Improving Glucose Management by Redesigning the Care of Diabetic Inpatients Using a Nurse Practitioner Service

Richard J. Comi, MD, Jeanne Jacoby, ARNP, Danielle Basta, ARNP, Mary Wood, RN, MS, and John Butterly, MD

Hyperglycemia in hospitalized patients has been associated with poor outcomes in retrospective studies.[1,2] This association has been found in patients admitted to medical, surgical, intensive care, and neurological care units. The association of poor outcomes and hyperglycemia upon admission to the hospital is usually stronger in patients without a prior diagnosis of diabetes, but it also extends to patients with known diabetes.[1,2]

Although such retrospective data cannot prove causality, it is generally agreed that hyperglycemia in patients who are significantly ill is detrimental to recovery and healing.[3–5] As a partial explanation for this, in vitro data indicate poor immune cell and inflammatory cell function in a hyperglycemic environment.[6–8] Intervention studies in surgical intensive care units have suggested improved outcomes when hyperglycemia is controlled.[9] However, there have been no randomized trials of in-hospital, noncritical care intensive management to demonstrate better outcomes from improved control.

Based primarily on intervention studies in critical care units,[9–12] two major professional organizations and many review articles in influential journals have recommended that blood glucose control in the hospital be maintained between 90 and 130 mg/dl before meals and < 180 mg/dl 2 hours after meals, with care to avoid hypoglycemia.[13–15] A recent meta-analysis of tight glucose control in intensive care units has called these recommendations into question, finding small benefits and a high risk of hypoglycemia.[16] Nonetheless, no study to date has suggested that higher glucose levels during illness confer any advantage to patients, and good control of glucose (blood glucose levels consistently < 150 mg/dl) without hypoglycemia is likely to constitute optimal care.[15]

Many medical centers have adopted the recommendations of professional societies for inpatient glucose control. These targets have often been achieved by creating a glucose management service (GMS) team that may be involved by consultation or by preset criteria.[17–19] Some of these teams involve an endocrinologist and endocrinology fellows; other teams are made up of nurse practitioners. Although some of these services have been described, there are few reports of actual effectiveness compared with standard hospital care. In one study on a vascular surgery service, the mean glucose levels were reduced from 165.4 mg/dl to 149.2 mg/dl, with reduction in hypoglycemic events by 50 %.[20] A major impetus to developing these teams is often a desire to reduce the cost of care by reducing length of stay and readmission rates, although data to support these outcomes are sparse.[21]

Intended Improvement

Dartmouth Hitchcock Medical Center in Lebanon, N.H., recently instituted a GMS to improve the overall care provided to inpatients with hyperglycemia. This service is made up of two nurse practitioners who must be consulted by the hospital care team. Once consulted, the nurse practitioners actively manage the patients' glucose control by writing insulin orders and also manage discharge communications with community physicians about posthospital diabetes management. The stated goal of care is to maintain premeal glucose concentrations through the day between 100 and 150 mg/dl. This GMS was instituted as part of larger efforts to focus attention on diabetes control at the hospital. That effort also included the institution of written insulin order sets that feature a basal/bolus approach for subcutaneous insulin and discourages the use of sliding scales.

Study Question

This study was designed to compare success in actual management of diabetes between the GMS and standard in-hospital care delivered by house staff and hospitalists. The hypothesis was that the GMS has improved average blood glucose control in hospitalized patients compared to standard management, even though the GMS patient cohort was referred to the service because of poor glucose control with standard management by hospital teams. The study also sought

to determine whether management by the GMS increased or decreased the likelihood of hypoglycemia.

Research Design and Methods
The study focused on glucose control in the month of May 2007. At this point, the GMS had been in operation for 6 months, and its team members were well experienced and well known throughout the hospital. At the same time, May is the month in which the house staff has its greatest collective experience in the management of inpatients.

Fingerstick glucose records were obtained for all inpatients during this month. To contrast management of glucose control, patients were excluded if they had their glucose managed by written protocol (those receiving intravenous insulin and total parenteral nutrition, and all patients in intensive care units); were in the Intermediate Cardiac Care Unit (because this unit has a programmatic special attentiveness to glucose control compared to the rest of the hospital); or had a hospital stay of < 2 days' duration.

