Published in final edited form as:

Med Care. 2015 March ; 53(3): 261–267. doi:10.1097/MLR.0000000000000316.

Nurse Workforce Characteristics and Infection Risk in VA Community Living Centers: A Longitudinal Analysis

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Abstract

Objective—To examine effects of workforce characteristics on resident infections in Veterans Affairs (VA) Community Living Centers (CLCs).

Data Sources—A six-year panel of monthly, unit-specific data included workforce characteristics (from the VA Decision Support System and Payroll data) and characteristics of residents and outcome measures (from the Minimum Data Set).

Study Design—A resident infection composite was the dependent variable. Workforce characteristics of registered nurses (RN), licensed practical nurses (LPN), nurse aides (NA), and contract nurses included: staffing levels, **skill mix** and tenure. Descriptive statistics and unit-level fixed effects regressions were conducted. Robustness checks varying workforce and outcome parameters were examined.

Principal Findings—Average nursing hours per resident day was 4.59 hours (sd = 1.21). RN tenure averaged 4.7 years (sd = 1.64) and 4.2 years for both LPN (sd= 1.84) and NA (sd= 1.72). In multivariate analyses RN and LPN tenure were associated with decreased infections by 3.8% (IRR= 0.962 p<0.01) and 2% (IRR=0.98 p<0.01) respectively. Robustness checks consistently found RN and LPN tenure to be associated with decreased infections.

Conclusions—Increasing RN and LPN tenure are likely to reduce CLC resident infections. Administrators and policymakers need to focus on recruiting and retaining a skilled nursing workforce.

Keywords

Nursing homes; quality; staffing; infections

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Declaration of Conflicting Interests:

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Introduction

Nursing homes (NHs) are increasingly focused on reducing infections¹. For NH residents, infections are a leading cause of morbidity and mortality despite often being preventable². Infections are also the most common reasons for hospitalizations, accounting for 27 to 63 percent of all resident transfers^{3, 4}. Recently, it was reported that 15 percent of the nation's NHs received annual deficiency citations for infection control, and low nurse staffing levels in NHs were positively associated with these citations⁵. As of 2011, the Department of Veterans Affairs (VA) operated 132 VA NH known as Community Living Centers (CLCs) and provided care to more than 46,000 veterans annually⁶. Improving resident safety and quality and reducing infections are top priorities in the VA^{6, 7}.

Previous researchers have examined relationships between staffing and quality outcomes in NHs^{8–14}. Associations between increased nurse staffing levels and decreased urinary tract infections (UTIs) and pressure ulcers (PUs) have been found in a number of studies; however, much of this work has been cross sectional or limited by the inability to identify nurse staffing levels to a specific month and/or NH unit^{8, 12}. For example, using an administrative dataset such as the Online Survey Certification and Reporting System (OSCAR), which is an annual survey collected every 9 to 15 months through the Centers for Medicare and Medicaid (CMS), only allows resident and nurse staffing data to be traced to the facility level; additionally, information on nurse staffing is the annual average and self-reported¹⁵. Annual data can hide much of the variance in staffing levels and staffing data at the monthly level will more likely detect differences in resident populations and represent a more accurate picture of resident case-mix. Using aggregate facility level data also poses disadvantages especially when attempting to link staffing to individual resident outcomes. Furthermore, expanding to include other important characteristics of the workforce such as experience and **skill mix** is needed and in a previous study conducted in acute care, we have found staffing, skill mix and tenure to be important predictors of quality¹⁶. Relative to acute care settings, which have a higher proportion of registered nurses (RN), NHs employ more licensed practical nurses (LPN), and nursing assistants (NA)¹⁷. Understanding how this workforce provides safe, high quality care to the nation's rapidly growing NH population is critical. Using a six-year panel of monthly, unit-specific VA data, this study examines the effects of important nurse workforce characteristics on changes in resident infection related adverse events in VA CLC units.

