American Journal of Infection Control ■■ (2016) ■■-■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Incidence and risk factors for surgical site infection post-hysterectomy in a tertiary care center

Aurora Pop-Vicas MD, MPH [a,*], Jackson S. Musuuza MBChB, MPH [b], Michelle Schmitz CIC [c], Ahmed Al-Niaimi MD [d], Nasia Safdar MD, PhD [a,c,e]

[a] Department of Medicine, University of Wisconsin School of Medicine and Public Health, Madison, WI
[b] Institute of Clinical and Translational Research, University of Wisconsin, Madison, WI
[c] Department of Infection Control, University of Wisconsin Hospital and Clinics, Madison, WI
[d] Department of Obstetrics and Gynecology, University of Wisconsin School of Medicine and Public Health, Madison, WI
[e] Department of Medicine, William S. Middleton Memorial Veterans Hospital, Madison, WI

Key Words:
Post-surgical infection
Predictors

Background: Preoperative antibiotic prophylaxis and surgical technological advances have greatly reduced, but not totally eliminated surgical site infection (SSI) posthysterectomy. We aimed to identify risk factors for SSI posthysterectomy among women with a high prevalence of gynecologic malignancies, in a tertiary care setting where compliance with the Joint Commission's Surgical Care Improvement Project core measures is excellent.

Methods: The study was a matched case–control, 2 controls per case, matched on date of surgery. Study time was January 2, 2012-December 31, 2015. Procedures included abdominal and vaginal hysterectomies (open, laparoscopic, and robotic). SSI (superficial incisional or deep/organ/space) was defined as within 30 days postoperatively, per Centers for Disease Control and Prevention criteria. Statistical analysis included bivariate analysis and conditional logistic regression controlling for demographic and clinical variables, both patient-related and surgery-related, including detailed prophylactic antibiotic exposure.

Results: Of the total 1,531 hysterectomies performed, we identified 52 SSIs (3%), with 60% being deep incisional or organ/space infections. All case patients received appropriate preoperative antibiotics (timing, choice, and weight-based dosing). Bivariate analysis showed that higher median weight, higher median Charlson comorbidity index, immune suppressed state, American Society of Anesthesiologists score ≥ 3, prior surgery within 60 days, clindamycin/gentamicin prophylaxis, surgery involving the omentum or gastrointestinal tract, longer surgery duration, ≥4 surgeons present in the operating room, higher median blood loss, ≥7 catheters or invasive devices in the operating room, and higher median length of hospital stay increased SSI risk ($P < .05$ for all). Cefazolin preoperative prophylaxis, robot-assisted surgery, and laparoscopic surgery were protective ($P < .05$ for all). Duration of surgery was the only independent risk factor for SSI identified on multivariate analysis (odds ratio, 3.45; 95% confidence interval, 1.21-9.76; $P = .02$).

Conclusions: In our population of women with multimorbidity and hysterectomies largely due to underlying gynecologic malignancies, duration of surgery, presumed a marker of surgical complexity, is a significant SSI risk factor. The choice of preoperative antibiotic did not alter SSI risk in our study.

Surgical site infections (SSIs) are the most frequent health-care associated infections,[1] and are associated with significant morbidity, prolonged hospital stays, and increased health-care costs.[2-4] Hysterectomy is a common major surgery in the United States; up to 4% of the approximately 433,000 hysterectomies performed annually may be complicated by SSI.[5]

Preventing SSI posthysterectomy is a major focus for quality improvement across the hospital setting. Posthysterectomy SSI is a metric tied to hospitals' ranking and financial penalties because it is included in the Centers for Medicare and Medicaid Services calculations for the Hospital-Acquired Condition Reduction Program. Most institutions have taken considerable steps toward SSI prevention. Compliance with the Joint Commission's Surgical Care

* Address correspondence to Aurora Pop-Vicas, MD, MPH, Division of Infectious Disease, University of Wisconsin School of Medicine and Public Health, 1685 Highland Ave, 5th Fl, Madison, WI 53705.
E-mail address: popvicas@medicine.wisc.edu (A. Pop-Vicas).
Conflicts of interest: None to report.

0196-6553/© 2016 Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.ajic.2016.10.008

Improvement Project core measures, with particular attention to preoperative antibiotic choice and timing, is high.[6] Despite these efforts, SSIs are not eliminated, and, in fact, the SSI reduction seems to be more modest than hoped.[7-9] Patients undergoing hysterectomies as part of complex surgical and medical treatments for advanced gynecologic malignancies, for example, might pose additional challenges. In this context, we aimed to study a population of women undergoing hysterectomies at a large, university-affiliated tertiary care center in an effort to identify additional, potentially modifiable SSI risk factors.

