The Association of Registered Nurse Staffing Levels and Patient Outcomes

Systematic Review and Meta-Analysis

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Objective: To examine the association between registered nurse (RN) staffing and patient outcomes in acute care hospitals.

Study Selection: Twenty-eight studies reported adjusted odds ratios of patient outcomes in categories of RN-to-patient ratio, and met inclusion criteria. Information was abstracted using a standardized protocol.

Data Synthesis: Random effects models assessed heterogeneity and pooled data from individual studies. Increased RN staffing was associated with lower hospital related mortality in intensive care units (ICUs) [odds ratios (OR), 0.91; 95% confidence interval (CI), 0.86–0.96], in surgical (OR, 0.84; 95% CI, 0.80–0.89), and in medical patients (OR, 0.94; 95% CI, 0.94–0.95) per additional full time equivalent per patient day. An increase by 1 RN per patient day was associated with a decreased odds ratio of hospital acquired pneumonia (OR, 0.70; 95% CI, 0.56–0.88), unplanned extubation (OR, 0.49; 95% CI, 0.36–0.67), respiratory failure (OR, 0.40; 95% CI, 0.27–0.59), and cardiac arrest (OR, 0.72; 95% CI, 0.62–0.84) in ICUs, with a lower risk of failure to rescue (OR, 0.84; 95% CI, 0.79–0.90) in surgical patients. Length of stay was shorter by 24% in ICUs (OR, 0.76; 95% CI, 0.62–0.94) and by 31% in surgical patients (OR, 0.69; 95% CI, 0.55–0.86).

Conclusions: Studies with different design show associations between increased RN staffing and lower odds of hospital related mortality and adverse patient events. Patient and hospital characteristics, including hospitals' commitment to quality of medical care, likely contribute to the actual causal pathway.

Key Words: nursing staff, hospital, quality, length of stay, mortality, safety, failure to rescue

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Nurses are crucial to providing high-quality care.[1–3] Hospital restructuring in the last 2 decades, in response to the advent of managed care and diagnosis-related groups, shortened hospitalizations of acutely ill patients and placed new stresses on nurses to provide safe patient care.[4–6] Increasing the nurse-to-patient ratios has been recommended as a means to improve patient safety.[7–9] California is the only state that has mandatory nurse-to-patient ratios, although mandatory nurse staffing legislation has been proposed in several other states[10,11] as well as all Medicare participating hospitals.[12] However, these mandatory staffing regulations are not supported by evidence-based optimal nurse-to-patient ratios.[13]

We undertook a systematic review of the extant literature on the association between registered nurse (RN)-to-patient ratios, and outcomes. These ratios have been expressed in 2 different ways.[14] One method uses a ratio of full time equivalents (FTEs) of RNs per patient day, whereas the second uses the number of patients assigned to 1 RN per shift in the unit (see Appendix A which can be found on the Medical Care website, www.lww-medicalcare.com). This study is part of a larger evidence report conducted for the Agency for Healthcare Research and Quality (AHRQ) to examine several key questions related to nurse staffing and patient outcomes in acute care hospitals. The full report can be found at http://www.ahrq.gov/clinic/evrptpdfs.htm.

METHODS

Search Strategy

The systematic review protocol was created according to the recommendations for Meta-Analysis Of Observational Studies in Epidemiology (MOOSE).[15] Several librarians and investigators searched electronic databases, including Medline, CINAHL, Cochrane databases, BioMed Central, federal reports, American Nurses Association, and Digital Dissertations from February to June 2006 to identify epidemiologic studies conducted in the United States and Canada that investigated the association between nurse staffing and patient outcomes. The search strategy used medical headings and keywords and their combinations: "nurses," "nursing staff, hospital," "nursing administration research," "nursing audit," "nursing education research," "clinical competence," "health care quality, access, and evaluation," "health services

research," "outcome assessment (health care)," "health care category," "personnel administration, hospital," "patients," "length of stay," "hospital units," "united states/epidemiology," and "personnel staffing and scheduling." We included unpublished dissertations and all studies with nurse staffing in multivariate analysis to reduce publication bias. Original investigations published in English between 1990 and 2006 that reported absolute and relative risk of patient outcomes associated with RN staffing were considered eligible. The quality of the studies and the level of evidence were assessed using US Preventive Services Task Force and AHRQ criteria.[16,17]

Outcomes

Two abstractors extracted the independent variables of RN-to-patient ratios, and the dependent variables as adjusted odds ratio of patient outcomes, using the standardized abstraction protocol.[18] Nurse-sensitive patient outcomes[19–21] included hospital-related mortality, failure to rescue (number of deaths in patients who developed an adverse occurrence divided by the number of patients who developed an adverse occurrence),[22] cardiac arrest, shock, unplanned extubation, respiratory failure, deep venous thrombosis, upper gastrointestinal bleeding, surgical bleeding, patient falls, pressure ulcers, nosocomial infection, urinary tract infection, hospital-acquired pneumonia, and nosocomial bloodstream infection. The measures were derived from several sources.[19–21]

We analyzed separately studies conducted with patient and hospitals as analytic units to reduce any bias related to nurse staffing allocation[23] and adjustment for patient acuity at the individual and hospital level. We also conducted separate analyses for intensive care units (ICUs) and for medical and surgical patients.[24] The design of the studies and adjustment for confounding factors were analyzed as possible effect modifiers in interaction models. Various authors had used different operational definitions for the RN-to-patient ratio, including number of patients cared for by 1 RN per shift and the number of RN FTEs per patient day, 1000 patient days, or occupied bed.

