# Association Between Labor and Delivery Unit Census and Delays in Patient Management: Findings from a Computer Simulation Module

Rose L. Molina, MD, MPH[1,2]

Matthew Gombolay, PhD[3]

Jennifer Jonas, BSE, BA[4]

Anna M. Modest, MPH[1,2]

Julie Shah, PhD[5]

Toni Golen, MD[1,2]

Neel Shah, MD, MPP[1,2]

[1]Department of Obstetrics and Gynecology, Beth Israel Deaconess Medical Center, Boston, MA

[2]Harvard Medical School, Boston, MA

[3]School of Interactive Computing, Georgia Institute of Technology, Atlanta, GA

[4]Albert Einstein College of Medicine, New York, NY

[5]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, MA

**Corresponding author**:

Neel Shah, MD, MPP

330 Brookline Ave., Kirstein 3

Boston, MA 02215

617 667-2932

ntshah@bidmc.harvard.edu

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**Short Title**: Labor and Delivery Census and Patient Delays

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**Précis**

Using a computer simulation module, we demonstrate an association between increasing census on Labor and Delivery units and delays in patient management.

**Abstract**

Objective:

To demonstrate the association between increases in labor and delivery (L&D) unit census and delays in patient care decisions using a computer simulation module.

Methods:

This was an observational cohort study of labor and delivery unit nurse managers. We developed a computer module that simulates the physical layout and clinical activity of the labor and delivery unit at our tertiary care academic medical center, in which players act as clinical managers in dynamically allocating nursing staff and beds as patients arrive, progress in labor, and undergo procedures. We exposed nurse managers to variation in patient census and measured the delays in resource decisions over the course of a simulated shift. We used mixed logistic and linear regression models to analyze the associations between patient census and delays in patient care.

Results:

Thirteen nurse managers participated in the study and completed 17 12-hour shifts, or 204 simulated hours of decision-making. All participants reported the simulation module reflected their real-life experiences at least somewhat well. We observed a 1.47-increased odds (95% CI 1.18, 1.82) of recommending a patient ambulate in early labor for every additional patient on the labor and delivery unit. For every additional patient on the labor and delivery unit, there was a 15.9-minute delay between delivery and transfer to the postpartum unit (95% CI 2.4, 29.3). For every additional patient in the waiting room, we observed a 33.3-minute delay in the time patients spent in the waiting room (95% CI 23.2, 43.5), and a 14.3-minute delay in moving a patient in need of a cesarean delivery to the operating room (95% CI 2.8, 25.8).

Conclusion:

Increasing labor and delivery unit census is associated with patient care delays in a computer simulation. Computer simulation is a feasible and valid method of demonstrating the sensitivity of care decisions to shifts in patient volume.

**Introduction**:

The ability to allocate resources optimally appears to be strongly associated with patient safety in several clinical domains (1,2). On labor and delivery (L&D) units, clinical managers (such as resource or charge nurses) are tasked with allocating a limited set of resources, such as beds and nursing staff. These decisions are particularly complex due to uncertainty regarding which patients will arrive, when they will arrive, and what their future needs will be. Increases in patient census on labor and delivery units have been associated with adverse perinatal outcomes, such as Apgar scores < 7, neonatal intensive care unit admission, neonatal seizures, and prolonged maternal length of stay, compared to low-volume time periods (3). One possible explanation for the relationship between increasing census and adverse outcomes is that managers may resort to a variety of mitigation strategies, including delaying new admissions, when the unit is particularly busy. We sought to test this idea by creating a computer simulation module to capture whether resource nurses delay patient care decisions as the labor and delivery unit census increases.

Decision-making strategies are difficult to identify retrospectively, as many electronic records do not capture the precise times at which decisions are made or the labor and delivery unit bed occupancy at the time when a decision was made. It is also challenging to collect these decisions prospectively given the time and resources required to directly observe and document these decisions along with the context in which the decisions are made. Lastly, it is not possible to directly manipulate the occupancy on the labor and delivery unit for such a study. Thus, we created a computer simulation module to monitor resource nurse decision-making under varying conditions in a controlled, safe environment.

