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

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Trends in the incidence of surgical site infections in the Netherlands

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ABSTRACT

Objective: To evaluate the time-trend in surgical site infection (SSI) rate in relation to the duration of surveillance in the Netherlands.

Setting: SSI surveillance data from 42 hospitals that participated in the Dutch PREZIES network between 1996 and 2006 and registered at least one of five frequently performed surgical procedures for at least three years: mastectomy, colectomy, replacement of the head of the femur, total hip prosthesis or knee prosthesis.

Methods: Analyses were performed per surgical procedure. The surveillance time to operation was stratified in consecutive 1-year periods, with the first year as reference. Multivariate logistic regression analysis was performed using a random coefficient model to adjust for random variation among hospitals. All models were adjusted for method of postdischarge surveillance.

Results: The number of procedures varied from 3,031 for colectomy to 31,407 for total hip prosthesis and the SSI rate from 1.6% for knee prosthesis to 12.2% for colectomy. For total hip prosthesis, the SSI rate decreased significantly by 6% per surveillance year (OR: 0.94, 95% CI: 0.90-0.98), indicating a 60% decrease after 10 years. Non-significant, but substantial decreasing trends in SSI rate were found for replacement of the head of the femur (OR: 0.94, 95% CI: 0.88-1.00) and for colectomy (OR: 0.92, 95% CI: 0.83-1.02).

Conclusions: Even though most decreasing trends in SSI rate were not statistically significant, they are encouraging. To use limited recourses as efficient as possible, we would suggest switching the surveillance to another surgical specialty when the SSI rate has decreased below the target.

INTRODUCTION

Even though a lot of attention has been paid to the prevention of nosocomial infections for many years, surgical site infections (SSI) continue to present a major proportion of adverse events in surgical patients. These infections have dramatic consequences for the patient as well as the hospital, because they lead to substantial attributable morbidity and increase costs. Although probably not all SSIs are preventable, adequate measures can substantially reduce the risk of SSI.

Many countries have established a national system for the surveillance of nosocomial infections. Such surveillance systems make comparison of infection rates between hospitals possible and stimulate optimization of infection control, including improvement of compliance to guidelines. The ultimate aim is to reduce the patients' risk of nosocomial infection.

In the mid-1980s, the SENIC project reported that nosocomial infection surveillance with appropriate infection control activities and feedback of surveillance results to surgeons and other involved staff, decreased nosocomial infection rates significantly by 30%.[1] Other studies demonstrated the effectiveness of surveillance with feedback, because comparison of a surgeons infection rate relative to their peers promoted awareness.[2]

In a review of 30 reports (25 intervention studies and 5 cross-transmission studies) that had been published since the 1990s, Harbarth et al. considered at least 20% of all nosocomial infections as probably preventable.[3]

In the Netherlands, the PREZIES surveillance system started in 1996 with the surveillance of SSIs.[4] According to the SSI surveillance data, 3% of all surgical patients in Dutch hospitals develop a SSI (data on website www.prezies.nl).

A reduction in SSI rate with longer participation in PREZIES was already shown by Geubbels.[5] She used SSI surveillance data from the period 1996-2000, and analyzed the trend in SSI rates over seven pooled procedures as to increase power.

In the current study, we evaluated the time-trend in SSI rate between 1996 and 2006, separately for five frequently-performed surgical procedures, using surveillance data from the Dutch PREZIES network.

