The feasibility and impact of implementing NICE guidance on diabetes control during delivery

UMESH DASHORA, SHEMITHA RAFIQUE, GIJI THARAYIL, SARAH JONES, ERWIN CASTRO, PERIASAMY SATHISKUMAR

Abstract

Aims**: The aim of this study was to report on the practicality, feasibility and impact of implementing the National Institute for Health and Care Excellence (NICE) guidelines for the control of diabetes in women during labour and birth.**

Methods**: We analysed case records of pregnant women with diabetes who delivered in the period between July 2014 and June 2015. The data were collected in relation to the availability of a plan in the notes, capillary blood glucose (CBG) monitoring, use of variable rate intravenous insulin infusion (VRIII), maintenance of CBG targets within 4–7 mmol/L, maternal hypoglycaemia during labour and neonatal hypoglycaemia.**

Results**: Fifty-one women with diabetes delivered during this period. Only 45% of women were monitored by complete hourly CBGs until delivery. 27.4% of women had CBG ≥7 mmol/L but only 17.6% were started on VRIII. The VRIII group had a 22.2% incidence of minor maternal hypoglycaemia. Neonatal hypoglycaemia occurred in 47% of the babies.**

Conclusion**: A CBG target of 4–7 mmol/L during labour and initiation of VRIII when levels are above this target in pregnant women with diabetes is difficult to achieve and is associated with some maternal hypoglycaemia. Repeat CBG measurements within half an hour and strict adherence to clear guidelines and protocols supported by more education and adequate staffing may improve results.**

Br J Diabetes 2017;**17**:ONLINE AHEAD OF PUBLICATION

Key words: feasibility, impact, NICE, diabetes, delivery

Introduction

Infants born to mothers with diabetes have higher morbidity, including the risk of neonatal hypoglycaemia. Neonatal hypoglycaemia is thought to be secondary to beta cell hyperplasia in the infant pancreas following maternal hyperglycaemia in pregnancy.[2–5] It has been hypothesised that the last 18 hours in utero is important to prevent neonatal complications, even in women with good glycaemic control during pregnancy.[6]

The National Institute for Health and Care Excellence (NICE) has suggested maintaining maternal blood glucose at 4–7 mmol/L to reduce neonatal hypoglycaemia.[1] The use of a combined insulin and glucose infusion during labour to maintain maternal blood glucose in a narrow range (4–7 mmol/L) is a common and clinically efficient practice.[1]

In contrast, some studies have questioned the definition of neonatal hypoglycaemia and its relationship to maternal hyperglycemia.[7] They also raised concerns that maintaining tight glycaemic control in the range of 4–7 mmol/L may increase maternal hypoglycaemia and resource burden without any clear reduction in neonatal hypoglycaemia.[8,9]

Our local protocol is to monitor capillary blood glucose (CBG) hourly from the onset of labour in all women with diabetes. If CBGs rise above 7 mmol/L, the variable rate intravenous insulin infusion (VRIII) is commenced (Figure 1). The rate of insulin infusion is then adjusted hourly depending on the CBG level, with the aim of keeping CBGs between 4–7 mmol/L throughout labour and birth.

This retrospective observational cohort study was undertaken to investigate the adherence, feasibility and effectiveness of our guidelines in reaching NICE targets and the resultant impact on neonatal hypoglycaemia and maternal hypoglycaemia.

Methods

A list of mothers with diagnosed diabetes mellitus (gestational, type 1 and type 2) who delivered during the period from July 2014 to June 2015 was compiled from the obstetric Euroking database.

Case records were analysed for the type of diabetes, insulin use and whether there were appropriate plans for labour with VRIII and CBG forms in their files. The plan that we use in our Trust is shown in Figure 1. Basal insulin when used is continued during labour and meal time insulin is continued as long as CBG levels are within the target range. Once the patient is in established labour and is either known to have type 1 diabetes or the

Conquest Hospital, Hastings, East Sussex, UK

Address for correspondence: Dr Umesh Dashora
Diabetes and Endocrinology, East Sussex Healthcare NHS Trust, Conquest Hospital, The Ridge, Hastings, Saint Leonards-on-sea, TN37 7RD, UK
Tel: +44 (0)1424 755255
E-mail: u.dashora@nhs.net

http://dx.doi.org/10.15277/bjd.2017.137

Figure 1. Intravenous Insulin Prescription and Fluid Protocol for Pregnancy and Labour: East Sussex Healthcare NHS Trust

