

Epidemiology of and Surveillance for Postpartum Infections

Deborah S. Yokoe,* Cindy L. Christiansen,† Ruth Johnson,‡ Kenneth E. Sands,§
James Livingston,* Ernest S. Shtatland,† and Richard Platt*†

*Channing Laboratory and Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, MA, USA; †Harvard Pilgrim Health Care, Boston, MA, USA; ‡Harvard Vanguard Medical Associates, Boston, MA, USA; and §Beth Israel Deaconess Medical Center, Boston, MA, USA

We screened automated ambulatory medical records, hospital and emergency room claims, and pharmacy records of 2,826 health maintenance organization (HMO) members who gave birth over a 30-month period. Full-text ambulatory records were reviewed for the 30-day postpartum period to confirm infection status for a weighted sample of cases. The overall postpartum infection rate was 6.0%, with rates of 7.4% following cesarean section and 5.5% following vaginal delivery. Rehospitalization; cesarean delivery; antistaphylococcal antibiotics; diagnosis codes for mastitis, endometritis, and wound infection; and ambulatory blood or wound cultures were important predictors of infection. Use of automated information routinely collected by HMOs and insurers allows efficient identification of postpartum infections not detected by conventional surveillance.

The epidemiology of postpartum infections has not been well characterized. In part this is because of the limitations of surveillance systems, which usually monitor infections that are recognized during hospitalization. Most postpartum and nonobstetrical postsurgical infections, however, occur after hospital discharge (1-3). Decreasing lengths of hospital stay may further compromise detection of these infections.

Several methods for postdischarge surveillance of postpartum infections have been evaluated. Hulton et al. (1) used physician questionnaires for postdischarge surveillance of patients undergoing cesarean section. With only inpatient surveillance, 59% of postpartum infections they ultimately detected would not have been identified. The overall infection rate after postdischarge surveillance was implemented was fourfold higher than the previous rate (6.3% vs. 1.6%). Holbrook et al. (2) used patient self-administered questionnaires to conduct large-scale, routine postdischarge surveillance following vaginal delivery or cesarean section. Despite a modest return of questionnaires, self-reported questionnaire results identified twice as many apparent postpartum infections (4% infection rate) as did concurrent prospective in-hospital surveillance. Only 48% of reported maternal infections, however, were confirmed by questionnaires to the patients' physicians. Sands et al. (3) evaluated the use of automated ambulatory diagnosis, testing, and pharmacy code screening combined with discharge diagnoses to identify surgical site infections in nonobstetric patients undergoing surgery. They found that ambulatory code screening was a sensitive method for detecting patients with surgical site infections and that 84% occurred after hospital discharge. Of the postdischarge surgical site infections, most (63%) were

diagnosed and treated entirely in the ambulatory setting. In addition, patient and surgeon questionnaires had low sensitivities (28% and 15%, respectively) for identifying postdischarge infections.

Routine surveillance for nosocomial infections is recommended by the Centers for Disease Control and Prevention and required by the Joint Commission on Accreditation of Healthcare Organizations, with the goal of using this information to compare infection rates over time and between institutions and to guide the allocation of resources towards improvements most likely to result in reduced infection rates.

In this study, we used the inpatient and outpatient data collected by a health maintenance organization (HMO) to identify postpartum infections and describe the epidemiology of these infections.

Methods

The study population consisted of all women who had a vaginal delivery or cesarean section at Brigham and Women's Hospital from January 1, 1993, to June 30, 1995, and who received postpartum care at Harvard Pilgrim Health Care (HPHC)/Harvard Vanguard Medical Associates (HVMA) centers with automated full-text ambulatory medical records. HPHC is a multimodel health maintenance organization that included a staff model division (now a multispecialty group practice, HVMA) with approximately 300,000 members in the greater Boston area at the time of the study. Brigham and Women's Hospital is the most active obstetrical facility for these members.

HMO data included three sources: an extensively automated ambulatory record, pharmacy dispensing data, and administrative claims for hospital, emergency room, and other care delivered outside the health center. The automated ambulatory medical record system (4) used standard-

Address for correspondence: Deborah S. Yokoe, 181 Longwood Ave., Boston, MA 02115; fax: 617-731-1541; e-mail: deborah.yokoe@channing.harvard.edu

Research

ized forms that were completed for every patient encounter at HPHC/HVMA centers, including telephone calls, office visits (scheduled or unscheduled), urgent care visits, and hospitalizations. Information was recorded on forms that are customized for the type of encounter. The provider either wrote in or selected from a list of all coded diagnoses, tests, procedures, and prescriptions relevant to that encounter and enters additional comments as free text. All information, including free text, is entered into an automated medical encounter record. The results of diagnostic tests are entered directly into the automated record linked to the patient encounter during which they were ordered. Information about hospitalizations and emergency room visits appears in both encounter records and separate administrative records. HPHC/HVMA pharmacies are also computerized and linked to the automated medical record. Ninety percent of HPHC members had prepaid coverage for pharmaceuticals and so are likely to use HPHC/HVMA pharmacies.