Methods

This study is a retrospective secondary analysis of data collected for a larger study examining VA CLC nursing care and resident safety (RWJF #63959). An existing longitudinal, unit-level dataset of VA CLC residents and nurse workforce data from fiscal years 2003–2008 was examined. Institutional review board approval was obtained from Columbia University Medical Center and Stanford University.

Data Sources

Data came from three major sources: first, from the VA Decision Support System (DSS) national data extracts; second, from the VA payroll data (PAID); and third, from the

Minimum Data Set (MDS) Resident Assessment Instrument. Other sources included VA administrative files for facility information and the VA Vital Status Mini File for resident age and gender. Nurse workforce characteristics came from the DSS and PAID. Characteristics of CLC residents and outcome measures came from the MDS. An overview of the variables, definitions, and the data sources is provided in Table 1. Detailed descriptions of the 3 major data sources and justification for our variables follow.

The DSS is VA's integrated accounting system. Within the DSS, several layers of data exist. First, monthly data on nursing hours were obtained from the DSS Account Level Budgeter Cost Center (ALBCC). The ALBCC tracks nursing personnel hours appropriated to each unit by the type of labor (e.g., RN or LPN), and the use of contract labor (agency nurse). We used the monthly total number of nursing hours worked on each unit to create the numerator for our staffing hour variables. Another layer of DSS data is the Inpatient Ward Files, which tracks the patient admission and discharge dates of each nursing unit. This file was used to create unit characteristic variables such as patient census and the total number of admissions on the units.

Nurse workforce characteristics for tenure were obtained from PAID. The PAID data includes employee information such as VA hire date, when the staff started at their current unit, and the type of nursing position.

Resident characteristics and outcomes data came from the MDS Version 2.0, a government mandated resident assessment tool. It serves as a core component of the resident assessment instrument and is used to collect information on clinical and functional status elements of all NH residents in facilities certified to participate in Medicare or Medicaid and in VA long-term care programs accredited under the Joint Commission on Accreditation of Healthcare Organizations. Residents are assessed on admission, quarterly, annually and at times of significant change in status. In non-VA settings, the MDS is used to determine Medicare reimbursement rates as a function of residents' assignment to resource utilization groups (RUG). While VA CLCs do not operate under this system, per diem reimbursement of individual CLC units is based in part on timely completion of MDS assessments and therefore all VA CLCs have recorded MDS data since 1998¹⁸.

All resident-level and nurse workforce data were de-identified and aggregated to the unit-month level. Unique facility identifiers were used in combination with ALBCC codes to identify VA CLC units used in our analyses.

Variables

Our primary outcome variable was a composite of resident infections defined as the summation of three outcomes (i.e., UTI, pneumonia, and PUs). Use of composites can compensate for the relatively low rates of individual infections and can therefore increase power. Composites also serve as important indicators of safety and quality improvements and have been increasingly reported in the literature and used in research^{19, 20}. While we also examined each of the infection outcomes separately, we report a composite of infections because all of these outcomes indicate adverse events that interrupt residents' quality care. The MDS was used to determine the various infection outcomes. To avoid

counting outcomes present on admission, MDS assessments coded as admissions were excluded. Because some MDS assessments were incomplete or had missing data, those assessment types were also excluded. Rates for the composite measure were calculated as adverse outcomes per 1,000 resident days. A resident day is defined as 24 hours of care starting the day of admission and excluding the day of discharge. In other words, the sum count of infections was our numerator and total resident-days were our denominator.

Nurse workforce characteristics were our main independent variables of interest and measured using 3 conceptual categories: nurse staffing levels, **skill mix**, and nurse unit tenure. Nurse staffing level was operationalized as nursing hours per resident day (HPRD). Nursing hours included the total number of hours worked (regular and overtime) either by RNs, LPNs, NAs, and contract nurses (with 85% paid RN wages). To represent the total nursing hours of care per resident day (Total Nursing HPRD), we added the total number of hours worked for all staff and divided it by resident days. Outlying unit-months with obvious erroneous total staffing data (i.e., < 2.0 and > 8.0 hours) were removed.

