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METHODS ARTICLE

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The effect of data aggregation on estimations of nurse staffing and patient outcomes

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Abstract

Objective: To examine how estimates of the association between nurse staffing and patient length of stay (LOS) change with data aggregation over varying time periods and settings, and statistical controls for unobserved heterogeneity.

Data Sources/Study Setting: Longitudinal secondary data from October 2002 to September 2006 for 215 intensive care units and 438 general acute care units at 143 facilities in the Veterans Affairs (VA) health care system.

Research Design: This retrospective observational study used unit-level panel data to analyze the association between nurse staffing and LOS. This association was measured over both a month-long and a year-long period, with and without fixed effects.

Data Collection: We used VA administrative data to obtain patient data on the severity of illness and LOS, as well as labor hours and wages for each unit by month.

Principal Findings: Overall, shorter LOS was associated with higher nurse staffing hours and lower proportions of hours provided by licensed professional nurses (LPNs), unlicensed personnel, and contract staff. Estimates of the association between nurse staffing and LOS changed in magnitude when aggregating data over years instead of months, in different settings, and when controlling for unobserved heterogeneity.

Conclusions: Estimating the association between nurse staffing and LOS is contingent on the time period of analysis and specific methodology. In future studies, researchers should be aware of these differences when exploring nurse staffing and patient outcomes.

KEYWORDS
length of stay, methods, nurse staffing, nursing workforce, skill mix

What is known on this topic

- Better nurse staffing and lower nurse-to-patient ratios are associated with reduced morbidity and mortality in acute care settings.
- Research to support better nurse staffing faces methodological limitations, such as data aggregation over varying time frames and across hospital units.

What this study adds

- Aggregation of data at the month level and unit level, versus annual and hospital-wide level, and controlling for unobserved heterogeneity across settings, changes the magnitude of the estimates of the association between nurse staffing and patient outcomes.

1 | INTRODUCTION

There is a growing body of evidence associating appropriate nurse staffing with improved patient safety.[1–14] These studies come at a time of increasing national awareness around the need to improve quality and safety in hospitals with the goal of reducing adverse outcomes.[15] Multiple outcome measures have been linked to nurse staffing, including patient mortality, "failure to rescue" rate (i.e., defined as death among patients with specific complications), length of stay (LOS), hospital readmissions, and health care-associated infections.[2,4,6–9,11–16] The correlation between higher nurse staffing and improved patient outcomes is thought to be partially attributable to nurses not missing care due to inadequate time or resources.[17–20] In addition to serious adverse events, 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.[21,22]

Researchers have used varying methods to measure the association between nurse staffing and patient outcomes. The methods used are often constrained by data availability and variation in the ways nurse staffing is measured, which may limit our understanding of the true magnitude of the relationship between nurse staffing configurations and patient outcomes.[23] In particular, prior research has been limited by the specificity of setting, shift-specific effects on patient outcomes, imperfect controls for patient acuity, incomplete controls for quality of health care providers caring for patients, and unit-specific factors that may influence outcomes.[24] These limitations have produced varying estimates of the magnitude of the relationship between nurse staffing and outcomes, as well as what particular outcomes are associated with nurse staffing.[5,6,13] The majority of published studies have used either annual measures of staffing or last shift estimates of patients per nurse that are aggregated at the hospital level and taken as representative of typical staffing levels that have then been associated with annualized, risk-adjusted rates of adverse outcomes. In a smaller group of studies, investigators have used unit-specific data or longitudinal data, panel data, and shift-specific data, sometimes disaggregated to the unit-level, to create a more precise measurement of staffing for different types of units (i.e., intensive care unit [ICU] vs. medical unit).[5,8,12,25,26] Various methods have been used to control for unobserved heterogeneity, such as including controls for the heterogeneity of patient load during different days of the week, patient acuity level, shift type, and staffing mix.[3,7,8,27–31]

