Risk factors for hospital-acquired ‘poor glycemic control’: a case–control study

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Abstract

Objective. To determine the patient and hospital characteristics associated with severe manifestations of ‘poor glycemic control’—a ‘no-pay’ hospital-acquired condition defined by the US Medicare program based on hospital claims related to severe complications of diabetes.

Design. A nested case–control study.


Participants. All cases (n = 261) with manifestations of poor glycemic control not present on admission admitted to California acute care hospitals from 2005 to 2006 and 261 controls were matched (1:1) using administrative data for age, sex, major diagnostic category and severity of illness.

Main Outcome Measure(s). The adjusted odds ratio (OR) for experiencing poor glycemic control.

Results. Deaths (16 vs. 9%, P = 0.01) and total costs ($26 125 vs. $18 233, P = 0.026) were significantly higher among poor glycemic control cases. Risk-adjusted conditional logistic regression revealed that each additional chronic condition increased the odds of poor glycemic control by 12% (OR: 1.12, 95% CI: 1.04–1.22). The interaction of registered nurse staffing and hospital teaching status suggested that in non-teaching hospitals, each additional nursing hour per adjusted patient day significantly reduced the odds of poor glycemic control by 16% (OR: 0.84, 95% CI: 0.73–0.96). Nurse staffing was not significant in teaching hospitals (OR: 0.98, 95% CI: 0.88–1.11).

Conclusions. Severe poor glycemic control complications are relatively rare but meaningful events with disproportionately high costs and mortality. Increasing nurse staffing may be an effective strategy in reducing poor glycemic control complications particularly in non-teaching hospitals.

Keywords: patient safety, poor glycemic control, hospital-acquired conditions, nurse staffing, case–control

Introduction

Errors and complications due to medical treatment remain unacceptably common occurrences even 10 years since the Institute of Medicine’s landmark report on patient safety [1]. One area of concern is hospital-acquired conditions—conditions that are reasonably preventable through evidence-based care. As part of an overall focus on improving healthcare quality, safety and efficiency through value-based purchasing, the US Congress, through the Deficit Reduction Act of 2005, authorized the Secretary of the Department of Health and Human Services (section 5001(c)) to identify preventable hospital-acquired conditions. Based on the 2009 Centers for Medicare and Medicaid Services Hospital Inpatient Prospective Payment System Final Rule establishing the hospital-acquired conditions [2], beginning 1 October 2008, hospitals did not receive additional payment from the Centers for Medicare and Medicaid Services (i.e. the case is paid as though the secondary diagnosis was not present) for cases where the hospital-acquired condition was not present on admission.

One of the hospital-acquired conditions is manifestations of poor glycemic control (hence forth referred to as poor glycemic control), which includes diabetic ketoacidosis, non-ketotic hyperosmolar coma and hypoglycemic coma (Table 1). These conditions are often clinically referred to as diabetic emergencies or hyperglycemic crises [3]. The Centers for Medicare and Medicaid Services, however, has referred to these severe conditions as ‘manifestations of poor glycemic control’ and so we have chosen to maintain this
The Joint Commission has identified insulin as one of the highest risk medications for error and adverse event [11]. The poor glycemic control conditions were selected as a hospital-acquired condition because they meet the criteria set forth in the Deficit Reduction Act as high cost, reasonably preventable conditions that are identifiable through ICD-9 coding as a complicating condition. The statute does not require that a condition be ‘always preventable’ in order to qualify as a hospital-acquired condition, but rather that it be ‘reasonably preventable,’ necessarily implying something <100%. Hyperglycemia and hypoglycemia are quite common among hospitalized patients with diabetes [5, 6]. Among potential manifestations along the spectrum of poor glycemic control that may indicate poor quality of care, the conditions of diabetic ketoacidosis, nonketotic hyperosmolar coma and hypoglycemic coma represent a few specific, narrow codes designating extreme and catastrophic events with potentially lethal consequences. They are, however, generally considered reasonably preventable by the Centers for Medicare and Medicaid Services [8]. The Final Rule establishing poor glycemic control as a hospital-acquired condition emphasized that ‘... they are preventable through the use of routine serum glucose measurement and control, which are basic elements of good hospital care’ [2].