East Sussex Healthcare NHS
NHS Trust

Ward	Consultant	Admission Date

Intravenous Insulin Prescription and Fluid Protocol PREGNANCY AND LABOUR ONLY

For use during pregnancy and labour for **ALL** patients receiving Variable Rate Intravenous Insulin Infusion (VRIII)
NEVER use an IV syringe to draw up insulin
ALWAYS draw up insulin using an insulin syringe
ALWAYS continue subcutaneous basal insulin

Patient Details
Please attach addressograph label

Surname	First Name
Hospital Number	NHS Number
Address	Date of Birth / Age

Dosing Algorithm

Algorithm ➡	1	2	3	4
CBG Levels (mmol/L) ⬇	Infusion Rate (Units/hr = ml/hr)			
<4	STOP INSULIN (recheck CBG in 10 minutes)			
4.0 - 6.0	0.2	0.5	1	1.5
6.1 - 6.6	0.5	1	2	3
6.7 - 8.2	1	1.5	3	5
8.3 - 9.9	1.5	2	4	7
10 - 11.6	2	3	5	9
11.7 - 13.2		4	6	12
13.3 - 14.9	3	5	8	16
15 - 16.6		6	10	20
16.7 - 18.2	4	7	12	24
18.3 - 19.9		8	14	28
>20	6	12	16	32
Signed				
Print Name				
Date				

Algorithm Guide

ALL women with diabetes should have Capillary Blood Glucose (CBG) testing **hourly** on admission
For women with **gestational diabetes and Type 2 diabetes** VRIII and IV Dextrose regime to start in established labour OR on admission for elective C-section **if CBG equal or >7 mmol/l**
For women with **Type 1 diabetes** to start VRIII from the onset of established labour

Algorithm 1 Starting point for most patients

Algorithm 2 For patients: Not controlled by algorithm 1
On glucocorticoids
Receiving > 80 units/day as an outpatient

Algorithm 3 For patients not controlled Algorithm 2
No patient starts here without medical review

Algorithm 4 For patients not controlled on algorithm 3
No patient starts here
Patients not achieving control with these algorithms need medical review
Conquest: Bleep 2681 or 2969
Out of Hours: Contact the medical SpR on call via switchboard

Target CBG Levels 4-7 mmol/l

Check CBG every hour whilst on IV insulin

Move Up if the CBG is> 7 mmol/l and has not reduced by at least 3mmol/L in 1 hour
Move Down when CBG is < 4mmol/L

Drug (approved name)	Dose	Volume	Route	Doctor's Signature	Date
HUMAN ACTRAPID INSULIN	**50 UNITS**	**Made up to 50ml with SODIUM CHLORIDE 0.9% (1 UNIT per ml)**	**IV**		

SYRINGE PREPARATION

Prepared & administered by	Date	Time start-ed	Time stopped

INTRAVENOUS FLUIDS

Date	Intravenous Fluid and Rate	Doctor's Signature	Nurse's Signature
	500 mls 10% Dextrose with 10 mmol KCl (0.15%) to run at 50 mls/hr		
	500 mls 10% Dextrose with 10 mmol KCl (0.15%) to run at 50 mls/hr		
	500 mls 10% Dextrose with 10 mmol KCl (0.15%) to run at 50 mls/hr		

GESTATIONAL DIABETES
STOP VRIII and IV Dextrose regime once placenta is delivered

TYPE 1 DM AND INSULIN TREATED TYPE 2 DM
Reduce the rate of VRIII by HALF once placenta is delivered
Contact diabetes team to review ongoing insulin requirements

Maintain IV infusion for 30 minutes after re-starting original insulin regime—IV insulin has a 5 minute half life

CBG is ≥7.0 mmol/L or she is not reliably eating and drinking, VRIII is started, basal insulin is continued and meal time insulin is withheld.

The records were also analysed for CBG levels during labour, appropriate use of VRIII, type of delivery, maternal hypoglycaemia and the incidence of neonatal hypoglycaemia. Fisher's exact test was used to determine statistical significance.

CBG monitoring was considered incomplete if any readings were missing from the chart. Maternal hypoglycaemia and neonatal hypoglycaemia were defined as a level below 4.0 mmol/L and 2.6 mmol/L, respectively, for the purpose of this study.

Results

Fifty-one mothers with diabetes were identified, of which 41 (80%) had gestational diabetes, five (10%) had pre-existing type 1 diabetes and five (10%) had pre-existing type 2 diabetes (Table 1). Forty-four patients (86%) had an appropriate prescription plan in their notes before admission for delivery.

