Standardized incidence rates of surgical site infection: A multicenter study in Thailand

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Background: No previous multicenter data regarding the incidence of surgical site infection (SSI) are available in Thailand. The magnitude of the problem resulting from SSI at the national level could not be assessed. The purpose of this study was to estimate the incidence of SSI in 9 hospitals, together with patterns of surgical antibiotic prophylaxis, risk factors for SSI, and common causative pathogens.

Methods: A prospective data collection among patients undergoing surgery in 9 hospitals in Thailand was conducted. The National Nosocomial Infection Surveillance (NNIS) system criteria and method were used for identifying and diagnosing SSI. The SSI rates were benchmarked with the NNIS report by means of indirect standardization and reported in terms of standardized infection ratio (SIR). Antibiotic prophylaxis was categorized into preoperative, intraoperative, and postoperative. Risk factors for SSI were evaluated using multiple logistic regression models.

Results: From July 1, 2003, to February 29, 2004, the study included 8764 patients with 8854 major operations and identified 127 SSIs, yielding an SSI rate of 1.4 infections/100 operations and a corresponding SIR of 0.6 (95% CI: 0.5-0.8). Of these, 35 SSIs (27.6%) were detected postdischarge. The 3 most common operative procedures were cesarean section, appendectomy, and hysterectomy. The 3 most common pathogens isolated were *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*, which accounted for 15.3%, 8.5%, and 6.8% of infections, respectively. The 3 most common antibiotics used for prophylaxis were ampicillin/amoxicillin, cefazolin, and gentamicin. The proportion of types of antibiotic prophylaxis administered were 51.6% preoperative, 24.3% intraoperative, and 24.1% postoperative. Factors significantly associated with SSI were high degree of wound contamination, prolonged preoperative hospital stay, emergency operation, and prolonged duration of operation.

Conclusion: Overall SSI rates were less than the average NNIS rates. The causative pathogens of SSI were different from those of other reports. There was a crucial proportion of operations that did not comply with the antibiotic guidelines. The risk factors for SSI identified in this study were consistent with most other reports. (Am J Infect Control 2005;33:587-94.)

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Supported by The Royal Golden Jubilee PhD Program of the Thailand Research Fund.

This article is a part of Nongyao Kasatpibal thesis to fulfill the requirements for a PhD degree in Epidemiology at Prince of Songkla University.

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0196-6553/$30.00

doi:10.1016/j.ajic.2004.11.012

Surgical site infection (SSI) is a common postoperative complication and causes significant morbidity and mortality, increases antibiotic usage, prolongs hospital stay, adds cost, and decreases patients' quality of life.[1-3] The challenge of hospitals is to improve the quality of care delivered to patients during surgery in a cost-effective manner through system redesign using proven, evidence-based practices.

Effective surveillance system and appropriate prophylactic antibiotics have been described as a preventive measure for reducing SSI. The landmark Study on the Efficacy of Nosocomial Infection Control (SENIC) project demonstrated that, to be effective, nosocomial infection programs must include the following components: (1) organized surveillance and control activities, (2) an adequate number of trained infection control staff, and (3) a system for reporting SSI rates to surgeons. The study showed that these strategies could reduce approximately one third of SSI.[4] An estimated 40% to 60% of SSIs are preventable with appropriate use of prophylactic antibiotics.[5-8] However, overuse, underuse, improper use, and misuse of antibiotics occurs in 25% to 50% of operations.[9-13] Inappropriate use of broad spectrum antibiotics, or prolonged courses of prophylactic antibiotics, puts all patients at even greater infection risk because of the development of antibiotic-resistant pathogens.[14] Reducing surgical infections while minimizing antibiotic resistance remains a challenge to hospitals.

In Thailand, no prospective study concerning incidence SSI on a national level has been published. The previous prevalence studies in 1988 and in 1992 revealed that SSI was the second and third ranked of all nosocomial infections in Thai hospitals, accounting for 19.6% and 16.6%, respectively.[15,16] Traditionally, SSI surveillance in Thailand has been stratified by only the degree of wound contamination. The major limitation of the system is its failure to capture the other intrinsic important patient risks of SSI, which is required before meaningful comparisons for mixed cases can be made.

