Screening for Diabetic Retinopathy and Reduced Vision among Indigenous Australians in Top End Primary Care Health Services: a TEAMSnet Sub-study

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ABSTRACT

Background

Diabetic retinopathy (DR) prevalence is higher in Indigenous Australians than in other Australians and is a major cause of vision loss. Consequently, timely screening and treatment is paramount, and annual eye screening is recommended for Indigenous Australians.

Aims

To assess the prevalence of DR, reduced vision, and DR treatment coverage among Indigenous Australian adults with diabetes attending Top End Indigenous primary care health services.

Methods

A cross-sectional DR screening study conducted from November 2013–December 2015 in two very remote Northern Territory Aboriginal primary healthcare services.

Results

In 287 subjects, the prevalence of non-proliferative DR, proliferative DR, and clinically significant diabetic macular oedema (CSMO) was 37.3%, 5.4% and 9.0%, respectively. Treatment coverage for PDR was 60% (of ten patients) and for CSMO was 17% (of 23 patients). Vision data were available from 122 participants at one site. The proportion with normal vision, reduced vision, impaired vision and blindness was 31.1%, 52.5%, 15.6% and 0.8%, respectively. Overall, ungradable monocular image sets (46%) were associated with poorer quality images and missing protocol images (both $p<0.001$). Ungradable images for DR were associated with presence of small pupils/media opacities ($p<0.001$). Ungradable images for diabetic macular oedema were associated with poorer image quality ($p<0.001$), cataracts ($p<0.001$), and small pupils ($p=0.04$).

Conclusions

A high prevalence of DR, CSMO and impaired vision was noted in Indigenous Australians with diabetes. Screening in primary care is feasible, but more effective screening methods are needed.

INTRODUCTION

Diabetic retinopathy (DR), a potentially sight-threatening condition, is usually asymptomatic until visual acuity (VA) is reduced and treatment outcomes are less effective and predictable than with pre-symptomatic intervention. Diabetic eye disease, primarily retinopathy and maculopathy, can affect reading, driving and self-care, which limits an individual's quality of life and independence. Consequently, timely screening and treatment is paramount. As DR prevalence is higher and screening coverage lower among Indigenous Australians,[(1)] more frequent (annual) screening is recommended than for non-Indigenous Australians. An estimate of risk of sight-threatening DR (STDR) i.e. of proliferative DR (PDR) or clinically significant diabetic macular oedema (CSDMO) can be determined using current retinopathy status, diabetes duration and HbA1c,[(2)] however, currently there is no risk calculator validated for Indigenous Australians. Our recent study employed a sensitive screening method using pharmacological mydriasis if required and clinical supervision was available.[(3)] In 300 Indigenous Australian adults with Type 2 diabetes (T2D) screened for eye disease in one Alice Springs primary-care clinic, we demonstrated a higher DR prevalence than previously reported.[(4)]

Using similar techniques, this study aims to determine DR prevalence and vision status in two very remote Northern Territory (NT) Indigenous community-controlled primary-care clinics and determine the main causes for ungradable retinal images.

METHODS

Indigenous Australians (age≥18 years, n=287) from the Top End area with diagnosed T2D were recruited from two remote primary-care services (Site 1 and Site 2, and satellite clinics) using active and opportunistic recruitment strategies (from 11/2013-12/2015). A detailed protocol has been published.[5] The study was approved by the University of Melbourne and Northern Territory Top End and Central Australian Human Research Ethics Committees. Each participant provided written informed consent.

Briefly, DR screening included presenting (aided or unaided) VA (Snellen's VA chart). VA was categorised as; normal (6/6 or better), reduced (<6/6 but no worse than 6/12), impaired (<6/12 but no worse than 6/60) and blind (<6/60)[6]. Pupils were dilated (one drop each of 1% tropicamide and 2.5% phenylephrine if indicated and clinical supervision was available. If undilated pupils were ≥4mm or mydriatic drops were contraindicated, dilation was not attempted. A digital retinal camera was used to capture five 45° retinal fields and one anterior eye field per eye (12 images/participant).

Site 1 included three locations, each with a Centervue DRS camera. Twelve local staff were trained as retinal imagers. Due to connectivity issues, rather than automatic image transfer, workers saved images on a hard-drive, which were collected on investigator site-visits.

At Site 2, a Canon CR-2 fundus camera was used and image sets captured by the Global Retinal images were transmitted using DICOM and HL7 standards over a Secure Socket Layer encrypted tunnel to the CERA server. For both sites, 1.0 FTE funding for a locally chosen worker/workers (0.5 FTE for imagers and 0.5 FTE for study coordinators) was provided for 2-years.