To further focus on management and remove bias because of poor control at the time services were initiated, the glucose measurements on day of admission and the next day for the patients on the house staff/hospitalist services and the glucose measurements on the day of consultation for the GMS were omitted from the analysis.

The remaining data were analyzed to find the mean, median, and standard deviation of the glucose concentrations measured by fingerstick. These were compared between the cohort of patients managed by the GMS and the house staff/hospitalist service. Researchers also looked at the same descriptive statistics for patients by hospital service: medicine, surgery, neuroscience, psychiatry, and hematology/oncol-

Table 1. Description of Patients	GMS	Non-GMS
n	27	85
Sex (male/female)	14/13	40/45
Age (years)*	62.4 ± 10.5	63.49 ± 14.2
Patients with known diabetes (%)	92.6	79
Mean duration of diabetes (years)**	15.6 ± 11.54	6.2 ± 7.20
Patients with prior insulin therapy (%)	78.7	43.5
Patients with microvascular complications (%)	60	35.3
Mean length of stay (days)*	17.25 ± 18.8	12.25 ± 20.7
A1 on admission (%)**	7.99 ± 2.02	6.99 ± 1.03
Readmitted within 3 months (%)	29.6	36.5
Readmitted within 6 months (%)	10.3	27.1
Readmitted within 12 months (%)	25.9	20
Deceased within 12 months (%)	22.2	34.11

* Not significantly different by t-test, $P > 0.05$; **Significantly different by t- test, $P < 0.05$.

ogy. Additional data abstracted from hospital records included age; history of diabetes; duration of diabetes; presence of diabetes complications; A1C on admission or within 6 months of hospitalization; use of steroids during hospitalization; lengths of stay; readmission rates within 3, 6, and 9 months; and death within 1 year. Because this was not a randomized study, outcomes such as readmission rates and death were of interest as indicators of severity of illness—not as outcomes of glucose management.

Results
After applying the exclusion criteria, there were 85 patients with 2,057 glucose values in the house staff/hospitalist cohort and 27 patients with 885 glucose values in the GMS cohort. The average age of the patients was 62.3 years, and 48% were male (Table 1). The GMS and house staff/hospitalist cohorts were similar in age and sex characteristics. There were significantly more patients with known diabetes and with preexisting diabetes

complications in the GMS cohort. The patients not treated by the GMS were readmitted within 3 months more frequently than those managed by the GMS, and there was a higher incidence of death within 12 months of the admission in patients who were not managed by the GMS. Patients were referred to the GMS from all major hospital divisions, and a greater proportion of the GMS patients came from the neuroscience floors than in the non-GMS cohort (Table 2).

The results for glucose control as a function of management are shown in Table 3. The average glucose and especially the standard deviation from the mean were reduced in patients on the GMS compared

Table 2. Primary Hospital Service	GMS	Non-GMS
Medicine (%)	51.2	44.7
Surgery (%)	33	43.7
Neuroscience (%)	11.1	4.7
Psychiatry (%)	3.7	5.9

Table 3. Managed Glucose Concentrations					
	Average glucose (mg/dl)	Median glucose (mg/dl)	Standard deviation glucose (mg/dl)	Number of glucose measurements per patient	Length of stay (days)
GMS	158.35	151	60.0	29.5	17.25
Non-GMS	161.80*	150	70.4	24.2	12.25
Medical	167.88**	156	75.9	29.2	17.49
Surgical	155.60	145	67.4	15.8	7.92
Neuroscience	150.38	152	46.9	14.4	5.86
Hematology/oncology	153.39	142	64.9	19.4	8.12

*No significant difference in mean glucose concentration between the GMS and the non-GMS teams ($P = 0.32$);
** Significant difference between the GMS and the Medicine team ($P = 0.03$)

to those managed by the non-GMS teams. However, this difference was not statistically significant ($P > 0.05$). The average glucose was slightly above the stated goal of the GMS to reduce the average glucose to < 150 mg/dl. There was no significant difference in the average number of glucose measurements per patient between patients managed by the GMS or non-GMS teams. The total average length of stay for patients managed by the GMS was longer than for the non-GMS cohort.

The rate of hypoglycemia in all patients studied was quite low; < 2% of all glucose levels measured in these patients were < 50 mg/dl. However, hypoglycemic events were more frequent in the non-GMS patients (1.2%) than in the GMS patients (0.67%) (Table 4). There were no adverse events related to hypoglycemia.