Adjustment for variables known to confound rate estimates is critical for valid comparisons of SSI rates. During the SENIC project, a simplified index was developed.[17] Despite improved performance over the traditional wound classification scheme, limitations in the SENIC index were still noted. Recently, the National Nosocomial Infections Surveillance (NNIS) System developed the SSI risk index to provide a satisfactory risk-adjusted SSI rate across a diversity of operative procedures.[18,19] The NNIS risk index has proven to have significantly better discriminatory power than the SENIC index.[20]

Standardized infection ratio (SIR) is one of the proven measures for interpretation of SSI rate. This measure is used in many countries such as Spain and United States. Monge Jodra et al explained the use of the SIR to benchmark their SSI rates to SSI rates reported by the NNIS System.[21] Gustafson stated that there were several advantages of using the SIR: (1) It is adjusted for known variations in patient risk levels, and (2) any reported standard could be used as a benchmark.[22] A study in Thailand proclaimed that use of the SIR enabled a single comparison of rates, adjusted for risk category, instead of multiple comparisons specific to procedure and risk category with small numbers.[23]

This study was conducted with the primary intention to describe the incidence, common pathogens, surgical antibiotic prophylaxis, and risk factors for SSI. An additional aim of this study was to compare SSI rates recorded in a multicenter study in Thailand with those published by the NNIS.

METHODS

Setting

Our study was conducted in 9 Thailand hospitals, including 1 university hospital, 4 tertiary care hospitals affiliated with medical schools, and 4 general hospitals. All participating hospitals had at least 100 beds; 1 infection control nurse (ICN) per 250 beds (ICN responsible for the whole hospital); 1 infection control ward nurse (ICWN) per ward (ICWN responsible for each ward); undertook surveillance by using prospective surveillance methods with an efficiency of at least 60%; and had a computer in the infection control unit, a hospital computer database, and adequate clinical and laboratory information for diagnosis of SSI. Participation was voluntary, and the hospitals were assured of confidentiality of their data. The participating hospitals would receive their own standardized and stratified infection rates quarterly to compare their own data with pooled data from all participating hospitals. Once a year, a meeting of these hospitals was organized for discussion of methodologic points and exchange of participants' experience using such data for surveillance and infection control practices.

Data collection

From July 2003 to February 2004, a prospective multicenter study was conducted in the 9 hospitals. The surveillance of SSI concentrated on 28 NNIS operative procedure categories. However, each participating hospital selected its own major operative procedures of interest (at least 5 operative procedures/hospital), such as high infection rate, high volume of procedures, or high cost, for data collection. After a 1-day training session in data collection and diagnosis criteria, infection control nurses in each hospital prospectively collected the pertinent data and recorded the data on the preprinted data collection forms. The collected data included patient's demographic data, diagnosis, operation, antibiotics administered, clinical signs and symptoms of infection, laboratory results including microbiology and serology results, and imaging results.

The log book in the operative theater was reviewed every day for operations that met the inclusion criteria, which were as follows: procedure performed in an operating room (OR), a surgeon made a skin or mucous membrane incision and primarily closed it before the patient left the OR, and the procedure was included in the list of NNIS operative procedure categories. The name and hospital number of the patient and ward in which the patient resided were identified via the records of the ORs. The patients' medical records, operative notes, anesthetic records, diagnostic imaging reports, microbiology investigation data, and other laboratory results were reviewed. Information on variables related to operative procedure (ie, duration of operation, type of operation, degree of wound contamination, surgeon, and antibiotic prophylaxis) was also reviewed. After discussion with the nurses and attending physicians in that ward, the pertinent data were recorded on preprinted data collection forms. The American Society of Anesthesiologists (ASA) score on the patient's physical status was identified from anesthetic records. Medical records of the discharged patients in the outpatient department and medical records of the readmitted patients were also reviewed for evidence of infection developing after hospital discharge. The intensity and methods of postdischarge surveillance were different from one hospital to another, ranging from no formal postdischarge surveillance system to mailing or telephoning all discharged patients.

The completed data collection forms were sent to the research center for editing, processing, and analysis. The data collection forms with identified errors or incomplete information were sent back to the hospital for correction.

