Special Article

NURSE-STAFFING LEVELS AND THE QUALITY OF CARE IN HOSPITALS

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ABSTRACT

Background It is uncertain whether lower levels of staffing by nurses at hospitals are associated with an increased risk that patients will have complications or die.

Methods We used administrative data from 1997 for 799 hospitals in 11 states (covering 5,075,969 discharges of medical patients and 1,104,659 discharges of surgical patients) to examine the relation between the amount of care provided by nurses at the hospital and patients' outcomes. We conducted regression analyses in which we controlled for patients' risk of adverse outcomes, differences in the nursing care needed for each hospital's patients, and other variables.

Results The mean number of hours of nursing care per patient-day was 11.4, of which 7.8 hours were provided by registered nurses, 1.2 hours by licensed practical nurses, and 2.4 hours by nurses' aides. Among medical patients, a higher proportion of hours of care per day provided by registered nurses and a greater absolute number of hours of care per day provided by registered nurses were associated with a shorter length of stay ($P=0.01$ and $P<0.001$, respectively) and lower rates of both urinary tract infections ($P<0.001$ and $P=0.003$, respectively) and upper gastrointestinal bleeding ($P=0.03$ and $P=0.007$, respectively). A higher proportion of hours of care provided by registered nurses was also associated with lower rates of pneumonia ($P=0.001$), shock or cardiac arrest ($P=0.007$), and "failure to rescue," which was defined as death from pneumonia, shock or cardiac arrest, upper gastrointestinal bleeding, sepsis, or deep venous thrombosis ($P=0.05$). Among surgical patients, a higher proportion of care provided by registered nurses was associated with lower rates of urinary tract infections ($P=0.04$), and a greater number of hours of care per day provided by registered nurses was associated with lower rates of "failure to rescue" ($P=0.008$). We found no associations between increased levels of staffing by registered nurses and the rate of in-hospital death or between increased staffing by licensed practical nurses or nurses' aides and the rate of adverse outcomes.

Conclusions A higher proportion of hours of nursing care provided by registered nurses and a greater number of hours of care by registered nurses per day are associated with better care for hospitalized patients. (N Engl J Med 2002;346:1715-22.)

HOSPITALS, wrote Lewis Thomas in *The Youngest Science*, are "held together, glued together, enabled to function . . . by the nurses."[1] More than 1.3 million registered nurses work in hospitals in the United States. As hospitals have responded to financial pressure from Medicare, managed care, and other private payers, registered nurses have become increasingly dissatisfied with the working conditions in hospitals. They report that they are spending less time taking care of increasingly ill patients and believe that the safety and quality of inpatient care are deteriorating.[2-7] Although the number of hours of care per patient-day provided by registered nurses rose through the mid-1990s,[8-12] some question whether the staffing of nurses has increased rapidly enough to keep pace with the increasing severity of illness among hospitalized patients and thus to ensure safe and high-quality care.[13]

Research on the relation between the level of staffing by nurses in hospitals and patients' outcomes has been inconclusive. Whereas some studies have reported an association between higher levels of staffing by nurses and lower mortality,[14-20] as well as lower rates of other adverse outcomes,[21-30] others have found no such relations.[30-39] Previous studies have assessed only a limited number of outcomes that are sensitive to the extent or quality of nursing care, such as falls by patients and errors in medication. Many studies have used small samples of hospitals, controlled only to a limited extent for the patient's initial risk for the outcomes under study, failed to include nurses' aides as part of the nursing staff, and used inconsistent measures of staffing levels. We examined the relation between the levels of staffing by nurses in hospitals and the rates of adverse outcomes among patients, using administrative data from a large multistate sample of hospitals.

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METHODS

Measures of Adverse Outcomes

The study was approved by the Harvard School of Public Health Human Subjects Committee. On the basis of published[21,27,28,30,39-47] and unpublished materials, we identified 14 adverse outcomes during hospitalization (11 for both medical and surgical patients and 3 for surgical patients only) that could be coded on the basis of hospital-discharge abstracts and that are potentially sensitive to staffing by nurses. Building on previous studies,[30,48-50] we developed coding rules to construct risk groups of patients and to identify patients with each outcome (listed in the Appendix).

