Reduced risk of surgical site infections through surveillance in a network

EVELINE L. P. E. GEUDBELS¹, NICO J. D. NAGELKERKE², A. JOKE MINTJES-DE GROOT³, CHRISTINA M. J. E. VANDENBROUCKE-GRAULS⁴, DIEDERICK E. GROBBEE⁵ AND ANNETTE S. DE BOER¹

¹Department of Infectious Diseases Epidemiology, National Institute of Public Health and the Environment (RIVM), ²Department of Computerization and Methodological Consultancy, National Institute of Public Health and the Environment (RIVM), ³Dutch Institute for Healthcare Improvement CBO, Utrecht, ⁴Department of Medical Microbiology and Infection Control, Vrije Universiteit Medical Centre, Amsterdam, and ⁵Julius Centre for General Practice and Patient Oriented Research, University Medical Centre Utrecht, Utrecht, The Netherlands

Abstract

Objective. To estimate the effect of multicentre surveillance for nosocomial infections on patients’ risk of surgical site infection (SSI).


Study participants. All 50 hospitals performing surveillance for one of seven selected procedures in the Dutch surveillance network for nosocomial infections PREZIES were invited. Thirty-seven hospitals participated (74%) and provided information on 21 920 operations, after which 885 (4%) SSI occurred.

Interventions. The surveillance comprised the following: Development of surveillance methodology by multidisciplinary team; use of a standardized registration protocol and software; regular training of data collectors; anonymous inter-hospital comparison of infection rates and feedback of results; appointment of one contact person per hospital, responsible for data collection; and dissemination of results to other health care professionals. Regular discussion of both successful and failing prevention strategies that had been instituted based on the surveillance results.

Outcome measure. Risk of SSI.

Results. The risk of infection was reduced for patients who had an operation during the fourth surveillance year (RR = 0.69; 95% confidence interval (CI) = 0.52–0.89) and decreased further for patients operated on during the fifth surveillance year (RR = 0.43; CI = 0.24–0.76) as compared with patients who underwent surgery within one year of the start of surveillance in their hospital. No significant risk reduction was observed for patients operated on during the second and third surveillance years.

Conclusion. Surveillance, supported by participation in a surveillance network, reduced the risk of SSI in surgical patients registered in the Dutch surveillance network PREZIES. Our results suggest that infection control teams need to be perseverant and that surveillance programmes should be given time before evaluation.

Keywords: health care quality, prevention, surgical wound infection, surveillance

In clinical patient care, surgical adverse events constitute approximately half of all adverse events [1–3]. Among surgical patients, surgical site infections (SSI) are a common complication [2,4,5]. SSI are a cause of increased morbidity, mortality, and costs. Plowman and colleagues estimated the in-patient costs of SSI for the UK to be £62.37 annually [6]. In the USA, SSI were estimated to be responsible for 20 000 in-hospital deaths, and cost hospitals over $3 billion each year for in-patient care alone [7]. Although not all SSI are preventable, adequate measures [8] can substantially reduce the risk of SSI. In the 1970s, the SENIC study in the USA showed that surveillance can lead to a reduction in the incidence of SSI. Depending on the presence of adequately trained and interested staff, hospitals with a strong surveillance and control programme were able to lower their SSI rates by 19–41% over the course of 6 years [9]. Other authors have also described a decline in infection rates after systematic surveillance was introduced in their hospitals [10–12]. After these findings, many countries established national surveillance systems for nosocomial infections. The premise of all these surveillance systems is that they enable hospitals to compare their rates with each other, thereby stimulating...
them to optimize their infection prevention policy to the best practices described in guidelines and employed by their peers. The ultimate aim is to reduce the patients’ risk of nosocomial infection.

The Dutch surveillance system, called the Network for Prevention of Nosocomial Infections through Surveillance (PREZIES), was established in 1996. Participants are Dutch hospitals, coordinated by the Dutch Institute for Health Care Improvement CBO and the National Institute of Public Health and the Environment. The first type of infection to be included in the PREZIES surveillance network was SSI.

