Identifying Complications and Low Provider Adherence to Normative Practices Using Administrative Data

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Objective. This study investigated whether unexpected length of stay (LOS) could be used as an indicator to identify hospital patients who experienced complications or whose care exhibited low adherence to normative practices.

Data Sources and Study Setting. We analyzed 1,477 cases admitted for one of three medical conditions. All cases were discharged from one of nine participating Department of Veterans Affairs (VA) hospitals from October 1987 through September 1989. Analyses used administrative data and information abstracted through chart reviews that included severity of illness indicators, complications, and explicit process of care criteria reflecting adherence to normative practices.

Study Design. We developed separate multiple linear regression models for each disease using LOS as the dependent measure and variables that could be assumed present at the time of admission as explanatory variables. Unexpectedly *long* LOS (i.e., discharges with high residuals) was used to target complications and unexpectedly *short* LOS was used to target cases whose care might have exhibited low adherence to normative practices. Information gleaned from chart reviews served as the gold standard for determining actual complications and low adherence.

Principal Findings. Analyses of administrative data showed that unexpectedly long LOS identified complications with sensitivities ranging from 40 through 62 percent across the three conditions. Positive predictive values all were at greater than chance levels ($p < .05$). This represented substantial improvement over identification of complications using ICD-9-CM codes contained in the administrative database where sensitivities were from 26 through 39 percent. Unexpectedly short LOS identified low provider adherence with sensitivities ranging from 33 through 45 percent with positive predictive values all above chance levels ($p < .05$). The addition to the LOS models of chart-based severity of illness information helped explain LOS, but failed to facilitate identification of complications or low adherence beyond what was accomplished using administrative data.

Conclusions. Administrative data can be used to target cases when seeking to identify complications or low provider adherence to normative practices. Targeting can be accomplished through the creation of indirect measures based on unexpected LOS. Future efforts should be devoted to validating unexpected LOS as a hospital-level quality indicator.

Relevance/Impact. Scrutiny of unexpected LOS holds promise for enhancing the usefulness of administrative data as a resource for quality initiatives.

Key Words. Quality of care, length of stay, administrative data

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Quality improvement efforts are shifting emphasis from attempts to minimize individual errors toward a desire to improve the process of typical care. Monitoring patterns often involves using administrative data to compare rates of outcomes or practice styles, frequently at the hospital or physician level. A familiar example was the annual hospital mortality rates released by the Health Care Financing Administration (HCFA). Patterns that deviate from a standard might result from poor process design, inadequate information, or poor training (Jencks and Wilensky 1992). After identifying patterns that deviate from a standard, potential causes can be carefully scrutinized.

CHALLENGES IMPEDING IDENTIFICATION OF APPROPRIATE MEASURES FOR MONITORING

Certain complications and low provider adherence to normative practices represent two indicators with strong potential links to quality. Yet these factors possess limited utility as currently represented in administrative databases. One concern involves the accuracy of diagnosis codes used to imply complication occurrence (Iezzoni 1990). The threat of coding errors involving complications is greater than such a threat for other types of outcomes. For example,

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while death is a concrete, objective measure, complications can be much more subtle. Further, financial incentives to record complications do not always exist under hospital reimbursement systems (Iezzoni 1990). Another concern involves inherent limitations created by the absence of measures intended to reflect provider adherence to normative practices. Obviously, identifying cases where care exhibited low adherence to norms is difficult without measures of adherence. Developing indirect measures of complications and low provider adherence might partially overcome concerns regarding the accuracy and scope of information contained in administrative databases.

Complications and Length of Stay. This article develops an indirect measure of complications based on length of stay (LOS). Complications arising as a consequence of care can increase LOS (Steel et al. 1981). For example, hospital stays increase by about four days when nosocomial infections develop (Haley, Schaberg, Crossley, et al. 1981). Knowledge that complications extend LOS might be exploited to create an indirect measure of complications. After statistically controlling patient characteristics existing at the time of admission, unexpectedly *long* LOS might be due to several factors.

Included among these factors are complications. As a group, cases with unexpectedly long LOS might possess a relatively high proportion of complications. Hence, pattern analysis might use unexpectedly long LOS as an indicator of complications; unexpectedly long LOS also could help screen individual cases for physician review if pattern analysis suggests a need for closer scrutiny.

Adherence to Normative Practices and LOS. While unexpectedly long LOS can be due to complications, low provider adherence to normative practices might be linked to unexpectedly *short* LOS. Several scenarios might contribute to the link between low adherence and short LOS. Patients might be admitted with non-acute conditions, and therefore adherence to practices developed for acute medical needs is unwarranted. Additionally, when patients first present to the physician, they might appear to need admission from a medical standpoint, but a few hours of observation shows that hospitalization is no longer needed. Another scenario involves poor delivery of care to patients with need. The physician might exhibit poor adherence and discharge the patient prematurely. In this case, recovery might be prolonged, but prolonged recovery would not be reflected in LOS because recovery occurred following discharge.

The present study develops an indirect measure of adherence using unexpectedly short LOS. After statistically controlling patient characteristics existing at the time of admission, possible reasons for unexpectedly short LOS include low provider adherence to normative practices. As a group, cases with unexpectedly short LOS might possess a relatively high proportion of care exhibiting low adherence. Hence, unexpectedly short LOS might be used in pattern analysis as an indicator of low provider adherence to normative standards and also could help screen individual cases for physician review if pattern analysis suggests a need for closer scrutiny.