Nonetheless, the inpatient management of blood glucose among patients with diabetes is time- [9] and cost-intensive work [10] fraught with many difficulties and potential perils. The Joint Commission has identified insulin as one of the highest risk medications for error and adverse event [11]. The National Quality Forum has made patient death or serious disability associated with hypoglycemia an indicator of a serious adverse event [12]. While there are guidelines for inpatient management of blood glucose [5], it is difficult to apply a one-size-fits-all approach. Despite calls for tight glycemic control, particularly among the critically ill who commonly experience hyperglycemia even without prior diabetes, evidence is incomplete or conflicting as to the optimal management strategy for all patients [13].

Many patient characteristics including diabetes, critical illness and injury, infection, chronic illness, various comorbidities and certain medications are known to result in diverse and dynamic blood glucose levels in the hospital [5, 14, 15]. Despite urging, however, from organizations such as the American College of Endocrinology and American Association of Clinical Endocrinologists [16] to focus on organizational determinants of adverse events in patients at risk for poor glycemic control, the organizational factors associated with poor glycemic control, particularly at the hospital level have not been studied well. Thus, the purpose of this investigation was to identify patient risk factors and hospital characteristics associated with the Centers for Medicare and Medicaid Services defined manifestations of poor glycemic control.

### Methods

**Design**

We conducted a matched (1:1) case–control study to examine the individual and hospital organizational factors related to poor glycemic control among hospitalized adult patients with diabetes in the State of California using data from the California Office of Statewide Health Planning and Development between 2005 and 2006. The case–control design is particularly suited for this study because of the rarity of the event and the need for data reduction across many institutions to generate appropriate comparisons for cases. The study data are derived from administrative discharge abstracts and the files include detailed information on service claims and demographic characteristics. The study data also include present on admission indicators necessary for evaluating hospital-acquired conditions. The present on admission indicators signal whether each ICD-9 diagnosis was present prior to the patient entering the hospital or developed during the hospitalization. The cohort for selecting cases and controls included adult patients aged 18 years and older with diabetes (ICD-9 codes 250.xx) treated in an inpatient prospective payment system participating adult, non-federal, acute care hospital in California for the years 2005–2006. Secondary diabetes codes (ICD-9 codes 249.1x and 249.2x) were not available in 2005–2006 and thus were not used for inclusion. Data from the American Hospital Association Annual Survey from the years 2005–2006 were merged with patient data to identify hospital characteristics. The investigation was approved by the institutional review board of the University of Pennsylvania.

### Table 1

<table>
<thead>
<tr>
<th>Manifestations of poor glycemic control</th>
<th>ICD-9 codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes with ketoacidosis</td>
<td>250.10–250.13</td>
</tr>
<tr>
<td>Diabetes with hypersomolar coma</td>
<td>250.20–250.23</td>
</tr>
<tr>
<td>Hypoglycemic coma</td>
<td>251.0</td>
</tr>
<tr>
<td>Secondary diabetes with ketoacidosis</td>
<td>249.10–249.11</td>
</tr>
<tr>
<td>Secondary diabetes with hypersomolarity</td>
<td>249.20–249.21</td>
</tr>
</tbody>
</table>

**a** A more common term for such conditions is diabetic emergencies.

**b** These diagnoses were not included in the analysis because they were new codes as of October 2008 and our data include 2005–2006.

Note: The table represents diagnoses categorized as manifestations of poor glycemic control.
Case and control selection

Cases were selected based on the fiscal year 2009 Centers for Medicare and Medicaid Services Final Rule [2] using ICD-9 codes indicating a diagnosis for one of the poor glycemic control conditions outlined in Table 1 and a corresponding present on admission indicator designating the condition as not present on admission. Because some cases of poor glycemic control, particularly hypoglycemic coma, can occur in non-diabetic patients, we conducted a 2-year lookback from the event date of admission to confirm the presence of diabetes as a pre-existing condition for cases. For each case, a matched control was randomly selected. Cases and controls were matched on four criteria: gender, age group (<45, 45–65, 65–75, 75–85 and >85), major diagnostic category (MDC—a set of diagnostic grouper categories based on DRG; see Supplementary material, Table S1), and All-Patient Refined Diagnosis Related Group (APR-DRG) severity of illness category. The 3M APR-DRG software was used to generate the APR-DRG indicator—a 4-level illness severity indicator, including minor, moderate, major and extreme categories [17]. The severity of illness categorization specifies the extent of physiologic decompensation or organ system loss of function for each patient.

Patient characteristics

Patient characteristics were evaluated for their relationship to poor glycemic control. Characteristics included the comorbidities outlined by Elixhauser et al. [18] (excluding fluid and electrolyte disorders and coagulopathy) [19], the number of chronic conditions for each individual [20], emergency room admission and payment type. Comorbidity indicator software [18] and chronic conditions indicator software [20] available from the Agency for Healthcare Research and Quality were used to assign variables that identified comorbidities and chronic conditions in the administrative data using ICD-9 coding.

