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CLINICAL APPLICATIONS

Professional Continuous Glucose Monitoring in Clinical Practice 2010

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Abstract

Professional continuous glucose monitoring (PCGM) is a 3–5 day test done to evaluate diabetes control. The PCGM test uses interstitial glucose measurements done every 5 min with a glucose-oxidase-impregnated membrane. The PCGM test evaluates glucose control retrospectively with the glucose results being unknown to the patient until the results are downloaded after the testing period. The PCGM test allows the practitioner and patient to evaluate the effect of diet, physical activity, medications, and lifestyle events on glucose control during the 24 h period. Developing a PCGM program at a medical office involves understanding reimbursement issues and having trained staff and a process in place to initiate the test and download and interpret the data.

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The advent of home glucose testing technology in the 1970s made urinary glucose testing obsolete. Self-monitoring of blood glucose (SMBG) quickly became a standard in diabetes management. However, SMBG provides only a "snapshot" approach to glucose monitoring. Self-monitoring of blood glucose tends to be done only premeal and misses postprandial, midmeal, and overnight glucose variability. Self-monitoring of blood glucose is also done when a patient has symptoms of hyperglycemia or hypoglycemia, and since many such episodes are asymptomatic, they are missed entirely. The current goal in diabetes management is to lower the hemoglobin A1c (HbA1c) to target and prevent diabetes-related complications while avoiding hypoglycemia. As we have pushed patients to lower HbA1c levels, a greater need for more frequent and comprehensive glucose information with better hypoglycemia detection has led to the development of continuous glucose monitoring technology. Retrospective glucose monitoring and real-time glucose are available. This paper will review the science, clinical utility, and usage of retrospective (professional) glucose monitoring.

"Professional continuous glucose monitoring" (PCGM) has become a commonly accepted term for the use of continuous glucose testing supervised by the health care provider's office. Previously used terms have been "retrospective continuous glucose monitoring," "historical continuous glucose monitoring," and "continuous glucose monitoring systems." With the advent of the continuous

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Abbreviations: (CGM) continuous glucose monitor (HbA1c) hemoglobin A1c, (MAD) mean absolute difference, (PCGM) professional continuous glucose monitoring, (SD) standard deviation, (SMBG) self-monitoring of blood glucose

Keywords: continuous glucose monitoring, continuous glucose monitoring system, glucose oxidase, glucose sensor, interstitial glucose, iPro, real-time glucose monitor

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monitoring devices for home use, a term that makes a distinction between the two types of monitoring is needed. The term PCGM will be used in this article.

Professional continuous glucose monitoring involves continuous glucose monitoring typically for a 3–5 day period with the patient being unaware of the result until the stored data are transferred to a data management system and analyzed. The patient is required to do routine SMBG and to record dietary intake and activity during the test period. The test is ideally done on days that are representative of "typical" days.

The goal of PCGM is to correlate the influences of diet, glucose-lowering medications, events, and physical activity on glucoses during an entire 24–72 h period on glucose control. The advantage of the test over "real-time" continuous glucose monitoring is that the patient's behavior is not influenced by the continuous feedback of glucose results. Therefore, the unbiased results can be used to make conclusions concerning various factors influencing the patient's diabetes control and therapeutic treatment recommendations, including changes in diet, activity, and medication, can be made (**Table 1**). The PCGM test is easier to use by the patient than the "real-time" or "personal" continuous glucose monitor (CGM) and requires minimal training and setup time. Another advantage is insurance reimbursement for PCGM (this has not been specifically defined up to this point), which is available to many more patients than for real-time or personal CGM. Professional continuous glucose monitoring has similarities to other aspects of retrospective monitoring in medicine and has been called the "Holter monitor of diabetes." Retrospective monitoring has been used for decades in cardiology.

The first PCGM device was the Minimed CGMS Physician-Use Glucose Monitoring System approved by the Food and Drug Administration in 1999. In 2003, the CGMS® System Gold™ was introduced by Medtronic Minimed. This device required data entry in a recorder that was attached to the subcutaneous sensor by a cable and could be downloaded after use. In 2008, the iPro was introduced and is the model currently in use. Dexcom, in 2009, developed a software adaption in the Dexcom 7, which allows it to be used for retrospective glucose monitoring.

Continuous glucose monitor technology utilizes a glucose sensor placed into the subcutaneous space, which measures the interstitial glucose continuously. The sensor consists of two semipermeable membranes that surround an impregnated glucose-oxidase-enzyme-containing material. When glucose and oxygen pass through the semipermeable membrane and react with the glucose oxidase enzyme in the presence of glucose, hydrogen peroxide is generated with two hydrogen ions, producing an electronic signal. The "signal" is then recorded and interpreted as glucose proportional to the level of glucose present in the interstitial fluid. Current sensor software stores and delivers a glucose result every 5 min (**Figure 1**).

Table 1.
Advantages of Professional Continuous Glucose Monitoring

1. Patient behavior is not influenced by the continuous feedback of glucose information, so the results are unbiased and can be used to make therapeutic treatment recommendations, including changes in diet, activity, and medication.
2. Professional continuous glucose monitoring is easier for the patient to use than the real-time monitor and requires minimal training and setup time.
3. Insurance reimbursement for PCGM is available to many more patients than for real-time glucose monitoring.

The CGM sensor measures glucose in the interstitial space while glucose meters measure glucose from blood vessels (mixed capillaries) (**Figure 2**). Because these two testing areas are physically separate, the glucose takes time to travel from one place to the other. When glucose levels are stable, such as in the fasting state, the glucose levels are usually nearly identical in the interstitial and capillary spaces. However, when glucose levels are rapidly changing, such as after a meal, the sensor glucose may lag behind metered glucose due to the time needed for glucose to travel from capillary to interstitial space. This delay can be up to approximately 20 min due to physiological delay and technology delay (filters and storage of data every 5 min). This delay has been called the "lead-lag phenomena."

Currently, SMBG is the reference for glucose levels, so the CGM sensor needs to be calibrated using a meter blood glucose value as the reference.

A number of studies have supported the utility and clinical benefit of using PCGM. One study by Boland and colleagues[1] used PCGM in pediatric patients with a mean HbA1c of 7.7% who were considered to have adequately controlled fasting glucoses. Professional continuous glucose monitoring demonstrated over 90% of patients had postprandial hyperglycemia, with almost half reaching levels over 300 mg/dl. Almost 70% of the

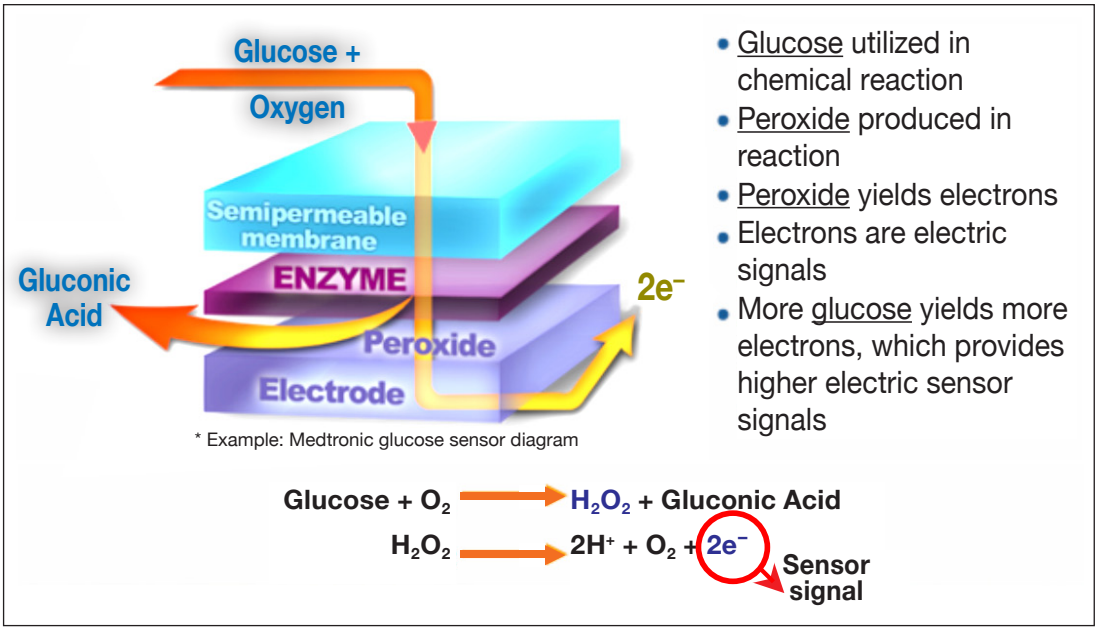

Figure 1. The sensor contains glucose oxidase impregnated in the sensor electrode, which translates the interstitial glucose level into a signal via a chemical reaction.

