HOSPITAL-RELATED DETERMINANTS FOR SURGICAL-SITE INFECTION FOLLOWING HIP ARTHROPLASTY

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ABSTRACT

OBJECTIVE: To determine hospital-related risk factors for surgical-site infection (SSI) following hip arthroplasty.

DESIGN: Prospective, multicenter cohort study based on surveillance data and data collected through a structured telephone interview. With the use of multilevel logistic regression, the independent effect of hospital-related characteristics on SSI was assessed.

SETTING: Thirty-six acute care hospitals in the Dutch surveillance network for nosocomial infections (PREZIES), from 1996 to 2000.

PATIENTS: Thirteen thousand six hundred eighty patients who underwent total or partial hip arthroplasty.

RESULTS: A high annual volume of operations was as-sociated with a reduced risk of SSI (risk-adjusted risk ratio [RR] per 50 extra operations, 0.85; 95% confidence interval [CI_{95}], 0.74–0.97). With each extra full-time–equivalent infection control staff member per 250 beds available for prevention of SSI, the risk for SSI was decreased (RR, 0.48; CI_{95}, 0.16–1.44), al-though the decrease was not statistically significant. Hospital size, teaching status, university affiliation, and number of sur-geons and their years of experience showed no important as-sociation with the risk of SSI.

CONCLUSION: Undergoing surgery in a hospital with a low volume of operations increases a patient's risk of SSI (*Infect Control Hosp Epidemiol* 2005;26:435-441).

Surgical-site infections (SSIs) are a common complica-tion of surgery and occur after both clean and contaminated procedures.[1] They prolong the hospital stay on average by 8 days, double the risk of death, and are associated with a five-fold higher risk of readmission.[2] Insight into variables that in-fluence the risk of SSI is important for two reasons.

First, they can indicate how or in which patient populations a reduction in SSI risk might be achieved. For example, because preoperative shaving is asso-ciated with a higher risk of SSI, abolishment of this practice may prevent SSI.[3] Likewise, because patients with remote infections are at increased risk of SSI,

these infections are best treated before surgery is per-formed.[3]

Second, knowledge about risk factors for SSI is need-ed to compare the incidence of SSI among surgeons and among hospitals or, in time, to detect potential quality prob-lems in preoperative, perioperative, or postoperative care.[4-6] For the comparison of SSI rates to provide insight into dif-ferences in quality of care, these rates must be adjusted for the patient's intrinsic, or nonmodifiable, risk of SSI.

Many authors have investigated the relative impor-tance of patient-related and procedure-related characteris-tics,[7] and several risk indices have been constructed to adjust

for intrinsic patient or procedure risk.[4] Some authors also have reported hospital-related or surgeon-related characteristics to be associated with SSI or other nosocomial infections. Examples are size and teaching status of the hospital, the annual number of operations performed in the hospital or by a surgeon, the experience of the surgeon, the amount of personnel available for prevention of infection, and feedback of surgeon-specific infection rates.[8-12] It is often unclear, however, whether these factors are associated with SSI independent of patient-related and procedure-related characteristics or other hospital-related characteristics. Except for the Study on the Efficacy of Nosocomial Infection Control (SENIC) performed in the 1970s,[8] the majority of these studies either were based on only one or a few hospitals or did not provide detailed information suitable for adjustment for patient-related, procedure-related, and other hospital-related factors. The Dutch Network for Prevention of Nosocomial Infections Through Surveillance (PREZIES) does provide these data.[1] Since its start in 1996, approximately 60% of all Dutch hospitals providing surgical services have participated in the network, which is coordinated by the Dutch Institute for Healthcare Improvement CBO and the National Institute of Public Health and the Environment. In this cohort study, conducted in the PREZIES network, we aimed to determine whether there was an independent association between hospital-related factors and the risk of SSI.