Hospital characteristics

Data on hospital organizational characteristics were drawn from the American Hospital Association Annual Survey and included hospital bedsize, ownership, teaching status and registered nurse (nurse) staffing. Hospital bedsize was defined as the number of hospital unit beds set up and staffed. Hospitals were categorized as small (fewer than 100 beds), medium (100–250 beds) and large (250 or more beds). Ownership was classified as non-profit vs. for-profit. Hospitals were classified as non-teaching vs. teaching if they had no postgraduate trainees. Nurse staffing at the hospital was calculated as the productive nursing hours per patient day based on the full-time equivalent (FTE) nurse positions per adjusted patient day and using a standard conversion where one FTE = nursing hours/(1768; the potential productive hours per year for an FTE) [21].

Statistical analysis

Cases were compared with matched and unmatched controls using the Cochran-Mantel-Haenszel chi-square test for categorical variables and two-tailed t-tests for continuous variables. Univariate conditional logistic regression models were estimated to evaluate the relationship between each risk factor and poor glycemic control using the matched case–control data. Odds ratios and 95% CIs were calculated using multivariate conditional logistic regression models to estimate the effect of hospital characteristics after controlling for patient risk factors using the matched case–control data. Analyses were conducted using the STATA version 10 statistical software program.

Results

Characteristics of cases of poor glycemic control

Characteristics of cases compared with controls and the unmatched cohort are presented in Table 2. Of 1 209 178 adult discharges with diabetes mellitus from 2005 to 2006, only 269 (0.02%) cases experienced a Centers for Medicare and Medicaid Services-defined poor glycemic control event not present on admission. Eight cases with hypoglycemia were eliminated because we could not confirm those patients as having pre-existing diabetes by present on admission indicator or 2-year lookback. Out of the 261 cases, 7 (3%) cases had hyperglycemic coma; 217 (83%) cases had ketoacidosis only; 28 (11%) cases had hyperosmolar hyperglycemic state only and 9 (3%) cases had both ketoacidosis and hyperosmolar hyperglycemic state. We found few significant differences across patient characteristics between the case and matched control groups indicating successful matching. Among poor glycemic control cases, the mean age was 56 (SD = 18), nearly a third (31%) were 65 years of age or older and 40% had Medicare as the primary payer. Most cases were admitted to the hospital from the emergency department. Most cases (67%) were admitted for medical illness. The average length of stay for cases was significantly longer than for matched controls (14 vs. 7 days, \( P < 0.001 \)). Over 75% of cases had more than five chronic illnesses. The most commonly reported comorbidity was hypertension (63%). Of the Elixhauser comorbidity indicators, only pulmonary circulation disease \( (X^2, 9.55; P = 0.002) \) was significantly different between the cases and matched controls. Comparisons of all comorbidities between cases and controls are shown in Supplementary material, Table S2.

The number of deaths were nearly twice as high among cases compared with controls (16 vs. 9%, \( P = 0.01 \)) and total costs (derived from total charges adjusted by the hospital cost-to-charge ratio) were higher for cases compared with controls ($26 125 vs. $18 233, \( P = 0.02 \)). While all cases and controls had diabetes, they may have been treated for different conditions and Table 3 shows the 10 most common DRG codes found among cases and controls. The top five most common among cases were diabetes (9.6%), septicemia (7.7%), pancreatic disorders excluding malignancy (4.98%),...
simple pneumonia/pleurisy (3.8%) and respiratory system diagnosis with ventilation (3.5%).

**Conditional logistic regression**

Following univariate analyses, we examined the association of patient and hospital characteristics controlling for covariates using conditional logistic regression models (Table 4). Among patient characteristics, pulmonary circulation disease (OR: 0.07, 95% CI: 0.01–0.59) and admission through the emergency room (OR: 1.96, 95% CI: 1.12–3.41) were significantly associated with poor glycemic control. The individual’s number of chronic conditions was also significantly associated with poor glycemic control suggesting that each additional chronic condition increased the odds of poor glycemic control by 12% (OR: 1.12, 95% CI: 1.04–1.22).

