ORIGINAL ARTICLE

Prospective Nationwide Surveillance of Surgical Site Infections after Gastric Surgery and Risk Factor Analysis in the Korean Nosocomial Infections Surveillance System (KONIS)

Eu Suk Kim, MD;[1] Hong Bin Kim, MD;[1] Kyoung-Ho Song, MD;[1] Young Keun Kim, MD;[2] Hyung-Ho Kim, MD;[3] Hye Young Jin, RN;[4] Sun Young Jeong, RN;[5] Joohon Sung, MD;[6] Yong Kyun Cho, MD;[7] Yeong-Seon Lee, PhD;[8] Hee-Bok Oh, PhD;[8] Eui-Chong Kim, MD;[9] June Myung Kim, MD;[10] Tae Yeol Choi, MD;[11] Hee Jung Choi, MD;[12,a] Hyo Youl Kim, MD[2,a] for the Korean Nosocomial Infections Surveillance System (KONIS)

OBJECTIVE. To evaluate the risk factors for surgical site infection (SSI) after gastric surgery in patients in Korea.

DESIGN. A nationwide prospective multicenter study.

SETTING. Twenty university-affiliated hospitals in Korea.

METHODS. The Korean Nosocomial Infections Surveillance System (KONIS), a Web-based system, was developed. Patients in 20 Korean hospitals from 2007 to 2009 were prospectively monitored for SSI for up to 30 days after gastric surgery. Demographic data, hospital characteristics, and potential perioperative risk factors were collected and analyzed, using multivariate logistic regression models.

RESULTS. Of the 4,238 case patients monitored, 64.9% (2,752) were male, and mean age (±SD) was 58.8 (±12.3) years. The SSI rates were 2.92, 6.45, and 10.87 per 100 operations for the National Nosocomial Infections Surveillance system risk index categories of 0, 1, and 2 or 3, respectively. The majority (69.4%) of the SSIs observed were organ or space SSIs. The most frequently isolated microorganisms were *Staphylococcus aureus* and *Klebsiella pneumoniae.* Male sex (odds ratio [OR], 1.67 [95% confidence interval (CI), 1.09–2.58]), increased operation time (1.20 [1.07–1.34] per 1-hour increase), reoperation (7.27 [3.68–14.38]), combined multiple procedures (1.79 [1.13–2.83]), prophylactic administration of the first antibiotic dose after skin incision (3.00 [1.09–8.23]), and prolonged duration (≥7 days) of surgical antibiotic prophylaxis (SAP; 2.70 [1.26–5.64]) were independently associated with increased risk of SSI.

CONCLUSIONS. Male sex, inappropriate SAP, and operation-related variables are independent risk factors for SSI after gastric surgery.

Infect Control Hosp Epidemiol 2012;33(6):572-580

Surgical site infections (SSIs) are the leading cause of nosocomial infection. The development of SSIs results in prolonged hospital stay, extra costs, and increased morbidity and mortality.[1,2] A system for infection surveillance and to provide feedback to practicing surgeons regarding infection rates was effective in reducing rates of SSI in previous studies.[3,4] In addition, it is important to establish the risk factors for SSI, to prevent infectious complications after surgery by improving correctable factors.

A nationwide prospective multicenter Web-based surveillance system for nosocomial infections, the Korean Nosocomial Infections Surveillance System (KONIS), was developed in Korea in 2006.[5] Gastric surgery was one of the most frequently performed surgical procedures in Korea in 2009 (39.64 operations per 100,000 population);[6] when employing surveillance for SSIs and risk factor analyses in Korea, gastric surgery was given priority over other surgical procedures. A number of studies have shown that wound class, patient age, body mass index (BMI), duration of operation, laparoscopic procedure, and multiple doses of prophylactic antibiotics

Affiliations: 1. Department of Internal Medicine, Seoul National University Bundang Hospital, Seongnam, Republic of Korea; 2. Department of Internal Medicine, Yonsei University Wonju College of Medicine, Wonju, Republic of Korea; 3. Department of Surgery, Seoul National University Bundang Hospital, Seongnam, Republic of Korea; 4. Infection Control Office, Ajou University Hospital, Suwon, Republic of Korea; 5. Infection Control Office, Ewha Womans University Mokdong Hospital, Seoul, Republic of Korea; 6. Department of Epidemiology and Institute of Environment and Health, Seoul National University School of Public Health, Seoul, Republic of Korea; 7. Division of Infectious Diseases, Gachon University Gil Hospital, Incheon, Republic of Korea; 8. Center for Infectious Diseases, Korea National Institute of Health, Osong, Republic of Korea; 9. Department of Laboratory Medicine, Seoul National University College of Medicine, Seoul, Republic of Korea; 10. Division of Infectious Diseases, Yonsei Medical Center, Seoul, Republic of Korea; 11. Department of Laboratory Medicine, Hanyang University Hospital, Seoul, Republic of Korea; 12. Department of Internal Medicine, Ewha Womans University, School of Medicine, Seoul, Republic of Korea; a. These authors contributed equally to this work.

Received October 25, 2011; accepted January 11, 2012; electronically published April 19, 2012.