OVERVIEW

This study advances methodologies that use quality indicators for pattern analysis and to screen cases for detailed review of process. The study develops separate expected LOS models for three diseases using patient characteristics available from an administrative database. Using information obtained through chart reviews as the gold standard, we test whether identifying complications using unexpectedly long LOS is superior to identifying complications using corresponding ICD-9-CM codes from an administrative database. Additionally, the chart reviews included the use of explicit process of care criteria to judge physician adherence to normative practices. This information allows assessment of unexpectedly short LOS as an indicator of low provider adherence.

Also, we test whether or not supplementing LOS models with severity of illness information abstracted from charts improves the ability to explain LOS. More importantly, we assess whether supplementing administrative data with chart-based clinical information enhances targeting of cases with complications or those whose care exhibited low adherence to normative practices. Information extracted through chart reviews contains a clinical richness unavailable in administrative data, but this richness comes at considerable expense. Because administrative databases are relatively inexpensive and accessible, they are preferred over clinical databases when similar performance levels can be achieved.

METHODS

DATA AND SAMPLE

Clinical data collection occurred as part of a larger study assessing associations between process of care and outcomes in Department of Veterans Affairs (VA) hospitals. A detailed description of the sampling methodology is described elsewhere (Ashton, Kuykendall, Johnson, et al. 1995). The sampling frame for the present study consisted of male veterans, discharged alive, who did not experience a readmission within 30 days of discharge, were not transferred in from another acute care facility, and did not leave against medical advice. Patients were eligible for inclusion when the VA's computerized hospital discharge database–the Patient Treatment File (PTF)–listed diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), or congestive heart failure (CHF) as the primary diagnosis. (ICD-9-CM codes are available from the authors.) The PTF uses primary diagnosis to indicate the diagnosis responsible for most of the hospital stay. The principal diagnosis, which refers to the reason for admission, is contained in many other administrative databases, and also was available in the PTF until the mid-1980s. The principal diagnostic code was eliminated from the PTF at that time because analyses revealed that the primary and principal diagnostic codes were duplicative (Beattie, Swindle, and Tomko 1992).

Of all medical records originally requested, approximately 80 percent were available for review. Analysis of demographics contained in the PTF showed that patients with unavailable charts did not differ from those with available charts with regard to age, race, marital status, or income. Patients were included when review of medical records confirmed that the patient presented to the hospital with symptoms and signs indicative of exacerbation of the condition in question, and that the primary diagnosis was the reason for admission. The data represent a random sample of patients from each disease who met eligibility criteria and who were discharged from one of nine participating VA hospitals in the southern United States between October 1, 1987 and September 30, 1989. Chart reviews for eligible patients with DM ($n = 374$), COPD ($n = 668$), or CHF ($n = 435$) included abstraction of information regarding (1) adherence to normative practices as measured by explicit process of care criteria, (2) complications, and (3) severity of illness. These data were merged with administrative data making both chart and administrative data available for analysis.

INFORMATION EXTRACTED THROUGH CHART REVIEWS

A physician and physician assistant were trained to review charts. Acceptable interrater reliability was achieved prior to sending reviewers to review charts at the sites. For each chart, one reviewer extracted information on complications and admission severity of illness using the Acute Physiology Score (APS) of the APACHE II (Knaus et al. 1985). The other reviewer was then given the chart to review the process of care. The reviewers were permitted to alternate functions.

Measuring Process of Care. Process of care was measured using explicit criteria developed for each of the diagnoses and described in detail elsewhere (Ashton, Kuykendall, Johnson, et al. 1994). An extensive literature review helped derive initial criteria. Criteria then were refined by expert panels composed of generalists and subspecialty physicians, and retained when consensus was reached that an item represented essential technical care (as opposed to optimal care) for hospitalized patients with the condition under question. Each criterion was unit-weighted (0,1), and could be either applicable or not applicable during a hospital stay.

The criteria were divided into three categories corresponding to the sequence of care: admission workup, evaluation and treatment, and readiness for discharge. Examples of the criteria used to evaluate care for CHF include: complete blood count performed within 24 hours of admission (admission workup), thyroid function tests (T3, T4) performed if etiology of heart failure is unknown *or* if thyroid status is unknown (evaluation), no change in cardiac medications verified as having been made for at least 24 hours (readiness for discharge). (Complete criteria sets are available from the authors.) For each category of care, the percentage of applicable criteria that were met was calculated. The mean percentage of met criteria from the three categories of care served as the overall adherence score. Low adherence was defined as an adherence score at or below the 25th percentile.

Chart reviewers underwent an extensive training period. A kappa statistic was calculated for each criterion to assess degree of interrater agreement. To circumvent the paradox of low kappa despite high percent agreement (Feinstein and Cicchetti 1990), we eliminated criteria due to low interrater reliability only when kappa $< .20$ and percent agreement was less than chance. This led to the retention of most items for each disease (DM 100 of 109; COPD 84 of 95; CHF 73 of 78). Items meeting the criterion of kappa $> .20$ possessed a mean kappa value substantially greater than .20 (DM: $M = .52$, s.d. $= .23$; COPD: $M = .44$, s.d. $= .19$; CHF: $M = .49$, s.d. $= .22$). Items retained when kappa was $< .20$ exhibited very high mean percent agreement (DM: $M = 92.0$, s.d. $= 7.37$; COPD: $M = 86.6$, s.d. $= 12.10$; CHF: $M = 88.7$, s.d. $= 11.85$).

Complications. Two physician coinvestigators defined generic and disease-specific complications of medical hospitalizations for the diseases under study. Complications were chosen based on current research and quality assurance efforts, as well as the clinical impression that they could be causally related to quality of care. The Appendix contains a list of the complications. Chart reviewers received instructions not to record adverse occurrences that could be part of the disease process (e.g., spontaneous pneumothorax on the admission x-ray in COPD patients). To guard against identifying coexisting admitting conditions as complications, the events must have occurred no less than 48 hours after admission. The interrater reliability for complication assessment was acceptable (agreement = 84 percent; kappa = .37; incidence of complications 11.5 percent–12.6 percent).