A formal validation of this tele-retinal screening program was not undertaken, but the protocol used should approximate results of other similar multi-field systems. In 2016, Horton *et al* summarised different telemedicine assessment programmes for DR which will assist readers in assessing our data reliability. The pooled sensitivity and specificity for studies using one 45° field was 77% and 92% respectively. For two and three 45° fields the sensitivity and specificity was 82%/86% and 88%/91% respectively. This data shows an increase in sensitivity and specificity with the increasing number of fields imaged[7]. The current study captured five 45° field digital photos, thereby increasing retinal coverage, hence the present study should approximate the sensitivity, specificity and kappa values of these validated studies, but likely higher ungradable rates due to greater imaging complexity.

Grading was by the CERA retinal grading centre (Royal Victorian Eye and Ear Hospital Melbourne) using ophthalmologist adjudicators and in-house retinal graders who had in-house training and UK screening programme international grader certification[3, 8]. The presence and number of lesions were documented electronically according to the ETDRS standardised grading protocol. A grading algorithm based on the Joslin grading algorithm and the ETDRS classification of DR analysed the electronically-entered retinal lesion data, automatically calculating a preliminary clinical DR level. This initial grading was accepted or modified by a grader who allocated a severity level for each eye after comparison with relevant ETDRS standard photographs for DR level/severity. The referral or review recommendation was based on the 'worse-eye' DR grade and 2008 National Health and Medical Research Council of Australia (NHMRC) Clinical Guidelines for the Management of Diabetic Retinopathy[9]. DR grade in each eye was reported as mild non-proliferative DR (NPDR), moderate NPDR, severe NPDR, PDR, DMO and CSDMO. CSDMO was defined as hard exudates ≤3000µm of the centre of the macula and diabetic macular oedema (DMO) was defined as hard exudates >3000µm of the centre of the macula (i.e. ETDRS definition).

Statistical analyses used IBM SPSS Statistics software (Version 25). Descriptive statistics were used to calculate frequencies of NPDR, PDR, DMO, CSDMO and sight-threatening DR (STDR), defined as PDR and/or CSDMO for both combined and individual sites). Chi-squared tests were used to explore associations between ungradable images and protocol factors. Significance was drawn at $p<0.05$.

RESULTS

Participants

Median (range) age was 53 (29–79) years and 39% were male.

Presenting binocular VA

For Site 1 only, presenting binocular VA was available in 122 (75.3%) participants (Table 1). Only 31.1% had normal VA, 52.5% had reduced VA, 15.6% had impaired VA and 1 (0.8%) participant was blind.

Prevalence of diabetes eye disease

For both sites combined, in images gradable for NPDR and PDR the prevalence of NPDR and PDR were 37.3% and 5.4%, respectively (Table 2). In images gradable for DMO, the prevalence of DMO and CSDMO were 0.8% and 9.0%, respectively. In images gradable for both PDR and CSDMO; i.e., STDR, prevalence was 10.1%, consisting of 6.2% CSDMO, 1.2% PDR and 2.7% combined PDR and CSDMO (Table 2). When comparing sites for prevalence of overall DR/DMO data for site 1 (25.2%) and site 2 (24.4%), ($p=0.84$) were similar, whereas NPDR was more prevalent at site 2 (40.2%) versus site 1 (28.9%), ($p=0.04$) as was PDR ($p=0.05$) (Table 2). Data for separate sites are in Table 2.

STDR treatment coverage

Of 23 adults with CSDMO, four had received laser treatment (17% treatment coverage). Six of ten cases with PDR had been laser-treated (60% treatment coverage), an overall STDR treatment coverage of 30%. In Site 1, of 13 adults with CSDMO, three had been treated (23%

treatment coverage). Four of five adults with PDR had received treatment (80% treatment coverage). In Site 2, one of ten cases of CSDMO had received treatment (10% treatment coverage); two of five adults with PDR had received treatment (40% treatment coverage). STDR treatment coverage for Site 1 and Site 2 was 39% and 20%, respectively.

Associations with ungradable images

Overall 46% of imaging sets (per eye) were ungradable for ≥1 criterion of diabetic eye disease, 43.5% were poor quality and 27% were both ungradable and of poor quality. Images ungradable for NPDR and PDR were more likely to be poorer quality ($p<0.001$) and missing protocol images ($p<0.001$). NPDR- and PDR-gradable images were less likely to have small pupils/media opacities than ungradable images ($p<0.001$). Images ungradable for DMO were associated with poorer image quality ($p<0.001$), cataracts ($p<0.001$) and small pupils/media opacities ($p=0.04$) vs. the DMO-gradable subset. Presenting VA was similar in eyes with gradable and ungradable image subsets (Table 3).

