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Original research

Real-world screening for diabetes in early pregnancy: Improved screening uptake using universal glycated haemoglobin

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ABSTRACT

Aims: To improve perinatal outcomes, screening for hyperglycaemia using 75 g oral glucose tolerance test (OGTT) is recommended for all pregnant women at 24–28 weeks gestation (routine), and earlier if high-risk. Screening coverage for remote and Aboriginal Australian women is less than ideal. This study examined OGTT completion (early and routine) by women from rural and remote Western Australia compared with early glycated haemoglobin (HbA_{1c}).
Methods: In 2015–2018, 27 primary health care sites recruited 600 (233 Aboriginal) women aged ≥16-years, without pre-existing diabetes, who delivered >30-weeks gestation. All women presenting <20-weeks gestation (541) were offered an early study HbA_{1c}. Early OGTTs were requested at the discretion of the local clinician, with routine OGTT offered at 24–28 weeks.
Results: HbA_{1c} uptake was high (85.7% Aboriginal, 86.4% non-Aboriginal); OGTT completion in Aboriginal women was low (early OGTT: 38.6% v 69.6% non-Aboriginal, $P < 0.001$; routine OGTT: 44.5% v 84.7% non-Aboriginal, $P < 0.001$). Aboriginal women with both early tests had HbA_{1c} completed 3-weeks prior to OGTT (9.6 ± 3.5 v 12.5 ± 3.5 weeks gestation, $P < 0.001$).
Conclusions: Universal early pregnancy HbA_{1c} appears feasible as an early screening test for women at risk of hyperglycaemia in pregnancy and would expedite and increase screening in Aboriginal women compared to an early OGTT.

1. Introduction

Diabetes in pregnancy is associated with adverse maternal and fetal outcomes including preeclampsia, stillbirth, congenital anomalies and excess fetal growth [1]. Optimisation of maternal blood glucose levels, both before and throughout pregnancy, can improve birth outcomes for women with known diabetes [2]. However, an estimated 92% of diabetes in pregnancy is detected during gestation and classified as either overt diabetes in pregnancy or gestational diabetes mellitus (GDM) [3,4].

Testing for overt diabetes should be conducted as early in pregnancy as possible to optimise maternal glycaemia and improve birth outcomes [4–6]. Early screening and diagnosis by 75 g oral glucose tolerance test (OGTT) or measurement of the long-term glycaemic marker glycated haemoglobin (HbA_{1c}) is often done in

Abbreviations: ADIPS, Australasian Diabetes in Pregnancy Society; GDM, gestational diabetes mellitus; HbA_{1c}, glycated haemoglobin; IADPSG, International Association of the Diabetes and Pregnancy Study Groups; NHMRC, National Health and Medical Research Council; OGTT, 75 g oral glucose tolerance test; RACGP, The Royal Australian College of General Practitioners; RANZCOG, The Royal Australian and New Zealand College of Obstetricians and Gynaecologists.

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primary healthcare settings. Currently, all Australian stakeholders recommend a risk-factor based approach to early screening: the Australasian Diabetes in Pregnancy Society (ADIPS) [7]; The Royal Australian and New Zealand College of Obstetricians and Gynaecologists (RANZCOG) [8]; the National Health and Medical Research Council (NHMRC) [9]; and the Royal Australian College of General Practitioners (RACGP) [10]. In addition to diagnosis of overt diabetes in pregnancy, ADIPS and RANZCOG both endorse the World Health Organization recommendation for a 75 g oral glucose tolerance test (OGTT) for diagnosis of GDM at any gestation and make no distinction between early and standard GDM diagnostic criteria [7,8,11].

Reliance on the OGTT in pregnancy, especially early in pregnancy, fails to recognise that it is a poorly tolerated test and difficult to achieve within the limited timeframe available. Rates of OGTT uptake in rural and remote Australian antenatal populations are low (41–56%) [12]. Clinicians anecdotally reported difficulty in achieving one, let alone two pregnancy OGTT for their antenatal patients, during co-design of the Western Australian Optimisation of Rural Clinical and Haematological Indicators for Diabetes in pregnancy (ORCHID) study (vide infra). Furthermore, Australian Aboriginal women are less likely to complete a pregnancy OGTT compared to non-Aboriginal women (OR 0.45) [12]. Low OGTT uptake in this population with a high background prevalence of diabetes is concerning [13,14].

Compared to an OGTT, HbA_{1c} presents as a more acceptable test as it can be measured on a single, non-fasting sample without requirement for glucose load [15]. However, ADIPS (2014) only recommend HbA_{1c} for classification of overt diabetes (≥6.5%, 48 mmol/mol) citing a lack of evidence for intervention below this level [7]. By contrast, the NHMRC (2017) and RACGP (2020) endorse International Association of the Diabetes in Pregnancy Study Groups (IADPSG) 2016 working group suggestions for classification of hyperglycaemia in early pregnancy (HbA_{1c} ≥5.9%, 41 mmol/mol) [9,10,16]. The IADPSG suggested threshold captures women with either overt diabetes in pregnancy or GDM (by OGTT), and elevated risk for adverse birth outcome [17]. RANZCOG continue to refer Australian clinicians to the ADIPS 2014 early HbA_{1c} recommendation but did reference the New Zealand HbA_{1c} study (the basis for the IADPSG working group recommendation) in the 'other suggested reading' section of their latest guideline for GDM [8,17,18].