Skill mix was measured as a function of RNs, LPNs, NAs and contract nurses. Percent RN was operationalized as RN worked hours as a proportion of total staffing hours (RN, LPN, NA, and contract nurses combined). LPN, NA and contract nurse percent hours measures were constructed similarly. While total nursing HPRD measures the extent of nursing hours available to provide resident care, the percent nursing hours variables characterize the extent to which different staffing expertise may be available on a unit to carry out specific care processes or shift tasks of care²¹. Nursing experience was measured by unit tenure, defined as the number of years RNs LPNs, and NAs had worked on the unit. Contract nurse tenure information was not available in this dataset.

To control for differences in risk for infections a number of covariates were included^{22, 23}. Indicators of the proportion of residents using indwelling urinary catheters, ventilator support and the proportion of residents on a turning/repositioning program were developed. Average age proportion of male residents were included. The percent of residents identified as black, non-Hispanic were included²². An ADL index was calculated based on the mean value of resident eating, toileting, and transferring ability (range 3–12). Cognitive impairment was defined as the percent of residents with either Alzheimer's disease or other dementia diagnosis.

A set of unit characteristics likely to affect outcomes was also included. The number of admissions received during the month of observation represents the unit volume. The average RUG scores (theoretical range 1–44) represent the case-mix severity. Higher RUG scores indicate greater resident care needs. The percent of residents expected to have a short-term stay (<90 days) is another measure of resident acuity.

Data Analysis

Descriptive statistics and bivariate correlations were examined. Monthly unit-level multivariate fixed effects models were developed. Based on the infection composite distribution (variance exceeded the mean), the negative binomial model was used. Time trends were controlled for using a set of monthly time dummy variables. Time invariant

variables such as unit culture were controlled for using fixed effects. Regression diagnostic statistics using the variance inflation factor (VIF) were examined. Analyses were performed with STATA 12.0 (College Station, TX).

Prior to multivariate analyses, a correlation matrix was constructed for all nurse workforce variables (results not shown). As expected, there was high correlation between RN HPRD and Percent RN ($r=0.78$ $p<0.01$). Because our objective was to simultaneously examine indicators of staffing levels, **skill mix** and experience, we used a model that allowed measures from all 3 nurse workforce categories. Therefore, we retained only Total Nursing HPRD to represent nurse staffing levels. To avoid collinearity among **skill mix** variables the percent LPN variable was treated as the reference variable. The proportion of residents with urinary catheters is provided under descriptive statistics but was not included in the multivariate model because of convergence problems.

Alternative models were examined. First, the various nurse workforce characteristics were lagged to examine whether staffing characteristics in the month prior (t-1) had an influence on outcomes observed in the current month (t). Second, because MDS assessments are not conducted monthly, we risk the potential sampling bias of not capturing all resident infections in the numerator. Because the dependent variable of our study was the sum of resident infection outcomes (counts), and were non-negative integers, early in our data preparation stage, we adopted the Poisson distribution because it is a widely used non-linear distribution of count data. We then used the Poisson pseudo-random number generator to pull forward infection outcomes recorded in the month of observation until the residents' next MDS assessment or whenever there was a significant change in status and or when the infection was no longer recorded. Third, we conducted random effects and population average models and compared the results.

Results

The final sample included 180 units from 84 VA facilities (10,611 unit-monthly observations). Facilities came from 20 VA integrated service networks across thirty-seven states.

