# Institutional Glucometrics to Determine Glucose Control as Practiced by General Medicine Wards

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**ABSTRACT:** **Background:** It is currently recommended that capillary glucose levels of non-critically ill hospitalized diabetic patients be maintained at between 140 and 180 mg/dl. Implementation of these recommendations and evaluation of their effectiveness require that data regarding the glucose control of these hospitalized patients be accessible.

**Objective:** To analyze glucose control and monitoring of all diabetic patients hospitalized in the general medicine wards of our medical center.

**Methods:** Capillary glucose measurements of all diabetic patients hospitalized in our departments of medicine between June and December 2008 were recorded by a central computerized institutional glucometer. Median glucose values and frequency of daily glucose checks per patient were analyzed in the internal medicine wards.

**Results:** We evaluated 14,366 capillary measurements from 2475 patients; 43% were taken before breakfast and 25% before dinner. A median of one daily determination per patient was obtained. This number increased 1.4-fold in patients with hyperglycemia › 200 mg/dl and 2.5-fold in patients with hypoglycemia. Seventy-five percent of the recorded glucose values were within the recommended target range, with a median daily level of 161 mg/dl and median fasting glucose of 142 mg/dl. A significant variance was found between wards.

**Conclusions:** The frequency of capillary glucose measurements in diabetic patients hospitalized in general medicine wards was low; most capillary glucose values, however, were within the recommended target range. The optimal monitoring of glucose in these patients remains to be determined.

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**KEY WORDS:** glucose control, internal medicine, capillary glucose, diabetes mellitus, glucometrics

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The American Diabetes Association recommends maintaining glucose control in general medicine wards at 140 mg/dl before meals to 180 mg/dl randomly and to use a basal-bolus insulin algorithm to treat patients [1,2]. These goals are arbitrary and are not derived from validated clinical outcome studies but require frequent capillary glucose monitoring. In order to implement these recommendations and to prove effectiveness, data on the glucose control of hospitalized patients must be accessible. Yet, almost no data are available regarding the actual levels of glucose control or current practices of glucose testing and monitoring in patients in internal medicine wards. Institutional computerized central glucose monitoring (glucometrics) allows recording of capillary glucose in all admitted patients and assessment of inpatient glucose management, as shown by Goldberg et al. [3] and Boaz et al. [4]. All capillary glucose measurements in our hospital have been centrally recorded since July 2008. Based on these data we report a retrospective, comprehensive analysis of glucose control and monitoring of all diabetic patients who were hospitalized between July and December 2008 in our general medicine wards.

## PATIENTS AND METHODS

The "Accu-Check Inform System" was introduced at Assaf Harofeh Medical Center in 2008. Exclusive use of the system for performing and centrally recording all capillary glucose measurements was begun immediately in all six medical wards. For this study, we evaluated all glucose values of all patients hospitalized in five wards during the period 1 July to 31 December 2008 and in the sixth ward from 1 September 2008. We assumed that all recorded glucose levels were of patients with either previously known or newly diagnosed diabetes mellitus, and that only sporadic glucose values were measured in euglycemic non-diabetic patients.

### LENGTH OF HOSPITALIZATION

The Accu-Check Inform system is connected to the registry of the hospital's central laboratories. Dates of admission and discharge are also registered and were extracted for each patient. If a patient was discharged on the same day of admission it was recorded as one day of hospitalization.

### GLUCOSE REGISTRATION

Capillary measurements were transferred to the central computer and registered with each patient's ID number,

date and time of test. The data were extracted for evaluation, transferred into an Excel spreadsheet and sorted according to pre-and post-prandial periods and bedtime. Only data from patients hospitalized in the general medical wards were analyzed; data from intensive care units and the emergency room were not included in the study.

### DATA EVALUATION

Data were analyzed for each patient, ward, and time of day. Median glucose values and the frequency of capillary glucose measurements were obtained accordingly. The frequency of capillary measurements was also investigated as a function of glycemia and length of hospitalization. The occurrence of extreme glucose values (< 60 mg/dl or > 300 mg/dl) and its effect on frequency of daily capillary glucose measurements were analyzed separately.