We created 2 standardized rates for purposes of comparison: the number of patients cared for by 1 RN per shift and RN FTE per patient day,[25] assuming a 37.5-hour work week on average; 48 working wk/yr, and 8-hour shifts[26] (see Appendix A online). We estimated the risks attributable to RN staffing proportions for various patient outcomes and the number of avoided events per 1000 hospitalized patients assuming causality of the association.[27,28]

Statistical Analysis

Meta-analysis[15,29–31] was used to assess the consistency of the association between RN staffing and patient outcomes across different studies. We analyzed separately the studies that adjusted for confounding patient and hospital characteristics to generate the most valid estimates of the association that was consistent in direction and strength across all available studies. We conducted sensitivity analyses of the pooled absolute risk of patient outcomes.

The analyses were conducted separately for classes of patients and hospital characteristics and to test effect modification by study design.[32] Pooled odds ratios and 95%

confidence intervals were calculated with fixed and random effect models, the latter to incorporate between study variability.[29,33] We included pooled estimates from random effects models only in the present article. Studies were weighted by sample size in the overall meta-analysis because most studies did not provide a measure of variability. Consistency in the results was tested by comparing the direction and strength of the association in models with nurse staffing variables as continuous (overall trend) and categorical, and with goodness-of-fit tests. χ^2 tests and I^2 statistics were used to assess heterogeneity in study results.[34–36] To ascertain whether the relationships were linear, both continuous and categorical forms of staffing variables were assessed, where the latter was arranged in quartiles.[31] When the authors reported relative risks in different categories, we assigned a mean or median of RN staffing variables, assuming a normal distribution. We transformed RN staffing levels into a risk estimate per unit of RN ratio and assigned an exposure value to each categorical group, assuming a specific parametric distribution for the exposure in the population.[31] This method can test a linear dose-response relation and assess the nonlinearity of the dose-response relation. Statistical significance was analyzed at the 95% confidence level. The calculations were performed using STATA[28] and SAS 9.2 Proc Mixed[33] software.

RESULTS

Of 2858 potentially relevant studies, 101 were eligible for review (Fig. 1), 96 were included into the meta-analysis. Twenty-eight studies (from 30 reports) reported adjusted odds ratios of the patient outcomes (see Appendix B which can be found on the Medical Care website, www.lww-medicalcare.com). We identified 17 cohort,[6,37–53] 7 cross-sectional,[24,32,54–58] and 4 case-control studies.[59–62] The overall quality of the studies averaged 43 (of a possible 50). We estimated the internal validity of the observational studies according to adjustment for confounding factors.[63] Four studies reported validation of staffing variables and 10 studies validated patient outcomes.

Eligible hospitals for the studies came from random samples of US community hospitals,[6,46,58] annual surveys of the American Hospital Association (AHA),[24,32,37,50,51,59] state health services databases,[38–43,45,49,54,56] ongoing multi-center investigations,[40,46,47] or single-hospital evaluations (see Appendix A online).[44,55,57,60–62] Patient outcome rates were measured using The Uniform Health Discharge Data Sets,[38,39,41–43,45,48,49,56–58] the Healthcare Cost and Urinary Tract Infection Project,[6,46] Centers for Medicare and Medicaid Services (CMS) databases,[6,47,50,52] and from patient medical records at the patient level of analysis.[40,44,55,59–62] RN staffing ratios were obtained from the AHA and nursing surveys,[37,39,41,42,48,49,54,57–59] hospital administrative databases,[44,51,60–62] and direct observations of nursing activities.[55] RN staffing averaged 3.0 ± 1.8 patients per RN per shift in ICUs, 4.0 ± 2.3 on surgical units, and 4.4 ± 2.9 for medical patients, which are comparable with published multihospital reports.[24,64]

Databases:
The National Library of Medicine via PubMed
CINAHL - Cumulative Index to Nursing & Allied Health Literature
The Cochrane Library
BioMed Central
Catalog of U.S. Government Publications (U.S. GPO)
LexisNexis™ Government Periodicals Index
Digital Dissertations
Agency of Health Care Research and Quality