After controlling for covariates, both nurse staffing (OR: 0.92, 95% CI: 0.84–1.00) and hospital teaching status (OR: 1.52, 95% CI: 0.99–2.35) were of borderline statistical significance. To evaluate the effect of nurse staffing at teaching and non-teaching hospitals, we considered a model that included an interaction between hospital teaching status and nurse staffing. In non-teaching hospitals, each additional productive nursing hour per patient day lowered the odds of a poor glycemic control event by 16% (OR: 0.84, 95% CI: 0.73–0.96). Nurse staffing was not significant in teaching hospitals (OR: 0.98, 95% CI: 0.88–1.11). Table 5 shows predicted probabilities of a poor glycemic control event based on our final model for different levels of nurse staffing in teaching and non-teaching hospitals. In both settings, the probability of a poor outcome is lower as staffing improves holding other covariates at their mean.

**Discussion**

We have shown that while manifestations of poor glycemic control as described by the Centers for Medicare and
Medicaid Services are relatively rare, these events are associated with disproportionately high costs and mortality. Having more chronic conditions and being admitted through the emergency room are associated with higher odds of poor glycemic control events. We have also shown a significant relationship between poor glycemic control and nurse staffing, particularly at non-teaching hospitals. This suggests one potential organizational intervention, which may reduce these events, is improved nurse staffing.

Nurses are at the frontlines of managing glycemia among hospitalized patients. Nurses conduct the core functions responsible for maintaining euglycemia—blood glucose monitoring and administration of insulin and other glucose-lowering medications. Nurses are responsible for the delivery

Table 3 Comparison of top 10 case and control DRG codes

| DRG description                          | Cases with poor glycemic control (n = 261) (%) | Controls (no poor glycemic control) (n = 261) (%)
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetesa</td>
<td>25 (9.58)</td>
<td>21 (8.05)</td>
</tr>
<tr>
<td>Septicemia</td>
<td>20 (7.66)</td>
<td>20 (7.66)</td>
</tr>
<tr>
<td>Disorders of pancreasb</td>
<td>13 (4.98)</td>
<td>10 (3.83)</td>
</tr>
<tr>
<td>Simple pneumonia/pleurisy</td>
<td>10 (3.83)</td>
<td>9 (3.45)</td>
</tr>
<tr>
<td>Respiratory system diagnosisc</td>
<td>9 (3.45)</td>
<td>9 (3.45)</td>
</tr>
<tr>
<td>O.R. procedure for infection</td>
<td>8 (3.07)</td>
<td>7 (2.68)</td>
</tr>
<tr>
<td>Cranial/peripheral nerve disorders</td>
<td>6 (2.30)</td>
<td>7 (2.68)</td>
</tr>
<tr>
<td>Diabetesd</td>
<td>6 (2.30)</td>
<td>6 (2.30)</td>
</tr>
<tr>
<td>ECMO or mechanical ventilatione</td>
<td>6 (2.30)</td>
<td>6 (2.30)</td>
</tr>
<tr>
<td>Renal failure</td>
<td>6 (2.30)</td>
<td>6 (2.30)</td>
</tr>
</tbody>
</table>

Table 4 Unadjusted and adjusted odds ratios for poor glycemic controla

<table>
<thead>
<tr>
<th>patient characteristics</th>
<th>Unadjusted OR (95% CI) (n = 522)</th>
<th>Adjusted OR (95% CI) (n = 522)</th>
<th>Adjusted OR with interaction (95% CI) (n = 522)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRG description</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary circulation disease</td>
<td>0.08 (0.01–0.64)</td>
<td>0.07 (0.01–0.66)</td>
<td>0.06 (0.01–0.59)</td>
</tr>
<tr>
<td>ER</td>
<td>1.69 (1.09–2.61)</td>
<td>1.96 (1.12–3.41)</td>
<td>2.04 (1.16–3.58)</td>
</tr>
<tr>
<td>Number of chronic conditions</td>
<td>1.05 (1.00–1.10)</td>
<td>1.12 (1.04–1.22)</td>
<td>1.13 (1.04–1.22)</td>
</tr>
<tr>
<td>Bedsizeb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium size (100–250 beds)</td>
<td>1.20 (0.84–1.72)</td>
<td>0.77 (0.32–1.85)</td>
<td>0.80 (0.33–1.96)</td>
</tr>
<tr>
<td>Large size (&gt;250 beds)</td>
<td>0.87 (0.62–1.23)</td>
<td>0.72 (0.31–1.70)</td>
<td>0.73 (0.31–1.76)</td>
</tr>
<tr>
<td>Teaching status</td>
<td>1.27 (0.91–1.77)</td>
<td>1.52 (0.99–2.35)</td>
<td>1.56 (1.00–2.42)</td>
</tr>
<tr>
<td>Teaching status when nurse staffing = 6.99 (mean)d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurse staffing</td>
<td>0.92 (0.85–0.99)</td>
<td>0.92 (0.84–1.00)</td>
<td>0.84 (0.73–0.96)</td>
</tr>
<tr>
<td>Nurse staffing in non-teaching hospitals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurse staffing in teaching hospitals</td>
<td></td>
<td></td>
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</tbody>
</table>

