Published in final edited form as:
Am J Crit Care. 2009 March ; 18(2): 106–114. doi:10.4037/ajcc2009487.

COMPETENCE AND CERTIFICATION OF REGISTERED NURSES AND SAFETY OF PATIENTS IN INTENSIVE CARE UNITS

Deborah Kendall-Gallagher, RN, JD, MS, PhD and
postdoctoral research fellow at the Center for Health Outcomes and Policy Research, University of Pennsylvania School of Nursing, in Philadelphia.

Mary A. Blegen, RN, PhD
professor in community health systems and director of the Center for Patient Safety in the School of Nursing at the University of California, San Francisco.

Abstract

Background—Adverse events that place patients at risk for harm are common in intensive care units. Clinicians' level of knowledge and judgment appear to play a role in the prevention, mitigation, and creation of adverse advents. Research suggests a possible association between nurses' specialty certification and clinical expertise. The relationship between specialty certification and clinical competence of registered nurses and safety of patients is a relatively new area of inquiry in nursing.

Objective—To explore the relationship between the proportion of certified staff nurses in a unit and risk of harm to patients.

Methods—Hierarchical linear modeling was used in a secondary data analysis of 48 intensive care units from a random sample of 29 hospitals to examine the relationships between unit certification rates, organizational nursing characteristics (magnet status, staffing, education, and experience), and rates of medication administration errors, falls, skin breakdown, and 3 types of nosocomial infections. Medicare case mix index was used to adjust for patient risk.

Results—Unit proportion of certified staff registered nurses was inversely related to rate of falls, and total hours of nursing care was positively related to medication administration errors. The mean number of years of experience of registered nurses in the unit was inversely related to frequency of urinary tract infections; however, the small sample size requires that caution be exercised when interpreting results.

Conclusions—Specialty certification and competence of registered nurses are related to patients' safety. Further research on this relationship is needed.

Ensuring that critically ill patients receive safe, high-quality care in the complex environment of the intensive care unit (ICU) is an ongoing challenge. The

Corresponding author: Deborah Kendall-Gallagher, RN, JD, MS, PhD, Center for Health Outcomes and Policy Research, University of Pennsylvania School of Nursing, 418 Curie Blvd, Philadelphia, PA 19104-6096 (e-mail: E-mail: debk@nursing.upenn.edu).

SEE ALSO
For more about certification and patient safety, visit the *Critical Care Nurse* Web site, www.ccnonline.org, and read the article by Briggs et al, "Certification: A Benchmark for Critical Care Nursing Excellence" (December 2006).

combination of complicated medical regimens, multiple caregivers, and unpredictability creates a marked risk of harm for patients.[1] ICU incidents involving harm of patients (adverse events) or risk of harm (near-misses) are relatively common, often preventable, and multidisciplinary.[2] Analyses of ICU data derived from self-reports of multidisciplinary incidents indicate that human-related factors such as the knowledge and skill of the clinician often contribute to adverse events.[3,4]

Understanding the role that a clinician's knowledge and skill play in the prevention of adverse events is essential for developing effective strategies for reducing the risk of harm to patients. Specialty certification is one method of validating clinicians' knowledge in a specific area of practice.[5] In medicine, board certification "is designed to provide an overall assessment of physician competence … meant to indicate that a physician has the knowledge, experience, and skills for providing quality health care within a given specialty."[6(p1365)]

In nursing, the link between specialty certification and competence has not yet been examined. The relationship between the competence and certification of caregivers and the safety of patients is a relatively new area of inquiry in nursing. The aim of this secondary data analysis was to explore, for the first time, the association between competence of registered nurses, measured by the proportion of staff nurses with specialty certification in the unit, and safety of patients, defined by rates of occurrence of 6 types of adverse events related to nursing care in the ICU.

Background

Adverse events are common in ICUs. Valentin et al,[2] in a 24-hour observational, cross-sectional study of 205 ICUs in 29 countries, identified 584 adverse events (defined as 5 types of sentinel events) that affected 391 patients. In order of decreasing frequency, observed rates of adverse events per 100 patient days were 14.5 for indwelling lines, catheters, and drains; 10.5 for medications; 9.2 for equipment; 3.3 for airways; and 1.3 for alarms. Bracco et al[7] reported that 777 critical incidents were detected in an observational study of 1024 patients admitted consecutively to an ICU during the course of a year; 2% of the incidents were attributed to technical failure, 67% to the patient's disease, and 31% to human error. Of the 241 human errors, 75 were related to planning, 88 to execution, and 78 to surveillance.

