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## Continuous Glucose Monitoring:

### The Experience of Women With Type 2 Diabetes

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### Abstract

**Purpose**—The purpose of this descriptive study was to document the experience of wearing a continuous glucose monitoring (CGM) device in women with type 2 diabetes (T2DM). The availability of CGM has provided patients and clinicians with the opportunity to describe the immediate effects of diet, exercise, and medications on blood glucose levels; however, there are few data examining patients' experiences and acceptability of using CGM.

**Methods**—Thirty-five women with T2DM wore a CGM for 3 days. Semistructured interviews were conducted to capture the self-described experience of wearing a CGM. Three open-ended questions were used to guide the participants' self-reflection. Interviews were transcribed and analyzed.

**Results**—The women verbalized both positive and negative aspects of needing to check their blood glucose more frequently and wearing the monitor. After viewing the results, most women were surprised by the magnitude and frequency of blood glucose excursions. They immediately examined their behaviors during the time they wore the CGM. Independent problem-solving skills became apparent as they attempted to identify reasons for hyperglycemia by retracing food intake, physical activity, and stress experiences during the period of CGM. Most important, the majority of women stated they were interested in changing their diabetes-related self-care behaviors, especially eating and exercise behaviors, after reviewing their CGM results.

**Conclusions**—CGM is generally acceptable to women with T2DM and offers patients and their health care practitioners a possible alternative to routine glucose monitoring for assessing the effects of real-life events on blood glucose levels.

Continuous glucose monitoring (CGM) is a novel method for continuously monitoring blood glucose levels. The earlier CGM monitors did not provide real-time blood glucose data. These meters were downloaded in a clinic office, where trends in blood glucose levels were evaluated and treatment decisions made. Real-time CGM (rt-CGM) systems provide immediate visual feedback about blood glucose levels to the patient. Both non-rt-CGM and rt-CGM methods provide visual graphs of blood glucose results over the period of CGM. In particular, CGM has successfully been used in clinical trials aimed at reducing A1C in children and adults with type 1 diabetes in which the subjects could make immediate adjustments to insulin dosages.<sup>1-4</sup> Only 3 studies have included CGM as a method to improve glucose control in patients with type 2 diabetes (T2DM).<sup>1-5-6</sup> In a study examining

the clinical effectiveness of continuous glucose sensing, 91 insulin-requiring adults with type 1 (n = 76) and type 2 (n = 16) diabetes were randomly assigned to wear a CGM with a visual display, or one without a visual display. Those with real-time access to the visual display had a reduction in time spent in low and high glucose numbers and increased the amount of time within their target blood glucose levels.<sup>1</sup> Yoo and colleagues<sup>6</sup> used rt-CGM in addition to education about increasing activity and eating less when the CGM alarmed, notifying the subjects that their blood glucose levels were high. After 12 weeks, the rt-CGM subjects had significant reductions in A1C, calorie intake, body mass index (BMI), and postprandial glucose levels when compared with subjects who used routine self-monitoring of blood glucose (SMBG) alone.<sup>6</sup> Allen and colleagues<sup>5</sup> studied the effects of non-rt-CGM combined with a counseling intervention on physical activity habits in adults with non-insulin-requiring T2DM. After 8 weeks, subjects in the intervention group showed significant increases in moderate-activity minutes and decreased A1C and BMI.<sup>5</sup> Each of these studies suggests that non-rt-CGM and rt-CGM may be efficacious interventions to improve healthy behaviors and decrease A1C; however, the studies did not address the subjective experiences related to wearing the CGM. Most recently, it has been reported that it is important to consider the psychosocial factors associated with CGM.<sup>7,8</sup> Because of limited information regarding the experience of wearing the CGM monitor, particularly in persons with T2DM, the following study was undertaken.