Total Citations 2,858

101 Eligible for review

2,757 excluded for the following reasons:
60 case reports
574 comments, success stories
54 editorials, expert opinions
21 letters
3 guidelines
24 interviews
44 legal cases
89 news, reprinting of original reports
1 web survey
112 reviews, secondary data analysis
158 no association tested
598 no information on nurse staffing and
    strategies
160 ineligible outcomes
859 ineligible target populations

5 excluded because
of inadequate data
presentation

96 studies included in meta-analysis
68 reported rates of outcomes
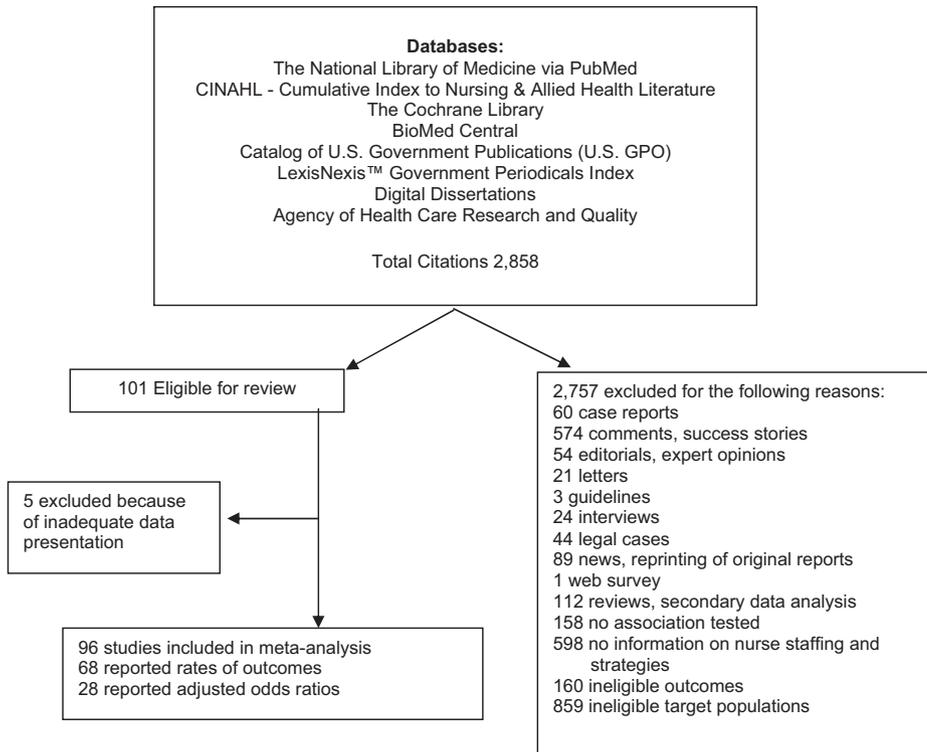28 reported adjusted odds ratios

FIGURE 1. Flowchart of the studies.

Hospital-Related Mortality

Greater RN staffing was consistently associated with a reduction in the adjusted odds ratio of hospital related mortality (Table 1). An increase by 1 RN FTE per patient day was associated with a 9% reduction in odds of death in ICUs [odds ratio (OR), 0.91; 95% confidence interval (CI), 0.86–0.96),[38,42,49,51,54] 16% in surgical (OR, 0.84; 95% CI, 0.8–0.89),[37,38,42,43,49,52,54,57] and 6% in medical patients (OR, 0.94; 95% CI, 0.94–0.95).[6,46,47,50,51,59] For studies that analyzed the association at the hospital level, the odds ratio was 0.96 (0.94–0.98).[6,43,46,50,52] From these data we estimated that, if the association was causal, an increase by 1 RN FTE per patient day would save 5 lives per 1000 hospitalized patients in ICUs, 5 lives per 1000 medical patients, and 6 per 1000 surgical patients (Table 1).

The dose response association between RN staffing and hospital-related mortality was consistent across quartiles of patients per RN per shift distribution (Fig. 2). Reducing the number of patients from an average of more than 3.3 (third quartile) to 2 (second quartile) patients per RN in ICUs was associated with a 6% relative decrease in death. In surgical patients, the odds of death was 38% less when 1 RN was assigned to 2 or less patients (first quartile) compared with more than 5 patients per shift (fourth quartile). A decrease from an average of more than 5 (fourth quartile) to 2.8 (second quartile) surgical patients per RN was associated with a 35% reduction in mortality.

Hospital-related mortality showed a nonlinear decline with increasing staffing. The goodness-of-fit of the linear slope varied across quartiles of RN FTE per patient day. The observed odds of mortality in the fourth quartile versus the first was 61% lower, whereas it would be 85% lower if the linear slope was applied to the differences in nurse to patient ratio. Estimated with linear slope odds of mortality would be 19% lower when the workload of patients per RN per shift decreased from 4 to 2 patients, but in fact odds were only 6% lower.