While there is significant evidence that there is a relationship between higher levels of nurse staffing and better patient outcomes, the estimated magnitude of that relationship may change depending on the estimation method and on the aggregation of data to the unit level or the hospital level. The aim of this paper is to explore how the level of data aggregation and different estimation methods affect estimates of the magnitude of the relationship between nurse staffing and patient outcomes, critical to understanding the cost/benefit trade-off of high versus low staffing. Specifically, we examine how the estimated relationship between nurse staffing and patient LOS changes (1) when aggregating data over the course of the month versus a year, (2) when estimating this relationship aggregated for the entire hospital, versus at the unit-level, with separate estimates for acute care units and ICUs, and (3) when using fixed effects to attempt to control for unobserved heterogeneity between units over time, versus no fixed effects. While we do not test the superiority of each of these methods, we argue that disaggregated data by location and unit of time reflects a more accurate estimate of the relationship between nurse staffing and LOS. This is especially important given the seminal findings by Needleman et al., which have been replicated by a couple of more recent single-site studies that exposure to shifts with inadequate staffing is associated with worse patient outcomes.[8,11,32] The more measurement of nurse staffing becomes more aggregated, it increases the ability to mask periods (e.g., shifts) where the staffing levels were below target staffing. Similarly, we argue that using fixed-effects estimates are conceptually superior as they control for what may be substantial unobserved heterogeneity across nursing units that could bias the effects of nurse staffing on patient outcomes. For example, several studies have reported that the unit work environment is associated with patient outcomes and with levels of nurse burnout.[33,34]

2 | METHODS

We conducted a retrospective observational study using panel data for all patients admitted to an ICU or general acute care inpatient unit in the Veterans Affairs (VA) health care system from October 1, 2002 to September 30, 2006. Data were obtained from 215 ICUs and 438 general acute care units at 143 VA facilities. Full details of the data and methods are reported in Bartel, Beaulieu, Phibbs, and Stone, 2014. The study was approved by the Stanford and Columbia University institutional review boards.

2.1 | Data sources

We integrated VA clinical data on each patient with staffing data on inpatient units from financial reporting systems. Available inpatient

data for VA-treated patients include admission-level discharge abstracts, data to track patients across their admission, including the time they are present on each unit to which they are admitted or transferred, and a separate discharge abstract using *International Classification of Diseases, 9th Revision, Clinical Modification* diagnoses and procedure codes and a diagnosis-related group (DRG) for each unit on which a patient is treated.

Summaries of the labor hours allocated to each unit by month were obtained from VA financial data (i.e., the decision support system or DSS). DSS contains an individual record for each VA nursing unit on which a patient received care during each hospital stay and tracks the actual hours work for each type of nursing labor (registered nurses [RNs], licensed professional nurses [LPNs], and unlicensed assistive personnel on a monthly basis).[3] For all permanent employees (RNs, LPNs, and unlicensed assistive personnel), paid time off (vacation or sick hours) were excluded. Administrative and specialty nurses (e.g., nurse managers and clinical nurse specialists) were excluded from staffing measures. The data included adjustments for floating to other units but were not adjusted for paid hours related to non-direct patient care activities (e.g., training).[23] For contract nurses (i.e., temporary nurses such as travelers and agency nurses), there is no identification of the type of personnel (RN, LPN, or unlicensed assistive personnel). These contract nurses were distinguishable as RNs, rather than LPNs or unlicensed assistive personnel, based on the level of their wages. For example, in ICUs, over 90% of the hourly costs were consistent with RN hourly wages, and in acute care units, over 85% of hourly costs were consistent with RN wages. VA payroll data were used to match nurses to each unit and create variables for RN experience and how long each nurse had worked on the unit.

2.2 | Variables

Our independent variables of interest were measures of nurse staffing. We calculated monthly total nursing (RNs, LPNs, unlicensed assistive personnel, and contract nurses) hours per patient day for each unit and the percentage of these hours provided by LPNs, unlicensed assistive personnel, and contract nurses.