Study Population

We obtained data on hospital discharges and the staffing by nurses from 11 states that collect both types of data: Arizona, California, Maryland, Massachusetts, Missouri, Nevada, New York, South Carolina, Virginia, West Virginia, and Wisconsin. We estimated 1997 staffing as the weighted average of staffing in the hospital's fiscal years 1997 and 1998, except in Virginia, for which only fiscal 1997 data were available. We obtained data on discharges for the 1997 calendar year (for Virginia, we obtained data for the four calendar quarters matching each hospital's fiscal year). The initial sample was 1041 hospitals. We then excluded hospitals with an average daily census of less than 20, an occupancy rate below 20 percent, or missing data on staffing, as well as those reporting extremely low or high levels of staffing per patient-day (below the 7.5th percentile or above the 92.5th percentile). The final sample included 799 hospitals, which together accounted for 26 percent of the discharges from nonfederal hospitals in the United States in 1997.

Measures of Staffing

The levels of staffing by registered nurses, licensed practical nurses, and nurses' aides were estimated in hours. For states reporting staffing as full-time equivalents, we used a standard year of 2080 hours (52 weeks at 40 hours per week). In California, the levels of staffing of nurses for inpatient and outpatient care are calculated directly from financial data reported by the California Office of Statewide Health Planning and Development. Using these data, we found that the standard measure, "adjusted patient-days," that was used to adjust total hours of nursing care to reflect the number of both inpatients and outpatients treated at the hospital (hospital volume)[51] underestimated staffing for inpatient care and overestimated staffing for outpatient care. To adjust for this bias, we constructed a regression model, using data from California, that predicted staffing for inpatient care per inpatient-day on the basis of the level of staffing per adjusted patient-day and the number of outpatients treated; we used this model to estimate staffing for inpatient care from the staffing levels per adjusted patient-day reported in the other 10 states.

For easier comparison of the levels of staffing by nurses in different hospitals, we adjusted the hours of nursing care per day for differences in the nursing care needed by the patients of each hospital. We used estimates of the relative level of nursing care needed by patients in each diagnosis-related group[28,52] to construct a nursing case-mix index for each hospital. We divided hours of nursing care per inpatient-day by this index to calculate the adjusted number of hours of nursing care per day.

Risk Adjustment and Characteristics of the Hospitals

To control for differences among hospitals in the relative risk of the outcomes as a result of variations in the mix of patients, we used patient-level logistic-regression analyses to predict each patient's probability of having each adverse outcome. Patient-level variables in these analyses included the rate of the outcome in the patient's diagnosis-related group, the state of residence, age, sex, primary health insurer, whether or not the patient was admitted on an emergency basis, and the presence or absence of 13 chronic diseases.[48] The regression analyses also included interactions between the specific rate of each outcome in each diagnosis-related group and all the other variables, as well as interactions between age and the variables related to chronic disease. We added the predicted probabilities for patients in each hospital to obtain the expected number of patients in that hospital who would have each outcome. We used the same variables in an ordinary least-squares regression analysis to estimate the expected length of stay. We obtained information on the other characteristics of the hospitals (number of beds, teaching status, state, and metropolitan or nonmetropolitan location) from the American Hospital Association's Annual Survey of Hospitals for 1997[51] and 1998.[53]

Statistical Analysis

The unit of analysis was the hospital. We calculated the length of stay, the rates of adverse outcomes, the hours of nursing care per inpatient-day, and the proportion of hours of nursing care provided by each category of nursing personnel.

For each outcome, we performed regression analyses with the use of nurse-staffing and control variables. In all analyses, the control variables included the state, number of beds, teaching status, and location of the hospital. We used ordinary least-squares regression to analyze the difference between the actual and expected length of stay. We report regression coefficients for these analyses. For other outcomes, we included the number of patients with the adverse outcome as the dependent variable in a negative binomial regression model (the appropriate model for this type of data[53]) and the expected numbers for each adverse outcome as the measure of exposure required by the model. We report incidence-rate ratios from these analyses.