Although rates of adverse events calculated from voluntary self-reported data are biased because of the difficulty in identifying specific populations at risk and the selective reporting (eg, underreporting), such data reflect the state of the science and provide valuable information for designing effective interventions to reduce the risk of harming patients.[8] Analyses of self-reported data on adverse events from 2 different systems indicated that human-related factors such as clinicians' knowledge, training, and use of protocols were categories often identified as contributing to harm of patients. Beckmann et al[3] found that human-related factors accounted for 66% of factors reported as contributing to 610 incidents; 42% were knowledge related (eg, error in problem recognition) and 30% were rule related (eg, failure to follow protocol). Pronovost et al,[4] in an analysis of 2075 incidents from 23 adult and pediatric ICUs, found numerous important system and human factors associated with harm of patients. Frequent contributing factors included training and education (49%) and knowledge, skills, and competence (32%).

Recent research[9,10] highlights that a similar, but nurse-specific, level of clinical competence is required to reduce risk of harming patients in the ICU. Hurley et al[10] provide a qualitative description of how expert nurses in a coronary care unit identified, interrupted, and corrected potentially fatal near-misses. Hurley et al identified antecedents of nurse-initiated interventions to reduce imminent risk of patient harm: knowledge and expertise comprising clinical skills, ethical comportment, and self-efficacy.

One method for measuring level of knowledge is specialty certification. Although definitions of certification vary slightly, the underlying concept of certification is validation of cognitive knowledge.[5,6,11] Certification in nursing, however, is not a unified construct. As of 2000, more than 410 000 nurses had been certified in the United States and Canada, representing 67 certifying organizations offering 95 different credentials across 134 specialty organizations.[12] Certification programs may be accredited, but the process is voluntary and accreditation standards may vary.[13,14] Certifying organizations may overlap in types of certifications offered but differ in standards, eligibility requirements, and examinations.[11,15]

Passing a cognitive certification examination neither validates nor ensures competency at the bedside,[6,11] but accumulating evidence suggests that certified nurses perform better than do noncertified nurses when tested on level of substantive specialty knowledge. Hart et al,[16] in a Web-based examination designed to test the reliability of the pressure ulcer measure of the National Database of Nursing Quality Indicators (NDNQI) and to assess 256 nurses' knowledge of pressure ulcers, found that registered nurses certified in wound, continence, and/or ostomy care scored significantly higher than did other nurses in staging of ulcers.

Zulkowski et al[17] examined knowledge differences among a convenience sample of 3 groups of nurses: registered nurses certified in wound care, registered nurses certified in areas other than wound care, and registered nurses with no certification. Knowledge scores differed significantly ($P < .001$) between registered nurses certified in wound care and registered nurses with either another or no certification (89% vs 78% or 76.5%); knowledge scores did not differ with the nurses' education or experience. Henderson-Everhardus[18] found that expert nurses with specialty certification demonstrated greater accuracy in palpitation of peripheral pulses and measurement of ankle-brachial pressures than did experienced but noncertified nurses.

The certification status of registered nurses is generally not tracked. Additionally, data that are collected may not differentiate among types of registered nurse certification, making it difficult to conceptually link cognitive knowledge validated on an examination with care at the bedside. However, detailed certification questions were included in the 2004 National Sample Survey of Registered Nurses; 70.1% of advanced practice nurses reported being certified; certifications other than advanced practice were collected but not reported.[19] Unit certification data also are collected through voluntary programs such as the NDNQI project,[20] with data being collected from self-report nurse surveys and nurse managers.[21] In a 2007 NDNQI survey of registered nurses from participating hospitals, 21% of critical care nurses surveyed reported being certified.[21]

Measuring the relationship between competence of individual registered nurses and safety of patients is methodologically difficult because nursing is practiced and characterized as a group; consequently, individual competency of registered nurses must be aggregated to the patient care unit level for purposes of study.[22–24] The nursing work group comprises individual registered nurses and other personnel who have different professional competencies. The proportion of certified staff registered nurses in a unit, represented in this study as registered nurse work group competence, theoretically incorporates individual nurses' competence at the bedside within a group practice model.[25]

In summary, risk of harm to patients as a result of adverse events in the ICU often involves clinically complex situations that demand a high level of competence among clinicians to identify and mitigate risk. Specialty certification has been associated with nursing expertise and presumably with competence. Although certification of registered nurses measures cognitive knowledge against preset principles and standards,[11] it is unknown if the knowledge translates to better care at the bedside.

