



# BMJ Open Pregnancy outcomes in women with gestational diabetes mellitus by models of care: a retrospective cohort study

Jackson Harrison <sup>1,2</sup> Sarah Melov <sup>1,2</sup> Adrienne C Kirby,<sup>2,3</sup> Neil Athayde,<sup>2</sup> Araz Boghossian,<sup>2</sup> Wah Cheung,<sup>1,4</sup> Emma Inglis,<sup>2</sup> Kavita Maravar,<sup>2</sup> Suja Padmanabhan,<sup>4</sup> Melissa Luig,<sup>5</sup> Monica Hook,<sup>2</sup> Dharmindra Pasupathy<sup>1,2</sup>

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For numbered affiliations see end of article.

## Correspondence to

Professor Dharmindra Pasupathy;  
Dharmindra.Pasupathy@sydney.edu.au

## ABSTRACT

**Objective** To compare birth outcomes of women with gestational diabetes mellitus (GDM) with background obstetric population, stratified by models of care.

**Design** Retrospective cohort study.

**Setting** A tertiary referral centre in Sydney, Australia.

**Participants** All births 1 January 2018 to 30 November 2020. Births <24 weeks, multiple gestations and women with pre-existing diabetes were excluded.

**Methods** Data were obtained from electronic medical records. Women were classified according to GDM status and last clinic attended prior to delivery. Model of care included attendance at dedicated GDM obstetric clinics, and routine antenatal care.

**Main outcome measures** Hypertensive disorders of pregnancy (HDP), pre-term birth (PTB), induction of labour (IOL), operative delivery, small for gestational age (SGA), large for gestational age, postpartum haemorrhage, obstetric anal sphincter injury (OASIS), neonatal hypoglycaemia, neonatal hypothermia, neonatal respiratory distress, neonatal intensive care unit (NICU) admission.

**Results** The GDM rate was 16.3%, with 34.0% of women managed in dedicated GDM clinics. Women with GDM had higher rates of several adverse outcomes. Only women with GDM attending non-dedicated clinics had increased odds of HDP (adjusted OR (adj OR) 1.6, 95% CI 1.2 to 2.0), PTB (adj OR 1.7, 95% CI 1.4 to 2.0), OASIS (adj OR 1.4, 95% CI 1.0 to 2.0), similar odds of induction (adj OR 1.0, 95% CI 0.9 to 1.1) compared with non-GDM women. There were increased odds of NICU admission (adj OR 1.5, 95% CI 1.3 to 1.8) similar to women attending high-risk GDM clinics.

**Conclusions** Women with GDM receiving care in lower risk clinics had similar or higher rates of adverse outcomes. Pathways of care need to be similar in all women with GDM.

## INTRODUCTION

Gestational diabetes mellitus (GDM) is the most common medical complication of pregnancy, with a prevalence of approximately 14% among pregnant women in Australia.<sup>1</sup> The rate of GDM has risen rapidly with increases in the population prevalence of risk factors associated with GDM, including maternal obesity, age and shifting

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ The study included data from multiple different models of care, all of which had high quality, complete and comparable datasets available.
- ⇒ Models were able to adjust for several important covariates.
- ⇒ The study population captured women participating in a GP-shared care model of antenatal care, results therefore account for women receiving antenatal care in the community and between community and hospital services.
- ⇒ Data were collected from a single obstetric centre in Western Sydney, Australia, this may limit the external validity of results.
- ⇒ Data were not available on glycaemic control or treatment for women on GDM, and thus models were not adjusted for the influence of glycaemic control on outcomes.

sociodemographics.<sup>2</sup> In addition, changes in diagnostic criteria based on recommendations from the International Association of Diabetes and Pregnancy Study Groups have led to a lower threshold for diagnosis.<sup>3</sup>

Adverse maternal and neonatal outcomes are associated with GDM, including but not limited to hypertensive disorders of pregnancy, preterm delivery, shoulder dystocia, caesarean section, birth weight >90th centile and neonatal hypoglycaemia.<sup>4</sup> The importance of treatment of women with GDM has been established.<sup>5</sup> Management is centred around monitoring of blood glucose (BG) levels, patient education and lifestyle modification, including monitoring of carbohydrate intake and increased physical activity. If glucose levels cannot be controlled using lifestyle modifications, or the disease is more severe, metformin or insulin may be required to manage glycaemic control.<sup>2</sup> Adverse outcomes are not limited to women with GDM requiring metformin or insulin. Higher rates of adverse outcomes are observed in

women with mild GDM<sup>6,7</sup> and those with glucose intolerance not classified as GDM.<sup>8</sup>

The rising prevalence of GDM presents a significant service delivery challenge for healthcare systems globally.<sup>9</sup> As a result of increasing requirements on maternity services, a 2018 meeting of the Australasian Diabetes in Pregnancy Society discussing the models of antenatal care for women with GDM found that centres across Australian and New Zealand have different models of care and protocols for women with GDM.<sup>10</sup> It was recognised that there was limited evidence available on how models of antenatal care impact the outcomes of women with GDM. In centres with sufficient numbers of women with GDM, dedicated GDM clinics can improve access to services such as dietetics, endocrinology and specific obstetric expertise with an interest in diabetes in pregnancy, as well as prompt clinicians to address issues related to GDM.