METHODS

Principles of the PREZIES system

The protocol of PREZIES regarding the surveillance of SSI is based on the US National Nosocomial Infections Surveillance (NNIS) system, with application of the standardized CDC criteria for a SSI.[4] Participation is voluntary and hospital-specific data are kept confidential. Hospitals can annually choose surgical procedures to include. Postdischarge surveillance is strongly recommended and a suggested method is described in the protocol.[6] The recommended methods for PDS are addition of a special registration card to the outpatient medical record, on which the surgeon notes clinical symptoms and whether a patient developed an SSI according to the definitions; an alternative method is examination of the outpatient medical record after the follow-up period has elapsed. A prerequisite for this is, that the status of the wound must be clearly described in the records. Per procedure, the used postdischarge surveillance method is registered for each hospital. Validation visits by a PREZIES team-member to each participating hospital occur every three years, and provide evidence for the reliability and accuracy of the surveillance data.[7] Deep incisional and organ-space SSIs were both evaluated under the umbrella term "deep SSI". Every time a hospital sends in data, it receives a feedback report per surgical procedure, including crude and expected SSI rates adjusted for the NNIS risk index. Feedback reports are usually spread and discussed in the hospital with the infection control committee, physicians, managers and staff. The necessity of infection prevention activities is left to the hospitals' discretion. Yearly workshops are organized by the PREZIES network. Currently about 90% of acute care hospitals in the Netherlands participate.

Study population

We focused on five frequently performed surgical procedures: mastectomy, colectomy, replacement of the head of the femur, total hip prosthesis, and knee prosthesis. Per surgical procedure, the duration of participation for each hospital was calculated from the start date of the surveillance of that particular procedure. Hospitals can start participating at any time. The surveillance time to operation was stratified in consecutive 1-year periods, with the first year as reference.

Per surgical procedure, hospitals that registered the procedures for at least three consecutive years were included. Per type of procedure, latter surveillance years which covered less than 200 operations (with data from all hospitals combined) were excluded for power considerations.

Many SSIs develop after the patient has left the hospital. Because the likelihood of detecting an existing SSI is higher when postdischarge surveillance is performed, the multivariate analyses were adjusted for this by comparing the recommended method for postdischarge surveillance versus another method or no postdischarge surveillance.[6] Records with unknown postdischarge surveillance method were excluded from the analyses (3%).

All analyses were performed for each of the five selected surgical procedures separately.

If a risk factor had <1% missing values, the records with a missing value were excluded from the multivariate analyses. The missing value indicator method was used for variables with >1% missing values (1%-9%).[8] Age was categorized into tertiles. Preoperative duration of hospitalization was dichotomized, with a cutoff point of 2 or 3 days (0-1 versus 2 days was applied to mastectomy, total hip prosthesis and knee prosthesis; 0-2 versus 3 days was applied to colectomy and replacement of the head of the femur). The 75th percentile of duration of surgery per procedure was calculated in minutes, using the current data. Other risk factors were the American Society of Anesthesiologists (ASA) physical status classification (1-2 / 3-5), wound contamination class (clean or clean-contaminated / contaminated or dirty), gender (male / female), emergency procedure (yes / no), antimicrobial prophylaxis (yes / no), university-affiliated hospital (yes / no).

Questionnaire

To gain information on whether interventions to decrease the number of SSIs were performed in the participating hospitals during their surveillance period, we sent out a questionnaire to all

42 hospitals. Twenty hospitals had already filled in a questionnaire in 2005, for a similar study. However, that questionnaire was restricted to interventions that might affect the SSI risk after knee and hip prosthesis surgery. Therefore, these twenty hospitals were asked to complete the new questionnaire for interventions performed since 2005 and for interventions concerning the SSI risk after mastectomy, colectomy or replacement of the head of the femur. The hospitals were asked to describe in detail all performed interventions (goal, type, time frame, and result of each intervention) that might have influenced the SSI risk and the date the intervention was started.

Statistical 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.

In the present multicenter study, patients were clustered by hospital. This level of hierarchy can introduce additional sources of variability and correlation (e.g., by hospital-specific treatment policies or risk factors). Therefore, a random coefficient model (procedure NLMIXED in SAS) was used to adjust the risk estimates for random variation among hospitals. Because regular logistic regression models do not take into account interhospital variability, they might overestimate the contribution of patient- and procedure-related factors and overestimate precision.