METHODS
Setting

This study was performed within the Dutch PREZIES surveillance network for SSI. Participation in this network is open to all hospitals in the country that provide surgical services. Hospitals were invited to take part in this study in June 1996. Data regarding operations were collected prospectively from January 1, 1996, through December 31, 2000. Data from the first half of 1996 came from the pilot study of the PREZIES network, but methods for data collection remained the same throughout the study period. Data regarding hospital-related determinants were collected during a single, structured telephone interview of personnel at each participating hospital. The Netherlands has a healthcare system in which patients are usually seen first by their own general practitioner, who can refer them for specialized treatment (eg, elective surgery) in the hospital. Casualties present directly to the hospital. The majority of Dutch hospitals are government-owned general hospitals that provide a broad range of clinical specialties such as surgery (general, orthopedic, eye, or ear, nose, and throat), obstetrics and gynecology, pediatrics, internal medicine, accident and emergency medicine, and all supporting diagnostic disciplines. The sizes of the hospitals ranged from 60 to 1,307 beds; 70% had more than 300 beds. Approximately 60% of all hospitals that provide surgical services in the Netherlands have participated in the PREZIES network. These include university-affiliated teaching hospitals, regional teaching hospitals, and non-teaching hospitals from all over the country. Large hospitals (> 600 beds) are slightly overrepresented.

The surveillance methods of the PREZIES network have been described previously.[1] Infection control professionals in hospitals performed active, prospective, in-hospital surveillance, according to a standardized protocol, using the Centers for Disease Control and Prevention definitions for SSI.[13,14] According to these criteria, an SSI is defined as nosocomial if it occurs within 30 days postoperatively. If a prosthetic device is implanted, this period is extended to 1 year postoperatively. Data were entered into computer software in the hospitals and sent to the national center, where they were analyzed. Regular feedback reports were sent to the hospitals. Participation of hospitals in the PREZIES network is voluntary and confidential and can start at any time. Hospitals in the PREZIES network are free to choose the types of procedures included in the surveillance. This allows them to tailor the national surveillance system to their own needs. To ensure meaningful comparison with other hospitals' rates, the feedback they receive is procedure specific.

Study Population

To provide enough power to determine the independent association of hospital-related factors with the risk of SSI, the study was limited to the procedure that was most commonly included, which was hip arthroplasty (both total hip replacements and replacements of the head of the femur). Hospitals were excluded if they had not included hip arthroplasties in their surveillance system or had stopped performing surveillance before January 1, 1999. Forty-nine hospitals met the inclusion criteria, and 36 agreed to participate in the study (73.5%) providing data from 1996 through 2000. Ten hospitals declined because of lack of time, two because they had stopped collecting surveillance data at the time of the invitation, and one because its surgeons refused. These 36 hospitals collected data on 13,680 operations, after which 458 SSIs occurred.

Data Collection

Data about possible hospital-related determinants of SSI were collected during the first trimester of 2000 through structured telephone interviews with the infection control professional responsible for SSI surveillance. The interview contained questions about the number of beds, university affiliation, annual volume of operations per selected procedure, and total number of full-time–equivalent infection control staff available and number available for the prevention of SSI specifically. Information was collected about teaching status, whether residents in teaching hospitals were allowed to perform the selected procedures without supervision, and the number of orthopedic surgeons and their years of experience. From the latter, the median number of years of surgeon experience was calculated for each of the departments. These data about hospital-related characteristics were taken as a proxy for their values during the whole study period.

Data about possible patient-related and procedure-related confounders for the association between hospital-related determinants and SSI were collected prospectively

by the infection control professional for each patient under surveillance. These possible confounders were age, American Society of Anesthesiologists score,[15] wound contamination class,[16] duration of preoperative stay in the hospital, type of procedure, duration of surgery, and whether the surgery was elective or emergent. Postdischarge surveillance was performed with the use of a registration card to be completed for each patient by the surgeon. Complementary postdischarge chart review by the infection control professional was recommended but not required. However, because use of postdischarge surveillance was found to not influence the relative risk of infection associated with size, teaching status, annual volume of surgery, or other hospital characteristics (Appendix), we did not include it as a confounder in the analysis. Teaching status was considered a possible confounder for all determinants except university affiliation. The number of surgeons was regarded as a potential confounding factor for the annual volume of operations and for the surgeons' median number of years of experience. The total number of infection control staff was considered a possible predictor of the prevention of SSI.

Data Analysis

We generated box-and-whisker plots to describe the distribution of hospitals' SSI rates for the two procedures. The boxes present the average and mean of all hospital rates plus the 25th and 75th percentiles. Whiskers extend to the maximum and minimum SSI rates.