This study is the first we know of in which the relationship between the proportion of nurses certified on a care unit, conceptualized as competence, and the quality and safety of care on that unit were evaluated. The importance of the study is 2-fold: (1) it provides an essential conceptual foundation for understanding how level of clinical knowledge and judgment influences the risk of harming patients at the point of care, and (2) it explores the methodological practicality of using the proportion of certified nurses in the unit as an indicator of the competence of registered nurses at the unit level.

Methods

Two primary research questions were proposed. The first concerned the relationship between the proportion of certified staff nurses in the unit and unit rates of occurrence of 6 adverse events (medication administration errors, total falls, skin breakdown, and 3 types of nosocomial infections). The second concerned the combination of organizational and nursing characteristics (magnet status, certification, education, experience, skill mix, and total hours of nursing care per patient day) associated with unit rates of adverse events. We hypothesized that an inverse relationship exists between the proportion of certified staff nurses in each unit and the rate of each type of adverse event in that unit. Medicare case mix index was used to adjust for risk. Independent variables and definitions of outcome measures are listed in Table 1.

Approval was obtained from the institutional review board before data analyses began. A correlational, cross-sectional, unit-level design was used to conduct secondary data analysis of 48 adult ICUs from a random sample of 29 hospitals. Study data were derived from a previous retrospective, cross-sectional study on the relationship between nurse staffing patterns and quality of care in 279 inpatient units from 47 community hospitals (NINR NR0104937).

Data from the parent study were collected quarterly during the year 2000 from unit nurse managers by using 2 questionnaires that addressed nurse staffing, rates of adverse events, and organizational nursing characteristics (ie, hospital magnet status, proportion of certified staff nurses in the unit, mean years of staff nurse experience in the unit, and proportion of staff nurses with a bachelor of science degree in nursing or a higher level of education). The study protocol required units to report rates of medication administration errors and falls along with rates of other adverse events, if data were available. Staffing data, excluding nurse managers and clinical specialists, were measured on the basis of hours of care reported for each provider type (registered nurse, licensed practical nurse, and certified nursing assistant) and standardized by dividing the hours by number of patient care days reported per quarter to produce total hours of nursing care per patient day. For purposes of analysis, quarterly staffing data were aggregated to a single annual value for each unit after repeated-measures analysis of variance and graphic displays showed no systematic differences in staffing from quarter to quarter. Similar statistical procedures were used to annualize unit rates of adverse events.

SPSS software[26] was used for descriptive and bivariate analyses. Hierarchical linear modeling (HLM)[27] was done to test the study model that a unit's proportion of certified staff nurses affects patients' safety. HLM accounts for bias in estimation of rates resulting from the interrelationship among units within each hospital.[28]

HLM improves statistical inference by better aligning theoretical models with natural data structures.[29,30] By creating submodels for each level of data (unit and hospital), HLM allows researchers to (1) study associations at the lowest level of data (eg, units), (2) examine how variables from one level affect associations on another level (eg, hospitals and units), and (3) understand how variance attributed to components of the model is partitioned between the unit

and hospital level.[30] In this study, the primary focus of interest was the relationships between variables at the unit level.

Results

The secondary data sample consisted of 48 adult ICUs (31 medical-surgical, 17 cardiac) in 29 hospitals. Most units were in hospitals with a mean of 338.2 (SD, 168) beds. The mean unit size was 14.7 (SD, 6.1) beds. Units were located in hospitals with populations of patients that were predominantly female (mean, 61%; SD, 6.6%), white (mean, 70%; SD, 21.6%), and insured (mean, 82%; SD, 8.5%). Most patients were 21 to 65 years old (mean, 52%; SD, 11.9%) or older (mean, 37.3%; SD, 12.2%). Of the 29 hospitals, 5 were designated as magnet facilities. The Medicare case mix index was between 1.18 and 2.01, with a mean of 1.46 (SD, 0.18).

Descriptive statistics for unit-level variables are outlined in Table 2. Denominators of independent variables varied slightly, with number of units ranging from 42 to 48. The proportion of certified staff nurses in the 48 units ranged from 0.07% to 97%. Adverse event rates for each unit were calculated as annual unit rates per 1000 patient days. A total of 47 units reported data on medication administration errors and fall rates. Because the remaining outcome measures had various denominators (numbers of units reporting data), each outcome measure was analyzed separately. HLM algorithms account for unbalanced group sizes that may result from missing data.[27,30] Caution was required in interpreting study results for measures other than medication administration errors and falls.