In Site 1, NPDR- and PDR-ungradable images were associated with poorer image quality ($p<0.001$) and missing protocol images ($p<0.001$). Small pupils/media opacities were more common in ungradable images for NPDR, PDR and DMO subsets ($p<0.001$). For images ungradable for DMO, these images were more often associated with poorer image quality ($p<0.001$) and cataracts ($p=0.002$) vs. gradable images. In Site 2, images ungradable for NPDR and PDR were associated with missing protocol images ($p<0.001$), and NPDR-ungradable images were also associated with small pupils/media opacities ($p=0.02$). DMO-ungradable images were associated with poorer image quality ($p<0.001$), missing protocol images ($p=0.01$) and cataracts ($p=0.002$) (Table 3). Table 4 shows the gradable and ungradable imaging studies for sites separately and combined. Site 1 (vs. 2) had a higher proportion of gradable images for NPDR ($p<0.001$), PDR ($p<0.001$) and DMO ($p=0.01$).

DISCUSSION

In Indigenous Australian adults with T2D attending remote Top End NT primary care clinics, eye screening by non-ophthalmic imagers and certified CERA graders revealed a prevalence of 37.3% for NPDR, 5.4% for PDR, 0.8% for DMO, 9.0% for CSDMO and 10.1% for STDR, with some patients with STDR not having been previously identified or treated. Only one-third of participants presented with normal VA, either aided or unaided, thus identifying an unmet need in this clinical population with diabetes. While teleretinal screening by non-ocular primary care clinical staff is feasible, there were high rates of ungradable or poor quality images, with differences between sites. The demographics of Top End and Central Australian T2D participants were similar for gender and age: The majority of participants in both sites were female, with a median age (range) among Central Australian participants of 48 (19–86) years vs. 53 (29–79) for Top End participants.

In previous Indigenous Australian studies, DR prevalence ranged from 16.8 to 47%.[3, 10-17] Although DR prevalence herein is higher than in some earlier Indigenous studies, results are similar to recent data from the Telehealth Eye and Associated Services Network Study (TEAMSnet) Central Australian site[3] and the 2016 National Eye Health Survey (NEHS),[11] which also reported a higher DR prevalence than earlier studies. A PDR prevalence of 5.4% herein is similar to that in the NEHS (6.0%)[11] and the South Australian Eye Health Programme (SAEHP) (5.4%).[15] Relative to other studies (conducted 2003–2017), the PDR rate in Top End sites is higher,[5, 10, 12-14, 17-19] but lower than in the Global Diabetic Retinopathy Prevalence Study (GDRPS) (7.2%).[20] The overall DR/DMO prevalence for site 1 (25.2%) and site 2 (24.4%) was similar to the prevalence of the NEHS non-Indigenous data (28.5%)[11] and lower than the NEHS Indigenous DR/DMO prevalence nationally. By contrast, the TEAMSnet Central Australian site, which had a lower prevalence of ungradable images (≈20%), reported a DR/DMO prevalence of 47.0%. In the current study NPDR prevalence differed between site 1 (28.9%) and site 2 (40.2%). This may in part be due to identified differences in the screening protocol and potentially risk factor management, and further studies are merited to increase understanding of the site differences.

Study differences may relate to differences in methodologies. Relative to the remote Central Australian TEAMSnet site, the very remote Top End sites had a lower prevalence of CSDMO. However, STDR (laser) treatment coverage in the current study was 30%, low compared to the TEAMSnet Central Australian site (80%)[3] and the NEHS[11] for both Indigenous and non-Indigenous Australians where treatment coverage was ≥75%. This may in part be due to delayed treatment as the Top End study sites lack a local ophthalmology service, unlike Alice Springs. Individuals referred to ophthalmology as a result of screening would have to travel by plane or wait for outreach ophthalmology services for detailed assessment and treatment. At the time of this study, first-line STDR treatment was laser therapy, so treated eyes were readily identifiable from images.

The high prevalence of DR detected in all three TEAMSnet sites may be in partly due to a more sensitive screening protocol; i.e., more fields of view (5/eye) than other camera-based studies, where typically 1–2 fields were imaged.[3] The more fields of view imaged, the greater the gradable retinal area. TEAMSnet's primary care clinic-based setting may also contribute to the higher DR prevalence than observed in population and community screening studies, due to people with diabetes and suboptimal risk factor management more regularly attending primary care.

Site disparities in retinopathy severity were observed: STDR prevalence was lower in Top End study sites (10.1%) than in our Central Australian site (16.2%)[5] and the Goldfields Eye Health Survey (15.2%).[17] Other comparable studies reported a lower or similar STDR prevalence than Top End sites.[10-12, 14, 15, 18, 20] In spite of lower STDR prevalence, treatment coverage was lower in the TEAMSnet Top End sites than in the Central Australian site, the latter being similar to that reported in national Indigenous and non-Indigenous populations.