## Methods

### Design

This is a descriptive study with an exploratory design to understand the experience and acceptability of wearing a CGM device in women with T2DM. This was part of a parent study (unpublished data, Fritschi, 2008) in which the physiological, psychological, and lifestyle correlates of fatigue were examined in women with T2DM and in which a subset of women wore a CGM to examine the relationship between glucose variability and self-reported fatigue. Because women willingly shared their experience with wearing the CGM and their initial responses were so dramatic, the study investigators amended the parent study to include a semistructured interview to capture their experiences. The interview consisted of 3 questions and was conducted by the principal investigator. It addressed the following: their subjects' experiences (both positive and negative) with wearing the device, their responses to the data that were generated from the CGM, and whether the CGM findings would affect their diabetes care in the future. Given the limited availability of data that analyze the use of the CGM monitor from the patient's perspective, this design was considered appropriate for gathering valuable information as a foundation for future research.

### Sample

Thirty-five women with T2DM participated in the CGM substudy. Participants were recruited through flyer distribution at diabetes clinics around Chicago and through Internet advertisement. Inclusion criteria included women aged 40 to 65 years, on any diabetes therapy, who had been diagnosed with T2DM for >6 months. The study was approved by the Institutional Review Board at the University of Illinois at Chicago.

### Data Collection Procedures

Participants completed 2 visits during this study. A Medtronic MiniMed CGMS Gold sensor was attached subcutaneously to subjects, who were then taught the proper technique and appropriate timing of fingerstick capillary blood glucose testing to be used in the home calibration of the CGM monitor. The subjects were given a blood glucose meter and enough test strips to monitor their blood glucose 4 times within each 24-hour period. In addition, the

subjects were instructed on how and when to remove the monitor. A second visit was scheduled within 3 to 5 days. During this visit, the CGM monitor was removed from the participant. The data were then downloaded into a software program that allowed the blood glucose data to be displayed in graphical format. Printouts of the blood glucose graphs were given to each participant. This was the first opportunity for the women to view their results. The investigator asked the women the following 3 open-ended questions about the CGM experience:

Question 1 (prior to viewing their blood glucose graphs): Thinking about wearing the CGM device, including having to check your blood glucose levels 4 times each day, how was this experience for you?

Question 2 (after viewing their blood glucose results): Were you surprised by any of the numbers you obtained?

Question 3: Does this experience make you want to change the way you take care of your diabetes at home?

### Continuous Glucose Monitoring

The Medtronic MiniMed CGM Gold system continuously measures the glucose concentration in interstitial fluid over a range of 40 to 400 mg/dL (2.2-22 mmol/L). The system consists of a small external monitor, approximately the size of a cell phone, which serves as the data collection unit processing the signals sent from the sensor. The sensor includes tiny glucose-sensing electrodes housed in a flexible polyurethane catheter, inserted just under the skin of the abdomen. A glucose sensor signal is acquired every 10 seconds, and a smoothed average of the signal is saved in memory every 5 minutes, resulting in 288 readings every 24 hours. Data are downloaded to an external computer, where they can be viewed in graphical format or as numerical data with summary statistics. The women were asked to perform 4 capillary blood glucose tests in each 24-hour period that the CGM system was worn and to enter the results into the CGM device for calibration purposes. Subjects were blinded to the CGM blood glucose levels during the study.

### Analysis of Semistructured Interviews

The principal investigator conducted all interviews individually with each participant, and each interview lasted approximately 30 minutes. Participants' responses to the questions were not recorded but were transcribed verbatim during the interview and read back to the participant. Upon the conclusion of the study, the responses to each question were reviewed. With the first question about "their experience of wearing the CMG," participants reported both positive and negative experiences. Thus, all of the positive experiences were placed into one group, and the negative experiences were placed into another group. Subsequently, broad, mutually exclusive categories/themes within these groups were identified by the principal investigator. Similarly, in response to the second and third questions, women answered either "yes" or "no" and provided an explanation for their response. Therefore, the percentage of women who answered yes and no to each question was noted. Subsequently, data were again grouped into broad, mutually exclusive categories/themes for each of these questions. Two collaborators independently reviewed the data for accuracy and agreement with data categorizations.