We tested each coefficient for statistical significance using t-tests in the ordinary least-squares regression analyses and z statistics in the negative binomial regression analyses.[54] After controlling for other variables, we estimated the differences in the outcomes between hospitals with staffing levels of registered nurses at the 75th percentile and hospitals with staffing levels of registered nurses at the 25th percentile (the "decrease" in outcomes with higher levels of staffing). The 95 percent confidence intervals for the decreases were calculated with the use of Huber–White standard errors.[55] All P values are based on two-tailed tests. Statistical analysis was performed with the use of Stata software.[55]

To examine whether the mix of skills or the number of hours of nursing care was more important in influencing patient outcomes, we analyzed 10 models involving nurse-staffing variables and compared the results. We present results from the two models that most closely match those used in previous published studies. Model 1 examines the mix of skills and includes the proportion of hours of care by licensed nurses (registered-nurse–hours plus licensed-practical-nurse–hours) that were provided by registered nurses, plus aide-hours and the total hours per day provided by licensed nurses. Model 2 measures all staffing of nurses — by registered nurses, aides, and licensed practical nurses — in hours per day. Results obtained with the other models we analyzed have been reported elsewhere.[56]

RESULTS

Rates of Adverse Patient Outcomes and Length of Stay

The patient outcomes and characteristics of the hospitals are summarized in Table 1. Complications that are common in hospitalized patients, such as urinary tract infection, pneumonia, and metabolic derangement, were the most frequent. The highest rates were for "failure to rescue," defined as the death of a patient with one of five life-threatening

TABLE 1. PATIENT OUTCOMES AND CHARACTERISTICS OF THE 799 HOSPITALS.*

VARIABLE	MEDICAL PATIENTS (N=5,075,969)†	SURGICAL PATIENTS (N=1,104,659)†
Outcome		
Length of stay (days)	5.0±2.0	4.7±1.4
Urinary tract infection (%)	6.3±2.3	3.3±2.1
Pressure ulcers (%)	7.2±4.5	5.8±6.6
Hospital-acquired pneumonia (%)	2.3±1.2	1.2±2.2
Shock or cardiac arrest (%)	0.6±0.8	0.5±0.6
Upper gastrointestinal bleeding (%)	1.0±0.6	0.5±0.5
Hospital-acquired sepsis (%)	1.3±0.9	1.0±0.8
Deep venous thrombosis (%)	0.5±0.3	0.4±0.4
Central nervous system complications (%)	0.6±0.4	0.3±0.4
In-hospital death (%)	3.2±1.2	1.6±1.6
Failure to rescue (%)	18.6±5.9	19.7±13.3
Wound infection (%)‡	—	0.8±0.6
Pulmonary failure (%)‡	—	1.2±2.0
Metabolic derangement (%)‡	—	6.8±7.2

	ALL HOSPITALS
Hospital characteristic	
No. of beds	226.6±198.9
Teaching status (%)	
Major teaching hospital	10.3±30.3
Other teaching hospital	19.0±39.3
Nonteaching hospital	70.7±45.5
Location (%)	
Large metropolitan area	53.9±49.9
Small metropolitan area	25.7±43.7
Nonmetropolitan area	20.4±40.3

*Plus–minus values are means ±SD. The number of hospitals is smaller than 799 for some outcomes because hospitals with expected counts of zero were excluded. For medical patients, one hospital was excluded from the analysis of upper gastrointestinal bleeding and one from the analysis of shock or cardiac arrest. For surgical patients, 2 hospitals were excluded from the analysis of urinary tract infection; 9 from the analyses of pressure ulcer and pneumonia; 1 each from the analyses of shock or cardiac arrest, sepsis, central nervous system complications, deep venous thrombosis, in-hospital death, pulmonary failure, and wound infection; and 14 from the analyses of failure to rescue (defined as in-hospital death of a patient with hospital-acquired pneumonia, shock or cardiac arrest, upper gastrointestinal bleeding, sepsis, deep venous thrombosis, or pulmonary failure). For both groups of patients, two hospitals were excluded from the analysis of length of stay.

†Numbers shown are the number of patients discharged.

‡This outcome was assessed in surgical patients only.

complications — pneumonia, shock or cardiac arrest, upper gastrointestinal bleeding, sepsis, or deep venous thrombosis — for which early identification by nurses and medical and nursing interventions can influence the risk of death. The mean death rates were 18.6 percent among medical patients with one of these complications and 19.7 percent among surgical patients with one of these complications. Rates for outcomes were similar in all 11 states. The low rates of deep venous thrombosis — 0.4 percent among surgical patients and 0.5 percent among medical patients — may reflect underreporting of this common complication.

TABLE 2. HOURS OF NURSING CARE.*

VARIABLE	VALUE
No. of hours of nursing care per patient-day	
Registered-nurse–hours	7.8±1.9
Licensed-practical-nurse–hours	1.2±1.0
Aide-hours	2.4±1.2
Total	11.4±2.3
Proportion of total hours of nursing care (%)	
Registered-nurse–hours	68±10
Licensed-practical-nurse–hours	11±8
No. of hours of care by licensed nurses per patient-day	9.0±2.0
Registered-nurse–hours as a proportion of licensed-nurse–hours (%)	87±10

*Plus–minus values are means ±SD. Licensed nurses are registered nurses and licensed practical nurses.

