Health

Vanguard Health were the successful tender to take over eye health service delivery in the Cape York area. We provided overviews of the project and walk-though of the portals to their National Director of Surgical Services. Discussions covered how the telehealth component could be incorporated into their service delivery activities, possibly as the "glue" of enabling images captured on the cameras in the southern Torres and Caper Hospital and Health Service to be diagnosed by a specialist who is part of the care team. This organisation was ultimately contracted to capture retinal images and clinical data and provide image reading and diagnoses via the telehealth system.

NPA Family & Community Services ATSI Corporation (Bamaga QLD)

Workflow familiarisation sessions were held with personnel from this Qld screening location at Injinoo (near Bamaga QLD). The clinic is not run by Qld Health but an Aboriginal Health organization which partners with Qld Health. A detailed walk-though of the portals was provided to one of their Senior Health Workers and information provided to allow them to begin using the service (training videos, screenshots and step-by-step breakdown of the workflow, patient and health worker surveys, patient information sheets and example appointment letter).

Telstra Health

We held numerous discussions with Telstra Health regarding secure messaging solutions for electronic referral model using their Argus product and with HealthLink.net secure messaging provider.

Queensland University of Technology

We met with the Head of QUT's School of Optometry and Vision Science), and staff from QUT Optometry to discuss project activities. The School is committed to improving eye health service for Indigenous people and staff often work with Indigenous patients and have undertaken research in Indigenous communities so it was good to get their thoughts on the project and advice.

Service Engineers and territory managers from Ellex Biomedical Services

Ellex undertook servicing and upgrading of the 3 DRS cameras from the Torres Strait. Ellex was consulted regarding some newly serviced DRS that went back to Bamaga not being correctly focused. They also quoted on two new automatic DRS cameras for Marthakal and Laynhapuy clinics including delivery/commissioning/initial setup and training. These cameras were procured by the CSIRO team funded from a successful internal CAPEX submission. The team had planned to set up the camera and deliver training in March 2020, but had to postpone this based on advice against unnecessary trips into remote Indigenous communities due to COVID-19. Training was provided to clinic staff by CSIRO and Ellex via videoconference, telephone and email.

OptiMed Pty Ltd (vendor of Canon retinal camera)

In addition to the procurement of equipment, the Services Manager at OptiMed was consulted in relation to connection issues being experienced with the Canon camera at Laynhapuy. Together we troubleshooted connection issues that were arising when trying to run Canon camera software on a new laptop windows 10 (AMD processor) at Laynhapuy. The CSIRO team successful resolved the solution enabling the camera to be recognized by the laptop and provided advice to OptiMed to make things easier for them in future installations.

The Royal Australasian College of Physicians

RACP issued an invitation for the team to present the project at the RACP's annual scientific meeting ("Congress 2021") as a face-to-face event in Adelaide in May 2021. This was presented with an educational aim, explaining what the project is, how it is operating at the clinics, the clinical aims/benefits over what otherwise is done, and how interested physicians could find out more if they to be involved. The event was co-presented between CSIRO and Laynhapuy Health.

Queensland Health

There has been extensive consultation with Queensland Health who have ultimately adopted CSIRO's telehealth platform for business-as-usual service delivery within the Torres and Cape Hospital and Health Service, North West Hospital and Health Service and Central Queensland Hospital and Health Service. This has included:

- Information Technology Services Managers and IT technicians from Torres and Cape Hospital and Health Service. Additional cybersecurity assessment undertaken by Qld Health was overseen this area. The team liaised with IT technicians regarding installing camera control software on end user laptops and trying to troubleshoot problems to enable users to open the camera control software.
- Service managers and Biomedical Engineers from Qld Health's Biomedical Technology Services. BTS undertook a medical device risk assessment on the DRS camera to assess risks in relation to connection with the Qld Health network. The assessment considered the DRS camera as a biomedical device in order to allow connection with the Qld Health wifi network.
- The Ophthalmology nurse at Thursday Island Primary Health Centre, the Diabetes Educator at Bamaga, Eye Health Coordinators at Weipa, numerous ophthalmologists and optometrists, and Directors of Medical Services. The team provided walk-throughs of the Remote-I platform to these staff members and received feedback on the application.   Some Qld Health staff were also consulted about the impact of COVID-19 on screening clinics, travel restrictions, the focus issues of the Bamaga camera and the potential redeployment of the desktop camera from Marthakal Health Service.
- Cairns Human Research Ethics Committee staff and Research Governance officers with the Torres and Cape Hospital and Health Service. The team liaised with these staff to obtain the necessary ethics and governance approvals that were required. Staff also conveyed a written directive from the Chief Executive of the Health Service that following the escalation of containment strategies for COVID-19, all non-essential travel had to immediately cease and all research activities needed to be indefinitely suspended in the region which significantly impacted the project.

- We discussed the project with the Executive Director of Medical Services for the Torres and Cape Hospital and Health Service, who also made an introduction for us to the Director of Medical Services and Chief Medical Officer at Cairns Hospital. We also spoke with the Director of Endocrinology at Cairns Hospital and a Townsville endocrinologist who expressed their enthusiasm about the project.
- In 2022, the Optometry Liaison Officer at Brisbane North PHN and Metro North HHS approached the CSIRO team to broaden the telehealth platform application beyond diabetic retinopathy and shape its evolution to target other eye health issues, including glaucoma and trauma. In June 2022, the team linked up with additional communities in central Queensland with diagnoses provided via telehealth by Brisbane-based specialists. This broader platform has also been applied for service delivery within Queensland correctional system with 9 exams from Wolston Park Correction Centre diagnosed by Queensland Health's Metro South PAH Eye Casualty.

Appendix C Additional Project Outcomes

This Appendix demonstrates four additional outcomes of the project:

- Broadening of the Remote-I application beyond retinopathy to other eye diseases (glaucoma, trauma etc.);
- New prison service commencement with Queensland correctional services;
- Participation of additional Hospital and Health Services in central Queensland;
- Successful DFAT tender for Proof of Concept for Diabetic Retinopathy screening in Vietnam.

At the request of Queensland Health, the team incorporated additional features in the platform to target other eye health issues, including glaucoma and trauma. In June 2022, five new health clinics in central Queensland (two in Rockhampton, two in Yeppoon and one in Emerald) were provided with access to this broader platform to enable regional central Queensland patients to receive diagnoses provided via telehealth by specialists at the Royal Brisbane and Women's Hospital. In June 2022, access to this platform was also provided to the Queensland correctional system with exams from Wolston Park Correction Centre diagnosed by Queensland Health's Metro South PAH Eye Casualty. The software design of this modification was not trivial such that the changes could be pushed to the live system where new users could get access to the additional fields without affecting existing users.

Screenings and analysis of outcomes from the prison screenings are not counted towards the quotas required for this project, since the sites are not within the definition of northern Australia maintained by the CRCNA (north of the Tropic of Capricorn). Nevertheless, this expansion demonstrates an outcome from the project valued by the end user (Queensland Health) which they are very happy about. It also positions the technology as a preferred platform that has undergone extensive cybersecurity system and suitable for additional national telehealth requirements.

A screenshot of the broader Remote-I platform applicable to other eye diseases is presented over.

During the course of this project, the team also leveraged its learnings in validating and establishing tele-ophthalmology services and AI-based image reading in locations in rural and remote Northern Australia to partner with The Fred Hollows Foundation to successfully win a tender issued by The Department of Foreign Affairs and Trade (DFAT) under its Australia-Vietnam Enhanced Economic Engagement Grant Pilot Program.

This project undertaken concurrently in the final year of the CRCNA project (2021-22 financial year) was to report on the feasibility and most appropriate approach to the introduction of Australian AI and telehealth solutions for the detection and management of diabetic eye diseases in Vietnam. The project involved desk-based reviews of relevant health and industry policies and existing telehealth initiatives in Vietnam; key informant interviews with representatives from the Ministry of Health and health providers involved in the delivery of eye care to people with diabetes; and the development of a proof of concept where the Remote-I platform was translated into Vietnamese and demonstrated to The Fred Hollows Foundation and Vietnamese stakeholders.

