Postpregnancy Glycemic Control and Weight Changes in Type 1 Diabetic Women

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OBJECTIVE—Pregnancy in type 1 diabetes requires excellent glycemic control. Most pregnant type 1 diabetic women achieve normoglycemia; however, there is scarce data on their postdelivery characteristics. We aimed to examine postpregnancy glycemic control and weight changes in type 1 diabetes.

RESEARCH DESIGN AND METHODS—We identified and followed (median 20 months) 254 women with singleton pregnancies receiving postdelivery medical care at a single institution.

RESULTS—Study subjects were 28.3 ± 4.7 years of age (mean ± SD), with a diabetes duration of 12.0 ± 7.7 years. Mean A1C before conception was 6.9 ± 1.4%, and preconception weight and BMI were 64.4 ± 10.0 kg and 23.9 ± 3.3 kg/m^2, respectively. Mean A1C decreased during pregnancy, reaching 5.7 ± 0.8% in the third trimester. We observed a mean weight gain of 14.4 ± 6.5 kg during pregnancy. Within 6 months after delivery, A1C increased by 0.8% ($P <$ 0.0001) compared with the last trimester, and body weight and BMI were 4.4 kg and 2.5 kg/m^2 higher ($P <$ 0.0001) compared with the preconception baseline. A1C further deteriorated by 0.8% until the end of follow-up. For women in the "pregnancy planning" program (n = 117), A1C >12 months after delivery was worse compared with before conception (7.1 vs. 6.5%, P = 0.0018), whereas in women with unplanned pregnancies, it was similar to the pregestational levels (7.3 vs.7.4%, P = 0.59). Weight and BMI in the entire study group did not return to prepregnancy levels and were 2.5 kg (P = 0.0079) and 0.9 kg/m^2 higher (P = 0.0058).

CONCLUSIONS—In this clinical observation, type 1 diabetic women showed postpregnancy deterioration in glycemic control and were unable to return to prepregnancy weight. Type 1 diabetic women seem to require special attention after delivery to meet therapeutic targets.

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The risk of maternal and fetal adverse outcomes is greater in pregnancies complicated by type 1 diabetes than in nondiabetic women (1). This is related to the degree of hyperglycemia during pregnancy (1,2). Optimized glycemic control improves the prognosis in these pregnancies, and most pregnant type 1 diabetic women achieve normoglycemia (3–5). Randomized trials and observational studies, including a report from our center, demonstrated that both multiple daily injections (MDIs) and continuous subcutaneous insulin infusion (CSII) are equally effective and safe (4,5). However, there is scarce data on glycemic control changes after delivery.

Several factors potentially deteriorate glycemic control in type 1 diabetic mothers after delivery: less incentive to achieve good metabolic control compared with during pregnancy, duties associated with childcare, and fear of hypoglycemic episodes during childcare. Additionally, women have different therapeutic goals and targets during and after pregnancy (6). On the other hand, extensive education programs during pregnancy could help new mothers maintain improved glycemic control after delivery (7). Only one small observational study exists for type 1 diabetes, showing that after a substantial improvement during pregnancy, glycemic control deteriorated, reaching pregestational levels after delivery (8). An urgent need exists for new, up-to-date studies, as the therapeutic aims and tools available 20 years ago have changed dramatically.

Weight gain is another poorly investigated clinical phenomenon in type 1 diabetic pregnancy. This problem should be further explored as intensive insulin therapy is associated with a large weight gain (9). Weight increases gradually during adult life, but for women, pregnancy can significantly alter their tendency to gain weight. Current literature demonstrates that in the general population, excess weight gain during pregnancy is related to a higher BMI later in life (10). We have recently reported that although modern insulin treatments provide excellent glycemic control in pregnancies complicated by type 1 diabetes, they also result in a substantial weight gain, particularly in women on CSIIs, where a 15-kg increase was observed (5).

In this study, we aimed to examine the following: *1*) postpregnancy glycemic control and weight changes in type 1 diabetic women, and *2*) potential modifying factors such as early pregnancy planning, glycemic control during pregnancy, and postdelivery diabetes treatment methods.

