Nurse Staffing and Mortality for Medicare Patients with Acute Myocardial Infarction

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Context: Recent hospital reductions in registered nurses (RNs) for hospital care raise concerns about patient outcomes.

Objective: Assess the association of nurse staffing with in-hospital mortality for patients with acute myocardial infarction (AMI).

Design, Setting, and Patients. Medical record review data from the 1994–1995 Cooperative Cardiovascular Project were linked with American Hospital Association data for 118,940 fee-for-service Medicare patients hospitalized with AMI. Staffing levels were represented as nurse to patient ratios categorized into quartiles for RNs and for licensed practical nurses (LPNs).

Main Outcome Measures. In-hospital mortality.

Results: From highest to lowest quartile of RN staffing, in-hospital mortality was 17.8%, 17.4%, 18.5%, and 20.1%, respectively ($P < 0.001$ for trend). However, from highest to lowest quartile of LPN staffing, mortality was 20.1%, 18.7%, 17.9%, and 17.2%, respectively $P < 0.001$). After adjustment for patient demographic and clinical characteristics, treatment, and for hospital volume, technology index, and teaching and urban status, patients treated in environments with higher RN staffing were less likely to die in-hospital; odds ratios (95% confidence intervals) of quartiles 4, 3, and 2 versus quartile 1 were 0.91 (0.86–0.97), 0.94 (0.88–1.00), and 0.96 (0.90–1.02), respectively. Conversely, after adjustment, patients treated in environments with higher LPN staffing were more likely to die in-hospital; odds ratios (95% confidence intervals) of quartiles 4, 3, and 2 versus quartile 1 were 1.07 (1.00–1.15), 1.02 (0.96–1.09), and 1.00 (0.94–1.07), respectively.

Conclusions: Even after extensive adjustment, higher RN staffing levels were associated with lower mortality. Our findings suggest an important effect of nurse staffing on in-hospital mortality.

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Over the past decade, many hospitals in the United States have undergone major operational reengineering in an attempt to both increase efficiency and decrease costs. These efforts often included reductions in the number of registered nurses (RNs) and increases in less well-educated "nurse extender" personnel.[1–5] Such changes frequently led to the movement of RNs into management roles and away from direct patient contact.[6] In response to these cost-containment measures, there has been a call for governmental regulation of minimum staffing levels to protect the quality of care received by hospitalized patients.[7]

Concerns about inadequate RN-to-patient ratios led to a congressionally mandated Institute of Medicine (IOM) report.[8] This report revealed that the effects of staffing reengineering on patient outcomes had not been adequately addressed and raised the possibility of deleterious effects on quality of care. There have been several studies of the association between nurse staffing ratios and patient outcomes.[2,9–15] However, the available studies typically do not account adequately for potential confounding influences. Consequently, the IOM urgently called for more empiric research. In an attempt to address concerns about quality of care, California became the first state to mandate minimum nurse to patient staffing ratios.[16]

We examined the association between nurse staffing ratios and mortality for Medicare patients with acute myocardial infarction (AMI) during 1994–1995. Although quality of care is influenced by all components of the healthcare team, we hypothesize that both physician and nursing actions influence mortality, each separately, and also in their actions as a team. Our main hypothesis is that nurse staffing ratios are associated with quality of care that is attributable to nursing. Specifically, we were interested in whether these ratios had an effect on in-hospital mortality independent of patient characteristics, treatment, and hospital characteristics. We obtained patient characteristics using medical record abstractions from the Cooperative Cardiovascular Project (CCP) dataset and nurse staffing ratios from the contemporaneous American Hospital Association (AHA) survey of hospital characteristics. By combining these data sets, we were able to perform extensive adjustment for both patient-level and hospital characteristics.

MATERIALS AND METHODS

Study Sample

The CCP was a national quality improvement project sponsored by the Centers for Medicare and Medicaid Services (CMS) to improve the care for Medicare patients hospitalized with AMI.[17,18] The original data set contained 234,754 randomly selected Medicare fee-for-service beneficiaries from all 50 states and almost all US acute care hospitals who were hospitalized with AMI from February 1994 through July 1995. Patients selected, using Medicare administrative data, were those having a principal discharge diagnosis code of 410 (AMI) according to the *International Classification of Diseases, Ninth Revision, Clinical Modification*. Included were patients from 6668 hospitals.[19] Medical record abstractors, centrally located and trained, reviewed the complete medical record to gather detailed clinical information for each hospitalization.[20]

Patients were excluded for the following reasons: AMI not confirmed by clinical criteria (n = 29,885), second hospital admission for AMI (n = 22,773), age younger than 65 years (n = 17,591), transferred to an index hospital (n = 39,025), transferred from an index hospital within 24 hours of admission (n = 42,176), or unclear nurse staffing ratios (n = 6254). Patients were confirmed as having AMI according to the clinical criteria listed by Marciniak et al.[20]

Hospital Characteristics

We merged the CCP dataset with the contemporaneous AHA Survey to obtain hospital characteristics.[21,22] To represent hospital volume, we used the total number of CCP patients at the hospital.[23] We quantified nurse staffing levels with 2 separate variables: the ratio of full-time equivalent RNs to average daily census (ADC) and the ratio of full-time equivalent licensed practical nurses (LPNs) to ADC. RNs constitute a more extensively trained category of nursing personnel than LPNs. In the AHA dataset, ADC was defined as the ratio of inpatient days to the number of days in the reporting period, and full-time equivalent was defined as the number of full-time personnel plus 0.5 times the number of part-time personnel. Vocational nurses were also counted as LPNs. If a hospital had an ADC equal to zero or if the ADC or number of full-time equivalent RNs or LPNs was unknown, then they were deemed to have unclear nurse staffing level and were excluded from the analyses. The number of RNs and LPNs were a representation of the entire hospital rather than specialized units. Staffing for both RNs and LPNs was categorized by their respective quartiles of nurse to ADC ratio. In addition to the nurse staffing variables, a variable representing nursing skill mix was constructed by taking the ratio of RNs to LPNs.