The ORCHID study was co-designed with community, health care professionals and researchers to retrospectively evaluate OGTT screening coverage and to prospectively evaluate the utility of alternative glycaemic markers, including HbA_{1c}. An early HbA_{1c} threshold ≥5.6% (38 mmol/mol) identified Aboriginal ORCHID study participants with apparent prediabetes in early pregnancy (specificity 93.9% [95% CI 87.2–97.7] and predictive value 71.4% [95% CI 47.8–88.7%] for a positive routine OGTT ≥24-weeks gestation) [19]. Apparent prediabetes was associated with elevated risk for adverse birth outcome in the entire cohort [19]. The aim of this paper was to compare completion of screening for hyperglycaemia by Aboriginal status (Aboriginal; non-Aboriginal) in women recruited to the ORCHID study prospective cohort. Specifically, uptake of an early pregnancy ORCHID study HbA_{1c} and uptake of clinician recommended early OGTT and universal OGTT between 24- and 28-weeks gestation.

2. Methods

2.1. Participants

Pregnant women at first antenatal presentation at a participating site, aged 16-years or older, singleton pregnancy and no documented pre-existing diabetes, were invited to take part. Data were collected from 9 January 2015 to 31 May 2018 at 27 sites in the Kimberley, Mid-West, Goldfields, Southwest and Great Southern regions of Western Australia (WA). Aboriginal women were deliberately overrepresented to allow sub-cohort analysis for this high-risk population.

Clinicians followed ADIPS 2014 guidelines for the duration of the study, which devolve recommendations for risk-factor based early screening to clinician discretion [7]. Antenatal care providers completed a questionnaire to report risk-factors for hyperglycaemia in pregnancy and whether an early OGTT was recommended. All participants were offered an early study HbA_{1c} at their first antenatal visit, irrespective of risk-factor assessment.

2.2. Laboratory testing and diagnostic criteria

Local procedures were relied on for collection and measurement of plasma glucose (fasting, random or as part of an OGTT). At first antenatal investigations an additional venous whole blood sample was collected into an EDTA tube (BD Biosciences, Australia) and transported to the central laboratory for measurement of HbA_{1c}. All HbA_{1c} results were reported to the antenatal care provider, with early OGTT recommended for women with HbA_{1c} 5.7–6.4% (39–46 mmol/mol).

Early HbA_{1c} and plasma glucose investigation was defined as measurement before 20-weeks gestation (<140 days). Routine OGTT was defined as measurement after 24-weeks gestation (≥168 days).

2.3. Statistical analysis

Study data were collected and managed using secure REDCap electronic data capture tools hosted at The University of WA [20]. All analyses were performed with Stata, version 15 (Statacorp). Differences in characteristics stratified by Aboriginal status (Aboriginal; non-Aboriginal) were compared using t-tests for continuous data and χ^2 tests for categorical data, except for differences in remoteness classification and risk-factor count. Post estimation following generalised estimating equations was used to determine if there was a linear trend across these ordered groups. Linear regression was used to determine associations with BMI at first antenatal presentation adjusted for gestational age at presentation.

As a first step regression models were created using a backwards stepwise approach to identify factors associated with early OGTT and routine OGTT completion. Following this, a nested mixed effect regression model with antenatal care sites (n = 27) included as a random effect, was fitted for the screening outcome. $P < 0.05$ was defined as statistically significant.

2.4. Ethics approval

Ethics approval was obtained from the Western Australian Aboriginal Health Ethics Committee (584), Western Australian Country Health Service Human Research Ethics Committee (RGS2924) and supported by the Kimberley Aboriginal Health Planning Forum Research Subcommittee.

3. Results

Of 694 participants, 600 continued study participation and delivered after 30-weeks gestation (Fig. 1). Aboriginal women were more likely to have additional risk-factors for hyperglycaemia in pregnancy than non-Aboriginal women, despite being younger (Table 1). Aboriginal women had higher booking BMI (Table 1) and this association was not attenuated by gestational age at first