To determine the association of hospital-related factors with SSI adjusted for confounding, the hierarchical structure of the data had to be taken into account. From a statistical point of view, operations can be regarded as first-level units of observation that are clustered within the second-level units, hospitals. Therefore, we applied multilevel modeling to assess both the crude and the adjusted association of hospital-related factors with the occurrence of SSI. We used MLWiN software (release 1.10.0006; Multilevel Models Project, Institute of Education, University of London, London, United Kingdom) for the multilevel modeling and SAS software (release 6.12 for Windows; SAS Institute, Inc., Cary, NC) for all other analyses.

The following strategy was used.[17] Crude risk ratios (RRs) and 95% confidence intervals (CI_{95}) were calculated for all eight potential determinants with multilevel logistic regression. For determinants that were measured at a procedure-specific level (eg, annual volume of operations), these crude models also included variables indicating the type of procedure. The adjusted association was then assessed by stepwise inclusion of possible confounders (ie, patient-related and procedure-related characteristics and, depending on the determinant, hospital-related characteristics). A factor was considered a confounder if it changed the estimate of the determinant by more than 10% of its last value. The maximum number of hospital-related variables to be included in a model was restricted to four because of the limited number of hospitals in the study. For the comparison of the goodness of fit of two consecutive models, the Wald test was used.[18]
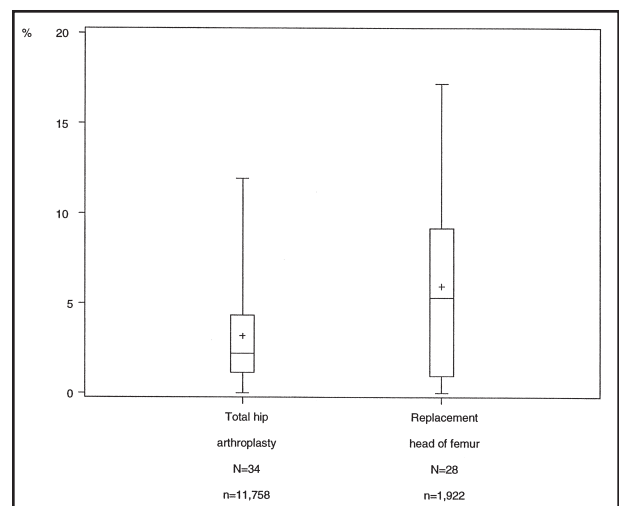

FIGURE. Box-and-whisker plots of the distribution of hospitals' surgical-site infection (SSI) rates per type of procedure. N = number of hospitals; n = number of operations; line inside of the box = median SSI rate; + = mean; upper and lower edges of the box = 75th and 25th percentiles, respectively; and whiskers = maximum and minimum SSI rates.

RESULTS

Incidence of SSI and Description of the Population

The distribution of hospital SSI rates per type of procedure is presented in the figure. The median of the hospitals' infection rates was 2.2% for total hip arthroplasties and 5.3% for replacements of the head of the femur. One-fifth of all infections were detected after discharge. Table 1 lists the patient-related and procedure-related characteristics for these operations. As could be expected for these procedures, the majority of patients were relatively healthy, and few were admitted to the hospital for more than 3 days preoperatively. The procedure characteristics revealed that the selected operations were primarily clean and elective. The distribution of hospital-related determinants is presented in Table 2. Approximately half of the hospitals were of intermediate size (300 to 600 beds). Approximately half were also teaching hospitals, but most were not affiliated with a university. The number of surgeons, their median number of years of experience, and the annual volume of operations showed wide variation between hospitals. As a median, almost 1 full-time–equivalent employee per 250 beds was available for infection control and prevention, of which one-sixth was devoted to SSIs, but these figures also varied substantially among the hospitals.

Risk Factors Associated With SSI

The results of the multilevel logistic modeling are presented in Table 3. RRs with CI_{95} are given for both the crude and the adjusted association of each hospital-related determinant with SSI.