A screenshot of the working translated prototype is also presented over.

The DFAT project was selected as a winner of the World Health Organization's (WHO's) first-ever Western Pacific Innovation Challenge "Innovation for the Future of Public Health" which sought to identify solutions that unlock greater health and wellbeing for more than 1.9 billion people across the 37 countries that make up the Asia Pacific. Over 400 public health innovators participated in the Innovation Challenge and 29 were awarded. Recognition for this from the WHO, the world's leading organization in the field of public health, is testament to the appeal of telehealth and AI solutions for increasing patient accessibility to DR screening and management, and a better understanding of the barriers and opportunities related to their uptake.

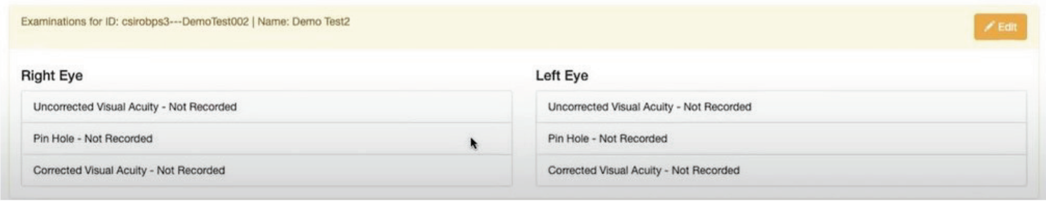
Practitioner Eye Exam Report

In all sections, please select each condition that applies:

☐ **New Urgent Patient** ☐ **Review Patient of** [ ]

☐ **New Non-Urgent Patient**

Visual Acuity (Existing Remote I data entry screen area for Visual Acuity)



Intraocular Pressure (mmHg): **R** [ ] **L** [ ]

Measured with: ☐ Applanation ☐ iCare ☐ Tonopen ☐ Air Puff

Patient Type: ☐ Lids ☐ Conjunctiva ☐ Corneal ☐ Anterior Segment ☐ Cataract ☐ Vitreous ☐ Retina

☐ Medical Retina

☐ Diabetic ☐ Glaucoma ☐ Infective ☐ Inflammatory ☐ Trauma ☐ Neuro

Diabetic History: ☐ T1DM ☐ T2DM Control: ☐ Diet ☐ Tablet ☐ Insulin ☐ Poor Diab Control HbA1c [ ]

Medical History: ☐ Heart Disease ☐ Hypertension ☐ Cholesterol ☐ Stroke ☐ Kidney Disease

☐ Auto Immune Disease ☐ Obesity ☐ Asthma ☐ Cancer ☐ Sleep Apnoea

☐ DM related amputation

Please attach a current GP Patient Health Summary where available.

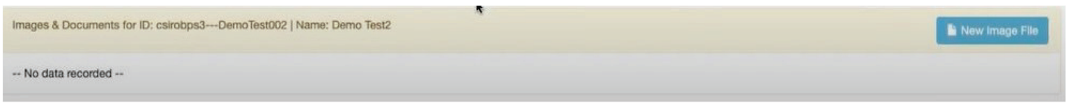
Further Eye & Medical History/My Interim advice and or treatment to Patient/Seeking your advice on:

[ ]