 0899-823X/2012/3306-0006$15.00. DOI: 10.1086/665728

were factors associated with SSIs after gastric surgery.[7-10] However, all of these studies except one were performed in a single center and with small numbers of patients. Moreover, they did not take into account the effects of surgical antibiotic prophylaxis (SAP) on the development of SSI after gastric surgery, and this might be one of most important risk factors.[11] We performed a prospective multicenter study of a large number of patients undergoing gastric surgery in Korea, to characterize SSI and identify the risk factors associated with SSI, including variables of SAP quality.

METHODS

Twenty hospitals across Korea participated in this prospective survey of SSI after gastric surgery from 2007 to 2009 as part of KONIS.[5] These hospitals volunteered to participate in KONIS on a yearly basis; to qualify for participation, it was mandatory that hospitals undergo consecutive 6-month surveillance from July to December. Participating infection control practitioners (ICPs) were trained before surveillance was started each year, to assure standardized practices. All of the data were collected prospectively according to a common protocol. Patients aged 20 years or younger were excluded from the surveillance. The ethics committee of Seoul National University Bundang Hospital approved the study.

Gastric surgery was defined according to the National Nosocomial Infections Surveillance (NNIS) system as incisions and excisions of the stomach performed in an operating room, including laparoscopic procedures.[12] Patients were routinely followed up during hospital stay and after discharge, and surgeons or surgical nurses, infectious diseases physicians, or ICPs prospectively monitored these patients for SSI until SSI developed or until 30 days after surgery. Participating patients visited the outpatient department (OPD) or emergency room of each hospital after they were discharged when they experienced any kind of wound problems or fever. The surgeons also performed a regular OPD-based follow-up for every discharged patient until 30 days after surgery was performed. If a patient did not visit the OPD as scheduled, ICPs interviewed the patient by telephone on the 30th day after surgery was performed.

We used the definition of SSI proposed by the Centers for Disease Control and Prevention.[13] Demographic data on the patients, the presence of underlying gastric cancer, hospital characteristics, and possible perioperative variables associated with the development of SSI were collected. Perioperative variables were as follows: length of preoperative hospital stay, wound class,[14] American Society of Anesthesiology physical score,[15] duration of surgery, emergency status, whether reoperation was performed at the same site within the surveillance period, packed red blood cell (PRBC) transfusion within 24 hours before or after surgery, laparoscopic versus open gastric surgery, simultaneous surgery at a different anatomical site through the same incision, presence of diabetes mellitus (DM), obesity (BMI ≥25), a history of smoking within 1 month before the surgery was performed, current use of any form of systemic steroid for 1 week or more before the surgery was performed, and presence or absence of infection at other sites. The following variables associated with SAP quality were also collected: type of antibiotic selected, timing of administration of the first dose, and duration of SAP. Clinical information about SSI, including microbiologic data, was collected for cases of SSI. All of the data were registered in the web-based system developed by KONIS. SSI rates were analyzed as numbers of infections per 100 surgical procedures and stratified by their NNIS risk index categorization.[16]

Statistical analyses were conducted to identify risk factors associated with SSI after gastric surgery was performed (PASW Statistics, ver 18.0.0). Univariate analyses were performed to screen potential risk factors with *P* values less than .10 (using Student *t* test, χ^2 test, or Fisher exact test, depending on the type of measurement). Multivariate linear logistic regression models were formulated and tested to adjust for covariates. Adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated, and type I error levels less than 0.05 were considered statistically significant. In the analysis of SAP quality, we excluded patients to whom antibiotics were administered preoperatively because of infection at any anatomical site. The NNIS risk index categories were not included in the multivariate analysis because each component was already included in the model.

TABLE 1. Pooled Means and Key Percentiles of the Distribution of Surgical Site Infection (SSI) Rates[a] by the National Nosocomial Infections Surveillance Risk Index Categories after Gastric Surgery in the Korean Nosocomial Infections Surveillance System from 2007 to 2009

Risk index category	No. of hospitals	No. of procedures	No. of SSIs	Pooled mean	Percentile 10	25	50 (median)	75	90
0	20	3,046	89	2.92	0	0	2.42	3.80	6.86
1	20	1,100	71	6.45	0	1.41	4.84	9.62	19.35
2 or 3[b]	16	92	10	10.87	...	...	...	...	...

[a] Per 100 operations.

[b] The percentile distribution was not calculated because the number of hospitals was small.

https://doi.org/10.1086/665728 Published online by Cambridge University Press

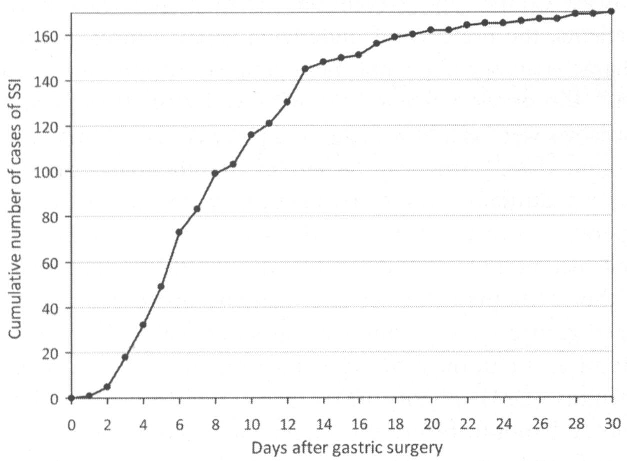

FIGURE 1. Cumulative number of cases of surgical site infection (SSI) developed during the 30-day surveillance period after gastric surgery in the Korean Nosocomial Infections Surveillance System between 2007 and 2009.

