Labor and Delivery Nurse Staffing: A Patient Safety Intervention

Team members:

Barbara L. Wilson, PhD, RN
Principal Investigator (PI)
Associate Professor
University of Utah College of Nursing
Barbara.wilson@nurs.utah.edu

Richard Butler, PhD
Consultant: Professor Emeritus, Department of Economics
Brigham Young University
Richard_butler@byu.edu

Kristi Nelson, MBA, RN
Data Manager: Women & Newborns Clinical Program
Intermountain Healthcare
Kristi.nelson@imail.org

Cempaka Martial, MStat
Senior Statistical Data Analyst
Women & Newborns Clinical Program
Intermountain Healthcare
Cempaka.martial@imail.org

Organization:
University of Utah
1471 East Federal Way
Salt Lake City, UT 84112-8930

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Federal Project Officer: Eileen Hogan (eileen.hogan@ahrq.hhs.gov)
Grant Specialist: Carol Kauffman (carol.kauffman@ahrq.hhs.gov)

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STRUCTURED ABSTRACT

Purpose: To determine if a relationship exists between labor and delivery (L&D) nurse staffing and adverse birth outcomes.

Scope: Numerous studies indicate a relationship between nurse staffing and adverse outcomes for medical/surgical patients, including pressure ulcers and patient falls, among others. Because adverse events are linked to staffing levels, they are often referred to as 'nurse sensitive'– a condition or state responsive to the action of the nurse. Despite studies on nurse-sensitive outcomes for medical/surgical patients, little has been published on nurse-sensitive outcomes for childbearing women and even less that assesses nurse staffing on adverse obstetrical (OB) events. It is not known to what extent (if any) L&D staffing influences newborn intensive care unit (NICU) admissions or unanticipated cesarean births in term low-risk first birth mothers with a single vertex fetus.

Methods: Retrospective model-testing designs (quadratic and piecewise) were used for a 1-year period with 11 Southwest hospitals. The treatment variable was hours of productive nursing time per delivery, which allowed us to distinguish optimal staffing patterns from ineffective staffing patterns.

Results: Although a simple linear regression of the likelihood of a C-section on nursing hours per delivery indicated no statistically distinguishable effect, our 'optimal staffing' model indicated that nurse staffing hours employed reduced cesarean births. The optimal staffing models did not appear to influence NICU admissions. However, there were significant differences between hospitals. In all specifications, we controlled for weeks' gestation, race, sex of the child, and mother's age.

Key words: NICU admissions; intrapartum nurse staffing; cesarean

PURPOSE

To help define and measure adverse hospital events, AHRQ developed Inpatient Quality Indicators (IQIs), which reflect hospital care including the utilization of procedures that have the potential for overuse, underuse, or misuse. IQI #33 is primary cesarean births, with lower rates representing better quality. AHRQ also developed Patient Safety Indicators (PSIs) to screen for problems that patients experience as a result of being in the healthcare delivery system, making them amenable to changes in processes or procedures. One PSI is Newborn Intensive Care Unit (NICU) admission or neonatal transfer in low-risk primiparous (first-birth) women, indicating that an NICU admission can be influenced by practices occurring in the hospital. Just as hospital-acquired pressure ulcers constitute an adverse hospital event and are sensitive to nurse staffing levels (nurse-sensitive outcome), an unintended cesarean birth or NICU admission in a low-risk term first-birth woman may also constitute outcomes that are sensitive to obstetrical nurse staffing

Using an established AHRQ PSI of NICU admissions and/or transfers and the AHRQ IQI of primary cesarean births, we examined the relationship between L&D nurse staffing and perinatal outcomes, including:

1. The influence of L&D nurse staffing on the likelihood of cesarean birth in term gestation ($\geq$37 weeks) low-risk primiparous women with a singleton fetus in a vertex (head-first) presentation.

2. The influence of L&D nurse staffing on the likelihood of NICU admissions or neonatal transfers (for those hospitals without an NICU) to term gestation ($\geq$37 weeks) low-risk primiparous women with a singleton fetus in vertex presentation.

SCOPE

Numerous studies have identified a relationship between nurse staffing levels and adverse outcomes for acute-care medical and surgical patients, including hospital-acquired pressure ulcers, pneumonia, patient falls, medication errors, and failure to rescue, among others. Because these unintended results reflect the structure, process, and outcomes of nursing care, they have been referred to as nurse-sensitive outcomes. Inadequate nurse staffing levels create risks and hazards that lead to increased medical errors, prolonged lengths of stay, and increased morbidity and mortality for certain patient populations. However, little is known about what constitutes ‘nurse-sensitive outcomes’ in obstetrical (OB) patients, and even less is known about the influence of nurse staffing on adverse OB events, if any.

In 2008-2009, the PI (Wilson) developed a staffing model for calculating intrapartum nursing hours, ultimately to determine safe levels of perinatal staffing, improving outcomes for the childbearing family (Wilson & Blegen, 2010). In 2011-2012, this staffing model was tested in a large-volume labor and delivery unit with over 8,000 annual births and shown to be an accurate predictor of nurse staffing needs (Simpson, 2015). The Wilson/Blegen staffing model was further validated by a gap analysis based on the staffing guidelines proposed by the Association of Women’s Health, Obstetrics, and Neonatal Nursing (AWHONN) (Simpson, 2015). Using this validated staffing model, this study determined whether L&D nurse staffing influenced nurse-sensitive perinatal outcomes, including cesarean births and NICU admissions, in low-risk, first-birth term gestation women with a vertex (head-first) singleton fetus.