Correlation matrices were constructed to assess potential multicollinearity between independent variables and to evaluate linear relationships between independent and dependent variables. Independent variables were not sufficiently correlated to pose a problem regarding multicollinearity. Evaluation of potential linear relationships between independent and dependent variables produced mixed results; unit proportion of certified staff nurses showed little correlation with outcome variables (Table 3). Nurse education was negatively related to skin breakdown, and nurse experience was positively related to medication administration errors. The total number of hours of nursing care per patient day was positively correlated with both central catheter infections and bloodstream infections. Nurse skill mix was correlated positively with medication administration errors and negatively with urinary tract infections.

Multivariate analyses revealed significant associations among outcomes and independent variables, with the associations varying by measure (Table 4). Bonferroni correction was used to adjust for possible inflation of type I error due to multiple comparisons, with unit proportion of certified staff nurses set at $\alpha = .05$ and all other covariates set at $\alpha = .01$. Proportion of certified staff nurses on the unit was inversely related to frequency of patient falls ($P = .04$). Other values of interest were those of urinary tract infections (inverse relationship; $P = .07$) and blood-stream infections (positive relationship; $P = .07$). For falls, the expected rate with no predictors was 1.1 per 1000 patient days, with fall rate decreasing by 0.04 for every 1 standard deviation change in the proportion of certified staff nurses in the unit. Urinary tract infection rate decreased by 0.19 and bloodstream infection rate increased by 0.04 for each 1 standard deviation change in proportion of certified staff nurses in the unit. The total number of hours of nursing care per patient day was positively related to medication administration errors ($P = .006$). Mean years worked by staff nurses was inversely related to urinary tract infections ($P = .01$). The expected rate of medication administration errors with no explanatory variables was 4.82 medication errors per 1000 patient days, with medication errors increasing by 0.39 for each 1 standard deviation change in total hours of nursing care per patient day. The expected rate of urinary tract infections with no predictors was 2.29 per 1000 patient days, decreasing by 0.86 with each 1 standard deviation change in mean years of experience of the staff nurses.

No significant associations were found for magnet status, nurse education level, and nurse skill mix.

Discussion

Our results supported the hypotheses in part. Research question 1 examined zero-order correlations between the proportion of certified staff nurses in the unit and rates of adverse events. Significant correlations were detected between (1) years of nursing experience and rate of medication administration errors, (2) skill mix and rates of both medication administration errors and urinary tract infections, (3) nurses' education level and rate of skin breakdown, and (4) total hours of nursing care per patient day and rates of both central catheter and blood-stream infections. No significant correlations were found between certification and outcomes. Under HLM analyses, only rate of falls demonstrated a significant relationship with certification (inverse).

Research question 2 examined multivariate relationships between adverse event rates in the unit and organizational nursing characteristics, inclusive of certification. Outcome measures showed both univariate and bivariate associations, except for skin breakdown, which showed no association. Certification was not related to rates of medication administration errors, skin breakdown, or central catheter infections. Total hours of nursing care per patient day had a positive relationship with rate of medication administration errors, and nurses' years of experience had an inverse relationship with rate of urinary tract infections. No significant relationships were found between central catheter infections and nurses' years of experience ($P = .05$) and between bloodstream infections and certification ($P = .07$); larger samples are required to clarify relationships, if any, among these variables. In small samples, only large differences, if they exist, can be detected.

Study results for the 2 outcome variables with data from relatively large numbers of units, medication administration errors and patient falls, align with results reported in the patient safety literature. The relationship between medication administration errors and staffing indicators (eg, total hours of nursing care per patient day, skill mix) is unclear; the literature reports a range of associations from none[31] to curvilinear relationships.[2,32] An association between rate of falls and proportion of registered nurses with a national certification, among other nursing characteristics, was examined in a study of 1610 units (6 unit types) participating in the NDNQI program. Of the 6 unit types, critical care units had the lowest rate of falls. No association was found between rate of falls and percentage of certified registered nurses at the unit level. This result was based on certification data collected from July 1, 2005, through June 30, 2006.[22] However, in a preliminary analysis of more recent NDNQI unit certification data defined with greater specificity as to type of certification, Dunton[21] reported an inverse relationship between proportion of certified nurses and fall rate at the unit level; Dunton's preliminary findings[21] align with our results.