Our outcome measure was residual log LOS. LOS has been endorsed by the National Quality Forum as a measure of quality, and which Needleman et al. found was the largest source of variation in costs associated with nurse staffing differences across hospitals.[21,35] Needleman and a more recent paper by Griffiths et al. both estimated that half the cost of improved staffing is offset by the saved costs from shorter LOS.[21,36] We used patients' total hospital LOS as an outcome with the rationale that while LOS may not capture specific patient outcomes (such as fall rate or infection rate), it represents a combined indicator of adverse patient outcomes and efficiency. The Medicare median LOS for admitting DRG for each patient was used as a predicted LOS to control for differences in expected LOS. This measure has the advantage of being calculated based on a large sample of patients and thus may be closer to the true median.[3] The dependent variable was the log of observed LOS minus the log of expected LOS (residual log LOS), which is favored over actual LOS as the residual reduces the potential for reverse causality (i.e., the potential for patient acuity or patient characteristics to influence nurse staffing), and log LOS controls for extreme outliers.[3] As a result, coefficients in the regression models can be interpreted as the percent change in residual LOS associated with a one-unit change in the independent variable.

Patient-level control variables included age, Elixhauser comorbidity index, and an indicator for a surgical DRG at admission.[37] Staff-level control variables included unit tenure, facility tenure, and work experience. We tested for the functional form of all noncategorical variables and used spline functions to account for the observed nonlinear effects of age.

2.3 | Nursing unit-month eligibility

Monthly observations for units with less than 100 patient days were excluded due to the small sample size. We screened the hours per patient day data for obvious data errors and excluded any month if reported hours per patient day were <12 or >48 for ICUs and <3 or >15 for acute care units. These ranges were selected based on widely accepted nurse-to-patient ratios in these settings and were derived based on examination of the distribution of hours per patient day for different types of units, followed by consultation with nurse staffing experts from both within and outside the VA. 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. Approximately 1%–2% of observations were excluded due to missingness.

2.4 | Data aggregation

The study datasets were initially built with nurse staffing measured at the unit-month level.[3] For the purposes of this paper, data are aggregated by setting (i.e., acute care, ICU, and total hospital) and time period (i.e., month and year).

2.5 | Data analysis

Descriptive statistics were analyzed for patient-level characteristics for the overall sample. Unit-level staffing characteristics were analyzed annually for hours per patient day, and monthly for overall, RN, LPN, and unlicensed assistive personnel hours per patient day by acute care, ICU, and overall hospital. Multivariate ordinary least-squares regressions with robust standard errors clustered by unit were estimated, and 95% confidence intervals (CI) were computed. Because of unobserved differences across units in the types of patients treated and their associated LOS, we treat each unit as independent rather than clustering units by hospital. Models were constructed for staffing, and its association with patient LOS was

estimated at the average monthly level for the unit, with and without fixed effects, for acute care units, ICUs, and hospital level. Fixed effects were used to account for unobserved heterogeneity between units over time. We used fixed-effects rather than random effects because many of the unobserved unit characteristics change minimally within units over time and because these unobserved characteristics are likely associated with some of the observed independent variables, such as DRG and staff unit tenure. To place our findings in context with previous results that used more aggregated data and different statistical methods, we re-estimated the models with staffing estimated at the average annual level for acute care and ICU units and the hospital overall, both with and without unit fixed effects.

In our initial analysis, the estimate of the hours per patient day of nursing to which a patient was exposed was the monthly average per patient on the unit to which they were initially admitted, and the regressions included unit fixed effects to account for variations in average unit staffing over the year and other unit-specific factors that might affect average unit LOS. Changes in exposure due to transfer across units were not incorporated into the analysis. LOS was estimated from the total admission, not just LOS on the initial unit of admission. 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.

3 | RESULTS

Sixty-nine percent of patients have only an acute care admission, 23% have only an ICU admission, and 8% have both an acute care admission and an ICU admission. Patient-level descriptive statistics are reported in Table 1. Average LOS is 6.08 days (standard deviation 8.91) for the hospitals overall, 6.48 days (standard deviation 10.57) in the ICU, and 5.64 (standard deviation 7.55) days in acute care units. The average age is around 65–66 years, and the Elixhauser index is mostly equivalent across settings (1.43 in ICUs, 1.44 in acute care, and 1.45 in the overall hospital).

