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House Bill 1272

A Study of Acute Care Staff & Patient Outcomes in Washington State Hospitals

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Executive Summary

In 2021, the Washington State legislature, through House Bill 1272, directed the Washington State Department of Health to contract with the University of Washington's School of Nursing to lead an interdisciplinary study to analyze the impact of acute care staff on patient outcomes. It required investigation of how the number, type, education, training, and experience of staff affects patient mortality and other patient outcomes, utilizing scientifically sound research methods found most effective for all involved stakeholders.

A four-phase process was used to conduct this study: (1) a literature review of studies assessing the impact of the workforce on patient outcomes, (2) a preliminary analysis plan based on the literature review and identified available data sources, (3) stakeholder interviews and a town hall meeting to collect feedback on variables that may combine with staffing to affect patient outcomes, and (4) a quantitative analysis guided by the refined causal model.

The literature review confirmed that our charge from HB1272 included unique elements emphasizing the need for our study. Strategies for how similar studies were conducted were identified to inform an initial causal model of variables that may combine with staffing to affect patient outcomes and mortality. Thirteen preliminary meetings and 35 interviews were held with 63 hospital representatives with multiple perspectives and expertise and leaders from healthcare associations and unions. Stakeholder feedback expanded data sources and variables to consider in the analysis. At a virtual town hall, attended by over 50 individuals, study staff disseminated "facility engagement sheets" of hospital-specific data, which provided opportunities for further engagement and feedback to inform the study.

Major takeaways from stakeholders included, for example, that a "one size fits all" approach to establishing staffing ratios in the acute care setting is not ideal, the analysis should include data prior to the COVID-19 pandemic, and that nurses often have increased workloads from absorbing additional care duties when other support staff are absent. Feedback led to a refined causal model that informed the quantitative analysis plan and controlling factors.

We examined 263 acute care hospital-years from 2016 through 2019, which included 8,989,222 patient-days, 27,758 total acute care nurse full-time equivalents (FTE), 66,968 other acute care staff FTE, 1,536 combined adverse events, and 110,374 patient deaths within 28 days of discharge.

Main findings

Critical Access Hospitals

- For Critical Access Hospitals, we did not find that acute care staff number, nurse education, or nurse experience are associated with adverse events or mortality, but we did find that a higher proportion of nurses among acute care staff is associated with decreased adverse events.

Acute Care Hospitals

- More patients per acute care staff is associated with increased adverse events, but we did not find an association with mortality
- A higher proportion of nurses among acute care staff is associated with decreased mortality, but we did not find an association with adverse events
- We did not find that either nurse education or experience are associated with adverse events or mortality; there is no agreed-upon or available data source for nurse training

For Critical Access Hospitals, while there is no evidence that changing staffing numbers would reduce 28-day mortality or adverse events, there is associational evidence that increasing the proportion of acute care nurses among acute care staff would reduce adverse events. For Acute Care Hospitals, while there is no evidence that changing staffing numbers would reduce 28-day mortality, there is associational evidence that 1) increasing the total acute care staff-to-patient ratio would reduce the number of adverse events, and 2) increasing the proportion of acute care nurses among acute care staff would reduce 28-day mortality. Although findings from this study suggest that neither nurse education nor experience are associated with patient outcomes, this does not mean that nurse education and experience have no

effect on patient outcomes. This finding could be due to limited data on education and experience to observe an association with patient adverse events or mortality. Further, this study could not assess training due to a lack of agreed-upon or available data. Data are insufficient or do not have enough variation to quantify the relative importance of each team member type and define the 'ideal' team composition to reduce poor patient outcomes. It is also important to note that although associations are actionable, an absence of evidence is not evidence of absence, and further inquiry with alternative methods or data might better reveal relationships that this study could not quantify.

Introduction

In 2021, the Washington State legislature, through House Bill 1272, directed the Washington State Department of Health to contract with the University of Washington's School of Nursing to lead an interdisciplinary team to analyze the impact of the number, type, education, training, and experience of acute care hospital staffing personnel on patient mortality and patient outcomes. According to House Bill 1272, the study should control for other contributing factors, including but not limited to, access to equipment, patients' underlying conditions and diagnoses, patients' demographic information, the trauma level designation of the hospital, transfers from other hospitals, and external factors impacting hospital volumes.

This report presents the results of this study, conducted by a research team composed of members from the University of Washington School of Nursing, the Institute for Health Metrics and Evaluation (School of Medicine), and the School of Public Health. To ensure the use of scientifically sound research methods deemed most effective for all involved stakeholders, we employed a four-phase process (Figure 1). First, we conducted a literature review of studies assessing the impact of the workforce on patient outcomes. Second, based on the literature review findings, we developed a preliminary analysis plan and identified available data sources. Third, we conducted interviews and a town hall meeting to collect feedback from stakeholders from acute care hospitals and professional organizations. Last, we used the feedback to iteratively refine the analytical strategy and conducted a statistical analysis.

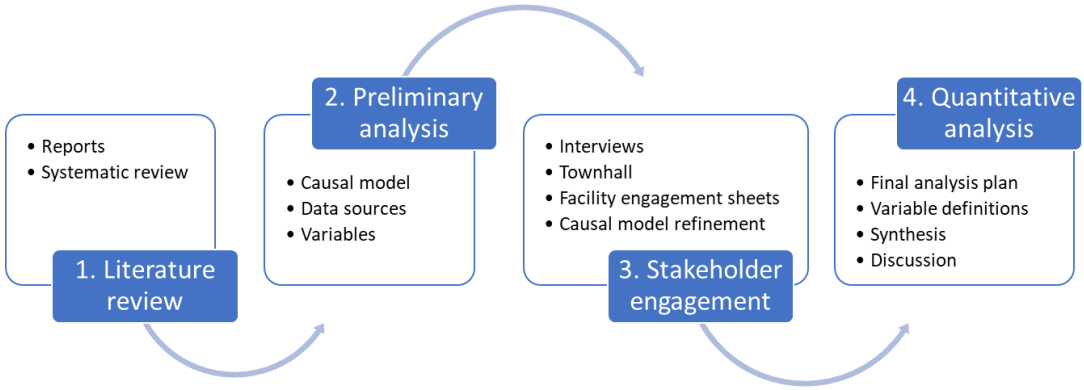

Figure 1. Overview of iterative study process

Phase One: Literature Review

During phase one, we reviewed the literature to ensure we were using scientifically sound research methods. This review aimed to identify how similar studies were conducted, including what variables were used as controls (e.g., equipment), how acute care teams were operationalized and defined, and commonly used research methods.

The 2013 State of Washington Ruckelshaus Center Nurse Staffing Steering Committee report *Nurse Staffing - A Summary of Current Research, Opinion, and Policy*,[1] served as a foundation for our review, stating that "having fewer patients per nurse or more direct nursing care hours per patient day is associated with fewer adverse outcomes" and "there is little research to guide understanding of the specific impact of variables that may combine with staffing to affect health

outcomes, particularly at a facilities level." Beyond the Ruckelshaus Center report, we identified 11 systematic reviews incorporating more than 300 studies that assessed the relationships between acute care hospital staff and patient outcomes over the last 10 years. From this review of the literature, we confirmed that our charge from HB1272 included unique elements emphasizing the need for our study. Our key findings are organized and summarized by elements of HB1272 below.

Staffing number and type

- Studies predominantly focus on the effects of nurse staffing on patient outcomes and infrequently consider non-nursing staff, indirect care providers (e.g., housekeeping), or multidisciplinary teams
- No studies quantified effects of a comprehensive acute care staff team on patient outcomes

Staffing education, training, and experience

- Several studies investigated the impact of or controlled for nurse education (e.g., type of degree such as Associate's, Bachelor's) by categorizing hospitals by highest credential in nursing staff (i.e., type of degree or diploma)
- One study examined the effect of differing levels of training in nurses on patient outcomes by measuring the proportion of registered nurses (RNs) to non-registered nurses (e.g., licensed practical nurses) over a given shift or number of hours worked
- Studies controlled for nurse experience using data from nurse surveys, measuring experience as years worked as a nurse, years worked on current medical unit, or years since nursing license obtained

Patient mortality and outcomes

- Mortality was commonly defined as in-facility or 28-day after-discharge mortality
- Readmission was commonly defined as a patient returning to the hospital within 30 days of hospital discharge
- Adverse events were often defined as medication errors, pressure injury/ulcers, nosocomial infections, and patient falls

Equipment

- Few studies controlled for equipment, and those that did had varying definitions
- Eight studies used whether facilities are approved for open-heart surgery as a proxy for their technology/equipment level

Patient characteristics

- Studies included underlying patient conditions and diagnosis variables such as comorbidities, percentage of patients with diagnosed dementia or symptoms of dementia, and self-reported health status
- Studies included patient demographic variables such as age, sex, race, ethnicity, education, socio-economic status, and insurance type

Hospital characteristics and external factors

- Studies included hospital characteristics and external factors impacting hospital volume, including trauma level, hospital size, hospital ownership type, teaching status, location, population density

Analytic methods

- Generalized linear regression models were the most common analytic method

Location

- No previous studies were specific to the state of Washington

Phase Two: Preliminary analysis

Expanding on the approaches identified in Phase One, we developed a causal model of how aspects of hospital staffing might impact patient outcomes and how this relationship might be confounded by other hospital and patient characteristics that our analysis would need to control for (Figure 2). We used this causal model to search for and organize the available data, and to identify gaps in the data where we needed proxy values to successfully conduct the analysis required by HB 1272.

