Hospital- and Patient-Related Characteristics Determining Maternity Length of Stay: A Hierarchical Linear Model Approach

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ABSTRACT

Objectives. The purpose of this study was to identify factors related to pregnancy and childbirth that might be predictive of a patient's length of stay after delivery and to model variations in length of stay.

Methods. California hospital discharge data on maternity patients (n = 499 912) were analyzed. Hierarchical linear modeling was used to adjust for patient case mix and hospital characteristics and to account for the dependence of outcome variables within hospitals.

Results. Substantial variation in length of stay among patients was observed. The variation was mainly attributed to delivery type (vaginal or cesarean section), the patient's clinical risk factors, and severity of complications (if any). Furthermore, hospitals differed significantly in maternity lengths of stay even after adjustment for patient case mix.

Conclusions. Developing risk-adjusted models for length of stay is a complex process but is essential for understanding variation. The hierarchical linear model approach described here represents a more efficient and appropriate way of studying interhospital variations than the traditional regression approach. (*Am J Public Health.* 1998;88:377–381)

Introduction

Obstetrical delivery is the most frequent cause of hospital admission and contributes to approximately 4 million admissions in the United States.[1] During the past few decades, the length of hospital stay associated with delivery has decreased steadily.[2] The issue of the appropriate length of stay after delivery is complex and hotly debated. The guidelines published jointly by the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists[3] recommend a 2-day stay after a vaginal delivery and a 4-day stay after a cesarean section if there have been no complications. On the other hand, several studies have also shown that early discharge of healthy mothers is beneficial to the mothers in terms of their physical and emotional health, as well as to the facilities in terms of economical considerations.[4–6] The arguments of both sides, however, provide little scientific evidence to guide discharge planning.[7,8]

The first step in developing any scientific basis and comprehensive guidelines is to understand the variation in maternity lengths of stay. This paper presents an analysis of California state hospital discharge data designed to identify and quantify predictive factors for maternity length of stay using the hierarchical linear model approach. This approach adjusted for patient case mix and hospital characteristics and accounted for the dependence of outcome variables within hospitals.

In late 1991, the California state legislature allocated funds for the collection, analysis, and dissemination of data related to risk-adjusted hospital outcomes for medical, surgical, and obstetrical patients.[9] The results presented here were based on 1994 hospital discharge data provided by the California Office of Statewide Health Planning and Development.

Methods

Data Description

Each hospital discharge abstract records the patient's demographic characteristics, including age and race, the principal diagnosis, the principal procedure, up to 24 secondary diagnoses, up to 20 secondary procedures, and hospital identification. In addition, data related to hospital characteristics, such as hospital size and hospital ownership, were obtained from the American Hospital Association's 1994 hospital guide.

Selection Criteria

Since the focus of this analysis was the maternity length of stay, we considered only patients with diagnosis-related groups from 370 through 375 (i.e., vaginal or cesarean delivery with various associated conditions). To develop a more appropriate risk adjustment model and to permit more valid comparisons across hospitals, we

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excluded from analysis patients who were readmitted to the same or any other hospital within 30 days of discharge (n = 6543) because such patients are likely to represent unusual cases. We excluded the following patients for the same reason:

- Patients less than 15 years of age (n = 1695) or greater than 45 years of age (n = 311)
- Patients with *International Classification of Diseases* (9th revision; ICD-9) E-codes (external cause of injury; n = 1201), patients with "emergency" (n = 7) or "urgent" (n = 39) hospital admissions, and patients with a disposition of "died" (n = 59)
- Patients with a nonchildbirth principal procedure (n = 339) or principal diagnosis (n = 172) (e.g., abortion).

Identification numbers (encrypted Social Security numbers) were missing for 95 085 patients for various reasons, preventing us from verifying their readmission status. Analyses with and without those patients were performed and yielded very similar results. The results presented here include patients with and without identification numbers.

Furthermore, hospitals with fewer than 730 deliveries per year (i.e., on average, fewer than approximately 2 deliveries per day [n = 116 of 341 hospitals]) were excluded from the analysis. This criterion is important for evaluating a hospital's performance, in that more accurate estimates of hospital effects are produced, and for avoiding an extremely unbalanced design that may create numerical difficulty.