RESULTS

All of the hospitals participating in the study were university-affiliated teaching hospitals; 8 (40.0%) of these hospitals had 900 beds or more. The total duration of surveillance for the 20 hospitals was 234 months: 6 months in 6 hospitals, 12 months in 9 hospitals, and 18 months in 5 hospitals. A total of 4,297 gastric operations were performed during the study period (41–766 cases, depending on the hospital), and the average frequency of procedures was 18.4 per month (4.5–87.8 cases per month). A total of 59 cases (1.4%) were excluded from the analysis because of loss to follow-up (33 patients), transfer to other hospitals (6 patients), or death before completion of surveillance (20 patients). The sex distribution did not differ between the excluded and included patients ($P = .123$). However, the excluded patients were older ($P = .035$) and belonged to higher NNIS risk index categories ($P = .02$). Of the 4,238 patients who received gastric surgery in the analysis, 64.9% (2,752) were male, with a mean age ± SD of 58.8 ± 12.3 years. The underlying illness leading to gastric surgery was gastric cancer in 3,968 cases (93.6%). The 75th-percentile cutoff value of the duration of surgery in this study was 260 minutes.

Data about SAP were collected in 4,136 cases; 102 cases (2.4% of 4,238) in which antibiotics were administered preoperatively to treat documented infection were excluded from analysis. Second-generation cephalosporins, most of which were cephamycins such as cefotetan or cefminox, and first-generation cephalosporins were selected for the SAP regimen in 52.8% (2,182/4,136) and 38.7% (1,600/4,136) of the cases, respectively. Prophylactic administration of antibiotics other than cephalosporins or antibiotic combinations was very uncommon. Most of the SAP (96.1% [3,974/4,136]) was performed within 60 minutes before the incision was made. The duration of SAP was analyzed in 4,125 cases, after 11 cases were excluded for which the data were not available. The median duration of SAP was 4 days (range, 1–30). The proportion of cases for which SAP was maintained for 24 hours or less after surgery was only 14.2% (584/4,125).

Among the 4,238 cases that were followed up for 30 days after surgery was performed, most were followed up as scheduled; contact by telephone was necessary in only 119 cases (2.8%). SSI occurred in 170 of the 4,238 cases, giving an overall rate of SSI of 4.01% (Table 1). The median length of time between surgery and diagnosis of SSI was 8 days (range, 1–30 days; Figure 1). A diagnosis of SSI was made after patient discharge in 27 (15.9%) of the 170 cases of the total confirmed SSI; none of these diagnoses were made via a telephone interview. The majority (69.4% [118/170]) of SSIs that occurred after gastric surgery was organ or space SSI; only 18.2% and 12.4% were deep-incisional and superficial-incisional SSIs,

TABLE 2. Microbiologic Findings for 142 Microorganisms Isolated from 112 Patients with Surgical Site Infections after Gastric Surgery from 2007 to 2009 in the Korean Nosocomial Infections Surveillance System

Microbiologic findings[a]	No. (%)
Gram-positive cocci	53 (37.3)
Staphylococcus aureus	14 (9.9)
Methicillin-resistant *S. aureus*	10
Viridans streptococci	12 (8.5)
Enterococcus faecalis	10 (7.0)
Coagulase-negative staphylococci	9 (6.3)
Enterococcus faecium	4 (2.8)
Vancomycin-resistant *E. faecium*	1
Streptococcus pneumoniae	2 (1.4)
Other[b]	2 (1.4)
Gram-negative rods	80 (56.3)
Klebsiella pneumoniae	14 (9.9)
Cefotaxime-resistant *K. pneumoniae*	3
Enterobacter cloacae	12 (8.5)
Enterobacter aerogenes	10 (7.0)
Pseudomonas aeruginosa	9 (6.3)
Escherichia coli	7 (4.9)
Citrobacter freundii	5 (3.5)
Acinetobacter baumannii	4 (2.8)
Serratia marcescens	4 (2.8)
Citrobacter braakii	3 (2.1)
Morganella morganii	2 (1.4)
Stenotrophomonas maltophilia	2 (1.4)
Other[c]	8 (5.6)
Other	9 (6.3)
Candida species	7 (4.9)
Erysipelothrix rhusiopathiae	1 (0.7)
Bacteroides species	1 (0.7)

[a] A total of 27 patients had polymicrobial infections.
[b] *Enterococcus* species (1) and unidentified gram-positive cocci (1).
[c] *Acinetobacter calcoaceticus* (1), *Aeromonas hydrophila* (1), *Chryseobacterium meningosepticum* (1), *Enterobacter* species (1), *Hafnia alvei* (1), *Klebsiella oxytoca* (1), *Proteus mirabilis* (1), and *Proteus vulgaris* (1).