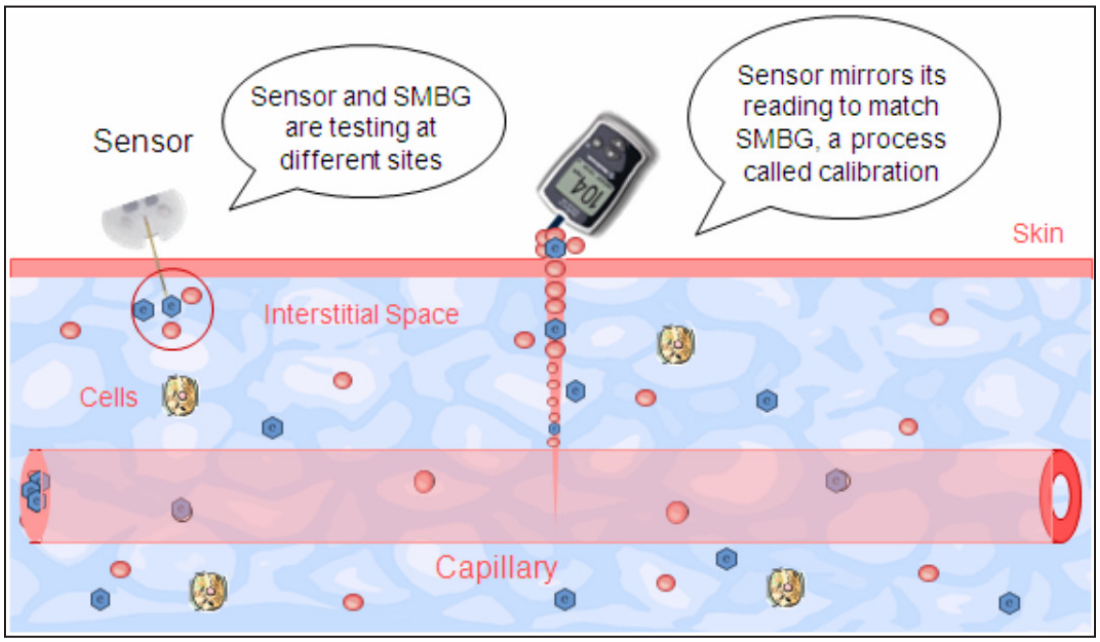

Figure 2. A CGM sensor and SMBG test at different sites.

CGMs revealed frequent and prolonged *asymptomatic* hypoglycemia (glucose <60 mg/dl). It was concluded that "repeated use of the CGMS [continuous glucose monitoring system] may provide a means to optimize basal and bolus insulin replacement in patients with type 1 diabetes." Clearly, uncovering hyperglycemia and hypoglycemia with PCGM is relevant to improvement in diabetes management.

Another study by Tanenberg and associates[2] evaluated insulin-treated patients with diabetes, ranging in age from 18–76 years, who were assigned to insulin therapy adjustments based on either CGM or SMBG values (51 in the CGM group and 58 in the SMBG group). There were no differences in HbA1c levels between the CGM group and the SMBG group at baseline (9.1% ± 1.1% versus 9.0% ± 1.0%, $p = .70$). Both groups showed statistically

significant ($p < .001$) and similar ($p = .95$) improvement in HbA1c levels after 12 weeks of study. However, the CGM group had a significantly shorter duration of hypoglycemia (sensor glucose ≤60 mg/dl) at week 12 of the study (49.4 ± 40.8 versus 81.0 ± 61.1 min/event, $p = .009$). This finding led to the conclusion that "use of the CGMS [continuous glucose monitoring system] to guide therapy adjustments in patients with insulin-treated diabetes reduces the duration of hypoglycemia compared with therapy adjustments guided by SMBG values alone."

A pediatric population was studied by Kaufman and coworkers[3] using PCGM. This study contained a total of 47 patients with a mean HbA1c value of 8.6 ± 1.6% (mean age 11.8 ± 4.6 years, youngest 2.7 years, and diabetes duration 5.5 ± 3.5 years) on three to four insulin injections per day ($n = 24$) or insulin pump therapy ($n = 23$). The patients were followed with the CGM for a mean of 69.5 ± 28 h. Comparisons were made between the number of high (>150 mg/dl) and low (<70 mg/dl) glucose patterns discerned with the sensor or the logbook. In addition, HbA1c levels were evaluated. In patients on injection therapy, 30 high or low glucose patterns were identified with the logbook records and 120 patterns with the CGM. Specific alterations of the diabetes regimen were made. An overall significant change in HbA1c, from three months before wearing the sensor to six months after (analysis of variance 0.04), was found in the subjects. *Post hoc* analysis showed a significant change in HbA1c from 8.6 ± 1.5% at baseline to 8.4 ± 1.3% at three months. The authors concluded that "the CGMS [continuous glucose monitoring system] can be used by pediatric patients to detect abnormal patterns of glycemia. The information that was obtained could be used to alter the diabetes regimen and impact glycemic outcome."[3]

The PCGM test has been evaluated in diabetes and pregnancy. Murphy and colleagues[4] studied 71 pregnant women, 16–45 years of age, with type 1 or type 2 diabetes. Standard prenatal care with SMBG was compared with prenatal care using PCGM. Continuous monitoring for up to 7 days, at intervals of 4–6 weeks between 8 and 32 weeks of gestation, was used to make therapeutic changes at intervals of 4–6 weeks. Use of PCGM during pregnancy was associated with improved glycemic control (lower HbA1c) in the third trimester (26–32 weeks), decreased birth weight scores, and reduced risk of macrosomia. There were no differences between groups in overall pregnancy outcomes.

Other studies have shown improved HbA1c,[5] greater detection of hypoglycemia,[6] and improved detection of severe hypoglycemia[7] with use of PCGM.

Indications for the PCGM include (**Table 2**) recurrent hypoglycemia, hypoglycemic unawareness, pregnancy, and HbA1c over target. Professional continuous glucose monitoring may be useful when discrepancies exist between SMBG and the HbA1c.

Table 2.
Candidates for Professional Continuous Glucose Monitoring

· Patients with repeated hypoglycemia
· Patients with hypoglycemia unawareness
· Patients with discrepancies between HbA1c and SMBG
· Patients unable to achieve goal with SMBG
· Patients who are pregnant

The iPro components include the glucose sensor that is inserted into the subcutaneous tissue, the recorder that attaches to the sensor to record the information, and the insertion device used to insert the glucose sensor (**Figure 3**). In addition, a charger is provided to charge the recorder and a "wand" is used to start communication between the iPro and the software. Lastly, there is a "tester" to test the iPro and facilitate downloading of the recorder. Software called Solutions is downloaded to a personal computer, and the iPro is downloaded wirelessly to the personal computer with a wireless link called ComLink. The only disposable component is the sensor. The other parts are reusable.

Once the data are downloaded via the wireless link, there are five available reports that can be customized. The reports include a sensor summary, sensor modal day, sensor modal time, sensor daily detail, and the patient log sheet. It should be emphasized that the patient log sheet, in which SMBG results, activities, and diet are recorded, is essential to interpreting the test results

The sensor summary report (**Figure 4**) provides the following three types of information:

1. Sensor information. The number of readings that are generated each day. A full day of sensor usage provides 288 readings. The first and last days of the test are usually not full days, so half or less of the usual number of readings will be available. The data

Figure 3. The components of the iPro system.

are less than optimal if the patient uses the sensor less than 50% of the time. Sensor information also includes the average and ranges of the sensor and glucose meter glucose readings and standard deviation (SD). Standard deviation indicates how variable sensor readings are. Patients who do not have diabetes may have a SD around 20, while someone with suboptimal diabetes control may have a SD of 60 or even more.

2. Optimal accuracy. Ideally sensors and meter readings should be identical. Realistically, this is impossible due to the reasons discussed earlier—measuring fluid in two different dynamic spaces. The sensor is automatically calibrated based on the meter readings, which should ideally be done by the patient four times each day of the test. The optimal accuracy part of the report is essentially a report on the quality of the test. It shows the number of paired readings, that is, the number of times that the meter readings were "paired" with the sensor readings, ≥3 is ideal. Less than this number per day may be associated with a less reliable result. A very important part of the optimal accuracy is the mean absolute difference (MAD). The MAD is the average difference between sensor and meter readings expressed as a percentage. Values of <28% are considered optimal. If the patient has a narrow glucose range (<100 mg/dl), then a value of <18% would be optimal.

3. Glucose excursion shows glucose ranges and displays the percentage of glucoses above, below, and at target in a color-coded pie chart format.

The next report is the sensor modal day. The sensor modal day overlays sensor readings of each day into one 24 h graph so that patterns of glucose on multiple days can be evaluated.

The sensor modal time report breaks the monitored days into time blocks that are programmed by the user. The software allows for setting times for meals and three other time blocks. The first time block is before and after breakfast, typically from 6–10 AM; the second is lunch, typically from 11 AM until 3 PM; and the third is supper at 5–8 PM. Time block A is commonly set to the overnight period, for example, 11 PM until 6 AM; block B might be set for the dawn effect period; and block C is commonly set for the entire 24 h period.