The pattern of associations among outcomes, certification, and other covariates in our study suggests that assessment of the influence of registered nurse certification on risk of harming patients is complex and difficult. Assigning a value to registered nurse certification at the unit level is also difficult; outcome measures used frequently in nursing research to examine safety of patients in acute care hospitals may not reflect higher-level cognitive processes used by ICU nurses to avoid harming patients.[6,10]

Types of registered nurse certifications in ICUs vary significantly Schmalenberg and Kramer, [33] in a study of nurses' work environments in 4 types of ICUs (medical/surgical, medical, surgical, neonatal/pediatric) in magnet hospitals, found that 27% of 698 staff nurse participants were certified nationally. The types of certification varied: 60% were certified in adult critical

care (CCRN) and 23% were certified as an RN, C (designates certification awarded by a specific organization),[34] with the remaining 17% representing certifications from 15 different types of specialties. These findings highlight the challenge in using generalized data on certification of registered nurses to study empirical links that may be knowledge specific to the outcome being measured.

Three limitations require that caution be exercised when interpreting our findings. Of the 6 outcome measures, 4 had marked amounts of missing data, and the small sample affects both the power to detect effects and the stability of HLM parameter estimates.[35] Type of registered nurse certification was unknown, thereby limiting the ability to conceptually link specific knowledge tested on a certification examination and differences in units' rates of adverse events. Use of secondary data with potentially different interpretations (eg, type of certification) and measurement of outcomes (eg, medication administration errors) could influence variation among rates of adverse events. Selection and reporting biases may have resulted in underreporting of adverse events, a recognized limitation of self-reported data on adverse events.[8]

The results provide a preliminary foundation for further research on the relationship between certification of registered nurses and safety of patients. Future studies would be strengthened by incorporating types of certification and by the development of outcome measures designed to reflect specific nursing actions at the bedside (eg, care associated with patients receiving mechanical ventilation).[9,36]

The overall focus of this study was to increase understanding of the relationships between competence and certification of registered nurses and safety of patients. Evidence is accumulating that competency of ICU nurses is an important factor in both the prevention and creation of adverse events. Certification of registered nurses is associated with expertise in a specialized area of practice. Whether or not the percentage of registered nurses in a unit who are certified becomes a nursing unit characteristic that provides an "additive effect" in combination with nurse staffing, nurse education, and healthy work environments in delivering safe, high-quality care[37] depends heavily on investment in nursing certification research and alignment of the nursing certification process.

Conclusion

The purpose of this secondary data analysis was to explore the relationship between the proportion of staff nurses in a unit who are certified and the safety of patients as measured by unit rates of adverse events. An inverse relationship between unit proportion of certified nurses and patients' outcomes was hypothesized. Even though the sample was small, significant relationships were detected but varied by outcome and direction of relationship. This study was the first in which quantitative data were used to explore the link between nurses' competence, as measured by certification status, and patients' outcomes. Further exploration of an empirical link between the cognitive knowledge validated on certification examinations for registered nurses and the safety of patients is recommended.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

ACKNOWLEDGMENTS

This project would not have been possible without the guidance of dissertation committee members Drs Amy J. Barton, Katherine N. Bent, Paul F. Cook, Ruth A. O'Brien, and A. Laurie W. Shroyer.

FINANCIAL DISCLOSURES

This project was supported by grant number F31NR009736 from the National Institute of Nursing Research. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute of Nursing Research or the National Institutes of Health. Collection of study data was funded by grant NR0104937 from the National Institute of Nursing Research to MA Blegen, principal investigator. Preparation of this article was assisted in part by a postdoctoral fellowship held at the Center for Health Outcomes and Policy Research under T32-NR-007104 (Advanced Training in Nursing Outcomes Research, principal investigator: Dr Linda Aiken).

