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Major article

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

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Objective: We sought to examine whether hospital and provider volumes and cesarean section rates influenced early postpartum invasive methicillin-resistant *Staphylococcus aureus* (MRSA) infection.
Methods: We used data from the Nationwide Inpatient Sample, a representative sample of US community hospitals. Multivariate hierarchical regression models were used to estimate odds ratios adjusted for hospital total discharges, nurse: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, which included 555 cases of MRSA infection. The total sample size for the provider analysis was 1,186,703 deliveries, with 221 cases of MRSA infection. 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.

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 deliveries were associated with risk of MRSA infection in the early postpartum (predischarge) period.

Hospital size and patient volume have been correlated with rates of both general nosocomial infections and MRSA infection and colonization in intensive care units and other hospital wards. The nature of the association is controversial, however, and may be related to confounding by patient factors.[2-7] We found only a single study that examined the relationship between obstetric patient volume and infectious morbidity. Janakiraman et al[8] found a greater risk of postpartum infection in hospitals with more deliveries, but a lower risk among providers who attended more deliveries.

There are several reasons to believe that high volume of deliveries at the hospital and provider levels may predispose mothers to MRSA infection. Larger hospitals allow exposure to more patients, and thus 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 his or her 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 examining whether the proportions of cesarean deliveries at the hospital and provider levels were associated with postpartum infectious morbidity independent of individual mode of delivery; nonetheless, there are plausible mechanistic reasons to suspect an association between facility and provider cesarean rates and MRSA. Women undergoing cesarean section are generally given prophylactic β-lactam antibiotic therapy,[11-13] which may increase the number of drug-resistant organisms in facilities with high rates of cesarean delivery. Clinicians who perform numerous cesarean sections may be more likely to be colonized or to have hands or clothing contaminated by resistant bacteria. It is also possible that a high rate of cesarean deliveries serves as a proxy for a

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highly interventionist style of labor and delivery management. In this scenario, women who deliver vaginally in hospitals with high cesarean delivery rates may be more likely to undergo other procedures that increase the risk of infection, such as urinary catheterization, internal fetal monitoring, instrumental delivery, and frequent vaginal examinations.

METHODS

Study data and population

For this study, we used data from the Nationwide Inpatient Sample (NIS), a stratified probability sample of approximately 20% of US community hospitals considered 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. A complete list of agencies that contribute data to the HCUP is available at www.hcup-us.ahrq.gov/hcupdatapartners.jsp.

Among the hospitals included in the NIS, all inpatient discharges are reported. Our study group comprised all women in the NIS who were admitted for delivery (defined by diagnosis-related groups [DRGs; 24th revision] 370-375) between 2005 and 2008 to hospitals with more than 50 deliveries per quarter.

Because the NIS consists of deidentified, preexisting, 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 before discharge after hospitalization for the delivery of an infant. In 2008, several new *International Statistical Classification of Diseases and Related Health Problems, Ninth Revision, Clinical Modification* (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.

Before 2008, invasive MRSA infection is defined by the presence of ICD-9-CM 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 HCUP.[15]

Exposures

The NIS provided a unique identification number for each participating hospital. Hospital volume of deliveries was determined by the number of discharges with DRGs 370-375 (vaginal and cesarean deliveries) in each quarter. In addition, some states provide a unique identifier for the clinician with overall responsibility for each patient's care. For the purpose of this study, we assumed that 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 DRGs 370 and 371 among patients with any DRG for delivery of an infant (370-379).

A total of 165 records from 2008 were excluded from these analyses because they lacked discharge quarter, precluding calculation of number of discharges and cesarean section rate per quarter. Exclusion of these records affected calculation of the exposure variables for the remaining records. However, the overall number of excluded patients was low (<1 of every 20,000 patients for the analyses with only hospital predictors, and <1 of every 7,000 for provider-level analyses), excluded records composed <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.

Table 1
Multivariate adjusted* ORs (and 95% CIs) for the association of hospital and provider patient volume and cesarean section delivery rate on early postpartum MRSA infection

Variable	OR	95% CI
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.

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. Owing to small numbers of women with lymphomas, solid tumors, and metastatic cancers, these 3 conditions were combined into a single variable for malignancies. In addition, owing to the small number of women with diabetic complications, complicated and uncomplicated diabetes were combined. Because 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 section.

Hospital-level covariates included total inpatient discharges, teaching status, and nurse:patient ratio (measured as full-time equivalent registered nurses per 1,000 inpatient-days). The analyses also included additional hospital variables—hospital urbanicity, bed size, geographic region, and hospital ownership—that were used to design the sampling frame.

Data analysis

Data were analyzed using hierarchical logistic regression with random intercepts. Two types of hierarchical data structuring were used: patient admissions nested within hospitals and patient