Severity of Illness. Clinical instability on admission was assessed using the APS of the APACHE II (Knaus et al. 1985). This is a generic severity of illness measure consisting of 12 physiologic variables commonly collected as part of the medical record. Most variables receive points from 0 to 4 based on the deviation from the range of normal values, where 0 points reflects a value falling within the normal range. The total APS is calculated by summing points across all 12 variables. Scores were based on data collected within 24 hours of admission. The APS is widely used to predict mortality in ICU settings, and has been used in other settings to predict mortality (Daley, Jencks, Draper, et al. 1988) and LOS (McMahon, Hayward, Bernard, et al. 1992).

INFORMATION EXTRACTED FROM ADMINISTRATIVE DATA

The administrative database containing the hospital discharge abstracts was the VA PTF. Up to ten diagnostic codes were available for analysis. A patient was counted as experiencing a complication based on ICD-9-CM codes if any of the 30 complications were recorded. Patient characteristics that could be assumed present at the time of admission were used to derive an expected LOS for each discharge. Patient characteristics included age, marital status, race, chronic comorbidities, number of hospital stays in the previous 24 months, and ICD-9-CM codes within diagnoses grouped to reflect reasons for the acute exacerbation of the primary (chronic) disease.

Unlike many diagnoses appearing in discharge abstracts, chronic comorbidities can be assumed present prior to hospital admission. These were defined by body systems using previously established definitions (Luft, Garnick, Mark, et al. 1990). Body systems have helped explain patient outcomes in other contexts (Kuykendall and Johnson 1995; Kuykendall, Johnson, and Geraci 1995). Dummy variables were created to represent the presence of chronic comorbidities involving each of eight body systems (endocrine, hematologic, neurologic, circulatory, respiratory, digestive, genitourinary, musculoskeletal). Models used to derive expected LOS included a count of the number of body systems with chronic comorbidities as well as the presence of chronic comorbidities affecting individual body systems when consideration of an individual body system exhibited a significant independent association with LOS.

Primary Diagnosis. The primary diagnosis was confirmed by chart review as the condition responsible for the hospital admission. For each disease, primary diagnoses reflecting common underlying conditions were identified by a physician investigator (CMA). For example, scrutiny of COPD primary diagnoses uncovered three underlying conditions responsible for admission: COPD decompensation, cause of decompensation not known; COPD decompensation secondary to infection (most of these are respiratory infections); and miscellaneous conditions causing decompensation of COPD. For each disease, variables reflecting common underlying conditions were used to help explain LOS. (The ICD-9-CM codes comprising specific underlying conditions are available from the authors upon request.) In addition, for DM a dichotomous variable was created to distinguish insulin- versus not insulin-treated.

ANALYTIC STRATEGY AND RATIONALE FOR MODELING

Overview

Analyses were conducted separately for each disease using the Statistical Analysis System (SAS) (SAS Institute, Inc. 1989). Multiple linear regression used LOS as the dependent variable and age, race, marital status, comorbidities, number of prior hospital stays, and primary diagnosis groups as explanatory variables. Continuous explanatory variables were analyzed both as continuous variables and by creating dummy variables based on quartiles. If analysis by quartiles suggested a nonlinear association with LOS, then either they were retained in the final analysis or they were consolidated if warranted based on associations with LOS. These "administrative models" relied solely on information available in the administrative database. "Clinical models" were constructed by adding to the administrative models the overall APS from the APACHE II and the individual clinical components that comprise the APS. Because the overall APS is based on weights assigned to individual components of the APS, and these weights were originally derived for a different outcome using a different population, some concern existed regarding appropriateness of item weighting for the current application (Daley, Jencks, Draper, et al. 1988; Romano, Roos, and Jollis 1993a,b). Therefore, individual components of the APS were assessed along with the overall APS to establish whether individual components possessed explanatory power independent of the overall APS. Individual APS components were incorporated into models by dichotomizing values as either falling within or outside the normal range as defined by the developers of the APS (Knaus et al. 1985). To check for model over-fitting, we calculated a R^2 adjusted for shrinkage. The adjusted R^2 is similar to cross-validation in that it seeks to estimate the likely amount of variance explained if the set of weights derived from the available data were applied to a second sample. The magnitude of shrinkage is usually greater for small values of R^2, and as the ratio of the number of independent variables to the number of subjects increases (Cohen and Cohen 1975).

UNEXPECTED LOS

Multiple linear regression allowed derivation of expected LOS. We defined unexpected LOS as the deviation of a patient's observed from expected LOS expressed as a percentage, for example, (*observed LOS* − *expected LOS*)/*expected LOS*. High-outliers consisted of cases with unexpected LOS in the upper 75th percentile. High-outlier patients, as a group, were targeted because of a belief that they might possess a relatively high proportion of complications. Low-outliers possessed unexpected LOS in the lower 25th percentile. Low-outlier patients, as a group, were targeted because we believed they might have experienced a relatively high proportion of care where providers exhibited low adherence to normative practices.

RESULTS

DESCRIPTIVE ANALYSIS

Table 1 shows that several similarities spanned all three diseases. Mean patient age ranged from 60 to 66 years, and the majority of patients were non-Hispanic white and married. Many patients possessed chronic comorbidities and experienced previous hospital stays, and the mean for the APS ranged from 5.4 to 6.8. The percentage of patients with complications, as determined by chart review, also varied within a relatively restricted range across diseases (11.5–12.6 percent). Provider adherence appeared somewhat lower for COPD than for the other diseases.