METHODS

Study design and population

We performed a matched case–control study of women aged ≥18 years undergoing hysterectomy (abdominal, vaginal, laparoscopic, or robotic-assisted) at University of Wisconsin Hospitals between January 1, 2012, and December 31, 2015. The study was conducted as part of a larger quality improvement initiative aimed at reducing posthysterectomy SSI, and thus met criteria for exempt status by the University of Wisconsin Institutional Review Board.

Definitions

Cases were defined as women diagnosed with SSI within 30 days posthysterectomy, and were identified through the hospital's active surveillance system for nosocomial infections. For each case, 2 controls were chosen from women undergoing hysterectomy on the same day, or chronologically as close as possible to the same day of surgery as the cases, who did not develop SSI. For days with more than 3 hysterectomies per day, procedures were chosen randomly from various times of the day. We defined SSI within 30 days of surgery as superficial, deep, or organ space infections according to the Centers for Disease Control and Prevention criteria.[10]

Data collection

We collected demographic and clinical variables, both patient-related and surgery-related, including detailed information on timing, choice, and weight-based dosing and/or redosing of preoperative antibiotics. Our institution follows Infectious Disease Society of America guidelines for weight-based dosing and intraoperative interval redosing of preoperative antimicrobial agents.[11]

Statistical analysis

For bivariate analyses, we used the χ^2 test for categorical variables, the Student *t* test for continuous variables, and the Wilcoxon and Mann-Whitney tests for nonparametric distributions. To identify independent risk factors for posthysterectomy SSI, we included variables found to be statistically significant on crude analysis ($P \leq .05$) into a conditional logistic regression model. All analyses were performed using Stata version 14.1 SE for Windows (StataCorp, College Station, TX).

RESULTS

Among the 1,531 hysterectomies performed during the study period, a total of 52 (3.4%) were complicated by an SSI. Of these, 31 (60%) were classified as deep incisional or organ/space infection. The majority (40%) were polymicrobial, with mixed aerobic and anaerobic flora, followed by infection with gram-negative bacilli (14%). Table 1 presents SSI details related to type of surgery and organisms recovered in clinical cultures.

Table 1
Surgical site infections (SSIs) by type of surgery and organisms recovered in clinical cultures

Type of surgery	n (%)	SSI incidence n (%)
Open abdominal*	67 (43)	34 (65)
Robot-assisted	9 (13)	
Laparoscopic	87 (56)	17 (33)
Robot-assisted	46 (53)	
Vaginal	2 (1)	1 (2)
Total	156 (100)	52 (100)
SSI organisms recovered		
Mixed aerobes and anaerobes	21 (40)	
Escherichia coli	6 (12)	
Coagulase negative *staphylococcus*	4 (8)	
Methicillin-resistant *Staphylococcus aureus*	3 (5)	
Anaerobes	2 (4)	
Streptococcus agalactiae	1 (2	
Pseudomonas spp	1 (2)	
No organism recovered†	14 (27)	
Total	52 (100)	

*Includes 3 laparoscopic and 2 robot-assisted surgeries converted to open abdominal hysterectomies.
†Cultures not obtained, or showed no growth, likely due to previous receipt of broad-spectrum antibiotics.

All patients (cases and controls) received antimicrobial prophylaxis within 60 minutes of incision. The most common antibiotics received were cefazolin (49%), cefoxitin (30%), and clindamycin plus gentamicin (17%). All preoperative antibiotics were appropriately dosed according to the patient's weight, although the opportunity for intraoperative redosing was missed in 25 of the 68 patients (37%) where this would have been appropriate. There was no significant difference between cases and controls in regard to missed antibiotic intraoperative redosing opportunities.

Demographic and clinical variables, both patient-related and surgery-related, that were significantly associated with posthysterectomy SSI on bivariate analysis are presented in Table 2. On multivariate analysis, duration of surgery was the only independent risk factor associated with posthysterectomy SSI in our study (odds ratio, 3.5; 95% confidence interval, 1.2-9.8; $P = .02$) (Table 3). Duration of surgery was significantly higher in patients undergoing hysterectomy due to underlying malignancy ($P = .0136$), in surgical procedures involving the bowel ($P < .001$), in procedures requiring ≥4 surgeons ($P < .001$), and in patients requiring placement of ≥7 invasive devices intraoperatively. Laparoscopic surgeries were associated with a shorter duration of surgery ($P < .001$).