ECMO, extracorporeal membrane oxygenation; AMI, acute myocardial infarction.

aEstimated by conditional logistic regression with one-to-one case–control matching and controlling for additional covariates including Elixhauser comorbidities, payer status and emergency room admission status.
bSmall hospital (<100 beds) as reference category.
cNon-teaching hospital as reference category.
dTeaching status in interaction model is interpreted when nurse staffing is equal to the mean (6.99).
eProduct of interaction between hospital teaching status and nurse staffing (OR: 1.17, 95% CI: 1.02–1.43).
of other care essential to successful outcomes for patients with diabetes including bedside symptom management and surveillance, coordination of nutrition and transportation services in order to avoid blood glucose derangements, implementation of physician order sets and protocols and educational programs focusing on enhanced glycemic control and diabetes self-management. The work that nurses do to manage diabetes and maintain glycemic control is time intensive, complex and requires good organization, training, communication and organizational support [9].

A nursing staff with an excessive workload is a systemic failure that can compromise patient safety [16, 22]. A broad literature base has linked poor nurse staffing to a number of adverse patient outcomes [23]. Medical errors, while occurring at the point of care where nurses interact with patients, are often the result of predictable systematic failures that undermine how nurses can effectively do their work [24]. Nurses are fundamental to error prevention and the rescue of patients from potential adverse events such as poor glycemic control. In a study of two hospitals for example, Leape et al. [25] demonstrated that nurses were responsible for intercepting 86% of all errors that would result in adverse drug events. Organizational system failures and impediments undermine nurses’ ability to carry out the complex surveillance and management required to control blood glucose in the hospitalized patient and can lead to errors and poor outcomes.

Although our research does not identify the mechanism by which insufficient nurse staffing leads to poor glycemic control events, poor staffing is associated with a number of conditions that might reasonably lead to breakdowns in a hospital’s ‘culture of safety.’ First, an overburdened staff is less able to provide back-ups and checks on each other. When there are holes in the resources and defenses against mistakes, errors are more likely to occur [24]. Under-resourced nurses may also be more likely to use workarounds to get their work done, leading to errors and inconsistent, inefficient care [26]. Finally, an overburdened nursing staff may be less able to communicate effectively with physicians and other members of the healthcare team. Nurse–physician communication is critical for the management of complex patients [27]. Optimally managed patients with diabetes often have complex insulin delivery orders, intensive blood glucose monitoring protocols, nutrition orders and scheduling and other factors that need to be communicated across many members of the healthcare team. Effective and timely communication is essential to promoting the highest quality of care. An excessive workload among nurses may result in information falling through the cracks particularly during critical moments such as hand-offs and shift-changes.

Despite controlling for patient factors, we found that the effect of nurse staffing depended on hospital teaching status. It is possible that the high-paced environment of the teaching hospital, with increased technological demands, rotating personnel and increased hand-offs, may undermine the potential benefits of additional nurse staffing. Evidence varies about the effect of hospital teaching status on patient outcomes with most papers showing that teaching status is associated with better patient outcomes but some research finding the opposite or no relationship [28]. The findings specific to the relationship between teaching status and adverse events is equally mixed. Brennan et al. [29] for example, found that adverse events occurred more frequently in teaching hospitals but were less likely to be due to substandard care. Other investigators have found that teaching status was associated higher rates of patient safety incidents [30].

One hypothesis for poorer outcomes in teaching institutions is that, in some cases, inexperienced resident physicians may be providing care for complex critically ill patients [31]. Another potential issue is that teaching hospitals may care for more complex patients and perform more complicated procedures—both of which may introduce factors that we could not control for. We matched our cases and controls on severity of illness and there was no statistically significant difference between the severity of illness or the number of chronic conditions of our sample in teaching hospitals compared with those in non-teaching hospitals. Additionally, the bulk of services provided by teaching hospitals are routine services provided to the general population. Nonetheless, the administrative data we used lacks the clinical specificity that we might like to use to examine more detailed patient risk factors. Although balance between cases and controls was good, as in many observational studies, we were only able to control for observable factors. More specific clinical data might have allowed us to control for additional severity of illness, the immediate availability of consulting endocrinologists, certain laboratory values and certain medication use that might be relevant to poor glycemic control.