This may relate to site differences in risk factor control and medical management practices. Unfortunately, traditional risk factor data were not available. It is widely accepted that DR screening is vital for STDR detection and important for detecting earlier eye disease, which guides timely systemic risk factor control (e.g. hyperglycaemia, hypertension and smoking) as well as potential use of oral fenofibrate, to retard DR progression.[21] Site differences in eye screening intervals may also have contributed to the observed differences in STDR rates.

Site differences in DR prevalence may also be due to differences in health behaviours of the communities. For example, in our TEAMSnet Central Australian cohort with a higher STDR prevalence, we reported suboptimal diet quality, physical activity and emotional wellbeing, although smoking prevalence was lower than in the national Indigenous population.[22] No comparable behavioural data are available for the Top End cohort, but it is plausible that the Top End coastal communities may have different health behaviours e.g., better diet than desert communities. To maximise benefit of diabetes eye screening in non-urban primary-care settings, integration of screening results and primary care electronic health records, as in the Central Australian TEAMSnet site, would add value to screening effectiveness and subsequently to diabetes-related health outcomes. Similar to findings in our TEAMSnet Central Australian study site,[3] unsurprisingly, ungradable images were linked to poorer image quality, missing images and small pupils/media opacities. This highlights the importance of providing retinal image capture training and imager accreditation to decrease ungradable image rates and build workforce capacity. A detailed image capture manual, pupil dilation protocol and continuous training could help reduce unnecessary referrals to ophthalmic clinics for re-examination due to ungradable images.

Images ungradable for DMO were associated with cataract in both Top End sites. Cataracts affect the central macula image in particular, making the retina ungradable for DMO. We recognise that optical coherence tomography,[23] rather than retinal imaging, is the gold standard for DMO detection, but is not feasible in primary care. A high number of ungradable images increases the number of referrals to ophthalmic clinicians, most of which will not result in a STDR diagnosis. These referrals may increase waiting times for people with proven pathology based on gradable screening and increase apprehension among participants. It may also discourage adherence to eye screening recommendations, increase administrative duties and ultimately reduce cost-effectiveness of screening.

Over two-thirds of the participants had impaired or reduced VA, which may reduce quality of life and self-care, including that related to diabetes foot care, blood glucose monitoring and insulin dosing. Visual impairment and blindness in Indigenous Australians with diabetes is largely preventable.[(24)] The observed low proportion with normal VA, likely due to prevalent DR, uncorrected refractive errors and cataracts, indicates suboptimal access to effective eye care services.

In the current study there was a high turnover of clinical and study staff, typical of remote and very remote settings, even with appropriate payment and workload. Schultz *et al* emphasised that concentrating on mental health and the role of services outside the health sector may positively impact wellbeing of Indigenous people in remote/very remote Australia.[(25)] More attention to overall worker wellbeing may empower workers, improve work morale and reduce high staff turnover rates.[(25)] Well-implemented resources to improve the overall wellbeing of the Indigenous population, including community needs, may directly benefit overall health. Concentrating on wellbeing and building excellent relationships between patients and health professionals may be key to reducing health and socio-economic disadvantage in Indigenous Australians.[(25)] The high proportion of ungradable images in this very remote setting raises the question of the relative merit of overcoming the barriers to obtaining quality images versus increasing visiting outreach services by optometrists and ophthalmologists.

Study strengths include use of clinically diagnosed diabetes and camera-based eye screening in primary-care practices by Aboriginal health workers and other clinical staff, which is reimbursable by Medicare, provided images are gradable. Studies based on self-reported diabetes may overestimate DR.[26] Use of a five-field protocol increases sensitivity for DR detection, and this assessment of unsuccessful screening and associated factors is an important contribution to the Indigenous diabetic eye disease literature. Study limitations include those of photography-based screening including lack of retinal thickness information requiring stereoscopic photography, optical coherence tomography, or other direct measurements. Use of surrogate markers for DMO reduces diagnostic sensitivity and specificity, introducing risk of under-referrals and lost opportunity for intervention of DMO. Other limitations are the lack of VA data from one site and of risk factor measures from both sites, restricting capacity for analyses of clinical and behavioural associations with eye health. The small sample size was inevitable due to geography, lack of a national Indigenous DR screening programme and high rates of ungradable images, potentially limiting generalisability. Furthermore, as participants were recruited both actively and opportunistically, referral bias may exist, however, in this very remote setting and patient population this is likely minor. Assuming that DR/DMO prevalence of is the same in gradable and ungradable cases may impact prevalence data accuracy.

