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Improving Glycemic Control Safely in Non-Critical Care Patients: A Collaborative Systems Approach in Nine Hospitals

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Background: Practice variations in insulin management and glycemic adverse events led nine Dignity Health hospitals to initiate a collaborative effort to improve hypoglycemia, uncontrolled hyperglycemia, and glycemic control.

Methods: Non–critical care adult inpatients with ≥4 point-of-care blood glucose (BG) readings in a ≥2-day period were included. Balanced glucometric goals for each hospital were individualized to improve performance by 10%–20% from baseline or achieve top performance derived from Society of Hospital Medicine (SHM) benchmarking studies. Baseline measures (2011) were compared to mature results (postintervention, 2014). Protocols for insulin management and hypoglycemia prevention were piloted at one facility and were then spread to the cohort. Interventions included standardized order sets, education, mentoring from physician experts, feedback of metrics, and measure-vention (coupling measurement of patients "off protocol" with concurrent intervention to correct lapses in care).

Results: The day-weighted mean BG for the cohort improved by 11.4 mg/dL (95% confidence interval [CI]: 11.0–11.8]; all nine sites improved. Eight of the sites reduced severe hyperglycemic days, and the percentage of patient-days with any BG > 299 mg/dL for the total cohort improved from 11.6% to 8.8% (relative risk, 0.76 [95% CI: 0.74–0.78]). The percentage of patient-days with any BG < 70 mg/dL remained unchanged at 3.6%. Eight of the sites either reduced hypoglycemia by 20% or achieved SHM best-quartile rates.

Conclusion: Multihospital improvements in glycemic control and severe hyperglycemia without significant increases in hypoglycemia are feasible using portable low-cost toolkits and metrics.

Hospitalized patients with uncontrolled hyperglycemia are at increased risk for a variety of adverse outcomes, including prolonged hospital stay, infectious complications, and death.[1–3] In the United States, one in four adult hospitalized inpatients has a known diagnosis of diabetes, and another 12% have hyperglycemia without a preexisting diagnosis.[4] Hypoglycemia is also an important inpatient problem. Insulin is one of the most common sources of inpatient adverse drug events, and more than half of these events are preventable.[5] Professional societies and standards organizations, on the basis of consensus and local experience, have highlighted the importance of optimizing inpatient glycemic control and reducing hypoglycemia.[1–6] Systematic reviews or meta-analyses regarding large-scale efforts to improve inpatient glycemic control and reduce hypoglycemia could not be located in the literature.

In late 2011 Dignity Health (San Francisco), the largest hospital provider in California, set out to significantly improve hypoglycemia, uncontrolled hyperglycemia, and glycemic control across a diverse group of 9 hospitals within its 39-hospital system in three states. Working with the Gordon and Betty Moore Foundation (GBMF), Dignity Health selected this initiative as a priority after significant variations in clinical practice and adverse events associated with glycemic excursions were observed. Barriers including lack of standardized insulin order sets, high prevalence of sliding-scale insulin orders, clinical inertia from fear of hypoglycemia or misunderstanding the significance of hyperglycemia,[7] and a lack of standardized "glucometrics"[8] were all acknowledged. We hypothesized that we could overcome these barriers by emulating the implementation of multiple mutually reinforcing evidence-based interventions used successfully by others,[9,10] leveraging a common electronic health record (EHR), and using glucometrics and benchmarking emerging from the Society of Hospital Medicine (SHM; Philadelphia) Glycemic Control Mentored Implementation experience.[11–14]

METHODS

Sample

A total of nine Dignity Health hospitals in and around Sacramento and San Francisco Bay areas were included in the glycemic effort under the auspices of the GBMF grant. The hospitals were chosen by the GBMF because of their geographic proximity and because they mimicked the diversity of settings, size, and teaching status seen across the larger system (Table 1), as opposed to selection of specific-site

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Table 1. Characteristics of Participating Hospitals

	Hospital Type	City*	Bed Size
Pilot Hospital			
St. Mary's Medical Center	Urban Community Teaching	San Francisco	403
Spread Hospitals			
Mercy General Hospital	Urban Community Nonteaching	Sacramento	342
Mercy Hospital of Folsom	Suburban Community Nonteaching	Folsom	106
Mercy San Juan Medical Center	Suburban Community Nonteaching	Carmichael	370
Saint Francis Memorial Hospital	Urban Community Nonteaching	San Francisco	356
Sequoia Hospital	Suburban Community Nonteaching	Redwood City	208
Sierra Nevada Memorial Hospital	Rural Community Nonteaching	Grass Valley	121
Woodland Memorial Hospital	Suburban Community Nonteaching	Woodland	129
Methodist Hospital	Suburban Community Teaching	Sacramento	162

*All in California.

expertise or baseline performance. One hospital acted as the pilot hospital, refining processes, protocols, and other tools before rollout to the remaining eight "spread" hospitals. Case studies from two of the nine hospitals are provided; one case study is focused on a hypoglycemia prevention and management bundle, and the other on the role of active surveillance—areas considered "most crucial to success and most important for the other hospitals."