Table 2 presents descriptive statistics for staffing at the unit-year and unit-month levels. Annual mean hour per patient day was 11.79 for the overall hospital. Mean ICU hours per patient day is 18.45, and the mean hours per patient day for acute care is 8.02. Monthly, unit-level total nursing hours per patient day for the overall hospital is 12.66, with a standard deviation of 6.03 and a between-group standard deviation of 5.94. ICUs had a mean of 18.98 hours per patient day, with a standard deviation of 4.63 and a between-group standard deviation of 3.65. Acute care units had a mean of 10.47 hours per patient day, with a standard deviation of 5.27 and a between-group standard deviation of 6.02.

We present patient-level estimates of the relationship between nurse staffing, hours per patient day, percent LPNs, percent unlicensed assistive personnel, percent contract nurses, and LOS. Table 3 presents regression results without fixed effects. Higher hours per patient day are consistently associated with shorter LOS. When monthly staffing data are used, the magnitude of the association between hours per patient day and residual LOS is substantially larger than when annual data are used: for instance, estimates of residual LOS are twice as great for patients admitted to acute care units (−0.030 vs. −0.015) and for the hospital as a whole (−0.017 vs. −0.007). The direction of difference is similar for patients initially admitted to ICUs but smaller (−0.007 vs. −0.006). This may reflect the fact that there is less month-to-month variability of staffing in the ICUs, so the two estimates are more similar.

As the proportion of hours of staffing provided by LPNs increases, residual LOS increases across all models. In the comparison of estimates derived from data at the monthly versus annual level, a similar pattern is observed in the estimates for an increasing proportion of LPN staffing as for total hours, with the magnitude of estimates from monthly data consistently higher than for annual data.

TABLE 1 Patient-level characteristics aggregated to the level of the month by unit type

	Mean	Standard deviation	Minimum	Maximum	Standard deviation between	Standard deviation within
Overall sample (n = 1,586,991)						
Length of stay	6.08	8.91	1	359	1.72	8.80
Age	65.72	12.68	18	109	2.21	12.51
Elixhauser	1.45	1.09	0	10	0.25	1.07
ICUs (n = 422,754)						
Length of stay	6.48	10.57	1	359	1.76	10.44
Age	65.45	12.02	18	108	1.95	11.88
Elixauser	1.43	1.09	0	9	0.26	1.06
Acute care units (n = 1,207,935)						
Length of stay	5.64	7.55	1	348	4.04	7.30
Age	65.68	12.85	18	109	2.61	12.67
Elixhauser	1.44	1.07	0	10	0.35	1.05

Abbreviation: ICU, intensive care unit.

TABLE 2 Nurse staffing characteristics aggregated to year and month level by unit type

	Mean	Standard deviation	Minimum	Maximum	Standard deviation between	Standard deviation within
Annual nursing hours per bed day						
Overall hospital	11.79	5.82	2.55	42.97	5.82	0
ICU	18.45	3.72	12.55	42.97	3.72	0
Acute	8.02	2.40	2.55	22.06	2.40	0
Monthly, unit-level staffing						
Overall hospital						
Hours per patient day	12.66	6.03	2.11	59.04	5.94	2.05
RN hours per patient day	10.21	7.06	0.65	47.63	6.83	1.78
% LPN	0.14	0.15	0	0.77	0.15	0.03
% Unlicensed assistive personnel	0.10	0.11	0	0.60	0.11	0.03
ICUs						
Hours per patient day	18.98	4.63	12.02	59.04	3.65	2.85
RN hours per patient day	17.93	3.88	12.01	47.63	2.92	2.63
% LPN	0.01	0.04	0	0.04	0.04	0.01
% Unlicensed assistive personnel	0.02	0.04	0	0.43	0.04	0.02
Acute care						
Hours per patient day	10.47	5.27	2.11	54.17	6.02	1.57
RN hours per patient day	7.51	5.86	0.65	41.72	6.86	1.25
% LPN	0.19	0.15	0	0.77	0.15	0.03
% Unlicensed assistive personnel	0.13	0.12	0.	0.60	0.11	0.03

Abbreviations: ICU, intensive care unit; LPN, licensed practical nurse; RN, registered nurse.