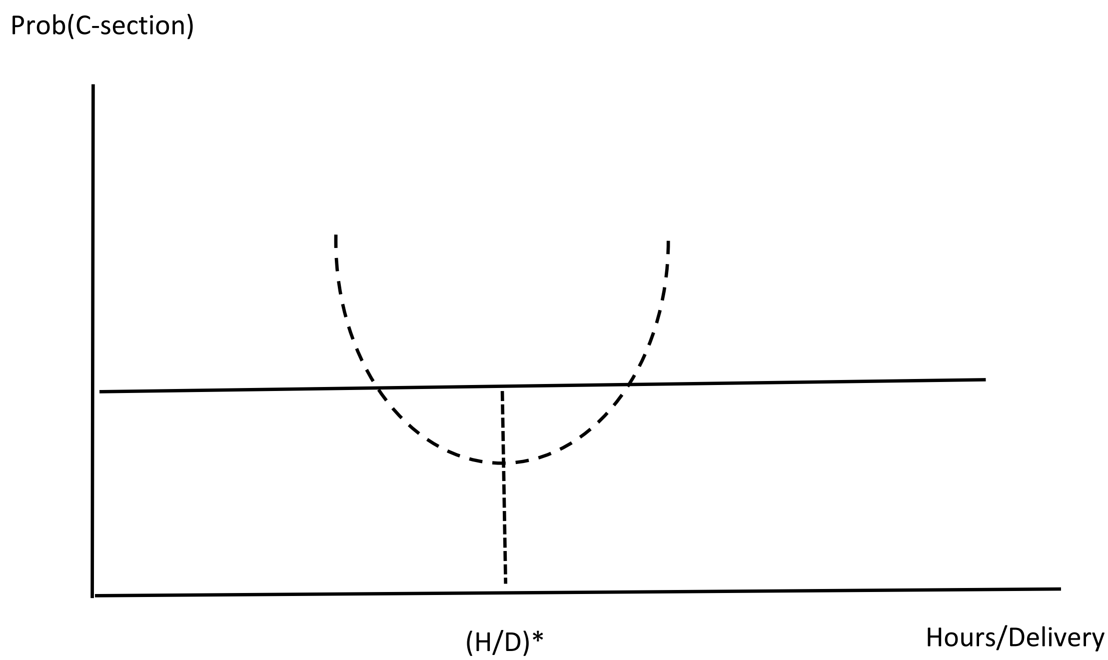
Two retrospective model-testing designs, quadratic and piecewise, were used with administrative data from 11 hospitals that are part of a large integrated healthcare system in the southwest for a 1-year period. Ultimately over 2,400 women met inclusion criteria. The treatment variable was hours of productive nursing time per delivery, which allowed us to distinguish optimal staffing patterns from ineffective staffing patterns. Nurse staffing (productive nursing hours) and patient care hours were examined for each hospital with analysis at three levels: (a) patient level; (b) by day (we examined productive nursing care hours and total L&D patient care hours by day, which were matched with maternal and newborn outcomes); and (c) hospital level.

METHODS

The importance of quantitative assessments for optimal nurse staffing protocols is just as true for the perinatal setting as it is in other fields. Though hospital systems frequently have the resources to test the efficacy of their protocols with inter-hospital and historical data, it is not always clear how that will, or should, be done. We used two simple, complimentary tests to help distinguish optimal nurse staffing protocols from ineffective protocols and applied them to a large sample of births within a large integrated hospital system, as previously described.

Our 'optimality test' can be implemented with most statistical software, as it is based on simple linear regression specifications. It was applied to a large sample of low-risk, term births for which gestation was restricted to at least 37 weeks with respect to the likelihood of having a C-section. The methodological issue here is distinguishing optimal nurse staffing protocols from ineffective protocols (Figure 1).

Figure 1: Likelihood of a C-section and L&D Nursing Hours



Suppose the following regression is used to examine the effect of hours of nursing care per delivery on the likelihood of a C-section:

1) $$Prob(C-section)_i = \beta_0 + \beta_1 (\frac{Hours}{Delivery})_i + \beta_3 (control\ variables)_i + \varepsilon_i$$

For a sample of births scattered round the point (H/D)* in Figure 1, the estimated coefficient for β_1 would be zero for *either* of the C-section rate-(hours/delivery) curves given in Figure 1. For the flat curve (the straight line), the $\beta_1 = 0$ response would reflect a situation where the probability of a C-section is independent of the number of nursing hours per delivery. In the flat line case, nursing hours don't matter for C-section outcomes, at least for the sample of observed outcomes. However, for the U-shaped, dashed-line response, the sample hospital has employed the optimal level of hours, and(H/D)* represents the level of nursing staffing that minimizes the likelihood of a C-section. In this case, the $\beta_1 = 0$ response reflects an optimal use of nursing hours, a practice that yields a best implicit or explicit "hours"-protocol, given other capital and regulatory constraints facing the hospital. For the U-shaped response curve, the estimated hours-response β_1 in equation 1 would again be estimated to be zero because the negative levels to the left of the sample mean, (H/D)*, just balance out the positive values o to the right of it.