RESEARCH DESIGN AND METHODS

—This study was performed at the Department of Metabolic Diseases (Jagiellonian University Medical College), a university referral center for diabetes care in southeastern Poland. All pregnant women with preexisting type 1 diabetes were registered between 1999 and 2011 (5). In this study, we included all patients who met the following criteria: *1*) clinical diagnosis of type 1 diabetes established at least 1 year prior to conception, *2*) medical care in the department

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initiated no later than in the first trimester of gestation, and 3) complete follow-up in the department until delivery and at least one postpartum visit. We excluded patients with miscarriages (<24 weeks of gestation). We initially identified 378 singleton pregnancies complicated by type 1 diabetes receiving medical care during pregnancy. The number of registered subjects had risen gradually from 26 in 1999; the highest number, 42 subjects, was recorded in 2009. The final analysis included 254 Caucasian patients with available follow-up data after delivery.

As described earlier (5), women with type 1 diabetes who were pregnant or planning to conceive received intensive diabetes education, frequent outpatient visits, and hospitalizations, if necessary, with the following therapeutic targets: *1*) A1C <6.1%, *2*) fasting self-monitored blood glucose within 60–90 mg/dL, and *3*) subsequent pre- and postprandial glucose self-measurements within 60–120 mg/dL. Prior to conception, 117 women (46%) started intensive diabetes management ("pregnancy planning"). They were advised on contraception methods until glycemic targets were achieved. The other 137 (54%) women entered the intensive diabetes management program in the first trimester. Therefore, the terms "pregnancy planning," "planned," and "unplanned" used in this paper refer to the time of entry into our diabetes program. Baseline characteristics, which included microvascular complications, were based on an examination during pregnancy planning or during the first visit in the first trimester. Retinopathy was diagnosed ophthalmoscopically, and diagnosis of nephropathy was based on the albumin excretion rate, with values >30 mg/24 h or urine albumin-to-creatinine ratio >30 mg/g considered abnormal. The glomerular filtration rate was calculated from serum creatinine with the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula.

All women received a thorough education covering self-monitoring of blood glucose (SMBG), glycemic targets, diet, physical activity, and self-adjustment of insulin doses. Subjects treated with CSII received additional instructions regarding pump usage. All women were advised to perform SMBG measurements with glucose meters at least eight times daily (typically fasting, before, and 1 h after main meals, at bedtime, and between 2:00 and 4:00 A.M.). Routine visits before and during pregnancy were held every 4 weeks.

After delivery, patients were encouraged to have a follow-up in the clinic 1 month postpartum and then approximately every 3 months. During these visits, glycemic control and weight were assessed. Women were instructed to perform SMBG at least six to seven times daily (fasting, before main meals, 2 h postprandial, and bedtime). Information was provided by the physician on postdelivery glycemic goals and diet. Additional sessions with a dietitian were scheduled if necessary.

We divided all postpregnancy follow-up measurements into three groups: within 6 months of delivery (n = 131), 6–12 months from delivery (n = 102), and after >12 months (n = 159). To examine the effect of CSII treatment discontinuation, we also obtained measurements taken during CSII treatment after delivery, within 6 months after CSII termination, and >6 months after CSII termination. The local bioethical committee accepted this observational study protocol.

A1C was analyzed using high-performance liquid chromatography on the Variant apparatus (Bio-Rad). The inter- and intra-assay coefficient of variation was <2%. The device remained within the system of international quality control throughout the study period.

To examine temporal trends in A1C, body weight, and BMI after pregnancy, the repeated-measures linear model was used. We used pregnancy planning, CSII treatment during and after pregnancy, and their interactions as covariates. We also examined the A1C profile for its impact on weight changes. By minimizing the Akaike information criterion, we selected the first-order antedependence covariance structure of longitudinal measurements. Model parameters were estimated with the restricted maximum likelihood method using a ridge-stabilized Newton-Raphson algorithm in SAS 9.2 (Cary, NC) PROC MIXED. P values <0.05 were considered significant.

RESULTS—Study group baseline clinical characteristics are presented in Table 1. Patients reached excellent glycemic control during pregnancy, with mean A1C 5.7% in the third trimester. They were followed for a median of 20 months (1st–3rd quartile, 6–44 months). Almost half of the patients (46%) participated in a diabetes management program for women planning pregnancy offered by the department. A majority of the women (56%) were treated with CSII during pregnancy, which was either introduced before conception or in the first trimester. Only 15% owned insulin pumps and continued this treatment through the follow-up period. The other women temporarily obtained CSII devices from the department and returned them after a median of 2.4 months after delivery.