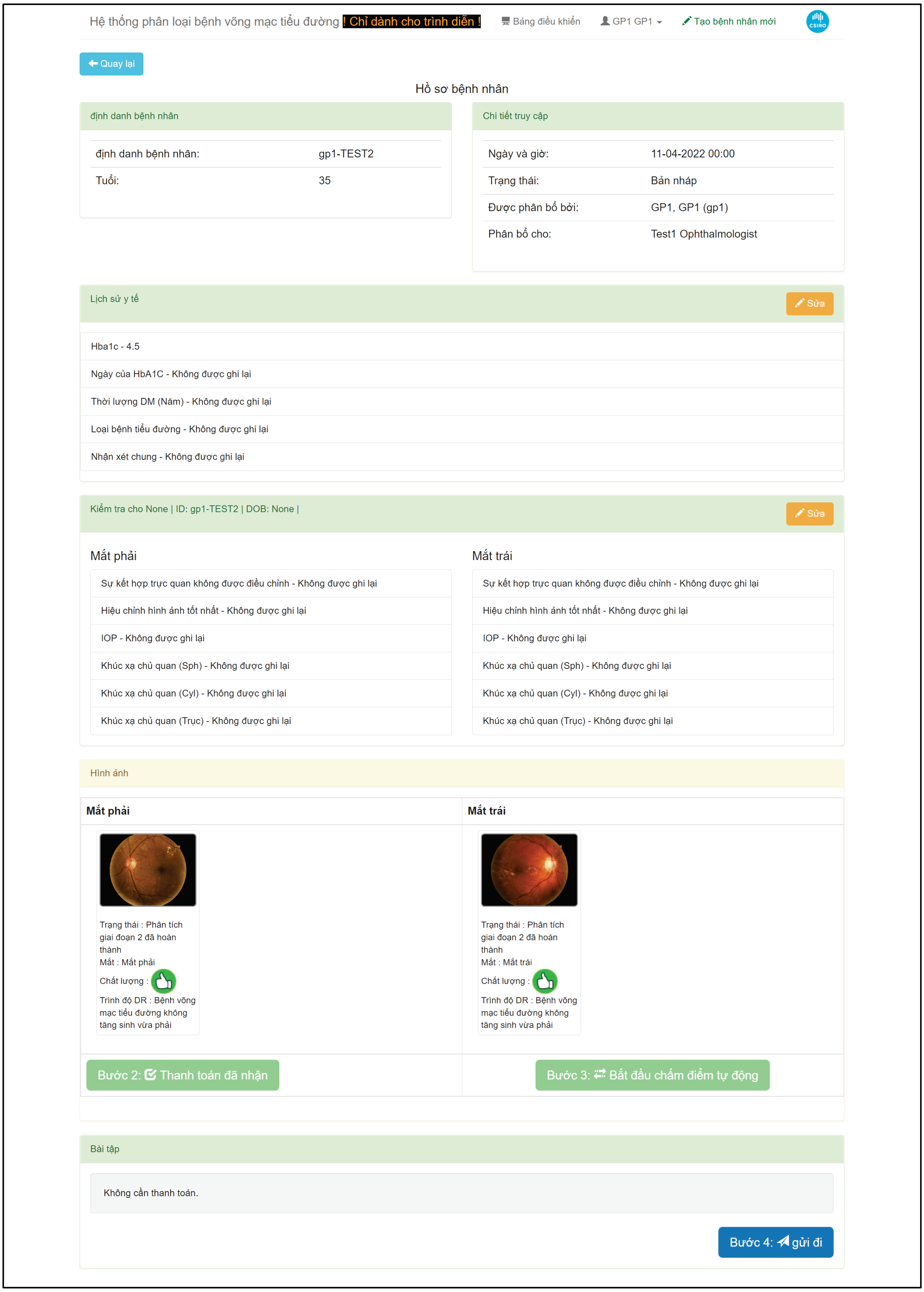
Name of Optometrist / Practitioner requesting:

[ ]

Image Upload (Existing Remote I data entry screen area for Image Upload)

