

The Impact of Nurse Staffing and Contract Nurses on Patient Outcomes:
New Evidence from Longitudinal Data

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Abstract

Context: While adequate nurse staffing has been identified as a probable key driver of the quality of hospital care, little is known about the use of contract nurses, and previous evidence of the effects of nurse staffing have been limited by data deficiencies.

Objective: To understand the impact of using different types of nurses, including contract nurses, on the quality of care and how data limitations affected previous results.

Design, Setting, and Patients: Patients admitted to a Veterans Affairs acute care unit or intensive care unit (ICU) during 2003-2006. Monthly, unit-level, nurse staffing variables were examined. Risk-adjusted, patient-level, fixed-effects multivariate analyses controlled for unobserved factors.

Main Outcome Measures(s): Total patient length of stay (LOS), a composite patient safety indicator (PSI), and 30-day mortality.

Results: 458,960 patients from 170 ICUs and 1,464,088 patients from 302 acute care units were included. A one hour increase in nursing hours per patient day (HPPD) was associated with LOS reductions of 0.9% (95% CI 0.8-1.1, $p<0.001$) in ICUs and 2.7% (95% CI 2.4-3.0, $p<0.001$) in acute care units. A 10% increase in the share of nurses who were contract nurses was associated with 2.9% (95% CI 2.1-3.7, $p<0.001$) LOS increases in acute care units. A one hour increase in HPPD was associated with 1% reductions in the odds of a PSI event ($p<0.05$) and mortality ($p<0.05$) in ICUs. Failure to control for unobserved factors had large effects on the results, including a quadrupling of the HPPD effect on LOS.

Conclusions: Data aggregation and failure to control for unobserved factors causes an over-estimate of the effects of nurse staffing on patient outcomes. Controlling for these,

we find significant benefits of better nurse staffing and adverse effects associated with use of contract nurses. Given adequate staffing levels, the use of contract nurses should be minimized.

In “*The Future of Nursing: Leading Change, Advancing Health*”, the Institute of Medicine (IOM) concluded that, based on existing evidence, the quality of patient care depends largely on nurses.¹ Nursing personnel are the largest work force in hospitals and adequate staffing is a key driver of the quality of care. However, not all nursing personnel have the same qualifications and employment conditions (*e.g.*, registered nurses [RNs] versus licensed practical nurses [LPNs] or unlicensed assistive personnel [UAPs]), and regular versus contract employees). Contract nurses are often used to maintain staffing levels in the face of short or long term nursing shortages.² As hospitals strive to improve operations in a budget-conscious environment, it is important to understand the impact of using different types of nurses on the quality of patient care delivery.

Higher levels of nurse staffing have been associated with reduced mortality,³⁻¹⁰ complications,^{4,5,7,10,11} and lengths of stay (LOS).^{5,7} While adequate nurse staffing was identified in the IOM report as a key driver of the quality of care, it was noted that the existing evidence is not causal. Most of the seminal studies of the effects of nurse staffing employed cross-sectional designs,^{3,7} which can be biased by the failure to control for unobserved factors. Repeated observations from the same hospitals (panel data), when combined with appropriate statistical methods, can reduce or eliminate this bias. In a few studies, researchers have employed panel data and found either reduced or no effects of higher levels of nurse staffing on patient outcomes.^{6,9,11} Some researchers have compared cross-sectional and panel estimates and found smaller effect sizes with longitudinal data.^{6,9} However, in these studies data were aggregated at the hospital level, usually with annual observations. Annual, hospital-level data can mask large variations

in nurse staffing, both over time and across units, and mixing heterogeneous patient groups across units can bias results.⁸ Other researchers have used unit-specific data to address these limitations, but these studies have used relatively small samples and cross-sectional data.^{10, 12, 13}

In many of the prior studies, researchers found that, controlling for the level of nurse staffing, higher levels of nursing skill-mix (the share of nursing hours provided by RNs) in acute care hospitals improves patient outcomes.^{3, 6, 7, 9-14} However, none of these studies examined the use of contract nurses. One study examined the impact of supplemental nurse staffing (i.e., nurses floating from other units and contract nurses) on patient outcomes, but data on the prevalence of supplemental nurses and the quality of care were self-reported by nurses.¹⁵

In this study we used data from a large integrated health care system (Department of Veterans Affairs [VA]) to examine the impact of nurse staffing levels, skill-mix, and use of contract nurses on patient outcomes, as measured by patients' LOS, nursing sensitive patient complications, and mortality. The methods used simultaneously address the aggregation bias, small samples, and lack of control for unobserved factors that have limited most previous studies in this area.