DISCUSSION

We found that surgical duration was the only independent factor associated with SSI in our study. Data exploring the association between hysterectomy duration and postoperative infection risk are sparse, with 1 previous retrospective, multicenter study finding a marginal association.[12] However, duration of surgery is a well-recognized risk factor for SSI, and is in fact included in the National Nosocomial Infection Surveillance risk index, which is widely used to stratify SSI surveillance data by risk[13] and for benchmark comparisons of SSI rates.[14] Previous studies of surgeries other than hysterectomies have also identified duration of surgery as an important risk factor for SSI.[15-17] Laparoscopic surgeries in our study had a shorter duration, and were associated with less SSI risk on bivariate analysis. Although this association was not maintained in our multivariate analysis, previous retrospective studies for patients undergoing hysterectomies have found robot-assisted and laparoscopic surgeries to have significantly lower SSI risks than open abdominal approaches.[18,19]

Table 2
Bivariate analysis of cases and controls by patient, surgical, and prophylactic antibiotic characteristics

Characteristic	Cases (n=52)	Controls (n=104)	Odds ratio (95% confidence interval)	*P* value
Patient characteristics				
Age, y	57.6 (11.8)	58.6 (12.6)		.64
Weight	101.4	79.4		.0260
Charlson comorbidity index, median	3	2		.0004
Immunosuppressed state	9 (17)	3 (3)	7.0 (1.6-41.8)	.0014
Underlying cancer	42 (81)	69 (66)	2.1 (0.9-5.3)	.06
ASA ≥ 3	26 (50)	25 (24)	3.2 (1.5-6.8)	.001
Smoking status				
Never smoker	24 (47)	58 (57)	Reference category	
Former smoker	20 (39)	31 (30)	1.6 (0.7-3.5)	.3
Current smoker	7 (14)	13 (13)	1.3 (0.4-4.0)	.6
Prior procedure within 60 d	18 (35)	13 (13)	3.7 (1.5-9.1)	.001
Surgical characteristics				
Robotic assisted surgery	11 (21)	44 (42)	0.4 (0.2-0.8)	.009
Laparoscopic surgery	17 (33)	71 (68)	0.2 (0.1-0.5)	<.001
Omentum or gastrointestinal involvement	31 (60)	23 (22)	5.1 (2.3-11.3)	<.001
Preoperative hair clipped	28 (54)	62 (60)	0.8 (0.4-1.6)	.5
Intraoperative skin prep*				
Chloraprep	38 (73)	72 (63)	1.2 (0.6-2.8)	.6
Chlorhexidine	31 (60)	64 (62)	0.9 (0.4-1.9)	.8
Povidone-iodine	20 (38)	38 (37)	1.1 (0.5-2.3)	.8
DuraPrep	11 (21)	30 (29)	0.7 (0.3-1.5)	.3
Surgery duration, h	3.47	2.65		<.001
≥4 Surgeons present	17 (33)	15 (14)	2.9 (1.2-6.9)	.008
Estimated blood loss, median	350	150		.0003
≥7 Catheters/invasive devices	17 (33)	10 (9)	4.6 (1.8-12.2)	.0003
Length of hospital stay, median	4	2		<.001
Preoperative antibiotic				
Cefazolin	20 (38)	57 (55)	0.5 (0.2-1.0)	.047
Cefoxitin	16 (31)	30 (29)	1.1 (0.5-2.4)	.8
Clindamycin/gentamicin	14 (27)	13 (13)	2.6 (1.0-6.5)	.026
Antianaerobic spectrum	30 (58)	46 (45)	1.7 (0.8-3.5)	.125
Antibiotic redosing missed‡	7 (13)	17 (16)	0.8 (0.3-2.2)	.6

NOTE. Values are presented as n (%) or median.
ASA, American Society of Anesthesiologists physical status classification.
*Most patients had > 1 product (ie, Chloraprep [Becton Dickinson and Company, Franklin Lakes, NJ] and chlorhexidine). DuraPrep; 3M Company, Maplewood, MN.
‡Redosing interval recommended: 4 hours for cefazolin, 2 hours for cefoxitin, 4 hours for cefuroxime, and 6 hours for clindamycin, if surgery still in process.[11]

Table 3
Multivariate analysis of cases and controls*

Characteristic	Adjusted odds ratio (95% confidence intervals)	*P* value
Duration of surgery	3.5 (1.2-9.8)	.02

*Adjusted for risk factors found significant ($P < .5$) on bivariate analysis, which were entered into conditional logistic regression.