In separate analyses of the studies that reported absolute risk differences, an additional RN FTE per patient day was associated with a 1.24% reduction in death rate (see Appendix C which can be found on the Medical Care website, www.lww-medicalcare.com).[12,17,34] A pooled analysis showed that an increase by 1 RN FTE per patient day was associated with a 1.2% reduction in mortality rates.[12,13,16,17,20,23,34]

Adverse Patient Events

Higher RN staffing was associated with lower odds of several patient adverse events (Table 1). Pooled analysis detected a significant and consistent reduction in odds of hospital-acquired pneumonia of 19% (OR, 0.81; 95% CI, 0.67–0.98) in all patients and 30% (OR, 0.7; 95% CI, 0.56–0.88) in ICUs.[38,42,44,46]

An increase by 1 RN FTE per patient day was associated with a 60% lower odds of respiratory failure in ICUs (OR, 0.4; 95% CI, 0.27–0.59).[38,41,42,48,58] Odds of unplanned extubation were 51% less[38,41,42,48,61] and odds of cardiac arrest 28% less[38,41,48] in ICUs per 1 additional RN FTE per patient day. In surgical patients, odds of failure to rescue[37,43,52,54,57] and of nosocomial bloodstream infection[38,41,44,48,60] were reduced by 16% and 36%, respectively. RN staffing was not associated with odds of urinary tract infections[44,46] and surgical bleeding.[48] We could not identify any studies that reported adjusted odds ratio of pressure

TABLE 1. Pooled Odds Ratios of Patient Outcomes Corresponding to an Increase of 1 Registered Nurse Full Time Equivalent per Patient Day*

Outcome	Studies	Odds Ratio (95% CI)	Attributable to Nurse Staffing Fraction of Events (%)	No. Avoided Events/1000 Hospitalized (95% CI)
All patients				
Mortality, hospital level analysis, all patients	5	0.96 (0.94; 0.98)	4.2	3 (2; 4)
Mortality, intensive care units	5	0.91 (0.86; 0.96)	9.2	5 (2; 8)
Mortality, surgical patients	8	0.84 (0.8; 0.89)	16	6 (4; 8)
Mortality, medical patients	6	0.94 (0.94; 0.95)	5.6	5 (4; 5)
Hospital-acquired pneumonia	4	0.81 (0.67; 0.98)	19.1	1 (0; 2)
Pulmonary failure	5	0.94 (0.94; 0.94)	6	1 (1; 1)
Cardiopulmonary resuscitation	5	0.72 (0.62; 0.84)	27.6	2 (1; 2)
Intensive care units				
Hospital-acquired pneumonia	3	0.7 (0.56; 0.88)	30.2	7 (3; 10)
Pulmonary failure	4	0.4 (0.27; 0.59)	60.3	7 (5; 9)
Unplanned extubation	5	0.49 (0.36; 0.67)	50.9	6 (4; 8)
Cardiopulmonary resuscitation	3	0.72 (0.62; 0.84)	27.6	2 (1; 2)
Relative change in length of stay	4	0.76 (0.62; 0.94)	24	7 (2; 11)
Surgical patients				
Failure to rescue	5	0.84 (0.79; 0.9)	16	26 (17; 35)
Surgical wound infection	1	0.15 (0.03; 0.82)	84.5	7 (1; 8)
Cardiopulmonary resuscitation	1	0.72 (0.62; 0.84)	27.6	1 (1; 2)
Nosocomial bloodstream infection	5	0.64 (0.46; 0.89)	36	4 (2;5)
Relative change in length of stay	3	0.69 (0.55; 0.86)	31	14 (6; 21)

*An increase of 1 registered nurse full time equivalent per patient day would result in 8 additional registered nurse hours per patient day and an increased cost of $24.57/h $\times$ 8 h or $196.56/patient day.[122] Attributable to nurse staffing fraction of events and number of avoided events per 1000 hospitalized patients were estimated assuming causality in the association.

ulcers, patient falls, and upper gastrointestinal bleeding in relation to RN staffing.

We estimated that if the association was causal, an increase by 1 RN FTE per patient day in ICUs would avoid 7 cases of hospital-acquired pneumonia, 7 cases of respiratory failure, 6 cases of unplanned extubation, and 2 cases of cardiac arrest per 1000 hospitalized patients. In surgical patients an additional RN per patient day would avoid 26 cases of failure to rescue, 7 cases of infected wounds, and 4 cases of nosocomial sepsis per 1000 hospitalized patients.