Target Population and Time Frame

The population of interest for intervention and analysis was all acute care (non–critical care, also known as non-ICU) inpatients admitted to medical, surgical, orthopedics, or telemetry units with at least four point-of-care (POC) blood glucose (BG) readings in at least two calendar days of an inpatient stay. Critical care patients, outpatients, pediatric patients, and maternal child health patients were specifically excluded. Calendar year (CY) 2011 was the baseline year, while our collaborative improvement effort spanned CYs 2012–2014. The pilot hospital was introduced to interventions six month before the spread sites. CY 2014 is considered the mature postintervention comparison time period.

All sites subscribed to the SHM electronic quality improvement program (eQUIPS), which enabled them to upload POC BG data in a secure and de-identified process. Demographics, diagnoses, medications, sex, and other data fields are not included in the data upload.

After these data were uploaded to the SHM Web-based data and reporting center, a variety of metrics and run charts summarizing rates of hyperglycemia, hypoglycemia, recurrent hypoglycemia, and timeliness of hypoglycemia management and resolution were all available to each hospital on demand. Generally, metrics with patient-day as the unit of analysis are preferred, but selected metrics are also expressed by patient-stay. Glycemic control metrics include the day-weighted mean BG for the population, percentage of patient-days with a mean BG ≥ 180 mg/dL, the percentage of patient-days with all BG readings of 70 mg/dL and 179 mg/dL, and the percentage of patient-days with any BG > 299 mg/dL. Hypoglycemia is summarized as the percentage of patient-days with at least one BG < 70 mg/dL, and severe hypoglycemia as the percentage of patient-days with any BG < 40 mg/dL. Mean time intervals from the initial hypoglycemic value to the next BG checked and to documented resolution of the hypoglycemic event allowed monitoring of hypoglycemia management. Details of the metrics are available in the literature.[6,13,14] Local process measures on utilization of order sets and protocol-driven insulin dosing complemented the glucometrics available from SHM, but these were not standardized or analyzed centrally for the cohort.

Key Metrics and Goals

Of the metrics available, three were chosen as key metrics, allowing for more streamlined reporting and goal-setting. These metrics were designed as a balanced group of metrics that would represent hypoglycemia (percentage of patient-days with any BG < 70 mg/dL), severe hyperglycemia (percentage of patient-days with any BG > 299 mg/dL), and glycemic exposure (day-weighted mean glucose). In the absence of consensus standards for the best metric for glycemic control, the choice to use the day-weighted mean BG metric over the alternatives was based on the perception that this goal would be more understandable and accepted by improvement teams.

Initial goals were reconsidered in early CY 2013, when the first round of SHM glucometric benchmarking became available. The earlier strategy (predefined relative decrease for all three key metrics) was deemed undesirable and potentially unsafe, as a priority to improve glycemic control too aggressively might be unwise for a hospital with very high hypoglycemia rates, and a hospital with very low hypoglycemia rates at baseline should not prioritize further hypoglycemia reduction at the expense of high rates of severe hyperglycemia. Goals were revised with these principles in mind and updated with the second round of SHM benchmarking on the basis of data from 94 hospitals in the SHM database (Table 2). Each hospital was expected to achieve or maintain a goal of the following:

Table 2. SHM Benchmarking for Selected Glucometrics from 94 Hospitals: Core Non-ICU Adult Units*

Key Metric	Range	Mean	Median	Top 25th Percentile
Patient day-weighted mean BG (mg/dL)	121–84	161	**160**†	≤156
% patient-days with any BG > 299 mg/dL	1.8%–17.7%	10.2%	10.5%	**≤8.0%**‡
% patient-days with any BG < 70 mg/dL	1.8%–14.8%	5.1%	4.7%	**≤3.9%**§

SHM, Society of Hospital Medicine; BG, point-of-care blood glucose.

*Six months of data from a total of 1,030 non-ICU adult units, representing 1.13 million monitored patient-days, were used to set goals for the Dignity Health glycemic control cohort. Dignity cohort hospitals goals were set to achieve or maintain the following:

- The median performance for glycemic exposure or 10% improvement from baseline.
- The top-quartile performance for severe hyperglycemia or a 20% improvement from baseline.
- The top-quartile performance for hypoglycemia or a 20% improvement from baseline.

†Median performance for glycemic exposure.

‡Top-quartile performance for severe hyperglycemia.

§Top-quartile performance for hypoglycemia.