Table 1 shows the descriptive statistics for the variables used in the analysis. Average nursing HPRD was 4.59 hours (sd= 1.21). Percentage of nursing hours worked by RNs, LPNs, NAs, and contract nurses were 31.3%, 25.8%, 41.5%, and 1.5% respectively. Unit tenure averaged 4.7 years for RNs (sd= 1.64) and 4.2 years for both LPNs (sd= 1.84) and NAs (sd= 1.72). Average unit tenure combined for the 3 staffing types was 4.3 years. Pairwise correlations of all the independent variables were examined (results not shown). Nurse workforce characteristics included in our final model were not highly correlated, with the highest correlation (−0.56) found between Percent RN and Percent NA. Using these variables, multi-collinearity was assessed using the VIF test. Across all the variables, VIF values were lower than 10 which indicated no multi-collinearity (overall mean VIF 1.48).

Table 2 presents the coefficient estimates for our main model. To facilitate interpretation, all coefficients have been exponentiated and can be interpreted as the incidence rate ratio of

having infection outcomes. Both RN and LPN unit tenure were significant independent predictors of the infection composite. Results indicate that for every one year increase in unit tenure, the incidence of infections decreased by 3.8% for RNs (IRR= 0.962 $p<0.01$) and 2% for LPNs (IRR=0.980 $p<0.01$) while controlling for all other variables in the model. That is, an increase in one year of RN tenure within a unit was associated with 38 fewer infections for every 1,000 resident days. Some of the resident and unit characteristics also had independent effects; increase in mean ADL index was positively associated with an increase in infections (IRR=1.03 $p<0.01$); average case mix severity on a unit represented by RUG scores was related to a more than five-fold increase in likelihood of developing infections (IRR= 5.77 $p<0.01$). A unit with a higher proportion of residents expected to have a short-term stay had an increased likelihood of infections (IRR= 3.01 $p<0.01$).

Results from the first two robustness checks are displayed in Table 3. In the lagged staffing model, RN and LPN tenure was associated with a lower incidence of infections (3.8%, $p<0.01$ and 2%, $p<0.01$ respectively). Similarly, when pneumonia counts were pulled forward in time, the results were very similar compared to when the infection was only counted in the month of observation. Additionally, increasing Total Nursing HPRD contributed to 3.9% reduction in pneumonia incidence ($p<0.05$). The random effects and population average models had similar results to the fixed effects model and the Hausman test favored the fixed effects model ($p<0.001$).

Discussion

To the best of our knowledge, this is the first study to use monthly, unit-specific longitudinal panel data to examine relationships between a comprehensive set of nurse workforce characteristics and infection outcomes in the VA CLCs. We found that RN and LPN tenure and resident acuity predict resident infections.

In acute care in the VA, nurse tenure has been found to be an important predictor of quality outcomes¹⁶. In NHs, facility tenure has been associated with important processes. Researchers have found that RNs with 5 or more years of experience at a facility was associated with decreased restraint use, resident pain, pressure ulcers and indwelling catheter use. NHs with higher retention rates for licensed nurses has been associated with a lower 30-day hospital readmission rate; and higher licensed nurse retention the year prior was associated with a decreased readmission rate²². These findings were based on a single state and the investigators were unable to distinguish differences between RN and LPN retention. Our study is the first to find a link between nurse tenure and infection outcomes.

In our study, staffing levels did not predict infections. This may be because of the high levels of staffing in the VA (i.e., average 4.59 hours, which exceeds recommended levels)^{24, 25}. Assuming diminishing returns and the fact that other studies have shown that it is really short staffing that matters²⁶, it is not surprising that we did not find a robust staffing effect.

Our results suggest that tenure, especially skilled nurse unit tenure is important for decreasing resident infection outcomes. This implies that it isn't only the hours of care that matters, but how well the nurse is familiar with the residents and of the unit. The findings

from this study have implications for NH administrators and policymakers and echo recommendations from previous researchers to focus attention on retaining a skilled workforce. The idea for building a business case for retention is not a new phenomenon²⁷. However, little is known about cost savings that could be realized from retaining a skilled workforce in NHs. Institutional awareness or ongoing support in the area of infection prevention and control could also be used to enhance training of an adequate workforce.