For our sample of 11 hospitals with 1 year of birthing information for low-risk women at 37 or more weeks of gestation, we demonstrated below that our estimated hours effect on the likelihood of a C-sections is, in fact, zero ($\hat{}_{1} = 0$). To distinguish between whether it is zero because nursing hours don't have any effect on C-sections or whether it is because the samples are employing optimal nurse staffing protocols, we supplement the specification of equation (1) as follows, employing the first of two regression specification checks (this quadratic regression specification, and then the piecewise regression):

2) $$Prob(C - section)_i = \beta_0 + \beta_1 \left(\frac{Hours}{Delivery}\right)_i + \beta_2 \left(\frac{Hours}{Delivery}\right)_i^2 + \beta_3(control\ variables)_i + \varepsilon_i$$

The squared hours/delivery term, with coefficient β_2, picks up the curvature of the hours response. If the squared term is zero, then our C-section response curve is flat, and hours has no effect on the likelihood of a C-section. But if the optimal protocol is being followed, and we are at the minimum point on the U-shaped curve pictured in Figure 1, then the coefficient associated with the squared-term will be positive. (Note the unambiguous sign on the squared term for minimizing optimal level of hours per delivery here—the coefficient on the square term must be positive in the optimal protocol case—as C-sections for healthy mothers is an adverse outcome on average and needs to be minimized. A negative coefficient estimated for the squared-term, on the other hand, indicates operating at the "worst" hours/delivery configuration, instead of the "best").

Though equation (2) approximately identifies hours that minimizes C-section risks, it imposes a constraint that the response is symmetric on either side of the estimated hours protocol that minimizes risk (that the U-shape is not skewed to the right or to the left). A piecewise regression specification allows us to test the symmetry assumption, given the C-section minimizing hours (suppose that is 31 hours, so that $\frac{H^*}{D} = 31$), by running the following piecewise regression:

3) $$Prob(C - section)_i = \gamma_0 + \gamma_1 \left(\frac{H}{D}\right)_i + \gamma_2 \left(\frac{H}{D} - 31\right)_i * Dum_i + \gamma_3\,(control\ variables)_i + \varepsilon_i$$

where Dum_i is a binary, dummy, variable equal to one for $(H/D)_i$ values greater than 30, and equals zero for $(H/D)_i$ values less than 31. In this equation, '31' is the "knot" value than connects the two line segments, with the left hand segment slope equal to γ_1 and the slope of the right hand segment equal to $\gamma_1 + \gamma_2$. When the response is symmetric on either side of the minimum, as equation (2) imposes, and we are at a minimum, then $\gamma_1 < 0$ and $-\gamma_1 = \gamma_1 + \gamma_2$, or $-2 * \gamma_1 = \gamma_2$ (at least approximately). If the response is asymmetric in the sense that C-sections decline until the optimal level, and thereafter are flat (there are no diseconomies of scale where the right hand segment rises), then $\gamma_1 < 0$ and $\gamma_1 + \gamma_2 = 0$.

Under the *Sample and Descriptive Statistics*, we address sample statistical summaries for the data employed in our analysis. In *Nursing Hours per delivery and C-section Outcomes*, model testing for likelihood of cesarean births is presented. We also examine our optimal check with respect to hours using induction, augmentation, and NICU hours outcomes to illustrate our methodology for other labor/delivery outcomes. We then address some alternative tests and results.

Sample and Descriptive Statistics

To examine the effect of nursing hours (per delivery) on C-section likelihood, an 11-hospital sample was drawn from a large integrated healthcare system for low-risk term gestation deliveries occurring between October 1, 2016, and September 30, 2017. Births were restricted to those with 37 to 42 weeks of gestation, with no known indicators of high-risk birth outcomes (see Table 1).

Given our sample restrictions, the average sample gestation period is just over 39 weeks (39.1675); about half the babies are male (.5089), and the average age of mothers in our sample is just under 25 years of age (24.98). We anticipate mother's age to be an important predictor of the likelihood of having a C-section, as it has been shown to be a significant determinant by Wilson (2007) and Sebastiao et al. (2016).

The relatively high proportion of White mothers and small proportion of Black mothers reflects the general population served by our sample of hospitals. In our sample, for each delivery for each facility each day, there are about 20 hours of nursing services provided (19 hours of regular nursing hours, 20 hours of total nursing services, including overtime hours).

The outcomes are also fairly typical of those observed in nursing practices for full gestation births. About 6 percent of the births are C-sections (.05929). With respect to other outcomes analyzed in a subsequent section, 56 percent of births receive augmentation, and 9.6 percent are induced. The average number of NICU hours per birth is 4.4 (4.38517) per birth, but these are highly skewed—less than 3 percent of the births have any NICU hours at all, also indicative of the low-risk population.

Nursing Hours Per Delivery and C-section Outcomes

For those mothers with term gestational periods, the effects of nursing hours on the likelihood of a C-section delivery are estimated with the linear probability model given in equation 1 (no distinction between the “no effects” model and “optimal effects” model) and equations 2 (distinguishing the models with the additional squared hours term in the linear probability model) and 3 (an alternative check on the quadratic check of equation 2 using piecewise regression). The control variables in the analysis include those discussed in section II as well as fixed effects for individual facilities (that is, each hospital has a separate dummy variable accounting for all time-invariant differences between facilities). Again, our control variables include age and race of the mother, sex of the baby, and gestation in weeks.