Additional limitations are worthy of note. First, the cross-sectional nature of our study limits our ability to draw conclusions about causation. It is also possible that there was systematic undercoding of manifestations of poor glycemic control. This is, however, the type of data that the Centers for Medicare and Medicaid Services will use in applying their ‘no-pay’ rule. While there are limitations to the use of

Table 5 Predicted probability of poor glycemic control for increasing levels of nurse staffing in teaching and non-teaching hospitals

<table>
<thead>
<tr>
<th>Nursing hours per patient day</th>
<th>Teaching hospital Predicted probability (95% CI)</th>
<th>Non-teaching hospital Predicted probability (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.74 (0.17–0.97) 0.84 (0.29–0.99)</td>
<td>0.66 (0.12–0.97) 0.79 (0.23–0.98)</td>
</tr>
<tr>
<td>6</td>
<td>0.58 (0.08–0.96) 0.73 (0.17–0.98)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.49 (0.05–0.95) 0.66 (0.12–0.96)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.40 (0.03–0.94) 0.57 (0.08–0.95)</td>
<td></td>
</tr>
</tbody>
</table>

*Predicted probabilities based on final model with nurse staffing and teaching hospital interaction holding all other covariates at their mean.
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Administrative data to identify safety indicators, many have been validated and are commonly used in health services and patient safety research and have been shown to have higher validity when used, as we have, with present on admission flags and lookback procedures [19, 32]. Administrative data are also particularly useful with matched case–control studies of extremely rare events [33]. Nonetheless, future research should consider chart review and clinical validation of data on these events. Additionally, because 2009 Medicare data—the first complete year of Medicare data with present on admission flags—were not available when we began our analysis, we utilized state discharge abstract data from the Office of Statewide Health Planning and Development. While these data have been shown to have reliable and valid present on admission indicators [34], we were unable to examine new secondary diabetes complications (ICD-9 codes 249.1x and 249.2x) that are part of the cluster of poor glycemic control events defined by the Centers for Medicare and Medicaid Services. We do not know if the factors we found related to poor glycemic control in our sample would be similarly related to secondary diabetes. Our sample also excluded hypoglycemic coma events among patients that we could not establish as having pre-existing diabetes. These critically ill patients are at risk for poor outcomes but were not within the scope of our study on patients with pre-existing diabetes. Likewise, we note that our findings represent only a small subset of the most extreme manifestations of poor glycemic control across a potentially wide range of blood glucose variation. Our findings may not be generalizable to the more common variations in blood glucose that occur in response to patient care or lack thereof. Finally, we acknowledge the view that the conditions we examined may not always be preventable. Even though the Centers for Medicare and Medicaid Services rule notes that the events should be ‘reasonably preventable,’ there may be instances when a negative outcome occurs despite very good care. On average, however, this is not the most likely scenario. While the most costly and time-intensive glucose monitoring is not indicated for all patients, systematic processes and safeguards, including adequate nursing staff and resources should be in place to prevent hypoglycemic and hyperglycemic crisis in all patients, and particularly those receiving glucose-lowering medications.

In conclusion, low nurse staffing undermines the ‘culture of safety’ necessary to provide safe and effective care to patients with diabetes. A projected US nursing workforce shortage has the potential to magnify the burdens on nursing systems to care for patients with complex conditions that require focused surveillance and intensive management such as diabetes mellitus. While policy interventions may be necessary to support robust nursing workforce nationally and internationally, hospital administrators must be proactive in investing in nursing as part of the culture of safety. Our results point to the need for prospective work to clarify the clinical significance of our findings and add to a mounting body of evidence supporting an investment in nursing resources, particularly in non-teaching hospitals.

Supplementary material

Supplementary material is available at International Journal for Quality in Health Care online.

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References

2. Centers for Medicare and Medicaid Services. Medicare program: changes to the hospital inpatient prospective payment systems and fiscal year 2009 rates; payments for graduate medical education in certain emergency situations; changes to disclosure of physician ownership in hospitals and physical self-referral rules; updates to the long-term care prospective payment system; updates to certain IPPS excluded hospitals; and collection of information regarding financial relationships between hospitals; final rule. Fed Regist 2008;73:48434–9083.
Poor glycemic control