From the basic model with surveillance time to operation and postdischarge surveillance, variables were sequentially added through manually performed forward selection. In each step, the variable with the smallest likelihood ratio test (LRT) *P* value was added. This was repeated until no other variable contributed significantly to the likelihood of the model (LRT *P* value >0.05), constituting the final model. Associations between SSI and exposures were estimated by odds ratios (OR) and 95% confidence intervals (CI) obtained by logistic regression. A *P* level of less than .05 was considered statistically significant.

All analyses were performed in SAS for Windows (SAS 9.1.3, SAS Institute Inc., USA).

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RESULTS

The number of surveillance years included in the analyses (years with >200 procedures) was six years for colectomy, nine years for replacement of the head of the femur, and ten years for mastectomy, total hip prosthesis and knee prosthesis (Table 1). This indicates that, per surgical procedure, the duration of surveillance of a single hospital could vary between three years and the above-mentioned number of surveillance years. Per procedure, at least four hospitals participated during all included surveillance years.

Table 2 shows the characteristics of the study population for each of the five included surgical procedures. The number of procedures varied from 3,031 for colectomy to 31,407 for total hip prosthesis. The SSI rate varied from 1.6% for knee prosthesis to 12.2% for colectomy. Patients undergoing replacement of the head of the femur were the eldest and had the highest ASA classification score. The 75th percentile of duration of surgery was shortest for replacement of the head of the femur (75 minutes) and longest for colectomy (135 minutes). Patients undergoing

Table 1. Number of hospitals and surveillance years.

Surgical procedure	No of surveillance years[a]	No of hospitals[b]	No of hospitals all years[c]
Mastectomy	10	19	4
Colectomy	6	19	6
Replacement head of femur	9	27	4
Total hip prosthesis	10	34	8
Knee prosthesis	10	33	7

[a] Only years included with at least 200 operations.
[b] In this study hospitals are included that registered the surgical procedure for at least three years.
[c] All years means the total number of years mentioned in the second column.

Table 2. Study population.

	Mastectomy	Colectomy	Replacement head of femur	Total hip prosthesis	Knee prosthesis
Procedures – no.	5785	3031	6113	31407	15176
SSIs – no. (%)	258 (4.5)	370 (12.2)	268 (4.4)	766 (2.4)	249 (1.6)
Age – median (25th percentile;75th percentile)	58 (49;70)	69 (57;77)	82 (77;87)	70 (63;77)	72 (64;77)
Gender – % woman	99	53	76	71	76
Wound contamination class – % ≥3	<1	24	<1	<1	<1
ASA classification – % ≥3	6	27	38	13	15
Duration of surgery – 75th percentile in minutes	90	135	75	95	105
Type of procedure – % emergency	<1	15	55	3	<1
Prophylaxis – % administrated	6	93	96	96	98
Preoperative hospitalization – % ≥2 days	3	39	26	7	4
Postdischarge surveillance – % recommended method	31	33	31	45	45
Type of hospital – % university-affiliated	9	1	0	4	3

colectomy or replacement of the head of the femur had on average a longer preoperative duration of hospitalization than the other three types of procedures. Overall, postdischarge surveillance was performed according to the recommended method by PREZIES in 42% of the data.

Figure 1 shows crude SSI rates according to surveillance time to operation, per surgical procedure. The results of the multilevel logistic modeling are presented in Table 3. The models were adjusted for the method of postdischarge surveillance and for risk factors. For total hip prosthesis, the SSI rate decreased significantly by 6% per surveillance year, indicating a 60% decrease after 10 years of surveillance. Non-significant decreasing trends in SSI rate were found for colectomy (8% per surveillance year), for replacement of the head of the femur (6% per surveillance year), and for knee prosthesis (3% per surveillance year). For mastectomy, the SSI rate hardly changed with increasing duration of surveillance.