The next report is the sensor daily detail, which separates each day individually and displays the days side by side so that the relationship of one day to another can be evaluated. For example, the glucose results from 12–6 AM can be related to the glucoses and events of the evening before. Event markers can be superimposed on the daily detail report to denote mealtimes and times when insulin is administered. Event markers can be entered by the patient in the One Touch Ultra glucose monitor and can then be downloaded directly to the software to be shown on the reports or can be manually entered when the logbook is reviewed at the time of the download.

Though not a classic report, the logbook is a critical part of the analysis of data since it contains information about diet and day-to-day occurrences such as exercise

Date		10/7/2008	10/8/2008	10/9/2008	10/10/2008	Total
Sensor	# of Sensor Values	143	288	288	70	789
	Average (mg/dL)	136	202	260	272	217
	Min-Max (mg/dL)	69-241	87-389	127-400	244-314	69-400
	STDev (mg/dL)	39	74	73	22	80
Meter	# of Meter Values	3	4	3	0	10
	Average (mg/dL)	139	195	224		187
	Min-Max (mg/dL)	100-168	100-358	102-331		100-358
Optimal Accuracy Criteria	Designation				Use Clinical Judgment	
	# of Paired Readings	3	4	3	0	10
	Mean Abs. Diff. [MAD%]	8.1	6.4	24.9	n/a	12.5
	Correlation Coeff. [R]	n/a	1.00	0.91	n/a	0.95
Excursions High >140mg/dL Low <70mg/dL	# of Excursions	3	3	2	0	8
	# of High Excursions	2	3	2	0	7
	# of Low Excursions	1	0	0	0	1
	Duration Above High Limit	05:30 (46%)	18:50 (78%)	21:50 (91%)	05:50 (100%)	52:00 (79%)
	Duration Within Limits	06:20 (53%)	15:10 (22%)	02:10 (9%)	00:00 (0%)	13:40 (21%)
	Duration Below Low Limit	00:05 (1%)	00:00 (0%)	00:00 (0%)	00:00 (0%)	00:05 (0%)
	Pie Chart Red: Above Limits Green: Within Limits Blue: Below Limits					
Note: 4 daily blood glucose tests recommended when using Professional CGM.						

Figure 4. Sensor summary report.

and activity. The logbook also details when and how much glucose-lowering medication is taken.

A concise and comprehensive approach to interpreting the CGM includes evaluating the sensory summary report and the sensor modal day and correlating the results to the logbook information. The following is a suggested approach to interpretation and reporting of results:

1. Sensory Summary Report
   a. Review the number of sensor readings—288 per day is ideal. The test is not optimal if <50% of the readings are available per day (except on the initial half day of the test and the last half day of the test).
   b. Review the number of paired readings (≥3 is optimal).
   c. Under optimal accuracy, evaluate the MAD (<28% is ideal).
2. Sensor Modal Time Report and Sensor Daily Detail
   a. Evaluate for consistent day-to-day patterns.
   b. Evaluate overnight glucoses first, followed by premeal and then postprandial glucose patterns.
3. Logbook Evaluation
   a. Evaluate for events and dietary intake and their relationship to findings on the sensor time and daily detail reports. Evaluate dose and relationship of dose of glucose-lowering medication to meals and events.
4. Render an overall impression and make recommendations.

The PCGM report template, including the above information, could be used in an electronic medical record, and a template can be used to formalize and standardize the report (**Table 3**).

Two patient examples are detailed in **Appendix 1**, which includes the patient history, the PCGM results, and the interpretation with recommendations.

General advice about reporting includes the following:

1. In the absence of a pattern, focus on events and occurrences and their effect on glucoses.
2. Aim to find 2–3 areas of improvement or "vignettes" and 2–3 recommendations or changes.

Table 3.
Professional Continuous Glucose Monitoring Report Essentials (Template)

Patient Name _____
1. Current glucose-lowering regimen (insulin/medication dose)
2. General observations concerning tracings (number of days of tracings available)
3. Statistics
1. # of paired readings
2. MAD
3. % above/below target
4. Analysis of data
1. Overnight
2. Premeal
3. Postmeal
5. Logbook evaluation events/occurrences
6. Impression
7. Recommendations
1. Medication changes
2. Diet changes
3. Changes in activities
4. Follow-up

3. Even when the data are partial, many times conclusions can be made.

Organizing the use of CGMs in a medical office requires a number of elements. An initial purchase of equipment and designated personnel in the medical office trained in the initiation and downloading of the CGMs are needed. (The PCGM equipment and software are owned by the medical office.) Having a process in place for initiation, downloading, and interpreting the results is essential.

The ideal process might include the following:

1. Order the CGM at the time of the office visit.
2. Initiate the CGM after the office visit on the same day.
3. Schedule the patient for another appointment in 3–4 days to have the sensor downloaded to review and discuss the result and make appropriate treatment changes.

Potential challenges to the use of the retrospective CGM include reimbursement issues and inconvenience for the patient. The current sensor is lightweight and unobtrusive and is water resistant. The patient can shower with the sensor in place. The old version, the CGMS Gold, was bulky and required entry of event markers by the patient. The iPro requires almost no attention. Occasionally, a patient may have skin hypersensitivity to the sensor adhesive.

Professional continuous glucose monitoring may be used as an introduction to continuous glucose monitoring for patients who are appropriate for the real-time or personal CGM yet who are reluctant to obtain it. The PCGM test allows such patients to experience the subcutaneous sensor and to evaluate the data obtained prior to committing to purchasing the personal CGM. In the author's experience, several patients have understood the utility of continuous glucose monitoring by first using the PCGM and, as a result, have eventually obtained the personal CGM device.

Reimbursement (**Table 4**) for the test is available by Medicare in patients with type 1 and type 2 diabetes. Reimbursement policies by commercial carriers vary by region, and some insurers do not cover the test in patients with type 2 diabetes.

Table 4.
Reimbursement for Professional Continuous Glucose Monitoring[4]

The American Medical Association has created two CPT codes that can be used for Professional CGM procedures:

CPT code 95250 covers all services relating to PCGM startup (i.e., sensor insertion, hookup of iPro recorder, patient training), sensor removal, and data download.

- The national average Medicare reimbursement for 95250 is $128 if billed under a physician provider number.[a] Private payors generally pay more for this code.
- Continuous glucose monitoring services performed by any qualified staff member (e.g., registered nurses, medical assistants, lab technicians, registered dietitians) under the supervision of the physician or midlevel practitioner can be billed under 95250 using the provider number of the physician, midlevel practitioner, or hospital. Payment may be lower if billed under a midlevel practitioner provider (typically 15% lower).

CPT code 95251 is specific to the service of interpreting CGM data from the PCGM evaluation.

- The national average Medicare reimbursement for 95251 is $40 if billed under a physician provider number.[a]
- Only an interpretation performed by a physician or a midlevel provider[a] can be billed under this code. Interpretation performed by other office staff members (e.g., registered nurses, medical assistants, lab technicians, diabetes educators) should not be billed under 95251.
- This code can be billed even if CGM interpretation is performed without face-to-face time with patients. Both codes 95250 and 95251 may be billed more than once for a patient in a given year, depending on pay or policy or criteria. Confirm with your local payors. This may apply if you need to conduct multiple PCGM evaluations to monitor a patient's progress.

[a] Given that Medicare rates and private payor rates will vary across the country, as with all reimbursement, physician offices should determine their specific levels of local 95250 and 95251 coverage and rates.

CPT code 95250 is used when the CGM is downloaded (**Figure 5**). CPT code 95251 can be used to bill for interpreting the report. If 95250 and 95251 are used with evaluation and management services done on the same day, then the modifier "-25" should be added. CPT code 95251 does not require face-to-face interaction and can be billed as separate from the patient encounter.