METHODS

We conducted a retrospective observational study using panel data for all patients admitted to an intensive care unit (ICU) or general acute care inpatient unit in the VA health care system from October 1, 2002 through September 30, 2006. Data were

initially obtained from 215 ICUs and 438 general acute care units at 143 facilities. The study was approved by the Stanford and Columbia University IRBs.

Data Sources

The VA Decision Support System (DSS) integrates clinical and financial data on each patient. This includes tracking patient admissions, discharges and transfers between units or “bed-sections.” The VA also creates a separate discharge abstract using *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD) diagnoses and procedure codes and a Diagnosis Related Group (DRG) for each bed-section in which a patient is treated. Thirty-day mortality (post-hospital discharge) was ascertained from a VA dataset that combines mortality data from multiple sources.

Summaries of the labor hours allocated to each unit by month were obtained from DSS. For all permanent employees (RNs, LPNs, and UAPs), paid time off (vacation or sick hours) was excluded. Administrative and specialty nurses (*e.g.*, nurse managers and clinical nurse specialists) were excluded from staffing measures. The data included adjustments for floating but not for paid hours related to non-direct patient care activities (*e.g.*, training).¹⁶ For contract nurses (travelers and agency nurses) there is no identification of the type of personnel (RN, LPN, or UAP). However, in ICUs (acute care units), over 90% (85%) of the hourly costs were consistent with RN hourly wages.

Variables

We calculated monthly total nursing (RNs, LPNs, UAPs, and contract nurses) hours per patient day (HPPD) for each unit and the percentage of these hours provided by LPNs, UAPs, and contract nurses. Our outcome measures were LOS, patient safety indicators, and 30-day mortality. All of these have been endorsed by the National

Quality Forum (NQF) as outcomes measures.¹⁷ In addition to serious adverse events,¹⁸ minor missed clinical care events or errors of omission (*e.g.*, not ambulating or turning the patient at optimum times, inadequate or skipped patient teaching or discharge planning, and lack of effective communication and documentation) may also increase LOS.¹⁹ We used patients' total hospital LOS as an outcome with the rationale that LOS represents a combined indicator of adverse patient outcomes and efficiency.

We used the Agency for Healthcare Research and Quality (AHRQ) Patient Safety Indicator (PSI) software to identify infections due to medical care, decubitus ulcers, failure to rescue (FTR), and deep venous thrombosis/pulmonary embolus (DVT/PE).²⁰ The AHRQ FTR measure was replaced by the Silber FTR measure.²¹ Because previous studies with hospital-level data have found only limited statistical significance for these rare events,⁷ we created a dichotomous variable indicating the presence of any of these four adverse events as a composite nursing sensitive outcome variable.

To control for patients' severity of illness upon admission we used the ICD codes from the admitting unit to calculate the Elixhauser Comorbidity Index.²² The Medicare median LOS for the admitting DRG for each patient was used as a predicted LOS to control for differences in expected LOS.

Nursing Unit-Month Eligibility

Monthly observations for units with less than 100 patient days were excluded. We screened the HPPD data for obvious data errors and excluded any month if reported HPPD was <12 or >48 for ICUs and <3 or >15 for acute care units. Monthly observations with incomplete data were excluded, and a unit was entirely excluded if more than half of the monthly observations for that unit were excluded.

Data Analysis

Descriptive statistics were examined for ICUs and acute care units separately. Standard deviations were estimated both between and within-units to understand sources of variation. Due to a skewed distribution, LOS was logarithmically transformed. We tested for the functional form of all non-categorical variables and used spline functions to account for the observed non-linear effects of age and predicted LOS.

Fixed-effects, patient-level, multivariate ordinary least squares and logistic regressions with robust standard errors clustered by unit were estimated, and 95% confidence intervals (CI) were computed. Patient-level control variables included age, Elixhauser co-morbidity index, an indicator for a surgical DRG at admission, and the median LOS for the patient's admitting DRG. We also included the number of patients admitted to each unit during the month to control for added nursing workload associated with admissions and monthly variation in patient census. Nursing inputs were monthly, unit-level data from the admitting unit. We avoided the potential endogeneity between LOS and HPPD by using each patient's total LOS on all units and monthly HPPD from the admitting unit only. To examine how the effect of nurse staffing varied across the range of staffing levels, we also estimated our models using deciles of HPPD. To place our findings in context with previous results that used more aggregated data and different statistical methods, we re-estimated the models with annual, hospital-level data, both with and without fixed-effects.