### Results

The women in the study (n = 35) represented a diverse group of racial and educational backgrounds (see Table 1). The duration of diabetes ranged from 0.5 to 20 years, with an average duration of  $6.1 \pm 6.0$  years. Most of the women used oral medications to control their diabetes. Chronic blood glucose control in the participants, as measured by A1C, was

slightly higher ( $7.2 \pm 1.8$ ) than the goal of  $<7\%$  set by the American Diabetes Association.<sup>7</sup> On average, the women performed SMBG 4.5 times per week, and 77% had insurance or medical care that covered the costs of blood glucose–testing supplies.

### Results From Question 1

Thinking about wearing the CGM device, including having to check your blood glucose levels 4 times each day, how was this experience for you?

Responses to this question were grouped into positive and negative responses (Table 2). The positive responses were then examined for common themes, as were the negative responses.

The most positive theme that emerged was “checking blood glucose more frequently.” Sixteen (46%) women mentioned the increased frequency of having to check their blood glucose level. More women described the experience as positive rather than as negative. Positive comments included the following:

Made me more conscious that I have to check my sugar. Normally, I only check when I’m feeling sick.

I liked the experience because I checked my blood glucose more. I only checked in the morning and before bed.

Negative comments about “checking blood glucose more frequently” most often pertained to sore fingertips; however, one woman described the frequency of blood glucose testing as follows:

Pain in the ass. To me diabetes is like having cancer or a heart attack. If I monitor 4 times a day, it would be like—I mean—it would be depressing. It would tell me I have diabetes and I’d have to accept it. If I accepted it, I’d have to do something about it.

The next positive theme was a “heightened awareness of the effects of activity, stress, and foods on blood glucose level.” One woman noted,

I’ve really strayed from monitoring, so it was really helpful to see how things I put in my body affected my blood sugar. . . . I ate a big bag of candy and saw my blood sugar go up to 320.

Whereas others noted,

I wouldn’t have tested my sugars 3 to 4 times a day. It kept me knowing my sugar because I was having to enter it into the machine. It was better than usual because I was able to know what was happening to my body. It’s a good aid.

Before, I didn’t take too much care of my diabetes. This time I checked my sugar 3 to 4 times per day and found out I didn’t have as many highs as I used to. I’m not as sick as I thought I was.

The remaining positive themes related to the experience of wearing the CGM monitor included “helping science,” “taking better care of self,” “and improved family understanding.”

Most negative themes related to the experience of wearing the CGM device and having to perform SMBG were “technology issues” (CGM size and weight, alarms, cord catching on things, and worry of/actual catheter falling out), “personal issues” (bathing difficulties, bathroom inconvenience, clothing issues), and “discomfort” (sleep loss, itchy tape). Comments included the following:

It was heavy—if it were more lightweight, you wouldn't realize it's there, but being heavy, you're conscious it's on you.

I had trouble finding things to wear—I had to cover it. I don't like showers so I had to take something called a “whore's bath.” I had to find half-slips—all I wear is whole slips. Dressing didn't work. Wearing it was funny.

Noticed it more at night when you go to turn over. It would wake me up to change sides.

The CGM monitor is not waterproof. The women were given shower bags to keep the CGM monitors dry, and 5 women made negative comments specifically about the shower bags, including,

Plastic shower bags didn't work—my husband had to hold it outside the shower to keep it dry.

While most women stated that they had no discomfort from wearing the CGM device, additional negative themes were uncovered relating to “sleep loss,” “being uncomfortable,” and “itchy tape.” The final negative theme was the “emotional issues associated with wearing the CGM monitor.” Two women offered these comments:

I hate anything artificial, so it was bothersome. It was yet another reminder that I had diabetes. Not physically bothersome, but emotionally bothersome. It heightened my sense of personal annoyance about having diabetes.