The cost of an iPro PCGM starter kit is $1299 (as determined through personal communication with Medtronic, February 2010). The Medicare reimbursement is $126 for CPT code 95250 and $39 for CPT code 95251 in Texas, and the cost of the PCGM sensor is $35. The average reimbursement at Texas Diabetes and Endocrinology in 2009 including Medicare and commercial carriers was

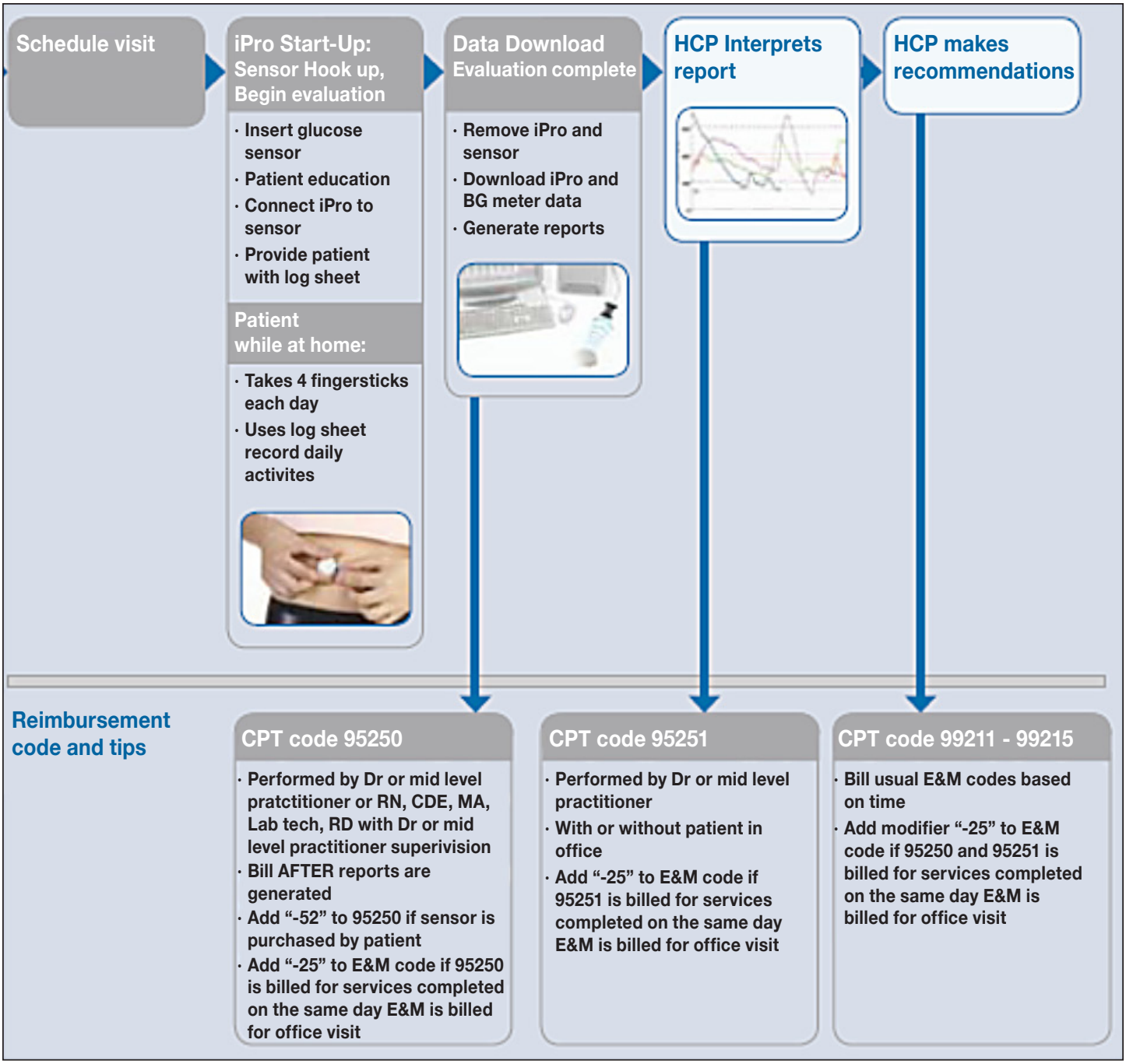

Figure 5. Example of a typical PCGM experience. (Reproduced from Reference 4 with permission.) BG, blood glucose; HCP, health care provider; RN, registered nurse; MA, medical assistants; CDE, diabetes educator; E&M, evaluation and management.

$148 (as determined through personal communication with Tiffany Reichle, office manager, Texas Diabetes and Endocrinology). No data are available on how many sensors would be recommended per number of patients with diabetes in a practice. The number of PCGM units needed is dependent on utilization, and most practices begin a PCGM program by obtaining one or, many times, two PCGM kits and purchasing additional units when needed. The typical lifespan of a PCGM recorder is one year, and the unit will likely have to be replaced yearly.

The Dexcom 7+ can also be used for retrospective continuous glucose monitoring by calling the Dexcom tech support department and obtaining a code that is entered into the Dexcom 7+ receiver to "blind" the device.

In conclusion, PCGM is a valuable tool in the evaluation of diabetes control by detecting episodes of hypoglycemia and hyperglycemia. The PCGM test requires very little patient interaction, and it offers a relatively unbiased assessment of 3–5 days of diabetes control. The use of real-time CGM is on the rise. However, reimbursement issues and patient acceptance limit its use. Reimbursement is available to many more patients with type 1 and type 2 diabetes for PCGM than real-time CGM. In addition, PCGM can be used as an introduction to continuous monitoring for patients with diabetes and may help patients understand the utility of continuous monitoring.

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Appendix 1

The following two cases are examples of PCGM that include a patient history, data presentation, and data analysis with interpretation. **Figures 6–15** represent the five PCGM reports for each case.

Case 1

A 66-year-old male with type 2 diabetes and coronary artery disease. Current meds include aspart (16 U at breakfast, 10 U at lunch, and 16 U at supper, plus correction dose of 1 U, 15>120) and detemir (32 U in the morning, 26 U in the evening). He reports home blood glucose readings of 91–125 mg/dl prebreakfast, 114–152 mg/dl prelunch, 99–195 mg/dl presupper, and 80–200 mg/dl at bedtime. Most recent lab results include an HbA1c of 6.6%. He experiences episodes of hypoglycemia at various times. He resisted changing his regimen, stating that, if he ate a snack in the mid morning and mid afternoon, "everything will be fine."

Indication for PCGM: Hypoglycemia and need to correlate medication, activity, and intake to hypoglycemia.

Interpretation

1. Statistics
   a. Number of sensor values is 288 on each of the full days.
   b. Number of meter values and paired readings is adequate (5–7).
   c. MAD is in good range at 7.1–10.2%.
2. Data evaluation
   a. Sensor modal day evaluation shows the following:
      i. The overnight ranges from low to mid 100s.
      ii. The premeal is usually in the target range.
      iii. The postmeal is high most days after breakfast and tends to be low after lunch and high after dinner.
3. Logbook correlation shows the following:
   a. He is on a somewhat high-carbohydrate diet.
   b. He overtreats lows.
   c. On a day that he used an exercise treadmill, his glucoses were lower overall.
4. Recommendation to the patient
   a. Consider reducing carbohydrate intake—see dietitian and learn to carbohydrate count.
   b. Increase aspart prebreakfast except on treadmill days to control postbreakfast readings.
   c. Reduce lunch aspart to avoid afternoon lows.
   d. Increase dinner aspart to control the evening readings.
   e. Reduce the evening detemir to avoid lows.
   f. Reduce the lispro given for the bedtime snack, as he is overdosing the snack. See dietitian for carbohydrate counting.
   g. Avoid overtreating lows. Use 15 g of carbohydrate for treating lows. (He was taking 40–45 g of carbohydrate for his afternoon lows.)

Date		12/18/2009	12/19/2009	12/20/2009	12/21/2009	12/22/2009	Totals
Sensor	# of Sensor Values	74	288	288	288	104	1042
	Average (mg/dL)	185	141	181	132	86	147
	Min - Max (mg/dL)	143-256	40-249	78-380	62-262	56-155	40-380
	STDev (mg/dL)	25	69	65	39	22	62
Meter	# of Meter Values	2	5	7	5	1	20
	Average (mg/dL)	200	167	183	117	95	160
	Min - Max (mg/dL)	186-213	49-255	76-281	94-164	95-95	48-281
Optimal Accuracy Criteria	Designation	X: Use Clinical Judgment				X: Use Clinical Judgment	
	# of Paired Readings	2	5	7	5	1	20
	Mean Abs. Diff. [MAD%]	4.0	10.1	7.8	7.2	8.5	7.9
	Correlation Coeff. [R]	n/a	0.98	0.99	n/a	n/a	0.98

Figure 6. Sensor summary report.