TABLE 3 How different levels of data aggregation affect the estimates of the effect of nurse staffing on patient length of stay (with robust standard errors but without fixed effects)

	Acute month $N = 1{,}157{,}959$	Acute year $N = 1{,}159{,}709$	ICUs month $N = 412{,}114$	ICUs year $N = 419{,}764$	Hospital month $N = 1{,}593{,}294$	Hospital year $N = 1{,}593{,}294$
Nursing hours per patient day	−0.030*** (0.001)	−0.015*** (0.003)	−0.009*** (0.001)	−0.006*** (0.002)	−0.017*** (0.002)	−0.007 (0.005)
Percent of nursing hours provided by LPNs	0.076** (0.034)	0.029 (0.072)	0.278** (0.138)	0.239 (0.216)	0.370 (0.056)	0.144 (0.156)
Percent of nursing hours provided by unlicensed assistive personnel	0.217*** (0.034)	0.250*** (0.069)	0.211** (0.090)	0.172 (0.172)	0.210*** (0.062)	0.341*** (0.122)
Percent of nursing hours provided by contract nurses	0.340*** (0.041)	0.284*** (0.083)	0.143* (0.085)	0.111 (0.141)	0.260*** (0.049)	0.270** (0.132)
R-squared	0.121	0.121	0.144	0.142	0.126	0.124

Note: Patient-level regression models with monthly, unit-level, and nurse staffing data. The models control for patient age, Elixhauser comorbidity index, admission diagnosis-related group, 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 and 161 ICUs and 266 other acute medical care units at 126 VA medical centers.

Abbreviations: ICU, intensive care unit; LPN, licensed practical nurse; VA, Veterans Affairs.

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

TABLE 4 How different levels of data aggregation affect the estimates of the effect of nurse staffing on patient length of stay (with robust standard errors and fixed effects)

	Acute month $N = 1{,}157{,}959$	Acute year $N = 1{,}159{,}709$	ICUs month $N = 412{,}114$	ICUs year $N = 419{,}764$	Hospital month $N = 1{,}593{,}294$	Hospital year $N = 1{,}593{,}294$
Nursing hours per patient day	−0.030*** (0.002)	−0.013*** (0.004)	−0.009*** (0.001)	−0.006*** (0.002)	−0.015*** (0.002)	−0.005 (0.005)
Percent of nursing hours provided by LPNs	0.028 (0.044)	−0.025 (0.083)	0.112 (0.204)	0.219 (0.224)	−0.195*** (0.063)	0.024 (0.188)
Percent of nursing hours provided by unlicensed assistive personnel	0.172*** (0.041)	0.219*** (0.077)	0.146 (0.099)	0.148 (0.178)	0.058 (0.063)	0.272** (0.128)
Percent of nursing hours provided by contract nurses	0.356*** (0.044)	0.276*** (0.088)	0.078 (0.091)	0.082 (0.143)	0.199*** (0.049)	0.255* (0.132)
R-squared	0.111	0.12	0.141	0.014	0.105	0.123

Note: Patient-level regression models with monthly, unit-level, and nurse staffing data. The models control for patient age, Elixhauser comorbidity index, admission diagnosis-related group, 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 and 161 ICUs and 266 other acute medical care units at 126 VA medical centers.
Abbreviations: ICU, intensive care unit; LPN, licensed practical nurse; VA, Veterans Affairs.
*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

While an increased proportion of hours provided by unlicensed assistive personnel are associated with greater residual LOS, the association estimated using monthly data are consistently greater in magnitude at the annual level (e.g., 0.217 vs. 0.250 for acute care units and 0.21 vs. 0.341 for the whole hospital).