Variations in Staffing Levels and Mix of Skills

The mean (±SD) numbers of hours of nursing care are shown in Table 2. Hours per inpatient-day averaged 7.8 for registered nurses, 1.2 for licensed practical nurses, and 2.4 for aides. Hours of care by licensed nurses per day averaged 9.0. The mean proportion of total hours of nursing care provided by registered nurses was 68 percent; aides provided 21 percent of total nurse-hours.

Association between Adverse Outcomes and Staffing by Nurses

The relations between adverse outcomes and the levels of staffing by registered nurses are shown in Table 3 for medical patients and in Table 4 for surgical patients. The ordinary least-squares–regression coefficients (for length of stay) or the incidence-rate ratios (for other outcomes) are given for both registered-nurse–hours as a proportion of total hours of care by licensed nurses and the number of registered-nurse–hours per patient-day. A negative regression coefficient or an incidence-rate ratio of less than 1.00 indicates that the frequency of the outcome declines as the staffing level increases. The estimated percent decreases in the rates of the outcomes associated with increasing nurse-hours from the 25th to the 75th percentile are also listed. We report results for death and outcomes for which a greater number of registered-nurse–hours or a higher proportion of licensed-nurse care provided by registered nurses was associated with lower rates of the outcome. Additional results are reported elsewhere.[56]

Registered Nurses and Adverse Outcomes

Among medical patients, we found an association between registered-nurse staffing and six outcomes. Both a higher proportion of licensed-nurse care pro-

TABLE 3. RELATION BETWEEN ADVERSE OUTCOMES AMONG MEDICAL PATIENTS AND THE LEVELS OF STAFFING BY REGISTERED NURSES (RNS).*

OUTCOME	REGRESSION COEFFICIENT OR INCIDENCE-RATE RATIO (95% CI)†	DECREASE IN RATE OF OUTCOME ASSOCIATED WITH INCREASING STAFFING OF RNS FROM 25TH TO 75TH PERCENTILE	
		% (95% CI)	P value
Length of stay			
Proportion of RN-hours	−1.12 (−2.00 to −0.24)	3.5 (1.4 to 5.7)	0.01
No. of RN-hours per patient-day	−0.09 (−0.13 to −0.05)	5.2 (3.4 to 7.1)	<0.001
Urinary tract infection			
Proportion of RN-hours	0.48 (0.38 to 0.61)	9.0 (6.1 to 11.9)	<0.001
No. of RN-hours per patient-day	0.99 (0.98 to 1.00)	3.6 (1.2 to 6.0)	<0.003
Upper gastrointestinal bleeding			
Proportion of RN-hours	0.66 (0.45 to 0.96)	5.1 (0.5 to 9.7)	0.03
No. of RN-hours per patient-day	0.98 (0.97 to 0.99)	5.2 (1.4 to 8.9)	<0.007
Hospital-acquired pneumonia			
Proportion of RN-hours	0.59 (0.44 to 0.80)	6.4 (2.8 to 10.0)	0.001
No. of RN-hours per patient-day	0.99 (0.98 to 1.00)	2.7 (−0.4 to 5.8)	0.08
Shock or cardiac arrest			
Proportion of RN-hours	0.46 (0.27 to 0.81)	9.4 (2.6 to 16.3)	0.007
No. of RN-hours per patient-day	0.98 (0.96 to 1.01)	4.1 (−2.5 to 10.8)	0.22
Failure to rescue			
Proportion of RN-hours	0.81 (0.66 to 1.00)	2.5 (0.0 to 5.0)	0.05
No. of RN-hours per patient-day	1.00 (0.99 to 1.01)	0.1 (−2.5 to 2.4)	0.96
In-hospital death			
Proportion of RN-hours	0.90 (0.74 to 1.09)	1.4 (−1.1 to 3.8)	0.27
No. of RN-hours per patient-day	1.00 (0.99 to 1.01)	0.3 (−2.1 to 2.7)	0.83