In this analysis, we considered those patients with a length of stay of less than or equal to 7 days. The sample of patients with a length of stay of greater than 7 days will be considered separately and reported elsewhere. The reasons are 2-fold. First, patients with lengths of stay of greater than 7 days are likely to represent unusual cases, since the average length of stay in the United States for all deliveries in 1993 was about 2.4 days.[10] Second, the sample with a length of stay of greater than 7 days represents an extremely long tail for the length of stay distribution, which creates analytical problems. In fact, less than 1% of the sample was excluded under this criterion.

Definitions of Outcome, Clinical Risk Factors, and Complication Index

The outcome variable (maternity length of stay) considered in this analysis was defined as the number of days after principal procedure (i.e., delivery) to discharge. This definition was chosen because many of the factors that may influence predelivery length of stay are not measurable or are not captured in hospital discharge abstracts.

In this study, clinical risk factors were defined as conditions that probably existed before the time of delivery and might have influenced the patient's length of stay. Severity of complications (if any) was defined by classifying each complication as mild (scored as 1), moderate (scored as 2), or severe (scored as 3); all severity scores were then summed to obtain a total severity index of complications for each patient. For example, if a patient had 2 secondary diagnoses classified as moderate and severe complications, then the patient's severity index would be 5. All of the clinical risk factors and complications were defined under the direction of medical experts and one of the authors (Karen S. Rees) using the ICD-9-CM [11] codes of the diagnoses recorded in the hospital discharge abstracts. Furthermore, the publication *Clinical Classification for Health Policy Research*, published by the Agency for Health Care Policy and Research,[12] was consulted for the purpose of grouping the clinical risk factors. Note that tables of the clinical risk factors and complication index are not presented here but are available upon request.

Statistical Analysis

One issue that needs to be considered when analyzing patient outcomes (e.g., length of stay) collected from hospitals is that the data are collected for a clustered sample (i.e., patients are nested within hospitals), so the observations within the same hospital are usually correlated. This violates the assumption of independence required in the traditional regression analysis. More important, because the dependence of clustered data is ignored, standard errors of the estimates are incorrect and are often underestimated.[13]

The hierarchical linear model (also known as the linear mixed-effect model)[14,15] provides a tool for analyzing such clustered data. Let Y_{ij} be the outcome variable of the jth patient in the ith hospital. Under a hierarchical linear model, Y_{ij} is assumed to be generated from the model

$$Y_{ij} = b_i + aX_{ij} + \epsilon_{ij}.$$

Here X_{ij} represents the covariates associated with the fixed parameter α (fixed effect), and the hospital effect (random effect) b_i and the random disturbances ϵ_{ij} are assumed to have normal distributions with mean zero and variance σ_e^2 and σ_b^2, respectively. Note that an approximate interpretation of the antilogarithm of b_i is the ratio of the expected length of stay in the ith hospital to the overall expected length of stay when logarithm of length of stay is modeled (a detailed derivation based on Taylor series expansion is available upon request).

The hierarchical linear model approach provides several advantages over the traditional regression analysis. First, by using clustering information, it provides statistically efficient estimators, correct standard errors (no adjustment is required), and, consequently, correct confidence intervals and significance tests. Second, it provides estimates of interhospital variation and hospital effects (b_i). Thus, one can evaluate hospital performance based on patient outcomes after adjustment for patient case mix.

In the analysis, the data set was randomly split into 2 sets by a ratio of 60% to 40%. The first sample, the "model developing sample," was used to develop the model. The second sample, the "validation sample," was used to evaluate the consistency and predictive ability of the model. Using the model developing sample, we fitted the data with all covariates (including all clinical risk factors) and all of the interactions with delivery type. When there are many variables considered in a model and the significant tests are not predetermined, adjustments for multiple comparisons are needed; otherwise, significance may be due to random occurrences with frequencies higher than the predetermined significance level. Thus, variables were retained only if they were significant at the 2-sided 5% significance level adjusted for multiple comparisons (by the Bonferroni correction). Because of the large sample size, statistical significance might be declared even if the variable was not significant in a practical sense. Thus, a further criterion for including a clinical risk factor was that the estimate must be at least ±0.1 (i.e., at least an approximately 10% difference). Models in this article were estimated with the MIXED procedure available in SAS.[16]