Glucose monitoring

Although all the patients had some CBG monitoring, only 23 patients (45%) received complete hourly CBG monitoring until delivery. The average number of CBGs missed per women for the whole cohort was 1.24, while the average for the group which missed at least one CBG record was 1.84. The expected average monitoring number per woman was 3.4.

Women who delivered by caesarean section (CS)

Of the 25 women who had caesarean section (CS) deliveries (17 elective and 8 emergency), only 36% of patients had complete CBG monitoring with the average CBG record missed per woman being 2, irrespective of whether elective or emergency. The missed readings were more common from the records in the operating theatre than in the labour room, although the numbers are too small to derive a quantitative judgement. Among those who underwent elective CS, only three had complete hourly CBG monitoring. All three had VRIII but could not be maintained in the target range. Neonatal hypoglycaemia of 2.3 and 2.4 mmol/L was seen in two of the babies delivered. Of eight women who had an emergency section, only three had complete CBG monitoring and nobody was put on VRIII. Three women in this group had CBG of 7, 7.3 and 7.9 mmol/L but missed VRIII in error (in violation of our local protocol) and delivered babies with neonatal hypoglycaemia of 1.3, 2.4 and 2.4 mmol/L, respectively. Two of these women had CS within 2 hours and missed the two possible CBGs that could have been done. The third woman, however, was in labour for 6 hours but had only four tests. Three of these tests were high as per our local protocol at 7.8, 7.4 and 8 mmol/L, but she missed VRIII. Her baby's CBG was 2.4 mmol/L. There were four other women in this group of emergency CS who delivered babies with neonatal hypoglycaemia of 1.7, 1.7, 1.9 and 1.7 mmol/L. In total, seven women out of eight who had an emergency CS had babies with neonatal hypoglycaemia. In three of these women there was evidence of macrosomia and polyhydramnios.

Table 1 Relationship between neonatal hypoglycaemia and various variables

Characteristics (n)	Neonatal hypoglycaemia, n (%)	No neonatal hypoglycaemia, n (%)	p value
Women with diabetes	24 (47)	27 (53)	NS for all pairs
Type 1 diabetes (n=5)	2 (4)	3 (60)	
Type 2 diabetes (n=5)	4 (80)	1 (20)	
Gestational diabetes (n=41)	18 (44)	23 (56)	
VRIII used (n=9)	4 (44)	5 (56)	NS
VRIII not used (n=42)	21 (50)	21 (50)	
CBG monitored hourly (n=23)	10 (42)	13 (48)	NS
CBG not monitored hourly (n=28)	14 (50)	14 (50)	
CBG within target (n=26)	10 (38)	16 (62)	NS
CBG >7 mmol/L (n=9)	5 (56)	4 (44)	
Insulin-treated patients (n=35)	17 (49)	18 (51)	NS
Non-insulin-treated patients (n=16)	7 (44)	9 (66)	
Assisted delivery (n=30)	17 (57)	13 (43)	NS
Normal delivery (n=21)	7 (33)	14 (67)	

CBG, capillary blood glucose; VRIII, variable rate intravenous insulin infusion.

Women who were insulin treated in pregnancy

There was no relationship between insulin treatment before delivery and the completeness of hourly CBG monitoring. Five patients received hourly CBG monitoring even though they were not being treated with insulin in the antenatal period. In contrast, 20 patients were on single or multiple dose subcutaneous insulin treatment with or without metformin before delivery but did not receive complete hourly CBG monitoring during labour and birth. The mean number of CBG records missed per woman was 1.93.

Women who received VRIII during delivery

The CBGs were >7 mmol/L in 14 mothers (27.4%). VRIII was started in nine of the 51 mothers (17.6%). The range of CBGs (available in eight patients) before starting VRIII varied from 4.6 to 13.8 mmol/L (individual levels being 7.3, 13.8, 7.2, 7.1, 7.4, 8.2, 7.9 and 4.6 mmol/L). One patient with gestational diabetes

was sent to the operating theatre before the CBG could be done but she was on VRIII and the baby had neonatal hypoglycaemia with CBG of 1.6 mmol/L. CBGs done in the theatre at half an hour and one hour were fortunately acceptable at 4.8 and 4.9 mmol/L. One woman with gestational diabetes was started on VRIII at a CBG of 4.6 mmol/L in error. VRII was not adjusted appropriate to the lower target CBG of >4 mmol/L and resulted in maternal hypoglycaemia with CBG of 3.9 mmol/L. The baby did not have any complications. VRIII was appropriately adjusted only in four of the eight women where CBG monitoring was available. VRIII was not adjusted properly in two women because of inadequate monitoring and in one case the scale was not moved up in spite of rising glucose levels over 4 hours. The fourth woman was the one who was started on VRIII at 4.6 mmol/L and she had a minor unexpected hypoglycaemic episode (mentioned above). In others the VRIII was adjusted adequately but the target was achieved only in one woman who delivered normally after being in labour for 6 hours. In the other three women there was insufficient time in labour for the VRIII to attain the required target before two of them had a CS and one had ventouse delivery. The target CBG of <7 mmol/L was maintained in only two of these eight women.

