Evaluation of the surveillance of surgical site infections within the Dutch PREZIES network

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Effect of optimized antibiotic prophylaxis on the incidence of surgical site infections

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ABSTRACT

Objective: To compare the rate of surgical site infection (SSI) before and after an intervention period in which an optimized policy for antibiotic prophylaxis was implemented. To demonstrate that a more prudent, restrictive policy would not have a detrimental effect on patient outcomes.
Design: Before-after trial with prospective SSI surveillance in the Dutch nosocomial surveillance network (Preventie Ziekenhuisinfecties door Surveillance [PREZIES]), using the criteria of the Centers for Disease Control, including postdischarge surveillance for up to 1 year.
Setting: During a preintervention period and a post-intervention period (both 6-13 months), 12 Dutch hospitals collected data on antimicrobial prophylaxis and SSI rates. The study was limited to commonly performed surgical procedures in 4 specialties: vascular, intestinal, gynecological and orthopedic surgery. Selected risk factors for analysis were gender, age, American Society of Anesthesiologists classification, wound contamination class, duration of surgery, length of hospital stay before surgery, and urgency of surgery (elective or acute).
Results: A total of 3,621 procedures were included in the study, of which 1,668 were performed before the intervention and 1,953 after. The overall SSI rate decreased from 5.4% to 4.5% (P = .22). Among the procedures included in the study, the largest proportion (55%) were total hip arthroplasty, and the smallest proportion (2%) were replacement of the head of the femur. The SSI rates varied from 0% for vaginal hysterectomy to 21.1% for femoropopliteal or femorotibial bypass surgery. Crude and adjusted odds ratios showed that there were no significant changes in procedure-specific SSI rates after the intervention ($P > .1$).
Conclusions: An optimized and restrictive prophylactic antibiotic policy had no detrimental effect on the outcome of clean and clean contaminated surgery, as measured by SSI rate.

INTRODUCTION

Surgical site infections (SSIs) account for 38% of surgical infections and 17% of all nosocomial infections.[1,2] In the United States in the 1990s, SSIs prolonged hospital stay by an average of 6.5 days, doubled the risk of death, and were associated with a risk of readmission to the hospital 5 times that for patients without SSI.[3] In the Netherlands, the mean postoperative length of stay for patients with an SSI is 8.2 days longer than for patients without an SSI.[4]

Decades ago, the effectiveness of antimicrobial prophylaxis in reducing SSI rates was demonstrated in randomized clinical trials.[5-10] For optimal prophylaxis, an antibiotic with a targeted spectrum should be administered at sufficiently high concentration in the serum, tissue, and the surgical wound during the entire time that the incision is open and at risk of bacterial contamination.[11] In the United States, the Surgical Infection Prevention Guideline Writers Workgroup (SIPGWW) reached a consensus that infusion of the first dose of antimicrobial should begin within 60 minutes before surgical incision and that antimicrobial prophylaxis should be discontinued within 24 hours after the end of surgery.[12] Studies showed that the prolonged use of antibiotic prophylaxis leads to emergence of bacterial resistance[13-15] and high costs,[16,17] and inappropriate timing of the administration leads to decreased efficacy.[18,19]

As part of the prospective, multisite, Surgical Prophylaxis and Surveillance (CHIPS) project, an optimized and restrictive antibiotic policy based on the national guideline was implemented in the Netherlands.[20] This guideline recommends prophylaxis with a single dose of antimicrobial administered intravenously within 30 minutes before the first incision. In view of the very low incidence of infection with methicillin-resistant *Staphylococcus aureus* in the Netherlands (less than 1% of all *S. aureus* infections), cefazolin (combined with metronidazole, if coverage for anaerobic pathogens is needed) is recommended.

The goal of the study intervention was to slow down the development of antibiotic resistance and reduce the costs of antimicrobial prophylaxis without decreasing the efficacy of prophylaxis, as measured by a higher SSI incidence. In the present report, the patient outcome of this optimized and restrictive antimicrobial prophylaxis policy is assessed by comparing the SSI rate before and after the intervention.

METHODS

Setting

The CHIPS project was a prospective intervention study conducted at 13 Dutch hospitals, which participated voluntarily. These hospitals give a representative picture of inpatient care in the Netherlands, since they were geographically spread over the country, according to the population density (Figure 1), various types of hospitals (small, large, university and general hospitals) were included. At 1 of the 13 hospitals, data on SSIs could not be recorded because of the sudden absence of the infection control professional (ICP).