MULTIVARIATE ANALYSIS

Administrative Models. Multiple linear regression of LOS on administrative data yielded R^2 values of .10 for DM, .09 for COPD, and .10 for CHF.

Table 1: Demographic and Clinical Characteristics for Diabetes Mellitus (DM), Chronic Obstructive Pulmonary Disease (COPD), and Congestive Heart Failure (CHF)

Variables	*DM* (n = 374)	*COPD* (n = 668)	*CHF* (n = 435)
Age			
Mean (s.d.)	59.6 (11.72)	65.2 (8.93)	66.2 (10.01)
Race			
% Non-Hispanic white	62.6	82.0	67.6
Marital Status			
% Married	61.8	65.6	63.7
Chronic Comorbidities			
% Endocrine	–	14.2	26.2
% Hematological	10.2	7.9	12.9
% Neurological	2.9	1.5	1.1
% Circulatory	55.3	48.5	–
% Respiratory	8.3	–	25.3
% Digestive	1.6	1.0	2.1
% Genitourinary	3.2	0.3	1.8
% Musculoskeletal	0.5	2.1	1.1
Number of Prior Hospital Stays			
Mean (s.d.)	1.08 (1.62)	1.47 (2.04)	1.25 (1.91)
Type of Diabetes Treatment			
% Insulin-treated	46.0	–	–
Acute Physiology Score			
Mean (s.d.)	5.4 (4.40)	6.8 (3.71)	6.2 (3.21)
Length of Stay			
Mean (s.d.)	8.2 (6.32)	7.7 (6.82)	8.4 (6.38)
Adherence Score			
Mean (s.d.)	70.1 (12.52)	67.3 (11.62)	74.2 (11.56)
Complications			
% Chart-based	12.6	11.5	12.4
% ICD-9 codes	15.2	13.9	12.6
Primary Diagnosis Group			
% Acute metabolic derangements	13.6	–	–
% Atherosclerosis	12.8	–	–
% Other related conditions and miscellaneous	61.0	–	–
% Decompensation, secondary to infections	12.6	28.1	–
% Miscellaneous	–	7.7	–
% Decompensation, cause unknown	–	64.2	82.1
% Decompensation, secondary to infections and miscellaneous	–	–	7.1
% Dysrhythmias	–	–	10.8

Note: Mean (s.d.) are presented for continuous variables, and percentages are presented for categorical variables.

All values are highly significant (see Table 2). Table 2 also shows that R^2 values adjusted for shrinkage are similar to R^2 values, which suggests acceptable model stability. For DM, older age, being unmarried, and insulin treatment were associated with longer LOS. In addition, a significant interaction existed between previous stays and insulin treatment. DM patients experienced longer stays if they had not been admitted in the previous 24 months and were being treated with insulin. For COPD, older age, not being married, more body systems with chronic comorbidities, reason for admission involving miscellaneous identifiable causes of decompensation, or general miscellaneous causes were associated with longer LOS. For CHF, older age, and more body systems with chronic comorbidities (especially comorbidities not involving endocrine, or respiratory systems) were associated with longer LOS. The count of body systems with chronic comorbidities is an index giving equal weight to each body system. By also including variables representing individual body systems, an adjustment is made when an individual body system exerts a relatively strong or weak influence. For example, in the CHF model a greater number of body systems increases LOS. However, the negative coefficients for endocrine, respiratory and, to a lesser extent, hematologic systems indicate that LOS is longer when other comorbidities involving other body systems are primarily responsible for the total count of body systems.

Clinical Models. Clinical models (administrative models with APS variables added) yielded R^2-values of .14 for DM, .10 for COPD, and .13 for CHF (see Table 3). For each disease, the incremental increase in R^2 contributed by the chart-based variables attained statistical significance [DM: $F(2, 359) = 7.69, p < .01$; COPD: $F(1, 658) = 4.65, p < .05$; CHF: $F(2, 421) = 5.10, p < .01$]. These results clearly show that chart-based APS data improve upon the ability of administrative data to explain LOS. Yet weights for individual variables used to construct the overall APS were originally derived to predict death in ICU settings (Knaus et al. 1985). Because the model shows that individual APS variables can make a significant contribution that is independent of the overall APS, it appears that recalibrating the weights for these variables can enhance the ability to explain LOS. Overall, greater APS scores were associated with longer LOS. A negative coefficient for an individual APS component reveals that the variable's contribution to the total APS score should be reduced, while positive coefficients suggest that the variable's contribution to the total APS score should be increased. For DM, the negative coefficient reveals that LOS does not increase as much as expected based on APS if heart rate outside the normal range contributed to the APS. For CHF, the positive coefficient

Table 2: Multiple Linear Regression Models of Length of Stay Using Administrative Data

	DM (n = *374*)		*COPD* (n = *668*)		*CHF* (n = *435*)	
Variables	*Beta*	*Std. Error*	*Beta*	*Std. Error*	*Beta*	*Std. Error*
Age						
(61 or more)	1.77**	0.65	–	–	–	–
(Continuous)	–	–	0.12***	0.03	–	–
(60 or more)	–	–	–	–	1.61*	0.72
Race						
Non-Hispanic white = 1	−0.26	0.66	0.84	0.66	0.09	0.64
Marital Status						
Married = 1	−1.30*	0.66	−1.69**	0.54	−0.48	0.62
Count of body systems	0.34	0.51	0.77*	0.36	5.93***	1.14
Individual body systems						
Endocrine	–	–	–	–	−6.39***	1.32
Hematological	2.20	1.19	–	–	−3.87**	1.45
Respiratory	–	–	–	–	−5.34***	1.34
Number of Prior Hospital Stays						
(Continuous)	–	–	0.21	0.13	–	–
(None)	Reference		–	–	Reference	
(1 or more)	−0.33	0.88	–	–	1.02	0.59
Type of Diabetes Treatment						
Insulin-treated	3.06***	0.91	–	–	–	–
Type of Diabetes • Number of Prior Hospital Stays	−2.72*	1.28	–	–	–	–
Primary Diagnosis						
Acute metabolic derangements	Reference		–	–	–	–
Atherosclerosis	1.00	1.27	–	–	–	–
Other related conditions and miscellaneous	1.65	0.97	–	–	–	–
Decompensation, secondary to infections	1.31	1.26	2.26***	0.57	–	–
Miscellaneous	–	–	3.52***	0.98	–	–
Decompensation, cause unknown	–	–	Reference		0.47	0.97
Decompensation, secondary to infections and miscellaneous	–	–	–	–	1.85	1.45
Dysrhythmias	–	–	–	–	Reference	