During the first 6 months after delivery, A1C increased by 0.8% (P < 0.0001) from a mean of 5.7% in the third trimester. After a subsequent 6 months, A1C further deteriorated by 0.6% (P < 0.0001). The last A1C recorded (>12 months from delivery) increased further by 0.2% as compared with the prior measurement (P = 0.055). Thus, during the entire follow-up, A1C deteriorated by 1.6% (P < 0.0001). Postpregnancy A1C was characterized by a larger dispersion, with variance increasing almost four times, compared with pregnancy values.

Women in the pregnancy planning program (n = 117) had significantly lower mean pregestational A1C (6.5 vs. 7.3%, P < 0.0001). These women, either on a CSII or MDI regimen, reached better glycemic control in the third trimester (5.6 vs. 5.8%, P = 0.011). However, after delivery, there were no significant differences in A1C between the planning and not planning women within 6 months of delivery (6.3 vs. 6.6%, P = 0.09), 6–12 months later (6.9 vs. 7.1%, P = 0.59), and after >12 months after delivery (7.1 vs. 7.4%, P = 0.32) (Fig. 1). At the end of follow-up, A1C returned to prepregnancy levels in women with unplanned pregnancies. However, in the pregnancy planning group, A1C deteriorated to levels significantly higher than before conception (P = 0.0018).

In women treated with CSII during pregnancy and who discontinued this treatment after delivery, we observed a significant increase in A1C while they still received CSII treatment (5.6–6.5%, P < 0.0001). We subsequently observed a further deterioration to mean A1C 7.1% within 6 months after switching to the MDI regimen in comparison with 6.5% on CSII (P = 0.018). More than 6 months after CSII discontinuation, A1C was 7.2%. Only women who continued CSII with their own pumps (n = 37) reached substantially better A1C levels at the end of follow-up (6.7 vs. 7.3%), although this difference had only borderline significance (P = 0.059). This CSII subgroup included both planning and not planning subjects (26 and 11 subjects, respectively).

During pregnancy, mean body weight increased by 14.4 kg, reaching 78.8 kg (P < 0.0001). Within 6 months after delivery, mean patient weight remained elevated (68.8 kg) compared with before

Table 1—*Patient characteristics*

	Total group	Pregnancy planning	Not planning	*P* value (planning vs. not planning)
Number of subjects (*n*)	254 (100)	117 (46)	137 (54)	—
Age (years)	28.3 ± 4.7 28.0 (25.0–31.3)	28.8 ± 4.2 28.2 (26.0–31.6)	27.9 ± 5.1 27.5 (24.3–30.7)	0.15
Diabetes duration (years)	12.0 ± 7.7 12.0 (5.0–18.0)	13.3 ± 8.2 14.0 (6.0–19.0)	11.0 ± 7.1 11.0 (5.0–17.0)	0.018
Preconception BMI (kg/m^2)	23.9 ± 3.3 23.3 (21.8–25.6)	23.7 ± 3.2 23.2 (21.7–25.1)	24.1 ± 3.4 23.5 (21.9–25.7)	0.34
Preconception body weight (kg)	64.4 ± 10.0 64.0 (58.0–70.0)	64.0 ± 10.3 63.0 (58.0–68.0)	64.8 ± 9.8 64.0 (59.0–70.0)	0.55
Weight gain during pregnancy (kg)	14.4 ± 6.5 14.0 (11.0–18.0)	14.2 ± 7.0 14.0 (10.0–19.0)	14.6 ± 6.2 15.0 (11.0–18.0)	0.66
Gestational age (weeks)	38.3 ± 2.5 39.0 (37.0–40.0)	38.2 ± 2.4 39.0 (37.0–39.0)	38.4 ± 2.5 39.0 (37.0–40.0)	0.49
A1C before pregnancy (%)	6.9 ± 1.4 6.7 (6.1–7.5)	6.5 ± 1.2 6.6 (6.0–7.1)	7.3 ± 1.5 7.0 (6.3–8.1)	<0.0001
CSII treatment during pregnancy (*n*)	143 (56.3)	72 (61.5)	71 (51.8)	0.12
CSII until end of follow-up (*n*)	37 (14.6)	26 (22.2)	11 (8.0)	0.0014
Cesarean section (*n*)	175 (68.9)	87 (74.4)	88 (64.2)	0.082
Retinopathy of any degree (*n*)	81 (31.9)	38 (32.5)	43 (31.4)	0.85
Proliferative retinopathy (*n*)	12 (4.7)	5 (4.2)	7 (5.1)	1.0
Abnormal urinary albumin (*n*)	7 (2.8)	3 (2.6)	4 (2.9)	1.0
GFR (mL/min/1.73 m^2)	125 ± 14 125 (119–133)	123 ± 9 122 (118–130)	127 ± 17 128 (122–135)	0.072
CKD stage 3 or higher	1 (0.4)	0 (0.0)	1 (0.7)	1.0