We examined the odds ratios of patient outcomes across categories of patients per RN per shift (Table 2). A decrease from 3.3 to less than 1.6 patients per RN per shift in ICUs was associated with a 43% reduction in odds of nosocomial sepsis, 34% in cardiac arrest, 41% in medical complications, 60% in respiratory failure, and 45% in unplanned extubation. This reduction would avoid 10 cases of nosocomial sepsis, 90 cases of respiratory failure, 66 cases of unplanned extubations, and 145 medical complications per 1000 ICU patients. A reduction from more than 5 to 2 or fewer surgical patients per RN per shift was associated with a 49% reduction in odds of nosocomial sepsis and 39% in failure to rescue. This reduction in RN workload would save 77 lives per 1000 surgical patients. An increase by 1 RN FTE per patient day was associated with a 34% shorter length of stay in ICUs and 31% in surgical patients.[38,42,49,51]
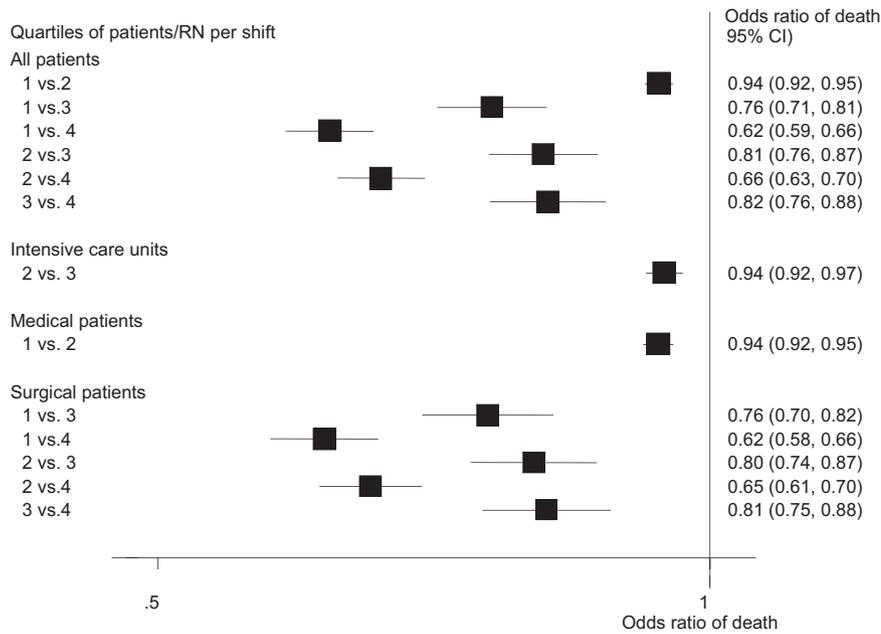
We calculated from the individual studies[10,15,16] that about 6–7% of deaths were attributable to an increase in patients per RN per shift (see Appendix B online, Tables 2 and 3).

Study Design

We examined the odds ratio of outcomes in studies conducted at patient and hospital levels. In 5 studies conducted at hospital level, an increase by 1 RN FTE per patient day was associated with a reduction in hospital related mortality (OR, 0.96; 95% CI, 0.94–0.98).[6,43,46,50,52] The same direction and strength of the association was detected in 8 studies with patient level analysis (OR, 0.92; 95% CI, 0.89–0.95).[37,38,42,47,49,54,57,59] An increase by 1 RN FTE per patient day was associated with 7 fewer hospital-related deaths at patient and 3 deaths at hospital level analysis per 1000 hospitalized patients. The observed death rate was 9–10% lower when there was 1 more RN FTE per 1000 patient days in studies conducted at hospital level.[6,46]

Studies conducted at the patient level reported generally larger effects of nurse staffing on mortality. A decrease in the nurse-to-patient ratio in the evening was associated with a 90% increase in mortality in a study at the patient level of analysis; 47% of deaths in patients after abdominal aortic surgery was attributable to nurse staffing in these hospitals.[49] Ten percent of avoided deaths in patients with acute myocardial infarction was attributable to an increase from 1.06 to 2.7 RN FTE per patient day in another study at patient level analysis.[47] Odds of failure to rescue was lower (OR, 0.91; 95% CI, 0.89–0.94) per additional RN FTE per patient day in 4 studies at patient level analysis.

FIGURE 2. Odds ratios of hospital related mortality in quartiles of patients/ registered nurse per shift ratio.

Odds ratios are based on pooled analysis consistent across the studies (heterogeneity not significant).