Note: DM: $R^2 = .10$, adjusted $R^2 = .07$, $F = 3.72$, df = (11,362), $p < .001$; COPD: $R^2 = .09$, adjusted $R^2 = .08$, $F = 9.15$, df = (7,660), $p < .001$; and CHF: $R^2 = .10$, adjusted $R^2 = .08$, $F = 4.91$, df = (10,424), $p < .001$.

*$p < .05$; **$p < .01$; ***$p < .001$.

for arterial pH indicates that LOS increases more than expected based on the APS if arterial pH falls outside the normal range.

IDENTIFICATION OF COMPLICATIONS AND LOW ADHERENCE

Table 4 depicts the ability of different methods to target complications and low provider adherence. Sensitivity, predictive value positive (*PV+*), and area under the receiver-operating characteristic curve (represented by the *c*-value) assessed targeting accuracy. All tests of statistical significance involving *PV+* were one-tailed. Patterns of results for all three diseases were identical. For illustrative purposes, the presentation describes results pertaining to DM. Table 4 presents the results from all diseases.

ICD-9-CM Codes. ICD-9-CM codes were poor at identifying patients who experienced complications. For DM, 47 of 374 patients (12.6 percent) experienced complications during their stays based on chart review. The sensitivity of ICD-9-CM codes in identifying complications was 25.5 percent (12/47) with a *PV+* of 21.0 percent (12/57). Given the complication incidence of 12.6 percent, a *PV+* of 21.0 percent represents more complications than expected by chance alone ($z = 1.94$, $p < .05$). The *c*-value was .559 indicating

Table 3: Multiple Linear Regression Models of Length of Stay Using Clinical Data

	DM (n = *374*)		*COPD* (n = *668*)		*CHF* (n = *435*)	
Variables	*Beta*	*Std. Error*	*Beta*	*Std. Error*	*Beta*	*Std. Error*
Acute Physiology Score	0.32***	0.08	0.15*	0.07	0.09	0.09
Heart Rate†						
Less than 70 or greater than 109	−1.97*	0.81	–	–	–	–
Arterial pH‡						
Less than 7.33 or greater than 7.49	–	–	–	–	3.57**	1.29

Note: Beta coefficients and standard errors for the APS variable and APS components from the clinical models (administrative model variables not shown).

DM: $R^2 = .14$, adjusted $R^2 = .11$, $F = 4.46$, df = (13,360), $p < .001$; COPD: $R^2 = .10$, adjusted $R^2 = .08$, $F = 8.64$, df = (8,659), $p < .001$; and CHF: $R^2 = .13$, adjusted $R^2 = .10$, $F = 5.02$, df = (12,422), $p < .001$.

*$p < .05$; **$p < .01$, ***$p < .001$.

†Heart rate between 70 and 109 represents the normal range (Knaus et al. 1985).

‡Arterial pH between 7.33 and 7.49 represents the normal range (Knaus et al. 1985).

Table 4: Targeting Complications and Low Provider Adherence Using ICD-9 Complication Codes and Length of Stay Outliers

	DM (n = *374)*	*COPD* (n = *668)*	*CHF* (n = *435)*
Complications			
ICD-9 Complication codes	Sensitivity: 25.5 Specificity: 86.2 PV+: 21.0* PV−: 89.0 c: .559	Sensitivity: 38.9 Specificity: 89.3 PV+: 32.3*** PV−: 91.8 c: .642	Sensitivity: 33.3 Specificity: 90.3 PV+: 32.7*** PV−: 90.5 c: .618
Administrative model high outliers	Sensitivity: 40.4 Specificity: 77.1 PV+: 20.2* PV−: 90.0 c: .587	Sensitivity: 62.3 Specificity: 79.9 PV+: 28.7*** PV−: 94.2 c: .711	Sensitivity: 53.7 Specificity: 79.0 PV+: 26.6*** PV−: 92.0 c: .664
Combined ICD-9 complication codes and administrative model high outliers	Sensitivity: 53.2 Specificity: 67.6 PV+: 19.1* PV−: 90.9 c: .604	Sensitivity: 79.2 Specificity: 72.4 PV+: 27.2*** PV−: 96.4 c: .758	Sensitivity: 66.7 Specificity: 72.4 PV+: 25.5*** PV−: 93.9 c: .696
Low Adherence			
Administrative model low outliers	Sensitivity: 45.2 Specificity: 81.1 PV+: 44.2*** PV−: 81.7 c: .632	Sensitivity: 32.9 Specificity: 77.6 PV+: 32.9** PV−: 77.6 c: .553	Sensitivity: 45.4 Specificity: 81.6 PV+: 45.0*** PV−: 81.9 c: .635

Note: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$ for one-tailed tests of observed PV+ compared to expected levels based on chance alone.

that ICD-9-CM codes achieved modest discrimination between cases who did and did not experience complications.

