Adjusted Hospital Death Rates: A Potential Screen for Quality of Medical Care

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Abstract: Increased economic pressure on hospitals has accelerated the need to develop a screening tool for identifying hospitals that potentially provide poor quality care. Based upon data from 93 hospitals and 205,000 admissions, we used a multiple regression model to adjust the hospitals crude death rate. The adjustment process used age, origin of patient from the emergency department or nursing home, and a hospital case mix index based on DRGs (diagnostic related groups). Before adjustment, hospital death rates ranged from 0.3 to 5.8 per 100 admissions. After adjustment, hospital death ratios ranged from 0.36 to 1.36 per 100 (actual death rate divided by predicted death rate). Eleven hospitals (12 per cent) were identified where the actual death rate exceeded the predicted death rate by more than two standard deviations. In nine hospitals (10 per cent), the predicted death rate exceeded the actual death rate by a similar statistical margin. The 11 hospitals with higher than predicted death rates may provide inadequate quality of care or have uniquely ill patient populations. The adjusted death rate model needs to be validated and generalized before it can be used routinely to screen hospitals. However, the remaining large differences in observed versus predicted death rates lead us to believe that important differences in hospital performance may exist. (*Am J Public Health* 1987; 77:1162–1167.)

Introduction

The new economic environment of prospective payment and preferred provider organizations has resulted in pressure on hospitals to provide less costly medical care. In one year the average length of hospital stay for Medicare patients has declined from 10.0 to 9.0 days.[1] With this and other changes, concern has been expressed about potential adverse effects upon the quality of hospital care. Ideally, the quality of care in all hospitals should be routinely and non-intrusively assessed. At the very least, this assessment could identify hospitals that might be providing inadequate care so that they could receive the attention needed to improve their performance.

Comparisons among hospitals have used both crude hospital death rates, unadjusted for differing patient characteristics, and adjusted rates. The adjusted death rates have controlled for length of hospital stay, patient age, and diagnosis.[2–7]

In this paper, with the aid of a more complete set of adjustments, we describe a method that explains an appreciable portion of the disparity among hospital death rates and identifies a subset of outlier facilities in need of closer examination.

Methods

We obtained, aggregated to the hospital level, a modified version of the Uniform Hospital Discharge Data Set (UHDDS) from 93 American Medical International (AMI) hospitals located in western, central, and southeastern United States. After medical records personnel abstract patient records at each hospital, the data are transferred to a single facility for verification and analysis.

The aggregated data included information about patient demographics and diagnosis, type of admission, patient origin, hospital charcteristics, death rates, and patient disposition (see Appendix A).

We used multiple regression to adjust each hospital's death rate (number of deaths/100 admissions) for age, origin of patient from the emergency department or nursing home, and hospital case mix index. A case mix index was calculated for each hospital by summing the products of the case mix weighting factor for each diagnosis related group (DRG) multiplied by the proportion of patients in each DRG. We retained independent variables when t-values were adequately large. We analyzed residual plots for evidence of randomness, and used normal probability plots to select the final model.

We identified potential outliers as hospitals where actual death rates differed from predicted death rates by more than two standard deviations. The variance term for this calculation incorporated both the error of the mean predicted value and the sampling error about each hospital's actual death rate. The latter variance assumes binomial probability. For further details see Appendix B.

Results

Data came from 93 hospitals and 205,000 hospital discharges during a six-month period in 1985. Twenty-one hospitals were in the west, 47 in the central, and 25 in the southeastern United States. The hospitals were proprietary, non-teaching, and non-governmental.

The average length of stays and occupancy rates were 5.5 days and 44 percent, respectively. Unadjusted hospital death rates ranged from 0.3 to 5.8 per 100 admissions (mean 2.4). The hospitals differed greatly with respect to the following variables: size (40–586 beds), occupancy rate (15–116 per cent), patients admitted during a six-month time period (377–11,986), admissions through the emergency department (0–58 per cent), admissions from nursing homes (0–15 per cent), readmission rate (0–28 per cent), and proportion of Medicaid patients (0–0.34) (Table 1).