Data on antimicrobial prophylaxis and SSIs were collected in these 12 hospitals between January 2000 and November 2001 (the preintervention period) and between July 2001 and November 2002 (the postintervention period). The duration of these periods in each hospital ranged from 6 to 13

Figure 1. Locations of participating hospitals (*filled circles*) in the Netherlands (population, 16 million; area, 41,526 km^2).

months, depending on how often the selected procedures were performed. During the intervention period, which lasted 6-11 months, a restrictive antibiotic-use policy was implemented. The policy was based on the national guideline for surgical prophylaxis issued by the Dutch Working Party on Antibiotic Policy (SWAB).[21]

Four major surgical specialties were selected for this study: vascular, intestinal, gynecological and orthopedic surgery. The study was limited to frequently performed procedures for which antimicrobial prophylaxis is generally recommended[21,22]: grafting of the aorta, femoropopliteal or femorotibial bypass, various colorectal procedures, abdominal and vaginal hysterectomy with or without vaginal repair, total hip arthroplasty and replacement of the head of the femur.

Only elective procedures were included, so that the normal daily routine of administering antimicrobial prophylaxis would be observed. To avoid assessment of procedures in which antibiotics were given for therapeutic reasons rather than prophylactic, procedures with a dirty or infected wound (i.e., wound contamination class 4)[1,23] were excluded.

Data collection

The methods used to collect data on antimicrobial prophylaxis have been described elsewhere.[20,24] Data were collected prospectively by infection control professionals from medical, nursing, anesthetic, and medication records. Before the start of the project, as well as during the study, the collection of data on antimicrobial prophylaxis was validated at regular intervals through on-site review of the 20 most recently recorded patient files.

All CHIPS hospitals participated in the module "Surgical site infections" of the Dutch national

nosocomial infections surveillance network (Preventie Ziekenhuisinfecties door Surveillance; PREZIES[4]; general information is available at the network's Web site, http://www.prezies.nl). From 1996 to 2003 within the PREZIES network, 62 of the 98 Dutch hospitals participated and collected SSI data on 129,142 procedures. According to the PREZIES protocol, infection control professionals collected information on the demographic characteristics of patients and on the surgical procedure, risk factors for SSI, and incidence of SSI. The selection of risk factors was based on the literature and included the patient's sex, age, and physical condition (American Society of Anesthesiologists classification);[25] wound contamination class; duration of surgery; preoperative length of hospital stay; and whether surgery was elective or acute.[26-29] The criteria of the Centers for Disease Control and Prevention were used for the assessment of SSIs.[22,30] If an SSI occurred in a patient, the surveillance staff recorded the day the SSI became manifest, whether it was a superficial or deep SSI, and which micro-organisms were isolated. Deep incisional SSIs and organ/space SSIs were combined and termed deep SSIs. All patients were followed up to 30 days postoperatively; in case of insertion of a prosthetic implant the duration of follow-up was 1 year. To monitor the quality and reliability of the surveillance data used in this study, SSI surveillance was validated in each participating hospital.

To achieve a significance level of 5% and a power of 80%, the required sample size for observing a change in the SSI rate was 1,600 surgical procedures before the intervention and 1,600 after. This was calculated using the assumptions that the overall risk of SSI before the intervention was 7.5% and that the estimated achievable SSI rate after the intervention was 5%. The figure of 7.5% was based upon PREZIES data for the selected procedures in previous years and assumed an equal distribution of the selected procedures (orthopedic, gynecological, vascular and bowel surgery) in the CHIPS study. However, the CHIPS study was dependent on the PREZIES protocol, according to which hospitals were free to choose the type of procedures for surveillance.

Data analysis

The χ^2 test or Student *t* test was used to screen potential risk factors for SSIs. Variables with a *P* value of less than .2 for their univariate association with SSI were candidates for multivariable analysis. Logistic regression analysis was used to calculate odds ratios (ORs) for SSI after the intervention compared with before the intervention, according to the type of surgical procedure, and after adjusted for procedure-specific confounders. The best model was selected by considering the -2 log likelihood as well as the c-index. The c-index is a measure of predictive performance and represents the proportion of instances in which a patient who develops an SSI is assigned a higher probability of SSI than a patient who does not develop an SSI.[31]

As recommended by the Cochrane Effective Practice and Organization of Care Group (EPOC),[32] we used segmented time series analysis, which includes changes in level and in trend, to estimate the effect size of the intervention. Data were collected on individual patient level, whereas the interventions were targeted towards hospitals with different mixes of surgical procedures. Therefore, the resulting hierarchical structure was taken into account in the analyses. As the response variable was binary (SSI present or absent), a non-linear mixed model analysis was

applied using SAS Proc NLmixed, version 8.2 (SAS Institute). In the model, the hospital where the procedure was performed was treated as a random variable, and surgical procedure and calendar time of the preintervention, intervention and postintervention periods were treated as covariables. In this way, the model corrected for unequal distribution of procedures in the preintervention and postintervention periods, for unequal distribution within hospitals, and for differences in length of registration and intervention periods. The following outcome measurements were generated: mean SSI rates in the preintervention and postintervention periods, change in SSI rate immediately after the intervention, and the slopes of the curve of the SSI rates before and after the intervention.