I wasn't worried, but once it was on I began to worry all the time—what happens if I drop it in the bathroom? It made me worried that it would fall off. Then it made me depressed and I cried a little. I worried about the shower, it made me worry that I would destroy it or that it would electrocute me or I would yank it out... I wore it to play poker with my friends and they were all worried that there was something really bad or wrong with me. I was so nervous I couldn't think straight. I couldn't have nookie with my boyfriend. My boyfriend wouldn't touch me—he was very worried. I felt so bad by what everyone said.

## Results From Question 2

Were you surprised by any of the blood glucose numbers you obtained? (after the women viewed their 3-day blood glucose graphs)

Responses from this question were categorized as positive “yes” or negative “no.” The positive and negative responses were then examined. Thirty (86%) women answered “yes,” they were surprised by their blood glucose numbers; 5 (14%) said “no,” they were expecting the results they obtained. Women were surprised by their blood glucose numbers because they did not realize that their blood glucose levels could rise so high. Comments from these women included the following:

I've never seen it go so high—I've never seen it 300!

Surprised by all of them! When I took my readings they were low, but on the graph, there are huge peaks after I took them!

I never thought it would get to 300. I was like, what?! I mean—not without eating cheesecake... I can't wait to show this to my nurse practitioner!

Women were also surprised at the blood glucose responses (or lack thereof) as they related to their eating behaviors:

Normally my blood sugar is below 100, but shocked with the 178 because I had nothing to eat! I don't usually test 4 times a day. I was kind of shocked the way they went up like that.

I don't know why it shot up to 400! I took my insulin, but I had a piece of candy. I thought it would be lower. In essence this means I'm not in control.

The spikes on Saturday. I almost got up to the 300s. I didn't eat any candy, sugar, chocolate, or anything. All I did was Seattle Sutton on Saturday.

Surprised by how high some of the peaks are, how low the valleys. Usually only do fasting blood glucoses and they're never high. Some of these are up to 300 almost. I certainly didn't think I was in great control and I know my HbA1c, but I've really been noncompliant—lots of cooking and eating out and even drinking—more family celebrations the last 6 weeks.

Friday after lunch it was over 300! That was the day I missed my insulin ... I was in the middle of a big project. I grabbed tacos off the kitchen. It's amazing that something that small can take you so out of control without the insulin to take care of it.

I don't understand why it's high in the morning... I don't do no eating in the middle of the night.

### Results From Question 3

Does this experience make you want to change the way you take care of your diabetes at home, such as the number of times you check your blood glucose level, your diet, or your exercise habits?

Responses to this question were categorized as positive “yes” (n = 33, 94%) or negative “no” (n = 2, 6%). The responses were then examined according to diabetes self-care categories: “diet,” “exercise,” “blood glucose monitoring,” “taking medications as prescribed,” and “other.” The most common diabetes self-care behavior was related to making diet changes. Twenty-one (60%) of the women stated that they wanted to make some sort of dietary change after viewing their blood glucose graph. Comments included the following:

Change my regimen of eating. It looks like I don't tolerate sweets too well... .  
When I eat them, it goes up real fast.

I don't cook for myself. My son-in-law makes everything really greasy. I want to eat more vegetables.

Definitely changed my mind about the cookies. The snack at night knocks it up at night. I have to watch that.

Twelve (34%) of the women stated they wanted to get more exercise and offered comments, including,

I see it's important to keep exercising because I see when my blood sugar is high, that's going to bring it down. I would take a walk when my blood sugar was high and that would bring them down.

While 10 women (29%) wanted to increase home blood glucose monitoring:

I want to monitor my blood sugar a couple of times per day so I can get regulated and see what happens in 2 to 3 weeks.

I still won't test 4 times a day, but I'll try to test more than once a week!



Three (9%) of the women noted that the blood glucose graphs reinforced their need to take insulin or oral diabetes medications. One woman stated,

Looking at it [the graph] I am definitely more struck by the need for me to utilize my insulin—especially when I'm eating.