No Hours Effects ***Hypothesis I****: Nursing hours per delivery has no effect on the likelihood of a C-section.* Given our sample restriction to those with normal gestation periods at time of birth, we anticipate that the estimated effects may be relatively small in any event, but under a strictly “no effects” outcome, the estimated coefficient for nursing hours per delivery (“H/D”) will be zero in equation 1, and, the squared H/D term in equation 2 will be zero as well.

“Optimal Protocol” in place for Hours Effects ***Hypothesis II****: If efficient nurse staffing hours protocols are in place, and the C-section safety function is convex as pictured in Figure 1 (or convex with declining gains from additional hours), then at the optimal hours point the estimated coefficient for nursing hours per delivery (“H/D”) will be zero in equation 1, but the squared H/D term in equation 2 will be positive, and the statistical significance (t-statistics in our results below) of these estimated parameters (in equation 2) will increase considerably over the H/D estimated effect from equation 1.* For approximately unique nursing hours per delivery, the piecewise specification should reveal $\gamma_1 + \gamma_2 > 0$, with diseconomies of scale (continuing to add more nurses in facilities of fixed size leads to worse outcomes rather than better outcomes) rather than $\gamma_1 + \gamma_2 = 0$, to indicate a range of good nursing outcomes (say, (H/D)* ≥ 31) rather than a single optimal level of good outcomes (say, just (H/D)* = 31).

Hours Effects ***Hypothesis III****: If the “optimal staffing hours protocol” is the result of general hours-protocols (rather than facility-specific hours policies), then within the same hospital size/class groups, there should be little difference in C-section outcomes as reflected in the facility fixed effects.* That is, the fixed estimators included in the analysis should be relatively similar and, hence, statistically insignificant (at least within the same size/type of hospitals).

Sociodemographic Determinants

Wilson (2007) found that the independent effect of being a primiparous woman with an elective induction significantly increased the probability of a cesarean birth (p<.01). Age was also a statistically significant predictor: after age 35, the likelihood of a cesarean birth increases by about 5% for each additional year, placing older first-birth women being electively induced in the highest risk category for a subsequent cesarean delivery. As anticipated, longer gestation within our sample period (again, when gestation is restricted from 37 to 42 weeks) is associated with higher likelihoods of a C-section or an induction (Table 2).

One more week of gestation is associated with 1.1 percentage point increase in the likelihood of a C-section (from a percentage point base of 5.9 percent). Hence, an additional 5 weeks of gestation (5 times 1.1 = 5.5 percentage points) for our sample almost doubles the likelihood of a C-section. The likelihood of a C-section also significantly increases with mother's age—going from a 20-year-old to a 40-year-old increases the likelihood of a C-section by 1.2 percentage points (20 additional years*.006=.012), or about 20 percent ((chance in likelihood)/ level=1.2/5.9=.20). Blacks are roughly twice as likely to have a C-section as the baseline groups (mainly Asians), and Whites are more likely than Asians, though the effect is not as large.

Hours Effects on C-section Procedures

In the no-distinction model (Table 2), it appears as if hours of nursing effort per delivery has no impact on C-section outcomes, because the coefficient for hours per delivery (H/D) is -.0002 (not different from zero) and statistically insignificantly different from zero. If nurse staffing hours really have no impact on C-sections and we could extrapolate outside of our sample range, hospitals could significantly cut back nursing hours without increasing the risk of more C-sections.

However, the results for the optimal-protocol detection model for the equation quadratic specification indicate a rather different story. The coefficient on the (H/D)-squared variable is positive (as required by minimization of C-sections), and the t-statistics for the coefficients for the (H/D) and (H/D)-squared variables generally more than double the (H/D) coefficient in the "No-Distinction Model" results in the left hand column. This is true whether we measure hours of work as just regular hours or include overtime hours in the analysis as well. When we control for the intrinsic heteroscedasticity of the linear probability model by employing weighted least squares (Table 6), the effects are even more dramatic in terms of statistical significance. The piecewise regression results in Table 7 indicate that the symmetry of the hours effects cannot be rejected (F-statistic values of .02 and .00 for regular hours, and total hours, respectively)—for this sample, the optimal hours range is around 30 hours per delivery, with additional hours per delivery not contributing to better outcomes (lower C-section rates).

Hence, we find support for hypothesis II over hypothesis I. This hospital has established, or evolved, hours protocol that appear to be optimal in the sense of minimizing C-sections. Without allowing for the nonlinearity of the hours impact, incorrect inferences about hours protocol would have been drawn based on an equation (1) analysis alone.

Moreover, we find that, for all hospital groups, hypothesis III is also supported—C-section outcomes are sufficiently described by sociodemographic variables and nursing hours, although there is no indication of differences in inter-facility practices. Nurse staffing hours protocols by themselves sufficiently minimize C-sections; there are no inter-facility differences that make a statistically significant difference in outcomes (that is, the fixed effects for the facilities are statistically insignificant).

Checking on Other L&D Outcomes: Induction, Augmentation, and NICU Hours

As a check for the robustness of our proposed method, we also re-estimate equations 1 and 2 for other procedures for which optimal nursing hours are likely to be less important and for which the restrictions in equation 2 are less likely to hold (in particular, an increase in statistical significance when adding the squared hours coefficient, and a positive coefficient on the squared-hours term). This is confirmed in the results for augmentation, inductions, and NICU hours. There appear to be no optimal staffing hours protocols specific to our sample of normal gestations for these conditions, unlike the C-section results. The fixed effects for these specifications (in Tables 3 through 5) are generally quite significant, strongly suggesting that inter-facility protocols matter a great deal for these outcomes in which there do not appear to be optimal staffing hours protocols.