RESULTS

The final sample included 472 units (170 ICUs and 302 acute care units, 7,148 and 11,637 monthly observations, respectively) at 126 facilities. Over four years, 1,464,088 patients were admitted to an acute care unit and 458,960 patients were admitted to an ICU. Nurse staffing and patient characteristics are shown in Table 1. The between and within unit standard deviations demonstrate considerable variation in the nurse staffing data. Staffing was higher and almost no non-RN staff were used in ICUs. While the mean use of contract nurses was low in both unit types (approximately 2%), there was considerable variation; up to 50% in some units in some months.

Table 2 presents the LOS regression results. The first row shows the marginal effect of a one hour increase in HPPD. Since the dependent variable was the natural logarithm of LOS, these estimates imply a one hour increase in HPPD was associated with a 2.7% (95% CI 2.4-3.0, $p < 0.001$) reduction in LOS for acute care units and a 0.9% (95% CI 0.8-1.1, $p < 0.001$) reduction in ICUs. The coefficients for the percent of LPNs, UAPs, and contract nurses represent the effect of shifting from 0 to 100 percent use of each type of nurse. Dividing the coefficients by 10 represents the effect of changing nursing staff composition of that type of nurse by 10 percentage points. Increasing the share of total nursing hours provided by contract nurses in acute care units from 0 to 10 percent was associated with 2.9% (95% CI 2.1-3.7, $p < 0.001$) increase in LOS; this effect was smaller and not statistically significant for ICUs. Increased use of LPNs was not associated with LOS in either type of unit. A 10 percentage point increase in the use of UAPs was associated with 1.2% (95% CI 0.5-1.9, $p < 0.001$) increase in LOS for acute care units.

Figure 1 illustrates the effect of nurse staffing by decile of HPPD. Additional staffing had significant and approximately linear effects across the entire range of staffing levels for both types of units. For acute care units, LOS was 14% shorter for units in the 10th decile of nurse staffing levels compared to those in the 1st decile, while this difference was about 12% for ICUs.

Table 3 presents the logistic regression results for 30-day mortality and the incidence of any of the four nursing-sensitive PSIs. In acute care, increased use of UAPs was weakly associated ($p=0.065$) with higher rates of PSIs and increased staffing was weakly associated ($p=0.097$) with reduced mortality. For ICUs, a 1 hour increase in HPPD was associated with a small (1%), but significant, reduction in the odds of both PSIs ($p<0.05$) and mortality ($p<0.05$).

Table 4 presents patient-level regression results with and without fixed-effects with the hospital-year as the unit of observation for the nurse staffing variables. Column 1 shows the results for LOS with fixed-effects included and column 2 shows the LOS results when fixed-effects are excluded. Comparing Column 1 of Table 4 to the results in Table 2 compares our monthly, unit-level, estimates with a fixed-effects model that uses annual, hospital-level data. Using hospital-level data masks the differences between different types of units in the effects of HPPD and contract nursing. Comparing columns 1 (fixed-effects) and 2 (no fixed-effects) of Table 4 shows the large impact of not using fixed-effects to control for unobserved factors correlated with nurse staffing; removing the fixed-effects results in a quadrupling of the estimated reduction in LOS associated with a 1 hour increase in HPPD and large increases in the estimated adverse effects on LOS of increased use of LPNs and UAPs. Conversely, the previously significant adverse

effect of contract nurses reverses sign. Similarly, compared to Table 3, there are marked changes in the results when the data are aggregated to hospital-year and the fixed-effects are dropped for the PSI (column 3) and mortality (column 4) models.

DISCUSSION

We used detailed data to extend analysis of the effects of nurse staffing on patient outcomes in two important ways. First, our data enabled us to extend previous literature to directly measure the effect of using contract nurses. Second, the data allowed us to address significant limitations that have biased most previous studies. Specifically, our use of monthly, unit-specific measures of nurse staffing to more accurately link patients with actual staffing levels and our use of longitudinal, fixed-effects models allowed for the control of many unobserved factors that are correlated with both nurse staffing and patient outcomes. We found that increased use of contract nurses was associated with longer LOS for patients on acute care units and that increased nurse staffing was associated with shorter LOS for both acute care units and ICUs. Increased staffing levels were also associated with lower PSIs and mortality in ICUs. The effect sizes we observed are smaller than those reported by most previous researchers, which reflects our ability to control for unobserved factors that affect the estimates.