To determine whether prevention of SSI is indeed accomplished in the PREZIES network and to determine the magnitude of risk reduction, we studied the effect of the duration of PREZIES surveillance in a hospital on the risk of SSI. We estimated the risk ratios, both crude and adjusted for patient-, procedure-, and hospital-related confounders, of the second, third, fourth, and fifth surveillance years in reference to the first year.

Methods

Design

Data were collected within the PREZIES surveillance network for SSI. Participation in PREZIES is voluntary and confidential. Hospitals can start participating any time. The calendar year corresponding to the first surveillance year in a hospital therefore varies. The surveillance methods have been described before [13]. In summary, hospitals conducted prospective in-hospital surveillance according to a standardized protocol, including SSI definitions of the Centers for Disease Control [14]. These define a SSI as nosocomial if it occurs within 30 days post-operatively or within 1 year in the case of a prosthetic implant. In addition to the in-hospital follow-up, one third of the hospitals continued surveillance for SSI after discharge of the patient. Furthermore, the hospitals collected data about patient- and procedure-related risk factors for SSI. Local data collection was validated during on-site visits by a validation team [13,15]. Upon sending their data to the PREZIES-team, hospitals received a feedback report. This included their hospitals’ crude and adjusted procedure-specific SSI rates, compared with their own historical rates and with other hospitals’ rates. The NNIS risk index [16], incorporating the wound contamination class [17], American Society of Anesthesiology (ASA) score [18] and duration of surgery were used for risk adjustment of SSI rates. A designated contact person (usually an infection control professional) was responsible for organization and quality of data collection and dissemination of surveillance results, for example, to the infection control committee, physicians, managers, and staff. Whether surveillance results necessitated a more profound evaluation of infection control practices and (re-)implementation of infection prevention guidelines was at the hospitals’ discretion. Twice yearly, workshops were held to discuss practical obstacles in the surveillance and to share experiences of successful or failing prevention strategies.

Setting

The hospitals participating in PREZIES constitute approximately 50% of acute care hospitals in The Netherlands, and comprise university-affiliated and regional teaching hospitals and non-teaching hospitals. Large hospitals (>600 beds) are slightly overrepresented.

Inclusion of procedures and hospitals

In this study, information about a number of possible confounding factors was not available from the regular surveillance data, but had to be collected by the contact persons. Because of the time investment involved, it was decided to restrict the study to seven procedures which were commonly registered within PREZIES, namely femoro-popliteal or -tibial bypass, mastectomy with axillary lymph node dissection, colectomy, total hip arthroplasty, replacement of the head of the femur, Caesarean section, and abdominal hysterectomy. Hospitals that did not perform surveillance for any of the selected procedure categories were excluded, as were hospitals that had stopped performing surveillance before 1 January 1999. Fifty hospitals met the inclusion criteria; 37 participated (74%). These 37 hospitals provided information on 21,920 operated patients who acquired 885 SSI. The main reason for non-participation was lack of time.

Data collection

Factors that potentially affected both the hospital’s duration of participation in PREZIES and the patient’s risk of SSI were regarded as possible confounders. On the hospital level: hospital size and annual volume of operations for each procedure, the teaching status of the department, the number of general surgeons, orthopaedic surgeons or gynaecologists in the department, and their median number of years of experience. On the patient- and procedure-level: age, ASA score and duration of pre-operative hospital stay of the patient and the type of procedure, duration of surgery, wound contamination class and timing of surgery (elective versus emergent). Because the likelihood of detecting an existing SSI is higher when post-discharge surveillance is performed, this variable was also adjusted for [19].

For patients not followed up after discharge, the median post-operative stay in the hospital might have influenced the proportion of SSI that was found. Because we did not observe a change in procedure-specific post-operative lengths of stay (as measured in non-infected patients) in the study period, this variable was not adjusted for in the analysis.