Other Robustness Checks

We also made a number of robustness checks to our specification, to help ensure our analysis is not driven by important but omitted factors. Because not all mothers deliver on the same day they are admitted into a hospital, yesterday's nursing care may affect today's outcomes. However, on average, we expect that prior's day care will be relatively small.

Hours Effects ***Hypothesis IV****: though yesterday's nursing hours can affect today's outcomes, on average the effect of yesterday's hours will be relatively small and highly collinear with the impact of today's hours (hence, the coefficients small in their magnitude).* With respect to the following specification:

4) $$(Y)_{i,j,t} = \gamma_{0,j} + \theta \qquad {}_{j,t} + \alpha \qquad {}_{j,t-1} + \beta + \mu_{i,t}$$

our fourth hypothesis is that $|\theta_{reg}| > |\alpha_{reg}|$. This hypothesis is tested, with the results reported in Table 8, by including yesterday's hours in our models. As seen there, including the effects of lagged hours has no impact on the results reported above; in that sense, hypothesis IV is supported.

Instead of fitting the ratio of nursing hours per delivery, we also ran specifications that separated nursing hours from number of deliveries (rather than a ratio of the two). This specification yielded the same small response in the expected outcomes, as did the ratio results as reported in Tables 2 through 5. (The SAS output is available upon request.)

RESULTS

As regulatory and public policy considerations and market pressures place increasing attention on best hospital practices, quantitative studies of optimal protocols flourish. Our research offers a precautionary note to such studies: often, simple linear effects of the treatment effect (here, hours of nursing care) on outcomes (the likelihood of a C-section) are not always sufficient to draw the appropriate conclusions. Had we stopped with the specification in equation (1), we would not have realized that nursing staffing hours protocols employed in our sample were indeed optimal in the sense of minimizing C-sections for our sample of low-risk, term-gestation births.

We find that the simplest model of the likelihood of C-sections on nursing hours erroneously indicates that nursing hours per delivery has no effect on C-sections. This conclusion is easily checked, and modified, with our optimal protocol models that a) estimate a quadratic hours effect (adds a squared-hours term to the specification) to test for an optimal hours for treatment effect and provide an estimate of the optimum that minimizes C-section risk and b) piecewise regression in turn to check the symmetry assumption of the quadratic model around the level of the optimal. Per modeling prediction, the minimization of C-sections by employing optimal nursing care yields a positive coefficient squared hours-term that is statistically significant. The piecewise regression confirms that the response is roughly symmetric around this optimum. For C-section outcomes, conditional on this protocol and other control factors in our models, there were no significant inter-facility differences in outcomes. Our set of variables employed here are not sufficiently rich to tell whether these optimal protocols have implicitly evolved over time without explicit formulation or have been more formally developed among our sample of hospitals by prior quantitative research and explicit development.

For other procedures used as a check on this methodology—augmentation, inductions, and NICU hours—although there was no optimal staffing hours protocol, there were quantitatively large and statistically significant differences in inter-facility protocols. Future research is needed to examine the tradeoff between implicit or explicit hours protocols for L&D nursing and hospital-specific practices unrelated to nursing hours protocols.

Studies involving nurse staffing have demonstrated that, when the workload of nurses is high in acute-care medical/surgical units, the ability of the nurse to adequately monitor and assess his or her patients is impaired, leading to a greater likelihood of adverse patient outcomes (Aiken, Clarke, & Sloane, 2002; Kane, Shamliyan, Mueller, Duval, & Wilt, 2007; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002; Needleman et al., 2011; Twigg, Duffield, Thompson, & Rapley, 2010). However, the ability to measure the influence of intrapartum nurse staffing on adverse birth outcomes, such as the mode of birth for low-risk women, has been missing until recent years.

Wilson & Blegen (2010) proposed an L&D staffing model that provided standardized measurements of nursing productivity, skill mix, and workload intensity based on Donabedian's structure, process, and outcomes model (Donabedian, 1980) using proxy variables. It since has been determined that this model adequately captures the complexity and intensity of nursing care needs in the intrapartum setting (Bingham & Ruhl, 2015; Simpson, 2015; Torbet, Mulkeen, Stringer, & Fitzpatrick, 2015) and was validated by a staffing gap analysis based on the AWHONN (2010) staffing guidelines (Simpson, 2015). Although the present study further validates the Wilson/ Blegen premise that intrapartum nurse staffing influences unanticipated cesarean births in low-risk women, it is clear that additional research is needed on the relationship between inadequate perinatal staffing and adverse outcomes for the childbearing family. Last, it also is clear that, as quantitative nursing models develop, it is important to avoid mistaken conclusions about best nursing practices based on incomplete specifications.