The existing literature on the effects of contract nurses is very limited. Using a cross-sectional hospital level design, Aiken found that nurses employed in hospitals with more supplemental nurses self-reported higher quality.¹⁵ These results are not directly comparable to ours as the “supplemental” nurses included nurses floating from other units, in addition to contract nurses, with no data about the split between them. Using our

panel, fixed-effects design, we found that increased use of contract nurses was associated with increased LOS. This result was sensitive to the estimation method and reversed when the fixed-effects were removed. This implies that the effect of contract nurses is quite sensitive to the ability to control for unobserved factors, something that previous researchers were not able to do. Thus, our results provide strong evidence that, controlling for overall staffing levels, outcomes are worse when the share of contract nurses increases.

According to the Health Resources and Services Administration, over 88,000 RNs are employed by temporary agencies.²³ These nurses may find it difficult to function as effectively as regular employees. Previous researchers have found high use of contract staff to fill individual shifts and accommodate short-term staffing needs arising from vacations and medical leaves.²⁴ While additional research is needed, our results imply that to maintain patient safety, the use of contract nurses should be minimized when possible; if contract nurses are needed to maintain adequate staffing, nursing managers need to adjust patient assignments to compensate for contract nurses' reduced productivity associated with working in an unfamiliar setting.

Our use of unit-level, panel data provides reliable evidence to support the notion that better nurse staffing results in better patient outcomes. Because our models were driven by the within-unit variance in staffing levels, they eliminate much of the unobserved heterogeneity that biased previous studies. Additionally, the extent of bias in most previous studies due to data aggregation and unobserved heterogeneity is evident; failure to control for unobserved heterogeneity resulted in quadrupling the estimated effect of HPPD on LOS. It also resulted in a reversal of the effect of using contract

nurses. Further, while some previous studies have found that the effect of better nurse staffing is concentrated at lower staffing levels,⁹ we found that the beneficial effects of increased nurse staffing levels were approximately linear across the entire range of staffing levels. We also found much smaller adverse effects of non-RN staff than some previous studies.¹⁴

Since most hospital payments are prospective, there are clear financial benefits to reducing LOS. These potential benefits may be magnified by the recent change in Medicare payment rules to disallow additional payment for hospital-acquired complications.²⁵ As these complications drive increases in LOS, it is possible that savings due to better nurse staffing will more than offset costs. Hospitals need to be careful about cutting nursing budgets, as reduced nursing personnel could well yield a net financial loss due to added patient care costs. It has been suggested that better nurse staffing could reduce hospital costs for at least some range of nurse staffing levels.^{19, 26, 27} Our study found smaller effects of nurse staffing on patient outcomes than were used in these estimates. But it is likely that the cost savings of better nurse staffing we observed are still similar to the costs of additional nurse staffing. A careful analysis is needed to determine how changes in nurse staffing affect net hospital costs. The results of such an analysis would have significant policy implications; financially pressed hospitals will be much more willing to invest in nurse staffing if it reduces net costs than if it increases them.

There are some limitations to our data. We observed hours worked by each nurse, not hours of direct patient care. Also, our results may not apply exactly to non-VA hospitals. The VA staffs nursing units based on an 85% occupancy rate and, unlike other

hospital systems, the VA does not reduce staffing when the patient census falls, so a drop in the patient census can produce an increase in HPPD. This could change the magnitude of the relationship between HPPD and LOS, which may not be linear or persist across the entire range of staffing levels in non-VA hospitals. We may also be under-estimating the effect of contract nurses because in the VA, nurses must be trained in how to use the VA electronic medical record system before they can work as contract nurses.

In summary, we have shown that data aggregation bias and failure to control for unobserved factors have over-estimated the favorable effects of higher nurse staffing. Nonetheless, we still found significant and clinically meaningful benefits of better nurse staffing. We also showed that use of larger shares of contract nurses was associated with longer lengths of stay. Given adequate staffing levels, the use of contract nurses should be minimized.