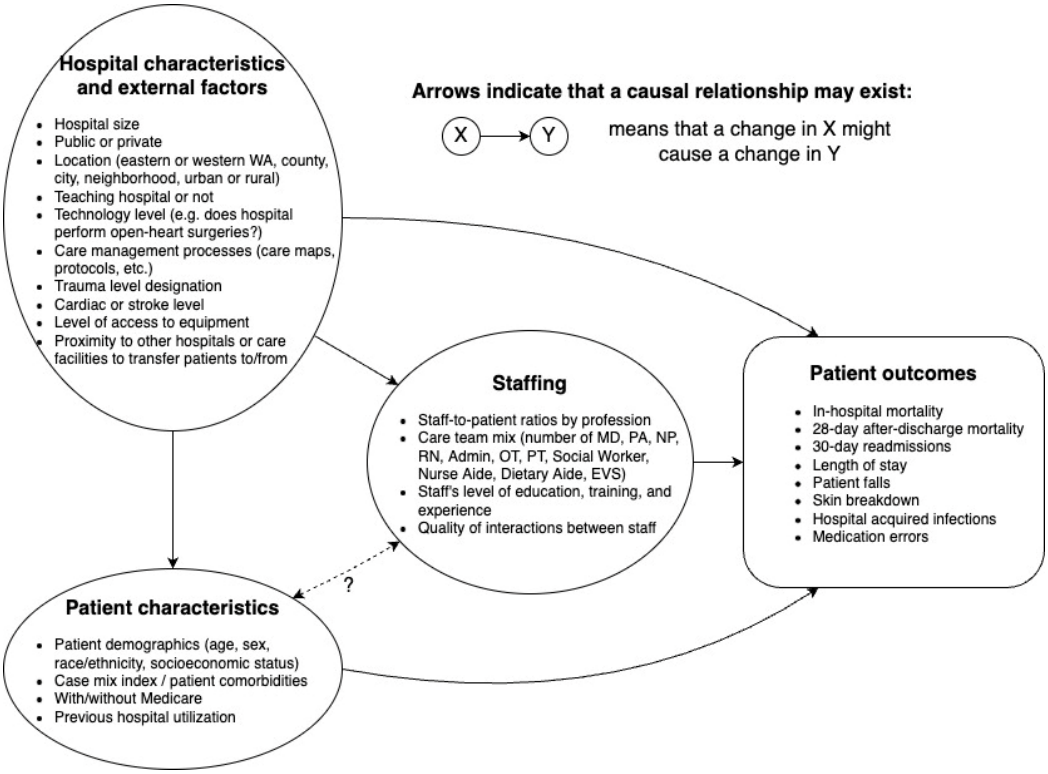

Figure 2. Initial causal model based on the literature review
MD=Medical Doctor, PA=Physician Associate/Assistant, NP=Nurse Practitioner, RN=Registered Nurse, OT=Occupational Therapist, PT=Physical Therapist, EVS=Environmental Service Worker

Data source identification

Because the timeline and budget for this study precluded primary data collection, we focused on research methods that relied on existing data sources available for most acute care hospitals. We held 13 meetings with organizational stakeholders to understand the landscape, available data sources, partners, and key stakeholders (e.g., associations, staff committee team). Washington State has several routinely collected data sources relevant to staffing and outcomes. The data sources we included are year-end reports, Comprehensive Hospital Abstract Reporting System (CHARS), certificate of need, adverse events data, Nursys e-Notify survey, and trauma facility designation. Descriptions of these datasets are summarized in Appendix A. There were several data sources evaluated but not included because the data was not available for all hospitals or quality issues (e.g., hospital culture surveys, nurse staffing plans).

Variables identified from data sources

A strength of this project was the creation of a database linking multiple complex data sources. The largest data source, CHARS, contained between 641,000 and 655,000 records each year. Each data source required a review of the variables

and processing to transform and/or link the datasets to the hospital, event type, and year in preparation for analysis. For example, in various datasets, hospital names were not formatted or spelled the same (e.g., UW Medicine - Harborview, UW Medicine/Harborview), names of facilities changed, or zip code rather than facility name was provided. Where data were not directly available, we identified proxy data variables based on prior research methods; for example, open-heart surgery is commonly used as a proxy for the level of equipment available at a facility.
The following lists variables and their sources for each of the causal model sections.

Hospital characteristics

- Hospital year-end reports contained volume data such as admissions, number of beds (acute care medical/surgical, intensive care unit), patient-days, and case mix
- Certificate of Need data contained facilities and services available (e.g., approved for open-heart surgery), which we used as a proxy to control for equipment and technology
- CHARS contained data on admission type (e.g., emergency, urgent, elective, trauma); type of stay (inpatient or observation)
- CHARS contained data used as a covariate, including patient-days and fraction of transfer admissions

Patient characteristics

- CHARS contained patient demographic data (age, sex, race, Hispanic or not); patient's zip code and county of residence; diagnoses given to the patient; procedures performed on the patient; type of payment for the visit (e.g., Medicare, Medicaid, private insurance, self-pay, charity care); length of stay; month of discharge; and status upon discharge
- CHARS contained data used as covariates, including the fraction of high-intensity patient-days, the fraction of obstetrics patient-days, the average patient age, the fraction of male patients, the fraction of non-white patients, the fraction of patients with Medicaid insurance

Patient outcomes

- Mortality data were obtained by 1) the Department of Health (DOH) matching each death certificate to the prior hospitalization (if present) and 2) the number of deaths (whether in a facility or community) within 28 days of discharge were calculated from the CHARS linked data
- The DOH Adverse Events dataset contained medication errors, patient falls leading to serious injury or death, and pressure ulcers

Staffing characteristics

- Hospital year-end reports contained full-time equivalent (FTE) for all acute care staff; acute care nurses; and other staff
- The Nursys e-Notify survey data contained the level of education and experience of acute care RNs, including, the average number of years since initial licensure, the proportion of nurses with bachelors' degrees, and the proportion of nurses with two years and five years of experience since receiving their license

Phase Three: Stakeholder engagement

We used the causal model developed in Phase Two to guide the stakeholder interviews. The purpose of these interviews was to build an analytic strategy using scientifically sound research methods most effective for all involved stakeholders. Stakeholder feedback informed the study design, research methods, measures, and data sources and built consensus. Findings from this qualitative phase informed the strategies of the analysis, discussion, and recommendations.

Table 1: Interviews by stakeholder type

Stakeholder interviews

Stakeholder type	Number of interviews
Acute Care Hospitals	10
Critical Access Hospital	7
Sole Community Hospital	2
Associations, Unions, Experts	16

Over six months, we conducted 35 interviews with 63 participants across Washington State (Table 1, Figure 3). Hospital representatives who participated in the interviews worked at three main hospital types: Acute Care Hospitals, Critical Access Hospitals, and Sole Community Hospitals. Hospital type definitions are nuanced; however, both Critical Access and Sole Community Hospitals are an official Medicare designation of an Acute Care Hospital type, Critical Access Hospitals being typically smaller and in rural settings.[2,3] Hospital representatives also included a broad range of hospital administrators and leadership such as Chief Executive Officers, Chief Nursing Officers, directors of facilities, care coordinator managers, financial analysts, utilization managers, nurse managers, as well as environmental service workers, nurses, and coders or billing staff from the three main hospital types. We also met with leaders from healthcare associations and unions, as well as experts in healthcare and workforce studies.

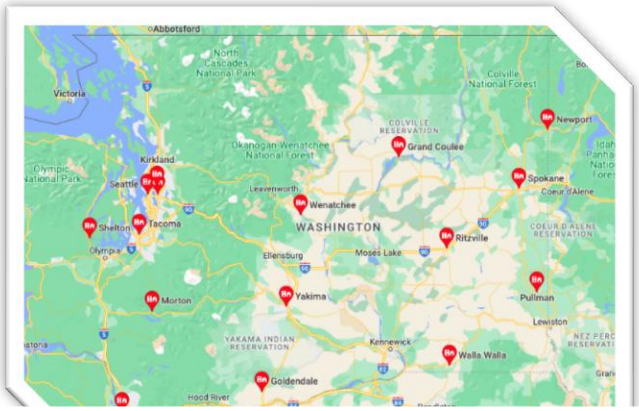

Figure 3. Interview participation across Washington State

Town hall and facility engagement sheets

To solicit additional stakeholder engagement, we held a virtual town hall and disseminated "facility engagement sheets." During the town hall, our team provided an overview of our research methods, data sources, and analysis plan, and offered a space for the more than 50 individuals in attendance to discuss and comment. Following the town hall, we organized data to be used in our analysis plan into individualized facility engagement sheets for each hospital, disseminated them to Chief Nursing Officers, and provided an additional opportunity for stakeholders to review for accuracy.