In conclusion, our Top End primary-care based diabetes eye disease screening study reveals a high prevalence of DR, suboptimal STDR treatment coverage, high rates of reduced VA and room for improvement in image acquisition quality. It highlights need for high-quality DR screening to facilitate effective DR management for the increasing number of Indigenous Australians with diabetes. Quality DR management in very remote Australia requires a multidisciplinary approach concentrating on overall wellbeing of Australians with diabetes and improved support of and access to primary-care and eye care services.

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REFERENCES

1. Foreman J, Keel S, Xie J, Van Wijngaarden P, Taylor HR, Dirani M. Adherence to diabetic eye examination guidelines in Australia: the National Eye Health Survey. Medical Journal of Australia. 2017;206(9):402-6.

2. Group DER. Frequency of evidence-based screening for retinopathy in type 1 diabetes. New England Journal of Medicine. 2017;376(16):1507-16.

3. Brazionis L, Jenkins A, Keech A, Ryan C, Brown A, Boffa J, et al. Diabetic retinopathy in a remote Indigenous primary healthcare population: a Central Australian diabetic retinopathy screening study in the Telehealth Eye and Associated Medical Services Network project. Diabetic Medicine. 2018;35(5):630-9.

4. Brazionis L, Jenkins A, Keech A, Ryan C, Brown A, Boffa J, et al. Diabetic retinopathy in a remote Indigenous primary healthcare population: a Central Australian diabetic retinopathy screening study in the Telehealth Eye and Associated Medical Services Network project. Diabet Med. 2018;35(5):630-9.

5. Brazionis L, Jenkins A, Keech A, Ryan C, Bursell S-E. An evaluation of the telehealth facilitation of diabetes and cardiovascular care in remote Australian Indigenous communities:-protocol for the telehealth eye and associated medical services network [TEAMSnet] project, a pre-post study design. BMC health services research. 2017;17(1):13.

6. Bourne RR, Flaxman SR, Braithwaite T, Cicinelli MV, Das A, Jonas JB, et al. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. The Lancet Global Health. 2017;5(9):e888-e97.

7. Horton MB, Silva PS, Cavallerano JD, Aiello LP. Clinical components of telemedicine programs for diabetic retinopathy. Curr Diab Rep. 2016;16(12):129.

8. Wong TY, Sun J, Kawasaki R, Ruamviboonsuk P, Gupta N, Lansingh VC, et al. Guidelines on diabetic eye care: the International Council of Ophthalmology Recommendations for screening, follow-up, referral, and treatment based on resource settings. Ophthalmology. 2018;125(10):1608-22.

9. Mitchell P, Foran S, Foran J. Guidelines for the management of diabetic retinopathy. National Health and Medical Research Council. 2008.

10. Xie J, Arnold AL, Keeffe J, Goujon N, Dunn RA, Fox S, et al. Prevalence of self-reported diabetes and diabetic retinopathy in indigenous Australians: the National Indigenous Eye Health Survey. Clinical & experimental ophthalmology. 2011;39(6):487-93.

11. Keel S, Xie J, Foreman J, Van Wijngaarden P, Taylor HR, Dirani M. The prevalence of diabetic retinopathy in Australian adults with self-reported diabetes: the National Eye Health Survey. Ophthalmology. 2017;124(7):977-84.

12. O'halloran RA, Turner AW. Evaluating the impact of optical coherence tomography in diabetic retinopathy screening for an Aboriginal population. Clinical & experimental ophthalmology. 2018;46(2):116-21.

13. Moynihan V, Turner A. Coordination of diabetic retinopathy screening in the Kimberley region of Western Australia. Australian Journal of Rural Health. 2017;25(2):110-5.

14. Jaross N, Ryan P, Newland H. Prevalence of diabetic retinopathy in an Aboriginal Australian population: results from the Katherine Region Diabetic Retinopathy Study (KRDRS). Report no. 1. Clinical & experimental ophthalmology. 2003;31(1):32-9.

15. Durkin SR, Casson R, Newland HS, Selva D. Prevalence of trachoma and diabetes-related eye disease among a cohort of adult Aboriginal patients screened over the period 1999–2004 in remote South Australia. Clinical & experimental ophthalmology. 2006;34(4):329-34.

16. Diamond JP, McKinnon M, Barry C, Geary D, McAllister IL, House P, et al. Non-mydriatic fundus photography: a viable alternative to fundoscopy for identification of diabetic retinopathy in an Aboriginal population in rural Western Australia? Australian and New Zealand journal of ophthalmology. 1998;26(2):109-15.

17. Clark A, Morgan WH, Kain S, Farah H, Armstrong K, Preen D, et al. Diabetic retinopathy and the major causes of vision loss in Aboriginals from remote Western Australia. Clinical & experimental ophthalmology. 2010;38(5):475-82.