**Figure 1.** Distribution of glucose readings throughout the day

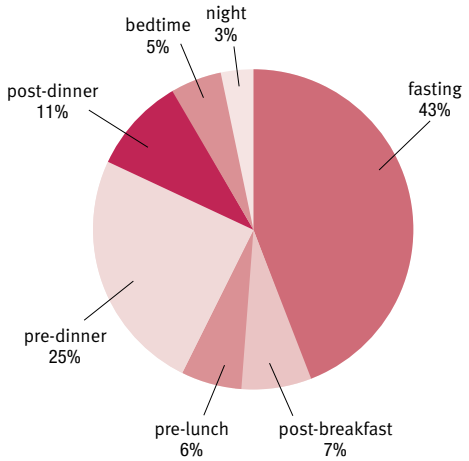



**Table 1.** Frequency of glucose determinations according to wards

| | Daily determinations | | | | |
|---|---|---|---|---|---|
| | Per patient | | | | |
| Medicine ward | Median | Minimum | Maximum | Per hospitalization | Average length of stay in hospital (days ± SD) |
| First (n=417) | 1 | 0.17 | 4.2 | 4.55 | 4.3 ± 5.1 |
| Second (n=417) | 0.67 | 0.5 | 0.99 | 6.03 | 3.9 ± 5.1 |
| Third (n=522) | 1.5 | 0.14 | 6.25 | 6.32 | 4.1 ± 4.4 |
| Fourth (n=341) | 1.43 | 0.16 | 8 | 7.92 | 4.9 ± 5.0 |
| Fifth (n=449) | 1.17 | 0.13 | 5 | 5.77 | 4.7 ± 5.6 |
| Sixth (n=329) | 1 | 0.19 | 4 | 4.15 | 3.7 ± 3.9 |
| Overall (n=2475) | 1 | | | | |
| Variance between wards | $P = 0.0001$ | | | | |

*Standard deviation

### STATISTICAL ANALYSIS

The variability between the different wards was evaluated by one-way analysis of variance (ANOVA). The effect of different glucose levels on the frequency within the wards was calculated with the unpaired Student's *t*-test.

## RESULTS

### CAPILLARY GLUCOSE MONITORING

- *Distribution of glucose readings throughout the day:* Between 1 July and 31 December 2008, the median length of hospitalization per patient in the general medicine wards was 2 to 3 days (range 1–31 days, average 4.3 ± 0.5 days). Overall, 14,366 capillary measurements were obtained from 2475 patients. As shown in Figure 1, 43.4% (35–58%) of these values were measured before breakfast and almost one-quarter (24.8%) before dinner (4–33%). The remaining measurements were equally divided as follows: after breakfast (6.9%, 3.8–11.2%), before lunch (6.1%, 1.3–10.2%), and after dinner or at bedtime (10.7%, 4.2–10.5%). This pattern of glucose monitoring was constant among five of the six wards. A different pattern was noted in one ward, where capillary glucose was measured after dinner or at bedtime (35%) instead of during the day.
- *Frequency of glucose testing:* In order to assess glucose monitoring in hospitalized patients, the total number of capillary glucose measurements per patient throughout hospitalization was divided by the days of hospitalization. As shown in Table 1 a median of 1.0 (0.17–8) capillary measurement was taken per patient per day. Separate evaluations for each ward revealed a significant variance in the practice of glucose monitoring ($P = 0.0001$). In order to assess the number of capillary glucose measurements per patient per hospital stay in each ward, the total number of tests per ward was divided by the number of hospitalized diabetic patients. Between 4.2 and 7.9 tests per patient were taken during the hospitalization.
- *Effect of glycemic control on glucose testing:* To test whether the incidence of routinely measured capillary glucose values outside the target range influenced the frequency of glucose measurements during hospitalization, we performed a separate analysis of patients with at least one hypoglycemic value (< 60 mg/dl, symptomatic or non-symptomatic) or one hyperglycemic value (> 200 mg/dl, fasting or non fasting). The hyperglycemic group had a median of 1.44 (0.1–11) measurements per day [Table 2], which was statistically more than the 1.0 (0.11–8) median number of overall readings obtained throughout the hospital. The number of capillary measurements in hyperglycemic patients varied significantly between the different wards. When hypoglycemia was discovered at least once during hospitalization, 2.5 (0.3–7.5) measurements per day

were obtained throughout hospitalization [Table 2]. This was in sharp contrast to the overall number of readings obtained and the difference is therefore highly significant. In this scenario, all the wards increased the frequency of glucose readings similarly (no significant variance).

- *Effect of hospital stay on glucose monitoring:* In order to investigate whether prolonged hospitalization was associated with an increased frequency in capillary glucose measurements, the 927 patients who were hospitalized for 4 or more days were investigated separately. Their median daily glucose reading was 1.33 (0.1–6.3) per day. In the 1540 patients hospitalized for ≤ 3 days, a median reading of 1 (0.1–6) was obtained [Table 2]. This difference was statistically significant ($P = 0.025$). Again, the pattern of glucose monitoring varied among the different wards: 0.57–1.75 readings per patient per day ($P = 0.001$).