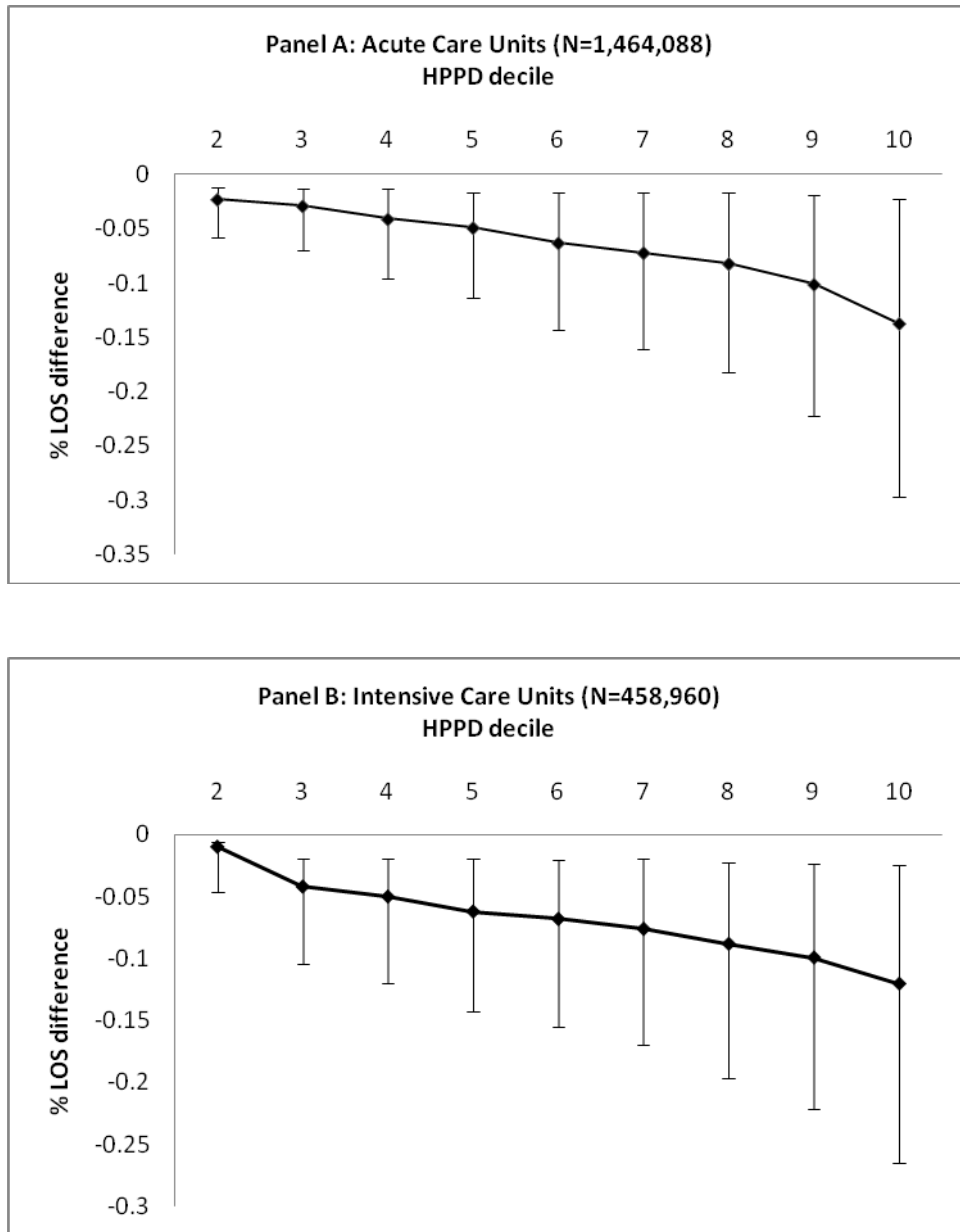
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Author contributions: All authors have reviewed and approve of the final manuscript. Dr. Phibbs wrote most of the initial draft of the manuscript, with significant contributions by Drs. Bartel, Schmitt, and Stone. All of the authors reviewed the many drafts of this manuscript and made numerous suggestions for revisions. Drs. Phibbs and Schmitt have full access to all of the data. Dr. Phibbs takes full responsibility for the integrity of the data and the accuracy of the data analyses. None of the authors have any conflicts of interest.

The study idea and the grant funding were jointly developed and obtained by Drs. Bartel, Phibbs, and Stone. Throughout the project they functioned as co-PIs and have jointly refined the analysis plan. Dr. Schmitt has been the project programmer for the entire project. This included figuring out how to merge together all of the different data sources used by the project, and creating all of the study variables. Various parts of the data analyses were programmed and run by Dr. Schmitt and Mr. Giovannetti. In addition to running the analyses, both Dr. Schmitt and Mr. Giovannetti made significant contributions to the design of the work, with Dr. Schmitt providing many key insights on how to measure different concepts and Mr. Giovannetti providing key input to the estimation methods.