Conclusions

This study reviewed the descriptive statistics for glucose concentration in hospitalized noncritical care patients managed by either the house staff/hospitalists (non-GMS) or a nurse practitioner GMS. The data represent

Table 4. Rates of Hypoglycemia (Blood Glucose < 50 mg/dl)	
GMS	6/885 (0.68%)
Non-GMS	25/2,057 (1.22%)

the management of glucose concentrations using insulin therapy because patients were eliminated from the study who did not receive long-term insulin (glargine or NPH) or who were seen for < 2 days or who were managed by special protocols such as those of the intensive care, coronary, and intermediate cardiac care units.

These data show that patients referred to and managed by a dedicated GMS have reduced blood glucose levels with much less variation compared to those managed by usual hospital teams. In addition, there were fewer hypoglycemic events despite somewhat improved control. This was particularly true for patients on the medicine service, where the average glucose for patients on the GMS is 160 ± 69 mg/dl, a level considerably lower than for non-GMS patients on the medicine service (average glucose 169 ± 75.86 mg/dl).

This study has several limitations. It was not a randomized or blinded trial; therefore, one cannot be confident that all sources of bias were eliminated. The GMS saw patients only by consultation, generally because the hospital care team wanted better glucose control. Therefore, the design of the study was biased against finding improved control by the GMS because most of the patients had inadequate glucose

control with routine management. In addition, GMS patients were more likely to have pre-existing, poorly controlled diabetes with complications. These patients may not have been as systemically ill as those managed by the non-GMS teams because the readmission rate and mortality rate at 1 year were higher for non-GMS patients. It is possible that some patients were not referred to the GMS because their poor short-term prognosis was known at the time. It is important to emphasize that the data on readmission and mortality are not outcomes of in-hospital glucose management because this was not a randomized trial of management that minimized other contributing factors.

Although many studies have linked elevated blood glucose in the hospital to worse outcomes such as infection, death, congestive heart failure, and longer lengths of stay, there has not been a trial to compare the outcomes of patients randomly assigned to tight glucose control versus usual control outside of the intensive care unit setting. Therefore, we cannot know whether there is clinical benefit from reducing the average glucose concentration from 161.3 to 158.35 mg/dl, or reducing the standard deviation in glucose concentrations from 70 to 60 mg/dl. However, the preponderance of

circumstantial data and the knowledge of the central role of insulin in metabolism strongly suggest that there is benefit in maintaining metabolic control in severely ill patients. Many of these patients had blood glucose levels > 200 mg/dl for most of the day before the GMS was consulted, and it is more likely than not that there is clinical benefit in keeping the average glucose at 150 mg/dl rather than > 200 mg/dl.

The degree of control achieved in the our study is not as tight as the degree of control explored in the intensive care unit studies of van den Berghe and others.[9,10] This probably explains the relatively low risk of hypoglycemia seen in our study (< 2% of all glucose values were < 50 mg/dl). The targets for blood glucose control in the critical care unit studies have generally been to achieve the same glucose levels as those seen in nondiabetic patients, but it is not known that this degree of control is necessary to see benefit and, in several centers, the pursuit of normal blood glucose levels in critically ill patients has led to hypoglycemia and adverse outcomes. Our goal to achieve blood glucose levels < 150 mg/dl is in keeping with a recently published expert review.[15]

In summary, this nonrandomized study of in-hospital management of glucose concentrations found that average glucose was slightly reduced and the standard deviation of glucose concentrations was markedly reduced when patients were managed by a dedicated GMS instead of usual hospital teams. Although it is likely that the reduction in average glucose concentration is beneficial to the course of illness, we do not have outcomes data to demonstrate this. The rate of hypoglycemia in each patient group was similar, and events were rare.

In our setting, the implementation of a GMS that cares for patients who cannot be managed well with standard care reduced variation in blood glucose and improved care for diabetic inpatients. Thus, we believe this study supports the benefit of inpatient glucose management by a team focused on glucose control.

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Richard J. Comi, MD, is section chief of the Section of Endocrinology; Jeanne Jacoby, ARNP, and Danielle Basta, ARNP, are members of the glucose management service; Mary Wood, RN, MS, is the inpatient diabetes clinical nurse specialist; and John Butterly, MD, is medical director at Dartmouth Hitchcock Medical Center in Lebanon, N.H.