*There were a total of 799 hospitals, but hospitals were excluded from the analysis of any outcome for which their expected count was zero. Two hospitals were excluded from the analysis of length of stay, one was excluded from the analysis of upper gastrointestinal bleeding, and one was excluded from the analysis of shock or cardiac arrest. The proportion of licensed-nurse–hours provided by registered nurses ("proportion of RN-hours") was measured by model 1; the number of RN-hours per patient-day was measured by model 2. Model 1 also included measures of aide-hours per patient-day and licensed-nurse–hours per patient-day, and model 2 also included measures of aide-hours per patient-day and licensed-practical-nurse–hours per patient-day. None of these other variables showed a consistent association with the rates of outcomes. The models are described further in the Methods section. No association was found between the measures of registered-nurse staffing and the following adverse outcomes among medical patients: sepsis, deep venous thrombosis, central nervous system complications, and pressure ulcers. CI denotes confidence interval.

†Data for length of stay are regression coefficients; data for all other outcomes are incidence-rate ratios. A negative regression coefficient or an incidence-rate ratio of less than 1.00 indicates that the frequency of the outcome declines as staffing increases. Confidence intervals have been rounded.

vided by registered nurses (model 1) and more registered-nurse–hours per day (model 2) were associated with a shorter length of stay and lower rates of urinary tract infections and upper gastrointestinal bleeding. A higher proportion of registered-nurse–hours (model 1), but not a greater number of registered-nurse–hours per day (model 2), was associated with lower rates of three other adverse outcomes: pneumonia, shock or cardiac arrest, and failure to rescue. The association for failure to rescue was not as strong as the associations for the other five outcomes, and it was more sensitive to the specifications of the models.[56]

Among surgical patients, a higher proportion of registered-nurse–hours (model 1) was associated with a lower rate of urinary tract infection. A greater number of registered-nurse–hours per day (model 2) was associated with a lower rate of failure to rescue; a greater number of licensed-nurse–hours per day was also associated with a lower rate of failure to rescue (incidence-rate ratio, 0.98; 95 percent confidence interval, 0.97 to 1.00; P=0.02). Because most licensed-nurse–hours are provided by registered nurses, these associations are consistent. Among both medical and surgical patients, we found no evidence of an association between in-hospital mortality and the proportion of registered-nurse–hours, the number of registered-nurse–hours per day, or the number of licensed-nurse–hours per day.

Measures of Staffing by Other Nurses

In addition to the association with a lower rate of failure to rescue among surgical patients, a greater number of licensed-nurse–hours per day was associ-

TABLE 4. RELATION BETWEEN ADVERSE OUTCOMES AMONG SURGICAL PATIENTS AND THE LEVELS OF STAFFING BY REGISTERED NURSES (RNS).*

OUTCOME	INCIDENCE-RATE RATIO (95% CI)†	DECREASE IN RATE OF OUTCOME ASSOCIATED WITH INCREASING STAFFING OF RNS FROM 25TH TO 75TH PERCENTILE	
		% (95% CI)	P value
Urinary tract infection			
Proportion of RN-hours	0.67 (0.46 to 0.98)	4.9 (0.3 to 9.5)	0.04
No. of RN-hours per patient-day	1.00 (0.98 to 1.02)	0.0 (−4.2 to 4.2)	1.00
Failure to rescue			
Proportion of RN-hours	0.73 (0.49 to 1.09)	3.9 (−1.1 to 8.8)	0.12
No. of RN-hours per patient-day	0.98 (0.96 to 0.99)	5.9 (1.5 to 10.2)	0.008
In-hospital death			
Proportion of RN-hours	0.99 (0.67 to 1.47)	0.1 (−4.7 to 4.9)	0.97
No. of RN-hours per patient-day	1.00 (0.99 to 1.01)	0.0 (−3.9 to 3.8)	0.98

*There were a total of 799 hospitals, but hospitals were excluded from the analysis of any outcome for which their expected outcome was zero. Two hospitals were excluded from the analysis of urinary tract infection, 14 from the analysis of failure to rescue, and 1 from the analysis of in-hospital death. The proportion of licensed-nurse–hours provided by registered nurses ("proportion of RN-hours") was measured by model 1; the number of RN-hours per patient-day was measured by model 2. Model 1 also included measures of aide-hours per patient-day and licensed-nurse–hours per patient-day, and model 2 also included measures of aide-hours per patient-day and licensed-practical-nurse–hours per patient-day. None of these other variables showed a consistent association with the rates of outcomes. The models are described further in the Methods section. Only results showing a consistent association with the rates of outcomes are presented. No association was found between the measures of registered-nurse staffing and the following outcomes among surgical patients: length of stay, pneumonia, sepsis, deep venous thrombosis, shock or cardiac arrest, gastrointestinal bleeding, pressure ulcers, metabolic derangement, central nervous system complications, pulmonary failure, and wound infection. CI denotes confidence interval.