Explanation of quartiles:

Quartiles	ICU	Surgical Patients	Medical Patients
	Patients/RN per shift	Patients/RN per shift	Patients/RN per shift
1	<1.6	<2	<2
2	2	2.8	3
3	3.3	4.9	4.8
4	>4	>5	>6
Quartiles	RN hours/patient day	RN hours/patient day	RN hours/patient day
1	>15	>12	>12
2	12.0	8.6	8.0
3	7.3	4.9	5.0
4	<6	<4.8	<4
Quartiles	RN cost/patient day	RN cost/patient day	RN cost/patient day
1	>$369	>$295	>$295
2	$295	$211	$197
3	$179	$120	$123
4	<$147	<$118	<$98

We examined how different measures of nurse staffing can change the association with patient outcomes. The studies that measured the number of patients per shift per RN reported that 1 additional patient was associated with 8% increase in hospital related mortality (OR, 1.08; 95% CI, 1.07–1.09, $P < 0.0001$).[37,38,42,49,54,57] In the studies that measured the number of RN FTE per patient day, 1 additional RN FTE was associated with a significant decrease in hospital related mortality by 6% (OR, 0.94; 95% CI, 0.93–0.95, $P < 0.001$).[43,47,50–52,59] The studies that assessed hospital averages of RN FTE per 1000 patient days reported a nonsignificant decrease in mortality by 1% per additional RN FTE (OR, 0.99; 95% CI, 0.95–1.04, $P = 0.8$).[6,43,46] A consistent positive association was observed between the number of patients per RN shift and patient outcomes. Each additional patient an RN was assigned to was associated with a 7% relative increase in hospital-acquired pneumonia (OR, 1.07; 95% CI, 1.03–1.11, $P <$ 0.001),[38,42,44] an 8% relative increase in failure to rescue (OR, 1.08; 95% CI, 1.07–1.09, $P < 0.0001$),[37,54,57] a 53% relative increase in pulmonary failure (OR, 1.53; 95% CI, 1.24–1.89, $P = 0.001$),[38,41,42,48] a 45% relative increase in unplanned extubation (OR, 1.45; 95% CI, 1.27–1.67, $P < 0.0001$),[38,41,42,48,61] and a 16% relative increase in cardio-pulmonary resuscitation (OR, 1.16; 95% CI, 1.05–1.29, $P = 0.008$).[38,41,48]

We also examined whether the following study characteristics modified the association between RN ratios and patient outcomes: cross-sectional design, patient populations, adjustment for patient comorbidities, provider characteristics, and clustering of patients and hospitals. We tested 152 models to examine the possible effects of study characteristics adjusted for patient comorbidities at the patient and hospital levels and for provider characteristics including hospital teaching and profit status, size and volume, technology index, HMO penetration, and staffing.

TABLE 2. Odds Ratios of Patient Outcomes in Quartiles of the Distribution of Patients/RN per Shift*

Quartile† of Patients/RN	Outcome	Odds Ratio (95%CI)	Attributable Fraction of Events %	Avoided Events per 1000 hospitalized (95% CI)
Intensive care units				
1 vs. 3	Sepsis	0.57 (0.36; 0.91)	42.7	10 (2; 15)
2 vs. 3		0.58 (0.36; 0.94)	42.2	10 (2; 16)
1 vs. 3	Cardiopulmonary resuscitation	0.66 (0.59; 0.73)	34.4	3 (2; 4)
2 vs. 3		0.54 (0.47; 0.61)	46.3	4 (3; 5)
2 vs. 4		0.75 (0.67; 0.83)	25.4	2 (1; 3)
1 vs. 3	Medical complications	0.59 (0.49; 0.71)	40.8	145 (101; 181)
2 vs. 3		0.54 (0.44; 0.66)	46.1	164 (119; 200)
2 vs. 4		0.75 (0.62; 0.9)	25.4	90 (36; 135)
1 vs. 3	Pulmonary failure	0.4 (0.23; 0.69)	60	90 (47; 116)
1 vs. 4		0.36 (0.19; 0.69)	63.7	96 (47; 122)
2 vs. 4		0.43 (0.21; 0.86)	57.1	86 (21; 118)
1 vs. 3	Unplanned extubation	0.55 (0.39; 0.78)	44.8	66 (33; 90)
1 vs. 4		0.32 (0.2; 0.51)	68	100 (72; 117)
2 vs. 4		0.43 (0.3; 0.62)	56.9	84 (56; 103)
3 vs. 4		0.58 (0.42; 0.8)	42	62 (30; 85)
Surgical patients				
3 vs. 4	Hospital-acquired pneumonia	0.75 (0.6; 0.95)	24.6	3 (1; 5)
3 vs. 4	Surgical wound infection	0.8 (0.68; 0.94)	20.4	2 (1; 3)
1 vs. 2	Sepsis	0.56 (0.37; 0.84)	44.4	4 (2; 6)
1 vs. 4		0.51 (0.28; 0.91)	49.4	5 (1; 7)
3 vs. 4		0.71 (0.55; 0.93)	28.5	3 (1; 5)
1 vs. 2	Cardiopulmonary resuscitation	0.69 (0.55; 0.87)	30.8	2 (1; 2)
1 vs. 3		0.75 (0.59; 0.95)	25.4	1 (0; 2)
1 vs. 3	Failure to rescue	0.75 (0.67; 0.83)	25.5	50 (34; 65)
1 vs. 4		0.61 (0.56; 0.66)	39.1	77 (66; 87)
2 vs. 3		0.79 (0.72; 0.88)	20.6	41 (24; 56)
2 vs. 4		0.65 (0.6; 0.7)	35.2	69 (59; 79)
3 vs. 4		0.82 (0.73; 0.91)	18.3	36 (18; 52)

*Odds ratio was based on pooled analysis consistent across the studies (heterogeneity not significant). Attributable to nurse staffing proportion of event and number of avoided events per 1000 hospitalized patients were estimated assuming causality in the association.
†For explanation of quartiles, please see legend to Figure 2.