Crude hospital death rates strongly correlated with the age distribution at each facility (Figure 1): per cent of patients over age 70 had an R = 0.75 with crude hospital death rate. Death rates also correlated with the per cent of hospital admissions from the emergency department (R = 0.53) (Figure 2), and with the percent of patients admitted from a nursing home (R = 0.29). Although the hospital case mix index was originally developed to explain resource utiliza-

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TABLE 1—Characteristics of the 93 Hospitals Studied

Characteristics	Mean	Standard Deviation	Minimum	Maximum
Size (number of beds)	143	88	40	586
Occupancy Rate (%)	45	15	15	116
Average Length of Hospital Stay (days)	5.5	1.1	3.4	8.2
Patients Admitted (number)	2216	1597	377	11,986
Age Less Than 14 years (%)	12	9	1.7	46
Age 14–44 (%)	12	9	15	66
Age 45–64 (%)	20	6	6	33
Age 65–69 (%)	7	2	0.9	13
Age Greater Than 70 (%)	24	9	2.4	54
Hospital Case Mix Index	0.882	0.113	0.553	1.208
Emergency Department Admissions (%)	29	12	0	58
Nursing Home Admissions (%)	1.6	2.8	0	15
Readmissions (%)	4	3.4	0	28
Medicaid Patients (%)	7	6	0	34
Discharged to a Nursing Home (%)	4	3	0	7
Transferred to Another Hospital (%)	1.7	1.3	0	7
Death Rate (overall) (%)	2.3	1.2	0.3	5.8

tion, it also correlated with hospital death rates (R = 0.55) (Figure 3). No hospital uniformly admitted all patients through the emergency department.

Using multiple regression, we predicted each hospital's death rate as a function of the percentage of patients over age 70, percentage of admissions from the emergency department, percentage of patients admitted from a nursing home, and hospital case mix index (adjusted R-squared = 0.64) (Table 2). Adjusted hospital death rates ranged from 0.36 to 1.69 (actual hospital death rate divided by predicted hospital death rate. Inclusion of average length of stay, hospital size, percentage of Medicaid patients, occupancy rate, or discharge to nursing home did not improve the model. All residual plots appeared random.

A plot of crude hospital death rate versus the predicted hospital death rate (based upon the regression model prediction for each facility) indicated several potential outliers (Figure 4). Death rates significantly exceeded their predicted value at 11 hospitals (high outliers) including one which exceeded its expected value by four standard deviations and another by five standard deviations. Nine hospital death rates fell significantly below the value predicted from the regression model (low outliers). Overall, there were 20 hospitals where actual death rates differed from predicted death rates by more than two standard deviations. Only five should be observed by chance alone.

Examination of the outlier hospitals revealed that 49 per cent (507/1,033) of all their deaths occurred within 10 diagnostic categories. The diagnostic categories consisted of either single diagnosis related groups (DRGs) or clinically meaningful collections of them (for example, myocardial infarction-DRG 121, 122, 123; urinary tract infection-DRG 320, 321, 322). Of the 507 deaths, the majority (92 per cent) occurred within the Medicare population.

High and low outlier hospitals were compared using death rates within each of these 10 diagnostic categories (Table 3). In each diagnostic category the death rate in the high outlier hospitals exceeded the death rate in the low outlier hospitals.

Discussion

We have developed a method to adjust hospital death rates based upon data from 93 hospitals and 205,000 admissions. The adjustment process utilized age, origin of patient from the emergency department or nursing home, and case mix index to account for two-thirds of the disparity in death rates among these hospitals. These adjusted death rates could be used as a screen in identifying hospitals potentially at risk for delivering inadequate quality of care.

The current work builds upon the work of others (Appendix C). Roemer, *et al*, described large differences in death rates among 33 Los Angeles County Hospitals and reduced this disparity by adjusting each hospital's death rate

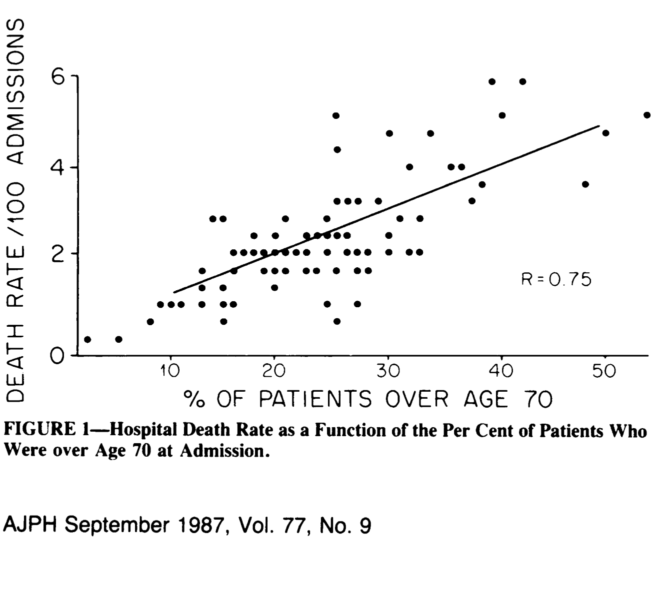

FIGURE 1—Hospital Death Rate as a Function of the Per Cent of Patients Who Were over Age 70 at Admission.