1. A day-weighted mean BG ≤ 160 mg/dL (median for SHM benchmarking) OR a 10% relative reduction from CY 2011 baseline performance
2. ≤8.0% of patient-days with any BG > 299 mg/dL (top quartile SHM benchmarking) OR a 20% decrease from CY 2011 performance
3. ≤3.9% of patient-days with any BG < 70 mg/dL (top quartile SHM benchmarking) OR a 20% decrease from CY 2011 performance

Interventions and Implementation

Collaborative Infrastructure. Each hospital formed an interdisciplinary team, as depicted in Table 3. Team meetings were held roughly monthly at each site. The GBMF Project Lead did the following:

- Facilitated monthly calls and webinars for all sites, fostering monthly sharing of barriers, solutions, progress, and best practices. These calls also allowed for review of data and targeted corrective actions.
- Communicated twice a month with each site to facilitate timely problem solving and provide recommendations informed by the stream of local data and tailored to the local environment.
- Conducted site visits at each hospital, with some return visits to validate that the recommended practices were in place and working successfully.

Physician Mentors. Outside experts with experience in local and SHM national glycemic control improvement efforts [G.M., D.C.] were secured to provide guidance for each individual site, and for the effort as a whole, as coordinated by the GBMF Project Lead. The outside experts (also known as mentors) provided advice on protocol and order set design and implementation, measurement, and benchmarking.

The physician mentors participated in one in-person meeting for all site teams as a group, as well as a kickoff overview webinar. Three additional webinars, outlining best practices, implementation, and troubleshooting tips were offered every two to three months. Each site completed an initial assessment of its infrastructure and performance provided by the mentor. This structured assessment collected information on demographics, institutional support, team composition and skill set, prior and ongoing efforts (including protocols and order sets), capacity for measurement, and a SWOT (strengths, weaknesses, opportunities, and threats) analysis. The self-assessment informed interactions with the mentor and GBMF Project Lead.

Table 3. Composition of Improvement Team

Role	Description
Glycemic Control Lead(s)	Responsible for leading local efforts, reporting to the hospital system and GBMF Project Lead. Varied professions (MD, RN, dietitians, clinical educators, ICU directors, pharmacists) played this role at different hospitals. Some hospitals had co-leads.
Clinical Specialists	Local content experts with an interest or education in glycemic control. Certified diabetes educators, clinical educators, clinical nurse specialists, pharmacists, and nurses played this role at different hospitals.
Physician Champion	Endocrinologists, hospitalists, intensivists, pulmonologists, and physician informaticists represent the variety of physicians in this role. Provided education and coached physicians reluctant to use the newly adopted evidence-based protocols.
Measure-ventionist	Day-to-day RN "super user" in glycemic control on the units providing daily feedback and just-in-time education and training. Performed active surveillance to identify uncontrolled or "off protocol" patients, and to intervene to encourage protocol-driven care.
Others	Pharmacists, information technology personnel, dietitians, and others were called into the team structure as required.

GBMF, Gordon and Betty Moore Foundation.

Three one-to-one calls for each individual site were held with a mentor, scheduled every three to six months, depending on the needs of the team, complete with written summary notes and suggested "next steps." The pilot hospital received an all-day site visit from its mentor, incorporating updates on current practice in the hospital, along with staff education and problem-solving sessions. In-person educational sessions were also held at selected non-pilot hospitals with the highest perceived need, identified by the GBMF Project Lead. Additional support from mentors was available by ad hoc e-mail or phone correspondence.

Subcutaneous Insulin Protocol and Order Set. Protocols to guide appropriate basal-bolus subcutaneous insulin ordering and glycemic monitoring were designed and standardized across all sites. The protocol integrated guidance for estimating an appropriate dose of insulin, and for allocating the dose into appropriate basal and nutritional insulin allotments, dependent on the mode and amount of nutritional intake. Reinforcement of appropriate glycemic targets range, glucose monitoring, and assessment of A1C (glycated hemoglobin) levels were integrated into the protocol. For example, patients eating regular meals had guidance to monitor glucose with meals and at bedtime, whereas nothing-by-mouth patients were monitored every six hours. Correction/sliding-scale insulin was discouraged as a primary strategy to control hyperglycemia, and oral hypoglycemic agents were also discouraged as a method to control hyperglycemia for inpatients. Guidance for transitions from insulin infusion to subcutaneous insulin, and for the transition from hospital to the outpatient setting, was integrated into educational materials and order sets whenever feasible to do so. Protocols, insulin management algorithms, order sets, and guidance for transitions were all developed with guidance consistent with the SHM Glycemic Control Implementation Guide.[6]

A standardized preformatted computerized provider order entry order set for subcutaneous insulin was designed and initially launched by the pilot site, with input from mentors and the Dignity Health EHR build team. The order set integrated clinical decision support (CDS) reinforcing the protocol. Preformatted insulin regimens matched a variety of nutritional intake patterns and informed insulin dosing. Standardized administration instructions, holding parameters, and monitoring instructions were also integrated. Although it was still feasible to order insulin by alternative methods, it became highly inconvenient, essentially establishing a forcing function to increase exposure to the protocol-drive CDS embedded in the order set. Adjustments to the order set suggested by the pilot site were incorporated, and the revised order set was then launched at all remaining hospitals.