Takeaways of stakeholder feedback

Below is a summary of major takeaways based on our engagement with stakeholders:

- A "one size fits all" approach to establishing staffing ratios in the acute care setting is not ideal due to the complexities of population care needs, external factors, and staffing characteristics
- Analysis should include data prior to the COVID-19 pandemic due to exacerbated challenges in addressing staffing and patient needs
- Ratios of staff to patients in one setting do not equate to the same workload in another setting due to variations in direct (e.g., respiratory therapist, certified nurse assistant) and indirect (e.g., housekeeping) patient support staff
- In the absence of ancillary team members, nurses absorb additional care duties, which often leads to time spent working at a lower scope of practice and increased workload
- Moral distress and burnout exist among hospital staff due to increases in turnover and higher levels of , has led many to reconsider their profession
- While hospitals and hospital systems capture their staffing data internally, no database captures state-wide staffing education, training, and experience
- Need to identify high-intensity patients who have conditions (i.e., dementia, aggressive behavior) that increase the workload for hospital staff (e.g., time, number of staff needed to provide care) but may not be sufficiently captured in medical diagnoses
- Social determinants of health (e.g., socioeconomic status, education, health literacy) are major factors impacting health care utilization and patient outcomes
- Hospitals in rural settings experience more challenges recruiting staff and accessing resources to meet patient care needs

- Healthcare equipment was often conceptualized as technology aids and was defined differently by stakeholders
- Significant challenges exist discharging patients who are ready to be discharged due to limited beds in long-term care facilities or home health care services

Refinement of patient characteristics based on stakeholder feedback

There was consensus that there are *high-intensity* patient characteristics that correspond to a need for more staff time and could reduce time spent providing care to other patients. As a result, we adjusted the analysis to go beyond the traditional diagnosis and case mix related measures to incorporate a high-intensity classification based on conditions stated by stakeholders, many of which were also identified in the literature. In addition, a consulted coding physician provided a list of codes representing high-intensity conditions or situations. These included codes such as 1:1 monitoring, conduct disorder, physical restraints, as well as social determinants of health codes like homelessness and food insecurity. We also considered procedure codes in billing data. Because no predefined list of high-intensity procedures was identified, three nurses, with a cumulative 32 years of bedside nursing experience and one with over four years of administrative leadership as both a surgical services manager and clinical quality program manager, reviewed and coded the 500 most frequently listed procedure codes occurring in CHARS. The class of procedure (e.g., minor diagnostic, major diagnostic, minor therapeutic, major therapeutic) along with the typical care following the procedure were considered.

High-intensity classification was based on:

- ICD-10 diagnosis codes that corresponded to stakeholder-recommended high-intensity conditions (e.g., patients with traumatic brain injury, obesity, substance use, self-harm, or dementia)
- ICD-10-PCS procedures likely to influence patient care intensity by requiring more frequent monitoring or higher-level care
- ICD-10-PCS codes beginning with '10' (indicating obstetrics) were separately coded. The percent non-intense obstetrics patient-days was defined as the percentage of patient-days corresponding to discharges with at least one code starting with 10 and no codes marked as high-intensity

Figure 4 presents the refined causal model based on stakeholder feedback. Appendix B presents a summary of the stakeholder interview themes for each section of the causal model that informed the refinement process.

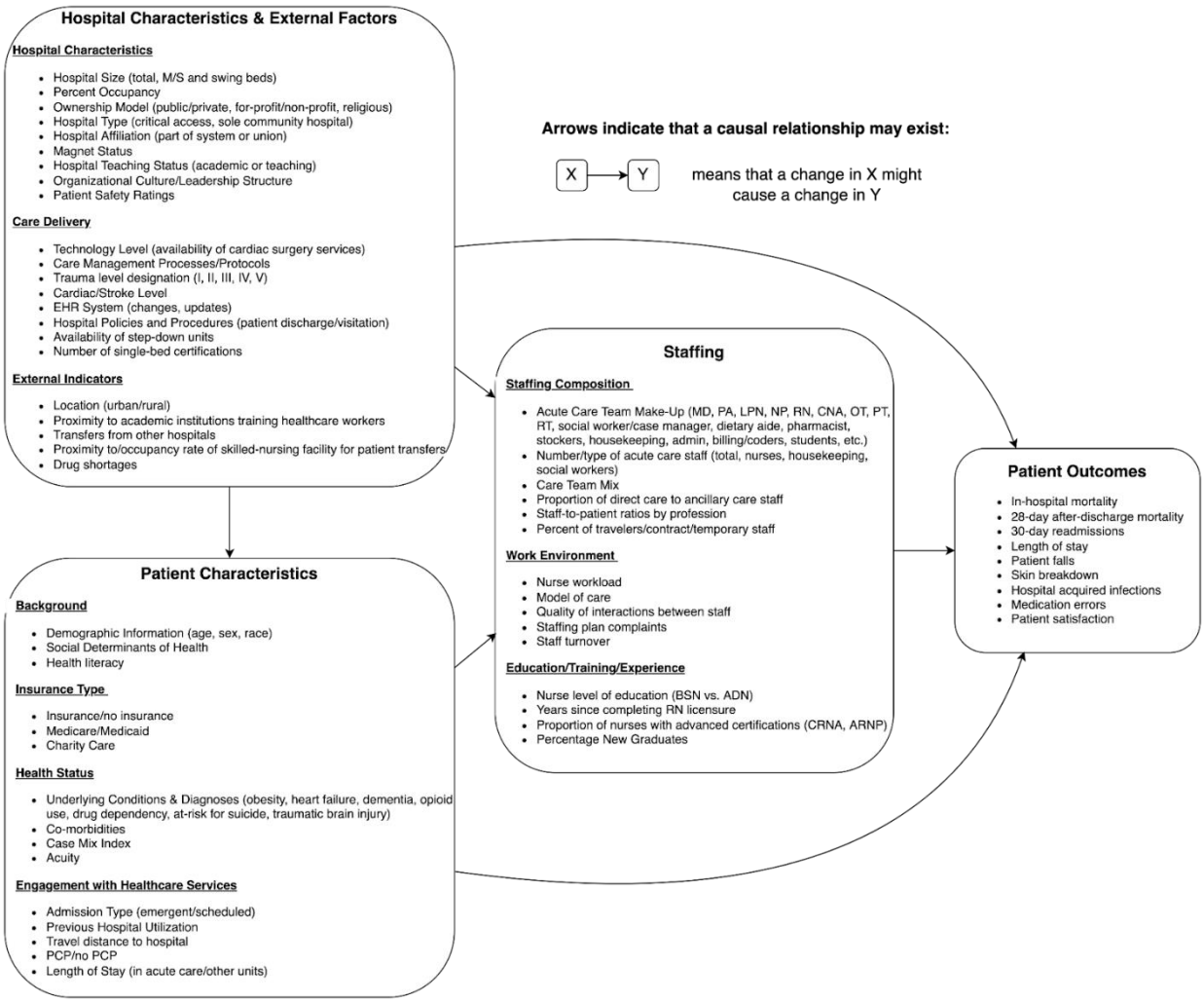

Figure 4. Refined causal model of relationships impacting staffing and patient outcomes
MD=Medical Doctor, PA=Physician Associate/Assistant, LPN= licensed practical nurses, NP=Nurse Practitioner, RN=Registered Nurse, CNA= Certified Nursing Assistant, OT=Occupational Therapist, PT=Physical Therapist, RT= Respiratory Therapist, EVS=Environmental Service Worker

Phase Four: Quantitative analysis

The refined causal model from Phase Three guided our quantitative analysis plan. In accordance with HB 1272, we assessed acute care staff number, type, education, training, and experience using scientifically sound research methods most effective for all involved stakeholders and controlled for the agreed-upon contributing factors. This included analyzing all acute care hospital data (excluding behavioral, psychiatric, and pediatric hospitals) from 2016-2019 and analyzing Critical Access Hospitals separately from Acute Care Hospitals (including large Sole Community Hospitals). Although all factors in the model were recognized as important, not all had associated data and could be included in our analysis. The methodological overview, including strategies for controlling contributing factors, is in Appendix C.

Definitions

- **Acute care staff** as the acute care hospital employees whose full-time equivalent (FTE) is recorded in the year-end reports under cost centers for:
    - Acute Care (including acute care nurse and other acute care staff)

- 14 “core ancillary staff” identified through stakeholder interviews: Respiratory Therapy, IV Therapy, Physical Therapy, Occupational Therapy, Speech Therapy, Central Services, Central Transportation, Nursing Float Personnel, Physical Rehab, Hospice, Laboratory (Including Blood Bank), Housekeeping, Social Services, and Other Ancillary Services.

