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Hospital and provider patient volumes, Cesarean section rates, and early postpartum invasive methicillin-resistant *Staphylococcus aureus* infection

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Abstract

Objective—We sought to examine whether hospital and provider volumes and Cesarean section rates influenced early postpartum invasive MRSA infection.

Methods—We used data from the Nationwide Inpatient Sample, a representative sample of United States community hospitals. Multivariate hierarchical regression models were used to estimate odds ratios adjusted for hospital total discharges, nurse to patient ratio, urbanicity, teaching status, bed size, ownership, and geographic region, and patient age, race, expected payer, and comorbidities.

Results—The total sample size for the hospital analysis was 3,487,350 deliveries, and there were 555 cases of MRSA infection. The total sample size for the provider analysis was 1,186,703 deliveries, and there were 221 cases of MRSA infection. We found that hospital and provider patient (deliveries) volumes and Cesarean section rates were not associated with early postpartum invasive MRSA infection.

Conclusions—Barring major bias in our estimates, our results suggest that transmission from providers may not be a predominant route of postpartum MRSA infection in US hospitals.

Introduction

Hospitalization is an important risk factor for methicillin resistant *Staphylococcus aureus* (MRSA) infection. Transmission via health care workers hands is thought to be the primary means of infection in hospitals.[1] We sought to investigate whether hospital and provider delivery volumes and Cesarean section s were associated with risk of MRSA infection in the early postpartum (pre discharge) period.

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Hospital size and patient volume have been correlated with both general nosocomial infections and MRSA infection and colonization in intensive care units and other hospital wards. However, the nature of the association is controversial and may be due to confounding by patient factors.[2–7] We found only one study that examined the relationship between obstetric patient volume and infectious morbidity. Janakiraman *et al.* (2011) found that risk of postpartum infection was higher in hospitals with more deliveries, but lower among providers who attended more deliveries.[8]

There are several reasons to believe that high volume of deliveries at the hospital and provider level may predispose delivering women to MRSA infection. Larger hospitals allow exposure to more patients, and more opportunities to come in contact with MRSA carriers, or fomites that have come into contact with carriers. A provider with a high volume of deliveries has more opportunity to come into contact with carrier patients, and may be more likely to become colonized with MRSA, or to transfer MRSA to other patients by hands or clothing.

Cesarean section is a well-established, major risk factor for postpartum infection at the individual level.[9–11] We could not find any previous studies that examined whether the proportions of Cesarean deliveries at the hospital and provider levels were associated with postpartum infectious morbidity independent of a woman's individual mode of delivery. However, there are plausible mechanistic reasons to suspect an association between facility and provider Cesarean rates and MRSA. Women undergoing Cesarean sections are generally given prophylactic β-lactam antibiotics,[11–13] which may increase the number of drug resistant organisms in facilities with high Cesarean rates. Clinicians who perform many Cesarean sections may be more likely to be colonized or have hands or clothing contaminated by resistant bacteria. It is also possible that high Cesarean rates serve as a proxy for a highly interventionist style of labor and delivery management. In this scenario, women who deliver vaginally in hospitals with high Cesarean rates may be at higher risk of other procedures, such as urinary catheterization, internal fetal monitoring, instrumental delivery, and frequent vaginal exams, which increase infection risk.

Methods

Study Data & Population

For this study, we used data from the Nationwide Inpatient Sample (NIS). The NIS is a stratified probability sample of approximately 20% of US community hospitals and is designed to create a sample that is representative of all US community hospitals. [14] The NIS is administered by the Healthcare Cost and Utilization Project (HCUP), a Federal-State-Industry partnership sponsored by the Agency for Healthcare Research and Quality (AHRQ). A complete list of agencies that contribute data to HCUP can be found at www.hcup-us.ahrq.gov/hcupdatapartners.jsp.

Among hospitals included in the NIS, all inpatient discharges are reported. The study group consisted of all women in the NIS from 2005 through 2008 who were admitted for delivery (defined by Diagnosis Related Groups, 24th revision, 370 – 375) to hospitals with more than 50 deliveries per quarter.

Because the NIS consists of de-identified, pre-existing, public-use data, this study was exempt from review by the Institutional Review Board of the University of California, Los Angeles.

Outcome

The outcome of interest was invasive MRSA infection prior to discharge after hospitalization for the delivery of an infant. In 2008, several new ICD-9 CM codes indicating MRSA infection or carriage were introduced including 038.12 (MRSA septicemia), 482.42 (methicillin resistant pneumonia due to *S. aureus*), and 041.12 (MRSA in conditions classified elsewhere and of unknown site), which are used to define invasive MRSA infections in 2008 admissions. Prior to 2008, invasive MRSA infection is defined by presence of ICD-9 codes 482.41 (*S. aureus* pneumonia), 038.11 (*S. aureus* septicemia), or 041.11 (*S. aureus* in conditions classified elsewhere and of unknown site) along with code V09.0 (infection with microorganisms resistant to penicillins). This definition of MRSA infection has been used by the Healthcare Cost and Utilization project.[15]

Exposures

The NIS provided a unique identification number for each participating hospital. The hospital volume of deliveries was measured as the number of discharges with DRGs 370 through 375 (vaginal and Cesarean deliveries) in each quarter.