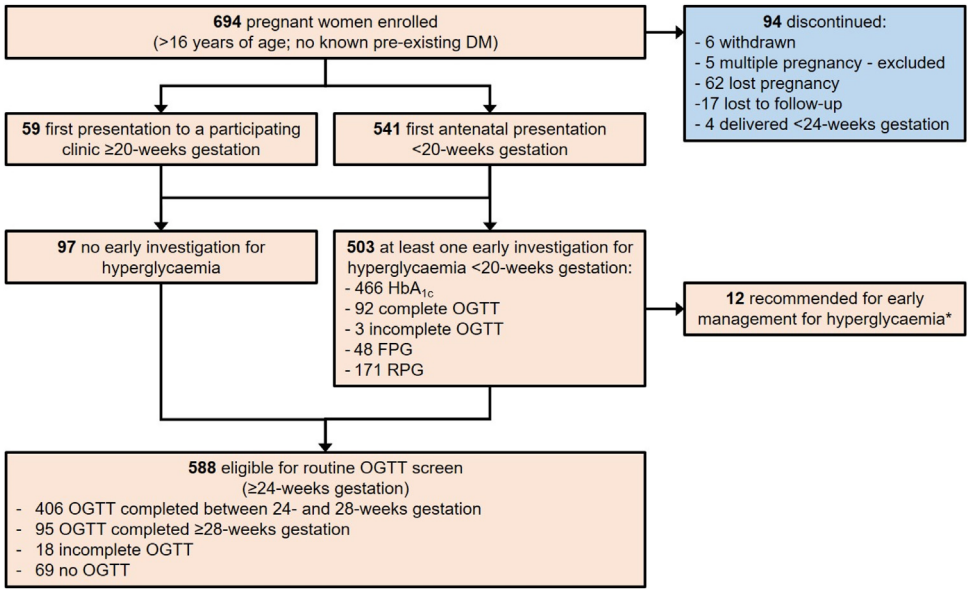

Fig. 1. Flow chart for prospective ORCHID study cohort participation and completion of early and routine screening for hyperglycaemia in pregnancy.
ORCHID = Optimisation of Rural Clinical and Haematological Indicators for Diabetes in pregnancy (study); HbA_{1c} = glycated haemoglobin; OGTT = 75 g oral glucose tolerance test; FPG = fasting plasma glucose; RPG = random (non-fasting) plasma glucose. Recommendation for early screening based on antenatal care provider judgement. Management based on Australasian Diabetes in Pregnancy Society 2014 classification criteria.

Table 1
Maternal characteristics and prevalence of risk-factors for hyperglycaemia in pregnancy in 600 ORCHID study participants, stratified by Aboriginal status.

	Aboriginal (*N* = 233)	Non-Aboriginal[a] (*N* = 367)	*P*-value
Maternal characteristic			
Age (years)	26.1 ± 5.2	30.3 ± 5.4	<0.001
BMI at first antenatal presentation[b] (kg/m^2)	28.0 ± 7.2	26.6 ± 6.0	0.009
Parity (prior delivery ≥20-weeks) ≥1 at enrolment	168 (72.1%)	242 (65.9%)	0.114
Any antenatal smoking	110 (47.2%)	54 (14.7%)	<0.001
Length of gestation at first presentation (weeks)	10.9 ± 6.9	9.4 ± 5.2	0.003
Remoteness classification of health service providing majority of antenatal care			
MMM2 (regional centres)	2 (0.9%)	49 (13.4%)	0.402
MMM3 (large rural towns)	115 (49.4%)	277 (75.5%)	0.076
MMM6 (remote communities)	54 (23.2%)	25 (6.8%)	<0.001
MMM7 (very remote communities)	62 (26.6%)	16 (4.4%)	<0.001
Risk-factor for hyperglycaemia in pregnancy[c]			
Age ≥40 years	2 (0.9%)	8 (2.2%)	0.218
Obesity (BMI[b] ≥30.0 kg/m^2)	81 (34.8%)	96 (26.2%)	0.024
Previous GDM[d]	23 (13.7%)	32 (13.2%)	0.891
Previous macrosomia[d] (birthweight >4500 g)	7 (4.2%)	9 (3.7%)	0.818
Family history of diabetes	100 (42.9%)	86 (23.4%)	<0.001
Polycystic ovarian syndrome	3 (1.3%)	27 (7.4%)	0.001
Use of corticosteroid or antipsychotic medication	5 (2.2%)	2 (0.5%)	0.075
Total number of risk-factors excluding ethnicity:			
No risk-factors	116 (49.8%)	233 (63.5%)	0.007
One risk-factor	95 (40.8%)	105 (28.6%)	0.003
Two or more risk-factors	22 (9.4%)	29 (7.9%)	0.002

Data are mean ± standard deviation for continuous variables. For categorical variables, data are number (%) of Aboriginal status group. Two-sided t-test *P*-value reported for comparison between groups for continuous data. Pearson Chi-square test *P*-value reported for comparison between groups for categorical data, *except differences in remoteness classification and risk-factor count for which postestimation following generalised estimating equations was used to test for trend across ordered groups.* ORCHID = Optimisation of Rural Clinical and Haematological Indicators for Diabetes in pregnancy study; MMM = Modified Monash Model. Data include 600 ORCHID study participants who continued study participation and delivered after 30-weeks gestation.

[a] The non-Aboriginal group was predominantly Caucasian (89.9%, *n* = 330), with the remainder of high-risk ethnicity (Māori (3.5%, n = 13); Asian (3.3%, *n* = 12); Pacific Islander (1.4%, *n* = 5); Other (1.9%, *n* = 7).

[b] Body mass index (BMI) calculated as maternal weight in kilograms at first antenatal visit divided by the square of maternal height in meters.

[c] Risk-factors for hyperglycaemia in pregnancy according to Australasian Diabetes in Pregnancy Society guidelines (2014).

[d] Denominator excludes nulliparous women (190).

antenatal presentation (*P* = 0.010). The non-Aboriginal group was predominantly Caucasian (89.9%).

3.1. Early pregnancy screening

Of 541 participants who presented to a participating site before 20-weeks gestation, 522 (96.5%) had routine first antenatal blood tests (Table 2). Most Aboriginal (85.7%) and non-Aboriginal (86.4%) women also had an early ORCHID study HbA_{1c} (Table 2 and Fig. 2A). Aboriginal women had HbA_{1c} collected two weeks earlier in gestation than non-Aboriginal women (9.0 ± 3.8 v 11.0 ± 2.8 weeks, *P* < 0.001). In those who had both early tests samples for HbA_{1c} were collected from Aboriginal women three weeks earlier than OGTT (9.6 ± 3.5 v 12.5 ± 3.5 weeks, *P* < 0.001).

Table 2
Screening completion for hyperglycaemia in pregnancy by 600 ORCHID study participants, stratified by Aboriginal status.