The use of computer-based simulation to improve the management of limited resources is becoming more common in both healthcare delivery and quality improvement settings of other industries (4,5). Such simulations have been used to detect bottlenecks in Emergency Department care (6), optimize staffing ratios in Emergency Departments (7-9), manage critical care resources (10), and reduce wait times for patients in clinic (11). More recently, computer simulation methods have been used to optimize patient flow on the labor and delivery unit (12). In this study, we used our computer simulation module to observe resource nurses' decisions as a function of patient census on the labor and delivery unit. The purpose of this study was to 1) demonstrate the face validity of the simulation among end-users in the environment it was designed to simulate, 2) identify whether the delays in patient management decisions were different based on scheduled vs. non-scheduled patient arrivals, and 3) quantify the delays in patient management decisions with increasing occupancy on the labor and delivery unit and in the waiting room.

**Materials and Methods**:

This was an observational cohort study of resource nurses at Beth Israel Deaconess Medical Center in Boston, Massachusetts, who completed the labor and delivery unit simulation module. Only nurses who worked in the resource allocation role on the labor and delivery unit were eligible to participate. Participants were recruited through multiple methods: 1) email notification sent to all nurses, 2) word of mouth, 3) direct referrals, and 4) formal announcement at a monthly resource nurse meeting. Recruitment started in November 2015, and participants were enrolled during three data collection phases: first in December 2015, second in April 2016, and third in

October-November 2016. Each data collection phase deployed a simulation module of increasing difficulty, which was defined as an increase in the rate of patient arrivals, decrease in the number of nurses available during the shift, as well as an increase in the number of patients on the labor and delivery unit, antepartum and postpartum units at the start of the module.

Study staff designed and wrote the software for the computer simulation module in JAVA using Agile program development methodology and previously described mathematical modeling methods (13) to simulate the flow of laboring patients through an academic, tertiary acre-level labor and delivery unit. The module allowed players to act as the clinical manager responsible for resource management decisions during a 12-hour shift on the labor and delivery unit. A user interface mirrored the actual labor and delivery unit board that nurse managers use to make and track decisions, and it allowed players to make the same decisions in the simulation module that they would on the unit, including deciding the timing of bed and staff assignments (Figure 1). Participants were able to assign patients to rooms (triage, labor and delivery room, operating room, recovery room, postpartum), send patients walking for a specific number of hours, discharge patients, assign nurses to patients (primary nurse, scrub nurse, baby nurse, covering nurse), grant/deny nurse breaks, administer oxytocin augmentation, administer artificial rupture of membranes, and administer a cesarean delivery. We analyzed the following decisions: 1) decision to move a patient in the waiting room to a room on the labor and delivery unit, 2) decision to send a patient from triage to ambulate while in early labor, 3) decision to assign a primary nurse to a patient admitted to a room on the labor and delivery unit, 4) decision to move a patient in need of a cesarean delivery to the operating room, and 5) decision to transfer a delivered patient to the postpartum unit.

Simulated patient arrival and progress was stochastic, based on published clinical parameters and historical patient arrival patterns at Beth Israel Deaconess Medical Center (14), (15). Demographic parameters within the simulation were drawn from medical textbooks and scientific articles to match the distribution of characteristics and co-morbidities of the general population of childbearing women in the United States. The primary developer (MG) spent more than 120 hours shadowing and interviewing nurse managers from September to December 2014 in order to select user features. The module was developed using an iterative design process, in which study staff tested the software multiple times to identify bugs, coding errors, improve the user interface, and ensure that the simulation closely resembled the patient population and clinical manager experience at Beth Israel Deaconess Medical Center.

The cohort was a convenience sample of available resource nurses who agreed to participate during their breaks or before or after their assigned shifts given the constraints of the study. Each participant watched a tutorial video about the functions of the simulation module and then completed the module under supervision for 30 minutes. The developer was available to troubleshoot technical difficulties, but did not provide any guidance regarding clinical decision-making. Players were not given any specific objective in completing the module other than to make decisions similarly to the way they would in real life. After a practice session, each player participated in one to four simulated shifts, as time allowed. Participants completed a short follow-up survey about their simulation experience through Research Electronic Database Capture (REDCap), a secure web-based application designed to support data capture for research studies (16).

For the analysis, the exposures were waiting room occupancy and labor and delivery unit occupancy at the time a decision was made. We separated waiting room occupancy from labor and delivery unit occupancy to reflect the different staffing needs for patient care in each area. Labor and delivery unit occupancy included patients in labor and delivery rooms, operating rooms, recovery rooms, and triage rooms. The outcomes were related to decisions about patient management: the time patients stayed in the waiting room before a decision was made about admission or discharge, odds of recommending a patient ambulate in early labor (a proxy for deferred admission to the labor and delivery unit), time elapsed before a primary nurse was assigned to an admitted patient, time between notification of a needed cesarean delivery (CD) and the patient's arrival into the operating room, and time between delivery and transfer to the postpartum unit.