### GLUCOSE CONTROL

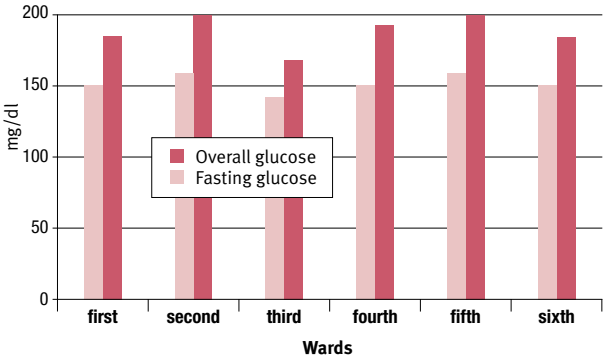
- *Global glucose assessment* [Figure 1]: In order to assess general glucose control in all our medical wards, median glucose was calculated from all glucose values obtained from all the observed patients. Overall, 14,366 values contributed to a median value of 161 mg/dl (34–598 mg/dl). Seventy-five percent of all values (n=10,744) were in the target range of 80–130 mg/dl. There was a vast variety in median glucose values between the different wards (143–177 mg/dl; statistically significant).
- *Fasting glucose values* [Figure 2]: To investigate whether fasting glucose at admission is different to that at discharge, medium fasting glucose was analyzed for each ward separately but also for all wards combined, according to the days of hospitalization. From the first to the last day of hospitalization, the median values ranged from 132 to 155 mg/dl; again, the readings differed significantly between the different wards ($P = 0.0001$).
- *Glucose variability throughout the day and during hospitalization:* Glucose readings throughout the day were also evaluated. Median values were similar before lunch, before dinner, and at bedtime (194 mg/dl, 173 mg/dl and 203 mg/dl, respectively); these values were, however, significantly higher than the pre-breakfast levels. Extreme glucose values were defined in the hyperglycemic range (> 300 mg/dl) or hypoglycemic range (< 60 mg/dl). The former occurred mainly at bedtime (more than 20%). Twenty-five percent of all hypoglycemic values (mainly asymptomatic) were discovered in the morning before breakfast. The remaining low glucose values were equally distributed throughout the day.

**Table 2.** Capillary glucose measurements according to glycemia and length of hospitalization

| | Glycemia over 200 mg/dl | | | | Glycemia below 60 mg/dl | | | |
|---|---|---|---|---|---|---|---|---|
| **Ward** | **Patients** | **Median** | **Minimum** | **Maximum** | **Patients** | **Median** | **Minimum** | **Maximum** |
| First | 67 | 1.55 | 0.28 | 5.25 | 9 | 1.71 | 0.33 | 5.25 |
| Second | 417 | 1.33 | 0.1 | 6 | 21 | 2.57 | 0.93 | 5 |
| Third | 135 | 1.75 | 0.27 | 7.5 | 24 | 2.31 | 0.71 | 7.33 |
| Fourth | 341 | 1.43 | 0.16 | 8 | 19 | 2.85 | 1.36 | 5.5 |
| Fifth | 273 | 1.33 | 0.2 | 11 | 14 | 2.13 | 1 | 7.5 |
| Sixth | 155 | 1.14 | 0.19 | 3 | 19 | 2.33 | 1 | 4 |
| Total | 1388 | 1.44 | | | 106 | 2.44 | | |
| Variance between wards | $P = 0.00001$ | | | | Non-significant | | | |
| | **Hospitalization ≥ 4 days** | | | | **Hospitalization ≤ 3 days** | | | |
| **Ward** | **Patients** | **Median** | **Minimum** | **Maximum** | **Patients** | **Median** | **Minimum** | **Maximum** |
| A | 143 | 1 | 0.17 | 4.2 | 277 | 1 | 0.17 | 3.3 |
| B | 125 | 1.75 | 0.1 | 4.9 | 292 | 1 | 0.67 | 6 |
| C | 186 | 1.75 | 0.14 | 5.75 | 336 | 1 | 0.67 | 4.5 |
| D | 150 | 0.57 | 0.14 | 6.33 | 191 | 1.5 | 0.13 | 2.7 |
| E | 184 | 1.5 | 0.13 | 3 | 254 | 1 | 0.67 | 5 |
| F | 139 | 1.33 | 0.19 | 5 | 190 | 1 | 0.33 | 4 |
| Median all wards | 927 | 1.33 * | | | 1540 | 1 | | |
| Variance between wards | $P = 0.001$ | | | | $P = 0.001$ | | | |