REFERENCES

1. Pronovost P, Wu A, Dorman T, et al. Building safety into ICU care. J Crit Care 2002;17(2):78–85. [PubMed: 12096370]
2. Valentin A, Capuzzo M, Guidet B, et al. Patient safety in intensive care: results from the multinational sentinel events evaluation (SEE) study. Intensive Care Med 2006;32(10):1591–1598. [PubMed: 16874492]
3. Beckmann U, Baldwin I, Hart GK, Runciman WB. The Australian Incident Monitoring Study in Intensive Care: AIMS-ICU. An analysis of the first year of reporting. Anaesth Intensive Care 1996;24 (3):320–329. [PubMed: 8805886]
4. Pronovost P, Thompson D, Holzmueller C, et al. Toward learning from patient safety reporting systems. J Crit Care 2006;21(4):305–315. [PubMed: 17175416]
5. Waddell D. Measurement issues in promoting continued competence. J Contin Educ Nurs 2001;32(3): 102–106. [PubMed: 11868700]
6. Landon B. What do certification examinations tell us about quality [editorial]? Arch Intern Med 2008;168(13):1365–1367. [PubMed: 18625915]
7. Bracco D, Favre J, Bissonnette B, et al. Human errors in a multi-disciplinary intensive care unit. Intensive Care Med 2001;27(1):137–145. [PubMed: 11280625]
8. Pronovost P, Holzmueller C, Young J, et al. Using incident reporting to improve patient safety: a conceptual model. J Patient Safety 2007;3(1):27–33.
9. Couchman BA, Wetzig SM, Coyer FM, Wheeler MK. Nursing care of the mechanically ventilated patient: what does the evidence say? Part one. Intensive Crit Care Nurs 2007;23(1):4–14. [PubMed: 17046259]
10. Hurley A, Rothschild J, Moore M, et al. A model of recovering medical errors in the coronary care unit. Heart Lung 2008;37(3):219–226. [PubMed: 18482634]
11. Salcido R. Beyond certification for wound care practitioners [editorial]. Adv Skin Wound Care 2007;20(8):424–426. [PubMed: 17762305]
12. Cary AH. Certified registered nurses: results of the study of the certified workforce. Am J Nurs 2001;101(1):44–52. [PubMed: 11211688]
13. Accreditation standards. American Board of Nursing Specialties Web site. [Accessed December 16, 2008]. http://www.nursingcertification.org.
14. NCCA standards. National Organization for Competency Assurance Web site. [Accessed January 5, 2009]. http://www.noca.org/NCCAAccreditation/StandardsInterpretations/tabid/93/Default.aspx.
15. Guide to nursing certification organizations: specialty certifications organizations. Dimens Crit Care Nurs 2008;27(4):171–172. [PubMed: 18580284]
16. Hart S, Bergquist S, Gajewski B, Dunton N. Reliability testing of the National Database of Nursing Quality Indicators pressure ulcer indicator. J Nurs Care Qual 2006;21(3):256–265. [PubMed: 16816607]
17. Zulkowski K, Ayello EA, Wexler S. Certification and education: do they affect pressure ulcer knowledge in nursing? Adv Skin Wound Care 2007;20(1):34–38. [PubMed: 17195785]
18. Henderson-Everhardus, MC. Denton, TX: Texas Woman's University; 2004. Does Nursing Expertise Contribute to the Accuracy of Vascular Assessment in the Detection of Peripheral Arterial Disease [master's thesis]?. Retrieved December 31, 2008, from Dissertations &Theses, A & I database (Pub No. AAT 1419275).