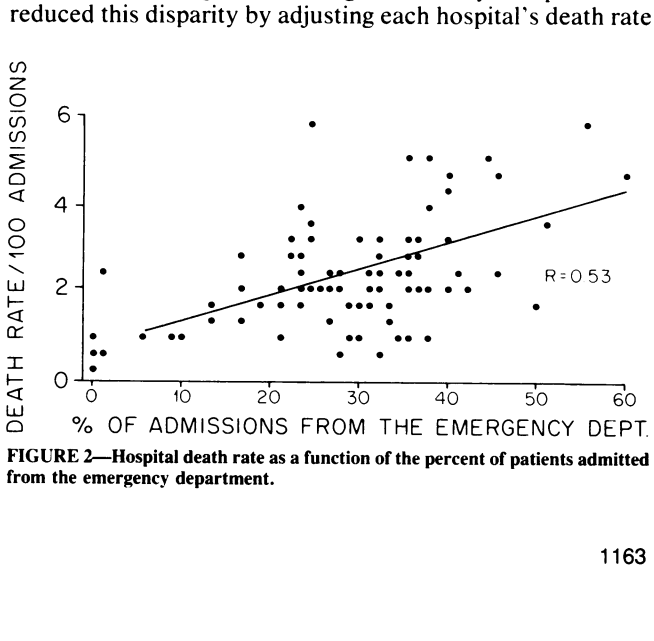

FIGURE 2—Hospital death rate as a function of the percent of patients admitted from the emergency department.

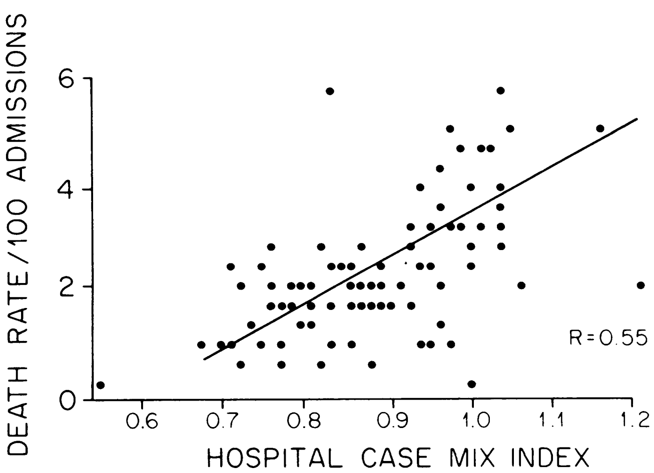

FIGURE 3—Hospital death rate as a function of hospital case mix index.

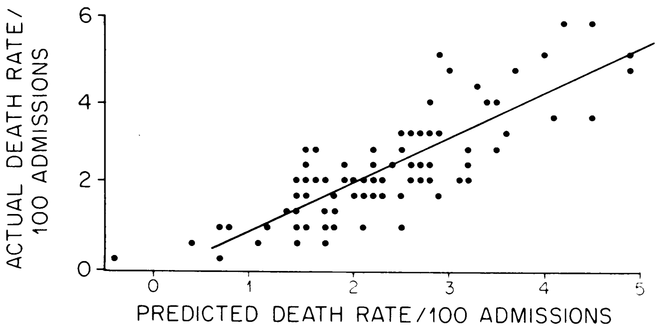

FIGURE 4—Predicted hospital death rate versus actual hospital death rate.

for its occupancy corrected average length of stay.[3] Goss, however, could not replicate Roemer's findings in another geographic area.[4] She found that Roemer's occupancy corrected average length of stay could explain only a small portion of the variance in New York City hospital death rates. Moreover, she noted that adjusted hospital death rates in New York City greatly exceeded those in Los Angeles County.

