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ORIGINAL ARTICLE

The epidemiology and cost of surgical site infections in Korea: a systematic review

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Purpose: To conduct a systematic literature review of the epidemiological and economic burden of surgical site infection (SSI) in Korea. **Methods:** A search of the EMBASE, Medline and KoreaMed databases for English and Korean language publications was conducted. Searches for epidemiological and economic studies were conducted separately and limited to 1995 to 2010 to ensure the pertinence of the data. **Results:** Twenty-six studies were included. The overall incidence of SSI in Korea was 2.0 to 9.7%. The National Nosocomial Infections Surveillance risk index was positively correlated with the risk of developing an SSI. Specific risk factors for SSI, identified through multivariate analyses included; diabetes, antibiotic prophylaxis and wound classification. SSIs were associated with increased hospitalisation cost, with each episode of SSI estimated to cost about an additional ₩2,000,000. A substantial portion of the increased cost was attributed to hospital room costs and the need for additional medication. Studies also found that post-operative stays for patients with SSIs were 5 to 20 days longer, while two studies reported that following cardiac surgery, patients with SSIs spent an additional 5 to 11 days in the intensive care unit, compared to patients without SSIs. **Conclusion:** Data from the included studies demonstrate that SSI represents a significant clinical and economic burden in Korea. Consequently, the identification of high-risk patient populations and the development of strategies aimed at reducing SSI may lead to cost-savings for the healthcare system.

Key Words: Surgical site infection, Epidemiology, Cost

INTRODUCTION

A surgical site infection (SSI) is a type of hospital-acquired infection that arises following surgery and is specifically related to the surgical site. Patients who develop an SSI are more likely to have an extended hospital stay, which results in additional healthcare costs. Indirect costs, such as productivity, further add to the burden of SSI.

The aim of this review is to summarise recent evidence pertaining to the clinical and economic burden of SSI in Korea. This systematic review will follow the general format of the publication by Leaper et al. [1] which describes the epidemiological and economic burden of SSI in Europe.

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METHODS

Literature search

In order to identify relevant epidemiological and economic data for this review, a systematic search of the literature was undertaken. A search of Embase (which includes the EMBASE and Medline databases) and a Korean medical journal database (KoreaMed) was conducted. Separate searches were conducted to identify epidemiological and economic data. The search was limited to the last 15 years (1995 to 2010) to ensure the relevance of these data. The search strategy and results are presented in Table 1.

Identification of studies

There were 1,206 unique citations identified from the literature search. The titles/abstracts of all citations were reviewed to identify publications most relevant to this systematic review. The following exclusion criteria were applied to determine eligibility:

1. Does not describe the rate, incidence, prevalence, bur den or cost of SSI.
2. Describes the effect of an intervention to reduce SSI.
3. Not conducted in Korea.
4. Not conducted in a hospital setting.
5. Includes <90 patients/procedures.

Following application of the exclusion criteria to the titles/abstracts, 32 publications were retrieved for full text review. Following detailed assessment of these publications, a further six were excluded leaving 26 studies.

Data extraction and analysis

SSI data from the 26 included studies were compiled into data extraction tables. The overall incidence of SSI was recorded, as well as the incidence of SSI by surgical procedure, wound classification and National Nosocomial Infections Surveillance (NNIS) risk score. Wound classifications were based on definitions by the Centre for Disease Control (CDC). SSIs were classified according to the location in which they occurred: 1) superficial (i.e., skin and subcutaneous tissue); 2) deep (i.e., fascia, muscle); and 3) organ / space. The NNIS categorizes patients according to their likelihood of developing an SSI. The NNIS system risk index comprises three components: 1) the American