All analyses were performed in SAS for Windows, release 8.2 (SAS Institute). A *P* level of less than .05 was considered statistically significant.

RESULTS

Overall results of the optimized antibiotic policy

The optimized antibiotic policies led to a decrease of 35% in the use of prophylactic antibiotics (calculated as the number of Defined Daily Doses (DDD) per procedure) and a decrease of 25% in the costs per procedure, mainly as a result of a shorter period of administration of prophylaxis.[24] After the intervention, antibiotics were administered inappropriately in 37.5% of the procedures, instead of the expected 93.5% had the intervention not occurred. Administration of doses after closure of the wound, instead of the recommended single dose before the first incision (with a second dose if there is major blood loss or the procedure has a long duration), was observed in 31.4% of procedures instead of the expected in 46.8%. Inappropriate timing of antibiotic administration (ie, not within 30 minutes before the first incision) was observed in 39.4% of procedures, instead of the expected 51.8%. Time series analysis showed that these improvements were statistically significant ($P < .01$) and that they could be fully attributed to the intervention.[24] The percentage of procedures in which antimicrobial prophylaxis was administered within 1 hour before the first incision changed only slightly, from 72% to 79%.[24]

Results before and after the intervention

The results described here are for a total of 3,621 procedures, of which 1,668 were performed before the intervention and 1,953 after. The overall SSI rate decreased from 5.4% (95% confidence interval [CI]: 4.3%–6.5%) before to 4.5% (95% CI, 3.6%-5.4%) after the intervention ($P = .22$).

Table 1 summarizes the characteristics of each participating hospital. Three of the 12 hospitals had fewer than 400 beds, and 3 hospitals had more than 800 beds. There were 5 teaching hospitals, of which 2 were university hospitals. The total recorded number of surgical procedures at each hospital varied from 97 to 581. Vascular procedures were recorded at 4 hospitals, intestinal procedures at 6 hospitals, gynecological procedures at 4 hospitals, and orthopedic procedures at 11 hospitals.

Table 1. Characteristics of the 12 study hospitals and number of surgical procedures performed during the 2 study periods.

			No. of procedures recorded before and after study intervention									
			Total		Vascular surgery		Intestinal surgery		Gynecological surgery		Orthopedic surgery	
Hospital	No. of beds	Type of hospital	Before	After	Before	After	Before	After	Before	After	Before	After
A	> 800	Teaching	271	310	…	…	…	…	131	175	140	135
B	400-800	General	206	254	…	…	…	…	…	…	206	254
C	400-800	General	94	103	…	…	…	…	…	…	94	103
D	< 400	General	114	131	…	…	40	49	…	…	74	82
E	> 800	University	165	181	…	…	39	43	67	70	59	68
F	400-800	Teaching	136	135	87	87	49	48	…	…	…	…
G	400-800	General	41	80	…	…	…	…	…	…	41	80
H	< 400	Teaching	134	178	…	…	…	…	68	88	66	90
I	400-800	General	50	47	…	…	…	…	…	…	50	47
J	< 400	General	99	86	9	5	41	26	…	…	49	55
K	400-800	General	182	238	23	15	45	45	…	…	114	178
L	> 800	University	176	210	46	45	36	46	62	69	32	50

Table 2. Comparison of risk factors identified before and after the intervention.

	Percentage of procedures with risk factor present		
Risk factor	**Before intervention (n = 1668)**	**After intervention (n = 1953)**	***P***
Age >65	56.4	58.1	.30
Male sex	30.9	30.4	.76
ASA classification ≥3	17.7	17.6	.89
Wound class ≥2	34.7	33.7	.54
Duration of surgery >P75	24.6	24.1	.76
Teaching hospital	48.9	47.3	.33
University hospital	20.4	20.0	.75

ASA, American Society of Anesthesiologists; *P75*, 75th percentile.