Results

In this analysis, 499 912 patients who had a delivery in 1994 were included. For these patients, the geometric mean length of stay was 1.40 days, and 80% had a vaginal delivery. The geometric length of stay means were 1.18 and 2.71 days for vaginal and cesarean section delivery, respectively. Table 1 presents the demographic characteristics of these patients and the characteristics of the hospitals. The age distribution was quite uniform between 20 and 34 years (mean age = 27 years, SD = 6). Among the patients, 43% were Hispanic, 38% were White (note that although Hispanics account for a smaller percentage of the population, the fertility rate of Hispanics is much higher[17]), 68% were admitted to nonprofit hospitals, 19% were admitted to government hospitals, 85% were admitted to medium-sized hospitals (100 to 499 beds), 49% were paid through Medi-Cal, and 34% were paid through health maintenance organizations (HMOs).

For the hierarchical linear models, logarithm of length of stay was used, since the length of stay distribution was skewed. We fitted the model using both the model developing sample and the validation sample and adapted the variable selection procedure described in the methods section. The covariates retained on the basis of the model developing sample and the validation sample were identical. The R^2 value of the final fitted model using the whole sample was approximately 66%. Table 2 summarizes the results and suggests the following phenomena.

First, patient demographic characteristics, including age, race, and source of payment, and hospital characteristics, including size and type of ownership, had very little effect on length of stay. These variables contributed less than 10% of the difference in length of stay.

Second, among all of the covariates, type of delivery had the largest effect on length of stay. The expected length of stay of a patient who was in all of the reference groups (including having a vaginal delivery and having no clinical risk factors and no complications) was approximately 1.2 days, while the expected length of stay of the same patient would be about 2.6 days if she had a cesarean section delivery.

Third, the clinical risk factors and severity of complications (if any) had the expected effects on length of stay. In particular, septicemia (except in labor), diabetes with complications, and pneumonia had the largest effects on length of stay. Note that the effect of some clinical risk factors, such as multiple gestation, was larger for patients who had a vaginal delivery than for patients who had a cesarean section delivery.

With the hierarchical linear model, we also estimated the hospital effect b_i and its standard error for each hospital. Figure 1 displays some of the estimated hospital effects and the associated 95% confidence intervals. Note that only 16 hospitals are included to avoid overcrowding. It is clear that significant hospital variation remained even after adjustment for patient case mix.

TABLE 1—Patient Demographic Characteristics and Hospital Characteristics

	Sample, No. (%)	Geometric Mean Length of Stay, d
Age group, y		
<20	60 782 (12.2)	1.37
20–24	123 477 (24.7)	1.37
25–29[a]	137 133 (27.4)	1.38
30–34	114 861 (23.0)	1.41
≥35	63 659 (12.7)	1.50
Source of payment		
HMO[a]	168 922 (33.8)	1.33
Medi-Cal	240 206 (48.8)	1.47
Commercial	76 924 (13.6)	1.39
Self-pay	18 467 (3.7)	1.27
Other	763 (0.2)	1.29
Race		
White[a]	190 696 (38.1)	1.36
Hispanic	215 124 (43.0)	1.44
Black	35 929 (7.2)	1.45
Asian	47 005 (9.4)	1.35
Other	11 158 (2.2)	1.39
Hospital ownership		
Government[a]	94 346 (19.1)	1.51
Nonprofit	334 430 (67.8)	1.36
Profit	64 610 (13.1)	1.48
Hospital size (no. beds)		
≤100	34 276 (6.9)	1.42
101–499	424 844 (85.0)	1.39
≥500[a]	40 792 (8.2)	1.52
Delivery type		
Vaginal[a]	397 812 (79.6)	1.18
Cesarean section	102 100 (20.4)	2.71

[a]Used as reference category when dummy variables were created.

For example, the expected length of stay of a patient who was in all of the reference groups but had a cesarean section delivery and moderate complications (severity level of 3) after delivery would be about 3.1 days. If she was admitted to hospital A, her expected length of stay would be 2.4 days; if she was admitted to hospital Z, then her expected length of stay would be 4.9 days. It is important to note that the estimates were based on patients without known readmission. The hospital variation may have been due to any of the following reasons: hospital efficiency and/or policy, physician practices, and unmeasured characteristics of the patients, such as family income.