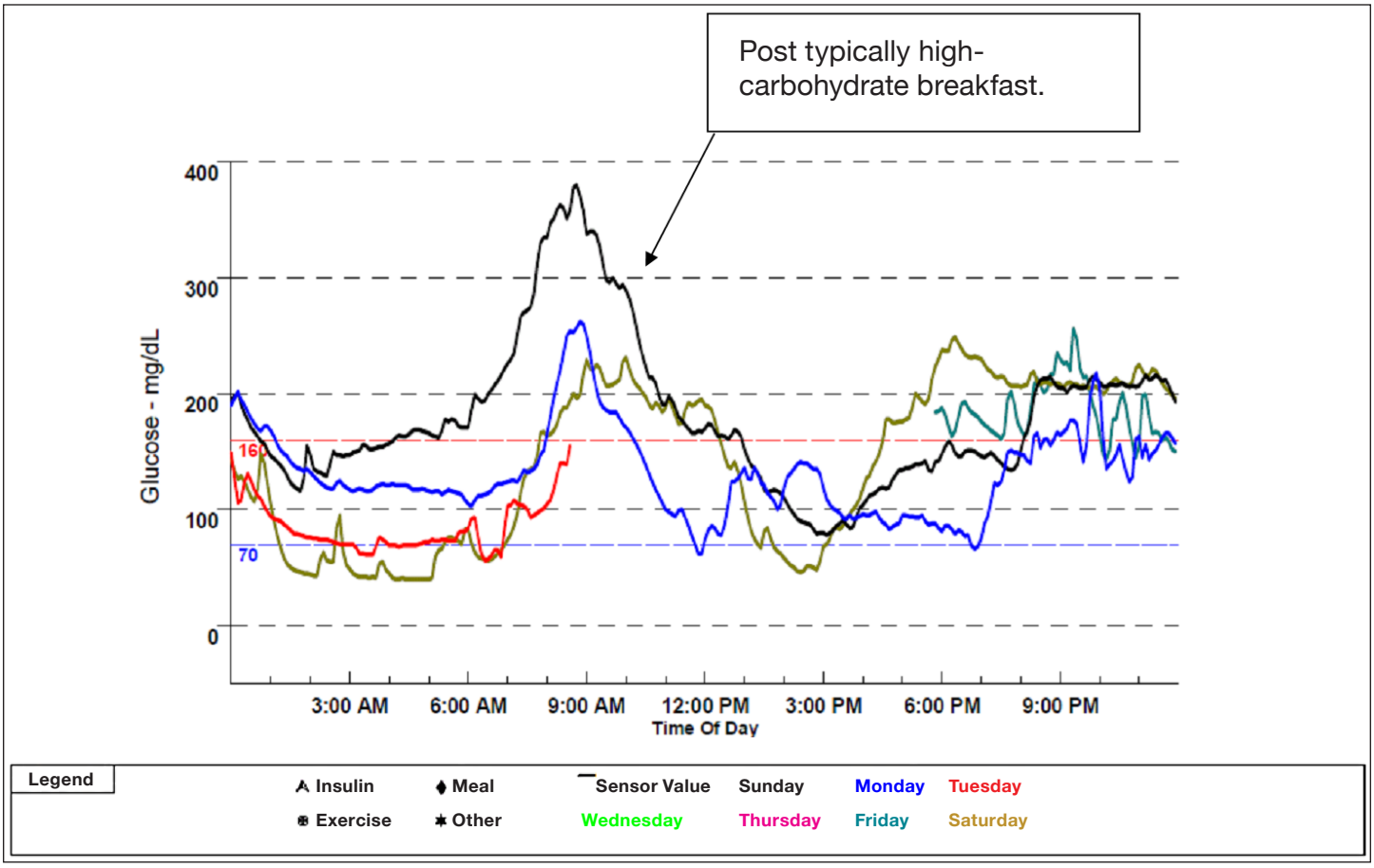


Figure 7. Sensor modal day.

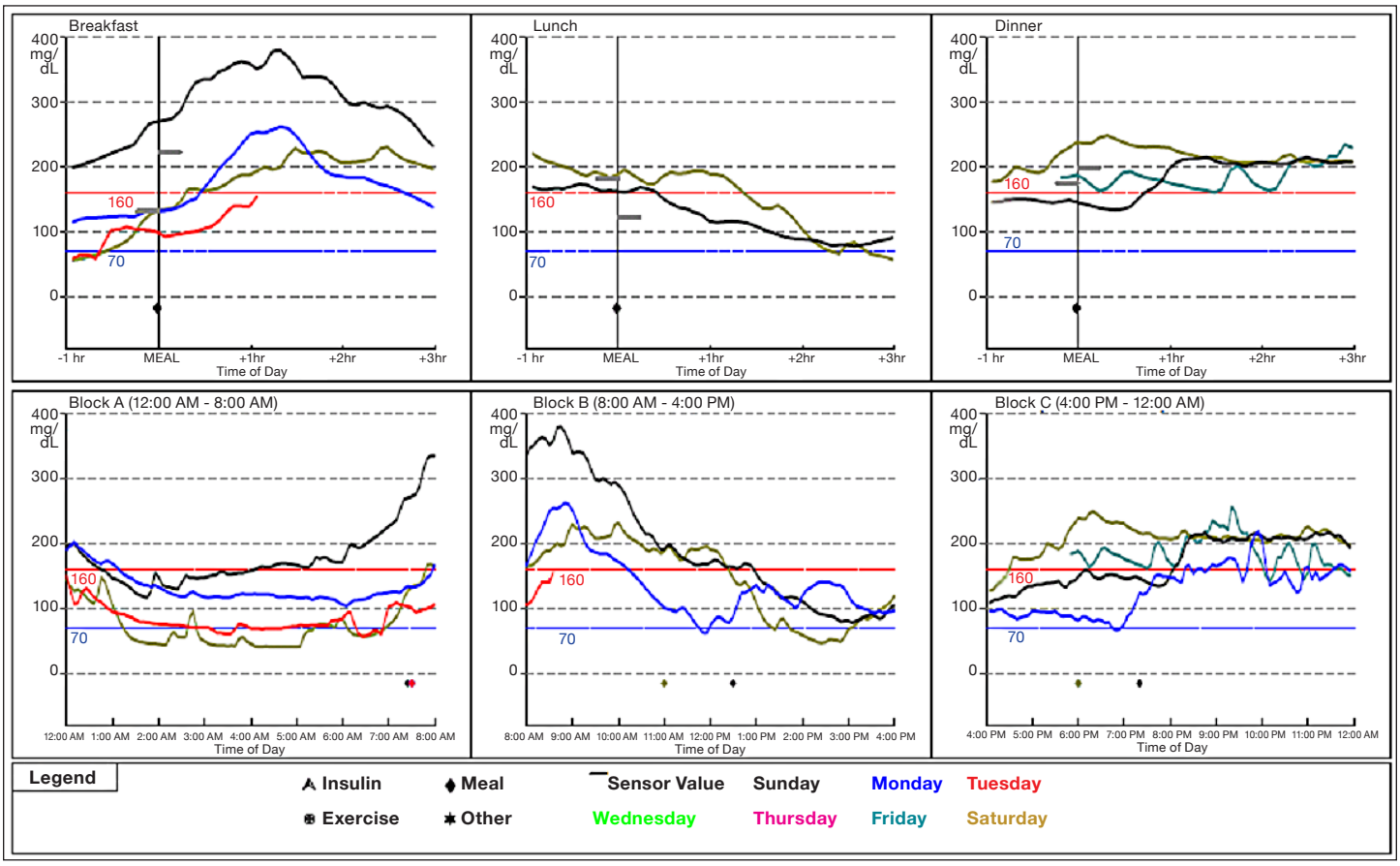


Figure 8. Sensor modal time.