Definition

The criteria of the Centers for Disease Control and Prevention (CDC) NNIS System were employed for diagnosing SSI and classifying the cases as superficial incisional, deep incisional, or organ/space SSI.[24] The ASA score was used to measure patient physical status as 1 (healthy), 2 (mild systemic disease), 3 (severe systemic disease), 4 (severe life-threatening systemic disease), or 5 (moribund).[25] The operative procedures were classified according to degree of contamination into 1 of 4 classes (clean, clean-contaminated, contaminated, or dirty/infected). The patients' final diagnoses and operations were coded according to the International Classification of Disease 10th Revision (ICD-10) and the International Classification of Disease 9th Revision, Clinical Modification (ICD-9 CM), respectively. The operative procedures were also classified and assigned risk index categories according to the NNIS.[18] For each patient, the NNIS system risk index was computed on the basis of an ASA score of more than 2, a wound class of contaminated or dirty/infected, and a duration of procedure more than T hours (T = 75th percentile), with each criterion met adding 1 point to the index. If a procedure was performed endoscopically, the NNIS risk index score was modified by subtracting 1 point.[19] Thus, the NNIS risk index score ranges from −1 to 3.

Statistical analysis

Data were processed using Microsoft Visual FoxPro version 6 (Microsoft Corp, Redmond, WA). Data were expressed as percentages for demographic data. Incidence of SSI was calculated, using the NNIS operative procedure categories, by dividing the number of infections by the number of operations performed and multiplying by 100. The frequency of the organisms identified as causative pathogens responsible for infection was calculated by dividing the number of isolates by the number of infections. The surgical antibiotic prophylaxis administration was classified as preoperative, intraoperative, or postoperative antibiotic prophylaxis.

SIR is the ratio between the observed number of events, which is assumed to be Poisson distributed, to the expected number of events, which is calculated from the standard rate. This ratio is a risk-adjusted summary measure that facilitates comparisons between smaller cohorts of surgical patients and comparisons of those in the NNIS system.

The expected number of SSI for each NNIS operative procedure was computed by multiplying the number of operations by the NNIS-reported rate for that category.[26] The sum of expected numbers for all risk-index categories of specific procedures was the expected number of SSIs for that procedure. The 95% confidence intervals of SIR were estimated assuming a Poisson distribution.[27]

Multiple logistic regression models were used to assess the magnitude and significant association of variables on SSI. The strength of association between various factors and SSI was reported in terms of odds ratio. The role of chance was evaluated and reported in terms of 95% confidence intervals and *P* value. The continuous and ordinal dependent variables including preoperative stay, age, duration of antibiotic prophylaxis, duration of operation, ASA score, and wound class were modified to dichotomous variables before modeling in multiple logistic regression models. Univariate analysis was initially carried out to search for the variables that were statistically significant associated with SSI. Only variables that showed statistically significant ($P < .05$) association with SSI were included in the multivariate models. All analyses were performed using the statistical software STATA version 7 (Stata Corp, College Station, TX).

RESULTS

Patient characteristics

The study involved 9 hospitals with 8764 patients who underwent 8854 major operations from July 2003 to February 2004. Women accounted for 73.4% of the studied patients. The average patient age (SD) was 37.2 (19.2) years, and the overall mortality rate was 1.02%. The median lengths (interquartile range) of preoperative, postoperative, and total hospital stay were 1 (1 to 2), 4 (3 to 5), and 4 (3 to 7) days, respectively.

Operation characteristics

Among 8854 operations, 45.6% were classified as emergency. The median duration of operation (interquartile range) was 50 (35 to 70) minutes. Prophylactic

Table 1. Surgical site infection rates (infections/100 operations) and standardized infection ratios stratified by characteristics

Characteristics	No. of operations	No. of infections	Rate	SIR	95% CI
Wound class					
Clean	1471	20	1.4	1.2	0.7-1.8
Clean-contaminated	6700	65	0.9	0.4	0.3-0.5
Contaminated	495	25	5.1	1.6	1.0-2.4
Dirty/infected	188	17	9.0	2.8	1.6-4.4
ASA classification					
I	6598	69	1.1	0.5	0.4-0.6
II	1827	45	2.5	1.2	0.9-1.6
III	321	11	3.4	1.2	0.6-2.1
IV	103	2	1.9	0.8	0.1-2.8
V	5	0	0.0	0.0	-
NNIS risk-index category					
−1	81	0	0.0	0.0	-
0	6705	55	0.8	0.4	0.3-0.5
1	1865	61	3.3	1.1	0.8-1.4
2	199	11	5.5	1.2	0.6-2.2
3	4	0	0.0	0.0	-
Type of operation					
Elective	4814	44	0.9	0.5	0.3-0.6
Emergency	4040	83	2.1	0.8	0.7-1.0
Total	8854	127	1.4	0.6	0.5-0.8

SIR, standardized infection ratio.