We presented descriptive summary data as median and interquartile range (IQR) or n (%). We employed a mixed-effects logistic regression model for categorical outcomes, where the fixed effect was room occupancy and the random effect was the particular participant. For analyses with continuous outcomes, we employed a mixed-effects linear regression model, where the fixed effect was room occupancy and the random effect was the particular participant. Patients coming to the labor and delivery unit could be scheduled, such as for induction of labor or cesarean delivery, or non-scheduled. Because managers often allocate resources for scheduled and non-scheduled patients differently, we assessed the effect of scheduled versus non-scheduled arrival using a stratified analysis. For example, managers can anticipate that a scheduled cesarean delivery requires an available operating room and a scrub nurse in addition to a primary

or circulating nurse at an approximate time of day based on the schedule. The need for such resources can be difficult to predict for unscheduled patients who arrive to the labor and delivery unit for a myriad of clinical reasons and requires flexibility in resource allocation. In addition, we adjusted for scheduled versus non-scheduled arrival in a complete model. There was insufficient data regarding the delay in moving a patient to the postpartum floor after delivery to employ a mixed-effects linear regression model, so a multiple linear regression model was employed for that decision specifically. Alpha error was defined as 0.05 for statistical significance. Statistical analyses were performed using R 3.4.1. The Beth Israel Deaconess Medical Center Committee on Clinical Investigations approved this study.

**Results**:

Thirteen out of 18 (72.2%) nurse managers were enrolled in the study between November 2015 and November 2016. We collected 8.5 hours of 13 nurses' decision-making time using the simulation module, which simulated 17 12-hour shifts, or a total of 204 simulated hours on the labor and delivery unit. Two nurses completed the module once, 6 nurses completed it twice, 4 nurses completed it 3 times, and one nurse completed it 4 times. This was an experienced cohort of nurses who reported a median of 13.5 years (interquartile range 10-16.5) of on-the-job experience as "resource" nurses, with oversight responsibility for managing staff and bed allocations during their shifts. Over half (7 out of 13, 53.8%) of the participants reported working in that role at least once per week. The majority of participants reported that the simulation module reflected their real-life experiences on the labor and delivery unit somewhat well (eleven out of thirteen, 84.6%), while the remaining two out of thirteen (15.4%) reported that it reflected

their experiences very well. The demographic information about these participants is shown in Table 1.

Mixed-effects logistic regression and multiple linear regression were performed on the association between unit occupancy and recommending a patient ambulate in early labor (thereby vacating a bed space) and delays in transferring a patient to the postpartum unit, respectively. There was a 1.47-increased odds (95% CI 1.18, 1.82) of recommending a patient ambulate in early labor (a proxy for deferred admission) for every additional patient on the labor and delivery unit, adjusted for scheduled vs. non-scheduled patient arrival. However, the odds of recommending a patient ambulate in early labor were not significantly different with additional patients in the waiting room (odds ratio 0.41, 95% CI 0.16, 1.04). There was a simulated 15.9-minute delay (95% CI 2.4, 29.3) between delivery and transfer to the postpartum unit with every additional patient on the labor and delivery unit, but there were no delays in these postpartum transfers associated with increasing numbers of patients in the waiting room (-8.4minutes, 95% CI -28.9, 12.2).

We performed a stratified analysis of the association between bed occupancy and decision delays between scheduled and non-scheduled patient arrival, as shown in Table 2. For every additional patient on the labor and delivery unit, there was a simulated 19.6-minute delay in moving a patient in need of a cesarean delivery to the operating room when the patient's arrival was scheduled (95% CI 5.5, 33.6). For every additional patient in the waiting room, there was a simulated 14.9-minute delay in moving a patient in need of a cesarean delivery to the operating room when the patient's arrival was non-scheduled (95% CI 3.2, 26.7). There were no

statistically significant delays in assigning a primary nurse to a newly admitted patient among scheduled or non-scheduled patients.

The mixed-effects linear regression models for the associations between increasing bed occupancy and patient care delays are shown in Table 3. For every additional patient in the waiting room, we observed a simulated 33.3-minute delay (95% CI 23.2, 43.5) for an action to be taken on a patient in the waiting room, and a simulated 14.3-minute delay (95% CI 2.8, 25.8) between a request for cesarean delivery and patient arrival in the operating room, adjusted for scheduled vs. non-scheduled arrival. For every additional patient on the labor and delivery unit, we observed a simulated 8.9-minute delay (95% CI 0.2, 17.7) in assigning a primary nurse to an admitted patient, adjusted for scheduled vs. non-scheduled arrival.