Table 1. Search strategy

Database/date searched	Hits
Epidemiological search	
EMBASE/31 Mar 2010	
1. (infection OR infections) NEAR/4 (surgical OR surgery OR wound OR nosocomial OR hospital OR 'post operative' OR post-operative OR 'post discharge' OR postdischarge OR icu OR 'intensive care')	152,064
2. 'Incidence'/exp OR incidence OR 'prevalence'/exp OR prevalence OR 'epidemiology'/exp OR epidemiology OR epidemiological OR surveillance OR rate	3,531,081
3. 'Korea'/exp OR Korea OR Korean	159,915
4. #1 AND #2 AND #3 AND [1995-2010]/py	485
KoreaMed/1 May 2010	
"post-operative infection" [ALL] OR "post-operative infection" [ALL] OR "post-surgical infection" [ALL] OR "postsurgical infection" [ALL] OR "surgical site infection" [ALL] OR "wound infection" [ALL] OR "nosocomial infection" [ALL] OR "hospital acquired infection" [ALL] OR "healthcare associated infection" [ALL] OR "post-discharge infection" [ALL] OR "postdischarge infection"	744
Economic/costing search	
EMBASE/31 Mar 2010	
1. (infection OR infections) NEAR/4 (surgical OR surgery OR wound OR nosocomial OR hospital OR 'post operative' OR post-operative OR 'post discharge' OR icu OR 'intensive care') AND ('Korea'/exp OR Korea OR Korean) AND [1995-2010] /py AND ('cost effectiveness analysis'/exp OR 'cost effectiveness analysis' OR 'economic evaluation'/exp OR 'economic evaluation' OR 'health economics'/exp OR 'health economics' OR 'cost minimization analysis'/exp OR 'cost minimization analysis' OR 'cost minimisation analysis' OR 'cost utility analysis'/exp OR 'cost utility analysis' OR 'quality adjusted life year'/exp OR 'quality adjusted life year' OR 'qaly'/exp OR 'qaly' OR 'life year saved')	14
Total number of unique citations	1,206

Table 2. Summary of included studies

Source	Study duration	Study design	Surgical procedures	Number of patients/ procedures	Focus	Definition of wound infection	Wound classification	Patient infection risk index	Surveillance period
Ahn and Sohng [3]	Sep 2002 - Nov 2002	Retrospective study	Any surgery with >48 hr hospital stay	527 procedures	SSI	CDC	CDC	NS	30 days post-operation
Chang et al. [8]	Mar 2001 - Mar 2003	Retrospective study	Open-heart surgery	123 patients	Wound infection	NS	NS	NS	NS
Chang et al. [9]	Apr 2004 - Dec 2008	Retrospective study	Median sternotomy	157 patients	Wound infection	NS	NS	NS	NS
Choi et al. [14]	Jul 2006 - Dec 2006	Prospective surveillance	Hip and knee joint replacement surgery	436 patients	SSI	CDC	CDC	NNIS	Over 1 month post-operation
Choi et al. [13]	Mar 1997 - May 1997	Prospective study	Cardiovascular surgery	222 patients	SSI	CDC	CDC	NNIS	30 days post-operation
Chung et al. [10]	Aug 1999 - Dec 2006	Retrospective study	Nuss procedure for pectus excavatum	630 patients	Post-operative complications	NS	NS	ASA	NS
Hong et al. [20]	Oct 1991 - Jun 2006	Retrospective study	Bowel surgery in Crohn's disease	160 patients	Post-operative complications	NS	NS	NS	Mean of 34 months (range, 1 to 179 months)
Jeong et al. [21]	Aug 2005 - Jul 2006	Retrospective study	Abdominal surgery	347 procedures	SSI	CDC	CDC	ASA	30 days post-operation
Kim et al. [26]	1993 - 2002	Retrospective study	Lumbar spine surgery	2,896 patients	Wound infection	NS	NS	NS	NS
Kim et al. [27]	1993 - 2002	Systematic review	Appendectomy	1,258 patients	Wound infection	NS	NS	NS	NS
Kim et al. [15]	Jul - Dec 2007	Prospective study	Hip and knee arthroplasty and gastrectomy	1,294 patients	SSI	CDC	CDC	NNIS	1 year for hip/knee arthroplasty. 30 days for gastrectomy
Kim et al. [22]	Jan 2003 - Apr 2009	Retrospective study	Peptic ulcer surgery	112 patients	Post-operative complications	NS	NS	POSSUM[a)]	30 days post-operation
Kim et al. [24]	Jul - Dec 2008	Prospective study	Craniotomy	1,020 patients	SSI	CDC	CDC	NNIS	30 days post-operation
Kim et al. [2]	Jun - Aug 1996	Prospective surveillance	All surgical procedures	85,547 patients	SSI	CDC	CDC	NS	4 weeks post-operation