Screening completion	Aboriginal (*N* = 233)	Non-Aboriginal (*N* = 367)	*P*-value
Early screening (<20-weeks gestation)			
Number presented early	203 (87.1%)	338 (92.1%)	0.046
Number with any first antenatal investigation[a,b]	197 (97.0%)	325 (96.2%)	0.425
Number with early HbA_{1c}[b]	174 (85.7%)	292 (86.4%)	0.958
Number with single FPG[b]	19 (9.4%)	29 (8.6%)	0.757
Number recommended for early OGTT[b]	114 (56.2%)	69 (20.4%)	<0.001
Number with complete early OGTT[c]	44 (38.6%)	48 (69.6%)	<0.001
Routine universal screening (≥24-weeks gestation)			
Number eligible for routine OGTT	229 (98.3%)	359 (97.8%)	0.693
Number with any routine investigation ≥24-weeks[a,d]	219 (95.6%)	354 (98.6%)	0.026
Number with complete routine OGTT[d]	169 (73.8%)	332 (92.5%)	<0.001

Data are number (%) of Aboriginal status group. Pearson Chi-square test P-value reported for comparison between groups. ORCHID = Optimisation of Rural Clinical and Haematological Indicators for Diabetes in pregnancy (study); HbA_{1c} = glycated haemoglobin; FPG = fasting plasma glucose; OGTT = 75 g oral glucose tolerance test. Data include 600 ORCHID study participants who continued study participation and delivered after 30-weeks gestation.

[a] Any first antenatal investigation or routine investigation includes full blood picture, iron studies and any glucose investigation done as part of a clinician requested assessment before 20-weeks gestation or after 24-weeks gestation, respectively.

[b] Denominator is number of women who presented early (<20-weeks gestation).

[c] Denominator is number of women with early OGTT recommended.

[d] Denominator is number of women eligible for routine OGTT; excludes 12 women recommended for early management of hyperglycaemia.

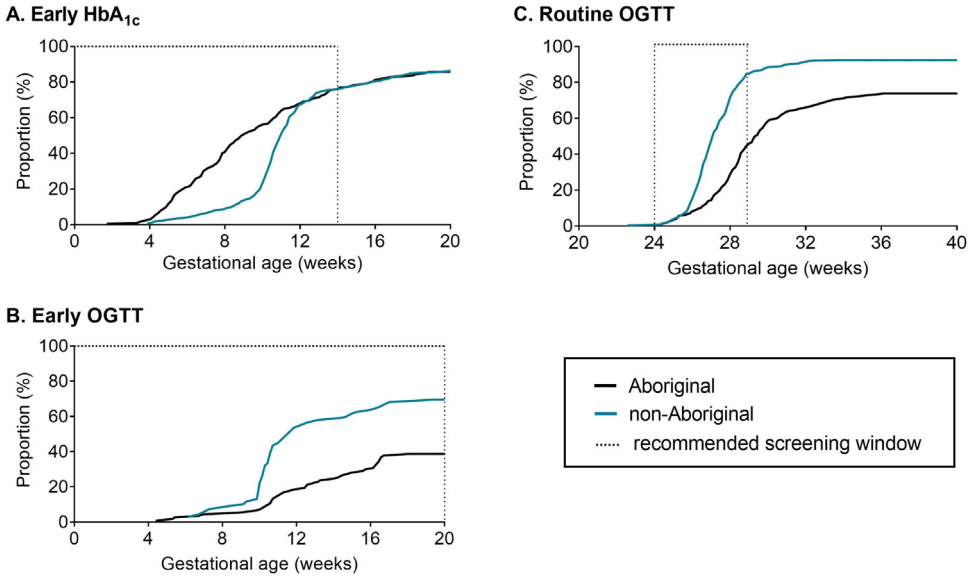

Fig. 2. Cumulative completion of study glycated haemoglobin (HbA_{1c}), clinician recommended early OGTT and routine OGTT in ORCHID study participants, stratified by Aboriginal status.
OGTT = 75 g oral glucose tolerance test; ORCHID = Optimisation of Rural Clinical and Haematological Indicators for Diabetes in pregnancy (study). (A) Data represent cumulative completion of early HbA_{1c} by gestational age in 541 ORCHID study participants (203 Aboriginal) with first antenatal presentation <20-weeks gestation. Screening window for first trimester (<14-weeks gestation) HbA_{1c} as recommended by the National Health and Medical Research Council (NHMRC). (B) Data represent cumulative completion of early OGTT by gestational age in 183 ORCHID study participants (114 Aboriginal) who were recommended by their clinician for early screening OGTT <20-weeks gestation. Recommendation for early OGTT was at the discretion of antenatal care provider. (C) Data represent cumulative completion of routine OGTT by gestational age in 588 ORCHID study participants (229 Aboriginal) who were not classified with overt diabetes in pregnancy or gestational diabetes mellitus earlier in pregnancy. Routine OGTT screening window between 24- and 28-weeks gestation as recommended by Australasian Diabetes in Pregnancy Society.

Clinicians referred 183 participants for an early OGTT based on a complete clinical picture including GDM risk-factor assessment. Common risk-factors in this group included previous GDM (26.8%, *n* = 49), obesity (47.0%, *n* = 86) and family history of diabetes (53.0%, *n* = 97). More Aboriginal participants were recommended for an early OGTT compared to non-Aboriginal women (56.2% v 20.4%, *P* < 0.001, Table 2). An early OGTT was more likely to be recommended for Aboriginal participants who had at least one additional risk-factor (74.1% v 37.4% no additional risk-factors, *P* < 0.001).