For several women, the visual blood glucose graphs helped them feel the need to make global changes in the way they cared for their diabetes and to see themselves as being the agents of change in their lives:

This study was like my wake-up call. I need to be diligent... My life can't be scheduled the same every day... I understand that I need to make changes. It does make me want to make changes.

Now when I see the [CGM] monitor, I feel more happy that I'm not as sick as before. I used to wake up sleepy and say, it's OK, I'm sick—whatever I do my blood sugar doesn't go down. My blood sugar used to be 200 to 250, but now I see my blood sugars go up and down and I can do something.

I have work to do—I want to do more journaling and refocusing on the need to keep things in those ranges.

Definitely. It [blood sugar] should be more consistent. It shouldn't be up/down/up/down like that. I know I'm doing damage to my body. It really opens my eyes ... it's basically the same time of day where the peaks are-spikes! ... I would like to do this like every month—it really helps me to see what my sugar does that I wouldn't get to see. I want to show my doctor.

I would love to get a read-out during the week that I try so hard to do everything right. When I went back to my doctor, he was annoyed because the numbers did not reflect my hard work. It made me discouraged. But this [CGMS graph] is encouraging because you can see a direct day-to-day correspondence with behavior... It's so easy to get exhausted about your illness. Doing this is like a shot of adrenalin. Periodically you need something to get you excited about your disease and think of it more like a friend than an enemy.

The graph is like gold to me. I wish I could have done a log with it.

## Discussion

The findings from this study provide insight into both the challenges of routine blood glucose monitoring and the potential use for novel blood glucose-monitoring methodologies in women with T2DM. Overall, the practical application of using CGM for 3 days had both positive and negative aspects. The positive benefits included checking blood glucose more frequently and the heightened awareness of the effects of activity/food/stress on blood glucose levels. There were also negative aspects of using the CGM. These included technological concerns with the size and weight of the CGM and the cord catching on things. Women were also concerned with personal issues including problems with clothing choices and use of the shower bags when bathing. Most problems associated with the size and weight of the CGM and the difficulty with wearing the CGM should be diminished with the recent release of new CGM technology, the Medtronic MiniMed *iPro* Glucose Sensor. This CGM is a small, flat disk that fits close to the body and requires neither the use of a long cord nor a plastic bag to keep it dry when bathing. Some women also had negative emotional responses to the need for checking their blood glucose levels 4 times daily. They made reference to SMBG being an intrusion on their lives and a reminder that they had diabetes. Another woman verbalized feelings of sadness and distress related to wearing the CGM. She mentioned the negative response from friends and family who saw her wearing

the monitor and thought she was very ill. The responses from women revealed the emotional difficulty of living with a chronic condition that must be self-managed. The experience of wearing the CGM and having to frequently monitor blood glucose levels caused women to verbalize their feelings of sadness and frustration with their disease. Sometimes referred to as “diabetes emotional distress,” this type of feeling is common in people with diabetes and often overlooked during office or clinic visits.

Also of interest was that women were quite surprised by their blood glucose readings, especially by the height of their blood glucose excursions following meals. However, once they saw the visual graph, they immediately examined their behaviors during the time they wore the CGM. They wanted to identify reasons for their results (both high and low) and sought to retrace their food intake, physical activity, and stress experiences from that time period. They were actively using diabetes problem-solving skills independently. Most were excited to be given a copy of the graph, and several made reference to showing it to their nurse or doctor. This finding suggests that use of CGM could prove to be an effective and individualized teaching aid when used in combination with diet and/or physical activity logs. The women were able to see the effects of their behaviors in relation to the excursions in their blood glucose levels. Data such as these would be beneficial in determining medication schedules or adjustments. Postprandial and nocturnal blood glucose patterns could be analyzed more effectively than with results from routine SMBG. The women in our study monitored their blood glucose levels an average of only 4.5 days per week. Most tested in the fasted state, before meals, or at bedtime. These static results would not reflect blood glucose excursions from meals or exercise bouts, nor would they show what happened to the blood glucose levels during the night. Weeks of routine SMBG would not give the same sort of detailed blood glucose trends data that the women received after only 3 days of CGM.