Table 2. Continued

Source	Study duration	Study design	Surgical procedures	Number of patients/ procedures	Focus	Definition of wound infection	Wound classification	Patient infection risk index	Surveillance period
Kim et al. [16]	Mar 1997 - Feb 1998	Prospective study	Biliary surgery	109 patients	Wound infection	NS	NS	ASA	NS
Lee et al. [19]	Jan 1995 - Mar 2003	Retrospective study	Percutaneous endoscopic gastrostomy	116 patients	Wound infection	NS	NS	NS	Mean of 26 days (Range, 7 to 63 days)
Lee et al. [25]	1990 - 2003	Retrospective study	Limb salvage surgery in Osteosarcoma patients	371 patients	Post-operative infection	NS	NS	NS	1 year post-operation
Lee et al. [18]	Jan 1996 - Jun 2000	Retrospective study	Endoscopic gastrostomy	134 patients	Wound infection	NS	NS	NS	2 weeks post-operation
Lee et al. [19]	May 2001 - Dec 2001	Prospective study	All surgical procedures[b)]	761 patients	SSI	CDC	CDC	ASA	30 days post-operation
Lee et al. [17]	Jan 1993 - Dec 2003	Retrospective study	Gastrectomy in cirrhotic patients	94 patients	Post-operative complications	NS	NS	NS	NS
Lee et al. [5]	Jan 2002 - May 2002	Retrospective study	All surgical procedures[c)]	1,239 patients	SSI	CDC	CDC	NS	30 days post-operation
Park and Jheon [12]	1987 - 2000	Retrospective study	Thoracotomy for pulmonary aspergilloma	110 patients	Wound infection	NS	NS	NS	Over 1 month post-operation
Park et al. [6]	Sep 2002 - Dec 2002	Prospective study	All surgical procedures	1,007 procedures	SSI	CDC	CDC	NNIS	30 days post-operation
Park et al. [23]	May 2003 - Oct 2006	Retrospective study	Laparoscopic gastrectomy	300 procedures	Wound infection	NS	NS	NS	30 days post-operation
Sakong et al. [7]	Sep - Nov 2006	Retrospective study	5 major surgeries[d)]	2,924 patients	SSI	CDC	CDC	NS	Between 30 days to 1 year, unless lost to follow-up
Song et al. [11]	May - Sep 2007	Retrospective study	OPCAB	100 patients	Post-operative complications	NS	NS	NS	Pre-discharge only

ASA, American Society of Anaesthesiology; CDC, Centre for Disease Control and Prevention; NNIS, National Nosocomial Infection Surveillance; NS, not stated; OPCAB, off-pump coronary artery bypass; SSI, surgical site infection.
[a)]POSSUM (physiological and operative severity score for enumeration of mortality and morbidity) score was developed to predict post-operative mortality and morbidity rates. [b)]Includes surgery of the colon, rectum, small bowel, hepato-biliary-pancreas, stomach and appendix. [c)]Includes orthopaedic surgery, plastic surgery, general surgery, neurosurgery, chest surgery, obstetrics and gynaecology, otolaryngology and ophthalmology. [d)]Includes cardiac, colon and gastric surgery, hysterectomy, hip/knee replacement surgery.