Undergoing a hip arthroplasty in a hospital with a higher annual volume of operations was the only studied

TABLE 1
PATIENT AND PROCEDURE CHARACTERISTICS FOR 13,680 HIP ARTHROPLASTIES PERFORMED IN 36 HOSPITALS

Characteristic	% of Operations*
Patients	
Age, y	
< 45	2.2
45 to 64	23.4
65 to 74	36.0
≥ 75	38.3
No severe systemic underlying disease (ASA score, 1 to 2)	79.9
Severe systemic underlying disease (ASA score, 3 to 5)	14.7
Severe systemic underlying disease not reported	5.5
Preoperative hospital stay, 1 to 2 d	93.5
Preoperative hospital stay, ≥ 3 d	6.5
Postdischarge surveillance according to recommended method	31.8
Postdischarge surveillance according to other method	25.8
No postdischarge surveillance performed	39.7
Postdischarge surveillance performance not reported	2.7
Procedures	
Replacement of head of femur	14.1
Total hip prosthesis	86.0
Clean or clean-contaminated surgery (wound class, 1 to 2)	99.2
Contaminated or dirty or infected surgery (wound class, 3 to 4)	0.3
Wound class not reported	0.5
Duration of surgery ≤ procedure-specific 75th percentile[†]	74.9
Duration of surgery > procedure-specific 75th percentile[†]	24.7
Duration of surgery not reported	0.4
Planned surgery	89.9
Emergency surgery	10.1
Type of surgery not reported	0.1

ASA = American Society of Anesthesiologists.
*Percentages have been rounded and may not always add up to 100%.
[†]Ninety minutes for replacement of head of femur and 105 minutes for total hip prosthesis.

variable associated with a significantly reduced risk of SSI (RR per 50 extra operations, 0.85; CI$_{95}$, 0.74 to 0.97). Hospital size, university affiliation, and the number of surgeons and their number of years of experience did not greatly influence the risk for SSI.

TABLE 2
DISTRIBUTION OF CATEGORICAL AND CONTINUOUS HOSPITAL-RELATED VARIABLES FOR 36 HOSPITALS PERFORMING HIP ARTHROPLASTY

Hospital-Related Determinant	No. (%) of Hospitals	Median (10th Percentile, 90th Percentile)
No. of beds		
< 300	10 (27.8)	
300 to 600	17 (47.2)	
> 600	9 (25.0)	
Non–university-affiliated hospital	33 (91.7)	
University-affiliated hospital	3 (8.3)	
Non-teaching hospital	19 (52.8)	
Teaching hospital, residents allowed to operate unsupervised	2 (5.5)	
Teaching hospital, residents not allowed to operate unsupervised	15 (41.7)	
Annual volume of operations		
Replacement of head of femur		35 (14, 65)
Total hip prosthesis		131 (52, 303)
Full-time–equivalent employees per 250 beds for prevention and control of infection		0.93 (0.64, 1.46)
Full-time–equivalent employees per 250 beds for prevention and control of SSIs		0.16 (0.06, 0.38)
No. of surgeons		3 (2, 6)
Median no. of years of surgeons' experience		13 (5, 21)

SSIs = surgical-site infections.

DISCUSSION

We found that a higher number of surgeries performed reduced the risk of SSI for a hospital. This finding was not explained by risk factors related to patients or procedures or by other characteristics of the hospital.

To appreciate our findings, several issues need to be addressed. Bias may have occurred through the selection of hospitals because not all hospitals participating in the PREZIES network took part in this study. However, the distribution of procedure-specific infection rates of nonparticipating hospitals did not differ from that of hospitals in this study nor was the distribution of known hospital characteristics such as size and teaching status any

TABLE 3
CRUDE AND ADJUSTED RISK RATIOS AND 95% CONFIDENCE INTERVALS FOR ASSOCIATION OF HOSPITAL-RELATED
DETERMINANTS AND SURGICAL-SITE INFECTION FOLLOWING HIP ARTHROPLASTIES