Based on stakeholder consensus and the available data sources, we defined the following for each hospital and each year:

- **Staff number** as total FTE for all acute care staff as defined above
- **Staff type** as the proportion of acute care nurse FTE among all acute care staff FTE
- **Education** as the proportion of acute care nurses with a Bachelor of Science in Nursing (BSN)
- **Experience** as the proportion of acute care nurses with five years or less since initial licensure
- **Mortality** as patient death within 28 days after discharge
- **Adverse events** as combined reported patient events, including pressure ulcers, medication errors, or patient falls leading to serious injury or death

Hypotheses

- **Staff number**: More patients per acute care staff is associated with more adverse events and mortality
- **Staff type:** A higher proportion of nurses among acute care staff is associated with fewer adverse events and decreased mortality
- **Nurse education:** A higher proportion of BSN-prepared nurses is associated with fewer adverse events and decreased mortality
- **Nurse experience**: A higher proportion of nurses with less than five years of experience is associated with more adverse events and mortality

To assess our hypotheses, we examined 263 acute care hospital-years between 2016-2019, which included 8,989,222 patient-days, 27,758 total acute care nurse FTE, 66,968 other acute care staff FTE, 1,536 combined adverse events, and 110,374 patient deaths within 28 days of discharge. One hospital-year consists of the merged data containing all of the model variables pertaining to a single hospital for one year. We ran separate analyses for Critical Access Hospitals and Acute Care Hospitals. Other data characteristics by hospital type are provided in Appendix D. Appendix E provides a table of the results of the main analyses.

Main findings

Critical Access Hospitals

For Critical Access Hospitals, we did not find that acute care staff number, nurse education, or nurse experience are associated with adverse events or mortality, but we did find that a higher proportion of nurses among acute care staff is associated with decreased adverse events.

Acute Care Hospitals

- More patients per acute care staff is associated with increased adverse events, but we did not find an association with mortality
- A higher proportion of nurses among acute care staff is associated with decreased mortality, but we did not find an association with adverse events
- We did not find that either nurse education or experience are associated with adverse events or mortality; there is no agreed-upon or available data source for nurse training

Sensitivity analysis

To measure the strength of our findings, we re-ran our analyses 10 times with 10% of the hospitals randomly removed from the data. This resulted in no change in our findings.

Discussion

Critical Access Hospitals

For Critical Access Hospitals, we found only one association, namely that a higher proportion of nurses among acute care staff is associated with decreased adverse events. The fact that we detected only one association within the data largely aligned with stakeholder feedback that within Critical Access Hospitals there is little variation in staffing numbers, and bed counts, patient days, and admissions are low. However, compared to larger urban counterparts, stakeholders from Critical Access Hospitals described numerous and substantial hospital and external characteristics impacting patient outcomes. Examples included limited equipment for high-intensity patient care and limited community resources important for timely patient discharge.

Acute Care Hospitals

Number of acute care staff

For Acute Care Hospitals, more patients per acute care staff is associated with increased adverse events. This finding is consistent with stakeholder feedback and similar studies, which demonstrate that fewer patients per nurse reduces adverse patient outcomes.[4-6] Another way to interpret these findings is that if all hospitals had at most the current median staffing ratio in Washington State (1.2 patient hours per staff hour), then the number of adverse events would be reduced by 10% (95% Uncertainty Interval [UI] 2.7 – 16.8). This means that among the 1,486 adverse events that occurred between 2016-2019, approximately 149 (95% UI 40 – 249) could have been averted by ensuring that all hospitals had sufficient staffing to guarantee at most 1.2 patient hours per staff hour worked by acute care staff.

The number of acute care staff was not found to be associated with mortality. Based on our literature review, we expected to find an association between staff number and patient mortality. However, our findings suggest that adding more acute care staff may not be associated with decreased mortality in the Washington State acute care setting.

Type of acute care staff

Staff type is associated with 28-day patient mortality but not with reported adverse events. Specifically, a higher proportion of acute care nurses among acute care staff is associated with lower 28-day mortality. Another way to interpret these findings is if all hospitals increased the fraction of acute care nurse FTE to at least the current median in Washington State (29% nurse FTE among all acute care staff FTE), then the number of 28-day deaths would be reduced by 1.58% (95% UI 0.23 – 2.90). This means that among the 105,970 28-day patient deaths that occurred during the study period, approximately 1,672 (95% UI 244 – 3,066) could have been averted by ensuring that all hospitals had at least 29% nurse FTE on the care team.

The proportion of nurses among acute care staff was not found to be associated with adverse events. Based on stakeholder feedback, we expected that with a higher proportion of non-nurses, registered nurses can work to their highest scope of practice and are not reallocated additional care duties, reducing adverse events. However, our findings suggest that the proportion of nurses among non-nurse acute care staff may not be associated with decreased adverse events.

Data are insufficient or do not have enough variation to quantify the relative importance of each team member type and define the 'ideal' team composition to reduce poor patient outcomes. This finding aligned with stakeholder feedback that staffing models vary within and across health care systems and make the comparisons across systems difficult. The documentation for how staffing cost center allocation (staffing time) is applied in the year-end reports may also vary across systems.

Education, training, and experience

We did not find that either nurse education or experience are associated with adverse events or mortality. While this finding was counter to what stakeholders predicted, they also described experience in one setting as not translating to experience in another setting. Capturing experience by years since initial licensure, which is standard in similar research, may overlook nurses moving to different units. Similarly, while studies have found that increasing the proportion of

BSN-prepared nurses reduces the risk of patient mortality, our results indicated no association between the proportion of BSN to non-BSN-prepared nurse and patient outcomes.[7,8] However, our findings do not mean that nurse education and experience have no effect on patient outcomes, but rather that there was insufficient data on education and experience to observe an association with patient adverse events or mortality.

While we were told that individual hospitals and hospital systems may capture staffing data internally on education, training, and experience, no database captures state-wide staffing data for all staffing types. Interviews predominantly focused on nursing education, training, and experience and not on other staff types. Additionally, there was no agreed-upon or available data sources for nurse training. Training was described in a number of ways (e.g., type of credentials, in-service training, specialty training programs). As there was no agreed-upon available data source for training, our analysis was limited to nurse staff education and experience.

Limitations

There are a number of limitations of the data to consider. Appendix F lists the limitations of the data included in this study.

Conclusion

This is one of the first studies to broadly analyze an acute care team and utilize a multiphase process to identify scientifically sound research methods most effective for all involved stakeholders. Stakeholder engagement guided the understanding of the specific variables that combine with staffing to affect patient outcomes and were incorporated into the iteratively refined causal model. This report presents findings about the impact of hospital, external, staffing, and patient characteristics on patient outcomes in Washington State's acute care hospitals from January 1, 2016, through December 31, 2019. For Critical Access Hospitals, while there is no evidence that changing staffing numbers would reduce 28-day mortality or adverse events, there is associational evidence that increasing the proportion of acute care nurses among acute care staff would reduce adverse events. For Acute Care Hospitals, while there is no evidence that changing staffing numbers would reduce 28-day mortality, there is associational evidence that 1) increasing the total acute care staff-to-patient ratio would reduce the number of adverse events, and 2) increasing the proportion of acute care nurses among acute care staff would reduce 28-day mortality. Although findings from this study suggest that neither nurse education nor experience are associated with patient outcomes, this does not mean that nurse education and experience have no effect on patient outcomes. This finding could be due to limited data on education and experience to observe an association with patient adverse events or mortality. Further, this study could not assess training due to lack of agreed-upon or available data. It is also important to note that although associations are actionable, an absence of evidence is not evidence of absence, and further inquiry with alternative methods or data might better reveal relationships that this study was not able to quantify.

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Appendices

A. Data sources, descriptions, and variable types
B. Themes of stakeholder feedback according to causal model section
C. Quantitative analysis methodological overview
D. Overview of data characteristics
E. Main analysis results table
F. Overview of data source limitations
G. Responses to stakeholder concerns

Appendix A. Data sources, descriptions, and variable types

Data Sources	Description of Data Source	Variable Types
Hospital Year-End Reports	Hospital-reported volume and cost center data submitted yearly to the Department of Health, including number of acute care beds, number of full-time equivalent (FTE) for numerous staffing types (e.g, acute care nurses, all acute care staff), and patient case mix	Staffing Hospital characteristics
Comprehensive Hospital Abstract Reporting System (CHARS)	Department of Health system that collects record level information on inpatient and observation patient community hospital stays. Dataset includes patient characteristics (demographics, insurance type, diagnoses) and patient outcomes (in-hospital mortality, 28-day-after discharge mortality), etc.	Patient characteristics Patient outcomes Patient mortality External factors: hospital types, transfers
Certificate of Need	Regulatory process that requires certain healthcare providers to get state approval before building certain types of facilities or offering new or expanded services. Dataset includes Number of Licensed Acute Care Hospital Beds; Number of Licensed Beds by Hospital Size; Hospital Operating Budget Data; Hospital Capacity for Open-Heart Surgery, etc.	Hospital characteristics Proxy for equipment/ technology
Adverse Event Data	Hospital-reported adverse events data reported quarterly to the Department of Health since 2006, including patient falls, skin breakdown, medication errors that lead to a serious injury.	Patient outcomes
Nursys e-Notify Survey Nursing Commission Survey*	De-identified Nursing Workforce Supply data. Nurse-reported data submitted yearly when renewing license, including level of education, training, employment information (e.g., position, specialty), etc.	Staffing
Trauma Facility Designation	Department of Health designated trauma designations (level I, II, III, IV, V) evaluated every three years based on facilities written trauma service applications and on-site surveys.	Hospital characteristics

*The data for this analysis were provided by the Nursing Care Quality Assurance Commission (NCQAC). NCQAC did not take part in, nor endorse, any data analysis or interpretation set forth herein.