When fixed effects are included (Table 4), the associations are similar in direction between monthly and annual estimates, with a few exceptions. For instance, the association of proportion of hours provided by LPNs in acute care units at the year level changes from negative to positive (with neither estimate statistically significant). The proportion of hours of staffing provided by LPNs for the hospital as a whole aggregated to the month level, the estimate of the association goes from being positive and not significant to negative and statistically significant. The magnitude of associations estimated for nursing hours is similar, while those for most other measures are somewhat reduced in magnitude for estimates using annual averages rather than monthly averages.

4 | DISCUSSION

Our analysis demonstrates that there are significant differences in the magnitude of the estimate of the association between nurse staffing and patient LOS when different methods of estimation and data aggregation are used. We also find that the point estimates for each of these associations are generally larger in magnitude for RN hours per patient day when more precise monthly data on staffing are used rather than annual data. We find differences in associations estimated for patients on acute units compared to ICUs, with less variation between monthly and annual estimates in ICUs, likely attributable to less month-to-month staffing variation in ICUs. Further, given their much higher staffing levels in ICUs, it is intuitive that the impact of a 1-hour reduction in hours per patient day would have less of an effect in the ICUs than in other units as this reduction represents a much smaller percentage reduction in staffing levels. Across a wide range of data aggregation and units, we find, consistent with the prior literature, patient LOS in the hospital is longer when there are fewer hours of nurse staffing.[3,9,13,29] In addition, LOS is longer when there are fewer RNs and a greater proportion of that staffing is provided by LPNs or unlicensed assistive personnel and contract nurses (i.e., skill mix). Using unit fixed effects to address unit-to-unit heterogeneity of LOS reduces the strength of these associations moderately or not at all across all variables studied except the proportion of hours provided by LPNs, where the impact on estimates from the monthly data are larger.

The considerable variation in point estimates indicates that calculations of the strength of the relationship between nurse staffing and outcomes may be underestimated when more aggregated staffing data are used, and less aggregated data may produce more accurate estimates. The fact that most of the studies in the literature that find relationships between staffing and outcomes are based on an annualized or single point in time estimates of staffing applied to annual data indicate that there is a robust relationship between nurse staffing levels and patient outcomes.

Aggregation of data over long time periods can significantly impact estimates of patient outcomes resulting from variations in nurse staffing to the extent that attenuation bias may influence results to the level that the null of no association cannot be rejected.

More discrete time periods of analysis, such as 1 month or one shift, can capture otherwise unobserved variation, such as changes in the work environment or seasonal changes. Having a narrower timeframe of data aggregation is essential to understand the correlation between nurse staffing and patient outcomes, as examined in previous studies. For example, Shang et al.[12] relied on narrow time aggregation of data used shift- and unit-level data from one medical center to conclude there is an association between nurse staffing and hospital-associated infections if two shifts 2 days prior to infection onset were understaffed, but found no significant association if only one of these shifts was understaffed. Shift type (day or night) has been found to be associated with different characteristics of the nursing workforce and resultant variations in LOS.[27] Others have examined daily changes in skill mix to measure the association between skill mix and patient mortality.[32] While shift-level data were not used for this study, this analysis demonstrates how the most de-aggregated time period of data may provide even less biased estimates than those at the month or year level.

Second, the change in point estimates between acute care unit-level ICU level, and hospital-level aggregation reinforces prior literature discussing how hospital-wide data, rather than unit-specific data, may not accurately reflect workload, actual hours of direct care, and patient turnover.[23] Prior investigators have restricted their data collection to exclusively the ICU setting, controlled for ICU admission, or distinguished between medical and surgical patients, in order to account for variation between types of units that may bias estimates when aggregated.[8,9,11,14]

Third, the estimates of the association between nurse staffing and LOS are different in models that used fixed effects to attempt to control for unobserved heterogeneity between units over time, and those that do not. The effect of heterogeneity between work environments at the hospital level has been shown to change the relationship between nurse staffing and patient outcomes, and fixed effects have been applied in longitudinal analyses regarding the relationship between nurse staffing and patient outcomes, including LOS.[4,7,30,38,39] Adding fixed effects to the statistical model is one method that can be used to attempt to account for hidden variabilities, such as hospital level of acuity, patient turnover, and unit culture, which may be difficult or impossible to measure.

