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Examining the Relationship between Nurse Staffing Levels and Inpatient Mortality: A Longitudinal Shift-Level Analysis

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Abstract:
Background: Healthcare facilities globally are under pressure to reduce expenses, leading some to operate with fewer nurses or personnel with lower qualifications.
Objective: This study aims to investigate the correlation between inpatient mortality rates and shifts characterized by varying nurse staffing levels.
Methods: Utilizing longitudinal data , this study analyzed shift-, unit-, and patient-level data for 55 units, 79,893 adult inpatients, and 3646 nurses (comprising 2670 registered nurses, 438 licensed practical nurses, and 538 unlicensed and administrative staff). A staffing model was developed to categorize shifts as high or low staffed, followed by logistic regression analysis to examine the association between nurse staffing and mortality.
Results: Exposure to shifts with higher levels of registered nurses correlated with an 8.7% decrease in mortality odds [odds ratio 0.91, 95% CI 0.89–0.93]. Conversely, lower staffing levels were linked to a 10% increase in mortality odds [odds ratio 1.10, 95% CI 1.07–1.13]. The impact of staffing levels among other personnel categories was less evident. Specifically, both high and low staffing of unlicensed and administrative personnel were associated with higher mortality rates, with odds ratios of 1.03 [95% CI 1.01–1.04] and 1.04 [95% CI 1.03–1.06], respectively.
Discussion and Implications: This longitudinal study at the patient level indicates a significant relationship between registered nurses' staffing levels and mortality rates. Higher registered nurse levels were found to positively influence patient outcomes, while lower levels had a negative impact. The contributions of other personnel groups to patient safety were inconclusive based on these findings, suggesting caution against substituting these groups for registered nurses.

Introduction:

Hospitals are confronted with the dual challenge of ensuring patient safety through adequate nurse staffing levels while also managing costs effectively. The relationship between nurse staffing and patient outcomes has long been a subject of interest, with numerous studies highlighting associations between nurse staffing levels, skill mix, and various patient complications such as falls, infections, and other care-related issues (Driscoll et al., 2018; Kane et al., 2007). Among these relationships, the correlation with mortality, a well-defined metric available in routine data, has been a focal point (Van den Heede et al., 2007).

The variability in nurse workload is primarily driven by patient needs, which fluctuate throughout the day and differ across units. This variability is influenced by factors such as patient-to-nurse ratios, which in turn are affected by patient turnover (e.g., admissions, discharges, and transfers between units) (Blay et al., 2017). High patient turnover and patient-to-nurse ratios have been linked to increased hospital-related mortality risks (Driscoll et al., 2018; Kane et al., 2007).

Despite numerous studies demonstrating the association between nurse staffing and patient mortality, our understanding of this relationship remains incomplete. Challenges include the use of aggregated data, cross-sectional designs that limit causal inferences, and the overlooking of variations between units, patients, and time periods (Griffiths et al., 2016; Twigg et al., 2011). Previous studies often did not account for individual patient exposure to nurse staffing, which hampers a comprehensive understanding of the association.

Given that nurse-patient interactions occur at an individual level and exposure to nurse staffing varies across shifts, days, and units, there is a need for more detailed and comprehensive analyses. Few studies have adopted longitudinal designs, analyzed data at the shift, unit, and patient levels, and considered the contributions of different types of nursing staff as independent variables (Griffiths et al., 2018; Needleman et al., 2011; Needleman et al., 2019).

In a recent study, we examined patient count and nursing staff fluctuations longitudinally, revealing significant variability throughout the day and highlighting challenges in providing consistent care (Musy et al., 2020). Building upon this, the current study links staffing data with patient outcomes, specifically exploring mortality rates based on patient exposure to shifts with varying numbers of registered nurses (RNs) and/or nursing assistants. Using an innovative approach to model long-term shift-level nurse staffing deviations, this analysis aims to identify optimal staffing levels. Additionally, unlike prior studies, we will investigate staffing effects between shifts and on weekdays versus weekends.

Methods:

Study Design and Setting: This retrospective observational study utilized routinely collected data , with an annual intake of approximately 48,000 inpatients. Data spanning were gathered from all hospital departments except Pediatrics and Maternity & Gynecology due to their distinct nursing care requirements. The final sample included 55 inpatient units with complete data for the entire study duration.

Participants: Patients: Inclusion criteria encompassed adult inpatients (18 years or older) without stays in non-study units, no emergency stays post-first day, and complete demographic and hospitalization data

Nurses: Nursing staff were categorized into registered nurses (RNs), licensed practical nurses (LPNs), and other personnel including unlicensed staff and administrative roles.

Data Sources and Variables: Data were sourced from the tacs® nurse staffing system capturing nurses' care activities, patient turnover, working hours, and medical discharge records containing patient demographics, admission/discharge details, diagnoses, and mortality information.

Nurse Staffing per Unit-Shift: Nurse counts during night, morning, and evening shifts were analyzed to represent staffing levels adequately.

Patient Counts and Turnover: Patient turnover was calculated for each shift and unit, considering admissions, discharges, and transfers.

Patient Characteristics: Variables such as age, gender, admission type, ICU and emergency stays, hospital length of stay, transfers, ICD-10-GM diagnoses, and Elixhauser comorbidity indices were used for mortality risk adjustment.

