Applying Diabetes-Related Prevention Quality Indicators to a National Cohort of Veterans With Diabetes

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OBJECTIVE — The Prevention Quality Indicators (PQIs) are measures of hospitalizations that reflect quality of ambulatory care. We applied the PQIs of metabolic decompensation to Veterans Health Administration (VHA) utilizers with diabetes. We identified patient-level characteristics associated with hospitalization for metabolic decompensation, developed a risk-adjustment model for the measures, and compared regional network performance using these PQIs.

RESEARCH DESIGN AND METHODS — This was a retrospective cohort study of 406,575 veterans with diabetes who used the VHA between 1997 and 1999. The outcomes were the PQIs of uncontrolled diabetes, short-term complications, or a combined measure. Patient-level variables were identified from administrative databases. Variation in performance of the networks was compared between full risk adjustment and age and sex adjustment only.

RESULTS — In fiscal year 1999, there were 1,719 VHA discharges (4.2 per 1,000 cohort members) for uncontrolled and short-term complications of diabetes. A logistic regression model including age, sex, marital status, Charlson Comorbidity Index, mental health condition, insulin use, and oral antihyperglycemic medication use was developed for risk adjustment of the combined PQI. Full risk adjustment changed performance ranks of the networks using the combined PQI outcome relative to age and sex adjustment only. Ten networks remained in the same quartile of performance, five moved one quartile, and seven moved two or more quartiles.

CONCLUSIONS — The PQIs of uncontrolled and short-term complications of diabetes are uncommon outcomes among veterans with diabetes and should be used only as a combined outcome. More complete risk adjustment should be used when comparing systems of care using the combined measure.

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Diabetes is an epidemic in the U.S., with a 49% increase in incidence in the 1990s (1). The costs and morbidity associated with the complications of diabetes make this an important public health issue (2). There are several ambulatory care interventions that have been shown to reduce microvascular and macrovascular complications, but they are generally underutilized (3,4). There are ongoing efforts to measure the quality of diabetes-related ambulatory care (5,6) with the expectation of improved outcomes, which is consistent with the goals of the Healthy People 2010 initiative (7). Although not as common as long-term complications in patients with type 2 diabetes, hospitalizations for acute metabolic decompensations are high-cost events associated with serious morbidity and high mortality. They are also considered preventable with appropriate ambulatory care (8–10).

The Agency for Healthcare Research and Quality (AHRQ) published Prevention Quality Indicators (PQIs): Hospital Admission for Ambulatory Care Sensitive Conditions in 2001 (11). The indicators were developed based on the assumption that high-quality ambulatory care results in fewer hospitalizations. The recommendations include two indicators for metabolic decompensation: hospitalizations for uncontrolled diabetes and hospitalizations for short-term complications of diabetes, i.e., diabetic ketoacidosis and hyperosmolar nonketotic coma. The measures do not differentiate by the type of diabetes. The Prevention Quality Indicators (PQIs) were introduced with the recommendation to use age and sex adjustment for population-based comparisons, such as among states.

The Veterans Health Administration (VHA) provides a unique opportunity to empirically evaluate the PQIs. The VHA is an integrated national health care system in which veterans receive health care at individual facilities organized into regional networks termed Veterans Integrated Service Networks (VISNs). The system uses an electronic medical record that centrally compiles patient-level information available for research and management purposes (12). In this study, we report the rates of hospitalization of patients with diabetes in the VHA during 1999 for metabolic decompensation as defined by the AHRQ PQI measures. Our first objective was to evaluate the contribution of patient-level demographic and clinical data to the risk of hospitalization for metabolic decompensation. Our sec-
RESEARCH DESIGN AND METHODS

Data sources
Veterans who possibly had diabetes in fiscal year (FY) 1997 or 1998 were identified. All veterans with at least one diabetes-specific ICD-9-CM inpatient or outpatient code were obtained from the National Patient Clinical Dataset from the VHA VISN Support Center (Austin, TX). The National Center for Cost Containment diabetes registry project supplied patient-level pharmacy data regarding prescriptions for insulin, sulfonylurea medications, other oral antglycemic agents (metformin, acarbose, and troglitazone), and blood glucose monitoring supplies. The program also identified patients who had an HbA1c test (13).

We created a file of patients who had any diabetes ICD-9-CM code (250.XX), HbA1c, or diabetes-specific medication and obtained Centers for Medicare and Medicaid Services (CMS) data files for calendar years 1996, 1997, and 1998. The files included part A, institutional inpatient care; part A, institutional outpatient care; and part B, physician care. We verified that the CMS claims were applied to the patient and not a dependent (e.g., spouse). We then merged the CMS and VA Utilization data.