Table 1: Descriptive Statistics

	Means	Std Dev
C-section	.05929	.23622
NICU hours	4.38517	38.58706
augmentation	0.56098	0.49637
induction	0.09630	0.29506
(Regular hours)/delivery, or	19.0299	15.3044
(Total hours)/delivery	20.1728	15.2367
gestation	39.1675	0.8511
male	0.5089	0.5000
mom's age	24.9832	4.3739
white	0.8937	0.3082
black	0.0083	0.0910

Notes: Sample size for the Oct 2016-Sept 2017 sample employed here was 2513 (but varied slightly depending on the specification)

Table 2: Probability of C-section and Nursing Hours per Delivery

	No Distinction Model				Optimal Protocol Detection Model			
Year	Regular Hours		Total Hours		Regular Hours		Total Hours	
Variables	Coeff	t-stat	Coeff	t-stat	coeff	t-stat	Coeff	t-stat
Intercept	-0.575	-2.64	-0.575	-2.64	-0.559	-2.56	-0.560	-2.57
Hrs/dlvry	-.0002	-0.70	-.0002	-0.69	-0.001	-1.80	-0.001	-1.68
(H/D)-sq					.00002	1.67	.00001	1.54
gestation	0.011	2.09	0.011	2.09	0.011	2.05	0.011	2.06
male	0.018	1.93	0.018	1.93	0.017	1.91	0.017	1.91
mom age	0.006	5.54	0.006	5.54	0.006	5.50	0.006	5.51
white	0.019	1.24	0.019	1.24	0.019	1.25	0.019	1.25
black	0.064	1.23	0.064	1.23	0.063	1.21	0.063	1.21
R-square	.0214		.0214		.0225		.0223	
N-sample	2419		2419		2419		2419	
optimal hours	NA		NA		31.2		32.2	
overall_FE	0.74		0.74		0.78		0.77	
lrg_same	1.53		1.52		1.76		1.71	
med_same	0.62		0.62		0.63		0.62	
smll_same	0.14		0.13		0.12		0.12	

Note: The data pertain to the third quarter of 2016 and quarters one, two, and three of 2017 (October 1, 2016-September 30, 2017). "Optimal hours," fifth row up from the bottom, is the implied optimal number of hours of nursing care per delivery for minimizing C-section probability. All specifications also included dummy variables for each hospital, controlling for all hospital-specific, time-invariant factors (though those coefficients are not reported here).
*=joint significance at 10 percent level or better for F-statistics in the last four rows.

Table 3: Probability of Augmentation and Nursing Hours per Delivery

	No Distinction Model				Optimal Protocol Detection Model			
Year	Regular Hours		Total Hours		Regular Hours		Total Hours	
Variables	Coeff	t-stat	Coeff	t-stat	coeff	t-stat	Coeff	t-stat
Intercept	0.152	0.33	0.152	0.33	0.135	0.29	0.136	0.30
Hrs/dlvry	.0001	0.22	.0001	0.26	0.001	0.84	0.001	0.75
(H/D)-sq					-.00002	-0.84	-.00002	-0.72
gestation	0.009	0.81	0.009	0.81	0.009	0.82	0.009	0.82
male	0.031	1.57	0.031	1.56	0.031	1.58	0.031	1.57
mom age	-0.003	-1.57	-0.003	-1.57	-0.003	-1.55	-0.003	-1.55
white	0.021	0.63	0.021	0.63	0.020	0.62	0.020	0.62
black	-0.176	-1.59	-0.176	-1.59	-0.175	-1.58	-0.175	-1.58
R-square	.0450		.0451		.0453		.0453	
N-sample	2419		2419		2419		2419	
ovrall_FE	9.37***		9.37***		9.40***		9.40***	
lrg_same	9.34***		9.33***		9.30***		9.30***	
med_same	13.86***		13.87***		13.85***		13.83***	
smll_same	7.73***		7.74***		7.81***		7.80***	

Note: The data pertain to the third quarter of 2016 and quarters one, two, and three of 2017 (October 1, 2016-September 30, 2017). All specifications also included dummy variables for each hospital, controlling for all hospital-specific, time-invariant factors (though those coefficients are not reported here). For the last four rows of joint tests: *=joint significance at 10 percent level for F-statistics; **=joint significance at 5 percent level for F-statistics; ***=joint significance at 1 percent level for F-statistics.

Table 4: Probability of Induction and Nursing Hours per Delivery

	No Distinction Model				Optimal Protocol Detection Model			
Year	Regular Hours		Total Hours		Regular Hours		Total Hours	
Variables	Coeff	t-stat	Coeff	t-stat	coeff	t-stat	Coeff	t-stat
Intercept	-1.947	-7.12	-1.948	-7.12	-1.941	-7.09	-1.942	-7.09
Hrs/dlvry	.0005	1.17	.0005	1.22	.0001	0.15	.0002	0.24
(H/D)-sq					.00001	0.48	.00001	0.41
gestation	0.050	7.31	0.050	7.31	0.050	7.30	0.050	7.30
male	-.0002	-0.02	-.0003	-0.02	-.0003	-0.03	-.0003	-0.03
mom age	.0001	0.06	.0001	0.06	.0001	0.04	.0001	0.05
white	0.008	0.44	0.008	0.44	0.008	0.44	0.008	0.44
black	-0.045	-0.69	-0.045	-0.68	-0.045	-0.69	-0.045	-0.69
R-square	.0459		.0460		.0460		.0460	
N-sample	2419		2419		2419		2419	
ovrall_FE	6.27***		6.28***		6.29***		6.29***	
lrg_same	12.56***		12.62***		12.65***		12.65***	
med_same	8.98***		9.00***		8.98***		8.98***	
smll_same	2.88***		2.86***		2.91***		2.91***	

Note: The data pertain to the third quarter of 2016 and quarters one, two, and three of 2017 (October 1, 2016-September 30, 2017). All specifications also included dummy variables for each hospital, controlling for all hospital-specific, time-invariant factors (though those coefficients are not reported here). For the last four rows of joint tests: *=joint significance at 10 percent level for F-statistics; **=joint significance at 5 percent level for F-statistics; ***=joint significance at 1 percent level for F-statistics.