We included data on operations performed between 1 January 1996 and 31 December 2000. We collected data concerning hospital-related confounders through structured telephone interviews with all contact persons during the first trimester of 2000. These data about hospital characteristics were taken as a proxy for their values during the whole study period.

Data analysis

We stratified surveillance time to operation, i.e. the number of days between the start of surveillance in a hospital and the
day of surgery of a patient, into five consecutive 1-year periods. We chose patients who underwent surgery during the first year of surveillance as the reference group. We analysed the crude and adjusted association between surveillance time to operation and risk of SSI with multilevel logistic regression [20], using the MLWiN software, release 1.10.0006 (Multilevel Models Project, Institute of Education, University of London, UK).

To calculate the crude association between surveillance time to operation and risk of SSI, we fitted a model that included only these two variables. We selected the best model for the adjusted association through step-wise inclusion of possible confounders. Factors were regarded as a confounder if they changed the parameter estimate for at least one of the strata of surveillance time to operation with more than 10% of its last value. Because a number of confounding factors were procedure-specific, we kept the type of procedure in all models. Owing to the limited number of hospitals, we included a maximum of four hospital characteristics in the second-level part of the model. We excluded patients with missing values for one or more of the confounders in the adjusted model from that analysis [21].

**Results**

**Study population**

The participation of hospitals in PREZIES varied from 6 to 60 months. The median surveillance time to operation for individual patients was 609 days (range: 0–1823 days). Eighteen hospitals started participating in 1996, 11 in 1997, 5 in 1998, and 3 in 1999. Table 1 describes the population. The composition of the population was roughly similar per surveillance year. A large proportion of procedures were total hip arthroplasties. Post-discharge surveillance was performed for more than half of all operated patients. Over 50% of all operations were performed in hospitals of intermediate size. Forty percent was carried out in teaching hospitals and only 14% of those (6% of total) in university-affiliated hospitals. One in nine operations was performed in a hospital where residents performed the selected procedures without supervision. The annual number of operations performed in a hospital, the number of surgeons per specialty, and the median number of their years of experience all varied greatly with the type of procedure.

**Incidence of SSI**

The incidence of SSI remained relatively stable at around 4.3% in the first three surveillance years and then dropped to 3.3% in the fourth year and further down to 1.8% in the last surveillance year (Figure 1). Table 2 shows that the trend seen in hospitals participating for a short time (≤3 years) was similar to that of hospitals participating longer (4 or 5 years). A reduction occurred for both superficial and deep infections, and for operations that are followed by PDS surveillance and for those that are not (data not shown). The SSI rate was highest in the calendar year 1998 (4.5%) and lowest in 2000 (3.2%), but no statistically significant differences in SSI rates were seen during the calendar years 1996–2000.

**Effect of surveillance**

The results of the multilevel logistic modeling are presented in Table 3. In the crude analysis, a reduced risk was observed for patients who underwent surgery in the fourth and fifth years of surveillance as compared with the risk in the reference group of patients operated on during the first surveillance year. Adjustment for the confounding effect of post-discharge surveillance, ASA score, age group, duration of preoperative stay in the hospital, type of procedure, wound contamination class, duration of surgery, timing of surgery, hospital size, teaching status, number of surgeons, and experience of surgeons only slightly altered the effect estimates. For 14% of all 21 920 patients, information on one or more variables included in the adjusted model was missing. For each surveillance year, these missing values were equally distributed between patients with and those without SSI. The adjusted risk of SSI for patients operated on during the fourth surveillance year was reduced by 31% (95% CI = 11% to 46%), and further decreased by 57% (95% CI = 24% to 76%) for patients operated on during the fifth surveillance year as compared with those operated on during the first surveillance year.

**Discussion**

In our study, surveillance performed in the context of a SSI-surveillance network was associated with a decreased risk of SSI for patients operated on during the fourth surveillance year and with a further reduction in the fifth year. The huge reduction in the fifth year of more than 50% had to be interpreted with caution: due to the small number of infections, the CI is wide.