To assess the impact of models of care on women with GDM, a retrospective cohort study was undertaken to assess maternal and neonatal outcomes in women with GDM between those who were referred to attend dedicated GDM clinics, to women with GDM who were managed in routine antenatal clinics and lower risk models of care. Referral to dedicated clinics occurred throughout pregnancy for women with poor glucose control or increasing treatment requirements. The outcomes of both groups were compared with women without GDM to provide context to the findings from the two GDM groups.

## MATERIALS AND METHODS

### Study design

Westmead Hospital is a tertiary referral service in Western Sydney, Australia. Over the study period, there were approximately 5360 deliveries per year. A range of models of antenatal care are practised at Westmead Hospital including midwifery-led care, general practice (GP)-obstetric shared care and obstetrician-led care. Specific obstetric clinics include two maternal fetal medicine (MFM) high-risk pregnancy clinics, and two GDM clinics. Of the GDM clinics, one is allocated for highest-risk women with higher-insulin requirements or with multiple medical or obstetric comorbidities. The GDM clinics provide a higher intensity of care with more frequent obstetric and endocrine follow-up and ultrasound scans. Women do not concurrently attend GDM and MFM clinics or routine obstetric clinics.

All women diagnosed with GDM receive dietary advice through standardised education pathways and a BG metre. Women with GDM requiring insulin therapy or with significant additional medical or obstetric comorbidities are referred to the dedicated GDM clinics, as these women are considered to be at greater risk. The decision to commence insulin is primarily based on the failure to meet the glucose targets, namely fasting glucose  $<5.5$  mmol/L and 2 hours postprandial  $<7.0$  mmol/L. Women were classified into four groups depending on GDM status and the last antenatal clinic attended prior

to delivery. The four groups were: (i) women without GDM, (ii) women with GDM attending non-dedicated GDM clinics, (iii) women with GDM attending dedicated clinic 1 and (iv) women with GDM attending dedicated clinic 2. 'Dedicated clinic 2' refers to the GDM clinic for higher risk women with GDM with higher-insulin requirements or with multiple medical or obstetric comorbidities. 'Dedicated clinic 1' refers to the other GDM-specific clinic. 'Non-dedicated clinics' refer to women with a diagnosis of GDM who received care through a model outside of the dedicated clinics either in obstetric, midwifery or general practice (GP) shared care-led antenatal clinics. These women do not see an endocrinologist but are expected to report their glucose levels back to diabetes nurse educators, who may then refer the women to a dedicated clinic to start insulin if glucose targets are not met.

Processes and outcomes of interest included hypertensive disorders of pregnancy (HDP), induction of labour (IOL), operative delivery, preterm birth, small for gestational age (SGA), large for gestational age (LGA), postpartum haemorrhage (PPH), obstetric anal sphincter injuries (OASIS), neonatal hypoglycaemia, neonatal hypothermia, neonatal respiratory distress and admission to neonatal intensive care (NICU)/special care nursery (SCN). Processes and outcomes were assessed by GDM status, and then by clinic last attended prior to delivery.

The study population included all births at Westmead Hospital between 1 January 2018 and 30 November 2020. Deliveries  $<24$  weeks gestation, multiple pregnancies and women with pre-existing diabetes were excluded. Routinely collected data were obtained from electronic medical records (EMR). Data on clinic attendance for all women within the cohort were obtained from the hospital administrative database and merged with the clinical dataset. Birth weight centiles were calculated using Fenton birth weight centiles.<sup>11</sup> All data were anonymised prior to analysis.

### Definitions

Gestational diabetes was diagnosed using the 1998 Australasian Diabetes in Pregnancy Society Criteria in keeping with the local guidelines.<sup>12</sup> On the basis of a 75 g oral glucose tolerance test results of fasting BG  $\geq 5.5$  mmol/L, or 2 hour BG  $\geq 8.0$  mmol/L was diagnostic of GDM. Preterm birth was defined as birth at gestational age  $<37$  weeks. SGA and LGA were defined as Fenton birth weight centiles  $<10$ th and  $>90$ th centile, respectively,<sup>11</sup> using routinely collected gender, birth weight and gestational age data. PPH was defined as recorded blood loss  $\geq 500$  mL. HDP included women with a diagnosis of gestational hypertension or pre-eclampsia. Medical comorbidities included cardiomyopathy, maternal congenital heart disease, ischaemic heart disease, asthma, cystic fibrosis, tuberculosis, cerebrovascular disease, epilepsy, multiple sclerosis, clotting disorders, sickle cell disease and von Willebrand disease. Ethnicity was defined by clinical staff at the time of initial consultation.

## Statistical analysis

Descriptive statistics were used to summarise demographic and clinical characteristics. Comparison between groups were made using  $\chi^2$ , and two-sample t-tests as appropriate. Logistic regression was used to assess the relationship between models of care and binary outcomes. Multivariable models were fitted to assess whether any relationships were attenuated after adjustment for other risk factors, including maternal age, ethnicity, previous preterm pregnancy, parity, hypertension, method of conception, body mass index (BMI) and medical comorbidities. The models were run with GDM clinics included as a factor variable with four levels, one for GDM other, one for each of the dedicated clinics and a reference group of women without GDM. In both sets of outcomes analysis, a sensitivity analysis was performed, excluding women who were managed in high-risk MFM antenatal clinics throughout pregnancy.