Administrative Model. Longer than expected LOS was a better indicator of complications than ICD-9-CM codes. Targeting complications based on long unexpected LOS possessed a sensitivity of 40.4 percent (19/47) and *PV+* of 20.2 percent (19/94). The *PV+* of 20.2 percent represents more complications than expected given the chance rate of about 12.6 percent ($z = 2.24, p < .02$). The *c*-value using the administrative model (.587) indicated better performance than classification based on ICD-9-CM codes.

Shorter than expected LOS successfully identified instances of low provider adherence. For the 93 cases with shorter than expected LOS, which represent the lower 25th percentile, the sensitivity for identifying low provider adherence was 45.2 percent (42/93). Of all targeted cases, the *PV+* of 44.2

percent (42/95) indicates that many more experienced low adherence than expected given a chance rate near 25 percent ($z = 4.36$, $p < .01$).

Identifying Complications Using ICD-9-CM Codes and Administrative Models. Targeting of complications was most accurate when combining patients who had either the ICD-9-CM complication codes or were targeted for prolonged LOS. The combined method possessed a sensitivity of 53.2 percent (25/47) and *PV*+ of 19.1 percent (25/131). The *PV*+ of 19.1 percent represents more complications than expected by chance alone ($z = 2.25$, $p < .02$). The *c*-value attained by combining methods (.604) indicated better performance than classification based on either method used alone.

Clinical Models. The addition of clinical data to the administrative model failed to improve targeting of complications or low adherence. The percentage agreement between administrative and clinical models regarding classification of cases experiencing unexpectedly long LOS was very high for all three diseases (DM: 91.9 percent; COPD: 97.0 percent; CHF: 98.6 percent). Percentage agreement also was high regarding classification of cases experiencing unexpectedly short LOS (DM: 94.9 percent; COPD: 98.2 percent; CHF: 98.2 percent).

DISCUSSION

This study demonstrated that an administrative database can be used to target cases experiencing complications or low provider adherence to normative practices. Consistent findings were observed across three common diseases. Particularly encouraging were findings based on the use of indirect measures derived solely from information contained in the administrative database. Although chart-based severity of illness information explained a significant proportion of LOS, this information did not enhance case targeting beyond what was accomplished using administrative data. Unexpectedly *long* LOS identified complications with sensitivities ranging from 40 to 62 percent and positive predictive values from 20 to 28 percent. This represents substantial improvement over the direct identification of complications using corresponding ICD-9-CM codes. Unexpectedly *short* LOS identified low provider adherence with sensitivities ranging from 33 to 45 percent and positive predictive values also ranging from 33 to 45 percent.

As far as we know, this is the first study to report the accuracy of administrative data as a source for identifying instances of low provider adherence where adherence was measured using explicit process of care criteria. Because our inclusion criteria required confirmation by reviewers that patients were admitted with signs and symptoms indicative of the conditions in question, non-acute admissions should have been minimized among patients included in the analyses. Therefore, patients included in our study whose care exhibited low adherence did experience illness that necessitated hospital admission but did not receive normative care during the analyzed hospital stay. The precise nature of the association between unexpectedly short LOS and low provider adherence is of interest to practitioners and administrators, and should be addressed in future research.

The administrative models used patient characteristics assumed present during admission (e.g., age, chronic as opposed to acute comorbidities) to explain LOS for a specific underlying disease. Models used to derive expected LOS exhibited predicted associations between patient characteristics and LOS. Older age, being unmarried, more comorbidities, abnormal values of chart-abstracted clinical variables, and certain specific primary diagnoses were associated with longer stays. Additionally, DM patients experienced longer stays if they had not been admitted in the previous 24 months and were being treated with insulin. Inspection of individual process of care criteria showed that these patients experienced longer LOS because they underwent more consults than insulin-treated patients with previous hospitalizations within 24 months. Overall, models performed as well as administrative models from other studies designed to look at associations between patient characteristics present on admission and LOS (Burns and Wholey 1991).

Severity of illness measured soon after admission appears comparable to what might be expected from patients with similar conditions admitted at other hospitals. APACHE II scores for our patients (DM: $M = 8.46$; CHF: $M = 11.05$; COPD: $M = 12.52$) were similar to scores from a nationally representative sample of Medicare patients hospitalized for CHF ($M = 12.28$) (Daley, Jencks, Draper, et al. 1988), and were well below scores for patients admitted to ICUs for a variety of medical reasons ($M = 17.25$) (Knaus et al. 1985). Without other variables in the models, APS and its reweighted components accounted for from 4 to 6 percent of the LOS variability, which is similar to other studies that used APACHE data to explain intra-DRG variation in resource use (McMahon, Hayward, Bernard, et al. 1992; Thomas and Ashcraft 1991). The results show that after accounting for effects attributable to administrative data, a significant, albeit modest amount of LOS variation was explained using APACHE data. Yet identification of complications or low adherence was not enhanced by adding chart-based information pertaining to acute physiologic instability. Lack of improvement based on the clinical model came despite attempts to maximize the utility of the APS by reweighting individual APS components when they improved model fit beyond that achieved using the composite APS.

Although we strongly believe that the administrative models can be improved, the present findings show that a commonly used generic, chart-based severity of illness measure modified to maximize its ability to explain LOS failed to facilitate identification of patients experiencing complications or low adherence. Although other severity of illness systems can outperform the APS in certain situations (Thomas and Ashcraft 1991), previous experience suggests that severity adjustment is not optimized unless variables are carefully selected to address issues germane to specific clinical populations and specific outcomes (Hannan et al. 1992). Shifting from generic to disease-specific measures validated to explain a specific outcome of interest might improve the ability to identify complications and low provider adherence using chart-based information.