Data are mean ± SD, median (1st–3rd quartile), or *n* (%). Planning vs. not planning compared with Student *t* test, χ^2 test, or Fisher exact test, where applicable. GFR, glomerular filtration rate.

pregnancy, by 4.4 kg ($P < 0.0001$), which corresponded to a mean BMI increase from 23.9 to 25.5 kg/m^2 ($P < 0.0001$) (Fig. 1). A decrease was observed during follow-up, as >12 months after delivery, weight dropped by 1.9 kg and BMI by 0.7 kg/m^2 ($P = 0.031$ and $P = 0.020$, respectively), reaching 66.9 kg (mean BMI 24.8 kg/m^2) (Fig. 1). Overall, at the end of follow-up, both body weight and BMI were greater than before pregnancy, by 2.5 kg and 0.9 kg/m^2, respectively ($P = 0.0079$ and $P = 0.0058$). A1C did not appear to have a significant effect on weight variation. No differences were observed between temporal trends of weight and BMI during follow-up, comparing planning and not planning cohorts, or between CSII- and MDI-treated women.

CONCLUSIONS—In this large clinical observation, type 1 diabetic women who achieved excellent glycemic control during pregnancy were found to experience substantial postdelivery glycemic control deterioration. This trend was observed not only in type 1 diabetic women with unplanned pregnancies but also in subjects with planned pregnancies who had better diabetes control during pregnancy. Additionally, study participants weighed on average 2.4 kg more at the end of the study than before pregnancy.

The problem of glycemic control in type 1 diabetic women during pregnancy and its impact on maternal and fetal outcomes has attracted a lot of attention over the recent years (1). Therapeutic aims specific for pregnancy complicated by diabetes are included into the major clinical guidelines (6). Interestingly, the problem of metabolic control after delivery remains almost unexplored. The current study is just the second investigating this problem, with the earlier report involving 30 type 1 diabetic patients examined between 1992 and 1994 (8). The conclusions were similar to ours; most type 1 diabetic patients had substantially improved glucose levels during pregnancy, and glucose control deterioration was observed after delivery. The current study is substantially larger than the U.K. cohort and majorly differs in the A1C levels achieved in the examined groups. Mean preconception A1C levels in the U.K. and our cohorts were 9.9 and 6.9%, respectively, 7.0 and 5.7% in the third trimester, and the last follow-up values were 9.7 and 7.3%, respectively. These data are likely the result of increasingly strict contemporary therapeutic aims and new tools such as insulin analogs, personal pumps, and monitoring devices. However, in spite of much better glycemic control in our cohort, A1C values after pregnancy were higher than recommended for type 1 diabetes (11). The guidelines for glycemic control, expressed as both glycosylated hemoglobin and SMBG values in type 1 diabetes in the general population, have been less strict than the targets for pregnant women. For example, the current recommended A1C goal in Poland has been 6.5% since 2006 (12). We previously mentioned several reasons for postdelivery deterioration of glycemic control. An underestimated cause may be the relaxed stringency of diabetes management. For example, after the delivery, the visits were less frequent and the minimal recommended SMBG measurements number was slightly lower. Although the postulate of maintaining pregnancy-level glycemic control after delivery is unrealistic, attention should be paid to reach general type 1 diabetes goals.