18. Landers J, Henderson T, Abhary S, Craig J. Prevalence and associations of diabetic retinopathy in indigenous Australians within central Australia: the Central Australian Ocular Health Study. Clinical & experimental ophthalmology. 2010;38(4):393-7.

19. Murray RB, Metcalf SM, Lewis PM, Mein JK, McAllister IL. Sustaining remote-area programs: retinal camera use by Aboriginal health workers and nurses in a Kimberley partnership. Medical journal of Australia. 2005;182(10):520-3.

20. Yau JW, Rogers SL, Kawasaki R, Lamoureux EL, Kowalski JW, Bek T, et al. Global prevalence and major risk factors of diabetic retinopathy. Diabetes care. 2012;35(3):556-64.

21. Keech AC, Mitchell P, Summanen P, O'Day J, Davis TM, Moffitt M, et al. Effect of fenofibrate on the need for laser treatment for diabetic retinopathy (FIELD study): a randomised controlled trial. The Lancet. 2007;370(9600):1687-97.

22. Xu D, Jenkins A, Ryan C, Keech A, Brown A, Boffa J, et al. Health-related behaviours in a remote Indigenous population with Type 2 diabetes: a Central Australian primary care survey in the Telehealth Eye and Associated Medical Services Network [TEAMS net] project. Diabetic Medicine. 2019.

23. Virgili G, Menchini F, Casazza G, Hogg R, Das RR, Wang X, et al. Optical coherence tomography (OCT) for detection of macular oedema in patients with diabetic retinopathy. Cochrane Database of Systematic Reviews. 2015(1).

24. Taylor HR, Xie J, Fox S, Dunn RA, Arnold AL, Keeffe JE. The prevalence and causes of vision loss in Indigenous Australians: the National Indigenous Eye Health Survey. Medical Journal of Australia. 2010;192(6):312-8.

25. Schultz R, Quinn S, Wilson B, Abbott T, Cairney S. Structural modelling of wellbeing for Indigenous Australians: importance of mental health. BMC health services research. 2019;19(1):488.

26. Foreman J, Xie J, Keel S, Van Wijngaarden P, Taylor HR, Dirani M. The validity of self-report of eye diseases in participants with vision loss in the National Eye Health Survey. Scientific reports. 2017;7(1):8757.

APPENDIX

TEAMSnet Study Group:

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Table 1. Presenting distance visual acuity [monocular and binocular] of participants screened at Top End Site 1

Presenting monoscopic visual acuity, Total number, n (%)			Presenting binocular visual acuity Total number, n (%)
Category	Definition	244 eyes (73.9%)	122 people (75.3%)
Blindness, n (%)	<6/60	1 (0.4)	1 (0.8)
Impaired vision, n (%)	< 6/12 and ≥ 6/60	30 (12.3)	19 (15.6)
Reduced vision, n (%)	<6/6 and ≥6/12	118 (48.4)	64 (52.5)
Normal vision, n (%)	6/6 or better	95 (38.9)	38 (31.1)