Table 2. Surgical site infection rates (infections/100 operations) and standardized infection ratios stratified by operative procedures

Operative procedures	No. of operations	No. of infections	Rate	SIR	95% CI
Mastectomy	18	2	11.1	5.9	0.6-21.5
Vascular surgery	18	2	11.1	4.7	0.5-17.4
Limb amputation	6	1	16.7	4.6	0.0-26.4
Cholecystectomy	251	9	3.6	3.2	1.5-6.2
Nephrectomy	138	3	2.2	2.0	0.4-5.8
Knee prosthesis	95	2	2.1	1.9	0.2-7.1
Hip prosthesis	43	1	2.3	1.9	0.0-10.6
Colon surgery	49	5	10.2	1.6	0.5-3.8
Herniorrhaphy	406	5	1.2	1.4	0.4-3.2
Spinal fusion	55	1	1.8	1.3	0.0-7.4
Craniotomy	383	7	1.8	1.3	0.5-2.6
Bile duct, liver, or pancreatic surgery	53	3	5.7	1.2	0.2-3.7
Appendectomy	1487	28	1.9	1.0	0.7-1.5
Open reduction fracture	515	7	1.4	1.5	0.6-3.0
Gastric surgery	57	2	3.5	0.8	0.1-3.0
Small bowel surgery	42	2	4.8	0.7	0.1-2.6
Ventricular shunt	31	1	3.2	0.7	0.0-3.7
Other musculoskeletal	224	1	0.5	0.6	0.0-3.6
Hysterectomy	646	6	0.9	0.6	0.2-1.3
Cesarean section	4033	39	0.9	0.3	0.2-0.4
Others	304	0	0.0	0.0	-
Total	8854	127	1.4	0.6	0.5-0.8

SIR, standardized infection ratio.

antibiotics were administered in 8127 operations accounting for 91.8% of all operations. Preoperative, intraoperative, and postoperative antibiotic prophylaxis was administered in 4192 (51.6%), 1972 (24.3%), and 1963 (24.1%) operations respectively. The 4 most common prophylactic antibiotics used were ampicillin/amoxicillin, cefazolin, gentamicin, and metronidazole, which were used in 39.9%, 22.6%, 20.2%, and 16.2% of all operations performed, respectively.

Incidence of SSI

There were 127 SSIs identified in 8854 operations, accounting for an overall crude SSI rate of 1.4 infections/100 operations. The incidences of SSIs and the SIR (with 95% CI) stratified by characteristics and operative procedures are shown in Tables 1 and 2.

Postdischarge SSI

Of 127 SSIs, 35 SSIs (27.6%) were detected after hospital discharge. The major postdischarge SSIs occurred in cesarean section, appendectomy, and cholecystectomy procedures. The details of postdischarge SSIs are given in Table 3.

Pathogens

The causative pathogens were isolated in 118 (92.9%) of the 127 recorded SSIs. Only 1 fungal infection, *Candida albican*, was identified in this study. The 5 most common pathogens identified from SSIs were *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, and *Acinetobacter baumanii*. The attributes of isolated pathogens are presented in Table 4.

Risk factors

Univariate analysis revealed 8 statistically significant variables associated with SSI, namely male sex, advanced age, elevated ASA class, high degree of wound contamination, lengthy duration of operation, emergency operation, prolonged preoperative hospital stay, and extended duration of surgical antibiotic prophylaxis. After controlling for confounding effects by multivariate analysis, the association between SSI and male sex, advanced age, high ASA class, and prolonged duration of surgical antibiotic prophylaxis became statistical insignificant (Table 5).