19. The registered nurse population: findings from the 2004 National Sample Survey of Registered Nurses. Health Resources and Services Administration Web site. [Accessed January 5, 2009]. http://bhpr.hrsa.gov/healthworkforce/rnsurvey04/.
20. NDNQI: the National Database of Nursing Quality Indicators. NDNQI Web site. [Accessed December 16, 2008]. http://www.nursingquality.org.
21. Dunton, N. The latest NDNQI research. [Accessed December 16, 2008]. http://www.nursingquality.org/Documents/Public/The%20Latest%20From%20NDNQI.pdf.
22. Dunton N, Gajewski B, Klaus S, Pierson B. The relationship of nursing workforce characteristics to patient outcomes. Online J Issues Nurs 2007;12(3)ms 3. http://www.nursingworld.org/MainMenuCategories/ANAMarketplace/ANAPeriodicals/OJIN/TableofContents/Volume122007/No3Sept07/NursingWorkforceCharacteristics.aspx. Accessed December 2, 2008.
23. Blegen MA, Vaughn T, Pepper G, et al. Patient and staff safety: voluntary reporting. Am J Med Qual 2004;19(2):67–74. [PubMed: 15115277]
24. Mark BA, Hughes LC, Belyea M, Bacon CT, Chang Y-K, Jones CA. Exploring organizational context and structure as predictors of medication errors and patient falls. J Patient Safety 2008;4(2):66–77.
25. Tucker A. An empirical study of system improvement by frontline employees in hospital units. Manuf Serv Oper Manage 2007;9(4):492–505.
26. Analytic software. SPSS Web site. [Accessed December 16, 2008]. http://www.spss.com/spss.
27. Raudenbush, S.; Byrk, A.; Congdon, R. HLM6 hierarchical linear and nonlinear modeling. [Accessed December 2, 2008]. http://www.ssicentral.com/hlm/student.html.
28. Park S, Lake ET. Multilevel modeling of a clustered continuous outcome: nurse's work hours and burnout. Nurs Res 2005;54(6):406–413. [PubMed: 16317362]
29. Adewale AJ, Hayduk L, Estabrooks CA, Cummings GG, Midodzi WK, Derksen L. Understanding hierarchical linear models: applications in nursing research. Nurs Res 2007;56(4 suppl):S40–S46. [PubMed: 17625473]
30. Raudenbush, S.; Bryk, A. Vol. 2nd ed.. Thousand Oaks, CA: Sage Publications; 2002. Hierarchical Linear Models: Applications and Data Analysis Methods.
31. Lang TA, Hodge M, Olson V, Romano PS, Kravitz RL. Nurse-patient ratios: a systematic review on the effects of nurse staffing on patient, nurse employee, and hospital outcomes. J Nurs Adm 2004;34(7–8):326–337. [PubMed: 15303051]
32. Blegen MA, Vaughn T. A multistate study nurse staffing and patient outcomes. Nurs Econ 1998;16(4):196–203. [PubMed: 9748985]
33. Schmalenberg C, Kramer M. Types of intensive care units with the healthiest, most productive work environments. Am J Crit Care 2007;16(5):458–469. [PubMed: 17724243]
34. New certification credentials to be issued. National Certification Organization Web site. [Accessed December 16, 2008]. http://www.nccnet.org/public/pages/index.cfm?pageid=476
35. Maas, CJM.; Hox, JJ. Robustness of multilevel parameter estimates against small sample sizes. 2001 [Accessed December16, 2008]. http://www.geocities.com/joophox/papers/p090101.pdf.
36. Dennison C, Mendez-Tellez P, Wang W, Pronovost PJ, Needham DM. Barriers to low tidal volume ventilation in acute respiratory distress syndrome: survey development, validation, and results. Crit Care Med 2007;35(12):2747–2754. [PubMed: 17901838]
37. Aiken LH. Economics of nursing. Policy Polit Nurs Pract 2008;9(2):73–79. [PubMed: 18480318]

Table 1

Study variables

Type	Level	Definition
Predictor	Unit	Registered nurse work group competence: percentage of certified staff registered nurses
Control	Hospital	Medicare case mix index: risk adjuster
	Hospital	Magnet status: nurse practice environment
	Unit	Registered nurse years of experience: mean years of experience of staff registered nurses
	Unit	Registered nurse education level: percentage of staff registered nurses with bachelor of science in nursing or higher
	Unit	Total hours of nursing care per day: mean total hours, all nurse staff care per day
	Unit	Registered nurse mix: percentage of nursing staff who are registered nurses
Outcomes	Unit	Medication administration errors: annual rate per 1000 patient days
	Unit	Total falls: annual rate per 1000 patient days
	Unit	Skin breakdown: annual rate per 1000 patient days
	Unit	Central catheter infection: annual rate per 1000 patient days
	Unit	Bloodstream infection: annual rate per 1000 patient days
	Unit	Urinary tract infection: annual rate per 1000 patient days

Table 2

Descriptive statistics for unit variables

Variable [a]	No. of units	Mean	SD
RN yrs work, y	42	12.4	4.0
RN BSN edu, %	48	44.3	21.5
RN cert, %	48	19.8	18.1
THPPD, h	46	15.8	3.1
RN skill mix, %	46	0.9	0.1
MAE[b]	47	4.9	4.6
Falls[b]	47	1.1	0.9
Skin brk[b]	21	4.7	3.5
CCI[b]	21	2.4	2.1
BSI[b]	19	1.7	2.4
UTI[b]	13	2.3	1.6

[a] Explanations: BSI, bloodstream infection rate in unit; CCI, central catheter infection rate in unit; MAE, medication administration error rate in unit; RN BSN edu, percentage of registered nurses in the unit with a bachelor of science in nursing or a higher degree; RN cert, percentage of staff registered nurses in unit who are certified; RN skill mix, percentage of nursing staff who are registered nurses; RN yrs work, mean years worked by staff registered nurses; Skin brk, skin breakdown rate in unit; THPPD, total hours of nursing care per patient day; UTI, urinary tract infection rate in unit.