Birth weight centiles were calculated using Stata V.17.0. Analysis was performed using R V.4.1.1 software.

## Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

## RESULTS

There were 15 636 births in our centre during the study period. Women with pre-existing diabetes (n=209), multiple pregnancies (n=350) and deliveries <24 weeks (n=112) were excluded. Of the remaining pregnancies (n=14 965, 95.7%), 16.6% (n=2491) were identified

as having GDM, and of these women 34.0% (n=847) attended dedicated GDM clinics ([figure 1](#)).

Women with GDM were more likely to be older, have a higher mean BMI and were more likely to be of Asian or Indian background ([table 1](#)). Multiparous women with GDM were more likely to have had a previous preterm birth or HDP. They were more likely to have chronic hypertension or thyroid disease. The rate of assisted reproduction in the GDM group was higher ([table 1](#)).

Women in the dedicated clinics had a higher mean age and BMI ([table 1](#)). Women with previous GDM requiring insulin were more likely to attend the dedicated clinics, while women with previous diet controlled GDM were more likely to attend non-dedicated clinics. Those in the dedicated clinics were more likely to have previous HDP.

Rates of outcomes by GDM status are reported in [table 2](#) and online supplemental table S1. Compared with women without GDM, pregnancies in women with GDM were more likely to be complicated by HDP (3.1% vs 5.4; adjusted OR (adj OR) 1.5, 95% CI 1.2 to 1.8), have their labour induced (37.9% vs 47.9%; adj OR 1.5, 95% CI 1.3 to 1.7), experience preterm birth <37 weeks (8.0% vs 12.0%; adj OR 1.2, 95% CI 1.1 to 1.3) and require an instrumental vaginal birth (12.7% vs 15.9%; adj OR 1.3; 95% CI 1.1 to 1.5) or caesarean section (30.5% vs 42.5%; adj OR 1.4, 95% CI 1.3 to 1.5). Neonates born to women with GDM were more likely to be LGA (6.5% vs 8.4%; adj OR 1.3, 95% CI 1.1 to 1.5), experience neonatal hypoglycaemia (1.3% vs 8.0%; adj OR 6.1, 95% CI 4.9 to 7.7), neonatal hypothermia (1.3% vs 3.3%; adj OR 2.3, 95% CI 1.7 to 3.0) and result in NICU/SCN admission (11.0% vs 16.7%; adj OR 1.4, 95% CI 1.2 to 1.6) compared with neonates born to women without GDM ([table 2](#)).

Figure 1. Cases included for analysis

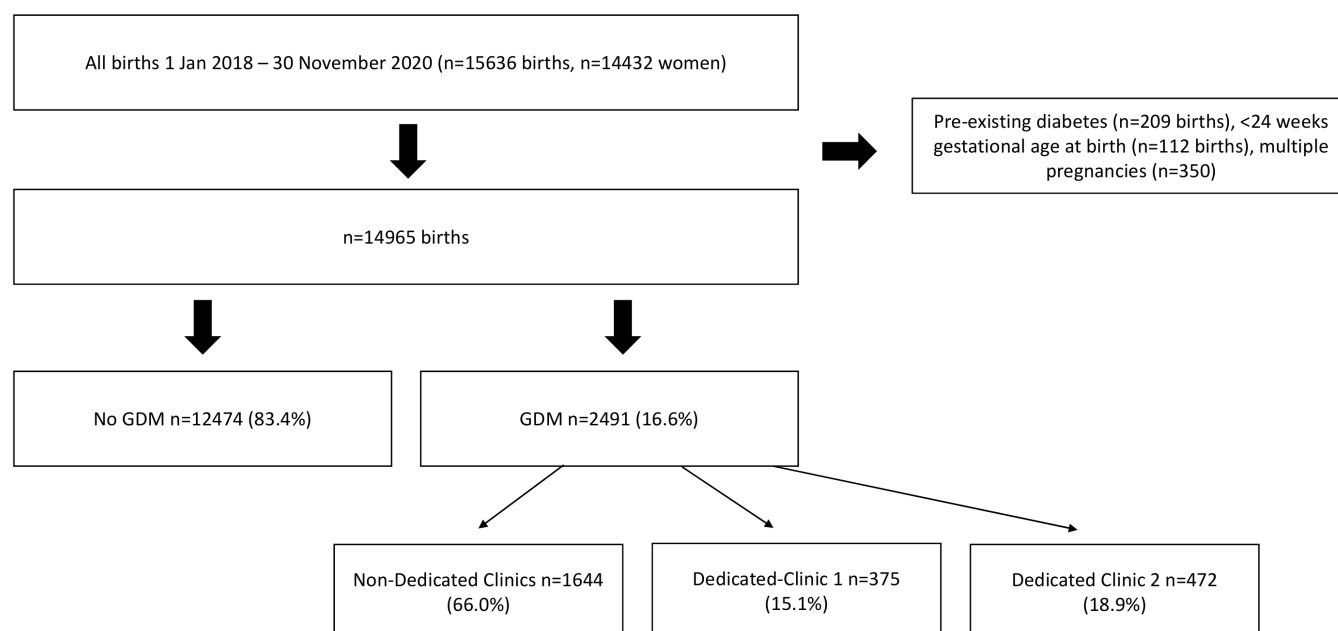


Figure 1 Cases included for analysis. GDM, gestational diabetes mellitus.