To determine hospital teaching status, we merged the CCP data set with CMS administrative data to derive the intern to bed ratio (I/B) for each hospital. Hospitals with ratio greater than 0.11 (the median I/B ratio of all teaching hospitals in our study data set) were classified as major teaching hospitals; those with an I/B ratio less than or equal to 0.11 but greater than 0 were classified as minor teaching hospitals; and those with an I/B of 0 were considered nonteaching hospitals.

As part of the CCP, key prescribing measures for the management of AMI were developed from the guidelines issued by the American Heart Association and the American College of Cardiology.[24] For our analyses, we chose 4 key prescribing measures that might be markers for better processes of care initiated by physicians but not necessarily directly related to nursing activities: 1) provision of acute reperfusion therapy (including thrombolysis or primary angioplasty) on admission, 2) administration of aspirin during hospitalization, 3) administration of angiotensin-converting enzyme inhibitors at discharge, and 4) administration of β-blockers at discharge. These measures have been previously validated[25] and are linked to favorable outcomes by clinical evidence.[26,27,20]

Mortality

We determined the mortality status of each patient during hospitalization and at 30 days after hospital admission from Medicare administrative data. We recognize that 30-day mortality is considered a standard for reporting hospital mortality, the reason for including this outcome in our analyses. However, we primarily modeled in-hospital mortality, which may be most directly affected by in-hospital nursing events.

Statistical Analysis

We categorized RN and LPN staffing ratios into their respective quartiles and compared patient baseline demographics and severity of illness across these levels using the χ^2 statistic for categorical variables, Cochran-Armitage test for trend,[28,29] and the *t* test for continuous variables.[30] Also, because 6254 patients were excluded due to unclear nurse staffing levels, we compared mortality rates between those that were excluded and those included in the analysis.

We considered the patient to represent a repeated measurement of hospital performance and developed 5 separate multivariable logistic models, all with in-hospital mortality as the dependent variable.[31] RN and LPN staffing quartiles were included as the main independent variables in 4 of the models (models 1, 3, 4, and 5). Model 1 adjusted for nursing skill mix (RN/LPN ratio), patient demographics (age, gender, and ethnicity), and severity of illness as defined by Krumholz et al,[32] using the clinical variables demonstrated to most parsimoniously predict short-term mortality in the CCP dataset. These variables included cardiac arrest on admission, congestive heart failure, systolic blood pressure on admission, serum creatinine levels, white blood cell count, and anterior or lateral AMI.

The predicted probability of death based on these variables was used in comparisons across nurse staffing levels. To replicate and expand upon results found by Allison et al[33] using this same dataset, model 2 only included teaching status, patient demographics, and severity of illness. To examine whether nurse staffing explains the associations of teaching status and mortality, model 3 included nurse staffing, teaching status, patient demographics, and severity of illness. Model 4 built upon the previous model by adding hospital characteristics, including those used in previous studies such as patient volume, rural/urban, and teaching status.[23,33] We also defined a hospital technology index based on the ability to perform coronary angiograms, percutaneous coronary interventions, and bypass grafting.

The final model (model 5) adjusted for patient demographics, severity of illness, hospital characteristics, and receipt of key prescribing measures for AMI. These measures were included for all patients and not restricted to ideal candidates. Previous work has shown that the teaching status/mortality association was partially explained by these treatment measures.[33] Since these treatment measures are mostly under the control of physicians rather than nurses, we used them in our final models to investigate potential residual confounding by other, unmeasured, hospital characteristics of the nurse staffing/mortality associations.

Out of concern for the possible introduction of bias due to excluding patients who transferred out of the hospital, all analyses were repeated without applying this exclusion criterion. All models adjusted for clustering within-hospital using generalized estimating equation methodology with an exchangeable correlation structure.[34] Before proceeding with models that used nurse staffing (both RN and LPN) as categorical variables, we first checked whether linearity assumptions would be violated by treating nurse staffing as a continuous variable.[35] Important 2-way interactions between RN staffing and LPN staffing, RN staffing and teaching status, LPN staffing and teaching status, RN staffing and urban status, and LPN staffing and urban status were examined. The c statistic was used to assess model discrimination[36] and the Akaike information criterion was used to compare relative model fit.[37] All analyses were conducted using SAS version 8.0.[38]

RESULTS

The study sample included 118,940 of the 234,754 patients and 4401 of the 6668 hospitals in the original CCP data set. The majority of the hospitals not included were excluded for criteria other than unclear nurse staffing (only 12% of the 2267 hospitals lost were excluded due to unclear nurse staffing). The 75th, 50th, and 25th percentiles for the RN to ADC ratios were 2.13, 1.72, and 1.40, respectively. The corresponding percentiles for LPN to ADC ratios were 0.38, 0.23, and 0.13, respectively. No difference in mortality was found between those with clear nurse staffing levels and those with unclear nurse staffing levels (results not shown). Patients treated in higher RN staffing environments had access to more technology and were more likely to be in teaching hospitals (Table 1). Our sample size was large, and there were many other statistically significant differences in the groups, but they were modest, and they were likely not clinically significant (Tables 1 and 2).

Linearity assumptions for treating nurse staffing as a continuous variable were not met; hence, only analyses that used categorical representations for nurse staffing (both RN and LPN) were considered. Mortality for patients treated in higher RN staffing environments was lower than for those treated in lower RN staffing environments (Fig. 1). In contrast, mortality for patients treated in higher LPN staffing environments was higher than those treated in lower LPN staffing environments (Fig. 1).