Appendix B. Themes of stakeholder feedback according to causal model section

Hospital Characteristics

- Facility culture and leadership structure are major influencing factors on work environment
- Vary across organizations and within the units due to care models
- No consistent definition used for equipment - often described as technology (e.g., lifts, blood pressure monitors that integrate data into electronic medical records, bedside tables)
- Urban versus rural setting is an important factor influencing patient outcomes
  - Urban hospitals have increased access to resources (e.g., availability of staff, long term care facilities)
  - Urban populations have better access to resources (e.g., transportation services, preventative care, specialty services)
- Facility type - profit, non-profit, unionized, teaching hospital, or has internal programs - is important
  - A university connection provides more access to students and training
- Lack of consistency of interdepartmental communication across hospitals due to lack of internal and external communication (leadership and culture)
- Uncertainty in how variables are captured and reported - unable to analyze at the unit level

External Factors

- Greatly impact organizational structure, staffing, types of care available to the population, and access to specialized patient care equipment
- Feelings of population shifts (e.g., seasonal influx) and changes in Social Determinants of Health factors within community
- Community resource availability (e.g, long term care facilities, home health care, outpatient mental or behavioral health such as dementia specialized facilities) impacts the ability to discharge patients who may be ready to be discharged

Patient Characteristics

- High-intensity patients (e.g., aggressive behavior, mental health exacerbation, traumatic brain injury, obesity, substance use, self-harm, dementia) increase staffing demands
- Social determinants of health impacts health care utilization and patient outcomes
- There are difficult to discharge populations (e.g., need for guardian assignment)

Staffing Characteristics

- Issues in recruiting and maintaining staff
- Contract staffing impacts patient outcomes and staff culture
- Rural areas experience a decreased ability to recruit staff, particularly for specialty services
- Different mix of staffing at each hospital and even within various units
- Staffing plans not always followed and only include nursing staff in plans
- Staffing complaints might be higher where staff feel they have a system in place to act on complaints. Where they felt that their complaint may not be heard fewer complaints submitted
- Various roles and responsibilities across the care team (nurses tended to absorb duties as needed)
- Various stakeholder roles and responsibilities - area of knowledge and various outlooks, recommendations, and vision for the future of healthcare.
- Some facilities capture internal data on education and training but none of that data are shared externally other than those participating in programs such as NDNQI - vs. external
- Hospitals that have unionization for certain staff types (e.g., CNAs) have policies in place that mandate roles and responsibilities for staff

Patient Outcomes

- Adverse events (nursing outcomes- many hospitals explain being dependent on multidisciplinary teams) (culture of safety- leadership type and team mix)
- Readmission (dependent on type of hospital and care plans - sometimes planned due to phased care)

Appendix C. Quantitative analysis methodological overview

The random effect Poisson regression model used to conduct this analysis has the following form, where h denotes the hospital, t denotes the time period (year), outcome_cnt_h,t is the number of patient outcomes for the hospital (h) in a given year (t), patient_days_h,t is the number of patient days for the hospital (h) in a given year (t), mu_h,t is the predicted log number of outcomes per patient day, staffing_ratio_h,t and X_h,t are the model covariates, gamma_0, gamma_1, and theta are the parameters for the fixed effect coefficients, u_h is the hospital-level random effect, and sigma_u is the standard deviation of the hospital-level random effects.

$$\text{outcome\_cnt}_{h,t} \sim \text{Poisson}\left(\exp\left(\mu_{h,t}\right) \times \text{patient\_days}_{h,t}\right)$$

$$\mu_{h,t} = \gamma_0 + \gamma_1 \text{staffing\_ratio}_{h,t} + \theta^T X_{h,t} + u_h$$

$$u_h \sim \text{Normal}(0, \sigma_u^2)$$

For the main analysis of the relationship between the number of staff and patient outcomes, the staffing ratio was defined to be the total number of patient hours recorded in CHARS divided by the number of acute care plus core ancillary staff hours as recorded in the year-end cost center reports, where the cost centers corresponding to acute care plus core ancillary staff were determined from conversations with stakeholders. To assess staffing type, we assessed the impact of the ratio of nurse FTE to all acute care plus core ancillary staff FTE. To assess experience, we assessed the fraction of nurses with five years or less of experience. To assess education, we assessed the fraction of nurses with a BSN.

Several hospitals were missing cost center data for one or more years; we dropped these hospital-years from our analysis since the model could not be run without staffing data from the cost center reports.

Strategies to control for other contributing factors

Per HB 1272, "The study should control for other contributing factors, including but not limited to access to equipment, patients' underlying conditions and diagnoses, patients' demographics information, the trauma level designation of the hospital, transfers from other hospitals, and external factors impacting hospital volumes." The following list briefly describes the model covariates we used to control for these other contributing factors, organized into the categories from the causal model.

External factors impacting hospital volumes

- Critical Access Hospital status – we conducted separate analyses for Critical Access Hospitals and other Acute Care Hospitals (excluding children's hospitals and rehabilitation hospitals)

Hospital characteristics

- Trauma level designation of hospital
  - Coded as 1 for hospitals designated level I or level II and 0 for all other hospitals
- Transfers from other hospitals
  - Percent of patients transferred in from other hospitals (from CHARS)
- Equipment and technology
  - Certification for open heart surgery (coded as 1 if the hospital has open-heart certification and 0 otherwise)

Patient characteristics

- Patients' underlying conditions and diagnoses
  - Case mix index (from the Year-End Volume Reports)
  - Average number of diagnoses among patients in each hospital-year (from CHARS)
  - Percentage of patient-days with any high-intensity diagnosis codes or high-intensity procedure codes (from CHARS)

    - Percentage of patient-days with obstetrics procedure codes (from CHARS)
- Patients' demographics (all from CHARS)
    - Average age
    - Percent male
    - Percent non-white
    - Percent with Medicaid insurance

Sensitivity analyses

To confirm that the findings were robust to the sample of hospitals, we conducted out-of-sample validation. We re-ran our analyses 10 times with 10% of the hospitals randomly removed from the data. This resulted in no change in our findings.

Counterfactual analysis

To quantify our findings in more understandable terms, we ran a counterfactual analysis. This involves using our fitted random effect Poisson regressions to predict how many adverse events and patient deaths would be averted in a hypothetical scenario in which staffing number or staffing type were different from what was observed in the data. We hypothesized two alternative scenarios, one in which all hospitals had the median staffing ratio or lower (with all other variables remaining the same), and one in which all hospitals had the median fraction of nurses or higher (with all other variables remaining the same). We chose the medians of the observed data as values that could be realistically achieved and that fall within the range of our models' predictions.

Appendix D. Overview of data characteristics

Table D.1: Data summary

Variable	Critical Access Hospitals	Acute Care Hospitals
Totals Across Observations		
Number of observations (hospital-years)	101	162
Total patient-days	236,579	8,752,643
Total acute care nurse FTE	1,855	25,903
Total non-nurse acute care plus core ancillary FTE	5,924	61,045
Total combined adverse events	50	1,486
Total 28-day deaths	4,404	105,970
Patient Volumes and Staff Size		
Median patient-days (Q1, Q3)	1,363 (769, 4,156)	40,164 (21,205, 73,404)
Median acute care plus core ancillary FTE (Q1, Q3)	55 (39, 80)	363 (222, 788)