In 1978, Duckett and Kristofferson developed another method to standardize hospital death rates.[5] In New South Wales, Australia they found that differing age distributions and the use of 11 diagnostic categories explained 35 per cent of the death rate variance among 33 hospitals. In contrast, several studies of hospital death rates throughout the United States have used detailed patient data such as patient physiologic parameters on admission and comorbid diseases.[6] These latter studies, however, have been primarily directed toward surgical conditions and thus their conclusions reflect only a portion of a hospital's patient population.

A hospital quality screen should incorporate both geographic and patient diversity. We based our analysis upon all patients admitted to 93 geographically dispersed hospitals. Using multiple regression, we developed a simple model that required only four variables, yet accounted for 65 per cent of the variance in death rates among these 93 hospitals.

All four of the variables, listed below, have strong intuitive appeal in identifying ill patients.

- The elderly (age greater than 70) have less resilience to sickness when it occurs;
- The nursing home patient usually has multiple often chronic medical problems;
- Patients admitted acutely from an emergency department usually have a more guarded immediate prognosis than an electively scheduled patient;
- Higher case mix indices reflect greater need for resources and often more severely ill patients.

Thus, all four of these independent variables identify patients with potentially worse in-hospital prognoses.

The model also identified 11 hospitals where the actual death rate greatly exceeded the adjusted value. These outliers may represent hospitals that provide inadequate quality of care or hospitals with uniquely ill patient populations. Examination of other characteristics such as hospital size, average length of stay, occupancy rate, percentage of Medicaid patients, or teaching status did not reveal any overt discrepancies between high and low outliers (Table 4).

Outliers could occur due to differences in a hospital's transfer policy. If a hospital transfers many of its very ill patients to other facilities, then its own death rate may appear quite low. This transfer policy would not alter the hospital's overall case mix index since the index reflects the variety of patient diagnoses on admission. Thus, a hospital which transfers many sick patients could have a low death rate with apparently high patient severity. Our data do not support this potential scenario. In fact, the low outlier hospitals transferred *less* patients than the non-outlier hospitals (Table 4).

Ten diagnostic categories accounted for one-half of the deaths in the outlier hospitals. Within each of these categories, the death rate in the high outlier hospitals exceeded the death rate within the low outlier hospitals (Table 3). These results suggest that the high outlier hospitals do not merely care for patients in different diagnostic categories. Rather, the death rate differences persist even for Medicare patients with similar diagnoses.

Although our model accounted for almost two-thirds of the variance in hospital death rates, outliers could still represent hospitals with uniquely ill or uniquely healthy patients. Several systems have recently been developed to assess patient severity of illness.[8–10] However, each of these requires additional on-site medical records review. In contrast, our methodology attempts to adjust a hospital's death rate using routinely collected and easily accessible claims data. If validated, our model could serve as an initial screening tool which identifies outlier hospitals. These hospitals could then undergo a more detailed chart-based audit of their quality of care and severity of patient illness.

Hospital death rate models depend upon the accuracy of hospital discharge data. The presence of many coding errors could cause a hospital's death rate to appear either higher or lower than its true value. These models also depend upon unbiased patient demographic and diagnostic information. For these reasons, death rate models should be viewed

TABLE 2—Predicting Hospital Death Rates Using Multiple Regression Analysis Based Upon Data from 93 Hospitals

Parameter	Coefficient	Standard Error
Age greater than 70 (%)	0.05	0.01
Admission from emergency department (%)	0.02	0.008
Admission from nursing home (%)	0.095	0.03
Case mix index	1.99	0.84

R-squared = 0.66
Adjusted R-squared = 0.64

TABLE 3—Examination of Low and High Death Rate Hospital Outliers, Comparison of Death Rates within Specific Diagnostic Groups

Diagnosis	Death Rate: Low Outliers	Death Rate: High Outliers	High Outliers–Low Outliers	(95% CI)
Cerebrovascular Accident	28/276	60/225		
DRG 14	0.10	0.27	0.17	(0.10–0.24)
Complicated Respiratory Infection*	10/59	30/90		
DRG 79	0.17	0.33	0.16	(0.02–0.3)
Pulmonary Edema/Respiratory Failure	16/124	28/143		
DRG 87	0.13	0.19	0.06	(−0.02–0.14)
Simple Pneumonia*	17/229	42/308		
DRG 89	0.07	0.17	0.10	(0.04–0.16)
Acute Myocardial Infarction	42/348	76/362		
DRG 121, 122, 123	0.12	0.21	0.09	(0.03–0.15)
Heart Failure/Shock	25/395	34/419		
DRG 127	0.06	0.08	0.02	(0–0.04)
Cardiac Arrhythmias	6/267	10/151		
DRG 138, 139	0.02	0.07	0.05	(0.01–0.09)
Nutritional/Metabolic	6/243	25/212		
DRG 296, 297, 298	0.02	0.12	0.10	(0.06–0.14)
Urinary Tract Infection	4/216	10/189		
DRG 320, 321, 322	0.02	0.05	0.03	(−0.01–0.07)
Septicemia: Age > 17	14/74	32/93		
DRG 416	0.19	0.34	0.15	(0.01–0.29)

*Age greater than 70 years and/or complications and/or comorbidities.