Table 3. Surgical site infection (SSI) rates in the Dutch national nosocomial infection surveillance (PREZIES) network and in the surgical prophylaxis and surveillance (CHIPS) project.

		CHIPS			
	PREZIES[a]	**Before intervention**		**After intervention**	
Procedure	**SSI rate, % (95% CI)**	**n**	**SSI rate, % (95% CI)**	**n**	**SSI rate, % (95% CI)**
Reconstruction of the aorta	1.9 (0.4-3.5)	95	5.3 (0.8-9.8)	95	7.4 (2.1-12.6)
Femoropopliteal or femorotibial bypass	6.3 (3.7-8.9)	70	14.3 (6.1-22.5)	57	21.1 (10.5-31.6)
Colorectal procedures	7.3 (5.6-9.0)	250	14.8 (10.4-19.2)	257	10.9 (7.1-14.7)
Abdominal hysterectomy	1.6 (0.6-2.5)	205	2.4 (0.3-4.6)	239	1.7 (0.0-3.3)
Vaginal hysterectomy	0.3 (0.0-0.8)	123	0	163	1.2 (0.0-2.9)
Replacement of the head of the femur	3.5 (2.5-4.5)	25	20.0 (4.3-35.7)	42	11.9 (2.1-21.7)
Total hip arthroplasty	2.8 (2.4-3.2)	900	3.1 (2.0-4.2)	1100	2.7 (1.8-3.7)

CI, confidence interval.

[a] PREZIES data between 2000-2002, without the CHIPS data.

The distribution of risk factors before and after the intervention is shown in Table 2. More than half of the patients were over 65 years old, 31% of the patients were male, and less than 20% of the patients had an American Society of Anesthesiologists classification of 3 or higher; 66% of the procedures were classified as clean procedures. Twenty percent of the recorded procedures were performed in university hospitals and 32% in other teaching hospitals. There were no significant differences in the distribution of the risk factors before and after the intervention ($P \geq .3$).

Table 3 shows PREZIES SSI rates[4] and SSI rates before and after the intervention in the present CHIPS study, according to the type of surgical procedure. The distribution of the surgical procedures was fairly similar before and after the intervention. However, the recorded number of femoropopliteal or femorotibial bypasses decreased significantly ($P = .04$).

For 4 procedures the SSI rate decreased after the intervention, and for 3 procedures the SSI rate increased after the intervention. Table 4 shows the crude and adjusted ORs, according to the type of procedure, for the comparison of the SSI rate after the intervention with the rate before the

Table 4. Crude odds ratio (OR) and adjusted OR of the surgical site infection rate after the intervention, compared with before the intervention.

Procedure	Crude OR (95% CI)	Adjusted OR (95% CI)	Variables adjusted for
Reconstruction of the aorta	1.4 (0.4-4.7)	1.4 (0.4-4.6)	Gender
Femoropopliteal or femorotibial bypass	1.6 (0.6-4.0)	1.1 (0.4-3.1)	Age (≥65 years), university hospital
Colorectal procedures	0.7 (0.4-1.2)	0.7 (0.4-1.1)	Age (≥65 years)
Abdominal hysterectomy	0.7 (0.2-2.6)	0.6 (0.2-2.4)	Duration of surgery (>P75)
Vaginal hysterectomy	Not calculable	Not calculable	
Replacement of the head of the femur	0.5 (0.1-2.1)	0.6 (0.1-2.6)	Age (continuous), duration of surgery (>P75)
Total hip arthroplasty	0.9 (0.5-1.5)	0.9 (0.5-1.5)	Age (≥75 years), ASA classification (≥3), duration of surgery (>P75)

ASA, American Society of Anesthesiologists; *CI*, confidence interval; *P75*, 75th percentile.

intervention, adjusted for procedure-specific confounders. These ORs did not differ significantly from 1, indicating that the SSI rates had not changed remarkably during the intervention.