Although attenuated, nurse staffing/mortality associations remained significant after adjustment for patient and hospital characteristics, nursing skill mix, and receipt of key prescribing measures (Table 3). Model 1 shows that patient characteristics did not explain our observed nurse staffing/mortality associations. Model 2 replicates a step in previous CCP analyses[33] and, combined with Model 3, shows that the association between teaching status and mortality is partially, but not entirely, explained by nurse staffing levels. In addition, Model 3 shows that the nurse/staffing mortality association is not explained by teaching status. Model 4 shows persistence, albeit somewhat attenuated, of the nurse staffing/mortality association after additional hospital characteristics are added to Model 3. Finally, Model 5 shows that when treatment is added to the previous models, the nurse staffing/mortality association is attenuated further, but significant associations between the highest levels of RN staffing and lowest levels of LPN staffing persist. Nursing skill mix was found not to have an independent association with mortality. No significant interactions between RN staffing levels and LPN staffing levels, nurse staffing (both RN and LPN), and teaching status or urban status were detected.

Mortality/nurse staffing associations, both before and after adjustments, were similar when in-hospital mortality was replaced with mortality at 30 days following admission

TABLE 1. Selected hospital characteristics by RN staffing level (mean, SD, and percents); Cooperative Cardiovascular Project, 1994-1995*

Characteristic	Overall (N = 118,940)	Quartile 4 RN staffing (N = 29,726)	Quartile 3 RN staffing (N = 29,669)	Quartile 2 RN staffing (N = 29,882)	Quartile 1 RN staffing (N = 29,663)	*P* Value for trend
Teaching status, %						
Major teaching	18.4	19.9	20.6	18.4	14.9	
Minor teaching	20.8	19.7	21.2	23.8	18.6	<0.001
Nonteaching	60.8	60.5	58.2	57.8	66.6	
Hospital volume	67.2 (52.7)	61.2 (52.4)	75.3 (56.2)	77.7 (54.0)	54.4 (43.6)	<0.001
Coronary angiogram capable, %	62.0	65.9	68.5	66.4	47.4	<0.001
Percutaneous transluminal coronary angioplasty (PTCA) capable, %	46.5	50.3	54.5	52.2	28.7	<0.001
Coronary artery bypass grafting (CABG) capable, %	42.6	46.8	52.2	46.2	24.9	<0.001
Bed size, mean (SD)	301.7 (194.9)	285.3 (206.8)	327.4 (195.4)	327.5 (184.1)	265.0 (180.2)	<0.001
Urban, %	81.1	79.9	85.5	85.8	72.9	<0.001
RN/ADC Ratio, mean (SD)	1.80 (0.7)	2.66 (0.6)	1.91 (0.1)	1.57 (0.1)	1.06 (0.3)	—
LPN/ADC ratio, mean (SD)	0.30 (0.3)	0.36 (0.4)	0.28 (0.3)	0.3 (0.2)	0.27 (0.2)	<0.001
Skill mix (RN/LPN) ratio, mean (SD)	14.6 (30.6)	19.8 (38.7)	16.3 (25.2)	12.3 (26.6)	10.0 (29.4)	<0.001

*Characteristics are for the hospital, but the patient is the unit of analyses (eg, 18.4% of all patients were admitted teaching hospitals, and 19.9% of all patients in highest RN quartile were admitted to teaching hospitals).

(results not shown). In addition, these findings held in analyses that retained patients who transferred out of the hospital (results not shown).

DISCUSSION

We found that Medicare patients with AMI who were treated in higher RN staffing environments had a significant in-hospital mortality advantage, as did patients treated in lower LPN staffing environments. These unadjusted survival advantages (approximately 2% differential between lowest and highest quartiles of both RN and LPN staffing) persisted after extensive multivariable adjustment for patient characteristics and hospital characteristics. The mortality differences we observed are related to differences in hospital

TABLE 2. Selected patient characteristics by RN staffing level (mean, SD, and percents); Cooperative Cardiovascular Project, 1994-1995

Characteristic	Overall (N = 118,940)	Quartile 4 RN staffing (N = 29,726)	Quartile 3 RN staffing (N = 29,669)	Quartile 2 RN staffing (N = 29,882)	Quartile 1 RN staffing (N = 29,663)	*P* Value for trends
Age, mean (SD)	77.4 (7.5)	77.3 (7.5)	77.2 (7.5)	77.3 (7.5)	77.9 (7.6)	<0.001
Female, %	50.7	50.0	50.3	50.4	51.9	<0.001
Race/ethnicity, %						
African American	6.5	5.3	7.0	6.5	7.3	
Caucasian	89.7	91.8	90.4	89.7	87.0	<0.001
Other	3.8	2.9	2.6	3.8	6.8	
Chronic renal failure, %	5.4	5.2	5.7	5.6	5.2	0.80
Congestive heart failure, %	44.8	43.1	44.3	45.3	46.6	<0.001
Diabetes, %	26.0	25.3	25.6	26.2	26.8	<0.001
Hypertension, %	37.9	38.4	38.4	38.1	37.0	<0.001
Prior myocardial infarction, %	69.2	68.4	68.5	69.3	70.0	<0.001
Stroke, %	15.3	15.4	15.4	15.0	15.3	0.35
Predicted probability of death, mean (SD)*	0.18 (0.2)	0.18 (0.2)	0.18 (0.2)	0.19 (0.2)	0.19 (0.2)	<0.001

*Predicted probability of death was calculated using severity of illness variables found to most parsimoniously predict short-term mortality. A listing of these variables can be found in the Statistical Analysis section.