To appreciate these findings, some issues need to be addressed. No change in definitions, protocol, and guidelines that may explain the decreased incidence rate occurred during the study period. It could be argued that the decreased risk observed in our study might be the result of declining surveillance intensity over the years. However, continuous training and validation of the use of surveillance criteria in the PREZIES network most likely preclude this possibility [13].

Bias may have occurred through the selection of hospitals, because not all hospitals that participated in PREZIES took part in this study. However, non-participating hospitals did not differ from hospitals in this study with regard to size, teaching status, and distribution of procedure-specific SSI rates (data not shown). PREZIES hospitals not included in the study showed a similar trend in SSI rates as hospitals included in this study. The rate started at 5.5% in the first year and decreased to 1.1% in the fourth surveillance year, with no observations in the fifth surveillance year. It is therefore unlikely that the preventive effect of surveillance as observed in this study results from selection of PREZIES hospitals that were successful in reducing their SSI rates.
Fourteen per cent of patients were not included in the adjusted model due to missing values for one of the founders. Because in all surveillance years, these missings were equally distributed between infected and non-infected patients, they cannot explain the observed reduction in risk of SSI over the surveillance years.

Hospitals that conducted surveillance for 4 years generally had higher SSI rates than others, although the trend of SSI rates observed over the years was similar to that of hospitals participating for 1–3 or in 5 years. A possible explanation might be that two-thirds of these hospitals were teaching hospitals, as opposed to 40% of other hospitals. However, because we adjusted the RR estimates for the confounding effect of teaching status, it is unlikely that this biased our results.

In our analysis, different types of operations were pooled to increase the power of the study. The relative proportion of low-risk procedures (total hip arthroplasty, Caesarean section,
Crude and adjusted risk ratios (RR) and 95% confidence intervals (CI) for association of surveillance time to operation with risk for surgical site infection after 21,920 selected operations

<table>
<thead>
<tr>
<th>Surveillance time to operation</th>
<th>Crude RR (CI)</th>
<th>Adjusted RR (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤1 year</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1–2 years</td>
<td>0.96 (0.80–1.14)</td>
<td>0.85 (0.70–1.03)</td>
</tr>
<tr>
<td>2–3 years</td>
<td>0.97 (0.80–1.18)</td>
<td>0.92 (0.74–1.14)</td>
</tr>
<tr>
<td>3–4 years</td>
<td>0.67 (0.52–0.86)</td>
<td>0.69 (0.52–0.89)</td>
</tr>
<tr>
<td>4–5 years</td>
<td>0.46 (0.26–0.81)</td>
<td>0.43 (0.24–0.76)</td>
</tr>
</tbody>
</table>

1 Adjusted for post-discharge surveillance method, ASA score, age group, duration of pre-operative stay in the hospital, type of procedure, wound contamination class, duration of surgery, elective versus emergent surgery, hospital size and teaching status, number of surgeons and experience of surgeons. Due to missing values for one or more of the above variables, 3077 patients were excluded from analysis.

Improvement of quality of care therefore is feeding back the information about the measured adverse health event to those who need to know, to enable them to take appropriate action [24].

The establishment of the successive phases of a surveillance system in a hospital takes considerable time. This might explain why we did not observe a reduced risk during the second and third years. It seems plausible that a longer period of surveillance has led to more progress in identifying and solving problems. This is suggested by an internal evaluation of the use of surveillance results in PREZIES hospitals, conducted 2 years after the start of the PREZIES network. Of 38 hospitals participating in this evaluation, only 16 hospitals had already started interventions on the basis of the surveillance results. Six of these had been able to evaluate the intervention, and five of them reported to have been successful in reducing SSI rates. A seeming delay in the effectiveness of surveillance was also present in a study on SSI after coronary artery bypass graft surgery by McConkey et al. They reported a marked reduction in SSI risk in their hospital, but not until

![Figure 1](https://academic.oup.com/intqhc/article-abstract/18/2/127/1844370/15727)