FTE = full-time equivalents, Q1 = first quartile, Q3 = third quartile

Table D.2: Data characteristics of model variables

Variable	Critical Access Hospitals	Acute Care Hospitals
Outcomes		
Average combined adverse events (st. dev.)	0.5 (0.9)	9.2 (10.4)
Average combined adverse events per 10,000 patient-days (st. dev.)	7.2 (23.7)	1.8 (2.3)
Average 28-day deaths (st. dev.)	44 (37)	654 (445)
Average 28-day deaths per 10,000 patient-days (st. dev.)	244 (255)	134 (45)
Staffing Characteristics		
Median staffing ratio = Median (patient-hours) / (acute care plus core FTE hours) (Q1, Q3)	0.34 (0.22, 0.47)	1.22 (0.97, 1.43)
Median % acute care nurse FTE among all acute care plus core ancillary staff FTE (Q1, Q3)	25 (19, 34)	30 (22, 34)
Median % new nurses (within 5 years of licensure) (Q1, Q3)	17 (8, 30)	32 (18, 37)
Median % nurses with BSN (Q1, Q3)	42 (25, 50)	58 (50, 70)
Hospital Characteristics		
Number of hospital-years with capacity for open heart surgery (proxy for equipment/technology)	0 (0.0%)	51 (31.5%)
Number of hospital-years with trauma level I or II	0 (0.0%)	26 (16.0%)
Average % transfer patients (st. dev.)	1.4 (5.8)	7.3 (8.8)
Patient Characteristics		
Average % high-intensity patient days (st. dev.)	42.9 (11.9)	63.6 (9.6)
Average number of diagnoses (st. dev.)	9.9 (3.2)	11.2 (2.3)
Average case mix index (st. dev.)	0.69 (0.16)	0.99 (0.27)
Average % Medicaid patients (st. dev.)	32.3 (15.1)	35.1 (13.1)
Average % non-white patients (st. dev.)	5.6 (9.7)	12.2 (8.4)
Average patient age (st. dev.)	56.5 (12.5)	51.2 (7.2)
Average % male patients (st. dev.)	43.1 (6.8)	46.5 (4.8)
Average % obstetrics patient-days (st. dev.)	5.0 (5.9)	4.0 (3.0)

st. dev. = standard deviation, FTE = full-time equivalents, Q1 = first quartile, Q3 = third quartile

Appendix E. Main analysis results table

Model	Combined Adverse Events	Pressure Ulcers	28-day mortality
Acute Care Hospitals			
Staff number Additional outcomes resulting from an increase of one patient-day per acute care staff-day (mean, 95% UI)	0.75 [0.31, 1.21]	1.38 [0.80, 1.91]	0.06 [-0.02, 0.15]
Staff type Additional outcomes resulting from an increase of the percent nurse FTE on acute care staff by one standard deviation (mean, 95% UI)	-0.14 [-0.32, 0.03]	-0.34 [-0.59, -0.10]	-0.04 [-0.08, -0.01]
Nurse education Additional outcomes resulting from an increase in the percentage of BSNs among nurses by one standard deviation (mean, 95% UI)	-0.15 [-0.41, 0.09]	0.02 [-0.33, 0.41]	-0.12 [-0.33, 0.08]
Nurse experience Additional outcomes resulting from an increase in the percentage of new nurses by one standard deviation (mean, 95% UI)	0.08 [-0.12, 0.27]	0.00 [-0.29, 0.31]	0.00 [-0.21, 0.20]
Critical Access Hospitals			
Staff number Additional outcomes resulting from an increase of one patient-day per acute care staff-day (mean, 95% UI)	-0.24 [-1.83, 1.61]	-0.12 [-1.90, 1.85]	0.05 [-0.28, 0.38]
Staff type Additional outcomes resulting from an increase of the percent nurse FTE on acute care staff by one standard deviation (mean, 95% UI)	-1.09 [-2.10, -0.20]	-0.93 [-1.87, -0.12]	-0.03 [-0.11, 0.05]
Nurse education Additional outcomes resulting from an increase in the percentage of BSNs among nurses by one standard deviation (mean, 95% UI)	-0.49 [-1.59, 0.47]	-0.15 [-1.09, 0.59]	-0.08 [-0.56, 0.37]
Nurse experience Additional outcomes resulting from an increase in the percentage of new nurses by one standard deviation (mean, 95% UI)	-0.94 [-2.18, 0.13]	-0.15 [-2.79, 2.40]	0.10 [-0.34, 0.51]

UI = uncertainty interval

Appendix F. Overview of data source limitations

Hospital characteristics

- Equipment challenging to measure and no agreed-upon equipment or data source
- Technology and environmental and unit design (e.g., size of units, pods, and architectural design) suggested but no identified corresponding data source
- Organizations that have focused on human factors science in re-engineering their work - make it easier for staff "to do the right thing and more difficult to do the wrong" - getting wasted steps, non-value-added work, workarounds, out of the workflow of an employee. We were unable to identify data to determine each facilities level or type of application of these processes

Staffing type

- Year-end reports All Acute Care FTE. Acute Care Nurse is separately reported; however, the All category is not detailed to fully describe the acute care team
- CNAs recognized as having a critical role in providing care and improving patient outcomes; however, they are not separately reported in costing allocations
- Staffing plans focus on nursing staff and other staffing type plans are not reported to inform team composition
- Contract nurses or other staff was suggested to be weighted or considered different from other permanent hospital staff; however, data on contract staff FTE per hospital or unit is not included in the reported data
- Direct patient care experience that each member of the care team has for the specific conditions of the patients being cared for would be ideal but is not captured or reported in the data

Experience and training of acute care staff limited to nurses

- No good measure of training - considered, for example, in-service FTE and certifications but no data source available for all hospitals
- No central source of certification data - that could be a way to capture training. Some hospitals capture internally but may not be maintained or shared

Patient outcome

- Data limited to adverse outcomes data
- Adverse event & CHARS data may underrepresent overall events
- Washington State Hospital Association collects detailed patient outcome data from all hospitals in Washington State; however, this data was not available for analysis in this study.
- Bed-days in CHARS not separated by unit e.g., does not distinguish patient-days in ICU from patient-days in acute care units

Patient characteristics

- A recognized challenge to addressing patient characteristics is that medical diagnoses may miss high-intensity patients that have a need for complex, technical registered nursing care or care from a non-nurse care team member for more frequent observation, assistance to prevent falls and pressure ulcers, perform activities of daily living, and to prevent self-injury. In this study, we attempted to address this issue by considering a number of factors and codes that could increase intensity of care provided by the acute care team. Although a robust process, this strategy needs further testing and validation.

Other limitations

- Time resolution of data is yearly rather than monthly or quarterly
- All factors in the model were recognized as important, not all had associated data and could be included in our analysis
- Data sets included missing data - missing data was removed from the analysis

Appendix G. Responses to stakeholder concerns

The following summarizes stakeholder concerns provided in writing and during the town hall and our responses to each.

Literature review

A dearth of literature analyzing hospital staffing beyond nursing staff. Studies that only analyze nursing staff do not present the full picture of how care is delivered or the multiple confounding factors that impact patient outcomes. Nurse staffing must be considered within the broader team-based approach to patient-centered care.

> **Response**: The primary purpose of our literature review was to assess how similar studies were conducted, the variables included in the models, and how the variables were defined. We did not limit our inclusion criteria to studies that looked only beyond nursing staff; however, the staff included in each study was extracted. We did find that the majority of studies focus on nursing staff without considering any other hospital staff. In the final report, we highlight and describe the studies that considered more than one hospital staff type and controlled for other variables, such as patient characteristics.

Conceptual model

The conceptual model describes data that would be considered causal when all other variables are held constant. The key limitation is that it is almost impossible to hold "all other variables" constant. The characteristics of hospitals, patients, and staff are dynamic in the clinical arena. To create an environment otherwise can only be considered an academic exercise and would not reflect actual patient care realities.

> **Response**: This is a really important concern. We have used a theoretical framework grounded in a causal model diagram to investigate how the dynamic characteristics are interrelated. Far from being an academic exercise, this was the center point for our conversations with stakeholders and a way to ensure that it reflects the realities of patient care. We agree that this limitation is an important consideration.
> We must be cautious in how much we change any one variable when considering counterfactuals. In our efforts, we have focused on counterfactuals that are within a range consistent with the observed data.

Available Data

The recommended characteristics for assessment in the conceptual model may be in line with industry standards. However, when we compare these characteristics to the data the research team proposes to use to measure them, we are concerned that the model will not be able to represent the impacts of hospital staffing as comprehensively as required by the statute.

For example, using DOH adverse event data as a marker for patient falls or medication errors doesn't provide the specificity needed to associate it with the hospital staff caring for that specific patient. Both in the slide deck and as presented during the town hall, the data planned to be used to complete the analysis is lacking, especially for professions beyond nursing, and even for nursing staff, it is too removed from the actual care and hospital staff providing the care to draw any conclusions about associations between staffing and outcomes. We agree that the data needed to reliably analyze the impacts of hospital staffing on patients at a population level and create a valid association or causality cannot exist given the inherently variable nature of individual patients, individual caregivers, and multitudes of confounding factors. We strongly recommend that this is clearly stated in your final report.

> **Response**: We acknowledge that this is a limitation of our study. We wish we had data to conduct an individual-level analysis, but the data doesn't exist. As we see it, the risk of the hospital-level analysis is one of lower statistical power – instead of analyzing millions of patient encounters, we analyzed hundreds of hospital-years of data. The results of our analysis are likely less certain than those of an individual-level analysis would have been. If individual-level analysis had been possible, we may have been more certain of effects that ended up being statistically insignificant in our current analysis.

Hospital Characteristics

An additional factor that is missing from the hospital characteristics that may impact both staffing and patient outcomes is the architectural design of the floor in relation to the care the patient is receiving. The environmental and human factors (how far staff needs to carry the patient or how far certain equipment may be located relative to the patient) can be highly influential and can impact staffing numbers, patient acuity, and how care is delivered.