We then identified a cohort, using the Medicare National Diabetes Cohort Study criteria for determination of diabetes (at least one inpatient or more than one outpatient 250.XX ICD-9-CM) (14) or at least one outpatient diabetes-specific medication (15,16). Deaths in FY97 and FY98 were identified using both the VHA Beneficiary Identification and Records Locator Subsystem and the CMS Denominator File. In total, 446,896 patients met the definition of diabetes and were alive as of 30 September 1998.

We eliminated 16 VHA health care facilities in which <50% of patients with diabetes were on glycemic-specific agents (facilities in which unnoticed reporting problems may have occurred), leaving a total of 406,575 unique patients from 134 facilities and 22 VISNs. We categorized patients hospitalized in the VHA in FY99 according to primary or admission diagnoses for uncontrolled diabetes (ICD-9-CM codes 250.02 and 250.03), short-term complications (codes 250.10–250.13, 250.20–250.23, and 250.30–250.33), and combined (in either group, but only the first hospitalization for these categories). We calculated the Charlson Comorbidity Index scores from inpatient and outpatient records from FY97 and FY98 using the Deyo modification, including both VHA and CMS data. This risk adjustment index controls for confounding of outcome variables by common clinical conditions (based on ICD-9-CM codes), including myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, rheumatologic disease, peptic ulcer disease, mild liver disease, diabetes, hemiplegia/paraplegia, renal disease, any malignancy, moderate, or severe liver disease, metastatic solid tumor, and AIDS. Points are assigned for each medical condition, producing a score of 0–32. Higher scores are associated with higher 1-year mortality (17). Demographic variables were extracted from the VHA National Patient Care Database, and missing values were filled in with CMS data whenever possible, with the exception of race, for which CMS data served as the primary source (18).

Conceptual model
In constructing risk adjustment models, a central issue is to control for factors known to influence the outcome of interest that are largely outside the control of a health system (19). We previously adapted the health care utilization model to risk adjust HbA1c levels using administrative data (20). We conceptualized our risk adjustment model using the domains of demographic factors, severity of diabetes, medical comorbidity, and psychiatric comorbidity. Demographic factors include age, sex, and marital status. Marital status has been found to be protective in some conditions (21) but not in others (22). While type of diabetes and diabetes duration are key patient-level factors that correlate with both glycemic control and metabolic compensation, this information is not available from these administrative databases. However, diabetes treatment modality is highly correlated with duration of type 2 diabetes (3,23,24). Insulin use, use of an oral antglycemic agent, and home glucose monitoring were included to capture diabetes severity. To assess comorbid medical illness, an adaptation of the Charlson Comorbidity Index was utilized (17,25). To our knowledge, there is no generally accepted risk adjustment method for examining the outcomes of metabolic decompensations. We (20) and others (26) have utilized the Charlson Comorbidity Index for risk adjustment of glycemic control. To avoid comorbid conditions that may have contributed to the need for hospitalization, we utilized diagnostic codes from the baseline period (FY97–98) in the index. Finally, control of diabetes may be compromised by mental illness; a patient suffering from mental illness may be less able to adhere to recommended diet, medications, and appointments than a patient without mental illness (27). We included a term that categorizes veterans as either having any or none of a list of ICD-9-CM diagnostic codes (295.00–298.9) corresponding to serious mental illnesses, such as schizophrenia, other psychotic illnesses, major depressive disorder, and bipolar disorders.

We considered interactions among age and serious mental health conditions and the proxy variables for diabetes severity (insulin use, oral medication use, and home blood glucose monitoring) clinically plausible. The more complex the diabetes treatment regimen, the more difficult it would be for an older patient or a patient with mental illness to manage his or her disease, thereby increasing the probability of experiencing a hospitalization for metabolic decompensation. We did not include race as a covariate in the model, finding no evidence that hospitalizations for metabolic decompensations are more likely in a particular race or ethnicity due to pathophysiological processes. We report model performance stratified by race because of the existence of racial disparities in the provision of some health care services (28).

Statistical analysis
We stratified our data by hospitalization for metabolic decompensations and randomly placed subjects into 50% derivation and validation subsets. We developed a logistic regression model by incrementally adding each patient-level variable from our conceptual model with interaction terms. The best performing model for each PQL (uncontrolled, short term, and combined) was determined by performance of the c statistic and the Hosmer-Lemeshow test (HLT). The c statistic

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evaluates the ability of the model to predict an outcome (discrimination or explanatory ability). A statistic of 0.5 implies explanatory ability no better than chance, whereas 1.0 implies perfect explanatory ability. The HLT evaluates the goodness-of-fit of the model (calibration), and a nonsignificant result indicates good model performance by this criterion. Variables were included if significant at the $P = 0.05$ level, with nonsignificant main effects remaining in the model when interaction terms were significant. The best model using the derivation dataset was validated on the second half of the data (29,30).