https://doi.org/10.1086/665728 Published online by Cambridge University Press

TABLE 3. Characteristics of Gastric Surgery Patients according to Surgical Site Infection (SSI) Status and Unadjusted Odds Ratios (ORs) for SSIs in the Korean Nosocomial Infections Surveillance System between 2007 and 2009

Variable	SSI status: Positive ($n = 170$)	SSI status: Negative ($n = 4,068$)	OR (95% CI)
Hospital-related variables			
Hospital size ≥900 beds	109 (64)	2,862 (70)	**0.75 (0.55–1.04)**
Monthly no. of operations			
<10	65 (38)	1,349 (33)	Reference
10–20	55 (32)	1,232 (30)	0.93 (0.64–1.34)
≥20	50 (29)	1,487 (37)	**0.70 (0.48–1.02)**
Duration of participation, months			
6	39 (23)	991 (24)	Reference
12	70 (41)	1,616 (40)	1.10 (0.74–1.64)
18	61 (36)	1,461 (36)	1.06 (0.70–1.60)
Patient- and operation-related variables			
Male sex	135 (79)	2,616 (64)	**2.14 (1.47–3.12)****
Age,[a] mean years ± SD	61 ± 11	59 ± 12	**1.16 (1.02–1.32)***
Age group, years			
<50	28 (17)	992 (24)	Reference
50–59	39 (23)	1,002 (25)	1.38 (0.84–2.26)
60–69	59 (35)	1,202 (30)	**1.74 (1.10–2.75)***
≥70	44 (26)	872 (21)	**1.79 (1.10–2.90)***
Underlying illness			
Benign diseases	11 (6)	259 (6)	Reference
Gastric cancer	159 (94)	3,809 (94)	0.98 (0.53–1.83)
Mean hospital-days before operation[b] ± SD	4 ± 4	4 ± 5	1.01 (0.97–1.04)
Contaminated or dirty wound	7 (4)	37 (1)	**4.68 (2.06–10.65)****
ASA score ≥3	17 (10)	283 (7)	1.49 (0.89–2.49)
Operation time,[c] mean minutes ± SD	244 ± 95	207 ± 83	**1.30 (1.18–1.42)****
Operation time >75th percentile	67 (39)	874 (22)	**2.38 (1.73–3.26)****
Laparoscopic surgery	38 (22)	1,201 (30)	**0.69 (0.48–0.99)***
NNIS risk index category			
0	89 (52)	2,957 (73)	Reference
1	71 (42)	1,029 (25)	**2.29 (1.67–3.16)****
2, 3	10 (6)	82 (2)	**4.05 (2.03–8.07)****
Reoperation	19 (11)	53 (1)	**9.53 (5.51–16.50)****
Emergency operation	12 (7)	88 (2)	**3.44 (1.84–6.41)****
Transfusion of packed RBC			
No transfusion	139 (82)	3,692 (91)	Reference
1–2 pints	16 (9)	274 (7)	1.55 (0.91–2.64)
3–4 pints	7 (4)	64 (2)	**2.91 (1.31–6.46)****
≥5 pints	8 (5)	38 (1)	**5.59 (2.56–12.21)****
Multiple procedures	38 (22)	397 (10)	**2.66 (1.83–3.88)****
DM	35 (21)	509 (13)	**1.81 (1.24–2.66)****
Body mass index			
<25	115 (68)	2,942 (72)	Reference
25–30	49 (29)	1,020 (25)	1.23 (0.87–1.73)
≥30	6 (4)	106 (3)	1.45 (0.62–3.37)
Smoking within 1 month before surgery	52 (31)	905 (22)	**1.54 (1.10–2.15)***
Current systemic steroid use	6 (4)	54 (1)	**2.72 (1.15–6.41)***
Infections in other anatomical sites	7 (4)	58 (1)	**2.97 (1.33–6.61)***
SAP, proportion (%) of patients[d]			
Type of antibiotic selection			
First-generation cephalosporin	53/149 (36)	1,547/3,987 (39)	Reference
Second-generation cephalosporin	76/149 (51)	2,106/3,987 (53)	1.05 (0.74–1.51)
Third-generation cephalosporin	8/149 (5)	175/3,987 (4)	1.33 (0.62–2.85)
Antibiotic combinations	6/149 (4)	109/3,987 (3)	1.61 (0.68–3.82)
Other	6/149 (4)	50/3,987 (1)	**3.50 (1.44–8.53)****

TABLE 3 (*Continued*)

Variable	SSI status: Positive (n = 170)	SSI status: Negative (n = 4,068)	OR (95% CI)
Timing of administration of first dose, minutes before incision			
>60	7/149 (5)	104/3,987 (3)	1.93 (0.88–4.24)
31–60	22/149 (15)	544/3,987 (14)	1.16 (0.73–1.84)
1–30	115/149 (77)	3,293/3,987 (83)	Reference
During or after incision	5/149 (3)	46/3,987 (1)	**3.11 (1.21–7.98)***
Duration of SAP, days			
0–1	12/147 (8)	572/3,978 (14)	Reference
2	16/147 (11)	697/3,978 (18)	1.10 (0.51–2.33)
3–4	44/147 (30)	1,415/3,978 (36)	1.48 (0.78–2.83)
5–6	35/147 (24)	765/3,978 (19)	**2.18 (1.12–4.24)***
≥7	40/147 (27)	529/3,978 (13)	**3.60 (1.87–6.95)****

NOTE. Data are no. (%) of patients, unless otherwise indicated. Bold values indicate factors with potential statistical significance ($P < .10$). ASA score, American Society of Anesthesiology physical score; DM, diabetes mellitus; NNIS, National Nosocomial Infections Surveillance System; RBC, red blood cells; SAP, surgical antibiotic prophylaxis.