Discussion

Developing risk-adjusted models for health care outcomes such as hospital length of stay is difficult but essential for understanding variation. This study addressed the methodological issue of modeling variation in obstetric care length of stay and identifying the important covariates that affect maternity length of stay. In particular, we estimated expected length of stay by patient case mix and by hospital and showed that there were no substantial variations in the length of stay among patients based on age, race, source of hospital payment, and hospital characteristics such as size. The variation was mainly attributed to delivery type, patient clinical risk factors, and severity of complications (if any).

To further validate the model and to examine any trends in maternity length of stay, we reanalyzed 1993 California hospital discharge data. In general, the distributions of patient characteristics and hospital characteristics were quite similar between 1993 and 1994. On the other hand, the average length of stay was slightly shorter in 1994 (1.57 days vs 1.67 in 1993). Comparing the results indicates that the fitted models based on 1993 and 1994 data were very similar, which suggests consistency over time (data not shown). Furthermore, the predictability of the model was "good," as reflected by the small mean square prediction error (0.075) when the 1993 fitted model was applied to the 1994 data.

Potential limitations of this analysis include the following. First, although the

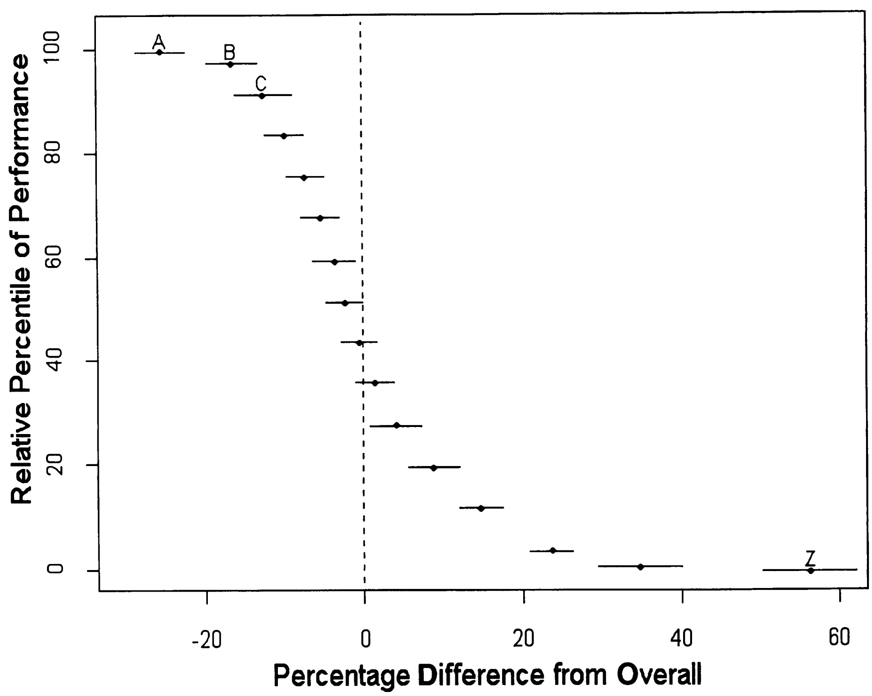
TABLE 2—Results of the Fitted Model Based on the Entire Sample