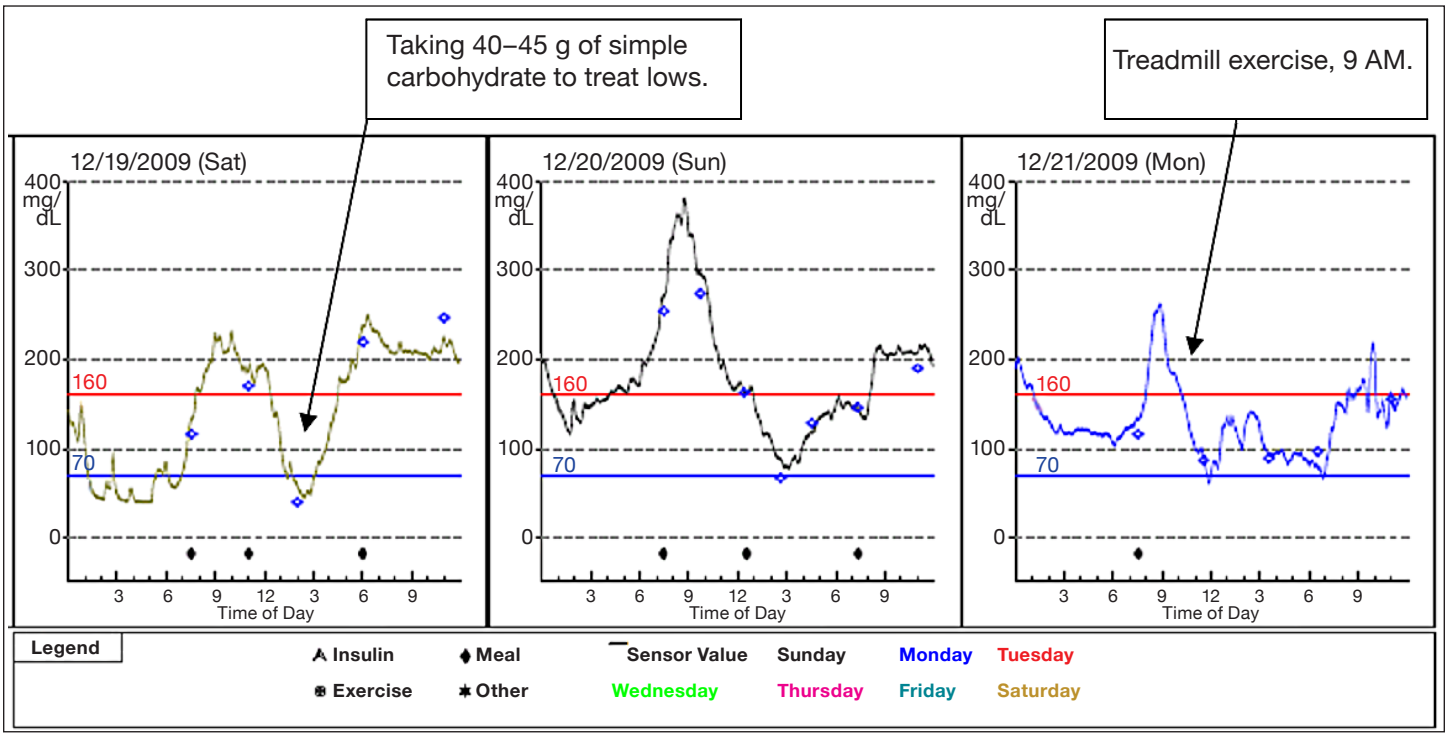
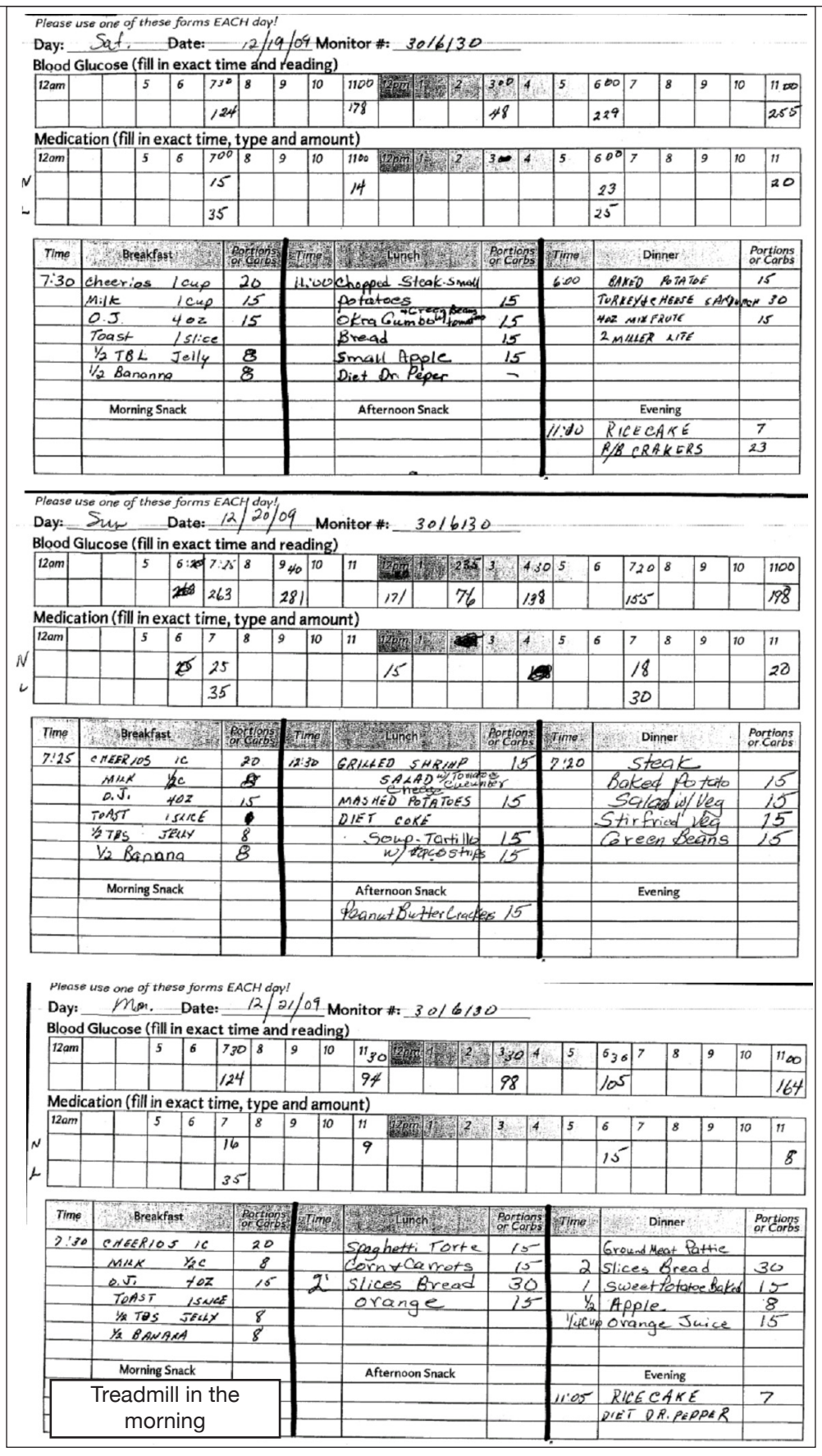


Figure 9. Sensor daily detail.



Please use one of these forms EACH day!

Day: Sat. Date: 12/19/09 Monitor #: 3016130

Blood Glucose (fill in exact time and reading)

12am			5	6	7:30	8	9	10	11:00	12pm	1	2	3:00	4	5	6:00	7	8	9	10	11:00
					124				178				48			229					255

Medication (fill in exact time, type and amount)

	12am			5	6	7:00	8	9	10	11:00	12pm	1	2	3:00	4	5	6:00	7	8	9	10	11
N						15				14							23					20
L						35											25					

Time	Breakfast	Portions or Carbs	Time	Lunch	Portions or Carbs	Time	Dinner	Portions or Carbs
7:30	cheerios 1 cup	20	11:00	Chopped Steak-Small		6:00	BAKED POTATOE	15
	Milk 1 cup	15		potatoes	15		TURKEY & CHEESE SANDWICH	30
	O.J. 4oz	15		Okra Gumbo w/ Creamy Beans & Tomatoes	15		4OZ MIX FRUIT	15
	Toast 1 slice			Bread	15		2 MILLER LITE	
	½ TBL Jelly	8		Small Apple	15			
	½ Banana	8		Diet Dr. Peper	-			
	Morning Snack			Afternoon Snack			Evening	
						11:00	RICE CAKE	7
							R/B CRAKERS	23

Please use one of these forms EACH day!

Day: Sun Date: 12/20/09 Monitor #: 3016130

Blood Glucose (fill in exact time and reading)

12am			5	6:20	7:25	8	9:40	10	11	12pm	1	2:35	3	4:30	5	6	7:20	8	9	10	11:00
					263		281			171		76		138			155				198

Medication (fill in exact time, type and amount)

	12am			5	6	7	8	9	10	11	12pm	1	2	3	4	5	6	7	8	9	10	11
N						25					15							18				20
L						35												30				

Time	Breakfast	Portions or Carbs	Time	Lunch	Portions or Carbs	Time	Dinner	Portions or Carbs
7:25	CHEERIOS 1C	20	12:30	GRILLED SHRIMP	15	7:20	Steak	
	MILK ½C	8		SALAD w/ Tomatoes & Cheese Cucumber			Baked Potato	15
	O.J. 4OZ	15		MASHED POTATOES	15		Salad w/ Veg	15
	TOAST 1 SLICE	8		DIET COKE			Stir fried Veg	15
	½ TBS JELLY	8		Soup-Tortilla w/ Pepperstrips	15		Green Beans	15
	½ Banana	8			15			
	Morning Snack			Afternoon Snack			Evening	
				Peanut Butter Crackers	15			

Please use one of these forms EACH day!

Day: Mon. Date: 12/21/09 Monitor #: 3016130

Blood Glucose (fill in exact time and reading)

12am			5	6	7:30	8	9	10	11:30	12pm	1	2	3:30	4	5	6:36	7	8	9	10	11:00
					124				94				98			105					164

Medication (fill in exact time, type and amount)

	12am			5	6	7	8	9	10	11	12pm	1	2	3	4	5	6	7	8	9	10	11
N						16				9							15					8
L						35																

Time	Breakfast	Portions or Carbs	Time	Lunch	Portions or Carbs	Time	Dinner	Portions or Carbs
7:30	CHEERIOS 1C	20		Spaghetti Torte	15		Ground Meat Pattie	
	MILK ½C	8		Corn & Carrots	15	2	Slices Bread	30
	O.J. 4OZ	15	2	Slices Bread	30	1	Sweet Potatoe Baked	15
	TOAST 1 SLICE			Orange	15	½	Apple	8
	½ TBS JELLY	8				¼ Cup	Orange Juice	15
	½ BANANA	8						
	Morning Snack			Afternoon Snack			Evening	
						11:05	RICE CAKE	7
							DIET DR. PEPPER	

Treadmill in the morning

Figure 10. Logbook.