**Figure 1** SSI rates with 95% confidence intervals per surveillance year for all hospitals.

Table 2 Number of operations with corresponding SSI rates (%) with 95% confidence intervals (CI) per surveillance year, stratified for duration of hospital participation since the start of surveillance

<table>
<thead>
<tr>
<th>Duration of hospital participation</th>
<th>1–5 years (37 hospitals)</th>
<th>1–3 years (28 hospitals)</th>
<th>4 years (9 hospitals)</th>
<th>5 years (8 hospitals)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>CI</td>
<td>n</td>
</tr>
<tr>
<td>Year 1</td>
<td>6709</td>
<td>4.38</td>
<td>3.8–4.8</td>
<td>3590</td>
</tr>
<tr>
<td>Year 2</td>
<td>6349</td>
<td>4.1</td>
<td>3.7–4.6</td>
<td>3268</td>
</tr>
<tr>
<td>Year 3</td>
<td>4833</td>
<td>4.3</td>
<td>3.8–4.9</td>
<td>1501</td>
</tr>
<tr>
<td>Year 4</td>
<td>3237</td>
<td>3.3</td>
<td>2.7–3.9</td>
<td>1548</td>
</tr>
<tr>
<td>Year 5</td>
<td>792</td>
<td>1.9</td>
<td>0.9–2.8</td>
<td></td>
</tr>
</tbody>
</table>
the fourth year after the start of a surveillance and control programme for SSI [25].

In conclusion, the results of our study demonstrate that surveillance, supported by participation in a surveillance network, may reduce the risk of SSI in surgical patients. This reduction most probably reflects the effect of successful interventions to lower SSI rates on the basis of surveillance. That the effect took several years to become apparent would imply that infection control teams need to be perseverant and that surveillance programmes should be given time before evaluation.

Acknowledgements

We gratefully acknowledge all infection control practitioners, medical specialists, and nurses of the following hospitals for their contribution to the data collection: t’ Lange Land Hospital, Zoetermeer; Albert Schweitzer Hospital at Amstelveen, Dordrecht; Albert Schweitzer Hospital at Dordrecht, Dordrecht; Albert Schweitzer Hospital at Zuidlaren, Zwolle; Beatrix Hospital, Gorinchem; Bernhoven Hospital at St. Anna, Os; Bosch Medicenter, Den Bosch; BovenIJ Hospital, Amsterdam; Catharina Hospital, Eindhoven; Deventer Hospitals Group, Deventer; Elkerleek Hospital, Helmond; Groene Hart Hospital, Gouda; Harbour Hospital, Rotterdam; Hospital De Gelderse Vallei at Bennekom, Bennekom; Hospital Hilversum, Hilversum; Hospital Nij Smeltinghe, Drachten; Hospital Rijnvliet, Tiel; Hospital Walcheren, Vlissingen; Isala Hospitals at Wezenlanden, Zwolle; Isala Hospitals at Sophia, Zwolle; Leiden University Hospital, Leiden; Medical Centre Molendael, Baarn; Medical Centre Leeuwarden South, Leeuwarden; Medical Spectrum Twente at Oldenzaal, Oldenzaal; Oosterschelde Hospitals Group, Goes; Regional Hospital Coevorden-Hardenberg, Coevorden; Regional Hospital Queen Beatrix, Winterswijk; Regional Hospital Zevenaar, Zevenaar; St. Carolus Lichuina Hospital, Den Bosch; St. Elisabeth Hospital, Tilburg; St. Franciscus Hospital, Rotterdam; University Hospital Groningen, Groningen; University Hospital Maastricht, Maastricht; Vlietland Hospital at Schieland, Schiedam; Vlietland Hospital at Holy, Vlaardingen; Wilhelmmina Hospital, Assen; Zuider Hospital, Rotterdam. We thank C. N. Lau for his help with the processing of data and J. Wille, Dr J. Keeman, and Dr G. Walenkamp for their valuable comments during the planning of the study. We also thank the Ministry of Health, Welfare, and Sports, who financially supported the study.

References


Accepted for publication 12 January 2006