Covariate (Reference Group)	Vaginal Delivery Estimate	Vaginal Delivery Difference, %	Cesarian-Section Delivery Estimate	Cesarian-Section Delivery Difference, %
Age group, y (25–29)				
<20	0.017	1.7	0.017	1.7
20–24	0.000	0.0	0.000	0.0
30–34	0.008	0.8	0.008	0.8
35–45	0.019	1.9	0.019	1.9
Source of payment (HMO)				
Medi-Cal	0.055	5.7	0.020	2.0
Commercial	0.014	1.4	−0.007	−0.7
Self-pay	−0.020	−2.0	−0.042	−4.3
Other	−0.018	−1.8	−0.016	−1.6
Race (White)				
Hispanic	0.003	0.3	−0.016	1.6
Black	0.009	0.9	0.020	2.0
Asian	−0.010	−1.0	−0.004	−0.4
Other	0.008	0.8	0.007	0.7
Control (government)				
Nonprofit	−0.073	−7.6	0.008	0.8
Profit	0.012	1.2	0.046	4.7
Hospital size (>500 beds)				
<100	−0.043	−4.4	−0.036	−3.7
101–499	−0.054	−5.5	−0.008	−0.08
Severity of complication (no complication)				
Severity 1	0.118	12.5	0.152	16.4
Severity 2	0.165	17.9	0.176	19.2
Severity 3	0.352	42.2	0.181	19.8
Severity 4	0.475	60.8	0.258	29.4
Severity 5	0.676	96.6	0.327	38.7
Clinical risk factors (no risk factors)				
Septicemia (except in labor)	0.618	85.5	0.298	34.7
Diabetes mellitus without complications	0.122	13.0	0.0	0.0
Diabetes mellitus with complications	0.200	22.1	0.113	12.0
Fluid and electrolyte disorders	0.161	17.5	0.105	11.1
CHF/cardiomyopathy/chest pain/conduction disorders	0.154	16.6	0.102	10.7
Pneumonia	0.530	69.9	0.314	36.9
Other respiratory disease	0.124	13.2	0.124	13.2
Intestinal disorders	0.227	25.5	0.125	13.3
Urinary tract infections	0.119	12.6	0.043	4.4
Genitourinary symptoms and ill-defined conditions	0.123	13.1	0.007	0.7
Other genitourinary system diseases	0.114	12.1	0.064	6.6
Symptoms and other conditions	0.098	10.3	0.098	10.3
Multiple gestations	0.139	14.9	0.060	6.2
Mulitparity	0.180	19.7	0.031	3.1
Preeclampsia and eclampsia	0.313	36.8	0.102	10.7
Other hypertension in pregnancy	0.138	14.8	0.045	4.6
Feto-pelvic disproportion	0.243	27.5	0.019	1.9
Infection of amniotic cavity	0.238	26.9	0.068	7.0
Procedures (none)				
Other incision and excision of uterus	0.894	144.5	0.217	24.2
Intercept	0.196	. . .		
Variance of random effect (b_i)	0.0123	. . .		
Delivery type (vaginal)				
Cesarean section	0.744	110.4		

Note. The approximate R^2 value was 66%. Through inclusion of interaction terms with delivery type, the results are presented separately for vaginal and cesarian-section delivery. Standard errors of the estimates were quite small (all smaller than 0.04) and are not reported here. Percentage difference is defined as the ratio of difference in the expected lengths of stay of patients with and without the condition to the expected lengths of stay of patients without the condition.

prediction was excellent for lengths of stay of 4 days or less, it was not very accurate beyond 4 days. The reason may have been that the severity of clinical risk factors was not available. Second, as a result of rounding up, the findings based on the current discharge abstracts (recorded in days) slightly overstate the actual length of stay. Thus, more comprehensive and accurate data from hospital discharge abstracts are required to achieve a better prediction model.

Further studies are needed to determine whether readmission of mothers and/or babies would be preventable if length of stay were extended. However, with data currently available in California, such an analysis is not possible at the state



Note. Expected length of stay (for the average patient case mix) for a specific hospital can be obtained by computing expected length of stay for the average hospital × (1.0 + percentage difference).

FIGURE 1—Estimated hospital effects (solid circles; converted to percentage differences) and 95% confidence intervals (solid lines).

level. For confidentiality reasons, patient identification information (e.g., Social Security number) was encrypted or converted into a less specific format before the data were released to the public, so we were unable to link the data to other databases in order to obtain more information about the mothers and the babies. This prevents researchers from investigating the relationship between infant outcomes and maternal characteristics such as age and prenatal care. In the future, we hope that public agencies that collect and manage health care data can produce and release linkable databases so that such important research questions can be answered.

Hospital length of stay has been used as a measure of hospital efficiency, and managed care companies are moving toward performance-based contracting with hospitals.[18] Heterogeneous clinical care implies that hospital comparisons are not appropriate without adjustment for patient case mix. The hierarchical linear model approach, which directly adjusts for patient case mix as well as the dependence of outcome variables within hospitals, provides a more appropriate and efficient way to study interhospital variations than the standardization approach. □

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