* $P = 0.025$: Significance for ≥ 4 days compared to < 3

**Figure 2.** Fasting and daily median capillary glucose




## DISCUSSION

We report here, for the first time in Israel, glucometrics of diabetic patients hospitalized in general internal medicine wards using an institutional glucometer, which allows central registration of all capillary glucose measurements. Our study yielded two main findings: The first was the extremely low number of daily glucose tests per patient; only slightly more than one capillary measurement per patient per day is commonly practiced in internal medicine wards. This number

was modestly increased by 30% in patients with significant hyperglycemia or hypoglycemia – whether symptomatic or asymptomatic, and in patients with prolonged hospitalization. The second finding was that 75% of these measurements were within the target range recommended by leaders in the field; namely between 140 mg/dl before meals and 180 mg/dl during the day [1].

The number of capillary measurements performed per patient per day in our patient population is rather disappointing when compared to other studies, such as that conducted by Cook et al. [5] who reported close to four measurements per patient a day in a general medicine ward. We cannot exclude the fact that some patients checked their capillary glucose with their personal glucometer and even took 'corrective measures' without informing the hospital staff. Nevertheless, we suspect that, at least in Israeli medical centers such as ours, the small number of glucose determinations in our hospitalized diabetic patients is the rule rather than the exception. Moreover, it should be pointed out that until now proof that tight glucose control improves clinical outcome was lacking. In fact, recent data from intensive care units underscore the risk of an aggressive approach to glucose control in hospitalized patients [6,7]. In view of these data, the value of frequent capillary measurements as a tool to improve glucose management and clinical outcome in diabetic patients hospitalized in general medicine wards remains questionable. Thus, as long as there is no proof of clinical benefit, one is entitled to question how much effort should be invested in in-hospital glucose control. It is of interest that the median glucose value of 160 mg/dl reported in patients followed four times a day by Cook et al. [5] is very similar to our findings based on approximately once-daily measurements. This suggests that the level of glucose control in these patients can be assessed by a relatively small number of daily glucose determinations or only fasting blood glucose. This concept is supported by data from Brunkhorst and co-workers [8] who demonstrated that fasting glucose levels correlated with clinical outcome of diabetic patients in an intensive care unit.

The median capillary glucose level of our patients can be extrapolated to an HbA1c value of approximately 7.5%. This implies that glucose control during hospitalization was better than the average glucose control seen in the Israeli outpatient population (approximately 8%). We are not sure that this observation reflects the reality. In their study, Boaz et al. [4] reported higher mean glucose values in their medical center over a 10 month period. They analyzed all adult hospitalized patients including those from surgical wards. We evaluated only the data from patients hospitalized in general internal medicine wards, which could possibly explain the difference. It is also possible that our limited number of glucose determinations may not accurately reflect the true glucose levels during hospitalization. Yet, during hospitalization, glucose monitoring and treatment in non-critically ill patients may be closer than that practiced in the outpatient setting.

Diabetic patients hospitalized in internal medicine wards are relatively old, suffer from multiple chronic diseases, and are treated with multiple drugs including insulin. These circumstances expose them to increased risk of clinically significant hypoglycemia. This suggests that the limited number of glucose determinations performed in our internal medicine wards may be insufficient for patient safety. However, our current data show that the intensity of glucose monitoring is increased in patients with extreme glucose values and in those with prolonged hospitalization. Furthermore, we recently showed that only 0.5% of these patients who were treated with intensive multiple daily insulin injections developed hypoglycemia [9]. Taken together, this indicates that the current practice of glucose monitoring does not expose these patients to excessive risk.

Our data revealed minor, but statistically significant differences between different wards in frequency of glucose measurements, glucose control and distribution of glucose monitoring. These differences did not result from different treatment algorithms. It is not known whether these differences have long-term clinical implications, but it is noteworthy that in-hospital mortality did not differ between these wards (unpublished).

Our study has several shortcomings: most importantly the lack of data regarding hypoglycemic treatment algorithms and patients' clinical data. Therefore, we could not analyze the glucometric data according to the patients' clinical profiles. In addition, food consumption is not strictly regulated, nor is it restricted in these patients. Thus, interpretation of glucose determination in relation to meals throughout the day is less reliable.

In conclusion, we showed that three-quarters of the glucose values obtained from the patients hospitalized in our institution are within the target range recommended by the professional organizations, but only slightly more than one capillary glucose measurement per day on average was obtained. In the absence of clear evidence that good glucose control, as documented by frequent capillary glucose measurements, has a beneficial effect on clinical outcome, the frequency of daily glucose determinations in diabetic patients hospitalized in general medicine wards remains to be determined.

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