The underlying assumption is that the potential for pathogen contamination increases with the length of exposure during open incision. In support of this hypothesis comes recent data suggesting that the contamination of surgeons' gloved hands after 5 hours of operating time reaches or exceeds prescrub levels.[20] In addition, the effective concentration of the prophylactic antibiotics decreases over time,[21,22] necessitating intraoperative redosing for prolonged procedures.[23] This infection prevention step was missed in more than one-third of our study patients, and previous studies have also identified intraoperative redosing of prophylactic antibiotics as a significant opportunity for improvement.[24-26]

Most hysterectomies in our study lasted longer than 120 minutes, which is the 75th percentile T time established by National Nosocomial Infection Surveillance as the cutoff for SSI risk in hysterectomies.[13] Given the association between surgical duration and underlying malignancy, bowel involvement, increased number of surgeons, and increased number of invasive devices needed during the procedure, we believe that duration of surgery was a surrogate marker of surgical complexity and patient risk in our study. Although a patient's underlying comorbidities are not modifiable, further research investigating techniques and modalities to reduce duration of surgery for very complex procedures may be useful.

Our study did not find a significant association between the type of prophylactic antibiotic administered and SSI risk, but our sample size may have been too small to detect a significant difference. Most of the older hysterectomy literature exploring the effect of different antibiotics on SSI risk did not find a clearly superior choice, and most guidelines recommend a variety of antibiotics as equally effective for antibiotic prophylaxis in hysterectomy.[27,28] However, a recent large, retrospective multicenter cohort study found β-lactams preferable to non–β-lactam combinations in SSI prevention for women undergoing hysterectomy,[29] suggesting that further research is needed to study this issue.

Our study has several limitations. Being retrospective in nature, it is likely to have the inherent biases associated with this study design. In addition, we did not have data on the maintenance of normothermia and normoglycemia, which have been found to be important factors in SSI prevention.[30,31] Lastly, our study reflects the experience of a single university center, and may not be generalizable to other institutions and settings.

CONCLUSIONS

In an era of excellent compliance with preoperative antibiotic prophylaxis, duration of surgery remains an important risk factor for SSI in hysterectomy. We need further research to determine the extent to which operation time can be reduced for women with gynecologic malignancies undergoing complex surgical procedures.