Society of Anaesthesiologists (ASA) score; 2) wound classification; and 3) the duration of surgery. Based on these factors, patients are assigned an NNIS risk score of 0, 1, 2 or 3. The NNIS risk index is scored as follows: 1) an ASA score of 3 to 5 is allocated 1 point; 2) wound sites classified as contaminated or dirty are allocated 1 point; and 3) surgeries exceeding specified time cut-off points are allocated 1 point. Risk factors for SSIs were also recorded, along with common pathogens associated with SSI. To evaluate the economic impact of SSI, SSI costs and extended hospital stay associated with SSI were summarised.

RESULTS

Characteristics of the included studies

A summary of the characteristics of included studies is presented in Table 2. The majority of the studies were retrospective cohort studies investigating SSI or wound infection following a range of hospital surgical procedures. There was significant variation in the size of the populations investigated, with the number of patients included ranging from 94 to 85,547. There were also differences in the surveillance period, which is likely to influence the opportunity to detect a SSI. SSIs were most commonly defined and classified using the CDC criteria.

Prevalence of SSI in Korea

None of the studies included in this systematic review reported the prevalence of SSI in Korea. However, the multicentre study by Kim et al. [2], involving 15 hospitals, reported that the prevalence of nosocomial infection was 3.7% in 2000, with SSIs accounting for 17.2% of all nosocomial infections.

Incidence of SSI in Korea

As shown in Table 3, five included studies reported the overall incidence rate of SSIs [3-7]. Each study followed up patients who had undergone a variety of different surgical procedures. Four of the studies examined the incidence of SSI at a single hospital [3-6] during a 30 day post-operative observation period, while one study examined the incidence of SSI across 20 hospitals during a one year post-operative follow-up period (Sakong et al. [7]). The incidence of SSI ranged from 2.0 to 9.7% across the five included studies.

Incidence by surgical procedure

As shown in Table 4, the incidence of SSI varied by surgical procedure. To facilitate comparison, groups were divided into four broad categories, namely, cardiothoracic surgery, orthopaedic surgery, gastrointestinal surgery, and other surgical procedures.

There were seven studies that reported SSI following cardiothoracic surgery [8-13]. Surgical procedures investigated included open-heart surgery, sternotomy, nuss procedure, off-pump coronary artery bypass, thoracotomy for pulmonary aspergilloma and non-specific

Table 3. Overall incidence of surgical site infection

Source	Surgical procedure	No. of hospitals surveyed	Surveillance period	Incidence
Ahn and Sohng [3]	Any inpatient surgical procedure	1	30 days post-operation	51/527 (9.7%)
Lee et al. [19]	All surgical procedures[a)]	1	30 days post-operation	15/761 (2.0%)
Lee et al. [5]	All surgical procedures[b)]	1	30 days post-operation	33/1239 (2.7%) 27 (pre-discharge) 6 (post-discharge)
Park et al. [6]	All procedures in surgery department	1	30 day post-operation	52/1007 (5.2%)
Sakong et al. [7]	Five surgical procedures[c)]	20	30 days to 1 year, unless lost to follow-up	86/2924 (2.9%)

[a)]Includes surgery of the colon, rectum, small bowel, hepato-biliary-pancreas, stomach and appendix. [b)]Includes orthopedic surgery, plastic surgery, general surgery, neurosurgery, chest surgery, obstetrics and gynecology, otolaryngology and ophthalmology. [c)]Includes cardiac, colon and gastric surgery, hysterectomy, hip/knee replacement surgery.