Hypoglycemia Prevention and Management Bundle. Hypoglycemia prevention focused on common sources of iatrogenic hypoglycemic adverse drug events from the literature: inappropriate dosing of insulin, failure to take appropriate action when nutritional intake was interrupted, and failure to assess contributing factors and make insulin adjustments after an initial hypoglycemic event.[5,6,10] Hypoglycemia management protocols featured structured assessment of the etiology and suggested mitigation strategies, as outlined in SHM materials.[6] Education and protocols offered guidance on proactive interventions to prevent hypoglycemia induced by nutritional interruption, and efforts were made to coordinate nutrition delivery, glucose testing, and insulin administration. Structured order sets guided appropriate insulin prescribing, as described earlier. Timeliness of hypoglycemia treatment and rates of recurrent hypoglycemia were made available to every unit to raise awareness and inform improvement efforts.

A case study regarding the experience at Sequoia Hospital (Redwood City, California) regarding the hypoglycemia prevention and management bundle illustrates how the team used SHM data to focus its efforts where they were needed most, including ancillary measures such as the timeliness of hypoglycemia management (Sidebar 1, Figure 1). It also reveals how a high-performing team, properly supported, can simultaneously improve hypo- and hyperglycemia.

Active Surveillance and Measure-Vention. Day-to-day active surveillance was tasked to an RN glycemic control "super user." A daily report scrutinizing the regimens of new patients admitted on hypoglycemic agents and/or with uncontrolled glycemic excursions were used to target timely education. This active surveillance, with real-time mitigation of defects in care, was recognized as being essential to reach high reliability in 2008 Agency for Healthcare Research and Quality (AHRQ) toolkits outlining successful venous thromboembolism prevention (VTEP) efforts. The term "measure-vention" was coined to highlight the importance of regular measurement of patients "off protocol", coupled with concurrent intervention to correct lapses in care.[15,16] Subsequent AHRQ and SHM toolkits and publications, as well as toolkits supporting National Health Service, England VTEP efforts incorporated measure-vention as a term and a central strategy to achieve reliability.[17–19] Measure-vention was described as an essential tool in glycemic control efforts from single-site efforts and from several SHM glycemic control collaborative efforts and in SHM toolkits addressing delirium prevention.[6,10,12,20] The term *measure-ventionist* was coined by Dignity Health team members during this collaborative to describe the super user who used measure-vention as an active strategy to improve care on a daily basis—these members found the method so useful they applied it to a wide range of improvement activities.[21] A case study regarding active surveillance and measure-vention, drawing on the experience at Woodland Memorial Hospital (Woodland, California), illustrates how the measure-ventionist played the major role in driving improvement forward and acting as part of the glue that held the local initiative together (Sidebar 2, Figure 2). The atmosphere of

Sidebar 1. Case Study: Hypoglycemia Prevention and Management at Sequoia Hospital

Sequoia Hospital (Redwood City, California) is a 208-bed community hospital with a preexisting glycemic control effort. At baseline in 2011, Sequoia enjoyed the lowest percentage of patient-days with blood glucose (BG) > 299 mg/dL (7.4%), and the lowest day-weighted mean BG (155.1 mg/dL) of the 9-hospital cohort. Society of Hospital Medicine (SHM) benchmarking placed its performance on these two metrics in the best quartile out of 94 hospitals. However, hypoglycemia rates at baseline were the second highest in the Dignity Health cohort (4.5% of patient-days with BG < 70 mg/dL) and near the SHM median performance. The Sequoia team also noted that SHM benchmarking results revealed a mean time interval of 122 minutes from the initial value <70 mg/dL and the next documented reading. This delay was greatly concerning to the team, as the top-quartile performance was ≤64.2 minutes, and the non-ICU areas were almost double this time response.

The Sequoia glycemic team took a multifaceted approach to implement the hypoglycemia prevention and management bundle, while maintaining glycemic control. The floor educator and measure-ventionist had a "roving posterboard," which they would share with staff on visits to the nursing units. The glycemic team lead, in collaboration with the measure-ventionist, created a newsletter that focused on goals, outcomes, and case studies. This same newsletter, along with ordering tips, was also shared with the medical staff.