[b] Annual rate per 1000 patient days.

Table 3

Correlation matrices[a]

	Intensive care unit independent variable correlation matrix						
	CMI (risk adj)	**Magnet hosp**	**RN yrs work**	**RN BSN edu**	**RN cert**	**THPPD**	**RN skill mix**
CMI (risk adj)	1						
Magnet hosp	**0.51**[b]	1					
RN yrs work	**−0.54**[b]	−0.09	1				
RN BSN edu	**0.34**[c]	**0.33**[c]	−0.01	1			
RN cert	−0.08	−0.05	0.13	−0.001	1		
THPPD	0.01	0.06	−0.10	0.22	0.21	1	
RN skill mix	−0.07	0.03	0.20	**0.31**[c]	**−0.31**[c]	**−0.41**[b]	1

	Independent-dependent variable correlations					
	MAE	**Fall**	**Skin brk**	**CCI**	**BSI**	**UTI**
CMI (risk adj)	−0.18	−0.16	−0.18	0.29	0.34	0.26
Magnet hosp	−0.17	0.03	−0.28	0.28	−0.07	0.28
RN yrs work	**0.31**[c]	−0.07	−0.16	0.32	−0.08	−0.28
RN BSN edu	0.04	−0.01	**−0.44**[c]	0.27	0.34	0.03
RN cert	−0.20	−0.06	−0.02	0.13	0.25	0.13
THPPD	0.07	0.07	−0.12	**0.62**[b]	**0.63**[b]	0.49
RN skill mix	**0.31**[c]	−0.09	0.14	−0.28	−0.07	**−0.64**[c]

[a]Variables: BSI, bloodstream infection rate in unit; CCI, central catheter infection rate in unit; CMI (risk adj). Medicare case mix index, risk adjuster; MAE, medication administration error rate in unit; Magnet hosp, magnet hospital; RN BSN edu, percentage of registered nurses in the unit with a bachelor of science in nursing or a higher degree; RN cert, percentage of staff registered nurses in unit who are certified; RN skill mix, percentage of nursing staff who are registered nurses; RN yrs work, mean years worked by staff registered nurses; Skin brk, skin breakdown rate in unit; THPPD, total hours of nursing care per patient day; UTI, urinary tract infection rate in unit.

[b]Correlation is significant at the .01 level (2-tailed).

[c]Correlation is significant at the .05 level (2-tailed).

Table 4

Results of hierarchical linear model, unstandardized multivariate coefficients[a,b]

Outcome (No. of units)	RN cert	RN yrs work	RN BSN edu	THPPD	RN skill mix	CMI	Magnet hosp
MAE (47)	−0.03	0.09	0.01	**0.39**[c]	−10.18	−2.88	−0.69
Falls (47)	**−0.04**[d]	−0.02	0.01	0.11	−7.9	−0.81	0.11
Skn brk (21)	0.07	−1.2	0.03	0.01	1.05	−2.94	−3.01
CCI (21)	0.23	1.69[e]	0.04	0.19	15.17	2.39	1.23
BSI (19)	0.04[f]	0.39	0.01	−0.07	1.85	3.8	−0.75
UTI (13)	−0.19[f]	**−0.86**[g]	0.00	0.08	−27.05	4.83	0.57

[a] Hierarchical linear model algorithms account for unbalanced group size.

[b] Variables: BSI, bloodstream infection rate in unit; CCI, central catheter infection rate in unit; CMI, Medicare case mix index, risk adjuster; MAE, medication administration error rate in unit; Magnet hosp, magnet hospital; RN BSN edu, percentage of registered nurses in the unit with a bachelor of science in nursing or a higher degree; RN cert, percentage of staff registered nurses in unit who are certified; RN skill mix, percentage of nursing staff who are registered nurses; RN yrs work, mean years worked by staff registered nurses; Skin brk, skin breakdown rate in unit; THPPD, total hours of nursing care per patient day; UTI, urinary tract infection rate in unit.

[c] $P = .006$.

[d] $P = .04$.

[e] $P = .05$.

[f] $P = .07$.

[g] $P = .01$.