Hospital-Related Determinant	Crude		Adjusted	
	RR	CI$_{95}$	RR	CI$_{95}$
No. of beds				
< 300	1*		1*	
300 to 600	1.15	0.61–2.16	1.26	0.71–2.22[†]
> 600	0.81	0.39–1.66	0.78	0.40–1.51[†]
Non–university-affiliated hospital	1*		1*	
University-affiliated hospital	1.39	0.53–3.59	1.32	0.55–3.19[‡]
Non-teaching hospital	1*		1*	
Teaching hospital, residents allowed to operate without supervision	0.57	0.21–1.54	0.60	0.23–1.54[‡]
Teaching hospital, residents not allowed to operate without supervision	1.23	0.79–1.90	1.28	0.83–1.97[‡]
Annual volume of operations (per 50 operations)	0.87	0.77–0.98	0.85	0.74–0.97[†]
Staff for nosocomial infection prevention and control (per full-time–equivalent employees per 250 beds)	1.24	0.61–2.16	1.21	0.64–2.30[†]
Staff for prevention and control of SSIs (per full-time–equivalent employees per 250 beds)	0.60	0.17–2.11	0.48	0.16–1.44[†]
No. of surgeons	1.09	0.95–1.24	1.08	0.92–1.25[§]
Median no. of years of surgeons' experience (per 5 y)	0.94	0.75–1.17	0.98	0.79–1.21[†]

RR = risk ratio; CI$_{95}$ = 95% confidence interval; SSIs = surgical-site infections.
*Reference category.
[†]Adjusted for characteristics of the patient (age, American Society of Anesthesiologists score, and duration of preoperative hospital stay) and the procedure (wound contamination class, type of surgery, duration of surgery, and whether surgery was elective or emergent) and for teaching status.
[‡]Adjusted for characteristics of the patient and the procedure.
[§]Adjusted for teaching status.

different (data not shown). We thus think it unlikely that the results were biased through selective participation of hospitals.

The cross-sectional measurement of the hospital characteristics may have biased our results. For several hospital characteristics (eg, experience and number of surgeons), changes might have occurred during the 5-year period of collection of data on operations. But because the extent and direction of change was unlikely to be associated with high or low SSI rates, we do not believe that these changes affected the results. However, changes in manpower for prevention and control of SSI may well have been driven by either high or low infection rates in some hospitals (ie, we think that a hospital that found high SSI rates in the beginning of the surveillance was more likely to have increased rather than decreased the number of staff dedicated to SSI prevention and control in later years). Likewise, it is plausible that low starting rates did not lead a hospital to increase its surveillance and control activities in later years. We therefore think that if a change in manpower occurred during the surveillance period, its direction would have resulted in an underestimation of the protective effect.

We used multilevel logistic modeling, which is increasingly used in health research.[19] The multilevel approach takes into account the hierarchical structure

of the data, with patients clustered within hospitals. Because part of our data were measured at the hospital level and part at the patient level, multilevel modeling was more suitable for our analysis than traditional logistic regression. In addition, although we included several hospital characteristics as confounders, it is probable that cluster effects remain, as patients from the same hospital are subject to similar treatment policies. Ignoring this clustering would likely have resulted in an underestimation of the standard errors for the effect estimates.

Our observation that the risk of SSI was lower for high-volume hospitals confirms the results of a study by Farber and Wenzel. They found an inverse relationship between the surgical volume for procedures of low complexity (eg, colectomies and abdominal hysterectomies) and the incidence of postoperative wound infection for 22 U.S. hospitals.[9] The SENIC investigators, who adjusted for severity of case mix, also found fewer SSIs with higher volume.[8] A recent study did not detect a relationship between hospital volume and mortality rate in common operations (eg, colectomies and total hip arthroplasties),[20] whereas others did report an effect for colon cancer surgery[21] and for breast cancer surgery.[22] For more complex operations, there is circumstantial evidence for an inverse relationship between volume and mortal-

ity.[23-26] This suggests that mortality is less sensitive than morbidity (SSI rate) to differences in hospital volume in procedures of low complexity.

Our finding of a lower risk of SSI with higher hospital volume may be the result of differences in the technical skills of individual surgeons. We were not able to investigate this, as individual surgeon data were not available. Still, other authors have shown that hospital volume is a stronger predictor of healthcare outcomes than individual surgeon volume.[27] Because prevention of SSI involves a multidisciplinary approach, it is likely that variations in the proficiency of entire operating teams also underlie our results. Insight into the differences in the perioperative processes of these teams and sharing of best practices may be a valuable tool to achieve a reduction of SSI risk.