**Discussion**:

Using a computer simulation module, we found that there was a statistically significant association between increasing patient census on the labor and delivery unit and in the waiting room, and delays in patient care. Increases in patient volume were significantly associated with delays in taking action on patients in the waiting room, delays in assigning primary nurses, and delays in moving patients to the operating room when a cesarean delivery is indicated, even after adjusting for differences in scheduled vs. non-scheduled patient arrival. The magnitude of the delays varied by labor and delivery unit and waiting room census. Our nurse managers frequently delay early labor admissions by recommending patients ambulate in early labor. While this decision may be clinically appropriate, we found they were significantly more likely

to delay these admissions when there were more patients on the labor and delivery unit, perhaps because there were fewer available beds for a new admission.

The delay in transferring patients who delivered from the labor and delivery unit to postpartum was significantly associated with increasing labor and delivery unit occupancy and not waiting room occupancy. This may have been because the primary nurse was frequently assigned to multiple patients at the same time. These findings may reflect the relative urgency of providing care to admitted patients on the labor and delivery unit compared to those waiting to be assessed in the waiting room, which is often reflected in how each area is staffed. These results indicate that there may be a tipping point in labor and delivery unit and waiting room occupancy at which delays in patient care become more likely, and suggests that patients may receive different types of care depending on the labor and delivery unit occupancy at critical resource decision points.

Our study captures resource nurses' decisions about nursing assignments and the flow of patients through the labor and delivery unit under varying unit occupancy. We demonstrated feasibility of completing the simulation module as well as the face validity in capturing key decisions among a cohort of nurse managers. Our observations that these decisions appear to be sensitive to unit occupancy suggest an opportunity to use this type of simulation to improve clinical training (17,18). Computer simulation may offer an efficient and broadly accessible means of training (19).

Our study has limitations and its results must be interpreted in the context of our study design. The structure of the simulated labor and delivery unit is modeled after a single academic tertiary

care medical center with an annual delivery volume of approximately 5,000, which may limit its generalizability to other labor and delivery units, particularly those that have less clinical volume. The schedule for nurses available during the simulated shift reflected the real staffing ratios at the same medical center and was available to players to use to make decisions in the module. We did not account for variation in pre-existing technology competency among the participants with regard to playing a computer module, though all players were provided with a tutorial and a member of the study team was available at all times to provide technical assistance if needed. Notably, 6 of the 13 participants only worked as a resource nurse twice per month or less, which may limit their comfort level in making resource decisions under various environmental pressures. Moreover, it is not possible to account for all potential covariates of complex decision-making in the environment of the labor and delivery unit. We created the simulation module to focus on the management of patient progress through labor and do not account for all of the ways clinical acuity may evolve. This version of the computer module allowed the player to react to patients with varying clinical acuity but our analysis did not account for the clinical characteristics of each patient in the module. However, we would expect that accounting for increased acuity would lead to greater delays in patient care, which is the key finding of this paper.

While prior literature suggests that increases in patient census are associated with adverse perinatal outcomes (20), the impact of delays in resource management decisions such as bed and staff assignments is not fully understood. Nonetheless, numerous healthcare organizations ranging from the United Kingdom's National Health Service to Intermountain Healthcare have promoted the importance of providing each patient with the "right care" at the "right time" in the