The within-unit fixed effect analysis controls for time invariant unobservables. For example, each unit could have its own unique organizational culture or communication style that would rarely change and may affect the outcomes of care. A CLC unit with a “good” nurse manager could impact staff motivation to improve outcomes versus a CLC unit with a “bad” nurse manager. Because we do not have measures in our dataset to control for such instances, omitting such unobserved individual unit specific variables may create bias in the estimation of our outcomes in a non-fixed effects analysis²⁸. Fixed effects models don’t allow a direct comparison of whether high versus low nurse staffing is better. Instead, fixed effects estimate the marginal effect of a deviation from the unit mean. For example, when compared to the unit’s norm how the outcome changes when nurse workforce characteristics either go up (increase nurse tenure) or down (decrease nurse tenure) controlling for changes in other workforce characteristics (e.g., staffing levels). In other words, each CLC unit acts as its own control and inferences can be made about how changes within the units across time affect outcomes. This allows the analysis to specifically control for important unobserved factors such as the work environment and overall average quality of care in each unit. While one could debate whether the fixed effects approach was appropriate or not, it ultimately depends on the assumptions one is willing to take into account²⁸ and because our interest was to estimate the within-unit variation which controls for unobserved variables that do not vary by month, we believe our reasons to use a fixed effects model are justified. Furthermore, this was substantiated in robustness checks.

This study has several important strengths that extend existing research. First, the dataset provides a unique opportunity to longitudinally examine monthly nurse workforce characteristics on resident infection outcomes with standardized data collection across all units. This helps overcome some of the weaknesses encountered in previous studies such as variations in data reporting for nurse workforce measures. Second, we measured nurse workforce characteristics at the monthly level rather than at the annual level because monthly data increases the precision of the data. Third, because the nurse workforce data came from payroll data, they are likely to be more accurate than other data sources that are compiled from self-reported surveys. This study also has limitations. We had to rely on the MDS to abstract resident characteristics and outcomes. We realize that use of large administrative data may be subject to coding inaccuracies and are not designed specifically for research. However, previously published studies in the VA have used the MDS to examine CLC resident outcomes²⁹. Furthermore, validity and reliability of this data source in the VA has been established previously³⁰. Fourth, we included a number of individual and unit characteristic control variables (e.g., percent of short stay residents) that may vary overtime and may be related to staffing.

Fifth, the infection composite may not reflect true quality of care and we did not perform psychometric testing (e.g., principle factor analysis) to take into account the weighting of individual factors as done by others³¹. This was necessary since we did not have individual level dataset; however, effort was made to group frequently occurring outcomes in NHs. Additionally, by using an aggregate infection composite, we may have double counted infections from the same resident (i.e., one resident could have both a PU and a UTI in the same MDS assessment); however, robustness checks using pneumonia counts pulled forward in time using the Poisson pseudo random number generator showed results that were similar to our main analytic model. Future analyses could use individual level resident data to more accurately capture the relationship between nurse workforce characteristics and resident infections. If individual data are used, other analytic methods such as survival analyses can be further explored to estimate the individual resident's time to acquiring an infection outcome.

Finally, this study was conducted in the VA and may not be generalizable to non-VA NH units. In addition, these results may not be transferrable to younger Veterans residing in CLCs because they are underrepresented in our sample. Further, VA tenure levels are high compared to the private non-VA sector and therefore marginal impact of changes in tenure could be greater with higher levels of tenure. Moreover, we did not examine education due to error in the measurement related to overwriting of the field to the highest degree.

Conclusion

Examining nurse workforce characteristics on resident quality of care generated results that have partially supported our hypothesis: As tenure of skilled nurses on a unit increase, the risk of resident infection outcomes will decrease while controlling for resident and unit characteristics. This adds to a rather large body of literature conducted over the past several decades also examining nurse staffing characteristics and resident outcomes. Moreover, our findings for RN and LPN unit tenure were robust, which calls for greater attention from NH administrators and policymakers to be directed towards recruiting and retaining a qualified skilled nursing workforce.