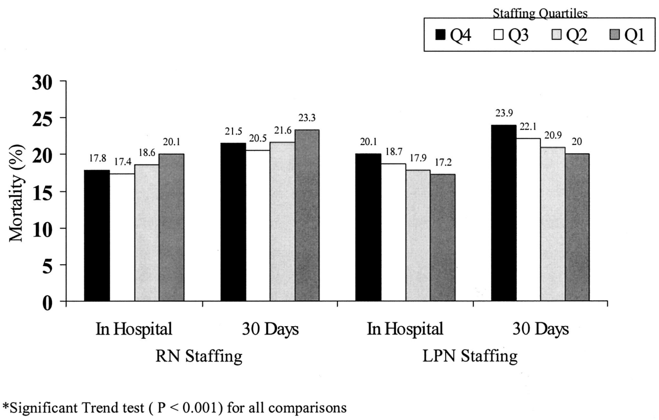

FIGURE 1. Unadjusted Mortality by Registered Nurse and Licensed Practical Nurse Staffing Levels, Cooperative Cardiovascular Project, 1994–1995*.

staffing patterns and may derive from substitution of personnel with less training or experience to perform required assessment, clinical judgment, and/or sophisticated technical functions.[39] These substitutions may result in poorer quality of care and higher mortality and are generally met with much resistance and concern by RNs for the safety of patients.[40]

Although some previous studies have found a positive relationship between level of nurse staffing and favorable patient outcomes,[2,6,12,41–47] this has not been a completely consistent finding.[9,48–50] In a recent study, Needleman and colleagues[51] found that a higher proportion of hours of nursing care by RNs was associated with better outcomes for hospitalized patients. This study was not conducted in an AMI population, however, and lacked detailed adjustment for treatment variables. The relationship between higher RN/patient ratios or RN/nursing staff ratios and better outcomes has also been observed in other studies.[2,42,44,51–56]

Focusing specifically on mortality, other studies have found an inverse relationship with nurse staffing.[8,43,57–59] For example, Hartz and colleagues[12] found that hospitals that had a higher RN to total nurse ratio had lower mortality. In addition, hospitals that had more RNs per bed had lower mortality.[60]

With this same CCP data set, Allison and colleagues[33] described the association of teaching status with better quality of care and lower mortality. Similarly, Thiemann and colleagues[23] found an association between mortality and AMI patient volume. Our study builds upon these previous analyses by demonstrating that nurse staffing explains part of these effects. Nonetheless, even after adjustment for technology index, teaching status, rural/urban status, and volume there was still a mortality advantage for those treated in environments with higher RN staffing. Allison et al[33] found that adjustment for patient characteristics and receipt of 4 key prescribing measures greatly attenuated the mortality difference between teaching and nonteaching hospitals. This suggested that the survival advantage of patients admitted to teaching hospitals may be due to better processes of care, as identified by these key prescribing measures.

Notwithstanding a pilot study showing that appropriately educated nurses can assess patients with suspected AMI accurately for thrombolytic therapy,[61] our 4 key prescribing measures reflect initiation of therapy by physicians and do not fall under the direct purview of nursing staff. These key prescribing measures might, however, also be markers of a more favorable hospital environment, possibly confounding the association between nurse staffing and mortality. Therefore, our final model adjusted for the same 4 key prescribing measures that Allison et al[33]used. We found that, although attenuated, the mortality advantage for those treated in higher RN staffing environments persisted. These results suggest that nurse staffing may have an independent effect beyond that of institutional resources and beyond the effect of better processes of care that are not directly related to RN staffing.

Plausible explanations for the nurse staffing/mortality associations include that RNs contribute independently and importantly to the quality of patient care. Possible mechanisms include the fact that RNs are skilled in delivering aspects of care that are highly relevant to patient well-being. Furthermore, because physicians have limited time to spend with patients, they often rely on RNs to alert them to evidence of complications of AMI such as congestive heart failure, recurrent ischemia,[62,63]and the development of pulmonary edema. In their landmark article published in 1967, Killip and Kimball[64] found that the delegation of some medical authority to trained nurses reduced mortality among AMI patients in a coronary care unit. In addition, RNs are critical for implementing standardized order sets and clinical assessments that may trigger further physician evaluation and action. These considerations are consistent with studies showing a direct link between nurse experience and quality of care.[65]

Still, the association of nurse staffing ratios with survival may partially reflect residual confounding by institutional and patient characteristics. For example, favorable nurse staffing ratios may be associated with greater institutional resources in general. In fact, important examples linking multiple organizational characteristics with patient outcomes have been reported.[9,12] For instance, Bradley et al[66] reported a positive association between local hospital quality improvement environment and use of β-blockers in AMI.

The need for caution in attributing increased mortality to decreased nurse staffing follows from the difficulties in measuring quality of care in general. Although Donabedian[67] in 1966 conceptualized quality measurement as reflecting the domains of structure, process, and outcome, devising a set of comprehensive and equitable quality measures remains elusive.[68] Progress has been made,[69] and we can point with relative certainty to areas that need improvement for a variety

TABLE 3. Odds ratios (OR) and 95% confidence intervals (CI) for in-hospital mortality models, Cooperative Cardiovascular Project, 1994-1995*