Identification of Postpartum Infections

Automated medical records, pharmacy dispensing records, and hospital and emergency room claims were screened by a computerized search of HPHC records for the 30 days following delivery for the presence of any of 32 diagnostic, testing, or pharmacy dispensing codes indicative of postpartum infections (Table 1), as described (3).

Full-text ambulatory medical records and relevant hospital records were reviewed for the 30-day postpartum period for a random sample of 100 patients with at least one of the ambulatory screening codes. Surgical site infections (including endometritis), episiotomy site infections, mastitis, and urinary tract infections were confirmed by the Centers for Disease Control and Prevention's National Nosocomial Infection Surveillance system definitions (5,6).

Infection rates for the entire study population of postpartum women were extrapolated by standard methods from the estimated infection rates for the sample of individual medical records reviewed (7).

Two previously described surveillance screening methods were used to assess the completeness of postpartum infection detection. In one method, patient self-reported questionnaires were mailed to all women approximately 6 weeks after their infants were discharged, by using previously described instruments (2). These self-administered questionnaires asked whether the mother had specific infections, received an antibiotic, or was rehospitalized for an infection. All study patients with questionnaire results suggestive of postpartum infection were identified. In the second method, prospective inpatient surveillance was conducted by infection control practitioners during the entire period, as described (8).

Full-text ambulatory medical records and relevant hospital records were reviewed for the 30-day postpartum period for all patients identified through inpatient surveillance or self-reported questionnaire results as described.

Resource use associated with infections during the 30-day postpartum period was evaluated through review of ambulatory records for patients with confirmed postpartum infection. All free-text notes were reviewed, and encounters for which the principal focus was the postpartum infection were identified.

Table 1. Ambulatory record codes used to screen postpartum medical encounters for infections

Screening code data source	Description
Hospital and emergency room claims	
ICD-9 diagnosis codes^a	
670.02	Major puerperal infection, with postpartum complication
670.04	Major puerperal infection, postpartum condition or complication
599.0	Urinary tract infection
674.34	Other obstetrical complication
675.14	Postpartum breast abscess
675.24	Postpartum nonpurulent mastitis
998.5	Postoperative infection
Ambulatory medical records	
COSTAR diagnosis codes	
DA140	Fever of unknown origin
DC150	Cellulitis
DC408	Abscess
DH140	Mastitis
DL101	Urinary tract infection
DM153	Endometritis
DR180	Wound infection
COSTAR therapy or test codes	
RR240	Incision and drainage
RT223	Bacterial culture taken
RY828	Fever control instruction
TB555	Blood culture
TB800	Wound culture
	Amoxicillin/clavulanate
	Amoxicillin
	Ampicillin
	Cefuroxime
	Cephalexin
	Cephadrine
	Ciprofloxacin
	Clindamycin
	Dicloxacillin
	Doxycycline
	Erythromycin
	Metronidazole
	Trimethoprim-sulfamethoxazole

^aHospital claims from delivery admission or any readmission within 30 days or emergency department claims. ICD-9 = International Classification of Diseases, 9th revision, clinical modification, 3rd edition.

Predictors of Infection

Univariate analysis and logistic regression were used to select predictors of infection by using data from the sample of records with full-text ambulatory medical record review. One thousand bootstrap samples of two-thirds of the data were then used to simulate the model's performance in a new setting. The models were tested with the remaining data, and measures of sensitivity, specificity, and predictive value positive were extrapolated to the entire cohort (9). Selection of the final model was based on predictive performance and stability of the regression coefficient estimates. A separate model was constructed by the same methods to specifically predict surgical site infections, including endometritis, among women who delivered by cesarean section.