Table 5: NICU Hours and Nursing Hours per Delivery

	No Distinction Model				Optimal Protocol Detection Model			
Year	Regular Hours		Total Hours		Regular Hours		Total Hours	
Variables	Coeff	t-stat	Coeff	t-stat	coeff	t-stat	Coeff	t-stat
Intercept	-12.26	-0.32	-12.28	-0.32	-11.15	-0.29	-11.30	-0.30
Hrs/dlvry	-0.01	-0.16	-0.01	-0.10	-0.07	-0.62	-0.05	-0.52
(H/D)-sq					0.001	0.62	0.001	0.53
gestation	0.51	0.53	0.51	0.53	0.50	0.52	0.50	0.52
male	2.00	1.23	2.00	1.23	1.99	1.22	1.99	1.22
mom age	0.09	0.48	0.09	0.48	0.08	0.47	0.09	0.47
white	-3.03	-1.10	-3.04	-1.10	-3.02	-1.10	-3.03	-1.10
black	-8.42	-0.94	-8.41	-0.94	-8.49	-0.95	-8.48	-0.95
R-square	.0128		.0128		.0129		.0129	
N-sample	2295		2295		2295		2295	
ovrall_FE	2.51***		2.51***		2.47***		2.47***	
lrg_same	2.94*		2.93*		2.68*		2.86*	
med_same	.03		.03		.03		.03	
smll_same	.02		.02		.02		.02	

Note: The data pertain to the third quarter of 2016 and quarters one, two, and three of 2017 (October 1, 2016-September 30, 2017). All specifications also included dummy variables each hospital, controlling for all hospital-specific, time-invariant factors (though those coefficients are not reported here – available upon request).
For the last four rows of joint tests: *=joint significance at 10 percent level for F-statistics; **=joint significance at 5 percent level for F-statistics; ***=joint significance at 1 percent level for F-statistics.

Table 6: Nursing Hours per Delivery—Weighted Least Squares Models for Respective Outcomes Optimal Detection Model Estimates

	Prob(C-section)				Prob(Augmentation)				Prob(Induction)			
Year	Regular Hours		Total Hours		Regular Hours		Total Hours		Regular Hours		Total Hours	
Variables	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat		t-stat	Coeff	t-stat
Intercept	-0.432	-3.65	-0.431	-3.65	0.177	0.39	0.179	0.39	-0.654	-3.20	-0.653	-3.19
H/D	-0.001	-3.17	-0.001	-3.19	0.001	0.76	0.001	0.69	-.0006	-0.99	-.0006	-0.88
H/D-sq	.0000	2.59	.0000	2.61	-.0000	-0.77	-.0000	-0.65	.0000	0.24	.0000	0.13
gestation	0.009	3.20	0.009	3.20	0.008	0.72	0.008	0.72	0.018	3.54	0.018	3.53
male	0.012	2.40	0.012	2.39	0.032	1.67	0.032	1.66	-0.007	-0.99	-0.007	-0.98
mom age	0.003	4.34	0.003	4.32	-0.003	-1.51	-0.003	-1.52	-0.001	-2.25	-0.001	-2.25
white	0.026	4.83	0.025	4.81	0.025	0.74	0.025	0.74	0.039	3.55	0.039	3.55
black	0.062	0.91	0.062	0.91	-0.156	-1.48	-0.156	-1.48	0.001	0.03	0.001	0.02
R-square	.0463		.0464		.0498		.0497		.0373		.0373	
N-sample	2419		2419		2419		2419		2419		2419	
opt.hours	30.0		30.5		NA		NA		NA		NA	

Note: The data pertain to the third quarter of 2016 and quarter one and quarter 2 of 2017 (Oct, 2016-June 2017). The weighted least squares was assumed to be proportional to the estimated inverse of the product p*(1-p) (probability of the respective outcome times one minus that probability), as commonly used in the literature to account for potential heteroscedasticity in linear probability models.

Table 7: Nursing Hours per Delivery--WLS Models of the Probability of the Respective L&D Practice
Piece-wise Regression Detection Models

	Prob(C-section)				Prob(Augmentation)				Prob(Induction)			
Year	Regular Hours		Total Hours		Regular Hours		Total Hours		Regular Hours		Total Hours	
Variables	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat		t-stat	Coeff	t-stat
Intercept	-0.739	-3.85	-0.482	-3.95	0.185	0.40	0.189	0.41	-0.644	-3.20	-0.619	-3.10
hrs/dlvry	-0.008	-19.4	-0.001	-4.81	.0004	0.44	.0003	0.36	-.0003	-0.85	-.0001	-0.44
piecewise	0.011	9.62	0.002	3.05	-.0009	-0.44	-.0006	-0.27	.0006	-0.60	-.0007	-0.69
gestation	0.028	5.71	0.011	3.77	0.008	0.71	0.008	0.71	0.018	3.51	0.017	3.39
male	-0.011	-1.22	0.011	1.93	0.032	1.67	0.032	1.66	-0.006	-0.89	-0.004	-0.68
mom age	-0.011	-8.96	0.002	2.93	-0.003	-1.53	-0.003	-1.53	-0.001	-2.25	-0.001	-2.23
white	0.100	10.15	0.029	4.64	0.024	0.73	0.024	0.73	0.037	3.45	0.036	3.32
black	0.076	0.68	0.064	0.88	-0.157	-1.50	-0.157	-1.50	.0001	0.00	-.002	-0.06