Two mothers (22.2%) on VRIII developed hypoglycaemia whereas no patients without VRIII had symptomatic hypoglycaemia requiring medical attention ($p<0.02$). In one mother the VRIII was not adjusted appropriately but, in the other woman, hypoglycaemia occurred in spite of appropriate changes in the VRIII. The degree of hypoglycaemia was mild with CBG levels of 3.6 and 3.9 mmol/L, and these women were treated promptly as per hospital protocol with no adverse consequences.

Women who missed VRIII in error

Five women were eligible for VRIII but did not receive it. Three of these women did not have complete hourly CBG monitoring. One had a CBG of 7.9 mmol/L but delivered within 2 hours by emergency CS and the neonate had a CBG of 2.4 mmol/L. The second had a CBG of 7.3 mmol/L and was in labour for 6 hours with two other readings of 7.4 and 7.8 mmol/L but was erroneously not put on VRIII. She also had an emergency CS and delivered a baby with CBG of 2.4 mmol/L. The third mother had a CBG of 7.6 mmol/L, but the subsequent hourly CBGs were 6.9 and 5.7 mmol/L and she had a normal delivery with a healthy neonatal CBG of 2.9 mmol/L. Two other women had complete CBG monitoring. One had a CBG of 7.0 mmol/L and had an emergency CS within 2 hours of arrival but the baby had a CBG of 1.3 mmol/L. The other had a CBG of 9.1 mmol/L and delivered normally within 1 hour but the baby's CBG was 2.5 mmol/L.

Women who delivered babies with neonatal hypoglycaemia

In total, four babies of nine mothers (44.4%) on VRIII had hypoglycaemia. In three of these mothers CBG was available and in all three of them it was >7 mmol/L (13.8, 7.4 and 7.9 mmol/L). Neonatal blood glucose was 1.2, 2.4 and 2.3 mmol/L, respectively. The fourth neonate had a CBG of 1.6 mmol/L but the mother's CBG was not recorded as she was sent to theatre on a VRIII. The baby with the CBG of 1.2 mmol/L spent 5 days in the Neonatal Intensive Care Unit. None of the babies born to the two mothers who were able to maintain CBG <7 mmol/L delivered a baby with neonatal hypoglycaemia (even though one of the mothers had a CBG of 8.2 mmol/L before starting VRIII).

The mothers of these four babies had evidence of poor long-term glycaemic control, as evidenced by one or more indicators such as very high HbA_{1c}, macrosomia and polyhydramnios. The first baby was born to the mother with type 1 diabetes who had an HbA_{1c} as high as 95 mmol/mol and macrosomia during pregnancy. The second was born to the mother with type 2 diabetes with HbA_{1c} of 90 mmol/mol before pregnancy. The third was born to the mother with gestational diabetes who had no pregnancy HbA_{1c} available but the baby suffered from both macrosomia and polyhydramnios. The fourth baby also had macrosomia.

Neonatal hypoglycaemia (CBG <2.6 mmol/L as per our hospital protocol) was seen in 24 babies (47%), severe in six (CBG ≤1.6 mmol/L). Eighteen (44%) of these babies were born to mothers with gestational diabetes, two (40%) to mothers with type 1 diabetes and four (80%) to mothers with type 2 diabetes. Neonatal hypoglycaemia was numerically more frequent in women with pre-existing type 2 diabetes, patients not receiving VRIII, patients not receiving appropriate CBG monitoring, CBGs outside the target range of 4–7 mmol/L, insulin-treated patients and assisted deliveries. However, none of these groups differed significantly by Fisher's exact test (Table 1).

Discussion

It was difficult for midwives to maintain hourly CBG monitoring until the end of labour. NICE has suggested a staffing level of one midwife for each mother in labour;[10] however, this can be difficult to achieve in some hospitals. In our hospital it is not uncommon for midwives to care for two patients at a time, at least immediately after admission.