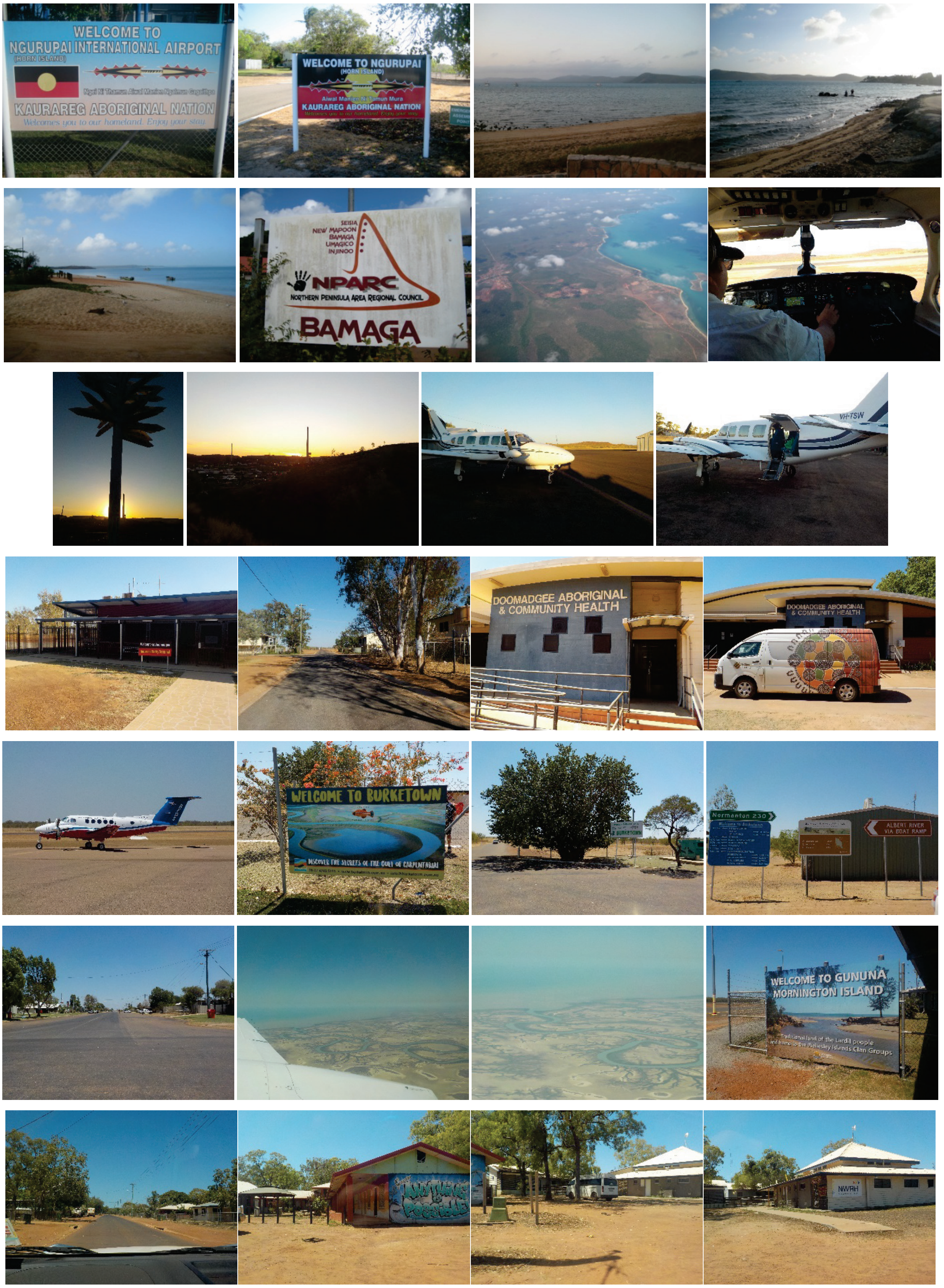


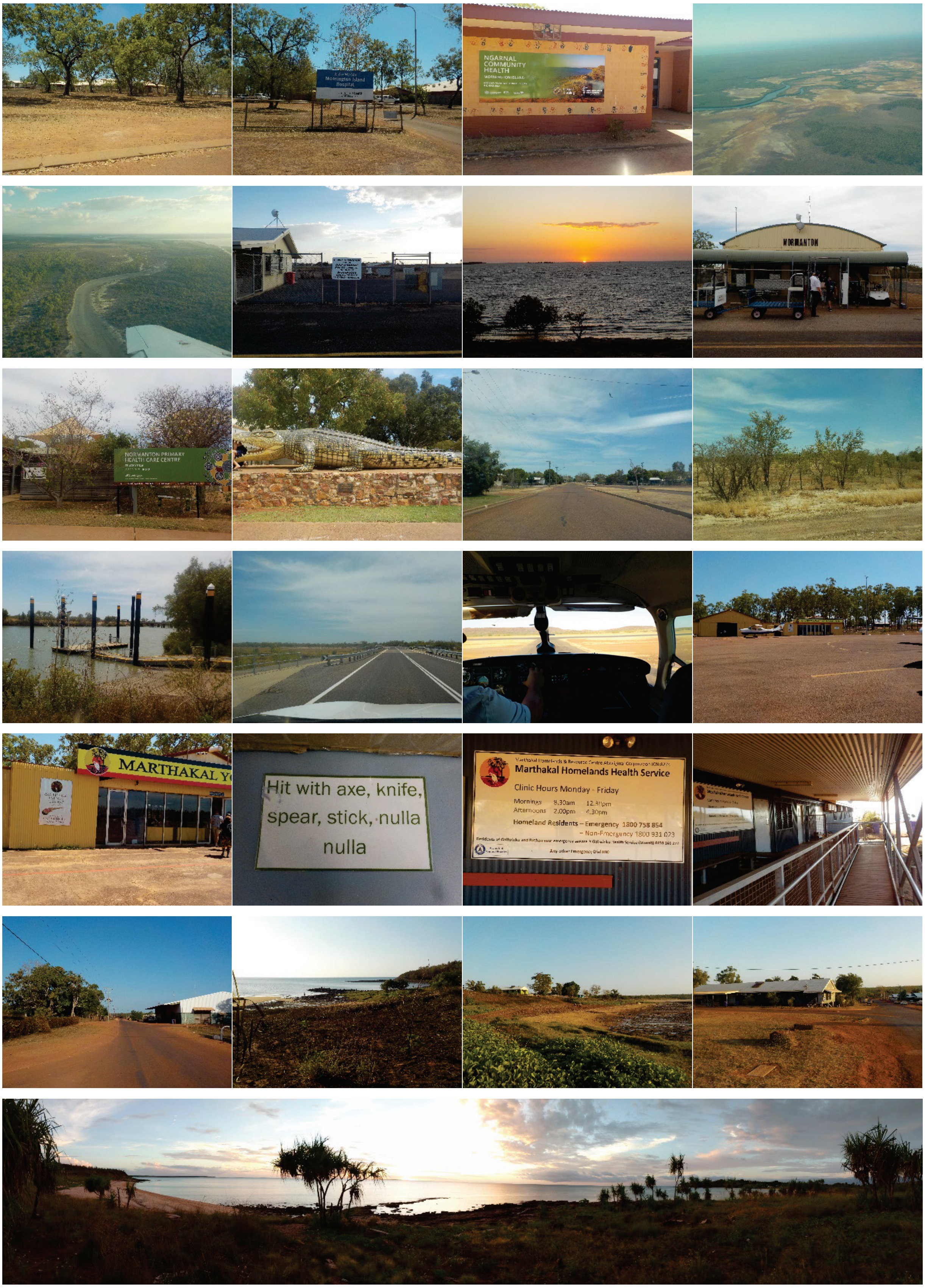
Data input fields showing the telehealth platform broadened beyond Diabetic Retinopathy



Screenshot of Remote-I translated into Vietnamese for DFAT project with The Fred Hollows Foundation

Appendix D Project Imagery




NGARNAL
COMMUNITY
HEALTH
NORMANTON
NORMANTON PRIMARY
HEALTH CARE CENTRE
MARTHAKAL
Hit with axe, knife, spear, stick, nulla nulla
Marthakal Homelands Health Service
Clinic Hours Monday - Friday
Mornings 8.30am
Afternoons 2.00pm 4.30pm
Homeland Residents – Emergency 1800 758 854

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