[a] Per 10-year increase.

[b] Per 1-day increase.

[c] Per 1-hour increase.

[d] We excluded 102 cases in which antibiotics were used for treatment of preoperative infections. We also excluded 11 cases in the analysis of duration of SAP because of missing data.

* $P < .05$.

** $P < .01$.

respectively. We isolated 142 microorganisms from 112 patients who had SSI, and 27 patients (24.1%) had polymicrobial infections (Table 2).

The results of univariate analysis of potential risk factors for SSI after gastric surgery are presented in Table 3. Several variables were associated with an increased risk of SSI, while there was evidence of laparoscopic surgery being associated with reduced risk. Hospital size, monthly volume of gastric surgery, the duration of participation in this study, and the presence of gastric cancer did not affect the risk of SSI. A multivariate logistic regression model excluding the variables for SAP quality demonstrated that male sex (OR, 1.70 [95% CI, 1.13–2.55]), longer operation time (1.19 [1.07–1.33] per 1-hour increase), reoperation (8.54 [4.76–15.32]), a transfusion of PRBC of 5 pints or more (2.54 [1.01–6.42]), additional procedures performed at other anatomical sites (1.94 [1.28–2.95]), and DM (1.71 [1.14–2.54]) were associated with increased risk of SSI (Table 4). We reanalyzed the data after including the variables related to SAP quality but excluding the 113 cases for which the data were not adequate for analyzing the effect of SAP. Male sex (1.67 [1.09–2.58]), longer operation time (1.20 [1.07–1.34] per 1-hour increase), reoperation (7.27 [3.68–14.38]), and multiple procedures (1.79 [1.13–2.83]) remained independent risk factors for SSI after adjusting for the effect of SAP (Table 4). In the analysis of the effect of SAP quality, the type of antibiotic selected was not associated with SSI. However, the risk of SSI for patients who received the first antibiotic dose during or after the skin incision was made was significantly higher than it was for those patients who received the first antibiotic 1–30 minutes before the incision was made (3.00 [1.09–8.23]). Prolonged duration of SAP did not reduce the risk of SSI. In fact, duration of SAP of 7 days or more was associated with an increased risk of SSI (2.70 [1.26–5.64]).

DISCUSSION

We have described the results of a large prospective nationwide survey of SSI that develops after gastric surgery in Korea. Twenty (21.7%) of the 92 hospitals nationwide that had 500 beds or more volunteered to participate in this study. A total of 4,297 patients who had gastric surgery were monitored during the study period; these patients accounted for 16.3% of the 26,310 gastric operations performed nationwide over the same period.[17] The 30-day period of surveillance was completed in 98.6% (4,238/4,297) of the cases; the effect of the excluded cases on the analysis of SSI rates and risk factors should be minimal.

The NNIS risk index category was also a significant variable predicting SSI after gastric surgery in our univariate analysis. Rates of SSI after gastric surgery in KONIS were higher than rates of SSI after gastric surgery performed during the same period in the United States according to the National Healthcare Safety Network (NHSN):[18] 3.86 versus 1.72, respectively, were in risk categories 0 or 1 ($P < .001$) and 10.87 versus 4.23, respectively, were in risk categories 2 or 3 ($P = .006$). The 75th-percentile cutoff point for the duration of gastric surgery in KONIS was 260 min, which is much longer than

https://doi.org/10.1086/665728 Published online by Cambridge University Press

TABLE 4. Multivariate Analysis of Risk Factors for Surgical Site Infections after Gastric Surgery With and Without Considering the Effect of Surgical Antibiotic Prophylaxis (SAP) in the Korean Nosocomial Infections Surveillance System between 2007 and 2009