Table 2. DR and maculopathy prevalence, by site, participant and eye

	Sites 1 and 2 combined		Site 1		Site 2		
Service delivery/Screening protocol differences			• 12 local staff members • Centervue DRS camera • Images downloaded and transferred manually		• 1 full time imager & 1 study coordinator • Canon CR-2 camera • Images transferred via secure server		Difference between sites [p value]
DR grade	Worse eye [count (prevalence); n (%)]	Per eye [count (proportion); n (%)]	Worse eye [count (prevalence); n (%)]	Per eye [count (proportion); n (%)]	Worse eye [count (prevalence); n (%)]	Per eye[count (proportion); n (%)]	
Total number imaged	287	574	163	326	124	248	
DR/DMO gradable subset		495 (100)		290 (100)		205 (100)	
1. DR/DMO Present		123 (24.8)		73 (25.2)		50 (24.4)	0.84
2. DR/DMO Absent		372 (75.2)		217 (74.8)		155 (75.6)	
NPDR severity level for gradable subset	188 (100)	339 (100)	130 (100)	242 (100)	58 (100)	97 (100)	
1. NPDR Present		109 (32.2)		70 (28.9)		39 (40.2)	0.04
1. NPDR Absent	118 (62.7)	230 (67.8)	86 (66.2)	172 (71.1)	32 (55.2)	58 (59.8)	
Mild	46 (24.5)	75 (22.1)	29 (22.3)	49 (20.3)	17 (29.3)	26 (26.8)	
Moderate	19 (10.1)	28 (8.3)	13 (10.0)	18 (7.4)	6 (10.3)	10 (10.3)	
Severe	5 (2.7)	6 (1.8)	2 (1.5)	3 (1.2)	3 (5.2)	3 (3.1)	
PDR severity level for gradable subset	184 (100)	331 (100)	129 (100)	240 (100)	55 (100)	91 (100)	
1. PDR present		14 (4.2)		7(2.9)		7 (7.7)	0.05
1. PDR absent	174 (94.6)	317 (95.8)	124 (96.1)	233 (97.1)	50 (90.9)	84 (92.3)	
PDR untreated	4 (2.2)	6 (1.8)	1 (0.8)	1 (0.4)	3 (5.5)	5 (5.5)	
PDR treated	6 (3.2)	8 (2.4)	4 (3.1)	6 (2.5)	2 (3.6)	2 (2.2)	
DMO severity level for DMO-gradable subset	256 (100)	477 (100)	148 (100)	282 (100)	108 (100)	195 (100)	
1. DMO present		36 (7.5)		22 (7.8)		14 (7.2)	0.08
1. DMO absent	231 (90.2)	441 (92.5)	135 (91.2)	260 (92.2)	96 (88.9)	181 (92.8)	
Non-clinically significant	2 (0.8)	2 (0.4)	0 (0)	0 (0)	2 (1.9)	2 (1.0)	
Clinically significant	23 (9.0)	34 (7.1)	13 (8.8)	22 (7.8)	10 (9.3)	12 (6.2)	
STDR for STDR gradable subset (worse eye)	259 (100)		149 (100)		110 (100)		
1. STDR present	26 (10.1)		14 (9.3)		12 (10.9)		0.69
1. STDR absent	233 (89.9)		135 (90.7)		98 (89.1)		
Clinically significant DMO	16 (6.2)		9 (6.0)		7 (8.2)		
PDR	3 (1.2)		1 (0.7)		2 (1.6)		
Clinically significant DMO and PDR	7 (2.7)		4 (2.7)		3 (2.4)		