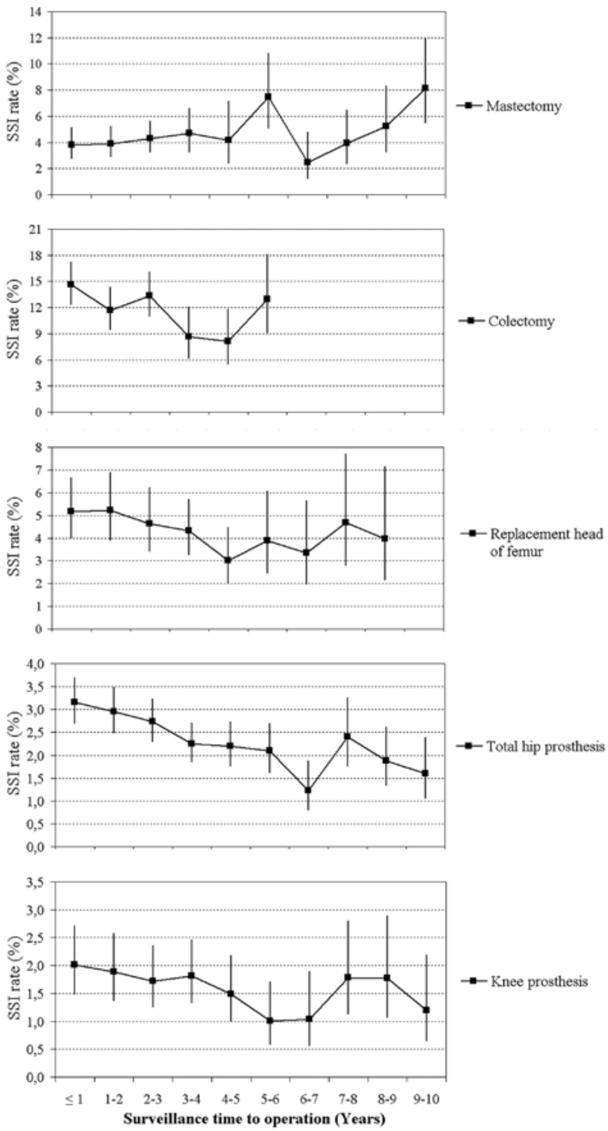

Figure 1. Crude SSI rates (with 95% confidence intervals) according to surveillance time to operation, per surgical procedure.

Overall, information regarding interventions to decrease the number of SSIs was received from 33 of the 42 hospitals. The performed interventions comprised improvements regarding preoperative administration of antimicrobial prophylaxis, hand hygiene, preoperative hair removal, and discipline and airflow in the operating room. For mastectomy, eight hospitals completed the questionnaire and five of them performed at least one intervention. However, no SSI data are available of the post-intervention period yet. Table 4 reveals that the SSI rate of patients undergoing

Table 3. Results of multilevel logistic regression analysis: change in SSI rate **per 1-year increase** in surveillance time to operation.

	OR (95% CI)	*P*
Mastectomy[1]	1.02 (0.96-1.09)	0.46
Colectomy[2]	0.92 (0.83-1.02)	0.10
Replacement of the head of the femur[3]	0.94 (0.88-1.00)	0.07
Total hip prosthesis[4]	0.94 (0.90-0.98)	0.01
Knee prosthesis[5]	0.97 (0.91-1.03)	0.32

OR, odds ratio; *95% CI*, 95% confidence interval.

[1] Adjusted for: postdischarge surveillance, age, duration of surgery, gender.

[2] Adjusted for: postdischarge surveillance, ASA classification, wound contamination class, duration of surgery, duration of preoperative hospitalization, emergency procedure.

[3] Adjusted for: postdischarge surveillance.

[4] Adjusted for: postdischarge surveillance, age, ASA classification, duration of preoperative hospitalization, wound contamination class, duration of surgery.

[5] Adjusted for: postdischarge surveillance, university-affiliated hospital, duration of surgery, gender, age.

mastectomy in the hospitals without interventions was lower than the SSI rate in the hospitals that did perform interventions. These hospitals probably saw no need to change infection control activities considering they performed relatively well compared to the other Dutch hospitals participating in the PREZIES surveillance system. For replacement of the head of the femur and for knee prosthesis, the SSI rate decreased after the interventions, but the change was not statistically significant. For total hip prosthesis, the SSI rate after the interventions was significantly lower than before the interventions, but was still higher than the SSI rate of hospitals that did not perform an intervention. Strangely, regarding colon resection the SSI rate increased after the interventions.