Covariates	Model 1, OR (95% CI)	Model 2, OR (95% CI)	Model 3, OR (95% CI)	Model 4, OR (95% CI)	Model 5, OR (95% CI)
RN staffing level					
Quartile 4 (vs. quartile 1)	0.87 (0.82, 0.92)	—	0.88 (0.83, 0.93)	0.89 (0.84, 0.95)	0.91 (0.86, 0.97)
Quartile 3 (vs. quartile 1)	0.88 (0.83, 0.93)	—	0.88 (0.84, 0.94)	0.91 (0.86, 0.96)	0.94 (0.88, 1.00)
Quartile 2 (vs. quartile 1)	0.91 (0.86, 0.96)	—	0.91 (0.87, 0.97)	0.94 (0.89, 1.00)	0.96 (0.90, 1.02)
LPN staffing level					
Quartile 4 (vs. quartile 1)	1.15 (1.08, 1.22)	—	1.13 (1.06, 1.20)	1.12 (1.05, 1.19)	1.07 (1.00, 1.15)
Quartile 3 (vs. quartile 1)	1.05 (0.99, 1.12)	—	1.04 (0.97, 1.10)	1.03, (0.97, 1.10)	1.02 (0.96, 1.09)
Quartile 2 (vs. quartile 1)	0.99 (0.93, 1.05)	—	0.99 (0.93, 1.05)	0.99 (0.93, 1.05)	1.00 (0.94, 1.07)
Nursing skill mix (RN/LPN)	1.00 (1.00, 1.00)	—	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
African American (vs. Caucasian)	0.80 (0.74, 0.86)	0.81 (0.75, 0.87)	0.81 (0.75, 0.87)	0.80 (0.74, 0.86)	0.78 (0.72, 0.85)
Other Races (vs. Caucasian)	1.02 (0.93, 1.11)	1.04 (0.95, 1.13)	1.02 (0.94, 1.12)	1.02 (0.93, 1.11)	0.98 (0.90, 1.08)
Male (vs. female)	0.79 (0.76, 0.82)	0.79 (0.76, 0.82)	0.79 (0.76, 0.82)	0.79 (0.76, 0.82)	0.82 (0.79, 0.85)
Age (1-year increment)	1.04 (1.04, 1.04)	1.04 (1.04, 1.04)	1.04 (1.04, 1.04)	1.04 (1.04, 1.04)	1.04 (1.04, 1.04)
Cardiac arrest on admission (yes/no)	11.54 (10.84, 12.28)	11.51 (10.82, 12.24)	11.52 (10.83, 12.26)	11.53 (10.83, 12.27)	9.89 (9.25, 10.57)
Congestive heart failure (yes/no)	1.22 (1.18, 1.27)	1.22 (1.17, 1.26)	1.22 (1.18, 1.27)	1.22 (1.18, 1.27)	1.37 (1.32, 1.43)
Admission systolic blood pressure	0.98 (0.98, 0.98)	0.98 (0.98, 0.98)	0.98 (0.98, 0.98)	0.98 (0.98, 0.98)	0.98 (0.98, 0.99)
Serum creatinine	2.01 (1.94, 2.08)	2.02 (1.95, 2.09)	2.01 (1.94, 2.09)	2.01 (1.94, 2.08)	1.78 (1.71, 1.85)
White blood cell count	1.05 (1.05, 1.06)	1.05 (1.05, 1.06)	1.05 (1.05, 1.06)	1.05 (1.05, 1.06)	1.05 (1.04, 1.05)
Anterior or lateral AMI (yes/no)	1.57 (1.51, 1.63)	1.58 (1.52, 1.64)	1.57 (1.51, 1.63)	1.57 (1.51, 1.63)	1.47 (1.41, 1.53)
Hospital teaching status					
Major teaching (vs. nonteaching)	—	0.87 (0.83, 0.93)	0.93 (0.88, 0.99)	0.98 (0.92, 1.04)	1.13 (1.05, 1.20)
Minor teaching (vs. nonteaching)	—	0.96 (0.92, 1.01)	0.99 (0.94, 1.04)	1.03 (0.98, 1.08)	1.09 (1.03, 1.15)
Urban (vs. rural)	—	—	—	1.04 (0.99, 1.10)	1.04 (0.98, 1.10)
Hospital volume	—	—	—	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
Technology index†		—	—		
Level 1 vs. Level 0	—	—	—	1.03 (0.97, 1.09)	1.04 (0.98, 1.10)
Level 2 vs. Level 0	—	—	—	0.92 (0.83, 1.02)	0.97 (0.87, 1.08)
Level 3 vs. Level 0	—	—	—	0.90 (0.85, 0.95)	0.91 (0.86, 0.97)
Receipt of therapy dummy variables‡					
Category 1	—	—	—	—	0.00 (0.00, 0.00)
Category 2	—	—	—	—	0.21 (0.20, 0.22)
Category 3	—	—	—	—	1.62 (1.43, 1.82)
Category 4	—	—	—	—	0.28 (0.26, 0.30)
c Statistic	0.806	0.806	0.806	0.806	0.854
Akaike information criterion	85,383	87,122	85,351	85,303	75,987

*Models are described in the Statistical Analysis section. OR indicates odds ratio; CI, confidence interval; and dashes, analysis not applicable.

†We created 4 mutually exclusive levels of technology availability: Level 0, hospital has no capacity to perform coronary angiogram, percutaneous coronary intervention (PCI), or coronary artery bypass grafting (CABG); Level 1, hospital has capacity to perform coronary angiography but not PCI or CABG; Level 2, hospital has capacity to perform coronary angiography and PCI but not CABG; Level 3, hospital has capacity to perform all 3 procedures.

‡Because of significant interactions between receipt of acute reperfusion and aspirin, we created 5 mutually exclusive groups of patients: therapy category 0, those who received no therapy (reference group); therapy category 1, those who received no aspirin and no reperfusion but did receive angiotensin-converting enzyme (ACE) inhibitors and/or β-blockers; therapy category 2, those who received no reperfusion but did receive aspirin and/or ACE inhibitors and/or β-blockers; therapy category 3, those who received no aspirin but did receive reperfusion and/or ACE inhibitors and/or β-blockers; therapy category 4, those who received aspirin and reperfusion and/or ACE inhibitors and/or β-blocker.

of conditions.[70] However, some of the most difficult aspects of quality measurement, such as how to incorporate patient perceptions[71,72] and how to perform risk adjustment,[73] have not been satisfactorily resolved. Hence, nurse-staffing ratios may be a marker for a latent core of unmeasured quality constructs.