**Table 1** Demographics by clinic attendance

Characteristic	No GDM (n=12474)	All GDM (n=2491)	GDM		
			Non-dedicated clinics (n=1644)	Dedicated clinic 1 (n=375)	Dedicated clinic 2 (n=472)
Age—mean (SD)	31.1±4.9	33.1±4.7	32.9±4.7	33.0±4.4	33.6±4.8
Nulliparous	3854 (30.9%)	770 (30.9%)	539 (32.8%)	114 (30.4%)	117 (24.8%)
Gestational age at delivery—mean (SD)	38.9±2.3	38.4±2.2	38.3±2.4	38.6±1.3	38.3±1.8
Previous preterm pregnancy*	684 (7.9%)	203 (11.8%)	132 (11.9%)	22 (8.4%)	49 (13.8%)
Previous pregnancy diabetes treatment*					
Diet	311 (3.6%)	262 (15.2%)	177 (16.0%)	32 (12.3%)	53 (14.9%)
Insulin and/or oral therapy	99 (1.1%)	214 (12.4%)	77 (7.0%)	54 (20.7%)	83 (23.4%)
Family history diabetes	5022 (40.3%)	1382 (55.5%)	854 (52.0%)	234 (62.4%)	294 (62.3%)
Previous HDP*	345 (4.0%)	92 (5.3%)	49 (4.4%)	17 (6.5%)	26 (7.3%)
Assisted (including IVF)	506 (4.1%)	159 (6.4%)	115 (7.0%)	15 (4.0%)	29 (6.1%)
Medical comorbidities					
Chronic hypertension	104 (0.8%)	33 (1.3%)	15 (0.9%)	2 (0.5%)	16 (3.4%)
Thyroid disease	389 (3.1%)	126 (5.1%)	74 (4.5%)	13 (3.5%)	39 (8.3%)
Other comorbidities†	1390 (11.1%)	242 (9.7%)	171 (10.1%)	33 (9.4%)	38 (8.6%)
Smoking at booking in	739 (5.9%)	99 (4%)	69 (4.2%)	12 (3.2%)	18 (3.8%)
BMI—mean (SD)	24.96 (6.1)	26.86 (8.7)	26.16 (9.6)	27.82 (5.9)	28.54 (6.6)
Ethnicity					
Aboriginal and/or Torres Strait Islander	139 (1.1%)	18 (0.7%)	12 (0.7%)	4 (1.1%)	2 (0.4%)
East Asian	1317 (10.6%)	397 (15.9%)	324 (19.7%)	32 (8.5%)	41 (8.7%)
Caucasian/European	2047 (16.4%)	255 (10.2%)	179 (10.9%)	32 (8.5%)	44 (9.3%)
Indian	1788 (14.3%)	458 (18.4%)	262 (15.9%)	101 (26.9%)	95 (20.1%)
Lebanese	1047 (8.4%)	117 (4.7%)	75 (4.6%)	11 (2.9%)	31 (6.6%)
Other	4561 (36.6%)	971 (39%)	602 (36.6%)	155 (41.3%)	214 (45.3%)
Not known/Missing	3144 (25.2%)	567 (22.8%)	351 (21.4%)	92 (24.5%)	124 (26.3%)
*Among multiparous women only.					
†Other comorbidities including cardiomyopathy, maternal congenital heart disease, ischaemic heart disease, asthma, cystic fibrosis, tuberculosis, cerebrovascular disease, epilepsy, multiple sclerosis, clotting disorders, sickle cell, von Willebrand disease.					
BMI, body mass index; GDM, gestational diabetes mellitus; HDP, hypertensive disorders of pregnancy; IVF, in vitro fertilisation.					

\*Among multiparous women only.

†Other comorbidities including cardiomyopathy, maternal congenital heart disease, ischaemic heart disease, asthma, cystic fibrosis, tuberculosis, cerebrovascular disease, epilepsy, multiple sclerosis, clotting disorders, sickle cell, von Willebrand disease.

BMI, body mass index; GDM, gestational diabetes mellitus; HDP, hypertensive disorders of pregnancy; IVF, in vitro fertilisation.