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Figure 1. The Effect of Increased Nurse Staffing on Length of Stay, by Decile of Staffing Level in All VA Acute Care and Intensive Care Units



Data are for all VA acute medical care and intensive care units for fiscal years 2003-2006. Reference group is the lowest decile of nurse staffing, measured as hours per patient day (HPPD) of care. LOS is measured at the patient level while nurse staffing is measured monthly, at the unit level. The models control for the share of nurses that are LPNs, UAPs, and contract nurses, patient age, Elixhauser comorbidity index, admission DRG, surgical cases, the number of patients admitted to the unit each month, time trends, and unit-level fixed-effects that vary by year.

Table 1: Summary Statistics of Monthly Unit-Level Staffing Data and Patient Characteristics for All Non-ICU Acute Medical Care Units and ICUs in VA Hospitals, Fiscal Years 2003-2006.

	Observations	Mean	Standard Deviation		
			Overall	Between	Within
Unit-Level Staff					
Non-ICU ¹ Acute Care Units					
Total Nursing hrs per Patient Day	12,469	7.948	2.50	2.01	1.65
Percent Nursing hrs by LPN ²	12,469	0.235	0.13	0.13	0.05
Percent Nursing hrs by UAP ³	12,469	0.162	0.11	0.11	0.05
Percent Nursing hrs by Contract Nurses	12,469	0.025	0.06	0.05	0.04
ICUs					
Total Nursing hrs per Patient Day	7,076	18.194	4.96	3.37	3.66
Percent Nursing hrs by LPN	7,076	0.012	0.04	0.03	0.02
Percent Nursing hrs by UAP	7,076	0.023	0.04	0.03	0.03
Percent Nursing hrs by Contract Nurses	7,076	0.016	0.05	0.03	0.03
Patient Characteristics					
Non-ICU Acute Care Units					
Total Hospital LOS ⁴ (days)	1,464,088	5.97	8.37		
Predicted LOS (median for DRG ⁵)	1,464,088	5.20	2.33		
Patient Age (years)	1,464,088	65.7	12.9		
Elixhauser Comorbidity Index	1,464,088	1.44	1.09		
Surgical Patients (percent)	1,464,088	16.5%	37.1		
ICUs					
Total Hospital LOS (days)	458,960	6.49	10.55		
Predicted LOS (median for DRG)	458,960	5.74	3.50		
Patient Age (years)	458,960	65.5	12.0		
Elixhauser Comorbidity Index	458,960	1.43	1.09		
Surgical Patients (patients)	458,960	33.3%	47.2		

Data are from all VA acute medical care (including ICUs) patients from 2003-2006 initially admitted to the 302 non-ICU acute care units and 170 ICUs that had complete data nurse staffing data. The predicted LOS is the Medicare median LOS for the patient's admitting DRG.

¹ICU: Intensive Care Unit

²LPN: Licensed Practical Nurse

³UAP: Unlicensed Assistive Personnel

⁴LOS: Length of Stay

⁵DRG: Diagnosis Related Group

Table 2. Monthly, Unit-Level Regression Estimates From Veterans Affairs Medical Centers of The Effect Of Nursing Hours, Use Of Non-RN Nursing Staff, And Use Of Contract Nurses On Length Of Stay

	Acute N=1,464,088	ICUs¹ N=458,960
Nursing Hours Per Patient Day	-0.027*** [-0.030, -0.024]	-0.009*** [-0.011, -0.008]
Percent of Nursing Hours Provided by LPNs ²	-0.071 [-0.156, 0.014]	0.102 [-0.307, 0.512]
Percent of Nursing Hours Provided by UAP ³	0.124*** [0.054, 0.194]	0.123 [-0.072, 0.317]
Percent of Nursing Hours Provided by Contract Nurses	0.287*** [0.207, 0.367]	0.112 [-0.069, 0.294]
R-squared	0.147	0.172

Patient-level regression models with monthly, unit-level, nurse staffing data. The models control for patient age, Elixhauser comorbidity index, admission DRG, surgical cases, the number of patients admitted to the unit each month, time trends, and unit-level fixed-effects that vary by year. Robust standard errors were used to control for the clustering of patients within units. Data from all VA inpatient acute medical care units in fiscal years 2003-2006 with complete data; 161 ICUs and 266 other acute medical care units at 126 VA medical centers.