DISCUSSION

This study showed a decreasing trend in SSI risk with increasing surveillance time for some surgical procedures. For total hip prosthesis a significant decrease in SSI rate of 6% per surveillance year was observed, indicating a 60% decrease after 10 years of surveillance. For knee prosthesis, replacement of the head of the femur, and colectomy the decreasing trend was 3%, 6% and 8% per surveillance year, respectively. Even though these latter trends were not statistically significant, they are encouraging. Hospitals are heterogeneous in their environment, patient-care practices, healthcare providers and patient population. By applying multilevel analysis, SSI risk estimates were adjusted for random variation between hospitals. In the multivariate analysis, the patients' and operations' characteristics were taken into account in the SSI risk estimation. Therefore, the observed decreasing trends are most likely a result of an improvement in the quality of care in the hospitals.

We think that the sensitivity of infection detection has not changed during the study period as the execution of the surveillance was validated in all participating hospitals.[7] Other favorable aspects of the current study are that the results were adjusted for the performed method of postdischarge surveillance and that a large dataset was used with data from 42 hospitals and ten surveillance years. In this study, the trend in SSI rate was analyzed for each surgical procedure separately, hereby allowing adjusting for procedure-specific risk factors.

Table 4. The SSI rate before and after an intervention for hospitals that did perform at least one intervention, and the overall SSI rate for hospitals without an intervention.

	Before intervention				**After intervention**			
	No of procedures	**No of SSIs**	**SSI rate**	**95% CI**	**No of procedures**	**No of SSIs**	**SSI rate**	**95% CI**
Mastectomy								
No intervention (n*=3)	747	24	3.2	(2.2-4.7)				
Intervention (n=5)	2957	161	5.4	(4.7-6.3)	0	-	-	-
Colectomy								
No intervention (n=2)	265	26	9.8	(6.8-14.0)				
Intervention (n=8)	739	73	9.9	(7.9-12.2)	858	161	18.8	(16.3-21.5)
Replacement of head of femur								
No intervention (n=6)	1578	74	4.7	(3.8-5.8)				
Intervention (n=12)	1412	70	5.0	(3.9-6.2)	1436	61	4.2	(3.3-5.4)
Total hip arthroplasty								
No intervention (n=7)	5909	88	1.5	(1.2-1.8)				
Intervention (n=14)	6966	196	2.8	(2.5-3.2)	9494	207	2.2	(1.9-2.5)
Knee arthroplasty								
No intervention (n=6)	2375	29	1.2	(0.9-1.7)				
Intervention (n=12)	2776	46	1.7	(1.2-2.2)	4562	58	1.3	(1.0-1.6)

* Number of hospitals.