Time series analysis that took into account possible changes over time in hospitals concerning unmeasured factors confirmed that the optimized and more-restrictive administration of antibiotic prophylaxis did not have a significant impact on the SSI rate (P = .99) and that there were no significant trends in SSI rates during the preintervention and postintervention periods. Specific changes in different aspects of prophylaxis (e.g. choice, timing, and duration of antibiotic prophylaxis) after the intervention are described elsewhere.[21]

DISCUSSION

Our results demonstrate that implementing an optimized and more-prudent antibiotic policy in hospitals did not change the risk of SSI. Our findings are in line with the results of studies that have shown that narrow-spectrum antimicrobials are as effective as broad-spectrum antimicrobials for preventing SSIs[33-35] and that single-dose prophylaxis is as effective as multiple-dose prophylaxis.[34-39] Furthermore, Classen et al.[18] have demonstrated that the SSI incidence is lower if antimicrobial prophylaxis is administered within 2 hours before the first surgical incision, compared with administration earlier or later. Despite the evidence, surgeons are still reluctant to follow guidelines that advocate use of narrow-spectrum antibiotics and single-dose prophylaxis, because they fear an increase in the incidence of SSI. Many guidelines, therefore, have not found their way into daily practice. However, in the present study, implementation of these recommendations was successful, and the improvement in quality resulted in less use and improved use of antibiotics,[24] and the effectiveness of the antibiotics concerning SSI prevention did not diminish. Since the timing of prophylaxis only slightly improved after the intervention, the positive effect of this improvement on the incidence of SSI might have been limited, although pharmacokinetic data indicate the desirability of administration as close as possible to the time of the first incision.[40,41]

The CHIPS multiple-site study was unique in several aspects. It involved 12 hospitals; measured

SSIs as patient-outcome in addition to the process-outcome parameters; and considered various common procedures in 4 surgical specialties. Of the many studies that have tried to implement an improved antibiotic prophylaxis policy, only a few considered an outcome parameter. A study by Gyssens et al.[17] recorded the number of nosocomial infections per 100 bed days. Two other implementation studies recorded the SSI rate but included only 2 hospitals[42] and 6 hospitals.[43] Schell et al.[42] focused solely on bowel surgery, and Weinberg et al.[43] focused on cesarean section. The present CHIPS study was conducted within PREZIES. Therefore, SSI surveillance was performed according to a standardized protocol, which included postdischarge surveillance and validation of the data collection in the hospitals, which yielded reliable data on SSIs.

A limitation of our study is the lack of a control group. However, it did not seem feasible to include a control group of hospitals that would be motivated to invest a lot of effort in the data collection without the possibility of implementing the national guideline and improving the overall quality of antimicrobial prophylaxis. The participating hospitals had agreed not to introduce any other intervention during this study. Consequently, there was no change in surgical personnel, surgical methods, operating room protocols, or postoperative wound care in the participating hospitals. Despite this agreement, changes in SSI rates could still have been the result of a gradual change in practices not related to the study intervention. However, by using segmented time series analysis, trends over time not related to the intervention could be excluded.

Another limitation might be that the preintervention SSI rate was 5.4%, mainly because of overrepresentation of orthopedic procedures in the study, which is less than the 7.5% on which the power calculation was based. However, more procedures were included in the study than we had anticipated: 1,668 before and 1,953 after intervention, instead of 1,600. With this sample size and given the preintervention SSI rate, the study had enough power to demonstrate a decrease in the overall SSI rate to 3.4% or lower or an increase to 7.7% or higher. However, we observed no change in overall SSI rate before and after intervention; the observed difference was minor, with overlapping 95% CIs. Unfortunately, this study had not enough power to demonstrate a significant change in SSI rate according to the type of procedure.

In this study, no data on antibiotic resistance were collected. Therefore, we were not able to investigate how antibiotic use was affected by the decreased use of antibiotics (from 121 to 79 defined daily doses per 100 procedures) and the decreased use of agents with a broader spectrum than cefazolin (from 85% to 34% of procedures).[24] However, it might be expected that the restricted antibiotic use that was achieved in this study will contribute to a decrease in antimicrobial selective pressure.[13]

Most aggregated procedure-specific SSI rates reported in the present CHIPS study were higher than the national SSI rates from PREZIES. It appeared that the national rates during the CHIPS study (during 2000-2002) were, by coincidence, lower than the average infection rates during the total national surveillance period of 1996-2004. A possible explanation for the higher rates in the CHIPS hospitals might be that the SSI surveillance during the CHIPS study was performed more accurately and thoroughly, resulting in a higher proportion of SSIs detected. Another explanation could be that not all hospitals participating in PREZIES performed postdischarge surveillance,

whereas all CHIPS hospitals did perform postdischarge surveillance. However, when only SSIs that developed during hospitalization were considered, the trend of higher SSI rates in the CHIPS study was still apparent. The difference in SSI rates might also be caused by differences in present risk factors between the CHIPS and PREZIES study population, since only the crude infection rates were compared.

In conclusion, this study shows that the implementation of an optimized and restrictive antibiotic policy had no detrimental effect on the outcome of clean and clean-contaminated surgery, as measured by SSI rate.

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