Results

The study population consisted of 2,746 HPHC/HVMA members who underwent 2,301 vaginal deliveries and 525 cesarean sections. Ninety-five confirmed infections were identified among the random sample of 100 women who had at least one screening code and whose ambulatory medical records were reviewed, plus the additional 210 women identified by patient questionnaire results or inpatient surveillance. Extrapolation of the reviewed sample to the entire source population predicted a total of 169 infections, for an overall infection rate of 6.0% (95% confidence interval [CI] 5.1%, 6.9%). The extrapolated postpartum infection rates were 7.4% after cesarean section (95% CI 5.3%, 10.0%) and 5.5% (95% CI 4.6%, 6.5%) after vaginal delivery.

Among women undergoing cesarean section, the site-specific infection rates (number of infections/100 deliveries) were mastitis 1.7% (0.8%, 3.2%), urinary tract infection 1.1% (0.4%, 2.5%), surgical site infection (excluding endometritis) 3.4% (2.0%, 5.4%), and endometritis 0.8% (0.2%, 1.9%). Following vaginal delivery, the infection rates were mastitis 3.0% (2.4%, 3.8%), urinary tract infection 2.0% (1.4%, 2.6%), episiotomy site infection 0.3% (0.2%, 1.9%), and endometritis 0.2% (0.1%, 0.5%) (Figure 1).

Approximately 94% of these infections were detected after hospital discharge. For these post-discharge infections, 74% of patients did not return to the hospital where they delivered for evaluation or treatment.

Completeness of Surveillance

Four hundred ten (15%) of the 2,826 deliveries were associated with at least one automated screening code for postpartum infection. Screening codes identified 65 of the 71 patients who had verified postpartum infections identified by either inpatient surveillance or self-reported questionnaire results. Using for comparison the extrapolated number of postpartum infections among patients identified by automated code screening, plus all verified infections identified by either prospective inpatient surveillance or self-reported questionnaire screening, we determined the sensitivity of ambulatory code screening for identifying patients with postpartum infections to be 96% (95% CI 92%, 99%), specificity to be 99% (95% CI 99%, 100%), and predictive value positive to be 40% (95% CI 35%, 45%).

In comparison, both inpatient surveillance and self-reported questionnaires missed most postpartum infections, with sensitivities of 21% (95% CI 15%, 28%) and 25% (95% CI 19%, 32%), respectively. The sensitivity of inpatient sur-

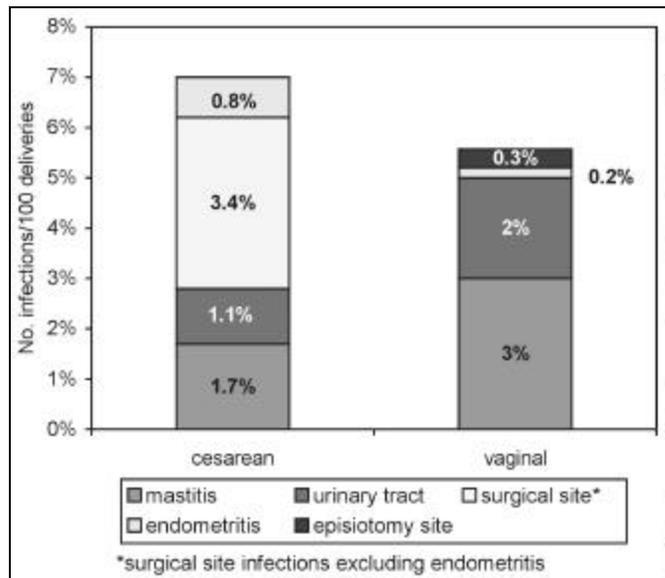


Figure 1. Extrapolated site-specific infection rates following vaginal and cesarean delivery.
*Surgical site infections, excluding endometritis

veillance for detecting infections diagnosed during the initial hospitalization or requiring readmission to the hospital, however, was 100%.

During the 30-day postpartum period, the 63 vaginal deliveries complicated by postpartum infection among women whose full-text ambulatory records were reviewed were associated with 14 emergency department visits, 106 scheduled visits, and 36 urgent-care visits. Of these ambulatory encounters, 9 (64%) emergency department visits, 44 (42%) scheduled visits, and 21 (58%) urgent-care visits could be verified as directly attributable to the postpartum infection. In addition, these infections resulted in 12 readmissions to the hospital and 85 nonappointment encounters, such as telephone calls or visits for laboratory tests. The 32 cesarean deliveries complicated by infection were associated with 10 emergency department visits, 102 scheduled visits, and 14 urgent-care visits. Of these ambulatory encounters, 8 (80%) emergency department visits, 74 (73%) scheduled visits and 12 (86%) urgent-care visits were directly attributable to the postpartum infection. These infections following cesarean section resulted in 8 readmissions to the hospital and 40 nonappointment encounters. The 74 postpartum infections that did not result in rehospitalization or emergency room visits were associated with 68% of postpartum infection-related ambulatory encounters.