Acknowledgments

Funding Sources: This paper was generously supported by the National Institutes of Health, National Institute of Nursing Research [F31NR013810 and R01NR013687], the Robert Wood Johnson Foundation [#63959], the U.S. Department of Veterans Affairs, Health Services Research & Development [#RWJ 08-274] and the Jonas Center for Nursing Excellence.

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Table 1

Characteristics of VA CLCs

Variable	Definition	Data Source	Mean (SD)
<u>Resident Characteristics</u>			
Age	Average Age of residents	Vital Status Mini File	72.63 (3.49)
Male	Percent of male residents	Vital Status Mini File	96.62 (3.56)
Race	Percent of non-Hispanic black residents	MDS	16.38 (15.30)
Percent Dementia	Percent of residents with diagnosis of Alzheimer's or Dementia	MDS	24.46 (17.46)
ADL Index	Average ADL score (eating, toileting, transferring)	MDS	4.65 (1.74)
<u>Unit Characteristics</u>			
Unit Volume-Admissions	Number of admissions	DSS	9.96 (10.18)
RUG	Average RUG value	MDS	0.85 (0.12)
Percent Short Stay	Percent of residents expected to have a stay < 90 days	MDS	16.60 (26.74)
<u>Nurse Workforce Characteristics</u>			
Staffing Levels	Total nursing hours per resident day	ALBCC (DSS) and PAID	4.59 (1.21)
	Percent of total nursing hours worked by RN		31.30 (9.65)
	Percent of total nursing hours worked by LPN		25.76 (10.48)
	Percent of total nursing hours worked by NA		41.46 (13.12)
Percentage of Hours Worked	Percent of total nursing hours worked by Contract Nurses		1.48 (4.57)
	RN Unit Tenure		4.67 (1.64)
	LPN Unit Tenure		4.16 (1.84)
Experience	NA Unit Tenure		4.17 (1.72)
<u>Care Processes</u>			
Percent Catheter	Percent of residents with an indwelling catheter	MDS	4.11 (4.17)
Percent Ventilator	Percent of residents on a ventilator	MDS	0.07 (1.39)
Percent Turn	Percent of residents on turning/repositioning program	MDS	26.85 (19.15)
<u>Outcomes</u>			
Count Pneumonia	Count of pneumonia	MDS	0.50 (0.88)
Count UTI	Count of urinary tract infections	MDS	1.17 (1.55)
Count PU	Count of pressure ulcers	MDS	1.67 (1.84)

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Variable	Definition	Data Source	Mean (SD)
Composite	Sum count of Pneumonia, UTI, PU	MDS	2.65 (2.52)

Notes: VA = Veterans Affairs, CLC= Community Living Centers, MDS = Minimum data set, DSS = Decision support system, ADL= Activities of Daily Living, RUG= Resource Utilization Group, ALBHR = Account Level Budgeter Hours, ALBCC = Account Level Budgeter Cost Center, PAID = VA payroll data, UTI= Urinary Tract Infection, PU= Pressure Ulcer, RN= Registered Nurse, LPN= Licensed Practical Nurse, NA= Nurse Aide, SD= Standard Deviation

All mean values are counts or percentages per month reported from final regression sample of 180 CLC units (84 facilities) and 10,611 unit monthly observations.