Our findings have policy implications. As a core strategy, hospital reengineering often includes cross-training of unit-based workers to take on tasks traditionally outside of the scope of their work.[6,74,75] Others have noted, and our findings also suggest, that additional continuing education, in-service education, and/or orientation may be required to prepare LPNs for those new roles and scope of practice.[76] Our interpretation of a possible deleterious effect of reduction in RN staffing is consistent with studies that have examined the effect of reducing skill mix on patient outcome.[77–81] These small studies suggest but do not conclusively support the idea that retaining a strong nursing skill mix has a positive effect on patient outcomes.

According to Clark and Thurston,[82] in a study of LPN roles and job descriptions, it was found that a high percentage of LPNs (43% of those surveyed) were assigned to Level III (Medicus classification) patients, who may have heavier physical care needs and may require special skills. Clark and Thurston[82] note that LPNs may not have the background to deal with this level of patient demand. In addition, although not objectively measured by their study, some LPNs reported activities outside of their level of expertise. Of note, the California Nurses Association protested 3 California hospitals' use of unlicensed personnel to perform technical nursing tasks.[83] Because our data are observational, however, we cannot infer that adjustment of nurse staffing ratios will automatically lead to improvement in patient outcomes.

Our study has several limitations. Although ADCs were used in calculating RN and LPN staffing ratios, they may not accurately reflect ratios in the specialty units most likely to contain AMI patients. Also, because of limitations in the data, the number of RNs and LPNs were representative of the entire hospital rather than a specialized unit such as cardiac care. In addition, we were not able to identify nursing personnel who work in the outpatient department. This dataset also did not allow for the quantification of the number of hours of contact supplied by each type of nursing personnel. Although we have complete data for RN staffing, there are significant gaps in the data for non-RN staffing. We did not have access to staffing levels of nursing assistants. Hospitals that depend on high levels of LPN staffing may also have an above-average reliance on nursing assistants, nursing assistants being a group we were unable to examine. This reliance might account for some of the difference observed in high-LPN-staffed hospitals. The AHA data set captures the number of ancillary personnel by facility but does not allow the association of ancillary personnel with specific patient care-related tasks. Therefore, we limited our analyses of non-RN staff to LPNs, who may be assumed with more certainty to have a direct patient-care role rather than including ancillary staff.

These cross-sectional data were collected from retrospective chart review and administrative files, which have known limitations.[84,85] Clearly, causal inference cannot be made from such data. Adjustment for patient socioeconomic factors was not performed. We considered all-cause mortality and did not examine cardiovascular deaths separately. However, because we focused on in-hospital deaths, we probably captured a larger proportion of cardiovascular deaths.

An additional concern may be that by excluding those patients who transferred out of the hospital we are introducing bias by retaining a cohort of patients with a greater severity of illness from lower-staffed or smaller hospitals (those that are more likely to transfer patients). However, in analyses that retained these patients, mortality differences persisted between nurse staffing levels.

In contrast, there are important strengths of this study. To our knowledge, this is the largest national study examining the relationship of nurse staffing levels with mortality and quality of care in Medicare patients with AMI. This large data set provided adequate power to detect important relationships that may have been missed by earlier negative studies. Because of the clinical richness of our data set, we were able to perform risk adjustment and include other potential explanatory and confounding variables as recommended by the IOM report on nurse staffing levels.

CONCLUSIONS

In this study of Medicare patients with AMI, higher RN staffing levels were associated with lower in-hospital mortality. We found a mortality *advantage* for those treated in high RN staffing environments and a mortality *disadvantage* for those treated in high LPN staffing environments. These differences were attenuated but not eliminated after extensive multivariable adjustment for patient and hospital characteristics. Although hospital staff restructuring often carries the admirable goal of increased efficiency, care must be given to how this goal is achieved. Our research suggests the need for further investigation of how nurse staffing affects patient outcomes. If the causal link suggested, but not proven, by our findings is substantiated, then the goal of increased efficiency that underlies hospital restructuring should not be achieved by reductions in nurse staffing without careful and complete examination.

REFERENCES

1. Bond CA, Raehl CL. Changes in pharmacy, nursing, and total personnel staffing in U.S. hospitals, 1989–1998. *Am J Health Syst Pharm*. 2000;57:970–974.
2. Blegen MA, Goode CJ, Reed L. Nurse staffing and patient outcomes. *Nurs Res*. 1998;47:43–50.
3. Seago JA. The California experiment: alternatives for minimum nurse-to-patient ratios. *J Nurs Admin*. 2002;32:48–58.
4. Kenney P. Maintaining quality care during a nursing shortage using license practical nurses in acute care. *J Nurs Care Q*. 2001;15:60–68.
5. McGillis-Hall L. Staff mix models: complementary or substitution roles for nurses. *Nurs Admin Q*. 1997;21:31–39.
6. Aiken LH, Clarke SP, Sloane DM. Hospital restructuring: does it adversely affect care and outcomes? *J Nurs Admin*. 2000;30:457–465.