Case 2

A 68-year-old woman with type 2 diabetes for 15 years. She reports that her glucoses are in the 100–200 mg/dl range, though she does not keep a log and did not bring her monitor for download. She denies hypoglycemia. Her regimen includes glargine (36 U morning and evening) and lispro (22 U premeal + correction scale, 1 U lispro for every 15 mg/dl over a premeal glucose of 100 mg/dl). She had HbA1c of 9.5% in November 2009.

Indication for PCGM: High HbA1c and need to clarify glucose levels so as to adjust insulin appropriately.

Interpretation

1. Statistics
   a. Adequate number of readings (288 on the two full days that she used the CGM and 187 on the third partial day).
   b. Adequate number of meter readings (four on the full days and three on the partial day).
   c. MAD is acceptable (ranging from 5.2–15.8%)
2. Data evaluation
   a. Sensor modal day evaluation shows the following:
      i. The overnight ranges from 70–200 and in the 70s at 2–3 AM on two nights.
      ii. The premeal is elevated.
      iii. The postmeal is very high most days.
3. Logbook correlation shows the following:
   a. She takes her lispro after meals frequently.
   b. She tends to skip her lispro if her premeal reading is below 100 mg/dl.
   c. Lack of consistency in her bedtime dosing of lispro. She is dosing to correct highs and for carbohydrate but not consistently, which led to an overnight glucose reading of <70 mg/dl.
4. Recommendation to the patient
   a. Change insulin:carbohydrate ratio to lower postmeal readings—see dietitian.
   b. Take the lispro premeal.
   c. Standardize bedtime lispro to correct for highs and for bedtime carbohydrate.
   d. Reduce bedtime glargine.
   e. Always dose with lispro premeal, even when the premeal glucose is normal.

Date		12/14/2009	12/15/2009	12/16/2009	12/17/2009	Totals	
Sensor	# of Sensor Values	70	288	288	187	833	
	Average (mg/dL)	101	107	228	241	217	
	Min - Max (mg/dL)	117-275	71-318	87-383	128-370	87-393	
	STDev (mg/dL)	50	59	93	72	77	
Meter	# of Meter Values	3	4	4	3	14	
	Average (mg/dL)	238	178	230	252	223	
	Min - Max (mg/dL)	190-298	94-300	123-363	190-289	94-363	
Optimal Accuracy Criteria	Designation	X: Use Clinical Judgment					
	# of Paired Readings	2	4	4	3	13	
	Mean Abs. Diff. [MAD%]	15.8	15.4	5.2	7.7	10.5	
	Correlation Coeff. [R]	n/a	0.99	0.99	n/a	0.95	

Figure 11. Sensor summary report.

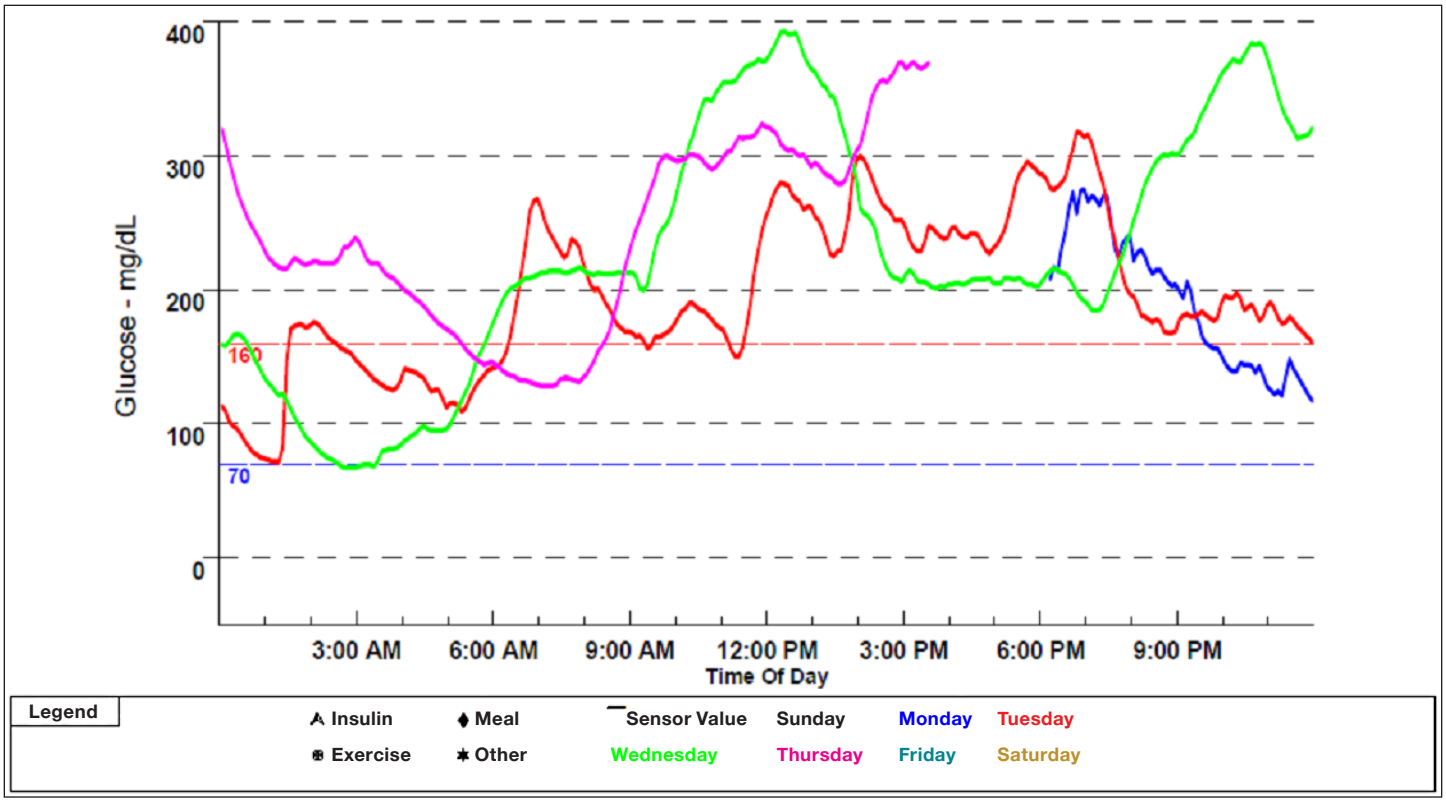


Figure 12. Sensor modal day.