Table 2

Effects of Staffing on Infection Composite (UTI, pneumonia, pressure ulcer)

Outcome: Infection Composite	Coefficient (IRR)	SE	p
Total Nursing HPRD	1.000	0.010	0.985
Percent RN	1.233	0.232	0.264
Percent NA	1.160	0.180	0.336
Percent Contract	0.986	0.205	0.947
RN Unit Tenure	**0.962	0.008	0.000
LPN Unit Tenure	**0.980	0.007	0.006
NA Unit Tenure	1.008	0.009	0.340
Male	1.467	0.407	0.167
Age	0.999	0.004	0.865
Race	1.161	0.161	0.282
RUG	**5.770	0.636	0.000
ADL Index	**1.070	0.008	0.000
Percent Short Stay	**3.057	0.133	0.000
Admissions	**0.994	0.001	0.000
Percent Dementia	1.067	0.107	0.520
Percent Turn	**1.250	0.086	0.001
Percent Ventilators	**42.106	59.582	0.008

Notes. N= 10,611; IRR= Coefficients are Incident Rate Ratios; SE= Standard errors; p= p-values

* Significant at $p < 0.05$

** Significant at $p < 0.01$

Infection Composite= urinary tract infections, pneumonia, and pressure ulcers.

HPRD= Hours per resident day, RN= Registered Nurse, NA= Nurse Aide, RUG= Resource Utilization Group value, ADL= Activities of Daily Living

Monthly time dummies were included in all models; output not shown.

Table 3

Robustness Checks on Infection Composite

Outcome: Infection Composite	Robustness Check 1			Robustness Check 2		
	Coefficient (IRR)	SE	p	Coefficient (IRR)	SE	p
Total Nursing HPRD_lag	0.983	0.010	0.103	—	—	—
Percent RN_lag	1.033	0.199	0.866	—	—	—
Percent NA_lag	1.094	0.174	0.572	—	—	—
Percent Contract_lag	1.176	0.248	0.442	—	—	—
RN Unit Tenure_lag	**0.962	0.008	0.000	—	—	—
LPN Unit Tenure_lag	**0.980	0.007	0.006	—	—	—
NA Unit Tenure_lag	1.003	0.009	0.714	—	—	—
Total Nursing HPRD	—	—	—	*0.961	0.018	0.036
Percent RN	—	—	—	0.927	0.305	0.819
Percent NA	—	—	—	0.989	0.263	0.966
Percent Contract	—	—	—	0.764	0.323	0.524
RN Unit Tenure	—	—	—	**0.957	0.014	0.002
LPN Unit Tenure	—	—	—	**0.957	0.012	0.001
NA Unit Tenure	—	—	—	1.004	0.015	0.757
Male	1.402	0.395	0.230	0.813	0.439	0.702
Age	0.999	0.004	0.965	1.013	0.008	0.075
Race	1.203	0.171	0.192	**0.541	0.117	0.004
RUG Score	**5.832	0.651	0.000	**7.844	1.673	0.000
ADL Index	**1.072	0.008	0.000	1.011	0.013	0.419
Percent Short Stay	**3.003	0.132	0.000	**3.504	0.319	0.000
Admissions	**0.994	0.001	0.000	**0.993	0.002	0.002
Percent Dementia	1.065	0.109	0.532	**1.663	0.296	0.004
Percent Turn	**1.256	0.087	0.001	—	—	—
Percent Vent	*32.720	45.941	0.013	29.795	60.15	0.093

Notes. IRR= Coefficients are Incident Rate Ratios; SE= Standard errors; p= p values

* Significant at p<0.05

** Significant at p<0.01

Robustness Check1 = Regression model for Infection Composite using nurse workforce variables from one month prior (t-1); N= 10,353

Robustness Check 2 = Regression model with pneumonia pulled forward in time (i.e., between minimum data set assessments); N= 10,570

Differences in N are due to having an unbalanced panel data and missing values for pneumonia.

Infection Composite= urinary tract infections, pneumonia, and pressure ulcers, _lag= Workforce variables lagged by one month, HPRD= Hours per resident day, RN= Registered Nurse, NA= Nurse Aide, RUG= Resource Utilization Group value, ADL= Activities of Daily Living; Monthly time dummies were included in all models; output not shown.