Predictors of Infection

Important predictors of postpartum infection included rehospitalization within 30 days of delivery; cesarean versus vaginal delivery; dispensing of antistaphylococcal antibiotics (cephalexin, dicloxacillin, or both); diagnosis codes for mastitis, endometritis, and wound infection; and test codes for blood and wound microbiology cultures (Table 2). Cesarean section, although not statistically significant in this model, is included because it is a significant predictor of surgical site infection and endometritis. A cutoff probability of infection of ≥ 0.20 yielded an expected sensitivity of 87% (95% CI 72%, 94%), specificity of 97% (95% CI 96%, 98%), and predictive value

Research

Table 2. Predictors of postpartum infection used in the logistic regression models

Variable	Odds ratio	95% confidence interval
Model 1: Urinary tract infection, mastitis, surgical site infection or episiotomy site infection following cesarean or vaginal delivery		
Cesarean section	1.21	0.59-2.47
Antistaphylococcal antibiotics	1.89	1.02-3.53
Rehospitalization within 30 days of delivery	3.23	1.32-7.91
Ambulatory diagnosis code for mastitis, urinary tract infection, or endometritis	5.70	2.97-10.95
Ambulatory blood or wound culture	5.85	1.97-17.84
Hospital or emergency department diagnosis code for mastitis, urinary tract infection, or other obstetrical complications	*	
Model 2: Surgical site infections (including endometritis) following cesarean section		
Ambulatory blood or wound culture	9.17	2.44-34.41
Ambulatory diagnosis code for endometritis or wound infection	*	

*In the prediction model, any woman with one or more of these codes was given an automatic probability of infection of 1.0 to maintain stability of the model during bootstrap sampling.

positive of 55% (95% CI 41%, 68%). A cutoff probability of infection of ≥ 0.40 yielded an expected sensitivity of 73% (95% CI 59%, 84%), specificity of 98% (95% CI 98%, 99%), and predictive value positive of 64% (95% CI 52%, 77%) (Figure 2).

A separate model was constructed to predict surgical site infections among women who delivered by cesarean section. This model included as important predictors of surgical site infection ambulatory medical record test codes for blood and wound culture and diagnosis codes for endometritis and wound infection (Table 2). A cutoff probability of infection of ≥ 0.25 yielded an expected sensitivity of 78% (95% CI 60%, 100%), specificity of 88% (95% CI 0%, 97%), and predictive value positive of 75% (95% CI 23%, 92%). The stability of this model in the simulation analysis was limited by the small number of surgical site infections (22) among women who had full-text ambulatory record review and who delivered by cesarean section.

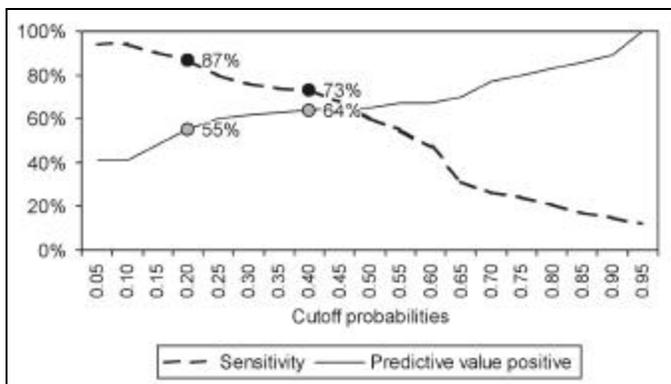


Figure 2. Sensitivities and predictive value positives of differing cutoff probabilities of infection based on 1,000 bootstrap samples. A cutoff probability of infection of ≥ 0.20 yielded a sensitivity of 87% and a predictive value positive of 55%. A cutoff probability of ≥ 0.40 yielded a sensitivity of 73% and a predictive value positive of 64%.

Conclusion

Accurate assessment of the epidemiology of postpartum infections has been hampered by the limitations of surveillance systems for identifying these infections, particularly infections detected after hospital discharge. In our study population, use of inpatient and ambulatory surveillance methods revealed that postpartum infections requiring medical attention were common following both vaginal delivery (5.5%) and cesarean section (7.4%). Mastitis and urinary tract infections accounted for $>80\%$ of these infections. The proportion of these infections directly attributable to health-care practices cannot be determined from the information available. Our study also does not address whether these infections were associated with modifiable (and therefore potentially avoidable) risk factors, for example, suboptimal administration of perioperative prophylaxis during cesarean section or bladder catheterization.