Other methodologic refinements should improve the accuracy of unexpected LOS as a criterion for targeting cases with complications or low adherence. For a given hospital admission, uncontrolled characteristics associated with patients, provider practices, or the health care system can contribute toward expected LOS. Targeting errors will occur when factors other than complications or low provider adherence contribute toward LOS and are not statistically controlled. Careful scrutiny of patients who are incorrectly targeted might reveal common characteristics that contribute toward LOS. Although beyond the scope of the present analyses, identifying such characteristics would lead to refinement of LOS models and should enhance targeting accuracy.

CODING ERRORS IN ADMINISTRATIVE DATABASES

Diagnosis codes used to identify complications exhibited inaccuracies at levels comparable to those uncovered in previous research. Across the three diseases, the sensitivity of ICD-9-CM codes in identifying patients with complications was only from 26 to 39 percent. This occurred even though all complications identified through chart abstraction are events for which ICD-9-CM codes are potentially available. A similar level of sensitivity was observed in another administrative database when investigators sought to identify important prognosis predictors in patients with cardiac disease (Jollis, Ancukiewicz, DeLong, et al. 1993). Another study found that 63 percent of administrative records contained at least one error relevant to the calculation of Medicare's risk-adjusted mortality rates developed by the HCFA (Green and Wintfeld 1993).

Inaccurate diagnostic coding has several origins. Potential causes include a limited number of fields to list diagnostic codes, financial considerations based on hospital reimbursement, and imprecise variable definitions (Iezzoni 1990). In addition, administrative databases fail to reveal whether an acute condition was present at admission or developed following admission. Errors involving identification of complications become inevitable when a specific condition is present at admission for some patients, but develops following admission for others. Another factor contributing toward inaccurate coding of complications is fear of reprisal. Unwanted internal and external scrutiny could result if complication codes are used to imply that patients might have experienced adverse events due to poor quality. Because LOS information is likely to possess greater accuracy than complication codes, creating indirect measures of complications based on LOS appears to be a promising alternative to targeting cases solely on the basis of ICD-9-CM codes.

Defining Parameters for Identifying LOS Outliers

Identifying complications or low adherence requires the establishment of cutpoints to define when observed LOS differs enough from the expected to justify medical record scrutiny. The cutpoints used in this article drew on earlier research that reported complication rates in a similar population ranged from 13 to 16 percent (Geraci, Ashton, Kuykendall, et al. 1995). A 25 percent cutpoint is greater than the complication incidence, which enables the possibility of high sensitivity even after assuming that some targeted cases will lack complications. Second, although the 25 percent cutpoint exceeds the expected incidence, the cutpoint and expected incidence are relatively close. The positive predictive value can reach unacceptably low levels when the cutpoint substantially exceeds expected incidence. Although the selected cutpoint of 25 percent achieved goals pertaining to sensitivity and positive predictive value, additional work is needed to establish criteria for determining optimal cutpoints.

Additionally, we defined low adherence simply as adherence in the lower 25th percentile. This was selected because it represents the lower quartile and does not imply that standards regarding acceptable levels of adherence are known. Recognizing that results could be dependent on the selection of an arbitrary cutpoint, analyses were conducted after varying the cutpoints for unexpected LOS and low adherence. Results showed that case-targeting occurred at greater than chance levels at all three cutpoints tested (i.e., 5th, 10th, and 25th percentiles). For example, analysis of DM indicated that when a cutpoint at 10th percentile for unexpected LOS was used to target provider adherence below the 10th percentile, the *PV+* was 35.9 percent (i.e., 35.9 percent of the unexpected LOS outliers falling in the lower 10th percentile also possessed adherence scores in the lower 10th percentile). Not surprisingly, sensitivity progressively declined as the cutpoint was lowered to target fewer patients. A cutpoint at the 25th percentile provided a stronger balance between *PV+* and sensitivity than other cutpoints. Future research is needed to refine definitions of low adherence and to articulate trade-offs associated with selected cutpoints.

LIMITATIONS

Although mortality rates have been used to screen hospitals for potential quality of care problems, data for those discharged dead were not collected for this study. Because quality is multifaceted, monitoring a single outcome cannot reflect all relevant dimensions of quality. Monitoring rates of unexpected LOS can complement monitors of other outcomes by suggesting possible problems with nonfatal complications and poor provider adherence. Future attention should be directed toward exploring whether combining several indicators such as mortality and unexpected LOS can provide information to enhance overall quality improvement efforts (DesHarnais, McMahon, and Wroblewski 1991).

Low adherence to normative practices, especially when patients are discharged within two days, can have several causes. Admission practices, omission of important process criteria, and early patient discharge are important to understand from a quality perspective, and all might be captured through consideration of unexpectedly short LOS. In other instances, poor adherence for care rendered during a specific admission might reflect tendencies to deliver some aspects of care in other settings such as outpatient clinics. Because investigation of links between unexpectedly short LOS and low provider adherence is a relatively new endeavor, a need exists for future research to articulate more precisely the reasons underlying low observed provider adherence.

Many variables that could have helped explain LOS were not included in our models. Our interest was in creating indicators for quality-related events using unexpected LOS. Therefore, it was inappropriate to control many variables related to quality of care that might have helped explain LOS. For example, DRGs are useful for understanding LOS as a resource, but are inappropriate to control when using unexpected LOS as a quality indicator; DRGs do not distinguish comorbidities present on admission from complications that develop during the hospital stay. Similarly, peak severity of illness predicts LOS better than severity of illness present on admission, but is more suited to investigations of resource use as opposed to quality (McMahon, Hayward, Bernard, et al. 1992). However, unexpected LOS should become a more accurate indicator of complications and low adherence as methods of adjusting patient characteristics present on admission become more precise.