7. Kovner CT. State regulation of RN-to-patient ratios. *Am J Nurs*. 2000; 100:61–63, 65.
8. Wunderlich GS. *Nursing Staff in Hospitals and Nursing Homes: Is It Adequate*? Washington, DC:Institute of Medicine, National Academy Press;1996.
9. Shortell SM, Zimmerman JE, Rousseau DM, et al. The performance of intensive care units: does good management make a difference? *Med Care*. 1994;32:508–525.
10. Blegen MA, Vaughn T. A multisite study of nurse staffing patient occurrences. *Nurs Econ*. 1998;16:196–203.
11. Aiken LH, Sloane DM, Lake ET, et al. Organization and outcomes of inpatient AIDS care. *Med Care*. 1999;37:760–772.
12. Hartz AJ, Krakauer H, Kuhn EM, et al. Hospital characteristics and mortality rates. *N Engl J Med*. 1986;321:1720–1725.
13. Hunt J, Hagen S. Nurse to patient rations and patient outcomes. *Nurs Times*. 1998;94:63–66.
14. Robertson RH, Hassan M. Staffing intensity, skill mix and mortality outcomes: the case of chronic obstructive lung disease. *Health Serv Manage Res*. 1999;12:258–268.
15. Lichtig LK, Knauf RA, Milholland DK. Some impacts of nursing on acute care hospital outcomes. *J Nurs Admin*. 1999;29:25–33.
16. Spetz J. What should we expect from California's minimum nurse staffing legislation: *J Nurs Admin*. 2001;31:132–140.
17. Jencks SF, Wilensky GR. The health care quality improvement initiative: a new approach to quality assurance in Medicare. *JAMA*. 1992; 268:900–903.
18. Ellerbeck EF, Jencks SF, Radford MJ, et al. Quality of care for Medicare patients with acute myocardial infarction: a four-state pilot study from the Cooperative Cardiovascular Project. *JAMA*. 1995;273:1509–1514.
19. Health Care Financing Administration. *International Classification of Diseases, Ninth Revision, Clinical Modification*. Publication no. (PHS) 97–1260. 6th ed. Washington, DC: Health Care Financing Administration, Government Printing Office; 1997.
20. Marciniak TA, Ellerbeck EF, Radford MJ, et al. Improving the quality of care for Medicare patients with acute myocardial infarction: results from the Cooperative Cardiovascular Project. *JAMA*. 1998;279:1351–1357.
21. Rosenthal GE, Harper DL, Quinn LM, et al. Severity-adjusted mortality and length of stay in teaching and nonteaching hospitals: results of a regional study. *JAMA*. 1997;278:485–490.
22. American Hospital Association. *American Hospital Association Guide to the Health Care Fields*. Chicago, IL: Healthcare InfoSource; 1996.
23. Thiemann DR, Coresh J, Oetgen WJ, et al. The association between hospital volume and survival after acute myocardial infarction in elderly patients. *N Engl J Med*. 1999;340:1640–1648.
24. Ryan TJ, Anderson JL, Antman EM, et al. ACC/AHA guidelines for the management of patients with acute myocardial infarction: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Acute Myocardial Infarction). *Circulation*. 1996;94: 2341–2350.
25. Lambert-Hubert D, Ellerbeck E, Wallace R, et al. Validating quality of care indicators for patients with acute myocardial infarction. *Clin Perform Qual Health Care*. 1994;2:219–222.
26. Collins R, Peto R, Baigent C, et al. Aspirin, heparin, and fibrinolytic therapy in suspected acute myocardial infarction. *N Engl J Med*. 1997; 336:847–860.
27. Hennekens CH, Albert CM, Godfried SL, et al. Adjunctive drug therapy of acute myocardial infarction: evidence from clinical trials. *N Engl J Med*. 1996;335:1660–1667.
28. Cochran WG. Some methods of strengthening the common chi-square tests. *Biometrics*. 1954;10:417–451.
29. Armitage P. Test for linear trends in proportions and frequencies. *Biometrics*. 1955;11:375–386.
30. Rosner B. *Fundamentals of Biostatistics.* 4th ed. Belmont, CA: Wadsworth Publishing Company; 1995.
31. Harrell FEJr, Lee KL, Mark DB. Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. *Stat Med*. 1996;15:361–387.
32. Krumholz HM, Chen J, Wang Y, et al. Comparing AMI mortality among hospitals in patients 65 years of age and older: evaluating methods of risk adjustment. *Circulation*. 1999;99:2986–2992.
33. Allison JJ, Kiefe CI, Weissman NW, et al. Relationship of hospital teaching status with quality of care and mortality for Medicare patients with acute MI. *JAMA*. 2000;284:1256–1262.
34. Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika*. 1986;73:13–22.
35. Hosmer DW, Lemeshow S. *Applied Logistic Regression.* 2nd ed. New York: John Wiley & Sons; 2000.
36. Centor RM. Signal detectability: the use of ROC curves and their analyses. *Med Decis Making*. 1991;11:102–106.
37. Akaike H. Autoregressive models for prediction. *Ann Inst Stat Math*. 1969;21:243–247.
38. SAS [computer program]. Version 8.0. Cary, NC: SAS Institute; 1999.
39. Peterson C, Keepnews D. Quality and staffing issues dominate the ANA agenda. *Am J Nurs*. 1997;97:53–54.
40. Huber DG, Blegen MA, McCloskey JC. Use of nursing assistants: staff nurse opinions. *Nurs Manage*. 1994;25:64–68.
41. Knaus WA, Draper EA, Wagner DP, et al. An evaluation of outcome from intensive care in major medical centers. *Ann Intern Med*. 1986; 104:410–418.
42. Kramer M, Schmalenberg C. Magnet hospitals, part I: institutions of excellence. *J Nurs Admin*. 1988;18:13–24.
43. Prescott PA. Nursing: an important component of hospital survival under a reformed health care system. *Nurs Econ*. 1993;11:192–199.
44. Aiken LH, Smith HL, Lake ET. Lower Medicare mortality among a set of hospitals known for good nursing care. *Med Care*. 1994;32:771–787.
45. Scott WR, Forest WH, Brown BW. Hospital structure and postoperative mortality and morbidity. In: Shortell SM, Brown M, eds. *Organizational Research in Hospitals*. Chicago: Blue Cross Association; 1976.
46. Kovner C, Jones C, Zhan C, et al. Nurse staffing and postsurgical adverse events: an analysis of administrative data from a sample of U. S. hospitals. *Health Serv Res*. 2002;37:611–629.
47. Unruh L. Licensed nurse staffing and adverse events in hospitals. *Med Care*. 2003;41:142–152.
48. Al-Haider AS, Wan TT. Modeling organizational determinants of hospital mortality. *Health Serv Res*. 1991;26:303–323.
49. Shortell SM, Hughes EF. The effects of regulation, competition, and ownership on mortality rates among hospital inpatients. *N Engl J Med*. 1988;318:1100–1107.
50. Needleman J, Buerhaus PI, Mattke S, et al. *Nurse Staffing and Patient Outcomes in Hospitals.* Boston: Harvard School of Public Health; 2001.
51. Needleman J, Buerhaus PI, Mattke S, et al. Nurse staffing levels and the quality of care in hospitals. *N Engl J Med*. 2002;346:1715–1722.
52. Shindul-Rothschild J, Long-Middleton EDB. 10 Keys to quality care. *Am J Nurs*. 1997;97:35–43.
53. Flood S, Diers D. Nurse staffing, patient outcome and cost. *Nurs Manage*. 1988;19:34–41.
54. Brennan T, Leape L, Laird N, et al. Incidence of adverse events and negligence in hospitalized patients: results of the Harvard Medical Practice study I. *N Engl J Med*. 1991;18:11–24.
55. ANA. *Implementing Nursing's Report Care: A Study of RN Staffing, Length.* Washington, DC: American Nursing Association; 1997.
56. Kovner C, Gergen PJ. Nurse staffing levels and adverse events following surgery in US hospitals. *J Nurs Scholarsh*. 1998;30:315–321.
57. Krakauer H, Bailey RC, Skellan KJ, et al. Evaluation of the HCFA model for the analysis of mortality following hospitalization. *Health Serv Res*. 1992;27:317–335.
58. Manheim LM, Feinglass SM, Shortell SM, et al. Regional variation in Medicare hospital mortality. *Inquiry*. 1992;29:55–66.
59. Silber J, Rosenbaum P, Ross R. Comparing the contributions of groups of predictors: which outcomes vary with hospital rather than patient characteristics? *J Am Stat Assoc*. 1995;90:7–18.
60. Bond CA, Raehl CL, Pitterle MS, et al. Health care professional staffing, hospital characteristics, and hospital mortality rates. *Pharmacotherapy*. 1999;19:130–138.
61. Quinn T. Can nurses safely assess suitability for thrombolytic therapy? a pilot study. *Intens Crit Care Nurs*. 1995;11:126–129.
62. Pelter M, Adams M, Wung S, et al. Peak time occurrence of myocardial ischemia in the coronary care unit. *Am J Crit Care*. 1998;7:411–417.
63. Small S. Assessment and intervention for ischemic chest pain: a case