Inpatient Mortality: Patients' vital status at discharge was recorded to create a binary mortality variable.

Statistical Analyses: All analyses were performed using R software.

Descriptive Analysis: Median, interquartile ranges, and Spearman's rank correlation coefficients were calculated for various nurse and patient metrics.

Mortality Model: A two-step approach involved estimating expected nurse counts using multivariate Poisson models and calculating observed-to-expected (O/E) ratios for staffing levels. Logistic regression models were then applied to explore mortality associations with staffing variables.

Ethical Considerations: The study adhered to Swiss regulations on human research, with all data anonymized to ensure patient, nurse, and unit confidentiality.

Results:
Participants: Out of 128,484 inpatient cases, 79,893 (62.2%) met inclusion criteria, alongside 3646 nurses (73.2% RNs, 12.0% LPNs, and 14.8% Others) across 55 units.
Descriptive Analysis: Overview: The median number of nurses per unit decreased throughout the day, with the highest in the morning and lowest at night. Patient-to-nurse ratios varied across shifts, with the lowest in Intensive Care. LPNs and Others had median nurse counts of 0.0–1.0 for most shifts.
Comparison between Patients' Demographics of Alive and Mortality Cohort: Patients who died (n = 2230) were on average older, predominantly admitted from emergency, had longer hospital stays, more diagnoses, longer ICU stays, and higher Elixhauser comorbidity scores compared to those discharged alive (n = 77,663). Patients who died were exposed to more shifts with low nurse staffing.
Mortality Predictive Model: High RN staffing was associated with lower odds of mortality (-8.7%), while low staffing increased mortality odds (+10%). Results for LPNs and Others were inconsistent. High LPN staffing was associated with lower mortality odds (-2.7%), while low LPN and Other staffing were associated with higher mortality odds (+1.5% and +4.4%, respectively). Sensitivity analyses produced similar results.

Discussion:
Main Results: Our study consistently found that shifts with high levels of registered nurses (RNs) were associated with lower odds of mortality, while shifts with low RN levels showed increased mortality odds. This aligns with previous research using longitudinal designs and detailed analyses of nurse staffing at different levels. Although our effect sizes differ due to methodological variations, the trend of more RNs leading to lower mortality rates remains consistent. (Fagerström et al., 2018)
Our study's positive association between more nurses and lower mortality rates is noteworthy, known for its high-quality care and relatively well-staffed hospitals compared to European countries. The findings suggest that certain shifts may benefit from higher nurse staffing levels than currently maintained, indicating potential areas for improvement in staffing practices. (Fullman et al., 2018)
Consideration of Nurse Categories: We examined not only RNs but also licensed practical nurses (LPNs) and other staff as independent variables to understand their contributions to patient mortality. This approach provides insights into task delegation and the impacts of different staff categories on patient outcomes. LPNs and Others showed inconsistent effects on mortality, indicating the complexity of staffing dynamics and the need for careful consideration in deployment strategies. (Griffiths et al., 2016)
Task Shifting and Patient Safety: The variability in mortality outcomes associated with LPNs and Others underscores the importance of task delegation and patient safety. For example, shifts with high LPN numbers were both positively and negatively linked to mortality, highlighting the nuanced roles different staff categories play in patient care. The potential limitations in detecting subtle health changes by less qualified staff, especially during evening shifts, emphasize the need for vigilant monitoring protocols. (Musy et al., 2020)
Methodological Considerations: Our study employed an intermediate step to define low and high staffing variables, using actual nurse counts rather than nurse hours per patient day. The use of observed-to-expected (O/E) ratios allowed for standardization and comparison across units, enhancing the interpretability of staffing effects on mortality. While concerns about overstating the association of mortality with nursing care exist, our methodological approach accounts for multidisciplinary factors influencing patient outcomes. (Needleman et al., 2019)
Future Directions: Further research is needed to delve into the specific contributions of LPNs and other staff categories to patient outcomes. Integrating additional workload indicators and exploring the impact of

staffing variability between sites could provide deeper insights into optimizing nurse staffing for improved patient safety and care quality. (R Core Team, 2017)

Conclusion:

This comprehensive longitudinal study provides evidence suggesting a potential relationship between high registered nurse (RN) staffing levels and improved patient mortality, aligning with findings from previous longitudinal studies. By employing detailed shift-, unit-, and patient-level analysis, this study strengthens the evidence supporting the association between nurse staffing and mortality, making a causal link more plausible. The consistent findings across multiple longitudinal studies emphasize the importance of adequate RN staffing levels in mitigating mortality risks.

However, while the link between low RN staffing and increased mortality is well-established, there remains uncertainty regarding other outcomes directly influenced by nursing care quality, such as pressure ulcers. Further understanding of these outcomes is crucial for accurately assessing nurses' contributions to patient care outcomes.

This study, highlights the significance of nurse staffing levels even in high-quality hospital environments. The findings underscore the benefits of high RN-staffed shifts and the risks associated with low RN staffing in terms of patient mortality. Notably, the study suggests caution against substituting RNs with licensed practical nurses (LPNs) and other staff categories.

In conclusion, there is an urgent need for ongoing research to define appropriate nurse staffing levels comprehensively. This research is vital for ensuring optimal patient outcomes and enhancing the quality of nursing care across healthcare settings.

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