References

1. Magill SS, Edwards JR, Bamberg W, Beldavs ZG, Dumyati G, Kainer MA, et al. Multistate point-prevalence survey of health care-associated infections. N Engl J Med 2014;370:1198-208.
2. Poulsen KB, Bremmelgaard A, Sørensen AI, Raahave D, Petersen JV. Estimated costs of postoperative wound infections. A case-control study of marginal hospital and social security costs. Epidemiol Infect 1994;113:283-95.
3. Schweizer ML, Cullen JJ, Perencevich EN, Vaughan Sarrazin MS. Costs associated with surgical site infections in Veterans Affairs Hospitals. JAMA Surg 2014;149:575-81.
4. Roy S, Patkar A, Daskiran M, Levine R, Hinoul P, Nigam S. Clinical and economic burden of surgical site infection in hysterectomy. Surg Infect (Larchmt) 2014;15:266-73.
5. Wright JD, Herzog TJ, Tsui J, Ananth CV, Lewin SN, Lu YS, et al. Nationwide trends in the performance of inpatient hysterectomy in the United States. Obstet Gynecol 2013;122(2 Pt 1):233-41.
6. Cataife G, Weinberg DA, Wong HH, Kahn KL. The effect of Surgical Care Improvement Project (SCIP) compliance on surgical site infections (SSI). Med Care 2014;52(2 Suppl 1):S66-73.
7. Munday GS, Deveaux P, Roberts H, Fry DE, Polk HC. Impact of implementation of the Surgical Care Improvement Project and future strategies for improving quality in surgery. Am J Surg 2014;208:835-40.
8. Weston A, Caldera K, Doron S. Surgical care improvement project in the value-based purchasing era: more harm than good? Clin Infect Dis 2013;56:424-7.
9. Awad SS. Adherence to surgical care improvement project measures and post-operative surgical site infections. Surg Infect (Larchmt) 2012;13:234-7.
10. 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.
11. Bratzler DW, Dellinger EP, Olsen KM, Perl TM, Auwaerter PG, Bolon MK, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Am J Health Syst Pharm 2013;70:195-283.
12. Olsen MA, Higham-Kessler J, Yokoe DS, Butler AM, Vostok J, Stevenson KB, et al. Developing a risk stratification model for surgical site infection after abdominal hysterectomy. Infect Control Hosp Epidemiol 2009;30:1077-83.
13. Culver DH, Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG, et al. Surgical wound infection rates by wound class, operative procedure, and patient risk index. National Nosocomial Infections Surveillance System. Am J Med 1991;91(3B):152S-157S.
14. Gaynes RP, Culver DH, Horan TC, Edwards JR, Richards C, Tolson JS. Surgical site infection (SSI) rates in the United States, 1992-1998: the National Nosocomial Infections Surveillance System basic SSI risk index. Clin Infect Dis 2001;33(Suppl 2):S69-77.
15. Procter LD, Davenport DL, Bernard AC, Zwischenberger JB. General surgical operative duration is associated with increased risk-adjusted infectious complication rates and length of hospital stay. J Am Coll Surg 2010;210:60-5 e1-2.
16. Golebiowski A, Drewes C, Gulati S, Jakola AS, Solheim O. Is duration of surgery a risk factor for extracranial complications and surgical site infections after intracranial tumor operations? Acta Neurochir (Wien) 2015;157:235-40, discussion 240.
17. Leong G, Wilson J, Charlett A. Duration of operation as a risk factor for surgical site infection: comparison of English and US data. J Hosp Infect 2006;63:255-62.
18. Colling KP, Glover JK, Statz CA, Geller MA, Beilman GJ. Abdominal hysterectomy: reduced risk of surgical site infection associated with robotic and laparoscopic technique. Surg Infect (Larchmt) 2015;16:498-503.
19. Mahdi H, Goodrich S, Lockhart D, DeBernardo R, Moslemi-Kebria M. Predictors of surgical site infection in women undergoing hysterectomy for benign gynecologic disease: a multicenter analysis using the national surgical quality improvement program data. J Minim Invasive Gynecol 2014;21:901-9.
20. Hosseini P, Mundis GM Jr, Eastlack R, Nourian A, Pawelek J, Nguyen S, et al. Do longer surgical procedures result in greater contamination of surgeons' hands? Clin Orthop Relat Res 2016.
21. Koopman E, Nix DE, Erstad BL, Demeure MJ, Hayes MM, Ruth JT, et al. End-of-procedure cefazolin concentrations after administration for prevention of surgical-site infection. Am J Health Syst Pharm 2007;64:1927-34.
22. Ohge H, Takesue Y, Yokoyama T, Murakami Y, Hiyama E, Yokoyama Y, et al. An additional dose of cefazolin for intraoperative prophylaxis. Surg Today 1999;29:1233-6.
23. Scher KS. Studies on the duration of antibiotic administration for surgical prophylaxis. Am Surg 1997;63:59-62.
24. Goede WJ, Lovely JK, Thompson RL, Cima RR. Assessment of prophylactic antibiotic use in patients with surgical site infections. Hosp Pharm 2013;48:560-7.
25. Riggi G, Castillo M, Fernandez M, Wawrzyniak A, Vigoda M, Eber S, et al. Improving compliance with timely intraoperative redosing of antimicrobials in surgical prophylaxis. Infect Control Hosp Epidemiol 2014;35:1236-40.
26. Steinberg JP, Braun BI, Hellinger WC, Kusek L, Bozikis MR, Bush AJ, et al. Timing of antimicrobial prophylaxis and the risk of surgical site infections: results from the Trial to Reduce Antimicrobial Prophylaxis Errors. Ann Surg 2009;250:10-6.
27. Bratzler DW, Dellinger EP, Olsen KM, Perl TM, Auwaerter PG, Bolon MK, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Surg Infect (Larchmt) 2013;14:73-156.
28. ACOG Committee on Practice Bulletins—Gynecology. ACOG Practice Bulletin No. 104: antibiotic prophylaxis for gynecological procedures. Obstet Gynecol 2009;113:1180-9.
29. Uppal S, Harris J, Al-Niaimi A, Swenson CW, Pearlman MD, Reynolds RK, et al. Prophylactic antibiotic choice and risk of surgical site infection after hysterectomy. Obstet Gynecol 2016;127:321-9.
30. Madrid E, Urrútia G, Roqué i Figuls M, Pardo-Hernandez H, Campos JM, Paniagua P, et al. Active body surface warming systems for preventing complications caused by inadvertent perioperative hypothermia in adults. Cochrane Database Syst Rev 2016;(4):CD009016.
31. Boreland L, Scott-Hudson M, Hetherington K, Frussinetty A, Slyer JT. The effectiveness of tight glycemic control on decreasing surgical site infections and readmission rates in adult patients with diabetes undergoing cardiac surgery: a systematic review. Heart Lung 2015;44:430-40.