Variable	Adjusted odds ratios (95% CI)	
	Without SAP effect	With SAP effect[a]
Hospital-related variables		
Hospital size ≥900 beds	0.75 (0.26–2.13)	0.48 (0.11–2.06)
Monthly no. of operations		
<10	Reference	Reference
10–20	1.15 (0.40–3.32)	2.22 (0.51–9.69)
≥20	1.19 (0.42–3.41)	2.66 (0.62–11.45)
Patient- and operation-related variables		
Male	**1.70 (1.13–2.55)***	**1.67 (1.09–2.58)***
Age[b]	1.13 (0.98–1.30)	1.14 (0.98–1.33)
Duration of operation[c]	**1.19 (1.07–1.33)****	**1.20 (1.07–1.34)****
Wound class		
Clean or clean-contaminated	Reference	Reference
Contaminated or dirty	1.71 (0.55–5.32)	3.36 (0.80–14.00)
Laparoscopic surgery	0.86 (0.58–1.27)	0.99 (0.66–1.51)
Reoperation	**8.54 (4.76–15.32)*****	**7.27 (3.68–14.38)*****
Emergency operation	1.24 (0.51–3.03)	1.11 (0.38–3.25)
Transfusion of packed RBC		
No transfusion	Reference	Reference
1–2 pints	1.00 (0.56–1.77)	1.11 (0.60–2.06)
3–4 pints	1.43 (0.59–3.47)	2.17 (0.90–5.24)
≥5 pints	**2.54 (1.01–6.42)***	2.49 (0.89–6.95)
Multiple procedures	**1.94 (1.28–2.95)****	**1.79 (1.13–2.83)***
DM	**1.71 (1.14–2.54)****	1.50 (0.96–2.33)
Smoking within 1 month	1.38 (0.96–2.00)	1.22 (0.81–1.83)
Current systemic steroid use	2.13 (0.84–5.39)	2.55 (0.94–6.92)
Infections in other anatomical sites	1.77 (0.70–4.44)	1.71 (0.56–5.26)
SAP-related variables		
Type of antibiotic selection		
First-generation cephalosporin	...	Reference
Second-generation cephalosporin	...	0.80 (0.52–1.22)
Third-generation cephalosporin	...	0.44 (0.17–1.15)
Antibiotic combinations	...	0.70 (0.27–1.82)
Other	...	1.19 (0.41–3.48)
Timing of administration of first dose		
>60 minutes before incision	...	1.21 (0.44–3.32)
31–60 minutes before incision	...	1.24 (0.76–2.03)
1–30 minutes before incision	...	Reference
During or after incision	...	**3.00 (1.09–8.23)***
Duration of SAP, days		
0–1	...	Reference
2	...	0.91 (0.42–1.99)
3–4	...	1.54 (0.76–3.13)
5–6	...	2.08 (0.99–4.35)
≥7	...	**2.70 (1.26–5.64)***

NOTE. Bold values indicate statistically significant ($P < .05$) findings. DM, diabetes mellitus; RBC, red blood cells.

[a] A total of 102 and 11 cases were excluded from the multivariate logistic model because of therapeutic antibiotic use by the patient before the surgical procedure was performed and because of missing data, respectively.

[b] Per 10-year increase.

[c] Per 1-hour increase.

* $P < .05$.

** $P < .01$.

*** $P < .001$.

the 160 minutes in NHSN. This could be one of the reasons for the higher rates of SSI after gastric surgery that are observed in Korea, because operation time is a significant risk factor for SSI (Table 4).[9,10] In Korea, gastric cancer, which is the main indication for gastric surgery, remains the most common cancer according to 2005 national cancer statistics.[19] A different distribution of underlying illnesses might also be responsible for the difference in SSI rates between the two countries. Although the NNIS risk index is a simple and widely used method for stratifying the risk of SSI after surgical procedure, better models that include more sensitive variables affecting SSI are needed for each surveillance system.

Male sex, longer operation time, reoperation, multiple procedures, and inadequate SAP were independent risk factors for SSI in this study. It is difficult to explain why SSI after gastric surgery was more common in male patients in Korea. One possible explanation derives from the finding that operation times for male patients are much longer than they are for female patients, for most types of surgical procedure.[20] The operation time for male patients was also significantly longer than it was for female patients in this study (214 ± 85 minutes vs 199 ± 81 minutes; $P < .001$). Differences between male and female patients in the distribution of underlying gastric illness and in the amount of abdominal muscle mass may be the reasons for these effects. In Korea, age-standardized incidence rates of gastric cancer are 65.5 and 26.3 per 100,000 population for male and female patients, respectively, according to 2005 national cancer statistics.[19] Surgery for gastric cancer, which takes longer to perform than other types of gastric surgery, was more frequently performed in male patients in this study (94.5% vs 91.9%; $P = .001$). Male sex was a risk factor for major infection, including SSI, after surgery in other studies.[21,22]

Reoperation and multiple surgical procedures were independent risk factors in this study. Reoperation is well known as a major predictor of tissue and wound complications, or SSI, in gastrointestinal surgery.[22,23] This is presumably due to the effect of longer exposure to the risk of bacterial contamination and impaired healing of the relatively avascular scar tissue of the previous incisional wound.[24] Concurrent multiple surgical procedures were also a major risk factor for SSI after gastric surgery in another study.[25] The increased risk may result from the longer operation time and the greater probability of exposure to microorganisms in other gastrointestinal organs such as the appendix during combined appendectomy.

The use of laparoscopy is widely recognized as a method to reduce the risk of SSI in gastrointestinal surgery;[26] SSI rates in laparoscopy-assisted gastric surgery were 60% lower than in open gastric surgery.[10] However, laparoscopic cholecystectomy is associated with a lower risk of incisional SSI but not organ or space SSI.[27] Moreover, laparoscopic appendectomy has been reported to have a significantly greater risk of organ or space SSI than open appendectomy in patients with complicated appendicitis.[28] In this study, we did not detect a lower risk of SSI with laparoscopic gastric surgery after we adjusted for confounding variables. One of the possible explanations is that most (69.4%) of the SSIs that occurred after gastric surgery in our study were organ or space SSIs. Moreover, some of the risk factors for SSI could be confounded in the surgeon's decision to perform laparoscopic surgery, because laparoscopic surgery was more frequently performed in this study in cases that involved hospitals with 900 beds or more, female patients, younger patients, obese patients, and clean or clean-contaminated wound classes (data not shown). Therefore, the effect of laparoscopic surgery on SSI in this study should be interpreted with caution.