A significant number of patients had emergency or early CS after hospital admission, which might explain the poor glucose monitoring in this group of patients. As these patients are not in labour, the hourly monitoring is delayed until the patient is ready to be taken to theatre. Early start of monitoring may pick up glucose abnormalities in some of these patients. Subsequent early and appropriate action has the potential to maintain patients within the NICE suggested target. This in turn has the potential to reduce neonatal hypoglycaemia. We suggest a second CBG test in patients who have a CBG of 7–8 mmol/L within half an hour and, if both are higher than 7 mmol/L, VRIII should be promptly started. This would give more time for the VRIII to be effective in patients waiting for CS or having accelerated deliveries.

We realised that our prescription chart did not adequately clarify the need to start CBG monitoring in all patients with pre-existing type 1 diabetes being admitted for elective CS. The prescription chart has since been revised. Similar difficulties with monitoring have been noted in other studies.[11] Our patient who was sent to theatre on VRIII without a prior CBG highlights a safety breach and

the ongoing need for education to the obstetric staff in hospitals.

In our hospital we have a protocol to start VRIII in patients with type 2 diabetes and gestational diabetes only when CBG is >7 mmol/L. A similar 'watchful wait' approach has been described in some other studies.[11] Again, given the practical difficulties, we found that five patients missed VRIII in our group despite their CBG being above the target range and one patient received the VRIII despite not requiring it. The reason for not starting VRIII in three of these women was quick delivery or CS within 2 hours. It is unlikely that a very short period of VRIII would influence the neonatal outcome significantly. NICE guidelines provide an excellent framework for managing patients with diabetes during delivery but, in some cases, the decisions to defer or avoid VRIII may be entirely appropriate, particularly if the delivery is iminent.The case of the fourth woman where three readings >7 mmol/L were ignored highlights the importance of clear guidelines, more education and strict adherence to the protocols. The case of the fifth woman where the first reading was 7.6 mmol/L but the subsequent readings were <7 mmol/L highlights the value of repeating CBG within half an hour if the first reading is >7 mmol/L. This way we may be able to avoid unnecessary VRIII in some cases.

In the nine women who received VRIII, only two achieved target CBG while on VRIII and their babies did not suffer from neonatal hypoglycaemia. We think the reason for not being able to achieve target CBG in spite of starting VRIII was a mixture of inadequate monitoring, lack of appropriate action on monitoring and the lack of time available to effectively manipulate the rate of VRIII in time before delivery or birth, as described in the Results section. The insulin dose was increased appropriately only in four patients. This highlights an educational issue. Effective use of continuous glucose monitoring and continuous subcutaneous insulin infusion may be other options to control CBGs in a tight target range without causing significant hypoglycaemia. However, this has not been studied in detail yet.[12,13]

Neonatal hypoglycaemia is not clearly defined in the literature, with values defining it ranging from 1.6–2.2 mmol/L to 2.5–2.6 mmol/L.[14] In our group hospital policy defines it as <2.6 mmol/L. The most recent publication involving huge numbers (n=17,094) suggests that the normal glucose threshold could be 2.2 for the 90th centile and 1.9 for the 95th centile for glucose in the neonate.[15] Routine measurement of neonatal blood glucose shows that 5% of apparently normal neonates have CBG <1.7 mmol/L in the first few hours of life.[16] Many experts, however, feel that symptomatic hypoglycaemia and a measured glucose of <2.5 mmol/L should be managed aggressively.[17] Others have recommended intravenous glucose for infants with glucose <1.4 mmol/L.[18]

In our study nine mothers received VRIII. Of these, four delivered babies with hypoglycaemia. VRIII use and neonatal hypoglycaemia did not seem to be related significantly, although the number is too small to derive any meaningful conclusion. Out of 24 studies reviewed recently, 19 studies specifically looked for a relationship between maternal glucose during labour and neonatal hypoglycaemia. In 10 of these studies there was an inverse relationship, with a similar trend in another three and only six found no relationship.[19] The inverse relationship was particularly strong in studies reporting on pre-gestational diabetes. In the same review the lower target range has varied from 2.8 to 4.0 mmol/L and the higher from 5.5 to 8.3 mmol/L, with no clear relationship with neonatal hypoglycaemia. The authors believe that a target CBG of 4–6 mmol/L can be used safely and results in a low rate of neonatal hypoglycaemia.[19] Some other authors did find an association with neonatal hypoglycaemia, but only at a threshold of maternal CBG >8 mmol/L. Interestingly, there was no increase in neonatal hypoglycaemia when CBGs were kept below 8 mmol/L.[8]