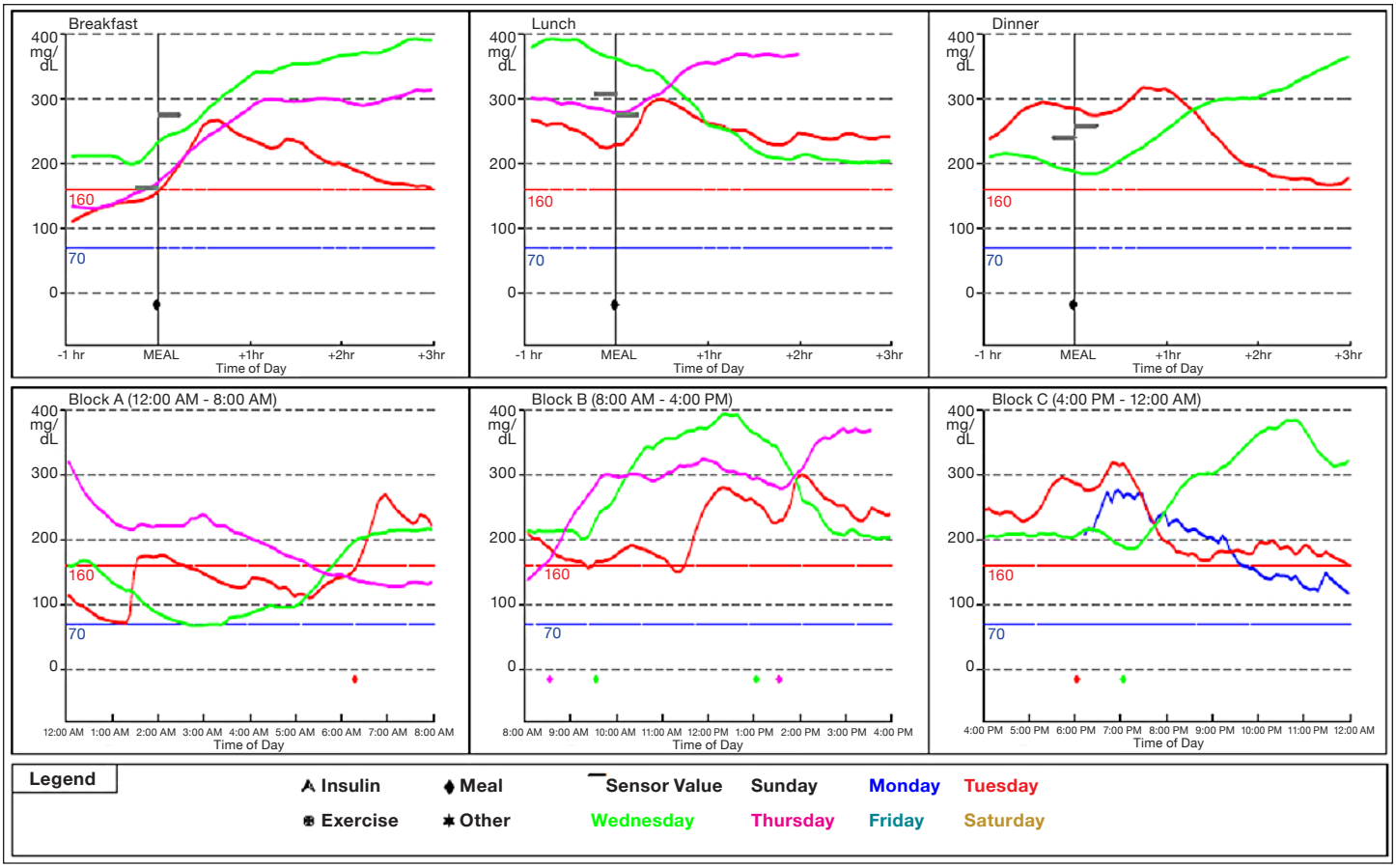


Figure 13. Sensor daily detail.

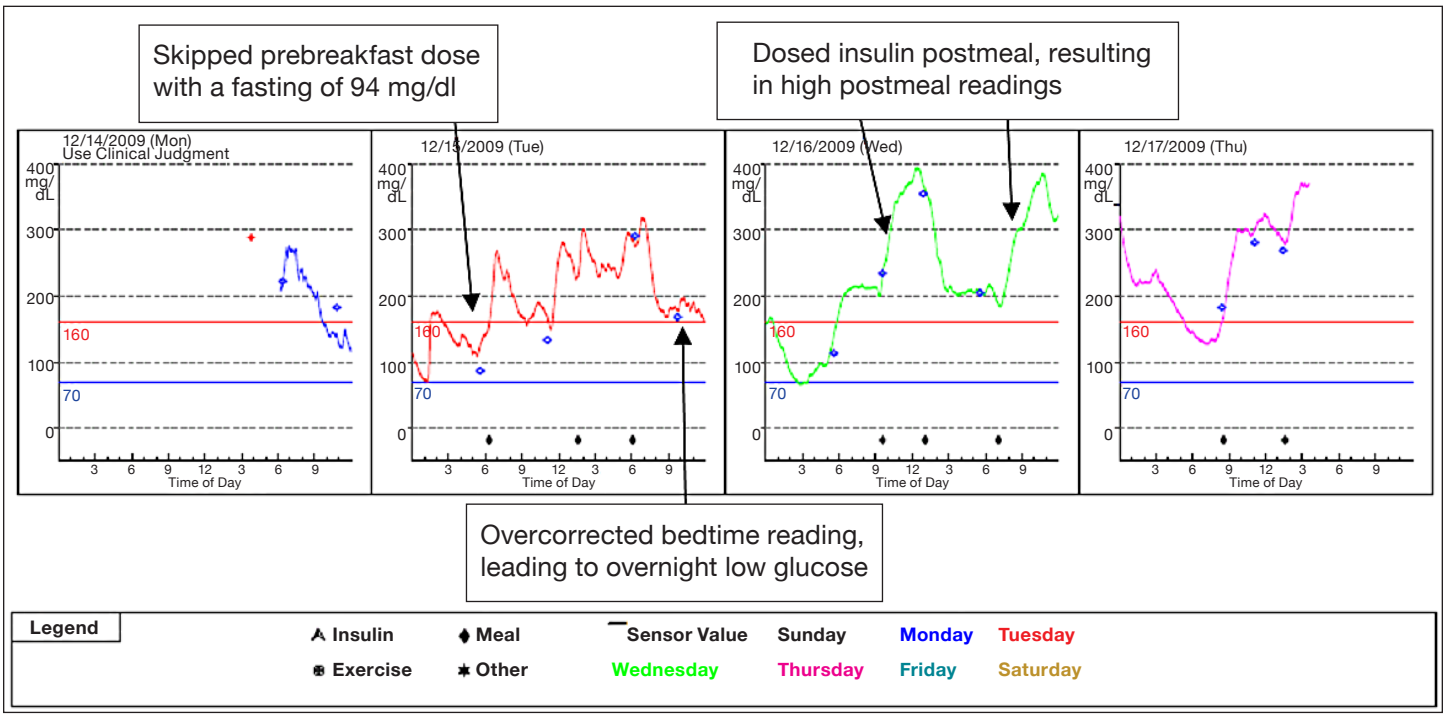


Figure 14. Sensor daily detail.

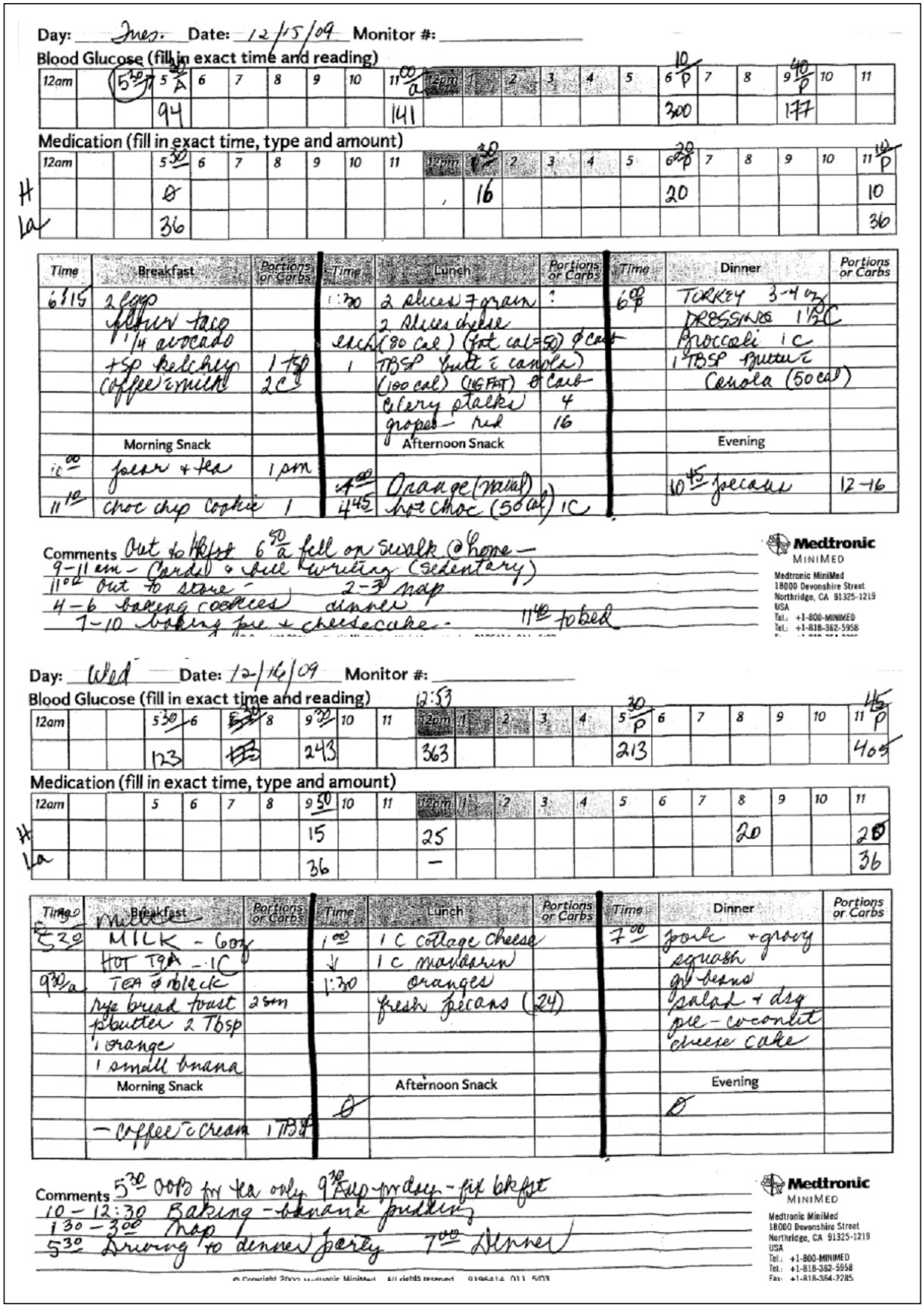


Figure 15. Logbook.