DISCUSSION

We conducted an 8-month prospective study in 9 secondary and tertiary care hospitals in Thailand. The participating hospitals were from all parts of the country. The objectives of the study were to document the incidence and patterns of SSI developed in the

Table 3. Postoperative hospital stays and surgical site infections diagnosed postdischarge

Characteristics	No. of SSIs	No. of postdischarge SSIs	Percentage of postdischarge SSIs	Postoperative hospital stays	
				Means	Medians
Classification of SSI					
Superficial	62	17	27.4	15.9	10.5
Deep	52	15	28.8	13.9	12.0
Organ/space	13	3	23.1	8.5	9.0
Operative procedure					
Mastectomy	2	1	50.0	10.3	9.0
Vascular surgery	2	0	0.0	17.7	9.5
Limb amputation	1	0	0.0	21.8	19.0
Cholecystectomy	9	2	22.2	5.7	4.0
Nephrectomy	3	0	0.0	6.6	6.0
Knee prosthesis	2	0	0.0	12.7	10.0
Hip prosthesis	1	0	0.0	11.2	9.0
Colon surgery	5	1	20.0	13.1	11.0
Herniorrhaphy	5	1	20.0	3.0	2.0
Spinal fusion	1	0	0.0	8.5	7.0
Craniotomy	7	1	14.3	18.3	10.0
Bile duct, liver, or pancreatic surgery	3	0	0.0	12.4	9.0
Appendectomy	28	10	35.7	3.6	3.0
Open reduction fracture	7	1	25.0	8.2	5.0
Gastric surgery	2	0	0.0	10.0	7.0
Small bowel surgery	2	0	0.0	9.5	7.0
Ventricular shunt	1	0	0.0	25.5	11.0
Other musculoskeletal	1	0	0.0	5.4	5.0
Hysterectomy	6	1	16.7	4.9	4.0
Cesarean section	39	17	43.6	3.8	3.0
Total	127	35	27.6	5.4	4.0

patients undergoing certain major operations. We used the Centers for Disease Control and Prevention (CDC) NNIS system criteria, which are used in many countries, for diagnosing SSI to make the results of the study comparable with the majority of reports.

We used the SIR to benchmark the SSI rates with SSI rates reported by the NNIS System. This method is also employed by the VICONOS network in Spain, which has 43 participating hospitals, all with more than 250 beds.[21] In addition, the SIR was calculated, as described by Gustafson in 2000, as a ratio of observed infections to expected infection.[22] To generate the denominator, for each procedure and NNIS system risk category, the number of operations performed was multiplied by the infection rate reported by the NNIS system for that operation, for that risk category. The numbers obtained for each risk category were added together to achieve a single SIR for each procedure. Gustafson[22] stated in his article that there were several advantages to using the SIR. First, it adjusts for known variations in patient risk levels. Second, any reported standard could be used as a benchmark. Using the SIR, we were able to generate a ''global comparison'' for each procedure. A recently published article reported the use of the SIR to benchmark a Thai hospital's nosocomial infection rates to NNIS system rates for various sites of nosocomial infections.[23] Those authors also stressed the utility of being able to make a single comparison of rates, adjusted for risk category, instead of multiple comparisons specific to procedure and risk category with smaller numbers. The third advantage to using the SIR is that it allows pooling of data to achieve adequate monthly or quarterly numbers to use for denominators in tracking trends over time. One of the other goals stated by Monge Jodra et al was to analyze their SSI rates by the quarter to assess better the trends over time while adjusting for changes in patient acuity during the same time frame.[21] Interestingly, the SSI rate and the SIR gave fairly similar trend results for both cholecystectomy and herniorrhaphy, implying a fairly stable risk category distribution during this time period for those procedures. Use of the SIR for surveillance trending could prevent overreaction to an elevation in the SSI rate that might be only reflecting an increased prevalence of patients in higher risk categories during that time. Gustafson,[22] however, found that using the SIR to develop specific types of control charts could identify special cause rate variations with greater sensitivity and could distinguish them from common or natural cause rate variations with greater specificity.

Table 4. Five most common pathogens isolated from 127 surgical site infections

Pathogen	Number of isolations (n = 118)	Percentage of isolations
Escherichia coli	18	15.3
Staphylococcus aureus	10	8.5
Pseudomonas aeruginosa	8	6.8
Klebsiella pneumoniae	8	6.8
Acinetobacter baumanii	4	3.4

Table 5. The association between selected variables and surgical site infections derived from multivariate analysis

Variables	Odds ratio	95% CI	*P* value
Contaminated wound or dirty/infected wound	5.0	3.3-7.6	<.001
Preoperative stay >6 days	2.3	1.1-4.6	.020
Emergency operation	2.1	1.4-3.2	<.001
Duration of operation >75 percentiles	1.9	1.2-2.9	.005
Age >35 years	1.4	0.9-2.0	.101
ASA score >2	1.3	0.7-2.4	.382
Male sex	1.1	0.7-1.6	.653
Duration of antibiotic prophylaxis >1 day	0.9	0.7-1.5	.897

It is also worth reiterating that the process control charts generated for a specific procedure using the SIR are not meant for continuous comparison with NNIS System rates but are an assessment of local trends. The control limits on the process control charts are derived from the local facility's own historical, data and are not a marker of the degree of deviation from the NNIS System.