A similar rate of overall neonatal hypoglycaemia (47%) to our study group has been reported in another study of 35 babies of mothers with diabetes.[20] The range of neonatal hypoglycaemia reported in the literature ranges from 0%[13,21] to 69%.[22]

We could not find a significant association between maintaining CBG <7 mmol/L and neonatal hypoglycaemia. In our group, 43% of babies had neonatal hypoglycaemia even when the mothers were maintained in the target range, similar to some other studies.[11] This may be because neonatal hypoglycaemia is caused not only by hyperinsulinaemia during labour but also during pregnancy, especially when the diabetes control is not tight.[4] Indeed, the four women in our group who had neonatal hypoglycaemia in spite of VRIII exhibited indicators of poor control during pregnancy, as detailed in the Results section. The fact that a disproportionately high proportion of women who had babies delivered by emergency CS with neonatal hypoglycaemia (7 of 8) also suggests a contributory role of factors other than glycaemic control during labour and birth. This is supported by the presence of indicators of poor antenatal glycaemic control such as macrosomia and polyhydramnios in some of these women.

Moroever, neonatal hypoglycaemia is commonly associated with maternal diabetes,[23] but can also be due to other reasons such as pituitary adrenal and other metabolic causes.[24,25]

In several studies maternal hypoglycaemia was a recognised complication when trying to keep CBG at 4–7 mmol/L.[26–30] In our group two women (22.2%) who used VRIII developed hypoglycaemia with CBG <4 mmol/L compared with none in those who did not require VRIII ($p<0.02$). This was appropriately treated. Maternal hypoglycaemia can be as high as 56% with tighter targets of 4–6.5 mmol/L.[22] Some other studies have reported a reduction in maternal hypoglycaemia from 40% to 22.2% when the target CBG is relaxed.[31,32]

A recent editorial in Anaesthesia warns against maternal hypoglycaemia in women on VRIII and suggests targeting capillary blood glucose of 6–8 mmol/L. It may not be unreasonable therefore to relax target CBGs to 4–8 mmol/L or even 6–8 mmol/L where hypoglycaemia can have disastrous consequences.[9] However, further research is urgently needed to confirm that such relaxation would not have a deleterious effect on the neonatal outcomes.

In the new JBDS-IP guidelines the group suggests maintaining CBG 4–7 mmol/L in general. Given that the CBG is not always absolutely accurate, it may be sensible to wait for at least two consecutive readings (preferably the second one within half an hour) to be high before VRIII is started. In patients who are undergoing regional analgesia or anaesthesia, CBG monitoring every half an hour and a more relaxed target has been suggested as an option (submitted for publication).

Key messages

- Neonatal hypoglycaemia remains a common and potentially avoidable complication in pregnancies complicated with diabetes
- Maintaining the NICE recommended capillary blood glucose target of 4–7 mmol/L during labour has the potential to reduce neonatal hypoglycaemia but led to minor maternal hypoglycaemia in 22.2% of patients in our group. There was, however, no harm to the mothers
- Neonatal hypoglycaemia was more common in women with poor glycaemic control in the antenatal period
- Neonatal hypoglycaemia was numerically more common in women with pre-existing type 2 diabetes, insulin-treated patients, patients not receiving variable rate intravenous insulin infusion (VRIII), patients not receiving appropriate capillary blood glucose (CBG) monitoring, CBGs outside the target range of 4–7 mmol/L and assisted deliveries
- Hourly CBG monitoring during labour and VRIII in appropriate patients can help achieve NICE targets and reduce neonatal hypoglycaemia in some patients
- Systems, prompts and clear guidelines should be in place for a more effective and safe implementation of NICE guidelines

This study has some limitations. We did not find a significant association between VRIII use or a labour CBG of 4–7 mmol/L and a lower incidence of neonatal hypoglycaemia. The VRIII was, however, not effective in maintaining CBG in the target range. The lack of relationship with CBG levels could have been purely because of low numbers and larger studies in well matched groups are needed. Statistical tests in these low numbers may not be relevant. Placental transfer of glucose during the antenatal period was a confounding factor that might have negated the benefit of VRIII and peripartum control.[4]

Summary and recommendations

Neonatal hypoglycaemia remains a common and potentially avoidable complication in pregnancies complicated with diabetes. It was more common in women with poor glycaemic control in the antenatal period, pre-existing diabetes, insulin-treated diabetes, poor monitoring, women not receiving VRIII during delivery, women whose CBG was outside the range of 4–7 mmol/L and women delivered by ventouse and CS in our study.