Most important, the majority of women stated they were interested in changing their diabetes-related self-care behaviors, especially eating and exercise behaviors after reviewing their CGM results. These findings, however, should be examined with caution. Verbalizing the intention to change behavior should not be equated with actively doing so. In their intervention study of the effects of counseling and CGM on physical activity behaviors, Allen and colleagues<sup>5</sup> included individualized exercise prescription, diabetes education, and counseling along with CGM in their intervention group.

In summary, there is growing support for use of CGM as a novel method for facilitating behavior change in people with T2DM.<sup>1,5,6</sup> Findings from this study suggest that use of CGM in women with T2DM is well tolerated and offers a vivid picture of blood glucose patterns that are ordinarily missed in routine diabetes management. Overall, the women were not overly burdened by the physical and logistical requirements associated with wearing the CGM. Most of the complaints were related to technological and personal aspects of CGM, which should be minimized with newer CGM technologies. For a small subset of the women, the experience elicited negative emotions (ie, the reminder that they had diabetes). Most of the women expressed the desire to change some facet of their diabetes self-care regimen.

In conclusion, continuous glucose monitoring offers patients with T2DM and their health care practitioners a new tool for assessing the effects of real-life events on blood glucose levels. Future research may determine that the use of CGM in the clinical setting may be more effective than routine use of SBGM at home for improving diabetes health outcomes.



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**Table 1**

## Sample Descriptives (N = 35)

|                                                                             |                |
|-----------------------------------------------------------------------------|----------------|
| Age, mean $\pm$ SD, y                                                       | 52.6 $\pm$ 6.7 |
| Education, y                                                                | 15.5 $\pm$ 2.8 |
| Race, n (%)                                                                 |                |
| Non-Hispanic white                                                          | 18 (51.4)      |
| Non-Hispanic black                                                          | 11 (31.4)      |
| Hispanic                                                                    | 6 (17.1)       |
| Duration of diabetes, mean $\pm$ SD, y                                      | 6.1 $\pm$ 6.0  |
| Hemoglobin A1C, mean $\pm$ SD, %                                            | 7.2 $\pm$ 1.8  |
| Diabetes therapy, n (%)                                                     |                |
| Diet only                                                                   | 5 (14.3)       |
| Oral medication                                                             | 26 (74.3)      |
| Insulin injections                                                          | 2 (5.7)        |
| Oral + insulin                                                              | 2 (5.7)        |
| Insurance or other financial coverage for diabetes care and supplies, n (%) | 27 (77.1)      |
| Diabetes health behaviors, mean $\pm$ SD, d/wk                              |                |
| Exercise 30 min                                                             | 2.9 (2.3)      |
| Healthy eating                                                              | 4.4 (1.9)      |
| Monitors blood glucose                                                      | 4.5 (2.5)      |
| Checks feet                                                                 | 2.9 (2.4)      |

**Table 2**

## Question 1 Negative/Positive Responses

| Response                                                                     | n  |
|------------------------------------------------------------------------------|----|
| Positive                                                                     |    |
| Checking blood glucose more frequently                                       | 10 |
| Heightened awareness of activity/stress/foods affecting blood glucose levels | 4  |
| Helping science                                                              | 2  |
| Taking better care of self                                                   | 1  |
| Improved family understanding                                                | 1  |
| Negative                                                                     |    |
| Checking blood glucose more frequently                                       | 6  |
| Technology issues                                                            |    |
| Monitor size/weight                                                          | 4  |
| Alarms                                                                       | 3  |
| Cord catching on things                                                      | 1  |
| Worry of/actual catheter falling out                                         | 4  |
| Personal issues                                                              |    |
| Bathing difficulties                                                         | 7  |
| Bathroom inconvenience                                                       | 2  |
| Clothing issues                                                              | 2  |
| Sleep loss/uncomfortable                                                     | 4  |
| Itchy tape                                                                   | 3  |
| Emotional issues                                                             | 2  |