*p<.10; ** p<.05; ***p<.01

¹ICU: Intensive Care Unit

²LPN: Licensed Practical Nurse

³UAP: Unlicensed Assistive Personnel

Table 3. Monthly, Unit-Level Regression Estimates From Veterans Affairs Medical Centers of The Effect Of Nursing Hours, Use Of Non-RN Nursing Staff, And Use Of Contract Nurses On Nursing-Sensitive Complications and 30-Day Mortality

	Acute PSI N=1,461,647	Acute Mort N=1,462,802	ICUs¹ PSI² N=458,432	ICUs Mort N=458,960
Nursing Hours Per Patient Day	0.991 [0.974, 1.008]	0.991* [0.981, 1.002]	0.987** [0.977, .998]	0.990** [0.982, .998]
Percent of Nursing Hours Provided by LPNs ³	1.152 [0.646, 2.054]	0.920 [0.669, 1.264]	1.866 [0.067, 51.710]	2.497 [0.250, 24.91]
Percent of Nursing Hours Provided by UAP ⁴	1.697* [0.968, 2.976]	0.971 [0.685, 1.376]	1.269 [0.346, 4.656]	0.936 [0.349, 2.511]
Percent of Nursing Hours Provided by Contract Nurses	1.372 [0.775, 2.430]	1.119 [0.764, 1.637]	2.026 [0.551, 7.449]	1.010 [0.395, 2.578]
Pseudo R-squared	0.075	0.099	0.082	0.105

Patient-level regression models with monthly, unit-level, nurse staffing data. The models control for patient age, Elixhauser comorbidity index, admission DRG, surgical cases, the number of patients admitted to the unit each month, time trends, and unit-level fixed-effects that vary by year. Robust standard errors were used to control for the clustering of patients within units. Data from all VA inpatient acute medical care units in fiscal years 2003-2006 with complete data; 161 ICUs and 266 other acute medical care units at 126 VA medical centers.

*p<.10; ** p<.05; ***p<.01

¹ICU: Intensive Care Unit

²PSI: Patient Safety Indicator

³LPN: Licensed Practical Nurse

⁴UAP: Unlicensed Assistive Personnel

Table 4. Sensitivity Analyses of the Effects of Nurse Staffing Using Annual Hospital-Level Data to Examine the Effects of Aggregation Bias and Unobserved Heterogeneity

	LOS¹ Hospital Year Fixed-Effects	LOS Hospital Year No Fixed-Effects	PSI² Hospital Year No Fixed-Effects	MORT Hospital Year No Fixed-Effects
Nursing Hours Per Patient Day	-0.007 [-0.016, 0.003]	-0.033*** [-0.034, -0.033]	1.007** [1.001, 1.012]	1.001 [0.998, 1.005]
Percent of Nursing Hours Provided by LPNs ³	0.018 [-0.307, 0.343]	0.277*** [0.260, 0.294]	1.107 [0.956, 1.282]	1.227*** [1.123, 1.341]
Percent of Nursing Hours Provided by UAP ⁴	0.225** [0.014, 0.437]	0.566*** [0.548, 0.584]	1.120 [0.960, 1.307]	0.835*** [0.759, 0.920]
Percent of Nursing Hours Provided by Contract Nurses	0.268** [0.011, 0.524]	-0.069*** [-0.101, -0.037]	0.925 [0.705, 1.214]	0.698*** [0.587, 0.831]
R-squared	0.140	0.130	0.061	0.087

Patient-level regression models that control for admission DRG, patient age, Elixhauser co-morbidity index, surgical cases, the number of patients admitted to the unit each month, time trends. Hospital-level fixed-effects were included for column 1, but not column 2. Robust standard errors were used to control for the clustering of patients within hospitals. Data from all VA inpatient acute medical care units in fiscal years 2003-2006 at the 126 VA medical centers included in Table 2.