**Table 2** Outcomes by clinic attendance

Outcome	No GDM (n=12 474)	GDM			Dedicated clinic 1 (n=375)	Dedicated clinic 2 (n=472)
		All GDM (n=2491)	Non-dedicated clinics (n=1644)			
HDP	392 (3.1%)	135 (5.4%)	95 (5.8%)	15 (4%)	25 (5.3%)	
IOL *	3896 (37.9%)	894 (47.9%)	526 (42.5%)	164 (67.5%)	204 (52.2%)	
PTB	996 (8%)	299 (12%)	232 (14.1%)	24 (6.4%)	43 (9.1%)	
Instrumental delivery*	1309 (12.7%)	297 (15.9%)	210 (17%)	44 (18.1%)	43 (11%)	
Caesarean section	3801 (30.5%)	1058 (42.5%)	697 (42.4%)	149 (39.7%)	212 (44.9%)	
SGA	987 (7.9%)	216 (8.7%)	154 (9.4%)	29 (7.7%)	33 (7%)	
LGA	810 (6.5%)	209 (8.4%)	128 (7.8%)	25 (6.7%)	56 (11.9%)	
PPH	2589 (20.8%)	577 (23.2%)	386 (23.5%)	87 (23.2%)	104 (22%)	
OASIS*	247 (2.4%)	58 (3.1%)	44 (3.6%)	7 (2.9%)	7 (1.8%)	
Neonatal hypoglycaemia	157 (1.3%)	199 (8%)	110 (6.7%)	28 (7.5%)	61 (12.9%)	
Neonatal hypothermia	164 (1.3%)	82 (3.3%)	55 (3.3%)	11 (2.9%)	16 (3.4%)	
Neonatal respiratory distress	995 (8%)	240 (9.6%)	172 (10.5%)	29 (7.7%)	39 (8.3%)	
Admission to NICU/SCN	1372 (11%)	416 (16.7%)	287 (17.5%)	45 (12%)	84 (17.8%)	

\*Percentage excluding those undergoing elective caesarean section.

GDM, gestational diabetes mellitus; HDP, hypertensive disorders of pregnancy; IOL, induction of labour; LGA, large for gestational age; NICU, neonatal intensive care unit; OASIS, obstetric anal sphincter injuries; PPH, postpartum haemorrhage; PTB, preterm birth; SCN, special care nursery; SGA, small for gestational age.

Outcomes stratified by models of care are reported in [table 3](#). Increased odds of HDP were isolated to women attending the non-dedicated clinics (adj OR 1.6, 95% CI 1.2 to 2.0). The odds of IOL was similar to the background population in women attending the non-dedicated clinics (adj OR 1.0, 95% CI 0.9 to 1.1), but was increased in both dedicated clinics (dedicated clinic 1 adj OR 1.8, 95% CI 1.4 to 2.2; dedicated clinic 2 adj OR 1.8, 95% CI 1.5 to 2.2). There was a similar increase in odds of instrumental delivery and caesarean section in all GDM groups. Higher odds of preterm birth in women with GDM was isolated to the non-dedicated clinics (adj OR 1.7, 95% CI 1.4 to 2.0). There was evidence for increased odds of OASIS in women attending non-dedicated clinics alone (adj OR 1.4, 95% CI 1.0 to 2.0). Odds of neonatal hypoglycaemia showed a dose-response pattern, with women in the dedicated clinic 2 group having the highest OR (adj OR 10.4, 95% CI 7.5 to 14.3). Higher odds of neonatal hypothermia were seen across all groups. Increased odds of neonatal respiratory distress were limited to the non-dedicated clinics (adj OR 1.2, 95% CI 1.0 to 1.4). Increased odds of NICU/SCN admission were seen in both the non-dedicated clinics (adj OR 1.5, 95% CI 1.3 to 1.8) and the dedicated clinic 2 group (adj OR 1.7, 95% CI 1.3 to 2.2). All these associations persisted following removal of the two high-risk MFM non-GDM clinics in the sensitivity analysis.

## DISCUSSION

### Main findings

There was evidence for increased risk of a range of adverse maternal and neonatal outcomes in women with GDM in our population. Stratification by clinic attendance revealed adverse outcomes distributed unevenly between the groups. Women receiving care in non-dedicated clinics alone had similar rates of induction to women without GDM, but higher risk of HDP, preterm birth, OASIS and rates of NICU/SCN admission similar to dedicated clinic 2. The odds of neonatal hypoglycaemia were distributed in a dose-response pattern with highest rates among neonates of women in dedicated clinic 2.

### Interpretation

Prevalence of gestational diabetes varies widely between populations,<sup>13 14</sup> and is increasing with advancing maternal age, increasing obesity rates and increases in the background prevalence of diabetes mellitus,<sup>15</sup> as well as changes in diagnostic criteria.<sup>3</sup> These changes place increasing pressure on healthcare systems providing antenatal care. There is little evidence available on the relationship between models of care and outcomes for women with GDM. Current National Institute for Health and Care Excellence guidelines for GDM suggest regular review in a diabetes-antenatal clinic to facilitate regular BG level monitoring and obstetric follow-up.<sup>16</sup> A study investigating Australian antenatal GDM clinics in 2018 showed heterogeneous models of care across different services,

using patient education across all the included clinics and a variety of combinations of dedicated GDM clinics, routine antenatal care and telehealth approaches.<sup>10</sup> The findings of this study highlight the need to further evaluate the impact of models of care in similar healthcare settings, given the limited evidence-based guidance in this area.