TABLE 4—Comparison of Adjusted Death Rate Hospital Outliers*

Hospital Characteristics	Mean (Standard Error): High Death Rate Outliers (11 Hospitals)	Low Death Rate Outliers (9 Hospitals)	Non-Outliers (73 Hospitals)
Beds (mean)	168 (53)	155 (131)	138 (86)
% Occupancy (mean)	45 (12)	46 (20)	45 (15)
Average Length of Hospital Stay	6.1 (1.3)	5.6 (0.8)	5.4 (1.1)
Medicaid (% of all patients)	9 (10)	5 (3)	6.8 (6.0)
Readmission (% of all patients)	2.6 (1.9)	5.7 (3.1)	4.0 (3.6)
Transfers to Other Hospitals (% of all patients)	1.3 (1.1)	1.5 (1.0)	1.8 (1.3)
Discharges to Nursing Home (% of all patients)	6.2 (4.4)	3.7 (2.6)	3.9 (2.7)

*Outlier: defined as actual death rate > 2 standard deviations above or below the predicted death rate for each hospital.
NOTE: All 93 hospitals were non-teaching status, proprietary ownership.

cautiously until on-site medical records review substantiates the computerized discharge data.

The Health Care Financing Administration recently published a list of hospital death rates throughout the United States. They also used multiple regression to adjust each hospital's death rate for a variety of patient parameters (age, sex, race, average length of hospital stay, and proportion of discharges in each of the 50 highest frequency DRGs). They provided their results to the 50 Peer Review Organizations which conduct review of hospital care provided to Medicare patients. Our study differs from the above analysis in several important ways. HCFA based its analysis only upon Medicare discharges whereas we used a hospital's entire patient population. In addition, we employed fewer (four vs 55) and different adjustment parameters, yet achieved similar explanatory power (R-squared 0.64). Finally, our model included several parameters (admission from the emergency room, admission from a nursing home) which reflect patient origin.

With the recent economic and legislative changes in the health care sector, the ability to monitor hospital quality of care becomes increasingly important. It is not feasible to closely monitor all hospitals at all times. A screening method using routinely collected data could narrow the choice of review to a much smaller subset. The adjusted death rate model may serve this purpose.

The model needs confirmation on other types of hospitals before it can be recommended for widespread use. In addition, the method must be carefully validated. We are currently performing an independent quality of care and severity of illness assessment in hospitals with high and low ratios of actual to predicted death rates. In this manner the sensitivity and specificity of the screening model developed in this paper can be ascertained.

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REFERENCES

1. National Center for Health Statistics, Utilization of Short-Stay Hospitals by Diagnosis-Related Groups, United States 1980–84, Vital and Health Statistics Series 13, No. 87, DHHS Pub. No. (PHS) 86–1748, Government Printing Office, July 1986.
2. Moses LE, Mosteller F: Institutional differences in postoperative death rates. JAMA 1968; 203:150–152.
3. Roemer MI, Moustafa AT, Hopkins CE: A proposed hospital quality index: Hospital death rates adjusted for case severity. Health Serv Res 1968; 3:96–118.
4. Goss ME, Reed JI: Evaluating the quality of hospital care through severity-adjusted death rates: Some pitfalls. Med Care 1974; 12:202–213.
5. Duckett SJ, Kristofferson SM: An index of hospital performance. Med Care 1978; 16:400–407.