Using the SHM data and reporting center to share unit-specific results, staff were able to decrease the mean documented response time for a hypoglycemic event from the baseline of more than 2 hours to a mean time of 37 minutes in December 2014 (Figure 1). At the same time, the percentage of hypoglycemic patient-days was reduced from 4.5% to 3.7%, and the already excellent glycemic control improved even further. These improvements placed Sequoia in the top quartile for all major SHM parameters tracking glycemic control, hypoglycemia prevention, and hypoglycemia management.

Statistical Process Control (SPC) Chart Demonstrating Marked Improvement in Timeliness (minutes) of Hypoglycemia Management and Follow-Up Testing at Sequoia

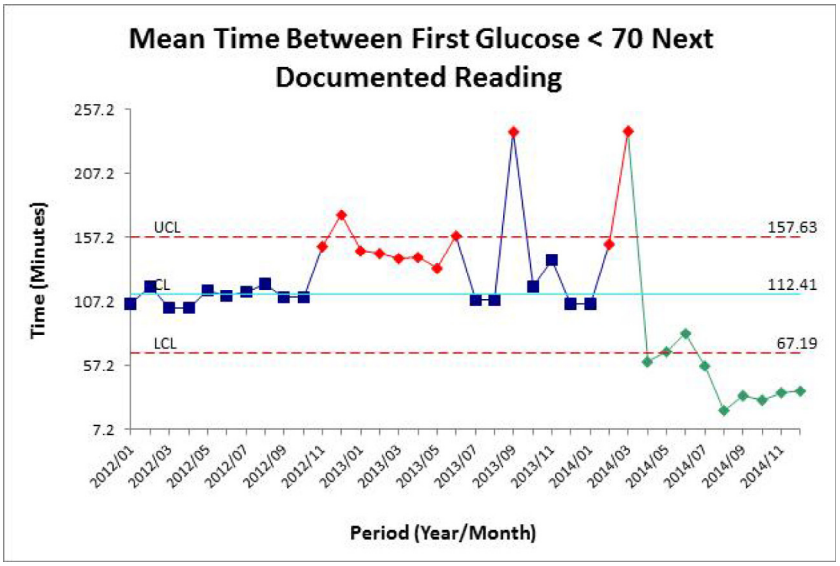

Figure 1: Improvement in this parameter coincided with reduced hypoglycemia, a common finding in Society of Hospital Medicine glucometrics data. Blue denotes data points consistent with baseline, red denotes time periods when a negative trend toward higher time intervals was developing or a breach of upper confidence limits (UCL), and green denotes positive trends or a breach of lower confidence limits (LCL). The aqua line represents the median or central limit (CL).

the small hospital fostered a relationship of familiarity between the staff (physicians and nurses) and the measure-ventionist, permitting ongoing education/feedback to occur in a non-threatening manner. The measure-ventionist was a major part of education, audit and feedback, and daily active surveillance interventions, facilitating steady improvement. At maturity of the initiative, the hospital had met all its goal metrics.

Education and Competency Training. Educational programs were convened to enhance health care workers' knowledge on diabetes and insulin, improve staff confidence in the management of diabetes, and improve adherence to the subcutaneous insulin order set. Educational interventions were as follows:

1. Glycemic control kickoff meeting for all cohort hospital improvement teams with an overview of inpatient management of diabetes
2. Diabetic resource nurse half-day education session on diabetes and insulin management plus a multisession designed to enhance critical thinking, patient safety, and leadership skills

Sidebar 2. Case Study: Measure-vention at Woodland Memorial Hospital

Woodland Memorial Hospital (Woodland, California) was one of the smaller participating sites, with a single measure-ventionist to cover the ICU as well as the non-ICU areas. At the beginning of the day, the nurse measure-ventionist would look at both the hyper- and hypoglycemia reports in the electronic health record (Cerner Corporation, North Kansas City, MO), which identify patients with fingerstick blood sugar ≥180 mg/dL or <70 mg/dL, respectively. This information was shared daily with the hospitalist assigned to the patient, the patient's primary nurse, and the lead nurse in the medical/surgical units. The measure-ventionist looked at each of the identified patients' charts to examine blood sugar trends during the stay, monitor for use of preformatted computer provider order entry (CPOE; called PowerPlans in the Cerner platform), and identify any other factors that would affect the patients glucose excursions. In the measure-ventionist's absence, the task of reviewing the daily hyper- and hypoglycemic reports was assigned to the lead nurse in the hospital's ICU. Phone calls were placed to the primary nurse of the patient with glycemic excursions, who was delegated with the task of further investigation and follow-up with the physician to expedite changes in glycemic control regimen as required.