study with legal implications for nursing practice. *Prog Cardiovasc Nurs*. 1996;11:17–22.
64. Killip T, Kimball J. Treatment of myocardial infarction in a coronary care unit: a two-year experience with 250 patients. *Am J Cardiol*. 1967;20:457–464.
65. Blegen MA, Vaughn TE, Goode CJ. Nurse experience and education: effect on quality of care. *J Nurs Admin*. 2001;31:33–39.
66. Bradley EH, Holmboe ES, Mattera JA, et al. A qualitative study of increasing beta-blocker use after myocardial infarction: why do some hospitals succeed? *JAMA*. 2001;285:2604–2611.
67. Donabedian A. Evaluating the quality of medical care. *Mil Mem Fund Q*. 1966;44(suppl):166–206.
68. Campbell SM, Roland MO, Buetow SA. Defining quality of care. *Soc Sci Med.* 2000;51:1611–1625.
69. Brook RH, McGlynn EA, Shekelle PG. Defining and measuring quality of care: a perspective from US researchers. *Int J Qual Health Care*. 2000;12:281–295.
70. Chassin MR. Is health care ready for Six Sigma quality? *Milbank Q*. 1998;76:565–591.
71. Sofaer S, Gruman J, Connaughton S, et al. Developing performance indicators that reflect an expanded view of health: findings from the use of an innovative methodology. *Jt Comm J Qual Improv*. 2000;26:189–202.
72. Oermann MH, Dillon SL, Templin T. Indicators of quality of care in clinics: patients' perspectives. *J Healthc Qual*. 2000;22:9–11.
73. Iezzoni LI. The risks of risk adjustment. *JAMA*. 1997;278:1600–1607.
74. Ingersoll G. Licensed practical nurses in critical care areas: intensive care unit nurses' perceptions about their role. *Heart Lung J Acute Crit Care*. 1995;24:83–88.
75. Eriksen L, Quandt B, Teinert D, et al. A registered nurse licensed vocation nurse partnership model for critical care nursing. *J Nurs Admin*. 1992;22:28–38.
76. Molzahn AE. Towards a clarification of the scope of practice of registered nurses and licensed practical nurses. *AARN News Lett*. 1992; 48:16–17.
77. Bostrom J, Zimmerman J. Restructuring nursing for a competitive health care environment. *Nurs Econ*. 1993;11:35–41, 54.
78. Grillo-Peck AM, Risner PB. The effect of a partnership model on quality and length of stay. *Nurs Econ*. 1993;13:367–372, 374.
79. Lengacher CA, Mabe PR, Bowling CD, et al. Redesigning nursing practice: the partners in patient care model. *J Nurs Admin*. 1993;23:31–37.
80. Mularz LA, Maher M, Johnson AP, et al. Theory M: a restructuring process. *Nurs Manage (Chicago)*. 1995;26:49–52.
81. Powers PH, Dickey CA, Ford A. Evaluating an RN/co-worker model. *J Nurs Admin*. 1990;20:11–15.
82. Clark T, Thurston N. The RN and LPN skill mix. *Can Nurse*. 1994;90: 19–22.
83. Nurses protest staff policy. *J Nurs Admin.* 1991;21:5.
84. Quam L, Ellis L, Venus P, et al. Using claims data for epidemiologic research. The concordance of claims-based criteria with the medical record and patient survey for identifying a hypertensive population. *Med Care*. 1993;31:498–507.
85. Allison JJ, Wall TC, Spettell CM, et al. The art and science of chart review. *Jt Comm J Qual Improv*. 2000;26:115–136.