The importance of timely administration of preoperative antibiotics is well established.[29,30] Inappropriate SAP was one of the factors that increased the risk of SSI in this study. When the first antibiotic dose was administered while or after the incision was made, the risk of SSI was significantly higher than when it was administered within 30 minutes before the incision was made (OR, 3.00 [95% CI, 1.09–8.23]). The type of antibiotic used was not a significant risk factor for SSI in multivariate analysis. Therefore, narrow-spectrum antibiotics such as cefazolin are acceptable for use as prophylaxis in gastric surgery, as recommended by most international guidelines.[31-33] These guidelines also recommend that SAP duration be reduced to a maximum of 24 hours after completion of surgery, and it can involve as little as 1 dose. Indeed, prolonged SAP did not reduce the risk of SSI in this study, and SAP of 7 days or more was actually associated with an increased risk of SSI. A SAP duration of 7 days or more was more frequently performed in older male patients and in cases of emergency operation and open gastric surgery. Therefore, prolonged SAP might be a marker of the patient's morbidity, or it might result from the surgeon's concern about a potential risk for SSI in this study.

This study has some limitations. First, it is possible that the data that came from hospitals with large volumes of surgical procedures had excessive influence on the overall SSI rates and on the analysis of the major risk factors. Of all of the cases, 30% were from the 2 hospitals with the largest monthly volume of gastric surgery. However, the participating hospitals were not very different in nature: they were all university-affiliated teaching hospitals, and there were no significant differences in SSI rates according to hospital size or monthly numbers of operations (Table 3). Another source for selection bias is that we did not gather data from smaller hospitals in this study. However, the cases we studied accounted for 16.3% of the total number of gastric operations performed nationwide,[17] and 20 participating hospitals were distributed nationwide in terms of location. We believe that the results of this study in part reflect the situation in hospitals in Korea nationwide. The second limitation is that information on the details of underlying comorbidities of the patients and the types of gastric surgery was not collected. Instead, the severity of a patient's underlying illness was assessed on the basis of the NNIS risk index categories,[16] and the complexity of the techniques involved in different surgical procedures was thought to be reflected in the duration of surgery. Moreover, the type of operative procedure used in patients with gastric cancer was not found to be a significant risk factor for SSI in a previous study.[10] The third limitation is the possibility that SSI was underestimated, especially superficial incisional SSI, which might not be reported to ICPs in the event of a mild case. However, it is not likely that there were many unidentified cases of SSI, because we implemented a multidisciplinary approach to identifying SSI that included frequent communication with healthcare workers in surgical departments and regular review of medical records and microbiologic findings.

In summary, we describe a prospective nationwide study of a large number of patients undergoing gastric surgery in Korea. Male sex, operation-related variables (increased operation time, reoperation, and combined multiple procedures), and inadequate SAP resulted in increased risk of SSI. To reduce SSIs, every effort should be made to ensure the quality of SAP and reduce perioperative complications, because the latter may result in prolonged operation times and unnecessary reoperations or multiple procedures such as splenectomy.

ACKNOWLEDGMENTS

We thank the participants of the Korean Nosocomial Infections Surveillance System (KONIS) and the associated staff for their cooperation in this study.

Financial support. This work was supported by a grant from the Korea Centers for Disease Control and Prevention.

Potential conflicts of interest. All authors report no conflicts of interest relevant to this article. All authors submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and the conflicts that the editors consider relevant to this article are disclosed here.

Address correspondence to Hyo Youl Kim, MD, Division of Infectious Diseases, Department of Internal Medicine, Yonsei University Wonju College of Medicine, 162, Ilsan-dong, Wonju, Gangwon-do, 220-701, Republic of Korea (hyksos@yonsei.ac.kr).

Presented in part: 21st European Congress of Clinical Microbiology and Infectious Diseases/27th International Congress of Chemotherapy; Milan, Italy; May 2011 (Abstract P1648).