†An incidence-rate ratio of less than 1.00 indicates that the frequency of the outcome declines as staffing increases.

ated with a shorter length of stay among medical patients (regression coefficient, −0.08; 95 percent confidence interval, −0.12 to −0.05; $P<0.001$). Measures of staffing by aides and licensed practical nurses had either nonsignificant associations with lower rates of the adverse outcomes we studied or significant associations with higher rates of the adverse outcomes (data not shown). Thus, whereas there was evidence that greater numbers of registered-nurse–hours or licensed-nurse–hours were associated with a shorter length of stay among medical patients and lower rates of failure to rescue among surgical patients, there was no evidence of an association between lower rates of the outcomes we studied and a greater number of licensed-practical-nurse–hours or aide-hours per day or a higher proportion of aide-hours.

DISCUSSION

In a large sample of hospitals from a diverse group of states, after controlling for differences in the nursing case mix and the patients' levels of risk, we found an association between the proportion of total hours of nursing care provided by registered nurses or the number of registered-nurse–hours per day and six outcomes among medical patients. These were the length of stay and the rates of urinary tract infections, upper gastrointestinal bleeding, hospital-acquired pneumonia, shock or cardiac arrest, and failure to rescue (the death of a patient with one of five life-threatening complications — pneumonia, shock or cardiac arrest, upper gastrointestinal bleeding, sepsis, or deep venous thrombosis). The evidence was weaker for failure to rescue than for the other five measures. As in other studies,[32,57] higher levels of staffing by registered nurses were associated with lower rates of failure to rescue among surgical patients, among whom we also found an association between a higher proportion of registered-nurse–hours and lower rates of urinary tract infections.

The fact that fewer outcomes among surgical patients than among medical patients were found to be associated with the level of staffing by registered nurses may have several explanations. Surgical patients may be healthier than medical patients and therefore have a lower risk of adverse outcomes. The smaller size of the samples of surgical patients may also have made it more difficult to detect associations.

Our findings clarify the relation between the lev-

els of staffing by nurses and the quality of care. We found consistent evidence of an association between higher levels of staffing by registered nurses and lower rates of adverse outcomes, but no similar evidence related to staffing by licensed practical nurses or aides. Our findings may reflect the actual contribution of these different members of the nursing staff to patients' outcomes in general, or they may be specific to the outcomes we examined. It is possible that the outcomes for which we found significant associations may be more sensitive to the contribution that the skills and education of registered nurses, in particular, make to patient care.

A higher proportion of total hours of nursing care provided by registered nurses was more frequently associated with lower rates of adverse outcomes than was a greater number of registered-nurse–hours per day. This difference may reflect a real effect, or it may simply indicate that we could measure differences in the mix of staff among hospitals with greater precision than we could nurse-hours adjusted for case mix.

We tested the association between staffing levels and 25 outcomes in medical and surgical patients and found an association for 8 of these outcomes. With the exception of failure to rescue among medical patients, these results were consistent across alternative regression models. Because of the large number of comparisons, however, it is possible that some of the associations we found may be false positive findings. In addition, differences among hospitals may be caused not by the staffing level of nurses per se but by other unmeasured factors associated with higher levels of staffing by registered nurses or other unmeasured characteristics of the hospitals' nursing work force. The level of staffing by nurses is an incomplete measure of the quality of nursing care in hospitals. Other factors, such as effective communication between nurses and physicians and a positive work environment, have been found to influence patients' outcomes.[58,59]

Other limitations of our study arise from weaknesses of currently available data. Constructing a data base on the staffing levels of nurses for inpatient care from the diverse data sets of multiple states required substantial efforts to standardize the data and to determine what proportion of a hospital's nursing staff was allocated to inpatient care. Because of the absence of reliable coding indicating whether secondary problems were present when the patient was admitted or developed later, constructing measures of quality from discharge abstracts involved defining appropriate coding and exclusion rules for each adverse outcome. These outcomes are likely to be underreported, and the degree of underreporting may be higher where staffing levels are low. Each of these limitations weakened our ability to observe associations between outcomes and staffing levels. We studied only adverse outcomes. Furthermore, not all outcomes among patients that are important to examine (for example, falls or medication errors) can be studied on the basis of discharge data. The outcomes for which we found associations with the levels of staffing by nurses should be viewed as indicators of quality rather than as measures of the full effect of nurses in hospitals.