Nearly all postpartum infections became manifest after hospital discharge (94%). Furthermore, most (74%) of these postdischarge infections were diagnosed and treated entirely in the ambulatory setting without the patients' returning to the hospital where they delivered for evaluation or treatment, emphasizing the need for postdischarge surveillance methods that are not dependent on hospital-based data.

Automated screening of ambulatory records was a sensitive method for identifying postpartum infections. Inpatient surveillance missed most infections that were diagnosed and treated in the ambulatory setting. Patient self-reported questionnaire results had limited sensitivity for detecting infections, explained in part by the large number of nonresponders. The questionnaire method was also more resource-intensive than automated ambulatory code screening. It is unclear whether questionnaire responders were representative of the entire postpartum patient population.

Although surveillance based on automated screening of ambulatory records depends on availability of ambulatory

Research

diagnoses, tests, and pharmacy information, an increasing number of patients receive their health care through managed care organizations that routinely collect this information for administrative purposes. The specific diagnosis and test screening codes used for this study were based on a coding system unique to this HMO; however, similar information could be obtained by using an ICD-9-based outpatient claims database (International Classification of Diseases, 9th revision, clinical modification, 3rd edition). In principle, this method or a modification of it should be applicable for most of the U.S. population who have health insurance that includes pharmacy benefits. An additional limitation of this study is that the accuracy of the extrapolated infection rates depends upon the assumption that very few infections occur among postpartum women with none of the screening codes. This assumption is supported, however, by the finding that even among women identified as potentially infected through patient questionnaire results and inpatient surveillance, very few infections were confirmed through medical record review without at least one screening code.

In conclusion, our results indicate that postpartum infections requiring medical attention are common and that most postpartum infections occur after hospital discharge, so that use of routine inpatient surveillance methods alone will lead to underestimation of postpartum infection rates. Use of automated information routinely collected by HMOs and insurers allows efficient identification of women who are very likely to have postpartum infections that are not detected by conventional surveillance. Information resulting from more complete surveillance could be used to identify settings with unusually high or low infection rates to identify practices associated with lower infection rates. This information could then be used to focus, motivate, and assess the effectiveness of practice changes aimed at improving infection rates in all settings. Additional research is needed to evaluate the generalizability of this surveillance methodology to other health-care provider and insurer systems especially those that are entirely claims based, and to assess resource utilization associated with these infections.

This research was supported by the Harvard Pilgrim Health Care Foundation and the Eastern Massachusetts-Centers for Disease Control and Prevention Epicenter (UR8/CCU115079).

Dr. Yokoe is an associate physician and associate hospital epidemiologist at Brigham and Women's Hospital, hospital epidemiologist at the Dana-Farber Cancer Institute, and an assistant professor of medicine at Harvard Medical School. Her research interests focus on the epidemiology of nosocomial infections and use of automated data for surveillance.

References

1. Hulton LJ, Olmsted RN, Treston-Aurand J, Craig C. Effect of postdischarge surveillance on rates of infectious complications after cesarean section. *Am J Infect Control* 1992;20:198-201.
2. Holbrook KF, Nottebart VF, Hameed SR, Platt R. Automated postdischarge surveillance for postpartum and neonatal nosocomial infections. *Am J Med* 1991;91(suppl 3B):125S-130S.
3. Sands K, Vineyard G, Platt R. Surgical site infections occurring after hospital discharge. *J Infect Dis* 1996;173:963-70.
4. Platt R. [Studies of prescription drugs at] Harvard Community Health Plan. In: Strom B, editor. *Pharmacoepidemiology*, 2nd edition. New York: John Wiley and Sons; 1994. p. 278-87.
5. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections, 1998. *Am J Infect Control* 1988;16:128-40.
6. Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: A modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol* 1992;13:606-8.
7. Casella G, Berger RL. *Statistical inference*. Pacific Grove (CA): Wadsworth & Brooks; 1990:101-2.
8. Hirschhorn LR, Currier JS, Platt R. Electronic surveillance of antibiotic exposure and coded discharge diagnoses as indicators of postoperative infection and other quality assurance measures. *Infect Control Hosp Epidemiol* 1993;14:21-8.
9. Carpenter J, Bithell J. Bootstrap confidence intervals: when, which, what? A practical guide for medical statisticians. *Stats Med* 2000;19:1141-64.