REFERENCES

1. National Nosocomial Infections Surveillance (NNIS) report, data summary from October 1986–April 1996, issued May 1996. A report from the National Nosocomial Infections Surveillance (NNIS) system. *Am J Infect Control* 1996;24:380–388.
2. Kirkland KB, Briggs JP, Trivette SL, Wilkinson WE, Sexton DJ. The impact of surgical-site infections in the 1990s: attributable mortality, excess length of hospitalization, and extra costs. *Infect Control Hosp Epidemiol* 1999;20:725–730.
3. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. *Am J Epidemiol* 1985;121:182–205.
4. Olson MM, Lee JT Jr. Continuous, 10-year wound infection surveillance: results, advantages, and unanswered questions. *Arch Surg* 1990;125:794–803.
5. Kwak YG, Lee SO, Kim HY, et al. Risk factors for device-associated infection related to organisational characteristics of intensive care units: findings from the Korean Nosocomial Infections Surveillance System. *J Hosp Infect* 2010;75:195–199.
6. National Health Insurance Corporation. *Statistics on major surgical procedures in Korea, 2009.* http://www.nhic.or.kr. Accessed September 8, 2011.
7. Utsumi M, Shimizu J, Miyamoto A, et al. Age as an independent risk factor for surgical site infections in a large gastrointestinal surgery cohort in Japan. *J Hosp Infect* 2010;75:183–187.
8. Ozalp N, Zulfikaroglu B, Gocmen E, et al. Risk factors for surgical site infection after gastrectomy with D2 lymphadenectomy. *Surg Today* 2009;39:1013–1015.
9. Imai E, Ueda M, Kanao K, Miyaki K, Kubota T, Kitajima M. Surgical site infection surveillance after open gastrectomy and risk factors for surgical site infection. *J Infect Chemother* 2005; 11:141–145.
10. Imai E, Ueda M, Kanao K, et al. Surgical site infection risk factors identified by multivariate analysis for patient undergoing laparoscopic, open colon, and gastric surgery. *Am J Infect Control* 2008;36:727–731.
11. van Kasteren ME, Mannien J, Ott A, Kullberg BJ, de Boer AS, Gyssens IC. Antibiotic prophylaxis and the risk of surgical site infections following total hip arthroplasty: timely administration is the most important factor. *Clin Infect Dis* 2007;44:921–927.
12. Horan TC, Emori TG. Definitions of key terms used in the NNIS System. *Am J Infect Control* 1997;25:112–116.
13. Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. *Am J Infect Control* 1992;20:271–274.
14. Altemeier WA. *Manual on Control of Infection in Surgical Patients.* 2nd ed. Philadelphia and London: Lippincott, 1984.
15. Owens WD, Felts JA, Spitznagel EL Jr. ASA physical status classifications: a study of consistency of ratings. *Anesthesiology* 1978; 49:239–243.
16. Haley RW, Culver DH, Morgan WM, White JW, Emori TG, Hooton TM. Identifying patients at high risk of surgical wound infection: a simple multivariate index of patient susceptibility and wound contamination. *Am J Epidemiol* 1985;121:206–215.
17. Korean Statistical Information Service. *Statistics on major surgical procedures in Korea.* http://www.kosis.kr. Accessed September 8, 2011.
18. Edwards JR, Peterson KD, Mu Y, et al. National Healthcare Safety Network (NHSN) report: data summary for 2006 through 2008, issued December 2009. *Am J Infect Control* 2009;37: 783–805.
19. Jung KW, Won YJ, Park S, et al. Cancer statistics in Korea: incidence, mortality and survival in 2005. *J Korean Med Sci* 2009; 24:995–1003.
20. Gastmeier P, Sohr D, Breier A, Behnke M, Geffers C. Prolonged duration of operation: an indicator of complicated surgery or of surgical (mis)management? *Infection* 2011;39:211–215.
21. Offner PJ, Moore EE, Biffl WL. Male gender is a risk factor for major infections after surgery. *Arch Surg* 1999;134:935–938.
22. Sorensen LT, Hemmingsen U, Kallehave F, et al. Risk factors for tissue and wound complications in gastrointestinal surgery. *Ann Surg* 2005;241:654–658.

23. Israelsson LA. The surgeon as a risk factor for complications of midline incisions. *Eur J Surg* 1998;164:353–359.
24. Lamont PM, Ellis H. Incisional hernia in re-opened abdominal incisions: an overlooked risk factor. *Br J Surg* 1988;75:374–376.
25. Watanabe A, Kohnoe S, Shimabukuro R, et al. Risk factors associated with surgical site infection in upper and lower gastrointestinal surgery. *Surg Today* 2008;38:404–412.
26. Richards C, Edwards J, Culver D, Emori TG, Tolson J, Gaynes R. Does using a laparoscopic approach to cholecystectomy decrease the risk of surgical site infection? *Ann Surg* 2003;237:358–362.
27. Biscione FM, Couto RC, Pedrosa TM, Neto MC. Comparison of the risk of surgical site infection after laparoscopic cholecystectomy and open cholecystectomy. *Infect Control Hosp Epidemiol* 2007;28:1103–1106.
28. Ingraham AM, Cohen ME, Bilimoria KY, Pritts TA, Ko CY, Esposito TJ. Comparison of outcomes after laparoscopic versus open appendectomy for acute appendicitis at 222 ACS NSQIP hospitals. *Surgery* 2010;148:625–635.
29. Stone HH, Hooper CA, Kolb LD, Geheber CE, Dawkins EJ. Antibiotic prophylaxis in gastric, biliary and colonic surgery. *Ann Surg* 1976;184:443–452.
30. Classen DC, Evans RS, Pestotnik SL, Horn SD, Menlove RL, Burke JP. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. *N Engl J Med* 1992;326:281–286.
31. Page CP, Bohnen JM, Fletcher JR, McManus AT, Solomkin JS, Wittmann DH. Antimicrobial prophylaxis for surgical wounds: guidelines for clinical care. *Arch Surg* 1993;128:79–88.
32. Dellinger EP, Gross PA, Barrett TL, et al. Quality standard for antimicrobial prophylaxis in surgical procedures. Infectious Diseases Society of America. *Clin Infect Dis* 1994;18:422–427.
33. Antimicrobial prophylaxis in surgery. *Med Lett Drugs Ther* 2001;43:92–97.