In addition, some states provide a unique identifier for the clinician with overall responsibility for the patient's care. For the purposes of this study, we assumed this clinician (provider) attended the delivery. Provider volume was also measured as the number of discharges with DRGs 370–375 per quarter.

Patients who delivered via Cesarean section were identified by DRGs 370 and 371. Cesarean section rates for hospitals and providers were measured as the proportion of patients with DRG 370 and 371 among patients with any DRGs for delivery of an infant (370 – 379).

One hundred sixty five records from 2008 were excluded from these analyses because they lacked discharge quarter, precluding calculation of number of discharges and Cesarean section rates per quarter. Exclusion of these records did impact the calculation of the exposure variables for the remaining records. However, the overall number of excluded patients was low (less than one out of every 20,000 patients for the analyses with only hospital predictors, and less than one out of every 7,000 for provider level analyses), excluded records made up less than 2% of the total number of patients for any given hospital, and none of these women were diagnosed with MRSA infection. Thus, the exclusion of these records had very little potential to bias our results.

Covariates

Patient level covariates were age, race (White, Black, Hispanic, Asian or Pacific Islander, Native American and Other), expected payer, and 29 Elixhauser comorbidity measures. Due to small numbers of women with lymphomas, solid tumors, and metastatic cancers, these three conditions were combined into a single variable for malignancies. Also, due to the small number of women with diabetic complications, complicated and uncomplicated diabetes were combined.

As we sought to identify the associations between hospital and provider Cesarean section rates and the outcome independent of individual mode of delivery, our analysis also included an indicator variable for whether or not the patient delivered via Cesarean.

Hospital level covariates included total inpatient discharges, teaching status, and nurse-to-patient ratio (measured as full time equivalent registered nurses per 1000 inpatient days). Additional hospital variables were included in the analysis because they were used to design the sampling frame. These included hospital urbanicity, bed size, geographic region, and hospital ownership.

Data Analysis

Data were analyzed using hierarchical logistic regression with random intercepts. We used two types of hierarchical data structuring: (i) patients' admissions nested within hospitals, and (ii) patients' admissions nested within providers who in turn were nested within hospitals. To control for covariates, exposure propensity scores were calculated using hierarchical linear regression models. We used the exposure propensity scores to fit the final models relating the exposures to the outcome. Hospital and provider volume were re-centered to 800 and 60 deliveries per quarter, and rescaled to 100 and ten deliveries per quarter, respectively. Cesarean rates were re-centered to 30%, and rescaled to 5%.

Missing values for confounders were imputed using PROC MI in SAS version 9.2. Exposure propensity scores were calculated separately for each imputation. For comparison, we performed analyses on datasets without imputation, using only records with no missing values.

Results

The total sample size for the analysis with only hospital predictors was 3,487,350, and there were 555 cases of MRSA infection. The total sample size for the analysis with provider predictors was 1,186,703, and there were 221 cases of MRSA infection

Results of the multivariate models are shown in Table 1. We did not detect an association between any of the exposure variables studied and invasive MRSA infections. The odds ratios for hospital delivery volume and Cesarean section rates in the model without provider level variables were both 0.98 (95% CI 0.95 to 1.01 and 0.90 to 1.06 respectively). Adding provider level predictors to the model did not appreciable change either of these estimates. The odds ratios for provider volume and Cesarean section rates were 1.00 (95% CI 0.98 to 1.02) and 1.01 (0.96 to 1.27). All estimates for product term coefficients in multiply imputed models were near null, and had narrow confidence intervals.

In the complete record analysis, the odds ratio for hospital Cesarean section rates decreased to 0.90, and the 95% confidence interval and associated confidence interval shifted downward somewhat. There were little changes in the values of the other point estimates.

Discussion

Maternity care delivered by high volume providers and facilities may have benefits. Risk of neonatal mortality and asphyxia have been found to be lower in hospitals with greater delivery volumes, and risk of maternal complications may be lower among providers who attend more deliveries.[8, 16, 17] Larger obstetric units may also be able to deliver maternity services at lower costs. However, it is important to investigate possible risks of increased obstetric volumes, including risk of infectious morbidity, in order to understand how to maximize benefits and minimize harms to women and their infants.

