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

Progress Review on CRCNA Project H.5.1718035
Lessons Learnt to Date - What have we learnt 2 years in?

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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 or future, of the lands where this project is being carried out.

Executive summary

In July 2018, CSIRO along with its project partners Queensland Health, Laynhapuy Homelands Aboriginal Corporation and Marthakal Homeland and Resource Centre Aboriginal Corporation, commenced a multi-year project to establish 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.

The outcome of this project is a working sustainable teleophthalmology service, to continue serving the communities after project completion. The primary project objective is to identify factors around successful implementation of service delivery for diabetic retinopathy management in remote communities in northern Australia using telehealth technologies. This service delivery involves connecting metropolitan-based ophthalmologists with remote health clinics via telehealth to prevent the leading cause of preventable blindness in working-aged people. Since commencement, the project partners have collaboratively delivered the following activities:

- identified and established relationships with remote communities that had limited or no access to eye screening services;
- developed a sustainable model of service delivery and referral pathways to ensure that patients identified with eye issues receive appropriate treatment;
- developed collaborative data governance and custodial frameworks between project participants;
- applied for and obtained ethics, research governance, and cybersecurity clearance from appropriate providers;
- refined and tested a secure telemedicine system;
- procured and implemented retinal cameras and peripheral equipment and trained staff to use the technology; and
- commenced screening service as a sustainable model to continue beyond the life of the project.

This document is an interim progress report for the project, describing lessons learnt two years into the project and the changes made in response to these learnings.



Flags at the end of the Thursday Island jetty QLD



Health clinic on Elcho Island NT

1 Introduction

The main eye condition targeted through this project is 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 the eye health needs of 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 like this one 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.

Project activities are being delivered via new partnerships between researchers from CSIRO, Queensland Health, Laynhapuy Homelands Aboriginal Corporation and Marthakal Homeland and Resource Centre Aboriginal Corporation. The sites that have been selected for undertaking remote screening are remote, regional areas of Australia: East Arnhem in Northern Territory (Yirrkala and Galiwinku) and the Torres Strait in Queensland (Bamaga and Thursday Island). Retinal cameras, servers and laptops have been procured and tested at all sites enabling the secure upload of patient records and images to the Remote-I telehealth system.

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[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 Dec 2020): https://www.industry.gov.au/data-and-publications/our-north-our-future-white-paper-on-developing-northern-australia
[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

Remote health workers have been trained to capture high quality images of the eye, data entry, and reviewing of diagnostic advice as tabled below.

Table 1 – Breakdown of staff training undertaken to date

REGION	SITE	# HEALTH WORKERS	TRAINING LEVEL (refer below)	REVIEWING OPHTHALMOLOGIST	TRAINING LEVEL (refer below)
NW QLD	Mt Isa (Gidgee Healing)	1	2	1 (Dr Andrew Foster)	4
	Doomadgee (Gidgee Healing)	6	1		
	Mornington Island (Gidgee Healing)	2	1		
TORRES STRAIT QLD	Thursday Island (Queensland Health)	1	2	1 (Dr Garry Brian)	4
	Bamaga (Queensland Health)	4	1		
	Injinoo (NPA Family and Community Services ATSI Corporation)	1	2		
EAST ARNHEM NT	Yirrkala, Nhulunbuy (Laynhapuy Health)	3	3	2 (Drs Tharmalingam Mahendrarajah (Dr Mahen) and Hema Karthik)	4
	Galiwinku (Marthakal Health)	8	3		
TOTAL		26		4	

Training Level:

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 and a clinical protocol have been developed to assist healthcare workers with the new workflow. This process was informed by previous projects in the area and refined based on feedback from health workers. A similar protocol has also been 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.

These training activities contribute to the ongoing benefit of research outcomes by the fact that services will ultimately be provided in the local community on an ongoing basis, rather than requiring patients 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 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.

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. The store and forward capability of the system has enabled electronic records to be maintained where previously none have been kept and the internet connection to remote clinics has so far found to be reliable.

However a significant impact on the project throughout 2020 has been COVID-19, causing all eye screening activity to be stopped and specialist clinics to be cancelled at all sites. The health clinics remain cautious about the potential introduction of the virus into the communities which need to remain isolated. in light of concerns around COVID-19, clinics have not been encouraging healthy patients to come into the health clinic. As of 30 June 2020, 13 patient examinations have been uploaded to Remote-I and diagnosed which was less than the number planned to have screened by this date (150).

Almost all cases of sight-threatening diabetic eye disease can be avoided by having regular eye checks, and these recruited patients include 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. Critically, one patient has been diagnosed with severe non-proliferative diabetic retinopathy. The remaining participants who were screened had no eye problems, which enables the removal of these patients from the queues of overwhelmed specialist lists, improving service efficiency. The premise of many telehealth programs is reducing unnecessary patient travel. An assessment of this benefit will be 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.

An evaluation of project outcomes including health worker and patient satisfaction will be reported at the end of the project. In the meantime, the team has been constantly liaising with the healthcare workers to ensure the service meets their needs which has resulted in improvements. To improve useability there have been refinements to the workflow design (eg. 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) have been modified and customised to suit the preferences of the ophthalmologists and screeners. In this project, all patient liaison is 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 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.