Health services that allocate only a subgroup of women with GDM to dedicated clinics imply a greater severity of disease requiring more intensive monitoring. Women in these clinics are often seen more frequently by both obstetric and endocrinology teams and likely have both GDM-related and GDM-unrelated issues addressed more promptly. Our service adapted a three-tiered system in which women with the insulin requirements and more complex comorbidities were allocated to dedicated clinic 2, those with GDM requiring insulin therapy but without significant comorbidities or with diet controlled GDM with comorbidities attend dedicated clinic 1, and those with diet controlled GDM attend non-dedicated clinics.

Our data suggest that, while all women with GDM are offered the same basic level of care including dietary advice and BG monitoring, the antenatal model is an independent factor in determining outcomes for women with GDM. Given the model of care offered to women in our cohort who are broadly stratified by the severity of GDM and complexity of pregnancy, one may expect either similar outcomes between women in non-dedicated and the background non-GDM population, or a dose-respondent pattern of outcomes if health service approach is appropriate for all risk profiles of GDM. First, women attending the non-dedicated clinics had higher rates of most adverse outcomes compared with women without GDM and with rates similar to GDM women attending dedicated clinics. The assumption of milder disease among women attending the non-dedicated clinics is not consistent with our findings. This may also be due to the differences in the intensity of BG monitoring, obstetric surveillance or compliance between models of care.

Second, the dose-response relationship with adverse outcome was only observed in neonatal hypoglycaemia. The isolated nature of increased risk of HDP and preterm birth and for women with GDM in non-dedicated clinics care suggest that the care provided, in comparison to women in dedicated clinics, is not as effective in preventing these adverse events. This constitutes an insufficient health service response to, and assumption of women otherwise considered at lower risk of GDM-related complications.

It is well established that treatment of GDM results in improved clinical outcomes. The Australian Carbohydrate Intolerance Study in Pregnant Women Trial in 2005 confirmed the benefits of treatment for gestation diabetes in preventing perinatal morbidity and improving health-related quality of life.<sup>5</sup> In 2008, the landmark Hyperglycaemia and Adverse Pregnancy Outcomes study described a continuous relationship between maternal

**Table 3** Measures of effect by clinic attendance for higher level of care clinics compared with women without GDM

Outcome	Non-dedicated clinics			Dedicated clinic 1			Dedicated clinic 2		
	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)	Adjusted OR† (95% CI)	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)	Adjusted OR† (95% CI)	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)	Adjusted OR† (95% CI)
HDP	1.8 (1.5 to 2.3)	1.6 (1.2 to 2.0)	1.6 (1.2 to 2.0)	1.4 (0.8 to 2.3)	1.2 (0.7 to 2.1)	1.2 (0.7 to 2.1)	1.9 (1.2 to 2.8)	1.2 (0.8 to 1.9)	1.2 (0.8 to 1.9)
PTB	1.8 (1.6 to 2.1)	1.7 (1.4 to 2.0)	1.7 (1.4 to 2.0)	0.8 (0.6 to 1.3)	0.8 (0.5 to 1.3)	0.8 (0.5 to 1.3)	1.2 (0.9 to 1.7)	1.1 (0.8 to 1.5)	1.1 (0.8 to 1.5)
IOL	1.0 (0.9 to 1.2)	1.0 (0.9 to 1.1)	1.0 (0.9 to 1.2)	1.8 (1.5 to 2.3)	1.8 (1.4 to 2.2)	1.8 (1.4 to 2.2)	1.8 (1.5 to 2.2)	1.8 (1.5 to 2.2)	1.8 (1.5 to 2.2)
Instrumental delivery	1.2 (1.0 to 1.4)	1.2 (1.1 to 1.5)	1.3 (1.1 to 1.5)	1.2 (0.9 to 1.7)	1.3 (1.0 to 1.9)	1.3 (0.9 to 1.7)	0.9 (0.7 to 1.7)	1.2 (0.9 to 1.7)	1.2 (0.9 to 1.7)
Caesarean section	1.6 (1.4 to 1.8)	1.3 (1.2 to 1.5)	1.3 (1.1 to 1.4)	1.7 (1.4 to 2.1)	1.3 (1.1 to 1.6)	1.3 (1.1 to 1.6)	2.1 (1.7 to 2.5)	1.3 (1.1 to 1.6)	1.5 (1.2 to 1.9)
SGA	1.2 (1.0 to 1.4)	1.1 (1.0 to 1.4)	1.1 (0.9 to 1.3)	1.0 (0.7 to 1.5)	1.0 (0.7 to 1.5)	1.0 (0.7 to 1.5)	0.9 (0.7 to 1.3)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.5)
LGA	1.2 (1.0 to 1.4)	1.1 (1 to 1.4)	1.1 (0.9 to 1.3)	1.1 (0.7 to 1.7)	1.0 (0.7 to 1.5)	1.0 (0.7 to 1.5)	2.1 (1.6 to 2.8)	1.6 (1.2 to 2.2)	1.7 (1.3 to 2.3)
PPH	1.1 (1.0 to 1.3)	1.0 (0.9 to 1.2)	1.0 (0.9 to 1.2)	1.3 (1.0 to 1.6)	1.2 (0.9 to 1.5)	1.2 (0.9 to 1.5)	1.2 (0.9 to 1.5)	1.1 (0.9 to 1.4)	1.1 (0.9 to 1.4)
OASIS	1.3 (1.0 to 1.8)	1.4 (1.0 to 2.0)	1.4 (1.0 to 2.0)	1.0 (0.5 to 2.2)	1.0 (0.5 to 2.1)	1.0 (0.5 to 2.1)	0.8 (0.4 to 1.7)	1.0 (0.5 to 2.1)	1.0 (0.4 to 2.1)
Neonatal hypoglycaemia†	5.4 (4.2 to 7.0)	5.1 (3.9 to 6.5)	4.7 (3.6 to 6.2)	6.8 (4.5 to 10.3)	6.0 (3.9 to 9.2)	6.1 (4.0 to 9.3)	12.6 (9.2 to 17.2)	10.4 (7.5 to 14.3)	10.5 (7.6 to 14.5)
Neonatal hypothermia†	2.5 (1.8 to 3.4)	2.3 (1.7 to 3.1)	2.1 (1.5 to 3.0)	2.4 (1.3 to 4.5)	2.2 (1.2 to 4.1)	2.3 (1.2 to 4.3)	2.8 (1.7 to 4.8)	2.4 (1.4 to 4.2)	2.5 (1.5 to 4.3)
Neonatal respiratory distress†	1.3 (1.1 to 1.5)	1.2 (1.0 to 1.4)	1.2 (1.0 to 1.4)	1.0 (0.7 to 1.5)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.4)	1.1 (0.8 to 1.6)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.4)
Admission to NICU/ SCNT*	1.6 (1.4 to 1.9)	1.5 (1.3 to 1.8)	1.4 (1.2 to 1.7)	1.2 (0.9 to 1.6)	1.1 (0.8 to 1.5)	1.1 (0.8 to 1.5)	1.9 (1.5 to 2.4)	1.7 (1.3 to 2.2)	1.7 (1.3 to 2.2)