Table 4. Incidence of surgical site infection by surgical procedure

Source	Surgical procedure	Surveillance period	Incidence (%)
Cardiothoracic surgery			
Chang et al. [8]	Open-heart surgery	NS	12/123 (9.8)
Chang et al. [9]	Sternotomy	NS	15/157 (9.6)
Chung et al. [10]	Nuss procedure	NS	14/630 (2.2)
Song et al. [11]	OPCAB	Pre-discharge only	4/100 (4.0)
Park and Jheon [12]	Thoracotomy for pulmonary aspergilloma	Over 1 month post-operation	4/110 (3.6)
Sakong et al. [7]	Cardiac surgery	30 days to 1 year, unless lost to follow-up	9/304 (3.0)
Choi et al. [13]	Cardiovascular surgery	30 days post-operation	10/222 (4.5) 8 (pre-discharge) 2 (post-discharge)
Orthopaedic surgery			
Choi et al. [14]	Hip joint replacement surgery	1 month post-operation	3/227 (1.3)
	Knee joint replacement surgery	1 month post-operation	3/209 (1.4)
Kim et al. [15]	Hip prosthesis	1 year post-operation	6/342 (1.8)
	Knee prosthesis	1 year post-operation	5/453 (1.1)
Sakong et al. [7]	Hip or knee replacement	30 days to 1 year, unless lost to follow-up	15/597 (2.5)
Gastrointestinal tract surgery			
Kim et al. [16]	Biliary surgery	NS	5/109 (4.8)
Lee et al. [17]	Gastrectomy in cirrhotic patients	NS	10/94 (10.6)
Lee et al. [18]	Endoscopic gastrostomy	2 weeks post-operation	19/134 (14.2)
Lee et al. [19]	Endoscopic gastrostomy	Mean of 26 days (range, 7 to 63 days)	37/116 (31.9)
Hong et al. [20]	Bowel surgery in Crohn's disease	At least 1 month post-operation	6/160 (3.8)
Jeong et al. [21]	Abdominal surgery	30 days post-operation	17/347 (4.9)
Kim et al. [15]	Gastrectomy	30 days post-operation	22/499 (4.4)
Kim et al. [22]	Peptic ulcer surgery	30 days post-operation	20/112 (17.9)
Lee et al. [19]	Colon and rectum surgery	30 days post-operation	7/113 (6.2)
	Hepato-biliary-pancreas	30 days post-operation	3/128 (2.3)
	Appendix surgery	30 days post-operation	3/193 (1.6)
Park et al. [23]	Laparoscopic gastrectomy	30 days post-operation	21/300 (7.0)
Sakong et al. [7]	Colon surgery	30 days to 1 year, unless lost to follow-up	18/537 (3.4)
	Gastric surgery	30 days to 1 year, unless lost to follow-up	29/589 (4.9)
Other surgical procedures			
Kim et al. [24]	Craniotomy	30 days post-operation	31/1020 (3.0)
Lee et al. [25]	Limb salvage surgery in osteosarcoma patients	1 year post-operation	41/371 (11.1)
Sakong et al. [7]	Hysterectomy	30 days to 1 year, unless lost to follow-up	15/897 (1.7)

NS, not stated; OPCAB, off-pump coronary artery bypass.

cardiac and cardiovascular surgery. The incidence of SSI ranged from 2.2 to 9.8%, with the highest incidence of SSI occurring in patients who had undergone open-heart surgery [8] and the lowest incidence in those undergoing the nuss procedure [10]. Choi et al. [13] reported an incidence of SSI of 4.5% following cardiovascular surgery, of which, 80% (8/10) occurred pre-discharge and 20% (2/10) post-discharge from hospital.

The three included orthopaedic studies examined knee or hip replacement surgery with patients monitored for up to one year post-operation (Table 4). Overall, the incidence of SSI was lower for patients undergoing orthopaedic surgery compared to those undergoing cardiothoracic surgery. The incidence of SSI ranged from 1.1 to 2.5%, with low variation between surgery types and duration of follow-up [7,14,15].