The measure-ventionist completed a monthly report sent to the Gordon and Betty Moore Foundation Project Lead, outlining Glycemic PowerPlan usage and accuracy of insulin dosing. These measures were incorporated into a metrics report card, along with glucometric summaries from SHM (Figure 2). The report card was reviewed with the measure-ventionist, who shared the findings with clinical directors, the physician lead, and appropriate committees.

Suboptimal participation of the assigned physician lead and development of a structured improvement team proved challenging at Woodland Memorial. These challenges were mitigated by the measure-ventionist. Reference articles on glycemic management were provided for physician use. The measure-ventionist would also circle back to physicians who were using "off protocol" insulin ordering and help problem-solve any discomfort they were having with using the standardized CPOE insulin order sets. The lead hospitalist was informed of physicians who continued to use "off protocol" ordering despite ongoing education efforts.

Excerpt from a "Report Card" Used to Track Performance, Target Interventions, and Facilitate Audit and Feedback on a Regular Basis

Woodland's GBMF Complication & Mortality Reduction Grant Report Card

Performance from January 2014 to November 2014

	Baseline	Current Performance	Goal	Status	GBMF (9)	Current Performance by Month
Glycemic Control	CY 2011					
Day-Weighted Mean Glucose—Non–Critical Care	161.9	151.5	160.0	●	157.61	
Patient-Days with Hyperglycemia Episode > 299—Non–Critical Care	10.4%	7.6%	9.0%	●	8.6%	
Patient-Days with Hypoglycemia Episode < 70—Non–Critical Care	3.4%	3.4%	3.9%	●	3.7%	
Patients with Evidence-Based Protocol Ordered						
Med/Surg (Non–Critical)		95.2%	90.0%	●	96%	
Tele (Non–Critical)		n/a	90.0%		96%	
ICU (Critical Care)		97.3%	90.0%	●	96%	
Patients with Accurate Insulin Doses Administered						
Med/Surg (Non–Critical)		99.5%	95.0%	●	99%	
Tele (Non–Critical)		n/a	95.0%		99%	

Figure 2: Metrics include a blend of locally derived process measures and glucometrics processed through the Society of Hospital Medicine data and reporting center. Local current performance is easily compared to baseline performance and goals, as well as the performance of the entire nine-hospital cohort. GBMF, Gordon and Betty Moore Foundation.

3. Web-based nurse education and competency on the new insulin protocols and management of diabetes
4. Site-specific didactic education (for example, noon conferences, grand rounds, unit-based in-services) on the basis of need or facility request
5. Online glycemic control toolkit with protocols, order sets, educational materials, best-practice examples, and links to references
6. Patient-specific educational materials targeting self-management of diabetes and insulin

Analysis

Glucometric summaries for each site, and for the cohort as a whole were summarized as previously described. Pearson's chi-square value with relative risk (RR) calculations with 95% confidence intervals (CIs) were used to compare the proportion of patient-days with severe hyperglycemia and hypoglycemia at baseline (CY 2011) vs. postimplementation (CY 2014). Differences between the total cohort day-weighted mean BG pre- vs. postimplementation were calculated, and a 95% CI for the difference between the means was performed to assess statistical difference.

RESULTS

Patients and Patient-Days

Each of CYs 2011 and 2014 contained more than 30,000 patients with 100,000 patient-days of glycemic observation

Figure 3: Goals were set to improve by 10%–20% from baseline (purple X), or to reach a level of performance derived from Society of Hospital Medicine (SHM) benchmarking studies (green lines). Panel A: Day-weighted mean blood glucose (BG); Panel B: Percentage of patient-days with any BG > 299 mg/dL; Panel C: Percentage of patient-days with any BG < 70 mg/dL.

at the nine sites (31,438 patients with 106,852 patient-days in CY 2011 vs. 30,993 patients with 105,377 patient-days in CY 2014.) The average length of stay and sex distribution of the adult medical/surgical acute care population was identical in 2011 and 2014 (average length of stay 3.4 days, 45% male sex). Age and case mix index were quite similar (mean of 64 years of age in 2011 vs. 62 in 2014, case mix index 1.36 in 2011 vs. 1.34 in 2014).

Performance on Key Parameters

Figure 3 depicts the performance on key parameters by individual site, as well as total cohort results in three panels. Table 4 depicts results for the cohort.

Baseline Day-Weighted Mean BG. The baseline day-weighted mean BG varied widely—from 155.1 mg/dL to 182.2 mg/dL (Figure 3, Panel A). All sites had a goal of

Table 4. Summary Results for Key Metrics for the Nine-Hospital Cohort: Comparison of CY 2011 Values (Baseline) to CY 2014 Values (Postintervention)

Key Metric	2011 (106,892 days)	2014 (105,377 days)	Δ 2011 vs. 2014 (95% CI)	Relative Risk (95% CI)
Day-weighted mean BG in mg/dL	169.2 (SD 50)	157.8 (SD 48)	11.4 (11.0–11.8)	
Patient-days > 299 mg/dL	12,426	9,265	2.8%	0.76
%	11.6%	8.8%	(2.6%–3.1%)	(0.74–0.78)
Patient-days < 70 mg/dL	3,863	3,860	–0.05%	1.01
%	3.62%	3.66%	(–0.21%–0.11%)	(0.97–1.06)

CY, calendar year; CI, confidence interval; BG, point-of-care blood glucose; SD, standard deviation.