We only used the combined PQIs to compare VISN performance. Using the age and sex risk adjustment and the full risk adjustment model for the combined PQIs, the expected number of outcomes was calculated from the individual level information using the validation approach. The individuals were ranked by probability of having a preventable hospitalization. The total number of individuals with the highest expected probability of being hospitalized equal to the total number of the actual observed hospitalizations was categorized as expected cases. The expected cases were then partitioned to the appropriate VISN. The 22 VISNs were ranked twice according to their observed-to-expected (O/E) ratios of hospitalizations calculated at the network level, once with full risk adjustment and once with age and sex adjustment only (31,32).

**RESULTS** — The final dataset was representative of our overall population despite the exclusion of individuals from 16 health care facilities. Age, sex, marital status, race, and prevalence of hospitalization for metabolic decompensation were similar between included and excluded individuals. The derivation and validation subsamples were also very similar to each other and the entire sample. The individuals were predominately older, married men (97.9% were male, median age 65 years, and 62.5% married). Seventeen percent were African American, 70.8% white, 6.3% other, and 5.9% unknown. In FY99, there were 889 VHA discharges (2.2 per 1,000 cohort members) for uncontrolled diabetes and 872 (2.1 per 1,000 members) for short-term diabetes complications. Combined, there were 1,719 discharged people (4.2 per 1,000 members) (Table 1).

The best candidate model for short-term complications (age, sex, marital status, Charlson Comorbidity Index, insulin use, and oral medication use without interaction terms) had a $c$ statistic of 0.806 and an HLT of 0.0733 in the derivation subsample and a $c$ statistic of 0.787 and an HLT of 0.0672 in the validation subsample. These results signify good discrimination by the model and adequate calibration. For the uncontrolled diabetes hospitalizations, the best model (age; sex; marital status; Charlson Comorbidity Index; insulin use; oral medication use; mental health condition; and interactions between insulin and age, Charlson Comorbidity Index and oral medication use, and Charlson Comorbidity Index and insulin use) had a $c$ statistic of 0.714 and an HLT of 0.5147 in the derivation subsample and a $c$ statistic of 0.690 and an HLT of 0.1131 in the validation subsample. This model has moderate ability to predict the outcome and fits the data (data not shown).

The final model for the combined PQIs included age, sex, marital status, Charlson Comorbidity Index, mental health condition, treatment with oral antiglycemic medications, treatment with insulin, and the interaction terms for age and oral antiglycemic medication use, age and insulin use, and oral antiglycemic medication use and mental health condition (Table 2). All variables except sex contributed significantly to the perfor-
The performance of the risk adjustment model stratified by race categories showed adequate discrimination and calibration for the white Americans ($c = 0.785$, HLT $P = 0.19$), but weaker discrimination and poor calibration for African Americans ($c = 0.737$, HLT $P < 0.0001$). The directions of the parameter estimates were consistent by racial subgroup, except that female sex was associated with lower risk of hospitalization for metabolic decompensation in African Americans. Female sex was associated with higher risk of hospitalization in whites and not significant in the “other” category (data not shown).

The variation among VISN performance as determined by the combined PQI outcome decreased with full risk adjustment relative to age and sex adjustment only (highest O/E ratio minus lowest O/E ratio decreased from 1.61 to 1.01), with five networks crossing one from worse-than-expected performance to better-than-expected performance (O/E ratio changing from $>1.00$ to $<1.00$) and three networks crossing one from better-than-expected performance to worse-than-expected performance (O/E ratio changing from $<1.00$ to $>1.00$). One network’s O/E ratio went from $>1.00$ to exactly $1.00$. One VISN moved three quartiles in rank, 6 VISNs moved two quartiles, 5 VISNs moved one quartile, and 10 VISNs remained in the same quartile of ranking when comparing age and sex and full risk adjustment. Of six VISNs in the best-performing (first) quartile using the age- and sex-adjusted method, four remained in the first quartile and none moved to the worst-performing quartile with more complete risk adjustment. Of five VISNs in the worst-performing (fourth) quartile, one remained in the fourth quartile, one moved to the first quartile, two to the second, and one to third quartile (Fig. 1).