297 "right place" (21, 22). Delays in care can originate from multiple sources: clinicians may delay
298 decisions based on clinical appropriateness, and resource nurses or clinical managers may delay
299 executing the clinical decision made by the physician or midwife due to resource constraints. We
300 demonstrated that computer simulation is a feasible and valid method of demonstrating the
301 sensitivity of care decisions to shifts in patient volume. Similar approaches may be used to
302 provide clinical training and ascertain improvement opportunities. Future efforts should aim to
303 broaden these findings among more diverse cohorts of labor and delivery unit managers.
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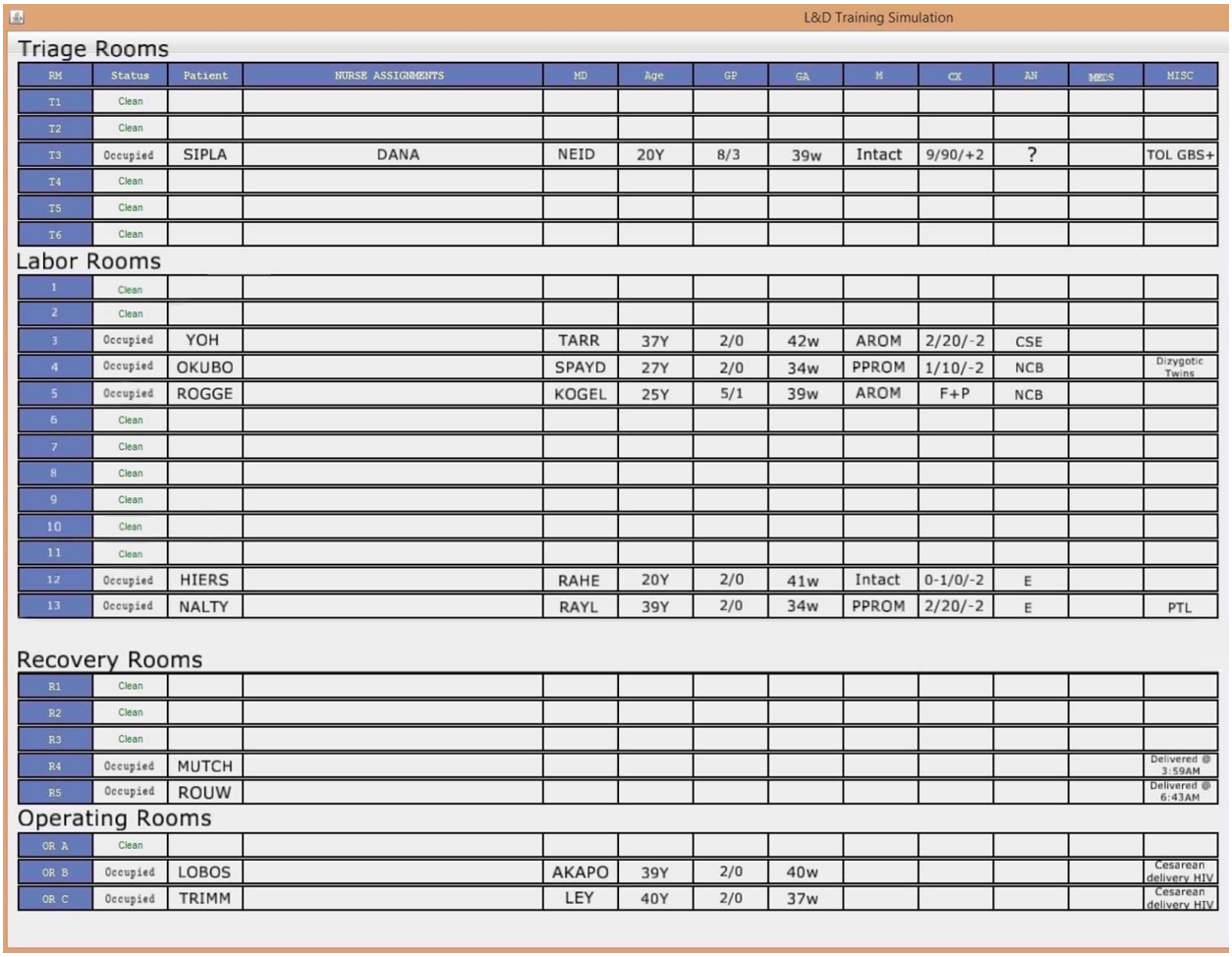

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306 **Figure 1: Computer Module Interface. Screenshot of the computer simulation interface**
307 **that each participant used during the module. The interface is organized as a labor and**

**delivery unit board with a list of all patients on the unit and their associated clinical characteristics. This virtual board updates throughout the course of the shift. The tabs on the right indicate additional information available to the player during the simulation.**