Patients undergoing surgery in a hospital with more infection control staff devoted to prevention and control of SSIs appeared to have a somewhat decreased risk of SSI, but this was not statistically significant. SENIC showed that establishing a strong surveillance and infection control program, including a system for feedback of SSI rates to surgeons, was essential for the prevention of SSIs.[8] Because most of the activities that make up surveillance and control of SSI are the work of infection control staff, our finding that having more full-time–equivalent infection control staff per 250 beds was associated with a trend toward lower risk of SSI seems plausible. In another study, we demonstrated that infection control capacity is well spent on SSI surveillance because a longer period of surveillance in hospitals substantially reduced the risk of SSI for their patients.[28]

Our study suggested that a low volume of surgery is associated with an increased risk of SSI for the patient undergoing hip arthroplasty, confirming the findings of previous studies. These findings may have implications for risk stratification of SSI rates that are used for comparison of hospitals or surgical teams. The reason for a reduced risk with a high hospital volume of operations deserves further study.

REFERENCES

1. Geubbels EL, Mintjes-de Groot AJ, van den Berg JM, de Boer AS. An operating surveillance system of surgical-site infections in the Netherlands: results of the PREZIES national surveillance network. Preventie van Ziekenhuisinfecties door Surveillance. *Infect Control Hosp Epidemiol* 2000;21:311-318.
2. Kirkland KB, Briggs JP, Trivette SL, Wilkinson WE, Sexton DJ. The impact of surgical-site infections in the 1990s: attributable mortality, excess length of hospitalization, and extra costs. *Infect Control Hosp Epidemiol* 1999;20:725-730.
3. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999: Hospital Infection Control Practices Advisory Committee. *Infect Control Hosp Epidemiol* 1999;20:250-280.
4. Haley RW. Measuring the intrinsic risk of wound infection in surgical patients. *Problems in General Surgery* 1993;10:396-417.
5. Roy MC, Perl TM. Basics of surgical-site infection surveillance. *Infect Control Hosp Epidemiol* 1997;18:659-668.
6. Lee TB, Baker OG, Lee JT, Scheckler WE, Steele L, Laxton CE. Recommended practices for surveillance: Association for Professionals in Infection Control and Epidemiology, Surveillance Initiative Working Group. *Am J Infect Control* 1998;26:277-288.
7. Wong ES. Surgical site infections. In: Mayhall CG, ed. *Hospital Epidemiology and Infection Control*. Baltimore: Williams & Wilkins; 1996:154-175.
8. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. *Am J Epidemiol* 1985;121:182-205.
9. Farber BF, Wenzel RP. Postoperative wound infection rates: results of prospective statewide surveillance. *Am J Surg* 1980;140:343-346.
10. Lau WY, Fan ST, Chu KW, Yip WC, Yuen WC, Wong KK. Influence of surgeons' experience on postoperative sepsis. *Am J Surg* 1988;155:322-326.
11. Gastmeier P, Kampf G, Wischnewski N, et al. Prevalence of nosocomial infections in representative German hospitals. *J Hosp Infect* 1998;38:37-49.
12. Schifman RB, Howanitz PJ. Nosocomial infections: a college of American pathologists Q-probes study in 512 North American institutions. *Arch Pathol Lab Med* 1994;118:115-119.
13. 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;13:606-608.
14. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections, 1988. *Am J Infect Control* 1988;16:128-140.
15. Owens WD, Felts JA, Spitznagel EL. ASA physical status classifications: a study of consistency of ratings. *Anesthesiology* 1978;49:239-243.
16. Altemeier WA, Burke JF, Pruitt BA, Sandusky WR. *Manual on Control of Infection in Surgical Patients*, ed. 2. Philadelphia: J. B. Lippincott; 1984.
17. Hox JJ. *Applied Multilevel Analysis*. Amsterdam: TT-Publikaties; 1995.
18. Greenland S, Rothman KJ. Fundamentals of epidemiologic data analysis. In: Rothman KJ, Greenland S, eds. *Modern Epidemiology*, ed. 2. Philadelphia: Lippincott-Raven; 1998:216-217.
19. Rice N, Leyland A. Multilevel models: applications to health data. *Journal of Health Services Research & Policy* 1996;1:154-164.
20. Khuri SF, Daley J, Henderson W, et al. Relation of surgical volume to outcome in eight common operations: results from the VA National Surgical Quality Improvement Program. *Ann Surg* 1999;230:414-432.
21. Schrag D, Cramer LD, Bach PB, Cohen AM, Warren JL, Begg CB. Influence of hospital procedure volume on outcomes following surgery for colon cancer. *JAMA* 2000;284:3028-3035.
22. Roohan PJ, Bickell NA, Baptiste MS, Therriault GD, Ferrara EP, Siu AL. Hospital volume differences and five-year survival from breast cancer. *Am J Public Health* 1998;88:454-457.
23. Bach PB, Cramer LD, Schrag D, Downey RJ, Gelfand SE, Begg CB. The influence of hospital volume on survival after resection for lung cancer. *N Engl J Med* 2001;345:181-188.
24. Laffel GL, Barnett AI, Finkelstein S, Kaye MP. The relation between experience and outcome in heart transplantation. *N Engl J Med* 1992;327:1220-1225.
25. Begg CB, Cramer LD, Hoskins WJ, Brennan MF. Impact of hospital volume on operative mortality for major cancer surgery. *JAMA* 1998;280:1747-1751.
26. Sosa JA, Bowman HM, Gordon TA, et al. Importance of hospital volume in the overall management of pancreatic cancer. *Ann Surg* 1998;228:429-438.
27. Hughes RG, Hunt SS, Luft HS. Effects of surgeon volume and hospital volume on quality of care in hospitals. *Med Care* 1987;25:489-503.
28. Geubbels ELPE, Nagelkerke NJD, Mintjes-de Groot AJ, Vandenbroucke-Grauls CMJE, Grobbee DE, de Boer AS. Reduced risk of surgical site infection through surveillance in a network. Submitted for publication.