Maintaining CBGs in mothers at 4–7 mmol/L during labour was difficult and created an increased risk of minor but easily treatable maternal hypoglycaemia. We suggest repeating CBG within half an hour of the first CBG reading >7 mmol/L and starting VRIII promptly if these two consecutive readings are >7 mmol/L. This would help avoid excessive use of VRIII but, at the same time, would drive appropriate metabolic control in women who may benefit, resulting in lower neonatal hypoglycaemia. Additional systems, protocols and prompts should be in place to safely maintain these target levels in women in the delivery areas. One-to-one staffing and regular education of all the staff involved is crucial. More randomised studies are urgently needed to ascertain the exact targets for this group of patients.

Conflict of interest None declared
Funding None declared

References

1. National Institute for Health and Clinical Excellence. Clinical practice guideline. Diabetes in pregnancy: management of diabetes and its complications from preconception to the postnatal period. February 2015. http://www.nice.org.uk/guidance/ng3 (accessed 2 Aug 2016).
2. HAPO Study Cooperative Research Group. Hyperglycemia and adverse pregnancy outcomes. *N Engl J Med* 2008;**358**:1991-2002. http://dx.doi.org/10.1056/NEJMoa0707943
3. Pedersen J. Weight and length at birth of infants of diabetic mothers. Acta *Endocrinol* 1954;**16**:330-42. https://doi.org/10.1530/acta.0.0160330
4. Desoye G, Nolan CJ. The fetal glucose steal: an underappreciated phenomenon in diabetic pregnancy. *Diabetologia* 2016;**59**:1089-94. http://dx.doi.org/10.1007/s00125-016-3931-6
5. Molsted-Pedersen L. Aspects of carbohydrate metabolism in newborn infants of diabetic mothers. I. Intravenous glucose tolerance tests (a) distribution and means of K values, and (b) correlation between K value and birth weight. *Acta Endocrinol* 1972;**69**:174-88.
6. Jovanovic L. Glucose and insulin requirements during labor and delivery: the case for normoglycemia in pregnancies complicated by diabetes. *Endocr Pract* 2004;**10**(Suppl 2):40-5. http://dx.doi.org/10.4158/EP.10.S2.40
7. Flores-le Roux JA, Sagarra E, Benaiges D, *et al*. A prospective evaluation of neonatal hypoglycaemia in infants of women with gestational diabetes mellitus. *Diabetes Res Clin Pract* 2012;**97**:217-22. http://dx.doi.org/10.1016/j.diabres.2012.03.011
8. Taylor R, Lee C, Kyne-Grzebalski D, *et al*. Clinical outcomes of pregnancy in women with type 1 diabetes. *Obstet Gynecol* 2002;**99**:537-41. https://doi.org/10.1097/00006250-200204000-00004
9. Modi A, Levy N, Hall GM. Controversies in the peripartum management of diabetes. *Anaesthesia* 2016;**71**:750-5. http://dx.doi.org/10.1111/anae.13487
10. National Institute for Health and Clinical Excellence. Clinical practice guideline Safe midewifery staffing for maternity settings. February 2015. Available at https://www.nice.org.uk/guidance/ng4/resources/safe-midwifery-staffing-for-maternity-settings-51040125637 (accessed 20 Nov 2016).
11. Barrett HL, Morris J, McElduff A. Watchful waiting: a management protocol for maternal glycaemia in the peripartum period. *Aust N Z J Obstet Gynaecol* 2009;**49**:162-7. http://dx.doi.org/10.1111/j.1479-828X.2009.00969.x
12. Fresa R, Visalli N, Di Blasi V, *et al.* Experiences of continuous subcutaneous insulin infusion in pregnant women with type 1 diabetes during delivery from four Italian centers: a retrospective observational study. *Diabetes Technol Ther* 2013;**15**:328-34. http://dx.doi.org/10.1089/dia.2012.0260
13. Iafusco D, Stoppoloni F, Salvia G, *et al*. Use of real time continuous glucose monitoring and intravenous insulin in type 1 diabetic mothers to prevent respiratory distress and hypoglycaemia in infants. *BMC Pregnancy Childbirth* 2008;**8**:23. http://dx.doi.org/10.1186/1471-2393-8-23
14. Koh TH, Eyre JA, Aynsley-Green A. Neonatal hypoglycaemia: the controversy regarding definition. *Arch Dis Child* 1988;**63**:1386-8. https://doi.org/10.1136/adc.63.11.1386
15. Metzger BE, Persson B, Lowe LP, *et al*. Hyperglycemia and adverse pregnancy outcome study: neonatal glycemia. *Pediatrics* 2010;**126**:1545-52.