\*Adjusted for maternal age, ethnicity, previous preterm pregnancy, parity, hypertension, method of conception, BMI and medical comorbidities.

†Adjusted as above, sensitivity analysis with other high-risk clinics removed.

‡The reference category for all unadjusted and adjusted analysis are women without GDM.

BMI, body mass index; GDM, gestational diabetes mellitus; HDP, hypertensive disorders of pregnancy; IOL, induction of labour; LGA, large for gestational age; NICU, neonatal intensive care unit; OASIS, obstetric anal sphincter injuries; PPH, postpartum haemorrhage; SCN, special care nursery; SGA, small for gestational age.

glucose levels and a number of adverse maternal and neonatal outcomes.<sup>4</sup> Following this, a multicentre randomised controlled trial including 958 women with mild gestational diabetes confirmed that treatment of women with GDM reduced the risks of fetal overgrowth, shoulder dystocia, caesarean delivery and HDP.<sup>6</sup> For both interventional studies, treatment was defined as dietary intervention, BG monitoring and insulin therapy as required. Subsequent cost-effectiveness analysis of the available data showed economic benefit to treating mild gestational diabetes.<sup>17</sup>

Our findings suggest model of care is to be an independent factor in determining outcomes for women with GDM. Our study found that current methods of stratifying women into dedicated or non-dedicated clinics based on insulin requirements and medical comorbidities appear ineffective, especially for women deemed to have milder GDM.

Dedicated care for women with GDM offers specialised diabetes and obstetric care, and potentially provide greater accountability for lifestyle management and BG monitoring, the opportunity to institute treatment at an earlier stage than might otherwise occur and higher obstetric surveillance such as frequency of antenatal visits and ultrasound. By virtue of being in a dedicated diabetes clinic, a more rigorous approach to management is likely to have been implemented. This is reflected in the rates of induction of labour seen in our cohort, which for women in non-dedicated clinics was similar to the non-GDM population but was increased in women in the dedicated clinics. Although there is limited evidence to guide practice in this area,<sup>18</sup> this result reflects the differing approaches taken towards patient management within and outside of the dedicated clinics.

Standardising models of care for all women with GDM would be an ideal approach, ensuring that all women have similar access to increased frequency of appointments, screening investigations such as ultrasound and early adjustment of treatments such as insulin. This will minimise inequity to care and outcomes in women with GDM. An evidence-based risk prediction tool at the time of diagnosis of GDM and response to initial treatment should be developed to inform stratification and escalation of care. Future studies randomising women with 'milder forms' of GDM to dedicated clinics or standard of care would serve to further validate our finding, and provide potential evidence for challenging the paradigm of allocation women with GDM to models of care based on perceived risk.

## Strengths and limitations

### Strengths

The study using contemporaneous data was undertaken in a large tertiary referral centre with high volumes of obstetric care and established dedicated gestational diabetes clinics. All clinics included antenatal care provided by obstetricians and midwifery teams within the hospital-led and community-led midwifery and GP shared

models of care, therefore, providing an assessment of antenatal care for women with GDM within the community through its interface with tertiary services and solely tertiary care services. This allowed for adequate sampling to assess outcomes of dedicated against standard models of care, and between different dedicated models of care. Large volumes of data were available, with very little missing or poor-quality data. There were identical practices for data collection and management across all groups of the study. As all women were included, there was likely limited selection bias introduced, baseline demographics of all clinic groups are available for comparison.