Of those referred for an early OGTT only 38.6% of Aboriginal and 69.6% of non-Aboriginal women completed the test (*P* < 0.001, Table 2 and Fig. 2B). Women with an early study HbA_{1c} 39–46 mmol/mol (5.7–6.4%) (*n* = 17) were recommended by the study protocol to have an early OGTT, however this was only completed by eight women. Women with obesity were almost twice as likely to complete testing than women without obesity. Aboriginal women were significantly less likely to complete testing (Table 3 and Fig. 2B). No other risk-factors were significantly associated with early OGTT completion in those recommended for testing.

Forty-eight women had an early fasting plasma glucose measurement (separate from any OGTT) and 171 participants had a random (non-fasting) plasma glucose measurement (Fig. 1). Twelve women met ADIPS 2014 diagnostic criteria for hyperglycaemia in pregnancy, and thus did not require a routine OGTT: overt diabetes in early pregnancy by OGTT (1 non-Aboriginal woman); early GDM by OGTT or by single fasting plasma glucose (4 Aboriginal; 7 non-Aboriginal). No participants were recommended for early

Table 3
Factors associated with completion of early and routine oral glucose tolerance test (OGTT).

Factors associated with OGTT completion:	OR [95% CI]	*P*-value
Early OGTT (<20-weeks gestation)		
Obesity (BMI at first antenatal presentation >30 kg/m^2)	1.90 [1.01–3.58]	0.047
Aboriginal status: Aboriginal	0.27 [0.09–0.78]	0.015
Routine OGTT (≥24-weeks gestation)		
Aboriginal status: Aboriginal	0.23 [0.12–0.44]	<0.001

BMI = body mass index. As a first step regression models were created using a backwards stepwise approach to identify factors associated with early OGTT completion and routine OGTT completion. Following this, a nested mixed effect regression model with antenatal care sites (n = 27) included as a random effect, was fitted for the screening outcome. Models for early OGTT completion used data from 183 ORCHID study participants recommended for an early OGTT by their clinician. Models for routine OGTT completion used data from 588 ORCHID study participants who remained eligible for a universal OGTT after 24-weeks gestation. As macrosomia (n = 17) predicted routine OGTT screening perfectly the model included data from remaining 571 participants. Factors with a *P*-value <0.05 were considered significantly associated with OGTT completion.

management of hyperglycaemia following random plasma glucose measurement.

3.2. Routine pregnancy screening

Five-hundred and eighty-eight participants remained eligible for routine screening. All 17 women who had a newborn macrosomia in a previous pregnancy completed a routine OGTT. In the remaining participants, Aboriginal women were significantly less likely to complete routine OGTT than non-Aboriginal women (Table 3), and less than half completed testing within the recommended timeframe (44.5% v 84.7% non-Aboriginal, $P < 0.001$) (Fig. 2C). There were no independent associations between early investigations or any other maternal characteristics and routine OGTT completion in the 588 eligible women.

Eighteen participants who attempted a routine OGTT were unable to complete it (vomited (10); did not return or ate during test (7); unable to ingest glucose load within 5-min (1)). A larger proportion of Aboriginal women had their OGTT cancelled due to vomiting compared to non-Aboriginal women (3.9% v 0.9%, $P = 0.019$).

4. Discussion

As anticipated due to study design, there was high uptake of early pregnancy HbA_{1c} testing by rural and remote Australian antenatal patients. As HbA_{1c} could be readily incorporated into routine non-fasting first antenatal investigations the HbA_{1c} result could be obtained much earlier in pregnancy and increased screening coverage fourfold for Aboriginal women, compared to an early OGTT (174 v 44). Similarly high acceptability for HbA_{1c} and improved screening coverage has been observed in rural and remote women and Māori women in New Zealand [21,22].

National guidelines [7,9,10] advise early screening for overt diabetes by OGTT (ADIPS preferred test), HbA_{1c} or fasting plasma glucose (NHMRC/RACGP preferred tests) in all Aboriginal women given the age-standardised fourfold higher prevalence of pregestational diabetes compared to non-Aboriginal women [23]. By contrast, local WA clinical protocols in use during the study period recommended the presence of an additional risk-factor before referral for an early OGTT [24,25]. Regardless, one in four Aboriginal women who presented early and had at least one other additional risk-factor for diabetes in pregnancy, were not recommended for an early OGTT. This was consistent with anecdotal reports at study design of clinician reluctance to recommend an early OGTT due to concerns of not obtaining a repeat OGTT later in pregnancy. Our group is currently conducting a qualitative study to more widely review clinician behaviours and attitudes to early and routine (24- to 28-weeks gestation) screening for hyperglycaemia across rural and remote WA.

Clinician uncertainty regarding early screening may have also resulted from variations in local and Australian stakeholder recommendations for tests and diagnostic criteria during recruitment. The ORCHID study commenced in 2015, three years after introduction of universal 24–28 week screening by OGTT in WA and the year following ADIPS endorsement of World Health Organization diagnostic criteria for GDM [7,11,12]. Local WA laboratories phased in reporting of the new GDM diagnostic criteria during 2015, often printing both old (ADIPS 1991) [26] and new (ADIPS 2014) [7] criteria on pathology reports. The RACGP endorsed the old ADIPS 1991 criteria throughout recruitment, however guidelines revised during the period included both the ADIPS 1991 (preferred) [26] and ADIPS 2014 (alternative) [7] diagnostic criteria for GDM [27]. The RACGP suggest general practitioners are aware of the criteria endorsed by their local obstetric service to avoid 'conflict and patient confusion' [10]. Adding to this potential confusion, the NHMRC endorsement for early pregnancy fasting plasma glucose and HbA_{1c} occurred in 2017, midway through the ORCHID study recruitment phase [9].