Assuming that the models used to generate our estimates were correct (absent any uncontrolled confounding or other bias), our results appear compatible with little to no effect of any of hospital and provider delivery volume and Cesarean section rates on the risk of pre-discharge MRSA infection in women admitted for delivery of an infant.

However, these results suffer from a number of limitations. The most serious limitation is our inability to track patients across multiple admissions, which restricts follow-up to the period between admission for delivery and discharge. Because the majority of postpartum infections are diagnosed after discharge, the predictors identified here may not be generalizable to all postpartum MRSA infections. There is potential for misclassification of the outcome variable. MRSA diagnosis typically requires antibiotic susceptibility testing, which may not be performed for all MRSA infections, particularly in cases of spontaneous recovery. False positives are also a possibility, as diagnostic cultures of infections caused by other organisms may become contaminated with MRSA if the patient is an asymptomatic carrier. Several states do not report clinician identifiers. Another limitation of these data is that, in every state other than New York, physicians are the only clinicians that are assigned identifiers. Per vital statistics data from the United States Centers for Disease Control and Prevention, nurse midwives or other practitioners deliver approximately 8% of infants born in US hospitals. Additionally, in teaching hospitals, medical students and residents, who may not be identified as the provider in the patient record, may perform deliveries. In some cases, the “attending physician” may not have been the person who delivered the infant, and may have had no contact with the mother at all.

Given these limitations, and the fact that no similar studies could be identified for comparison, it would be imprudent to conclude that the risk of MRSA infection is completely unaffected by hospital and provider delivery volumes and Cesarean section rates. Investigation of these research questions using a data source that allows tracking of patients across multiple admissions would add information about postpartum readmissions for infection, and would do much to alleviate the uncertainty inherent in this analysis. Linkage to birth certificate information could also be helpful, as it could be used to exclude women who were attended by providers who are not assigned identifiers in the NIS.

The chief strength of this study is the large sample size, which permits study of rare outcomes with adequate power. Even when the analysis is limited to states that report provider identifiers, more than 1.8 million women are included. Also, the NIS is designed to be representative of the population of non-Federal US hospitals. Within selected hospitals, all patients are included, which limits the potential for selection bias at the individual level.

Assuming that our results are unbiased, and reflect actual relative risks of infection, the findings are interesting. Given aforementioned evidence of relationships between provider and facility volumes and risk of healthcare acquired infections, as well as the mechanistic reasons for increased risk with increasing (hospital and provider) patient volumes, it is noteworthy that we found that neither provider nor hospital delivery volume had any substantial effect on the risk of early postpartum MRSA infection. This finding suggests that the dynamics of MRSA transmission in labor and delivery patients may differ from those of other inpatients. Furthermore, it is possible that transmission from providers is not a predominant route of infection. Additional studies on facility-level predictors of postpartum MRSA infection are needed to uncover probable modes of infection in this population.

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Table 1

Multivariable adjusted* odds ratios and 95% confidence intervals for the association of hospital and provider patient volume and Cesarean rate on early postpartum methicillin-resistant *Staphylococcus aureus* infection

	Odds Ratio	95% Confidence Interval
Hospital predictors only, no imputation		
Hospital deliveries per quarter	0.98**	0.95 – 1.02
Hospital Cesarean section rate	0.90†	0.81 – 1.00
Product term	0.99	0.97 – 1.00
Hospital and attendant predictors, no imputation		
Hospital deliveries per quarter	0.99**	0.94 – 1.04
Hospital Cesarean section rate	0.93†	0.77 – 1.11
Hospital product term	0.98	0.95 – 1.00
Attendant deliveries per quarter	0.95 ‡	0.81 – 1.12
Attendant Cesarean section rate	0.98†	0.90 – 1.06
Attendant product term	1.01	0.99 – 1.03
Hospital predictors only, multiple imputation		
Hospital deliveries per quarter	0.98**	0.95 – 1.01
Hospital Cesarean section rate	0.98†	0.90 – 1.06
Product term	0.99	0.98 – 1.00
Hospital and attendant predictors, multiple imputation		
Hospital deliveries per quarter	1.00**	0.95 – 1.05
Hospital Cesarean section rate	0.98†	0.85 – 1.13
Hospital product term	0.99	0.97 – 1.01
Attendant deliveries per quarter	1.00‡	0.98 – 1.02
Attendant Cesarean section rate	1.01†	0.96 – 1.07
Attendant product term	1.01	1.00 – 1.01

* All models adjusted for patient age, race, expected payer, and comorbidities and hospital total discharges, nurse to patient ratio, urbanicity, teaching status, bed size, ownership, and geographic region

** For an increase of 100 deliveries per quarter

† For a 5% increase in Cesarean rate

‡ For an increase of 10 deliveries per quarter