The generalizability of the findings also must be considered. Average LOS can change over time and across medical care systems. This suggests that the use of unexpected LOS as an indicator of complications and low provider adherence may be context sensitive. For example, HMOs might have few unexpectedly long stays if modeled with discharges from the VA medical system due to system incentives that encourage shorter stays, not because of fewer complications. However, system characteristics can be controlled by modeling within a system (e.g., all hospitals affiliated with an HMO), rendering certain system characteristics implausible as explanations for unexpected LOS. Additional research is needed to validate unexpected LOS as an indicator of complications and low provider adherence across medical care systems.

This study was designed to test the association of unexpected LOS with complications and low provider adherence to normative standards. Our findings indicate that patients with longer than expected stays tend to experience more complications and patients with shorter than expected stays tend to receive care that exhibits low adherence to normative standards. These results do not imply that sufficient evidence exists to use unexpected LOS as an indicator for monitoring patterns and screening cases for physician review at the hospital level. The use of unexpected LOS as a quality indicator at the hospital level requires additional validation. Our design included only nine hospitals, and two-thirds of the time the number of discharges per hospital for each disease was under 50. A study to determine whether unexpected LOS is an appropriate indicator at the hospital level needs to demonstrate that hospitals having higher rates of patients with unexpectedly long or short stays are the same hospitals with more complications or lower provider adherence. This requires more hospitals and more discharges per hospital than are included in the present design, to ensure that sample sizes are adequate to produce statistically stable estimates of provider level rates. Methods for combining discharges admitted to the same hospital for different diseases were recently developed and should be considered in future investigations as a way to guarantee an acceptable number of discharges per hospital (Iezzoni, Daley, Heeren, et al. 1994).

POTENTIAL IMPACT

The findings extend earlier efforts to target cases experiencing poor quality care using administrative data (Hannan et al. 1989). Earlier work was limited to patients who died in the hospital and emphasized surgical care. This article showed that administrative data can be used for quality improvement efforts when patients are discharged alive and treated for medical conditions. We developed indirect indicators of complications and low provider adherence based on unexpected LOS. Such indirect measures represent a substantial improvement over the reporting of complications based solely on ICD-9-CM codes and extend the scope of potential quality indicators to include low provider adherence to normative practices, a measure not directly reported in administrative data. Administrative data are relatively inexpensive and accessible; hence, developing their potential through the creation of indirect quality indicators is highly desirable.

The present study represents the first step in the development of unexpected LOS as an indicator of complications and low provider adherence. Future refinements in the methodologies used to account for patient illness at time of admission should improve the accuracy of case targeting based on unexpected LOS. From a practical standpoint, the present study leaves unanswered the question of whether unexpected LOS represents a valid indicator for quality improvement efforts that rely on patterns analysis. Future health services research is needed to assess whether hospitals with significantly more long or short stays than expected are the same hospitals with more complications or lower provider adherence. Such validation would establish that indirect indicators available from administrative databases can be used to identify hospital patterns that deviate from quality-related standards. Once validated at the hospital level, unexpected LOS might be used to identify outlier hospitals, which would undergo more focused scrutiny to investigate possible linkages between aberrant patterns and specific processes of care.

Appendix: ICD-9-CM Codes Used to Define Code Complications

Accidental injury (E884.2, E885, E888)
Acute respiratory failure (518.81, 518.82)
Bacteremia (038, 999.3)
Cardiac arrest (427.5)
Delirium (290.3, 290.41, 780.09)
Dilantin toxicity (E936.1)
Hemorrhage requiring transfusion (531.0, 531.2, 531.4, 531.6, 532.0, 532.4, 532.6, 533.0, 533.2, 533.4, 533.6, 534.0, 534.2, 534.4, 534.6, 535.1, 537.83, 562.02, 562.03, 562.12, 562.13, 569.85, 597.7)
Ketoacidosis/hyperosmolar coma (250.1, 250.2, 250.3)

Myocardial infarction (410.01, 410.11, 410.21, 410.31, 410.41, 410.51, 410.61, 410.71, 410.81, 410.91)	Hypoglycemic reaction (E932.3, 251.0, 251.2)
Theophylline toxicity (974.1, E944.1, E945.7)	Hypotension (458, 785.5)
Urinary tract infection (599)	Other complication (E9445, 999)
Ventricular tachycardia (427.1, 427.4)	Other nosocomial infection (999)
Acute renal failure (584, 586)	Pneumonia (482.9, 507.0)
Antibiotic-associated diarrhea (008.45)	Pressure ulcer (707.0)
Bowel obstruction (560.1, 560.8, 560.9)	Procedure complication (998.8, 998.9, 999)
Cellulitis (682.3, 996.62, 999.2)	Pulmonary edema (518.4)
Digoxin toxicity (972.1, E942.1)	Pulmonary embolism (415.1)
Heparin excess (E934.2)	Stroke (436, 437)
	Urinary retention (788.2)
	Venous thrombosis (451.1)

Note: Most of the codes used to identify complications were regular ICD-9-CM codes for medical diagnoses. In our database, we found that E-codes were used as indicators of complications and occurred more frequently than regular ICD-9-CM poisoning codes. The E-codes included represent adverse events of medications that, according to the ICD-9-CM coding manual, may result from medications properly administered in the therapeutic or prophylactic dosage. However, because E-codes reflect the occurrence of an adverse event, and coder judgment is used to determine whether the adverse event was avoidable, complications represented by E-codes were included. A recent study of digitalis adverse events included E-codes to identify study cases (Warren et al. 1994).

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