**Table 1: Baseline Participant Characteristics**

| **Characteristic** | **N=13*** |
|---|---|
| Age (years) | |
| 31-35 | 1 (7.7) |
| 36-40 | 5 (38.5) |
| 41-45 | 2 (15.4) |
| 51-55 | 3 (23.1) |
| 56-60 | 1 (7.7) |
| Missing | 1 (7.7) |
| Professional Training† | |
| Nurse (RN) | 13 (100.0) |
| Advanced Practice Clinician (NP, PA) | 2 (15.4) |
| Years in Practice since Training Completed | 16.5 (15.5-24.0) |
| Years of on-the-job experience as a resource nurse on Labor and Delivery | 13.5 (10.0-16.5) |
| Frequency of working as a resource nurse | |
| More than once per week | 4 (30.8) |
| Once per week | 3 (23.1) |
| Twice per month | 3 (23.1) |
| Once per month | 2 (15.4) |
| Infrequently | 1 (7.7) |
| Never | 0 (0.0) |

| | |
|---|---|
| Simulation module reflected real-life experiences on Labor and Delivery | |
| Very well | 2 (15.4) |
| Somewhat well | 11 (84.6) |
| Not well at all | 0 (0.0) |

**Data are presented as median (interquartile range) or n (%).*

†*Participants could choose more than one level of professional training.*

**Table 2: Association between Delays in Patient Management and Increasing Bed Occupancy in L&D and Waiting Room Stratified by Scheduled vs. Non-scheduled Patient Arrival***

| | **Additional Time Spent in Waiting Room (minutes)** | | |
|---|---|---|---|
| **Variable** | **Time Difference (mins)** | **95% CI** | **P-value** |
| L&D Occupancy† | | | |
| Scheduled | 4.6 | -4.2, 13.4 | 0.30 |
| Non-scheduled | 0.5 | -8.5, 9.5 | 0.92 |
| Waiting Room Occupancy‡ | | | |
| Scheduled | 41.7 | 27.0, 56.5 | < 0.01 |
| Non-scheduled | 28.4 | 15.7, 41.0 | < 0.01 |
| | **Delay in Assigning a Primary Nurse (minutes)** | | |
| **Variable** | **Time Difference (mins)** | **95% CI** | **P-value** |
| L&D Occupancy† | | | |
| Scheduled | 3.9 | -4.5, 12.4 | 0.36 |
| Non-scheduled | 21.3 | -2.4, 45.1 | 0.08 |
| Waiting Room Occupancy‡ | | | |

| | | | |
|---|---|---|---|
| Scheduled | 4.4 | -10.8, 19.6 | 0.57 |
| Non-scheduled | 6.3 | -51.2, 63.8 | 0.83 |
| | **Delay between Cesarean Delivery Request and Arrival in Operating Room (minutes)** | | |
| **Variable** | **Time Difference (mins)** | **95% CI** | **P-value** |
| L&D Occupancy[†] | | | |
| Scheduled | 19.6 | 5.5, 33.6 | <0.01 |
| Non-scheduled | -0.2 | -9.1, 8.7 | 0.97 |
| Waiting Room Occupancy[‡] | | | |
| Scheduled | -19.9 | -47.8, 8.0 | 0.16 |
| Non-scheduled | 14.9 | 3.2, 26.7 | 0.01 |

**Mixed-effect linear regression model with random effect defined as clustering by participants.*

[†]*Adjusted for waiting room occupancy.*

[‡]*Adjusted for L&D occupancy.*

[§]*β1 presented for L&D occupancy or waiting room occupancy within strata of scheduled and non-scheduled patient arrival.*

**Table 3: Association between Delays in Patient Management and Increasing Bed Occupancy in L&D and Waiting Room***

| | **Additional Time Spent in Waiting Room (minutes)** | | |
|---|---|---|---|
| **Variable** | **Time Difference (mins)** | **95% CI** | **P-value** |
| L&D Occupancy† | 2.0 | -5.8, 9.8 | 0.62 |
| Waiting Room Occupancy‡ | 33.3 | 23.2, 43.5 | < 0.01 |
| | **Delay in Assigning a Primary Nurse (minutes)** | | |
| **Variable** | **Time Difference (mins)** | **95% CI** | **P-value** |
| L&D Occupancy† | 8.9 | 0.2, 17.7 | 0.04 |
| Waiting Room Occupancy‡ | 0.2 | -18.6, 19.0 | 0.98 |
| | **Delay between Cesarean Delivery Request and Arrival in Operating Room (minutes)** | | |
| **Variable** | **Time Difference (mins)** | **95% CI** | **P-value** |
| L&D Occupancy† | 0.8 | -7.4, 9.1 | 0.84 |
| Waiting Room Occupancy‡ | 14.3 | 2.8, 25.8 | 0.01 |

**Mixed-effect linear regression model with random effect defined as clustering by participants.*

325 †*Adjusted for waiting room occupancy and scheduled patient arrival.*

326 ‡*Adjusted for L&D occupancy and scheduled patient arrival.*

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