*p<.05; **p<.01

¹LOS: Length of Stay

²PSI: Patient Safety Indicator

³LPN: Licensed Practical Nurse

⁴UAP: Unlicensed Assistive Personnel

Reference List

1. Institute of Medicine (IOM). *The Future of Nursing: Leading Change, Advancing Health*. Washington, DC 2011.
2. PricewaterhouseCoopers' Health Research Institute. *What works: healing the healthcare staffing shortage*: PricewaterhouseCoopers LLP; 2007.
3. Aiken LH, Clarke SP, Sloane DM, Sochalski J, Silber JH. Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. *Jama*. Oct 23-30 2002;288(16):1987-1993.
4. Harless DW, Mark BA. Nurse staffing and quality of care with direct measurement of inpatient staffing. *Med Care*. Jul 2010;48(7):659-663.
5. Kane RL, Shamliyan TA, Mueller C, Duval S, Wilt TJ. The association of registered nurse staffing levels and patient outcomes: systematic review and meta-analysis. *Med Care*. Dec 2007;45(12):1195-1204.
6. Mark BA, Harless DW, McCue M, Xu Y. A longitudinal examination of hospital registered nurse staffing and quality of care. *Health Serv Res*. Apr 2004;39(2):279-300.
7. Needleman J, Buerhaus P, Mattke S, Stewart M, Zelevinsky K. Nurse-staffing levels and the quality of care in hospitals. *N Engl J Med*. May 30 2002;346(22):1715-1722.
8. Sales A, Sharp N, Li YF, et al. The association between nursing factors and patient mortality in the Veterans Health Administration: the view from the nursing unit level. *Med Care*. Sep 2008;46(9):938-945.
9. Sochalski J, Konetzka RT, Zhu J, Volpp K. Will Mandated Minimum Nurse Staffing Ratios Lead to Better Patient Outcomes? *Med Care*. Jun 2008;46(6):606-613.
10. Stone PW, Mooney-Kane C, Larson EL, et al. Nurse working conditions and patient safety outcomes. *Med Care*. Jun 2007;45(6):571-578.
11. Unruh L. Licensed nurse staffing and adverse events in hospitals. *Med Care*. Jan 2003;41(1):142-152.
12. Blegen MA, Goode CJ, Reed L. Nurse staffing and patient outcomes. *Nurs Res*. Jan-Feb 1998;47(1):43-50.
13. Sovie MD, Jawad AF. Hospital restructuring and its impact on outcomes: nursing staff regulations are premature. *J Nurs Adm*. Dec 2001;31(12):588-600.
14. Aiken LH, Clarke SP, Cheung RB, Sloane DM, Silber JH. Educational levels of hospital nurses and surgical patient mortality. *Jama*. Sep 24 2003;290(12):1617-1623.
15. Aiken LH, Xue Y, Clarke SP, Sloane DM. Supplemental nurse staffing in hospitals and quality of care. *J Nurs Adm*. Jul-Aug 2007;37(7-8):335-342.
16. Spetz J, Donaldson N, Aydin C, Brown DS. How Many Nurses per Patient? Measurements of Nurse Staffing in Health Services Research. *Health Serv Res*. May 5 2008.

17. National Quality Forum. *National Voluntary Consensus Standards for Nursing-Sensitive Care: An Initial Performance Measure Set*. Washington, DC: National Quality Forum; 2004.
18. Zhan C, Miller MR. Excess length of stay, charges, and mortality attributable to medical injuries during hospitalization. *JAMA*. Oct 8 2003;290(14):1868-1874.
19. Needleman J, Buerhaus PI, Stewart M, Zelevinsky K, Mattke S. Nurse staffing in hospitals: is there a business case for quality? *Health Aff (Millwood)*. Jan-Feb 2006;25(1):204-211.
20. Agency for Healthcare Research and Quality. *Guide to Patient Safety Indicators Version 3.1*. Rockville, MD: Department of Health and Human Services; 2007.
21. Silber JH, Romano PS, Rosen AK, Wang Y, Even-Shoshan O, Volpp KG. Failure-to-rescue: comparing definitions to measure quality of care. *Med Care*. Oct 2007;45(10):918-925.
22. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. Jan 1998;36(1):8-27.
23. HRSA. *The national sample survey of registered nurses 2008*. Rockville, MD: Bureau of Health Professions, Health Resources and Services Administration; 2010.
24. May JH, Bazzoli GJ, Gerland AM. Hospitals' responses to nurse staffing shortages. *Health Aff (Millwood)*. Jul-Aug 2006;25(4):W316-323.
25. Rosenthal M. Nonpayment for Performance? Medicare's New Reimbursement Rule. *New England Journal of Medicine*. October 18, 2007 2007;357(16):1573:1575.
26. Dall TM, Chen YJ, Seifert RF, Maddox PJ, Hogan PF. The economic value of professional nursing. *Med Care*. Jan 2009;47(1):97-104.
27. Shamliyan TA, Kane RL, Mueller C, Duval S, Wilt TJ. Cost savings associated with increased RN staffing in acute care hospitals: simulation exercise. *Nurs Econ*. Sep-Oct 2009;27(5):302-314, 331.