At this mid-way point in the project, the lessons learnt so far are documented along with the changes made by the team in response. One of the key outputs from this project is identifying factors around successful implementation of service delivery for diabetic retinopathy management. While it is expected the activities will improve access to ophthalmic health services for people residing near the project screening locations, the lessons learnt and insights can be applicable to broader health initiatives in remote communities.

[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.

2 Lessons learnt

Lessons learnt so far during the project are presented below. These 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.

2.1 Establishing relationships

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

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

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

Response: 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 tech has to work, and they have to build the trust and rapport with patients (who are 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.

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

Response: On announcing the funding for this project, the CRCNA Board requested that the project be expanded to cover more sites across northern Australia. A monumental effort was expended in approaching additional 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. 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.

2.2 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. For example, the Cape York Eye Health model has been described to the project team as "the best in the world", attributed to a team of a visiting optometrist and ophthalmologist along with the claim that if this was replicated in other areas, eye health would be fixed. Such visits by an optometrist/ophthalmologist team were described as the gold standard in eye care and a first-world service, whereas telehealth was described as a third-world solution. On the other hand, in the Torres Strait, we have been 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 are looking forward to wider telehealth availability. In this region, the ophthalmologist regards screening via telehealth vital to help prioritise their caseload and pick up cases requiring urgent attention.

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. We have worked out how to complement a specialist's workload and have demonstrated that telehealth offers clinical value to a point where now, two years into the 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, and has not replaced it altogether. 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 have agreed to be involved in the 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).

Response: We have ensured that the Patient Information Sheet contains information about the process and the fact that future treatment may be required which is conveyed at the time of examination. Patient information sheets have been reviewed by the CSIRO Health and Medical Human Research Ethics Committee and the Far North Qld HREC and modified based on their comments. Showing a patient a picture of their eye during an examination can help 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 we

continue to consult with specialists in order to 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[7] (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 have indicated they don't have a preference for camera as long as the images are of good quality. Although mobile OCT would offer advantages for outreach teams, purchase of a mobile OCT device is 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.

2.3 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.

Our evaluation will quantify the level of satisfaction from health workers and patients, and ideally try to uncover the reasons behind that assessment (for example, patients are being asked to rate the service out of 10 and optionally provide a reason why they gave that score).

[7] Public Health England Guidance Document. Diabetic eye screening: guidance on camera approval. January 2018, available online (accessed Dec 2020): https://www.gov.uk/government/publications/diabetic-eye-screening-approved-cameras-and-settings/diabetic-eye-screening-guidance-on-camera-approval

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 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 recently received feedback from the ophthalmologist 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, where we have 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). These AI-based components are being built into the implementations being done as part of this CRCNA project, and we are further developing these techniques using the images collected in the project.

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 as opposed to conducting an academic survey as suggested.

The project is 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 is genuine willingness to screen patients' eyes which shouldn't be hampered by technology. The team have 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 has 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 needs 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 the 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 have been procured and delivered to sites and staff trained in their use. After receiving concerns about the tricky operation of the Canon desktop camera, we 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 are being tested in CSIRO labs and will be implemented in this project. High image quality is crucial for correct diabetic retinopathy grading, especially for evaluating algorithms for automated DR grading. Although the quality of captured images is improving over the course of the project, numerous captured images have been assessed as unable to be graded due to insufficient quality or insufficient retinal coverage which has been 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 are promoting that eye screening can be included in 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 have 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 evaluation trial, 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 have also learnt that video conferencing is not necessary for tele-ophthalmology, particularly diabetic retinopathy screening.

Response: So far, store-and-forward capability has found to work well, as consultations do not require specialists and patients to be available simultaneously, the need for coordinating schedules is removed, and the efficiency of the health care services is increased.

2.4 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 has been undertaken on the Remote-I server, including Vulnerability Assessment and Penetration Testing, to ensure the security of system is watertight and patient privacy cannot be compromised. Privacy Impact Assessments have been undertaken to ensure privacy legislation is not breached (for example, no information is sent to an offshore server). This applies for all sites. In addition to this testing, the security of the system has also been independently tested and accepted by Queensland Health's cyber security committee.

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: 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 need 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 ios with a range of browsers. The software works best with Google Chrome though Firefox or 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 has been successfully tested to support Canon CR2, Welch Allyn RetinaVue Pro and DRS cameras. The team have 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. We have implemented automatic quality assessment inside a Canon camera system, while in other implementations 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 $1800 per quarter).

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.

2.5 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. As the numbers of patients screened to date is far below that expected, the team is unable to claim completion of the milestones despite significant project work and effort expended.

Response: Future projects should be setup to focus on value and define a minimum equitable viable service for demonstrating the value of investment. This point is highlighted in the recent situational analysis of northern Australia health service delivery[6]:

> *"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. 6]

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 from the project organisations has suggested 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 is 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 have developed a set of training materials (user guides, workflow documents and YouTube videos) to assist with remote training of new staff.

2.6 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 are recommended 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. Such cultural barriers to telehealth adoption have been reported by other researchers,[8] where 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.

Response: From the outset of this project the team have been attempt 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. We have shaped our project by first approaching Fred Hollows foundation and ophthalmologists that have worked for many years delivering services in these communities. The team have also shared material with the screening clinics that can 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 clinical services scheduled as remaining project activities will ideally become business-as-usual services and will form the basis of evaluating outcomes of the project.

The insights are applicable to similar health initiatives that may be undertaken in remote communities in the future.

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

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