### Limitations

The study was undertaken with data from a single institution potentially limiting its external validity. It is however informative for local changes and adaptations required to improve outcomes in pregnancy in women with GDM in our service. Larger population-based studies evaluating models of care are limited and attempts at such studies must be underpinned by the ability to measure confounders at institutional level. All data were routinely collected, some data points such as neonatal respiratory distress required subjective interpretation from clinical staff performing data entry. Routinely collected electronic data were not available in the maternity information system on profiles of glycaemic control and thus this could not be adjusted for.

## CONCLUSION

GDM is associated with a range of adverse outcomes and is increasing in prevalence worldwide. Results of this study suggest that the antenatal model of care has an independent relationship with adverse outcomes for women with GDM in Western Sydney. Pathways of care need to be similar in all women with GDM, development and implementation of an evidence-based system for stratifying risk would be of benefit.

### Author affiliations

<sup>1</sup>Reproduction and Perinatal Centre, Faculty of Medicine and Health, The University of Sydney, Sydney, New South Wales, Australia

<sup>2</sup>Westmead Institute for Maternal & Fetal Medicine, Westmead Hospital, Westmead, New South Wales, Australia

<sup>3</sup>NHMRC Clinical Trials Centre, University of Sydney, Sydney, New South Wales, Australia

<sup>4</sup>Westmead Diabetes and Endocrinology, Westmead Hospital, Westmead, New South Wales, Australia

<sup>5</sup>Westmead Department of Neonatology, Westmead Hospital, Westmead, New South Wales, Australia

**Contributors** JH, SM and DP were involved in the conceptualisation, design, data collection and analysis, manuscript construction and review. ACK was involved in the data analysis and manuscript review. MH was involved in data collection. NA, AB, WC, EI, KM, ML and SP were involved in conceptualisation and manuscript construction and review. DP is the guarantor for the overall content of this article.

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# ORCID iDs

Jackson Harrison <http://orcid.org/0000-0002-4102-5453>

Sarah Melov <http://orcid.org/0000-0002-7569-1016>

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Table S1 – Outcomes stratified by GDM status

Outcome	Total (n=14965)	No GDM (n=12474)	GDM (n=2491)	OR (95%CI)		
				Unadjusted OR (95%CI)	Adjusted OR* (95%CI)	Adjusted OR** (95%CI)
HDP	527 (3.5%)	392 (3.1%)	135 (5.4%)	1.8 (1.5-2.2)	1.5 (1.2-1.8)	1.5 (1.2-1.8)
IOL***	4790 (39.4%)	3896 (37.9%)	894 (47.9%)	1.6 (1.4-1.8)	1.5 (1.3-1.7)	1.4 (1.2-1.7)
PTB	1295 (8.7%)	996 (8%)	299 (12%)	1.5 (1.4-1.9)	1.2 (1.1-1.3)	1.3 (1.1-1.4)
Instrumental delivery***	1606 (13.2%)	1309 (12.7%)	297 (15.9%)	1.2 (1.0-1.3)	1.3 (1.1-1.5)	1.3 (1.1-1.5)
Caesarean section	4859 (32.5%)	3801 (30.5%)	1058 (42.5%)	1.6 (1.6-1.9)	1.4 (1.3-1.5)	1.3 (1.2-1.5)
SGA	1203 (8%)	987 (7.9%)	216 (8.7%)	1.1 (0.9-1.3)	1.1 (0.9-1.3)	1.1 (0.9-1.3)
LGA	1019 (6.8%)	810 (6.5%)	209 (8.4%)	1.3 (1.1-1.5)	1.3 (1.1-1.5)	1.3 (1.1-1.5)
PPH	3166 (21.2%)	2589 (20.8%)	577 (23.2%)	1.2 (1.0-1.3)	1.1 (1.0-1.2)	1.1 (0.9-1.2)
OASIS***	305 (2.5%)	247 (2.4%)	58 (3.1%)	1.3 (0.9-1.6)	1.3 (1.0-1.8)	1.3 (1.0-1.8)
Neonatal hypoglycaemia	356 (2.4%)	157 (1.3%)	199 (8%)	6.8 (5.5-8.4)	6.1 (4.9-7.7)	6.1 (4.8-7.6)
Neonatal hypothermia	246 (1.6%)	164 (1.3%)	82 (3.3%)	2.5 (1.9-3.3)	2.3 (1.7-3.0)	2.2 (1.6-2.9)
Neonatal respiratory distress	1235 (8.3%)	995 (8%)	240 (9.6%)	1.2 (1.1-1.4)	1.1 (1.0-1.3)	1.1 (1.0-1.3)
Admission to NICU/SCN	1788 (11.9%)	1372 (11%)	416 (16.7%)	1.6 (1.5-1.8)	1.4 (1.2-1.6)	1.3 (1.2-1.5)

^ The reference category for all unadjusted and adjusted analysis are women without GDM

\*Adjusted for maternal age, ethnicity, previous preterm pregnancy, parity, hypertension, method of conception, BMI, and medical comorbidities

\*\*Adjusted as above, sensitivity analysis with other high-risk clinics removed

\*\*\*Percentage excluding those undergoing elective caesarean section