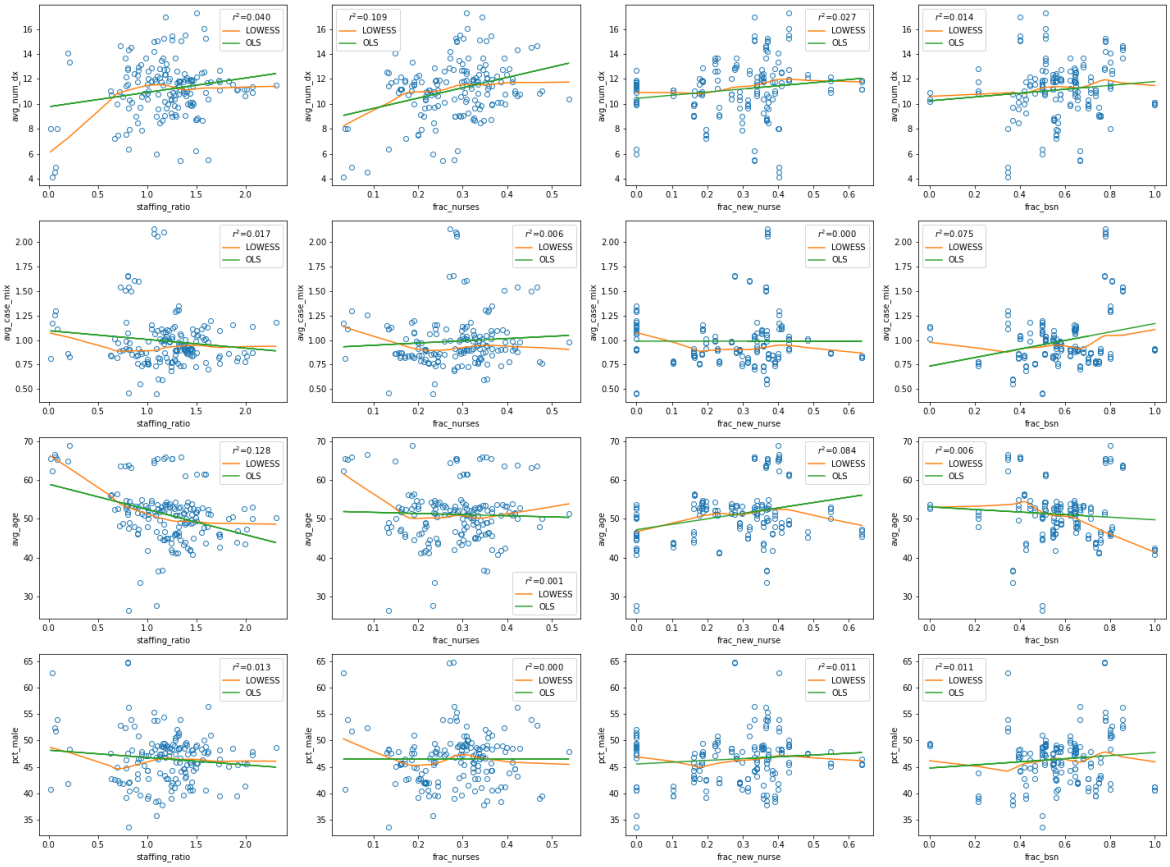
> **Response**: We agree that this additional factor could be an important factor in patient outcomes and perhaps also mediate the relationship between staffing and outcomes. It was a topic of discussion in at least one of our qualitative interviews as well. With no widely available data to quantify the variation in built environment between hospitals, we were unable to include it in our analysis.

Patient Characteristics

The list of characteristics is quite comprehensive. We suggest the study authors selectively identify and group these elements by association. Having too many characteristics that are very similar may negatively impact the model. Our data analytics team suggests using techniques like Principal Component to identify and group select predictors to reduce the interdimensional relationship among the variables.

> **Response**: We appreciate the assessment that our patient characteristics are comprehensive, as this was precisely our goal in response to our charge from HB 1272. Due to our selected statistical approach having too many patient characteristics would only risk a negative impact on our model if the characteristics were highly correlated with the staffing variables we included. Our theoretical model hypothesized that the causal structure of these variables would not exhibit such correlations, but in response to this important concern, we have also examined these correlations empirically. The figure below shows that the largest R^2 value for an association between any of our four staffing variables and our eight patient characteristics is 25% and most are much lower.

Scatterplots of patient characteristics 1-4 against staffing characteristics



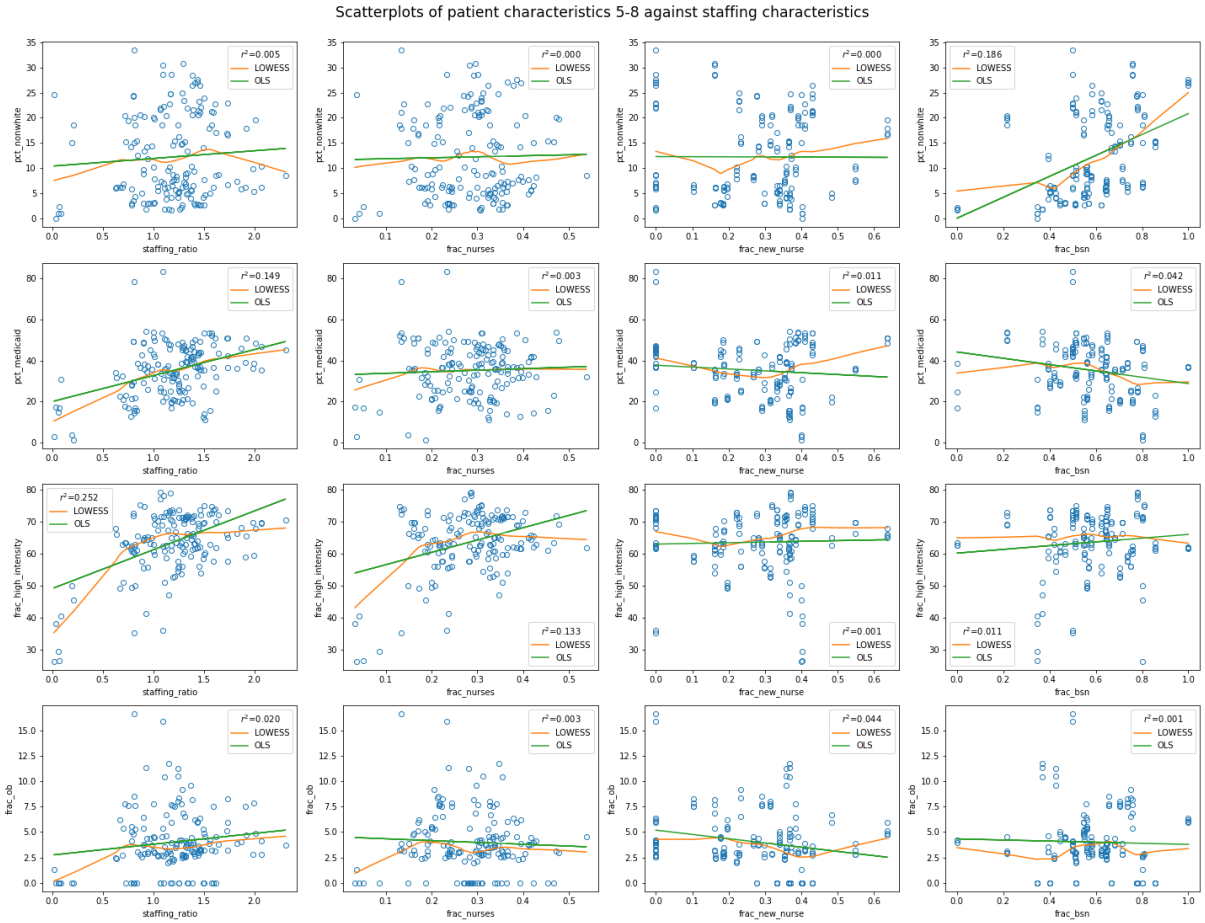


Figure 1: each row is a patient characteristic (8 rows) and each column is a staffing variable (4 columns), and each cell is a scatter plot with a lowess regression line plotted over the points and R^2 values listed numerically as well.

Patient Characteristics

There is a patient characteristic listed as "Time spent in ICU or length of stay prior to acute care bed." Since the authors only intend to study acute care units, we question the relevance of this characteristic. Regardless of its inclusion in the analysis, we strongly recommend that the study authors make it very clear that the study is limited to only acute care units of a hospital and cannot be extrapolated to other types of beds, units, or services.

> **Response**: In response to this concern, we have added more clarification that this study is limited to only acute care units of a hospital. We also have removed the time spent in ICU variable from our analytic model, and we must also note an additional limitation of some of our data sources (e.g. CHARS) is that they do not afford a way to distinguish patient-days in ICU from patient-days in acute care units.