Note: The coefficient on the piecewise variable indicates the shift in slope on the respective probability when nursing hours per delivery equals or exceeds 31 hours. Weighted Least Squares passed on the variance constructed from the predicted value of the dependent variable (the linear probability model is necessarily heteroscedastic). Hence, in the far two left hand columns, the implied C-section probability falls by X for each additional hour of nursing care per deliver up to 31 hours, and then the probability per nursing hours jumps to (.003= -.008 +.011) for hours worked after 31 hours per care. Note that, in this model,we cannot reject symmetry of the response for C-section hours response, providing some validation for the equation 2 specification.

Table 7 (continued): Nursing Hours per Delivery--OLS Models of NICU hours

	NICU hours			
Year	Regular Hours		Total Hours	
Variables	Coeff	t-stat	Coeff	t-stat
Intercept	-11.231	-0.30	-11.176	-0.29
Hrs/dlvry	-0.038	-0.51	-0.036	-0.49
piecewise	0.102	0.59	0.105	0.61
gestation	0.499	0.52	0.497	0.52
male	1.993	1.22	1.985	1.21
mom age	0.091	0.47	0.091	0.47
white	-3.002	-1.09	-3.008	-1.09
black	-8.429	-0.94	-8.437	-0.95
N-sample	2340		2295	

The coefficient on the piecewise variable indicates the shift in slope on the respective probability when nursing hours per delivery equals or exceeds 31 hours.

Table 8: Nursing Hours per Delivery--OLS Models of the Probability of the Respective L&D Practice
No Detection Models with Lagged values of H/D added to the model

	Prob(C-section)				Prob(Augmentation)				Prob(Induction)			
Year	Regular Hours		Total Hours		Regular Hours		Total Hours		Regular Hours		Total Hours	
Variables	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat		t-stat	Coeff	t-stat
Intercept	-0.597	-2.94	-0.560	-2.75	0.354	0.78	0.215	0.47	-2.006	-7.32	-1.964	-7.04
hrs/dlvry	-.0003	-0.89	-.0002	-0.61	-.0000	-0.05	.0001	0.17	.00034	0.78	.0005	1.13
lag(hrs/d)	-.0002	-0.52	-.0000	-0.04	.0007	1.19	.0008	1.30	.00001	0.03	.0001	0.21
gestation	0.012	2.44	0.011	2.21	0.004	0.43	0.007	0.67	0.052	7.63	0.051	7.33
male	0.020	2.16	0.020	2.16	0.024	1.23	0.029	1.49	-.0002	-0.01	.0000	0.00
mom age	0.005	4.66	0.005	4.54	-0.004	-1.90	-0.003	-1.61	.00032	0.24	.0000	0.03
white	0.022	1.82	0.019	1.51	0.031	0.91	0.024	0.70	0.011	0.59	0.008	0.43
black	0.065	1.03	0.066	1.03	-0.175	-1.60	-0.175	-1.60	-0.046	-0.94	-0.045	-0.91
R-square	.0220		.0210		.0395		.0413		.0443		.0453	
N-sample	2419		2385		2419		2385		2419		2385	

Note: The data pertain to the third quarter of 2016 and quarter one and quarter 2 of 2017 (Oct, 2016-June 2017), after losing observations due to the lag structure of the model and a few for those employing only the steadily employed (nurses with at least 60 hours of work in either the third or fourth quarter).

Table 8 (continued): Nursing Hours per Delivery--OLS Models of NICU hours

	NICU hours			
Year	Regular Hours		Total Hours	
Variables	Coeff	t-stat	Coeff	t-stat
Intercept	-14.880	-0.28	-13.824	-0.25
Hrs/dlvry	0.003	0.06	-0.001	-0.04
lg(hrs/d)	-0.015	-0.19	-0.023	-0.28
gestation	0.561	0.39	0.543	0.37
male	1.938	1.31	2.004	1.31
mom age	0.104	0.36	0.111	0.37
white	-3.681	-0.98	-3.175	-0.83
black	-8.610	-2.47	-8.445	-2.42
R-square	.0120		.0124	
N-sample	2340		2261	

Note: The data pertain to the third quarter of 2016 and quarter one and quarter 2 of 2017 (Oct, 2016-June 2017), after losing observations due to the lag structure of the model and a few for those employing only the steadily employed (nurses with at least 60 hours of work in either the third or fourth quarter). All specifications employed robust standard errors (reflected in the t-statistics).

LIST OF PUBLICATIONS AND PRODUCTS

No publications to date – one submitted and currently under review in the *Journal of Nursing Scholarship* (JNS)
Title: *Identifying Optimal Labor and Delivery Nurse Staffing: The Case of Cesarean Births and Nursing Hours*.
Authors: Wilson, B. L., Nelson, K., Martial, C., & Butler, R. J. (in review).

No patents and no additional products.

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