Despite amenability at study recruitment, it is concerning that a quarter of Aboriginal participants did not complete an OGTT after 24-weeks gestation and that only half were tested within the recommended 24- to 28-week gestation timeframe. Given the high (95.6%) uptake by Aboriginal women of other investigations after 24-weeks gestation, this suggests comparatively low acceptability of the OGTT. Reported barries include aversion to fasting during pregnancy, childcare issues, travel difficulties, and nausea and vomiting [12]. Regarding the latter, although numbers were small, Aboriginal women were less able to tolerate (i.e., hold down) the glucose load compared to non-Aboriginal women. This has not been previously reported as a specific barrier to achieving an OGTT for Aboriginal women and warrants investigation in a larger population-based dataset.

The overall disparity in OGTT completion between Aboriginal and non-Aboriginal women is consistent with previous reports for this population [12]. Low OGTT uptake has also been reported for some ethnic groups residing in New Zealand (Māori, 33.4%; Pacific People 38.5%) [22]. Likewise, postpartum screening by OGTT in Aboriginal women with previous GDM from the Northern Territory was suboptimal (31%) despite high (97%) attendance for postpartum care [28]. Reasons for lower OGTT uptake in Aboriginal women were not directly explored in the ORCHID study. As inferenced from qualitative explorations of antenatal care with Aboriginal women, social disadvantage, lack of culturally safe healthcare, lack of continuity of care, and challenges travelling for care in remote settings could be significant contributors [29–31]. Our findings warrant additional co-designed strategies for improving screening for diabetes during and after pregnancy, including evaluation of alternative tests to the OGTT.

The strength of this study is that participants were recruited from 27 sites across WA representing a broad rural and remote population. However, there are several study limitations. Although high, HbA_{1c} completion (86%) was lower than the 96–97% completion of clinician requested early antenatal investigations (including full blood picture and iron studies). This suggests that HbA_{1c} completion may be even more achievable for women who present for antenatal care before 20-weeks gestation, if requested as part of the first antenatal visit panel of investigations (i.e., not on a sepa-

rate study pathology request form for a study). Barriers to HbA_{1c} completion in this study included requests on a separate study pathology form, reluctance for women to participate in a research study and required transfer of study HbA_{1c} samples to the central State pathology laboratory when collected by a private pathology provider.

Recruitment of participants who were amenable to an OGTT later in pregnancy likely biased completion rates for OGTT between 24- and 28-weeks gestation in the study sample. This may have led to selection of women who were also more amenable to early investigations including HbA_{1c}. Furthermore, the proportion of women who presented before 20-weeks gestation in our study was at the higher end of the range reported for regional WA in 2015 (median 76.6%, range 65.4–90.9%) [32]. Therefore, our cohort is not necessarily representative of all Australian rural and remote antenatal patients.

In 2017, Aboriginal Community Controlled Health Organisations (ACCHO) and WA Country Health Services in the Kimberley region of WA implemented universal HbA_{1c} at first antenatal visit to screen for overt diabetes in pregnancy [24]. This change to clinical practice guidelines was part of one of our studies in improving maternal health (Nini Helthiwan) which included a review of all Kimberley maternal and child health protocols in 2015–2016 [33]. Protocols were updated to ensure that they continued to reflect the best evidence available [24]. Our group is currently auditing records for Kimberley Aboriginal ACCHO antenatal patients between 2018 and 2021 to evaluate early pregnancy HbA_{1c} completion and validate thresholds for classification of apparent prediabetes in pregnancy at a population level. Randomised controlled trials (RCTs) assessing the benefit of earlier intervention in women with apparent prediabetes in pregnancy are needed. However, before we can conduct an RCT with Aboriginal women we need to understand what interventions will be acceptable for this group and feasible for rural and remote clinics to deliver.

In conclusion, measurement of HbA_{1c} at first antenatal presentation for Aboriginal women and other women at risk of prediabetes and diabetes could lead to earlier and more comprehensive detection in pregnancy, compared to an early OGTT as the sole test. Expedited management of hyperglycaemia in pregnancy using co-designed family-centred self-management strategies should improve birth outcomes for high-risk populations.

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Conflict of interest

The authors declare that they have no conflicts of interest.

Ethics approval

Ethics approval was obtained from the Western Australian Aboriginal Health Ethics Committee (584), Western Australian Country Health Service Human Research Ethics Committee (RGS2924) and supported by the Kimberley Aboriginal Health Planning Forum Research Subcommittee. The research was undertaken with appropriate informed consent of participants.