APPENDIX

ASSOCIATION OF HOSPITAL-RELATED DETERMINANTS AND SURGICAL-SITE INFECTION FOLLOWING HIP ARTHROPLASTIES FOR ORIGINAL MODELS AND MODELS INCLUDING POSTDISCHARGE SURVEILLANCE AS AN EXPLANATORY VARIABLE

Hospital-Related Determinant	Adjusted Model Without PDS		Adjusted Model With PDS	
	RR	CI_{95}	RR	CI_{95}
No. of beds				
< 300	1*		1*	
300 to 600	1.26	0.71–2.22[†]	1.21	0.69–2.14[†]
> 600	0.78	0.40–1.51[†]	0.72	0.36–1.46[†]
Non–university affiliated	1*		1*	
University affiliated	1.32	0.55–3.19[‡]	1.22	0.49–3.01[‡]
Non-teaching hospital	1*		1*	
Teaching hospital, residents allowed to operate without supervision	0.60	0.23–1.54[‡]	0.55	0.21–1.43[‡]
Teaching hospital, residents not allowed to operate without supervision	1.28	0.83–1.97[‡]	1.21	0.77–1.89[‡]
Annual volume of operations (per 50 operations)	0.85	0.74–0.97[†]	0.85	0.73–0.97[†]
Staff for nosocomial infection prevention and control (per full-time equivalent employee per 250 beds)	1.21	0.64–2.30[†]	1.30	0.67–2.51[†]
Staff for prevention and control of SSIs (per full-time equivalent employee per 250 beds)	0.48	0.16–1.44[†]	0.49	0.17–1.45[†]
No. of surgeons	1.08	0.92–1.25[§]	1.06	0.90–1.24[§]
Median no. of years of surgeons' experience (per 5 y)	0.98	0.79–1.21[†]	0.98	0.79–1.22[†]

SSIs = surgical-site infections; PDS = postdischarge surveillance; RR = risk ratio; CI_{95} = 95% confidence interval.
*Reference category.
[†]Adjusted for patient characteristics (age, American Society of Anesthesiologists score, and duration of preoperative hospital stay) and procedure characteristics (wound contamination class, type of surgery, duration of surgery, and elective or emergent surgery) and for teaching status.
[‡]Adjusted for patient and procedure characteristics.
[§]Adjusted for teaching status.