6. Flood AB, Scott WR, Ewy W: Does practice make perfect? The relationship between hospital volume and outcomes for selected diagnostic categories. Med Care 1984; 22:98–114.
7. Hebel JR, Kessler II, Mabuchi K, McCarter RJ: Assessment of hospital performance by use of death rates: a recent case history. JAMA 1982; 248:3131–3135.
8. Brewster AC, Karlin BG, Hyde LA, Jacobs CM: MEDISGRPS: A clinically based approach to classifying hospital patients at admission. Inquiry 1985; 22:377–387.
9. Horn SD, Horn RA, Sharkey PD: The severity of illness index as a severity adjustment to diagnosis-related groups. Health Care Fin Rev (ann suppl) 1984; 33–45.
10. Knaus WA, Draper EA, Wagner DP: APACHE II: A severity of disease classification system. Crit Care Med 1985; 13:818–829.
11. Brinkley J: US releasing lists of hospitals with abnormal mortality rates. New York Times March 12, 1986; 1.

APPENDIX A
Available Hospital Data Elements: All Definitions Aggregated to the Hospital Level

Hospital Characteristics
1. Age distribution in years (<14, 14–44, 45–64, 65–69, >70)
2. Case Mix Index*
3. Admissions from emergency department (proportion of total admissions)
4. Readmission to same hospital within 14 days
5. Admissions from nursing home (proportion of total admissions)
6. Size (number of beds)
7. Occupancy rate
8. Average length of hospital stay
9. Number of patients admitted in six months
10. Medicaid (proportion of all patients with this reimbursement)
11. Death rate (surgical, non-surgical, overall)
12. Discharged to a nursing home (proportion of all discharges)
13. Transfers to other hospitals (proportion of all discharges)

*A case mix index was calculated for each hospital by summing the products of the case mix weighting factor for each DRG multiplied by the proportion of patients in each DRG.

APPENDIX B
Statistical Background

We assume that each hospital has a true death rate p_i which is unknown to us, but is measured by the observed death rate P_i. The observed death rate P_i has (approximately) a binomial distribution with expected value p_i and variance $p_i(1 - p_i)/n_i$. Actually, this is an upper bound because each patient has a different probability of death.

Each patient has a probability of death p_{ij}, so $p_i = \Sigma p_{ij}/n_i$, and variance of the P_i is

$$\mathrm{var}(P_i) = \Sigma\, p_{ij}(1 - p_{ij})/n_i^2 \leq p_i(1 - p_i)/n_i$$

by Jensen's inequality.

The true rate p_i itself varies according to the hospital i's case mix, represented by the variables x_i as well as particular factors in that hospital. It is these factors, called q_i, that we are interested in learning more about. We have postulated a linear relationship

$$p_i = \beta x_i + q_i$$

which we estimate with the dependent variable P_i, since $EP_i = p_i$.

That is, we estimate β by b and q_i by

$$Q_i = P_i - bx_i = (P_i - p_i) + (p_i - bx_i).$$

For the purpose of this study, q_i is a fixed but unknown constant. If we took another sample of patients from hospital i, we would expect the same x_i, q_i, and thus p_i. Estimating the variance of Q_i in this problem, we are principally interested in the variance of P_i around p_i. There is also some uncertainty about b minus β which is related to the choice of hospitals in our sample; this term is approximately

$$\mathrm{var}\,(bx_i) = x_i'\ \mathrm{var}\,(b)\ x_i$$

Because we estimated the regression relationship with the observed P_i's instead of the actual hospital rates p_i, there is a small positive correlation between P_i and bx_i. This contribution would slightly decrease the variance of Q_i and is omitted.

Based on this reasoning, an approximate estimate of the variance of Q_i is:

$$\mathrm{var}(Q_i) = P_i\,(1 - P_i)/n_i + \mathrm{var}(bx_i).$$

APPENDIX C
Use of Hospital Adjusted Death Rate Models

Author	Year	Model Elements	Hospitals Studied	Strengths	Weaknesses
Moses[2] (National Halothane Study)	1968	Age, sex, operation, physical status	34	Identified three-fold variation in surgical death rates among hospitals	Limited to surgical patients
Roemer[3]	1968	Occupancy corrected average length of stay	33	First overall hospital adjusted death rate model	1) Hospitals in only one geographic area; 2) Findings not reproduced in New York City
Duckett[5]	1978	Age, 11 major diagnoses	33	Included age in overall hospital model	Hospitals in only one geographic area
Flood[6]	1976–84	Age, sex, physiologic parameters, admission laboratory results	1,224	1) Geographically diverse hospitals; 2) Patient level death rate adjustment	Examined death rates only in primarily surgical diagnoses
Hebel[7]	1984	Age, sex, race, major diagnoses, payer	3	Used 83 major diagnostic categories.	1) Small sample size; 2) Hospitals in only one geographic area