**CONCLUSIONS** — To our knowledge, our study reports the first empirical results of the application of the proposed quality-of-care performance measures of metabolic decompensation PQIs in a large, national health care system. Our
findings suggest that while the metabolic decompensation PQIs have validity at face as a proxy for quality of ambulatory care, there are a number of concerns that should be addressed before these measures should be applied for comparison purposes. First, the incidence of hospitalization for these acute complications of diabetes is 4.2 per 1,000 veterans with diabetes who utilized the VHA in 1999. Because of the uncommon nature of these events, we believe limiting the denominator to the subset of a population at risk for the outcome, i.e., those people with diabetes, is more appropriate than using a total population denominator. This difference explains the order of magnitude difference between our calculated rate in the VHA and the target for Healthy People 2010 of 5.4 incidences per 10,000 people aged 18–64 years and the unadjusted empirical rate derived from Medicaid data of 3.47 incidences per 10,000 people (11).

Second, risk adjustment with age and sex only does not adequately address the sources of external variation that affect hospitalization for metabolic decompensation. The addition of patient-level demographic and clinical information beyond age and sex produced a model better able to predict metabolic decompensation in this population, as reflected by the higher c statistic, and with a good fit across the range of subjects, as reflected by the nonsignificant HLT. This risk adjustment model improves the validity of the metabolic decompensation PQI for comparing health care delivery systems.

Third, the performance of the risk adjustment models for the separate PQIs of uncontrolled diabetes and short-term complications of diabetes is evidence of their borderline acceptability as potential indicators of quality of care in this population. This may be due to several issues, including the rare nature of these events, differences in coding of the diagnoses, or inability to control for other contributors to the outcomes. Because of the better performance of our risk adjustment model for the combined PQIs, we recommend using only the combined measure.

One purpose of measuring the occurrence of these events is to increase awareness of these complications and identify opportunities to improve care. Because the patient characteristics included in the full risk adjustment model for the combined PQIs are beyond the expected influence of health care delivery systems, they can be used to identify patients at increased risk for uncontrolled diabetes and short-term complications of diabetes (33). Our model indicates that VHA users with diabetes who are unmarried, have more medical comorbidities, suffer from mental illness, and use insulin are at highest risk for experiencing hospitalization for acute metabolic decompensation. Younger individuals in this population have a higher risk, likely due to the fact that younger patients using insulin have a disproportionately higher probability of being hospitalized for these complica-
tions, as do mentally ill individuals who take oral medications. Veterans of African-American or Hispanic descent with personal characteristics similar to their white counterparts are likely at similar risk of hospitalization for these complications of diabetes, although more study is required. Interventions, such as intensive case management, could be implemented to reduce the risk of hospitalization for metabolic decompensation, especially in unmarried men <55 years old with a higher disease burden (including mental illness) who use insulin.

The second purpose of measuring these outcomes is to compare health care delivery units, such as VHA VISNs, on the basis of these proposed quality performance measures. The use of the full risk adjustment model alters the portrayal of the individual networks when comparing their performance on the combined PQIs. The O/E ratio of seven VISNs moved from one side of 1.00 to the other, indicating a switch between better-than-expected performance to worse-than-expected performance, or vice versa when the age- and sex-adjusted model was enhanced with the additional patient-level factors in the validated risk adjustment model. This demonstrates the importance of risk adjustment when reporting comparisons of health care quality based on the metabolic decompensation PQIs; sources of variability external to the risk adjustment model seriously compromise the validity of the comparison (34). Looking at the results of the VISN comparison, after more complete adjustment, four of six VISNs remained in the best-performing quartile, perhaps indicating higher quality performance. These networks may serve as models for good care. The VISN that remained in the worst-performing quartile may be a candidate for quality improvement initiatives.

Our study has the benefits of a large sample of people with diabetes and a longitudinal nature. In addition, we were able to include outpatient care, pharmacy data, and marital status in our analysis. Limitations of this study include our inability to accurately determine whether insulin users had type 1 or type 2 diabetes. In the veteran population, the prevalence of type 1 diabetes is likely lower than the national average, and this issue is relatively minor. Another issue is the challenge of accurately coding an outcome as uncontrolled (two ICD-9-CM codes) versus a short-term complication of diabetes (nine ICD-9-CM codes). The possibility of coding errors is a well-known limitation of this type of research that could not be addressed in this study.

Like many other studies, we captured only hospitalizations to the VHA system, likely missing hospitalizations for metabolic decompensations that occurred in non-VHA facilities. However, we were able to include CMS data for the cohort of veterans for the purposes of risk adjustment and determination of diabetes diagnosis. While additional research is required in other settings, the application and relevance of these PQIs in the large, national health care delivery system of the VHA provides guidance to other organizations considering these measures.

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References