Patient Characteristics

Medical diagnosis is insufficient to consistently/accurately differentiate high-intensity and normal-intensity patients, as it does not take into account technical nursing care needs. Underlying conditions and diagnoses would be used to specify the fraction of high-intensity patients. That same slide [presented at town hall] included six characteristics: heart failure, traumatic brain injury, obesity, substance use, self-harm, and dementia. What is believed to be missing is the identification of high-intensity patients that need more than frequent observation/assistance to prevent falls, perform activities of daily living, and prevent self-injury. Much of the care provided to those with the characteristics listed (heart failure excluded), may be provided by non-RN members of the care team. For example, those with a diagnosis of self-

harm may require a trained sitter who performs frequent monitoring/documentation/redirection and multidiscipline therapy, while the RN may provide less care than the sitter and CNA on the care team.

Response: We agree, there was consensus that there are high-intensity patient characteristics that correspond to a need for more staff time and could reduce the time spent providing care to other patients. As a result, we adjusted the analysis to go beyond the traditional diagnosis and case mix related measures to incorporate a high-intensity classification based on conditions stated by stakeholders, many of which were also identified in the literature. In addition, a consulted coding physician provided a list of codes representing high-intensity conditions or situations. These included codes such as, 1:1 monitoring, conduct disorder, physical restraints, as well as social determinants of health codes like homelessness and food insecurity. We also considered procedure codes in billing data. Because no predefined list of high-intensity procedures was identified, three nurses, with a cumulative 32 years of bedside nursing experience and one with over four years of administrative leadership as both a surgical services manager and clinical quality program manager, reviewed and coded the 500 most frequently listed procedure codes occurring in CHARS. The class of procedure (e.g., minor diagnostic, major diagnostic, minor therapeutic, major therapeutic) along with the typical care following the procedure were considered.
As the legislature directed, the purpose of this study is to examine hospital staffing personnel, and not nursing staff alone. The consideration is for increasing intensity of care for any staff or team member including nurses. For example, 1:1 monitoring and physical restraints may increase the workload for other care team members but also include technical nursing care and monitoring.

Staffing Characteristics

The statistical model used to predict staffing thresholds does not reflect the current industry standards. It is critical that sufficient sample data be used to identify the function of all staffing characteristics. Lack of sufficient data and representation of the varying staffing models unique to each hospital and each unit in the hospital could lead to over-extrapolation of the model. Similar to the hospital characteristics, careful consideration of each staffing characteristic and its strength of association to the outcome should be evaluated for validity. The model currently outlined: $outcome_{h,t} \sim f(staffing_{h,t}; \theta) + hosp\_chars_{h,t} + patient\_chars_{h,t}$ (M3) fails to consider several factors that significantly impact hospital staffing models. These characteristics are critical and exclusion or insufficient sample size would render this model incomplete:

- Contract staff (traveler) to employed staff ratios;
- Care team variability, such as the availability of CNAs, techs, environmental services staff, and many others who constitute a complete patient care team; and
- The amount of direct patient care experience that each member of the care team has for the specific conditions of the patients being cared for.

Response: Although these characteristics are all logical, we found no existing data sources suitable to quantify them to the level of detail demanded here. While we agree that their inclusion, if such variables were available, would produce a more complete model, it is clear from our literature review that much of the current work has been useful with even less complete quantification of the care team. The vast majority of prior work has considered the nurse staffing only, and our work is one of the few contributions to go beyond nurses and consider other workers in the acute care staffing team.

Staffing Characteristics

Additionally, we find it completely inappropriate to use unverified nurse staffing complaint data as a proxy for hospital capacity. Nurse staffing complaints can be made by anyone, and the fact that a complaint was submitted does not mean the complaint was valid. The DOH evaluates complaints, investigates those that are within its jurisdiction, and determines if each complaint has merit. Nurse staffing complaints should not be used in the model at all, but if used, only complaints verified by the Department of Health as requiring corrective action should be considered, and not as a proxy for capacity. The report should also be clear that the complaints are only about nurse staffing, not hospital staffing as directed by the statutory language.

Response: Thank you for explaining your concerns with this data source. We did not use nurse staffing complaint data in our model.

Outcomes Evaluation

Based on the town hall presentation, the authors are only considering the following five patient outcomes in the analysis, two of which have very small sample sizes:

- In-hospital mortality (n=30,019)
- 30-day readmission
- Pressure ulcers (n=1,070)
- Patient falls causing severe injury or death (n=513)
- Medication errors (n=102)

Due to the low outcome to high number of predictor ratio, the study author should take caution in identifying potentially misleading associations. Again, our data analytics team recommends the study authors carefully evaluate which predictor is most representative of the outcomes they are trying to measure and test each association.

Response: We agree, some of the outcomes have low numbers. In response to this concern, the final analysis combined all adverse events, increasing sample size but limiting our ability to determine which adverse event was most affected.
We did not separately test the association of outcomes with each predictor, but rather used a single model specifically designed to test associations with all four staffing variables simultaneously. As described above, including a large number of additional control variables is not a problem for the model unless there is a high correlation with the four staffing variables, which was demonstrated not to be a problem in Figure 1. Additionally, our four staffing variables were specifically designed to be as uncorrelated as possible with each other so that the model would not have a problem simultaneously estimating their effects. Figure 2 shows that the highest R^2 value between any pair of staffing variables is only 5.5%.

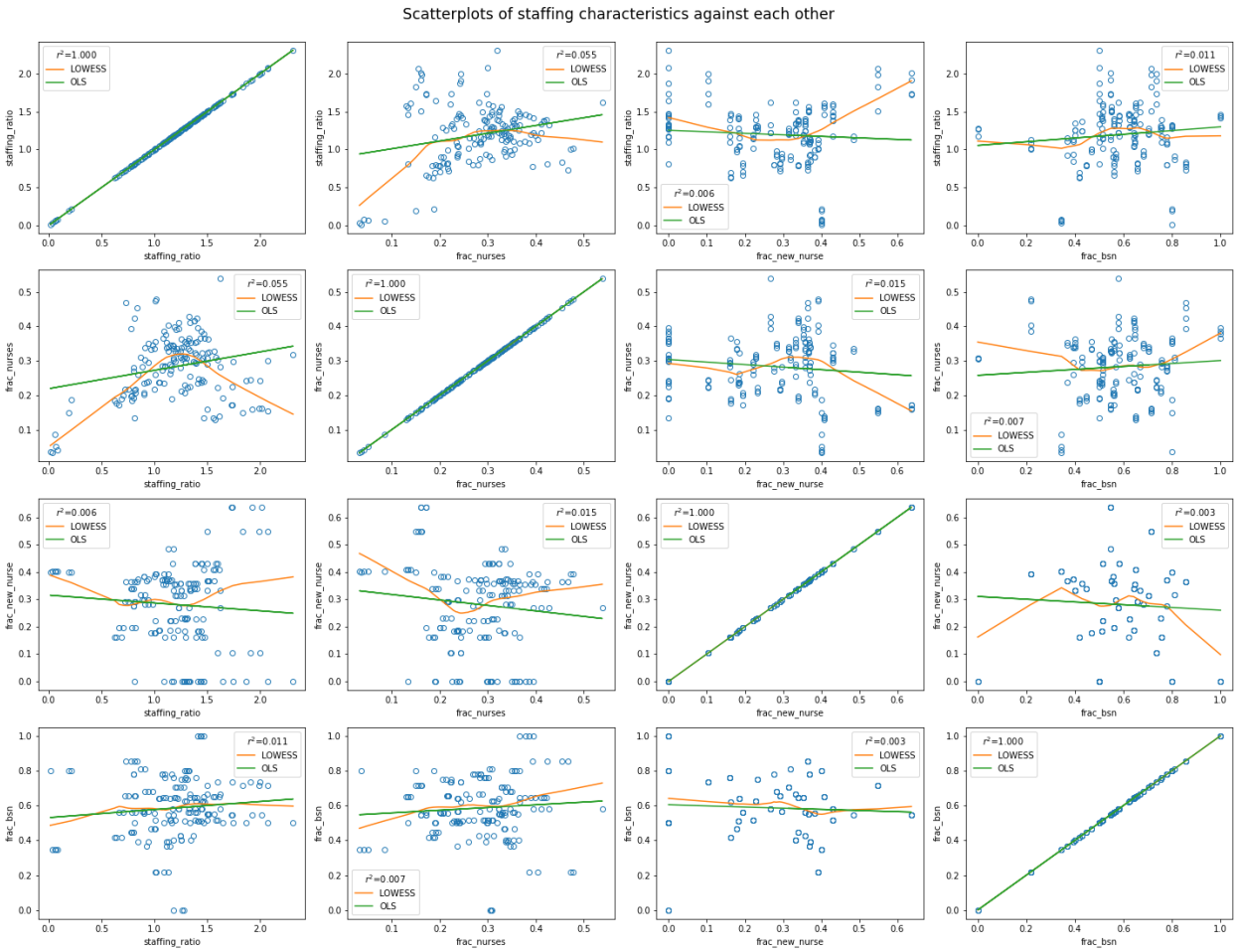


Figure 2: Each row and column represent one of the four staffing variables in our model. Each cell is a scatterplot with a LOWESS regression curve and an ordinary least squares (OLS) regression line plotted over the points, along with the R^2 value for the data points, showing that the variables are very weakly correlated.