In comparison of the procedure-specific SIR observed in this study with the NNIS system reports, some procedures show higher SIR with statistical significance, such as cholecystectomy. On the other hand, some procedures have very low SIR, such as cesarean section.

This phenomenon could be explained by the underestimation from short postoperative hospital stay because, in recent years, the health care system in Thailand has been reformed, with more patients undergoing short-stay operative procedures to reduce hospital costs of patient care. As well as insufficient postdischarge surveillance because of the high cost of full postdischarge surveillance, some infections that developed after discharge may have been missed, especially in patients with short postoperative stay. Weigelt et al[28] reported that 96% of postoperative superficial SSIs occurred within 28 days after surgery, and 30 days has become the accepted period of surveillance for SSIs after operations that do not involve prosthetic implantation.[24] However, the study did identify a substantial number of patients in whom infection developed after hospital discharge.[28]

In this study, 27.6% of SSIs were detected after discharge from hospital, which is comparable with previous reports.[29-32] The study confirmed the fact that most postdischarge SSIs were intraoperative originating because these patients had short preadmission or same day admission for their operations and also short postoperative hospital stay, such as cesarean section, appendectomy, cholecystectomy, and herniorrhaphy.

Antibiotic prophylaxis administration in our study was similar to that in others studies.[5-14] In only 37.2% of operations was administration done at an appropriate time according to the American Society of Health System Pharmacists (ASHP) Therapeutic Guidelines on Antimicrobial Prophylaxis in Surgery[33] and Guideline for Prevention of Surgical Site Infection, 1999,[34] which indicate that the time of administration should be within 30 minutes to 1 hour before the incision for most procedures. The exceptions are cesarean procedures, in which the antimicrobial should be administered after clamping of the umbilical cord. In addition, we found that more than 70% of patients had a duration of antibiotic prophylaxis administration beyond the 24 hours postoperatively recommended by the ASHP.[33]

The finding that *Escherichia coli* was the most common pathogen for SSI seems to be inconsistent with other reports. This may be because the surgical procedures under surveillance were composed in large part of gastrointestinal tract surgery such as appendectomy and gastric, colon, bile duct, liver, and pancreatic surgery. Moreover, *Escherichia coli* is normal flora of the gastrointestinal tract.

We benchmarked our results with incidence published by NNIS.[26] However, this incidence may not be comparable because the inadequate posthospital discharge surveillance in our country, the resource-intensive nature of surveillance for SSI, and variation in intensity of case finding may also have an impact on the results. For many categories of operative procedures, the rate for an individual hospital may be based on a small number of procedures and will therefore be imprecise. Difference in selected operative procedures under surveillance among participating hospitals was another limitation. In spite of these caveats, the SSI surveillance in this study has a key role to play in supporting surveillance of SSI and enabling hospitals to use data to monitor rates of infection and guide the review or change of practice, of which results indicate that quality of care may need to be improved.

We suggest that postdischarge surveillance of SSI is necessary to obtain precise incidence rates. The hospital with an inadequate postdischarge surveillance system should select only operative procedures with long postoperative stay for surveillance. The choice of procedures to survey should be inclusive of operations in which patients are at risk for SSIs. Most hospitals do not have adequate postdischarge surveillance programs other than monitoring readmissions for SSIs; this is due to insufficient trained human resources to do follow-up contact with the patients for any signs and symptoms and/or treatment for SSIs. This is not unique to Thailand facilities. In addition, an increased number of hospitals participating in the SSI surveillance is also important to provide larger national databases for determining the rate and establishing local practice guidelines.

The authors thank the directors of participating hospitals, infection control nurses, hospital wards, clerical staff, and others who assisted with the data collection and Dr. Alan Geater for his valuable advice in editing the manuscript.

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