Our study is the first that describes weight changes after delivery in a group of

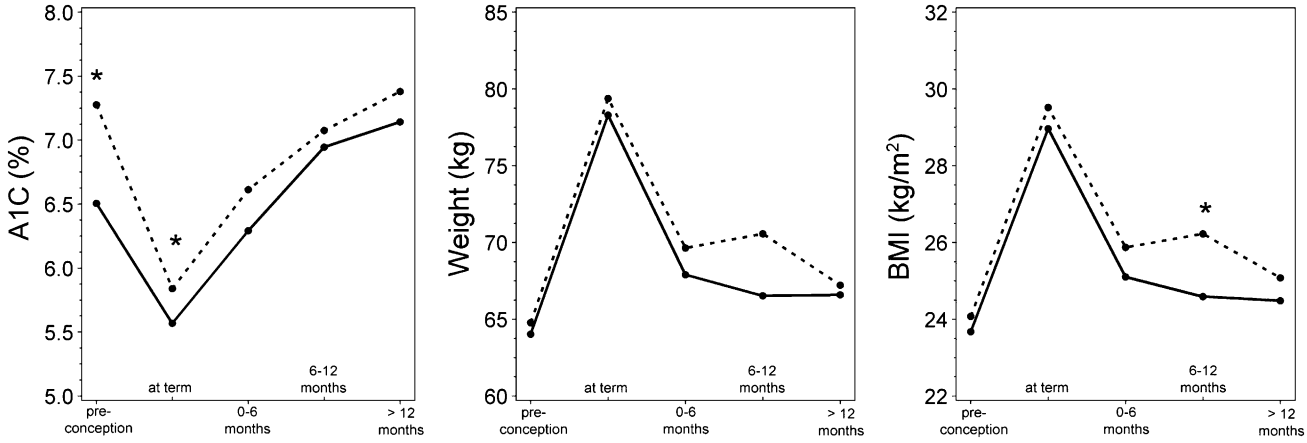

Figure 1—*Temporal trends in A1C, body weight, and BMI during and after pregnancy. Solid line, pregnancy planning; dotted line, not planning. Asterisks indicate differences significant at* $P < 0.05$.

type 1 diabetic women. The patients in our study experienced a large weight increase during pregnancy. A weight gain of 2.5 kg measured after a median of 20 months after delivery as compared with the prepregnancy baseline seems to be similar to the general female population (10). One may postulate that less weight gain during pregnancy than observed in this cohort (14.4 kg) would likely make it easier to return to the preconception baseline. This may be particularly true for the CSII method, as in our earlier report, it was more predisposing to weight gain than the MDI model in type 1 diabetes–complicated pregnancy (15 vs. 13 kg, respectively) (5). We also recently reported a cohort of type 2 diabetic women who gained <10 kg during pregnancy, likely due to the special attention paid to caloric restriction in an education program (11).

The current study is characterized by shortcomings related to nonrandom factors possibly influencing the results. For example, >100 women did not show up in the clinic after the delivery. Medical care of pregnant type 1 diabetic women in Lesser Poland (the administrative region of which Krakow is the capital) is centralized and patients are encouraged to register at the Department of Metabolic Diseases, optimally during pregnancy planning or, at the latest, in early pregnancy. It is likely that most of the missed postpartum follow-up appointments resulted from the women returning to their local diabetes centers, which is particularly understandable in the light of duties related to childcare. However, one cannot entirely exclude that they were less motivated and, thus, characterized by poor glycemic control. Nevertheless, this possibility seems to be very unlikely, as during pregnancy, women who dropped from observation had similar glycemic control as the rest of the study group (data not shown). Additionally, although women who continued CSII may seem to be less prone to postpregnancy glycemic control deterioration, the possibility that they were better educated about diabetes therapy and more motivated should be considered. In women who discontinued CSII, deterioration of glycemia was observed when still on CSII, which paralleled the A1C changes seen in MDI-treated women.

In conclusion, type 1 diabetic women showed postpregnancy deterioration in glycemic control. They were also unable to return to their prepregnancy weight. Type 1 diabetic women seem to require special medical attention after delivery to maintain their diabetes control within therapeutic targets.

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K.C. designed the study, developed the protocol, searched medical databases, analyzed, researched, and interpreted data, and wrote the manuscript. A.H.-S. searched medical databases, researched and interpreted data, and critically reviewed the manuscript. J.S. analyzed, researched, and interpreted data and wrote the manuscript. I.J., J.W., and S.B. searched medical databases, researched and interpreted data, and critically reviewed the manuscript. A.L. researched and interpreted data and wrote the manuscript. M.T.M. designed the study, developed the protocol, coordinated the project, researched and interpreted data, wrote the manuscript, and approved the final version of the manuscript. M.T.M. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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