http://dx.doi.org/10.1542/peds.2009-2257
16. Cornblath M, Reisner SH. Blood glucose in the neonate and its clinical significance. *N Engl J Med* 1965;**273**:378-81. https://doi.org/10.1056/NEJM196508122730707
17. Inder T. How low can I go? The impact of hypoglycemia on the immature brain. *Pediatrics* 2008;**122**:440-1. http://dx.doi.org/10.1542/peds.2008-1417
18. Cornblath M, Hawdon JM, Williams AF, *et al*. Controversies regarding definition of neonatal hypoglycemia: suggested operational thresholds. *Pediatrics* 2000;**105**:1141-5. https://doi.org/10.1542/peds.105.5.1141
19. Ryan EA, Al-Agha R. Glucose control during labor and delivery. *Curr Diab Rep* 2014;**14**:1-9. http://dx.doi.org/10.1007/s11892-013-0450-4
20. Agrawal RK, Lui K, Gupta JM. Neonatal hypoglycaemia in infants of diabetic mothers. *J Paediatr Child Health* 2000;**36**:354-6. https://doi.org/10.1046/j.1440-1754.2000.00512.x
21. West TE, Lowy C. Control of blood glucose during labour in diabetic women with combined glucose and low-dose insulin infusion. *Br Med J* 1977;**1**:1252-4. https://doi.org/10.1136/bmj.1.6071.1252
22. Kline GA, Edwards A. Antepartum and intra-partum insulin management of type 1 and type 2 diabetic women: Impact on clinically significant neonatal hypoglycemia. *Diabetes Res Clin Pract* 2007;**77**:223-30. http://dx.doi.org/10.1016/j.diabres.2006.10.024
23. Van Haltren K, Malhotra A. Characteristics of infants admitted with hypoglycemia to a neonatal unit. *J Pediatr Endocrinol Metab* 2013;**26**:525-9. http://dx.doi.org/10.1515/jpem-2013-0009
24. Henquin JC, Sempoux C, Marchandise J, *et al*. Congenital hyperinsulinism caused by hexokinase I expression or glucokinase-activating mutation in a subset of β-cells. *Diabetes* 2013;**62**:1689-96. http://dx.doi.org/10.2337/db12-1414
25. Hussain K, Aynsley-Green A. Hyperinsulinaemic hypoglycaemia in preterm neonates. *Arch Dis Child Fetal Neonatal Ed* 2004;**89**:F65–7. https://doi.org/10.1136/fn.89.1.F65
26. Feldberg D, Dicker D, Samuel N, *et al*. Intrapartum management of insulin-dependent diabetes mellitus (IDDM) gestants. *Acta Obstet Gynecol Scand* 1988;**67**:333-8. https://doi.org/10.1111/j.1600-0412.1988.tb07810.x
27. Achong N, Duncan EL, McIntyre HD, Callaway L. Peripartum management of glycaemia in women with type 1 diabetes. *Diabetes Care* 2014;**37**:364-71. http://dx.doi.org/10.2337/dc13-1348
28. Lean ME, Pearson DW, Sutherland HW. Insulin management during labour and delivery in mothers with diabetes. *Diabet Med* 1990;**7**:162-4. https://doi.org/10.1111/j.1464-5491.1990.tb01352.x
29. Balsells M, Corcoy R, Adelantado JM, *et al*. Gestational diabetes mellitus: metabolic control during labour. *Diabetes Nutr Metab* 2000;**13**:257-62.
30. Rosenberg VA, Eglinton GS, Rauch ER, Skupski DW. Intrapartum maternal glycemic control in women with insulin requiring diabetes: a randomized clinical trial of rotating fluids versus insulin drip. *Am J Obstet Gynecol* 2006;**195**:1095-9. http://dx.doi.org/10.1016/j.ajog.2006.05.051
31. Njenga E, Lind T, Taylor R. Five year audit of peripartum blood glucose control in type 1 diabetic patients. *Diabet Med* 1992;**9**:567-70. https://doi.org/10.1111/j.1464-5491.1992.tb01840.x
32. Brown SC, Kyne-Grzebalski D, Mwangi B, Taylor R. Effect of management policy upon 120 type 1 diabetic pregnancies: policy decisions in practice. *Diabet Med* 1999;**16**:573-8. https://doi.org/10.1046/j.1464-5491.1999.00124.x