≤160 mg/dL (the SHM median in benchmarking), except for Hospital H, which had a goal of 164 mg/dL, representing a 10% improvement from its baseline of 182.2 mg/dL. Six of the 9 sites met these goals. The remaining 3 sites all improved numerically from baseline but just missed the threshold for goal. The day-weighted mean BG for the population improved significantly by 11.4 mg/dL [CI: 11.0–11.8], decreasing from 169.2 to 157.8 mg/dL.

Severe Hyperglycemic Days. The baseline performance for severe hyperglycemic days varied widely—from a low of 7.4% to a high of 15.6%. Two sites (Hospitals A and F) had goals of ≤8.0% of patient-days with any BG > 299 mg/dL (SHM benchmarking top-quartile performance), while the remaining seven sites with high baseline values targeted a 20% reduction (Figure 3, Panel B). Seven of the nine sites met their goals. One of the remaining two sites improved but just missed the threshold for goal, while the other site was marginally worse (8.7% postimplementation, 8.2% baseline). The percentage of patient-days with any BG > 299 mg/dL for the total cohort population improved from 11.6% to 8.8% (RR 0.76 [95% CI: 0.74 – 0.78]).

Baseline Hypoglycemia. Like the other two parameters, baseline hypoglycemia was highly variable, ranging from 2.0% of patient-days with any BG < 70 mg/dL at Hospital H to 6.3% at Hospital G (Figure 3, Panel C). As a cohort, the hospitals had an overall low rate of baseline hypoglycemia, with six sites enjoying SHM top quartile performance of ≤3.9% in the preintervention phase. Eight of the nine sites met collaborative goals by reducing hypoglycemic days by 20% from baseline or by achieving/maintaining hypoglycemia under SHM best-quartile rates. Five sites improved hypoglycemia postimplementation and met collaborative improvement goals. All of the four sites with trends to higher hypoglycemia had very low baseline rates below the SHM benchmark, and three of them remained at benchmark or lower. Across the cohort as a whole, the percentage of patient-days with any BG < 70 mg/dL remained low and essentially unchanged at 3.6%.

DISCUSSION

We demonstrated that substantial improvements in glycemic control and severe hyperglycemic events are feasible on a large scale across multiple hospitals without adversely affecting hypoglycemia rates. The reduction in day-weighted mean BG for the cohort population was significant, improving by 11.4 mg/dL (CI: 11.0–11.8). This is clinically important because hyperglycemia is associated with prolonged hospital stay, increased incidence of infections, more disability after hospital discharge, and increased mortality.[1] The risk for severe hyperglycemic days was also reduced significantly (RR 0.76 [CI: 0.74–0.78]), representing a reduction of more than 3,000 severe hyperglycemic days in 2014 vs. 2011. Fear of hypoglycemia is a major barrier for glycemic control programs.[5] Our experience should be reassuring and informative to hospitals in this regard. Overall hypoglycemia rates did not get worse, and, in fact, five of nine sites reduced hypoglycemia in the course of the initiative, and seven were top-quartile performers for low hypoglycemia rates in SHM benchmarking studies of 94 hospitals.

Many hospitals strive to improve glycemic control and hypoglycemia without any reliable means of tracking performance or comparing their performance to like hospitals.[5,6] In our opinion, such hospitals are highly unlikely to have similar results. The complexity of constructing and maintaining such measures, the lack of standardized glucometrics, and the paucity of mandatory objective quality measures are all contributing reasons for lack of measurement capacity, but these barriers are being overcome. Standardized metrics for severe hyperglycemia and hypoglycemia have a recommendation for endorsement at the National Quality Forum.[22] SHM and Yale have devised metrics that have many common principles that are practical and available at low or no cost.[6,12,13,23]

We found the high-quality glucometrics available from SHM to be indispensable. The metrics offered insights into process (for example, time intervals to manage hypoglycemia), as well as enabling establishment of baseline performance and tools to track and trend outcomes over time. When those metrics were coupled with local measures that assessed order set usage and appropriateness of insulin dosing, the improvement teams were able to target efforts and interventions where they were needed most and to reassure medical staff that gains in glycemic control were not resulting in undue hypoglycemia.