Table 3. Ungradable imaging studies and associations, by site and eye

Site 1		Gradable eyes for NPDR [n (%)]	Ungradable eyes for NPDR [n (%)]	p-value	Gradable eyes for PDR [n (%)]	Ungradable eyes for PDR [n (%)]	p-value	Gradable eyes for DMO [n (%)]	Ungradable eyes for DMO [n (%)]	p-value
Total eyes [n = 326]		242 (74.2)	84 (25.8)		240 (73.6)	86 (26.4)		282 (86.5)	44 (13.5)	
Visual acuity	Normal	78 (41.7)	17 (29.8)	0.39	79 (41.6)	16 (29.6)	0.4	84 (40.2)	11(31.4)	0.66
	Reduced	86 (46.0)	32 (56.1)		88 (46.3)	30 (55.6)		100 (47.8)	18 (51.4)	
	Impaired	22 (11.8)	8 (14.0)		22 (11.6)	8 (14.8)		24 (11.5)	6 (17.1)	
	Blind	1 (0.5)	0 (0)		1 (0.5)	0 (0)		1 (0.5)	0 (0)	
Image quality	Excellent	47 (19.6)	7 (10.3)	<0.001	47 (19.7)	7 (10.0)	<0.001	52 (18.8)	2 (6.3)	<0.001
	Good	120 (50.0)	7 (10.3)		121 (50.8)	6 (8.6)		124 (44.9)	3 (9.4)	
	Poor	73 (30.4)	54 (79.4)		70 (29.4)	57 (81.4)		100 (36.2)	27 (84.4)	
Small pupils/Media opacities	Yes	0 (0.0)	10 (11.0)	<0.001	0 (0.0)	10 (11.8)	<0.001	2 (1.3)	8 (17.0)	<0.001
	No	108 (100)	81 (89.0)		114 (100)	75 (88.2)		150 (98.7)	39 (83.0)	
Missing protocol images	Yes	30 (25.9)	50 (63.3)	<0.001	26 (22.8)	54 (66.7)	<0.001	61 (40.1)	19 (44.2)	0.63
	No	86 (74.1)	29 (36.7)		88 (77.2)	27 (33.3)		91 (59.9)	24 (55.8)	
Cataract	Yes	1 (0.9)	4 (5.1)	0.07	1 (0.9)	4 (4.9)	0.08	1 (0.7)	4 (9.3)	0.002
	No	115 (99.1)	75 (94.9)		113 (99.1)	77 (95.1)		151 (99.3)	39 (90.7)	
Site 2		Gradable NPDR [n (%)]	Ungradable NPDR [n (%)]	p-value	Gradable PDR [n (%)]	Ungradable PDR [n (%)]	p-value	Gradable DMO [n (%)]	Ungradable DMO [n (%)]	p-value
Total eyes [n = 248]		97 (39.1)	151 (60.9)		91 (36.7)	157 (63.3)		195 (78.6)	53 (21.4)	
Image quality	Excellent	42 (44.2)	57 (41.6)	0.07	36 (40.0)	63 (44.4)	0.07	97 (50.8)	2 (4.9)	<0.001
	Good	15 (15.8)	10 (7.3)		15 (16.7)	10 (7.0)		25 (13.1)	0 (0)	
	Poor	38 (40.0)	70 (51.1)		39 (43.3)	69 (48.6)		69 (36.1)	39 (95.1)	
Small pupils/Media opacities	Yes	0 (0.0)	15 (9.8)	0.02	1 (1.9)	14 (9.3)	0.08	13 (8.3)	2 (4.3)	0.35
	No	50 (100)	138 (90.2)		51 (98.1)	137 (90.7)		143 (91.7)	45 (95.7)	
Missing protocol images	Yes	23 (39.7)	122 (84.1)	<0.001	18 (34.6)	127 (84.1)	<0.001	119 (76.3)	26 (55.3)	0.01
	No	35 (60.3)	23 (15.9)		34 (65.4)	24 (15.9)		37 (23.7)	21 (44.7)	
Cataract	Yes	2 (3.4)	3 (2.1)	0.57	2 (3.8)	3 (2.0)	0.46	1 (0.6)	4 (8.5)	0.002
	No	56 (96.6)	142 (97.9)		50 (96.2)	148 (98.0)		155 (99.4)	43 (91.5)	
Both sites		Gradable NPDR [n (%)]	Ungradable NPDR [n (%)]	p-value	Gradable PDR [n (%)]	Ungradable PDR [n (%)]	p-value	Gradable DMO [n (%)]	Ungradable DMO [n (%)]	p-value
Total eyes		339 (59.1)	235 (40.9)		331 (57.7)	243 (42.3)		477 (83.1)	97 (16.9)	
Visual acuity	Normal	78 (41.7)	17 (29.8)	0.39	79 (41.6)	16 (29.6)	0.40	84 (40.2)	11 (31.4)	0.66
	Reduced	86 (46.0)	32 (56.1)		88 (46.3)	30 (55.6)		100 (47.8)	18 (51.4)	
	Impaired	22 (11.8)	8 (14.0)		22 (11.6)	8 (14.8)		24 (11.5)	6 (17.1)	
	Blind	1 (0.5)	0 (0)		1 (0.5)	0 (0)		1 (0.5)	0 (0)	
Image quality	Excellent	89 (26.6)	64 (31.2)	<0.001	83 (25.3)	70 (33.0)	<0.001	149 (31.9)	4 (5.5)	<0.001
	Good	135 (40.3)	17 (8.3)		136 (41.5)	16 (7.5)		149 (98.0)	3 (2.0)	
	Poor	111 (31.1)	124 (60.5)		109 (33.2)	126 (59.4)		169 (36.2)	66 (90.4)	
Small pupils/Media opacities	Yes	0 (0)	25 (10.2)	<0.001	1 (0.6)	24 (10.2)	<0.001	15 (4.9)	10 (10.6)	0.04
	No	158 (100)	219 (89.8)		165 (99.4)	212 (89.8)		293 (95.1)	84 (89.4)	
Missing protocol images	Yes	53 (30.5)	172 (76.8)	<0.001	44 (26.5)	181 (78.0)	<0.001	180 (58.4)	45 (50.0)	0.16
	No	121 (69.5)	52 (23.2)		122 (73.5)	51 (22.0)		128 (41.6)	45 (50.0)	
Cataract	Yes	3 (1.7)	7 (3.1)	0.38	3 (1.8)	7 (3.0)	0.45	2 (0.6)	8 (8.9)	<0.001
	No	171 (98.3)	217 (96.9)		163 (98.2)	225 (97.0)		306 (99.4)	82 (91.1)	

Table 4. Ungradable imaging studies by screening grade and site

	Site 1 & Site 2 combined [n (%)]	Site 1 [n (%)]	Site 2 [n (%)]	Difference between sites [p-value]
Total number of eyes	574	326	248	
NPDR				
1. Gradable	339 (59.1)	242 (74.2)	97 (39.1)	<0.001
2. Ungradable	235 (40.9)	84 (25.8)	151 (60.9)	
PDR				
1. Gradable	331 (57.7)	240 (73.6)	91 (36.7)	<0.001
2. Ungradable	243 (42.3)	86 (26.4)	157 (63.3)	
DMO				
1. Gradable	477 (83.1)	282 (86.5)	195 (78.6)	0.01
2. Ungradable	97 (16.9)	44 (13.5)	53 (21.4)	