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References

[1] A.M. Egan, M.L. Dow, A. Vella, A review of the pathophysiology and management of diabetes in pregnancy, Mayo Clin. Proc. 95 (2020) 2734–2746, http://dx.doi.org/10.1016/j.mayocp.2020.02.019.
[2] A.S. Alexopoulos, R. Blair, A.L. Peters, Management of preexisting diabetes in pregnancy: a review, JAMA 321 (2019) 1811–1819, http://dx.doi.org/10.1001/jama.2019.4981.
[3] International Diabetes Federation (IDF) Diabetes Atlas 9th Edition Committee, IDF Diabetes Atlas Ninth Edition 2019, IDF, Brussels, 2019, pp. 26–65, . (Accessed June 2020) http://www.diabetesatlas.org.
[4] B.E. Metzger, S.G. Gabbe, B. Persson, T.A. Buchanan, P.A. Catalano, P. Damm, A.R. Dyer, A. Leiva, M. Hod, J.L. Kitzmiler, L.P. Lowe, H.D. McIntyre, J.J. Oats, Y. Omori, M.I. Schmidt, International Association of Diabetes and Pregnancy Study Groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy, Diabetes Care 33 (2010) 676–682, http://dx.doi.org/10.2337/dc09-1848.
[5] T. Wong, G.P. Ross, B.B. Jalaludin, J.R. Flack, The clinical significance of overt diabetes in pregnancy, Diabet. Med. 30 (2013) 468–474, http://dx.doi.org/10.1111/dme.12110.
[6] American Diabetes Association, Standards of medical care in diabetes—2021: 14. Management of diabetes in pregnancy, Diabetes Care 44 (2021) S200–S210, http://dx.doi.org/10.2337/dc21-S014.
[7] A. Nankervis, H.D. McIntyre, R. Moses, G.P. Ross, L. Callaway, C. Porter, W.S. Jeffries, C. Boorman, B. De Vries, A. McElduff, Australasian Diabetes in Pregnancy Society (ADIPS) Consensus Guidelines for the Testing and Diagnosis of Hyperglycaemia in Pregnancy in Australia and New Zealand, ADIPS, 2014 http://adips.org/downloads/2014ADIPSGDMGuidelinesV18.11.2014_000.pdf.
[8] The Royal Australian and New Zealand College of Obstetricians and Gynaecologists (RANZCOG), Routine Antenatal Assessment in the Absence of Pregnancy Complications, RANZCOG, 2019 https://ranzcog.edu.au/RANZCOG_SITE/media/RANZCOG-MEDIA/Women%27s%20Health/Statement%20and%20guidelines/Clinical-Obstetrics/Routine-antenatal-assessment-in-the-absence-of-pregnancy-complications-(C-Obs-3b)_2.pdf?ext=pdf.
[9] Australian Government Department of Health, Clinical Practice Guidelines: Pregnancy Care, Commonwealth of Australia, Canberra, Australia, 2019 https://www.health.gov.au/resources/pregnancy-care-guidelines.
[10] The Royal Australian College of General Practitioners (RACGP), Management of Type 2 Diabetes: a Handbook for General Practice, RACGP, East Melbourne, Australia, 2020 http://racgp.org.au/clinical-resources/clinical-guidelines/key-racgp-guidelines/view-all-racgp-guidelines/diabetes/introduction.
[11] World Health Organization (WHO), Diagnostic criteria and classification of hyperglycaemia first detected in pregnancy: a World Health Organization Guideline, Diabetes Res. Clin. Pract. 103 (2014) 341–363, http://dx.doi.org/10.1016/j.diabres.2013.10.012.
[12] A.B. Kirke, D. Atkinson, S. Moore, K. Sterry, S. Singleton, C. Roxburgh, K. Parrish, C. Porter, J.V. Marley, Diabetes screening in pregnancy failing women in rural Western Australia: an audit of oral glucose tolerance test completion rates, Aust. J. Rural Health 27 (2019) 64–69, http://dx.doi.org/10.1111/ajr.12465.
[13] Australian Institute of Health and Welfare (AIHW), Rural and Remote Health, AIHW, Canberra, Australia, 2019 http://aihw.gov.au/reports/rural-remote-australians/rural-remote-health.
[14] Australian Institute of Health and Welfare (AIHW), Diabetes in Pregnancy 2014–2015, AIHW, Canberra, Australia, 2019 http://www.aihw.gov.au/WorkArea/DownloadAsset.aspx?id=6442472729&libID=6442472710.
[15] R.C. Hughes, J. Rowan, C.M. Florkowski, Is there a role for HbA1c in pregnancy? Curr. Diab. Rep. 16 (2016) 5, http://dx.doi.org/10.1007/s11892-015-0698-y.
[16] H.D. McIntyre, D.A. Sacks, L.A. Barbour, D.S. Feig, P.M. Catalano, P. Damm, A. McElduff, Issues with the diagnosis and classification of hyperglycemia in early pregnancy, Diabetes Care 39 (2016) 53–54, http://dx.doi.org/10.2337/dc15-1887.
[17] R.C. Hughes, M.P. Moore, J.E. Gullam, K. Mohamed, J. Rowan, An early pregnancy HbA_{1c} ≥5.9% (41 mmol/mol) is optimal for detecting diabetes and identifies women at increased risk of adverse pregnancy outcomes, Diabetes Care 37 (2014) 2953–2959, http://dx.doi.org/10.2337/dc14-1312.
[18] The Royal Australian and New Zealand College of Obstetricians and Gynaecologists (RANZCOG), Diagnosis of Gestational Diabetes Mellitus (GDM),