Baseline performance was highly variable across our 9-hospital cohort. For each measure, improvement teams could gauge their performance against the 94 hospitals enrolled in SHM benchmarking studies. This increased buy-in for performance goals from stakeholders made it clear that goals were achievable in a variety of hospitals. By juxtaposing glycemic control and severe hyperglycemia measures with measures for hypoglycemia, pursuing excellence for one metric did not lead to deterioration in the balancing measure. The availability of benchmarking data allowed for individualization of goals while retaining a common and cohesive framework. This is the first report we are aware of featuring these goal-setting techniques.

Our approach is unusual in modeling the use of mentoring from outside experts and a measure-ventionist in addition to a local champion at each site, and for the unique method of setting goals using national benchmarks. Our collaborative used methods that are largely portable and sustainable and that provide an excellent platform for spread of improvement across a system. Toolkits that describe the interventions (such as order sets, educational tools, measures, and measure-vention) are freely available, and the metrics and benchmarking are also available at no or low cost. Our collaborative model is consistent with successful models published in the literature.[6,24] The health care system prioritizes and helps summarize the evidence, distilling it down

into important best practices and processes that need to occur with the lowest barriers to use. Metrics, expert advice, and toolkits are assembled centrally, while each hospital identifies local barriers to implementation, educates all levels of staff, engages medical staff, executes implementation, and continually evaluates performance, modifying interventions accordingly. Interventions and order sets are piloted before being spread to others in the system. Embedding clinical decision support into insulin order sets and documentation tools helps sustainability.

Our project enjoyed assistance from GBMF project leads and some funding for local project leads, collaborative infrastructure, outside expert mentors, and measure-ventionist. We believe this model is cost-effective, as the chances for initial success are markedly enhanced, and it sets the stage for efficient spread across multihospital systems. In this instance, order sets, metrics, and other interventions were spread efficiently from these 9 hospitals to the other 30 hospitals in the Dignity Health system. Ongoing maintenance for all 39 hospitals includes enrollment in the SHM glucometrics, participation in national benchmarking, ongoing refinement of standardized order sets, SHM webinars every six months, and inclusion of hypoglycemia prevention efforts in Partnership for Patients collaborative efforts.[25] Spread of improvement and improvement techniques was not limited to inpatient glycemic control efforts. Measure-ventionists were so successful in this role that Dignity Health now uses measure-ventionists for a whole host of improvement programs, and they credit this form of active surveillance with success in driving improvement in a variety of health care–associated infections, as well as glycemic control.[21]

The study of our improvement work has some limitations. This was a longitudinal nonrandomized study; thus, factors other than our efforts conceivably could have influenced outcomes. Protocols, order sets, education, audit and feedback, and measure-vention are all part of a bundled intervention, making it difficult to understand which interventions have the most impact. Our glucometrics include only POC BG values, which have some inherent limitations in accuracy, and by excluding glucose values captured in laboratory tests and blood gasses, we miss some glycemic excursions of potential importance. However, POC BG tests are the most common source of data used to guide care in the hospital setting, we avoided duplicate or "mirror" BG readings, and prior studies showed a minimal impact on metrics with the addition of laboratory BG readings.[8] All sites implemented the same subcutaneous insulin order set and made the order set difficult to bypass. Although monitoring order set usage and insulin use patterns were encouraged, we did not standardize measures for this, and these data were not collected or analyzed centrally. All glucometrics data were outsourced to SHM, and they were not linked to personal health information, which is a limitation of all outsourced glucometrics. This limitation does not allow for correlation of glycemic control with clinical outcomes. In the absence of randomized trial design, multivariate analysis controlling for comorbidities is sometimes performed to examine the impact of improvement efforts on outcomes such as infection rates, readmissions, and hospital length of stay. We did not perform such an analysis because it could not control for all other improvement efforts deployed between 2011 and 2014 that could affect those outcomes and because we could not link glycemic control data to other personal health information. Further studies are needed to explore these relationships.

These limitations are balanced by a number of strengths. The number of patients and patient-days of glycemic observation did not change over time, suggesting that testing pattern changes were minimal and not a major contributor to improved glycemic control outcomes. Our improvement effort affected large populations across multiple sites for prolonged observation periods, using high-quality metrics. The magnitude and consistency of results argues against demographic changes as a causative factor.

CONCLUSION

Our results demonstrate that large-scale multihospital improvements in glycemic control and severe hyperglycemia are feasible and can be done safely without significant increases in hypoglycemia rates. External sources of toolkits, benchmarking, and metrics are available at no or low cost and can accelerate improvement.[6] Taking into account both national comparative benchmarks and baseline performance was beneficial when setting balanced goals for glycemic control and hypoglycemia. Investments in mentoring, measure-vention, and protocol-driven order sets enable better staff acceptance, sustainability, and spread across hospital systems.

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