Only a small proportion (16%) of the models showed a significant influence of study design on the association between RN staffing and patient outcomes. None of the design factors examined showed an effect on the outcomes of interest. The design of the studies did not modify the association between RN staffing and hospital related mortality. However, the odds ratio of failure to rescue was lower in cohort studies that attempted to assess temporality in the association (OR, 0.84; 95% CI, 0.75–0.93) compared with cross-sectional designs (OR, 0.92; 95% CI, 0.91–0.93). Case control studies that examined outbreaks of nosocomial sepsis reported a larger protective effect of improved RN ratios.

DISCUSSION

This analysis supports previous contentions that increased nursing staffing in hospitals is associated with improvements in patient care outcomes[7,24,65] and quality of care.[66] But does this association reflect a causal relationship? Because large randomized controlled trials to investigate the

causal association with nurse staffing are unlikely, inferences will rest largely on observational data.

An analysis of causality should address several components[63]:

1. The direction of the association in individual studies and pooled analysis was generally consistent. The evidence consistently suggests that the odds of hospital-related mortality was 9–16% lower for each additional RN FTE per patient day. The strength was frequently substantial and significant.
2. The consistency of the association was shown by statistical tests of heterogeneity, meta-regression, and sensitivity analysis.
3. The present analysis showed statistically and clinically significant associations consistent in dose-response models and among quartiles of staffing. Confirming previous observations,[65,67] we detected a curvilinear association between staffing and outcomes.
4. Because the analysis of the specificity of the association by comparing crude differences in absolute risk and ad-

justed relative risk of patient outcomes showed the same improvement in patient outcomes, we conclude that confounding factors did not influence the direction and consistency of the association. We also attempted to examine the effect modification by adjusting for patient and provider characteristics, but the effect was not consistent in direction and strength (data not shown).

5. When we analyzed the temporality in the association through a sensitivity analysis among the studies that addressed temporality and provided cross-sectional comparisons, we found a larger protective effect for only 1 patient outcome—failure to rescue—in cohort studies.

Another test of causality in observational reports holds that higher staffing levels produce stronger effects for nurse sensitive outcomes than for more general outcomes. The effect of additional nurse staffing on nurse-sensitive outcomes, including failure to rescue, unplanned extubation, and cardiac arrest, was substantially higher than that for mortality. However, several prevalent nurse-sensitive adverse events, including patient falls, pressure ulcers, and urinary tract infections did not demonstrate a consistent association with staffing ratios.

Previous systematic reviews did not estimate the dose-response association with different nurse staffing measures.[65,68] One systematic review considered associations to be clinically important when a 10% difference in staffing levels was associated with significant changes in outcomes.[68] Other authors attempted to find an optimal nurse staffing ratio and hours, but concluded that the effect size cannot be estimated reliably because of differences in the studies and possible curvilinear associations.[65]

The arguments for a causal relationship are thus mixed. Several lines of evidence suggest that overall hospital commitment to a high quality of care in combination with effective nurse retention strategies leads to better patient outcomes, patient satisfaction with overall and nursing care, and RN satisfaction with their job and the care they provide.[59,69–74] Hospital volume,[43] physician practice patterns, and collaboration with nurses[49,51] affected patient outcomes. Hospital environment, including nurses' job satisfaction and perceptions of autonomy and governance, was associated with nurse retention and better patient outcomes in several reports.[37,57,75–81] Early reports suggest that magnet hospitals with better nursing foundations for quality of care, nurse manager ability and support, and collegial nurse–physician relations may provide better care.[70–72,82–88]

Longitudinal studies would control for many of these hospital characteristics better than cross-sectional designs. Applying the results of the present review to improve the quality of hospital care, we need to remember that system-level interventions in combination with nurse staffing strategies provided better patient benefits.[89–93] Implementing evidence-based clinical pathways that involve nurse and physician education and collaboration may increase the effectiveness of nursing work and improve patient outcomes.[94,95] Several randomized clinical trials reported a significant improvement in nurse performance and patient outcomes as a result of quality improvement initiatives.[96–101]

The strength of the association between nurse staffing and patient outcomes can be affected by the sources of staffing data. The multivariate analysis suggested that the association was stronger when nurse staffing was obtained from the California Office for Statewide Health Planning and Development compared with the AHA Annual Survey of Hospitals database.[102] Large multicenter studies that used the AHA database relied on estimated hospital averages of nurse staffing. When we compared the direction and the strength of the association from such studies to the results of patient level analysis that could carefully adjust for patient and nurses characteristics, we did not detect substantial differences.