RANZCOG, 2017 https://ranzcog.edu.au/RANZCOG_SITE/media/RANZCOG-MEDIA/Women%27s%20Health/Statement%20and%20guidelines/Clinical-Obstetrics/Diagnosis-of-GDM-(C-Obs-7)-review-July-2017.pdf?ext=.pdf.
[19] E.L. Jamieson, E.P. Spry, A.B. Kirke, E. Griffiths, C. Porter, C. Roxburgh, S. Singleton, K. Sterry, D.N. Atkinson, J.V. Marley, Prediabetes and pregnancy: early pregnancy HbA1c identifies Australian Aboriginal women with high-risk of gestational diabetes mellitus and adverse perinatal outcomes, Diabetes Res. Clin. Pract. (2021), 108868, http://dx.doi.org/10.1016/j.diabres.2021.108868.
[20] P.A. Harris, R. Taylor, R. Thielke, J. Payne, N. Gonzalez, J.G. Conde, Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support, J. Biomed. Inform. 42 (2009) 377–381, http://dx.doi.org/10.1016/j.jbi.2008.08.010.
[21] N.M. McGrath, C. Baker, A. Simkins, Increased detection of gestational diabetes mellitus by using HbA1c screening in the first antenatal blood tests, Diabet. Med. 31 (2014) 1277, http://dx.doi.org/10.1111/dme.12519.
[22] R.C. Hughes, J. Williman, J.E. Gullam, Universal HbA1c measurement in early pregnancy to detect type 2 diabetes reduces ethnic disparities in antenatal diabetes screening: a population-based observational study, PLoS One 11 (2016) e0156926, http://dx.doi.org/10.1371/journal.pone.0156926.
[23] Australian Institute of Health and Welfare (AIHW), Australia's Mothers and Babies 2018 — in Brief, AIHW, Canberra, Australia, 2020 https://www.aihw.gov.au/reports/mothers-babies/australias-mothers-and-babies-2018-in-brief/summary.
[24] Kimberley Aboriginal Health Planning Forum, Kimberley Clinical Protocols: Diabetes in pregnancy. Ratified by the Kimberley Aboriginal Medical Services and WA Country Health Services, Kimberley, 2017 https://static1.squarespace.com/static/5b5fbd5b9772ae6ed988525c/t/5d9bfc58e77d8a0f62503e14/1570503770811/kahpf_diabetes_pregnancy.pdf.
[25] Women and Newborn Health Service, Antenatal Shared Care Guideline for General Practitioners, seventh ed., Government of Western Australia Department of Health, 2016 [Accessed November 2016].
[26] F.I. Martin, A. Vogue, R. Dargaville, C. Ericksen, J. Oats, C. Tippett, The diagnosis of gestational diabetes: recommendations from an Australasian Diabetes in Pregnancy Society ad hoc Working Party, Med. J. Aust. 155 (1991) 112.
[27] The Royal Australian College of General Practitioners (RACGP), General Practice Management of Type 2 Diabetes: 2016–18, RACGP, East Melbourne, 2016 https://www.racgp.org.au/FSDEDEV/media/documents/Clinical%20Resources/Guidelines/Diabetes/General-practice-management-of-type-2-diabetes_1.pdf.
[28] A. Wood, D. MacKay, D. Fitzsimmons, R. Derkenne, R. Kirkham, J.A. Boyle, C. Connors, C. Whitbread, A. Welsh, A. Brown, J.E. Shaw, L. Maple-Brown, Primary health care for aboriginal australian women in remote communities after a pregnancy with hyperglycaemia, Int. J. Environ. Res. Public Health 17 (2020) 22, http://dx.doi.org/10.3390/ijerph17030720.
[29] K.H. Seear, E.P. Spry, E. Carlin, D.N. Atkinson, J.V. Marley, Aboriginal women's experiences of strengths and challenges of antenatal care in the Kimberley: a qualitative study, Women Birth (2021), http://dx.doi.org/10.1016/j.wombi.2020.12.009.
[30] N. Sivertsen, O. Anikeeva, J. Deverix, J. Grant, Aboriginal and Torres Strait Islander family access to continuity of health care services in the first 1000 days of life: a systematic review of the literature, BMC Health Serv. Res. 20 (2020) 829, http://dx.doi.org/10.1186/s12913-020-05673-w.
[31] A.E. Brown, P.F. Middleton, J.A. Fereday, J.I. Pincombe, Cultural safety and midwifery care for Aboriginal women — a phenomenological study, Women Birth 29 (2016) 196–202, http://dx.doi.org/10.1016/j.wombi.2015.10.013.
[32] M. Hutchison, A. Joyce, A. Pierce, Western Australia's Mothers and Babies, 2015: 33rd Annual Report of the Western Australian Midwives' Notification System, Department of Health, Western Australia, East Perth, Australia, 2019 https://ww2.health.wa.gov.au/-/media/Files/Corporate/Reports-and-publications/Perinatal-infant-and-maternal/WA_Mothers_Babies_2015.pdf.
[33] Kimberley Aboriginal Health Planning Forum Diabetes in Pregnancy Protocol Working Group, S. Woodland, C. Howard, K. Newett, W. Hughes, J. Watts, P. Walker, P. Wilson, S. Peterson, J. Barton, J. Martin, B. O'Brien, M. Harding, E. Griffiths, E. Robinson, Kimberley Clinical Protocols: Diabetes in Pregnancy Protocol Evidence and Rationale, Kimberley Aboriginal Medical Services, WA Country Health Services and Boab Health, Kimberley, 2017 https://static1.squarespace.com/static/5b5fbd5b9772ae6ed988525c/t/5d9bfc729d666c083dbc1e15/1570503800964/Diabetes-in-Pregnancy-Protocol-Evidence-and-Rationale.pdf.