The decreases in SSI rates found in this study are smaller than the decreasing trend that Geubbels et al. described earlier with a different subset of the PREZIES database.[5] They found a decrease in SSI rate of 31% in the fourth surveillance year and of 57% in the fifth year compared with the first year of surveillance. There were several differences in methodology between these two studies that might partly explain the different results. Geubbels et al. included only five surveillance years, additionally included hospitals with a surveillance period less than three years, pooled data from seven surgical procedures, and included hospital-related factors.
The limitation of this study was that the trend in SSI risk was not adjusted for changes in length of hospitalization. The average length of hospitalization reduced over the ten years included in this study. This reduction was larger per calendar year than per surveillance year, because many hospitals started participating in PREZIES later than 1996. Only for 16 of the 42 hospitals (38%) that started SSI surveillance in 1996 (of at least one of the five included types of procedures), the first surveillance year corresponded to the calendar year 1996. Ten (24%) hospitals started not earlier than January 2001. The largest decrease in median length of hospitalization was recorded for total hip prosthesis and knee prosthesis, i.e., a decrease of five days between the 1st and 10th surveillance year. We think that this decrease can not solely have caused the reduction in SSI rate of 6% per surveillance year (60% after ten years) for total hip prosthesis. Besides, because of the fact that many hospitals perform postdischarge surveillance, the length of hospitalization has only a minimal effect on the detection of SSIs. This was supported by the fact that the time between operation and SSI diagnosis did not decrease but even increased with increasing surveillance time (data not shown). The shorter length of stay led to an increase in the relative number of SSIs that were diagnosed after discharge, which were captured by postdischarge surveillance.
Feedback of infection rates to hospital staff can make them more aware of infection risk and increase their discipline in working according to infection prevention protocols. As early as 1970s, the American NNIS data demonstrated the benefits of properly designed wound infection surveillance. Haley et al. suggested that an effective infection surveillance program can reduce a hospital's wound infection rate by 30%.[1]
During the last decade, some other SSI surveillance networks have also investigated the change in SSI rate with increasing duration of surveillance. In Germany, the KISS surveillance network was set up in 1997, and recently two studies have been performed on the effect of surveillance on the SSI rate. The first included data between 1997 and 2003.[9 10] The SSI rate of the third surveillance year was compared with the first year. For total hip arthroplasty the SSI decreased with 43% (95% CI: 22-58%), for cesarean section with 36% (95% CI: 17-51%), and the trend for knee arthroplasty was not statistically significant. Most hospitals did not perform any particular intervention, and some improved the administration of antimicrobial prophylaxis or skin disinfection. The second German study compared the fourth surveillance year with the first.[11] A decreasing trend in SSI rate was found for 14 of the 19 included procedure categories. Overall, the SSI rate decreased with 25% (95% CI: 17-32%) as a result of surveillance-induced infection control efforts. Limiting factors of these German studies were that the results were not adjusted for a reduced postoperative length of stay, nor for postdischarge surveillance, and that multilevel analysis was not applied.

A study in Northern France included six years of SSI surveillance data, with postdischarge surveillance until 30 days.[12] All types of procedures were pooled. The crude SSI rate decreased from 3.8% to 1.7% (*P* for trend <.0001), and the standardized infection ratio decreased from 1.24 to 0.74. Recently, a comparable study with data from the SSI surveillance network in southeast France reported an overall decrease in SSI rate of 5% per year (45% after 9 years), which was observed for almost all different types of surgical specialties.[13] They included hospitals that participated for at least two years. Only this last study included many of the aspects that we consider vital for analyzing trends in SSI risk, namely adjust for random variation between hospitals, adjust the SSI risk estimates for surgical specialty or perform separate analyses per procedure, and follow up all patients after surgery for at least 30 days or one year if a prosthesis had been implanted or adjust for the performed method of postdischarge surveillance.

At least one study observed no general preventive effects of the continuous monitoring of SSI rates, maybe because of the short study period of two years.[14] Of course, this might be an underestimation as results of studies that revealed a positive effect of SSI surveillance are probably more often published than those of studies that failed to do so.

Many studies have measured the effect of surveillance combined with several interventions on the SSI risk.[15-17] In our study, about two thirds of the hospitals executed at least one intervention. However, as the implementation of interventions was inquired retrospectively, it was difficult to link these interventions to the SSI data in order to assess its effectiveness. We would suggest to more often link SSI surveillance data to multicenter intervention studies, like done in a Dutch study on improvement of antimicrobial prophylaxis[18] and in Breakthrough series.

In conclusion, a high-quality surveillance system might be an effective strategy to reduce the SSI incidence. As the applied methodology of analyzing trends in SSI risk might influence the results it is essential to pay attention to these methods when comparing results with those of other surveillance networks.

To use limited recourses as efficient as possible, we would suggest switching the surveillance to another surgical specialty when the SSI rate has decreased below the target. The next step is to estimate the savings due to the observed decrease in SSI rate and thus the cost effectiveness of the national SSI surveillance system.

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