There are some limitations to this analysis. Nursing hours were measured by hours worked, rather than exclusively by hours of direct patient care. Addition of fixed effects to the model may provide some control for heterogeneity, but it may not fully account for the unknowable differences between units and hospitals. The generalizability of our findings is limited due to differences in how the VA staffs nursing units, in comparison with non-VA facilities. For instance, the VA staffs nursing units based on an 85% occupancy rate and does not reduce staffing when the patient census falls; a drop in the patient census with no change in staffing levels produces an increase in nursing hours per patient day. This factor could change the magnitude and the direction of the relationship between hours per patient day and LOS, which may not be linear or persist across the entire range of staffing levels in non-VA hospitals. This staffing methodology incorporates patient-level variables, such as LOS, number of medication doses per day, patient body mass index, and average daily patient turnover, as a tool to determine the staffing needs of individual hospital units; such a tool may exist in non-VA settings, but maybe substantially different.[40] We may also be under- or over-estimating the effect of contract nurses because in the VA, while nurses must be trained in how to use the VA electronic medical record system before they can work, there is variability in their familiarity with the physical, cultural, or team norms of the unit, which may impact their ability to work effectively.[41,42] The data used for this study are from over a decade ago, and while the statistical methods for estimating the association between staffing and patient outcomes are enduring, changes to the health care delivery environment may affect generalizability of the specific findings to the present day.

While LOS may serve as a general substitute for elements of cost and quality of care during a hospital stay and is considered a measure that is considered to have strong evidence for being a nursing-sensitive patient outcome, exploration of other specific outcomes (e.g., readmissions, infection rate, cost, etc.) using some of the methodology discussed above could further illuminate the influence of nurse staffing in this population.[3,43] It would also be revealing to formally test, which of the estimation methods produces the most accurate results by means of a simulation study or similar technique, and to estimate the cost implications of increased staffing.

5 | CONCLUSIONS

Our analysis indicates that estimates of the correlation between nurse staffing characteristics and patient outcomes may vary significantly depending on how the data are aggregated over time, the specificity of the setting of the analysis, and with control for unobserved heterogeneity. This study aids in the interpretation of prior research that examines nurse staffing characteristics and patient outcomes, and how these estimates may be biased based on the level of data aggregation. Future research should endeavor to reduce this bias through data gathering with high construct validity and focus on data that have increased specificity of measurements that more closely estimate nurse staffing and patient outcomes, controlling for setting and changes over time. More objective measurement and estimation may more accurately explain the magnitude of the relationship between nurse staffing and patient outcomes and may better support policies aimed at ensuring appropriate nurse staffing in hospitals and health care systems to improve the quality of patient care.

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CONFLICT OF INTEREST

The authors state no conflicts of interest.

DISCLAIMER

The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of VA, AHRQ, or the United States.

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APPENDIX A.

List of regression models presented in the main text tables showing the association between nurse staffing and residual log length of stay

- Acute care units aggregated to the month level, with fixed effects
- Acute care units aggregated to the month level, no fixed effects
- Acute care units aggregated to the year level, with fixed effects
- Acute care units aggregated to the year level, no fixed effects
- Intensive care units aggregated to the month level, with fixed effects
- Intensive care units aggregated to the month level, no fixed effects
- Intensive care units aggregated to the year level, with fixed effects
- Intensive care units aggregated to the year level, no fixed effects
- Hospital aggregated to the month level, no fixed effects
- Hospital aggregated to the month level, with fixed effects
- Hospital aggregated to the year level, no fixed effects
- Hospital aggregated to the year level, with fixed effects