Further research is needed to refine the measurement of the nursing case mix on the basis of discharge data and to elucidate the factors influencing the staffing levels of nurses and the mix of nursing personnel in hospitals. Given the evidence that such staffing levels are associated with adverse outcomes, as well as the current and projected shortages of hospital-based registered nurses,[60,61] systems should be developed for the routine monitoring, in large numbers of hospitals, of hospital outcomes that are sensitive to levels of staffing by nurses. Beyond monitoring, hospital administrators, accrediting agencies, insurers, and regulators should take action to ensure that an adequate nursing staff is available to protect patients and to improve the quality of care.

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APPENDIX. CODING RULES FOR ADVERSE OUTCOMES.*

OUTCOME	DEFINITION	
	INCLUDED	EXCLUDED
Length of stay	Length of stay as reported on discharge abstract	None
Urinary tract infection	ICD-9-CM: 599.0, 996.64	Primary diagnosis, MDC 11–15; ICD-9-CM: 646.60–646.64, 639.8
Pressure ulcers	ICD-9-CM: 682, 707.0	Primary diagnosis, hemiplegia,† quadriplegia,† paraplegia,† IV drug abuse†
Hospital-acquired pneumonia	ICD-9-CM: 507.0, 997.3, 514, 482.0–482.2, 482.4–482.9, 485, 486	Primary diagnosis — ICD-9-CM: 480–487, 507.0, 514, 997.3; secondary diagnosis — ICD-9-CM: 480, 481, 483, 484, 487; MDC 4, AIDS,† immunocompromised states†
Shock or cardiac arrest	ICD-9-CM: diagnoses — 427.5, 785.5, 785.50, 785.51, 785.59, 799.1; procedures — 93.93, 99.6, 99.63	Primary diagnosis, MDC 4, MDC 5, hemorrhage,† trauma†
Upper gastrointestinal bleeding	ICD-9-CM: 531.00–531.31, 531.9, 532.00–532.31, 532.9, 533.00–533.31, 533.9, 534.00–534.31, 534.9, 535.01, 535.4, 578.9, 530.82	Primary diagnosis, MDC 6–7, trauma,† burn,† alcoholism,† ICD-9-CM: 280.0, 285.1
Hospital-acquired sepsis	ICD-9-CM: 038, 790.7	Primary diagnosis, immunocompromised states,† AIDS,† length of stay <3 days, DRG: 20, 68–70, 79–81, 89–91, 126, 238, 242, 277–279, 320–322, 415–417, 423
Deep venous thrombosis	ICD-9-CM: 415.1, 415.11, 451.11, 451.19, 451.2, 451.81, 453.8	Primary diagnosis, ICD-9-CM: 673.2
Central nervous system complications	ICD-9-CM: 780.0, 293.0, 298.2, 309.1–309.9	Primary diagnosis, MDC 1, MDC 19, MDC 20
Death	Discharge status — death	None
Failure to rescue	Discharge status — death, with sepsis, pneumonia, upper gastrointestinal bleeding, shock or cardiac arrest, or deep venous thrombosis	Absence of sepsis, pneumonia, upper gastrointestinal bleeding, shock or cardiac arrest, or deep venous thrombosis
Wound infection	ICD-9-CM: 958.3, 998.5	Primary diagnosis
Pulmonary failure	ICD-9-CM: 514, 518.4, 518.5, 518.81, 518.82	Primary diagnosis, MDC 4, MDC 5, trauma†
Metabolic derangement	ICD-9-CM: 250.10, 250.11 (excluding diabetes as primary diagnosis), 998.0 (excluding those without operation or procedure during hospital stay), 788.5 (excluding acute myocardial infarction,† cardiac arrhythmia,† cardiac arrest,† or gastrointestinal hemorrhage† as primary diagnosis), 276 (excluding MDC 5, MDC 7, MDC 10, MDC 11), 251.0	Primary diagnosis, trauma

*ICD-9-CM denotes *International Classification of Diseases, 9th Revision, Clinical Modification;* MDC major diagnostic category; AIDS acquired immunodeficiency syndrome; and DRG diagnosis-related group.

†The condition was as defined in Iezzoni,[49] updated to match the 1997 codes.

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