Geographic variations in RN distribution[103] may change the effect size of RN staffing on patient outcomes. Few multi-hospital studies used random effects models to incorporate geographic differences in the estimation[104,105]; less than half of the included studies reported random sampling and assessments of sampling bias. We compared means of RN staffing in the studies we included in the meta-analysis with published means[32] and did not detect substantial differences. However, the report of the Institute of Medicine suggested that a larger proportion of hospitals have poorer nurse staffing than published in scientific research.[1] Therefore, the effect size of RN staffing on patient outcomes from the present report can be generalized only to hospitals with similar nurse staffing patterns.

The effect of nurse staffing differed across care settings. The relative effect of adding 1 unit of nursing care may vary with the baseline rate. We found a greater reduction in the relative risk of hospital-related mortality and adverse patient events in ICUs and in surgical patients compared with combined patient populations. As shown in previous studies,[24,32] the present meta-analysis found consistent evidence that surgical patients would demonstrate a great cost-benefit from improved nurse staffing. Increasing the care of surgical patients by 1 RN FTE per patient day would eliminate 16% of hospital-related death compared with 5.6% for medical patients.

The primary independent variable examined here is the volume of nursing, tempered by some attention to the training level. But other factors may also be relevant. Differences in contextual factors and work environment at the unit and hospital level can influence the association.[106]

Skill, education, experience, organization, and leadership undoubtedly determine the effectiveness of professional nursing performance but are much more difficult to assess. Usually we work in just the opposite direction, inferring skill from outcomes after other factors have been accounted for. The studies in this review did not provide information on the quality of medical and surgical treatment. The importance of nurses' professional competence and performance have been discussed with regard to developing standards of nurse performance to encourage high quality care.[8,107–109] One large study suggests a 5% reduction in hospital-related morality in surgical patients corresponding to a 10% increase in RNs with BSN degrees.[54]

Possible staffing decisions to improve quality of care would involve comparing existing RN ratios with estimated

changes in RN staffing needed to achieve desirable patient outcomes. However, defining the best level of nurse staffing requires cost-effectiveness analysis,[10] which was beyond the present study. Because hospitals are paid a fixed rate under diagnosis-related groups that does not reflect the quality of care they provide, they may be reluctant to take on substantial cost burdens. The estimation of the threshold in terms of marginal costs and benefits depends on the value placed on survival, patient satisfaction, and quality of life.[110]

Policymakers can consider several approaches to regulate nurse staffing. Our calculations suggest that it is difficult to set fixed standard RN ratios. Indeed, fixed minimum RN-to-patient ratios implemented in California did not provide the expected patient safety benefits.[11] To maintain a reasonable staffing level in the face of an increasing RN shortage, hospitals may need to reduce capacity. Mandatory nurse-to-patient ratios without legislative agreement to increase reimbursement may result in administrative decisions to reduce support staff positions and investments in other quality initiatives.[10] Patient-acuity–based staffing requirements adjust RN ratios for patient diagnosis and comorbidities but do not regulate shift-to-shift fluctuations in RN staffing that have an important influence on quality of care.[111,112] Moreover, no consensus exists about patient classification systems, which are different among hospitals.[113–117] Public disclosure of nurse staffing was introduced in 1 state, but its effect on quality of care is not known.[11] Pay-for-performance has been proposed to provide incentives for quality of care, but its effect on cost effectiveness is not well understood.[10] Ideally, we should monitor every hospital in the United States to see how differences in policies and financial performance affect the cost effectiveness of staffing and its effect on quality of health care.[10,11]

The analysis of cost-effectiveness of increasing RN staffing is inconsistent and restricted to gross differences between increased cost of nurse staffing and avoided patient adverse events.[118–120] Interpreting cost-effectiveness depends on the perspective of the party involved. Although the value of lives saved and adverse events forgone may justify more nursing staff, the business case for hospitals is harder to make.[110,121] Societal cost-effectiveness analysis should also include the cost of posthospital care for the patients who experienced adverse events during hospital stay.

In conclusion, the available evidence indicates that there is a statistically and clinically significant association between RN staffing and adjusted odds ratio of hospital-related mortality, failure to rescue, and other patient outcomes. The effects are consistent in surgical patients and in ICUs. The causal pathway to safe patient care includes other structure and process factors. Hospital commitment to high-quality care, implementation of collaborative evidenced-based clinical practice, and access to affordable health care may provide better patient outcomes in relation to nurse staffing. Although a clinical trial that can establish causal pathways seems hard to envision, future research should address the role of nurse staffing and competence on the effectiveness of patient care, taking greater cognizance of other relevant factors such as patient and hospital characteristics and quality of medical care.

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