The majority of the included studies in this systematic review examined SSI following gastrointestinal tract surgery [4,7,15-23]. Overall, the incidence of SSIs was generally higher and the range of rates was larger for patients undergoing gastrointestinal tract surgery compared with other surgery types. The lowest rate of SSI was reported by Lee et al. [4] for patients undergoing appendix surgery (1.6% after 30 days follow-up). In contrast, Lee et al. [19] reported that 31.9% of patients undergoing endoscopic gastrostomy experienced a SSI up to 2 months after surgery. Although the range of SSI rates was larger than rates from other surgery types, the majority of studies still reported SSI rates less than 7 .

Table 5. Classification of surgical site infections

Source	Surgical procedure	No. of SSI cases	Classification of SSI		
			Superficial	Deep	Organ/space
Kim et al. [24]	Craniotomy	31	12.9%	6.5%	80.6%
Kim et al. [15]	Hip arthroplasty	6	33.3%	50.0%	16.7%
	Knee arthroplasty	5	20.0%	40.0%	40.0%
	Gastrectomy	22	23.0%	9.0%	68.0%
Park et al. [6]	General surgery	26	53.8%	46.2%	0.0%

SSI, surgical site infection.

Among the included studies investigating SSIs following other surgical procedures, Kim et al. [24], Lee et al. [25] and Sakong et al. [7] examined craniotomy, limb salvage surgery in osteosarcoma patients and hysterectomy, respectively. The incidence of SSI up to one year following surgery was 3.0%, 11.1% and 1.7%, respectively.

Classification of surgical site infection

As shown in Table 5, three studies reported information on the classification of SSI [6,15,24]. In patients undergoing general surgery, the majority of SSIs occurred in superficial tissue (53.8%) [6]. In contrast, organ/space SSIs were most frequent following craniotomy and gastrectomy [15,24]. The incidence of superficial, deep and organ/space SSI appeared to be similar among patients undergoing hip and knee replacement surgery. However, due to the small number of SSI cases observed for these surgeries, N = 6 and 5, respectively, the results should be interpreted with caution.

Incidence by wound classification

The incidence of SSI by wound classification is shown in

Table 6. Incidence of surgical site infection by wound classification

Source	Procedure	Surveillance period	Wound classification			
			Clean	Clean-contaminated	Contaminated	Dirty
Ahn and Sohng [3]	Any inpatient surgery	30 days post-operation	5.7% (10/167)	8.5% (19/215)	3.5% (2/56)	29.4% (20/48)
Choi et al. [13]	Cardiovascular surgery	30 days post-operation	3.7% (8/216)	0% (0/0)	25% (1/4)	50% (1/2)
Jeong et al. [21]	Abdominal surgery	30 days post-operation	1.6% (1/63)	5.2% (12/233)	6.8% (3/43)	12.5% (1/8)
Lee et al. [19]	All surgical procedures	30 days post-operation	0% (0/227)	1.4% (2/138)	1.8% (6/341)	12.7% (7/55)
Lee et al. [5]	All surgical procedures	30 days post-operation	2.6% (15/585)	1.3% (7/579)	6.1% (2/33)	12.5% (9/72)

Table 7. Incidence of surgical site infections by NNIS risk score

Source	Procedure	Surveillance	Overall incidence	NNIS risk score			
				0	1	2	3
Choi et al. [14]	Hip joint replacement	1 month post-operation	1.32%	1.2% (2/166)	1.64% (1/61)	-	-
	Knee joint replacement	1 month post-operation	1.44%	0.64% (1/156)	3.85% (2/52)	0% (0/1)	-
Choi et al. [13]	Cardiovascular surgery	30 days post-operation	4.5%	0% (0/3)	3.1% (4/129)	4.6% (4/87)	66.7% (2/3)
Kim et al. [15]	Hip prosthesis	1 year post-operation	1.75%	0.98% (2/205)	3.31% (4/121)	0% (0/16)	
	Knee prosthesis	1 year post-operation	1.1%	0.93% (3/323)	1.65% (2/121)	0% (0/9)	
	Gastrectomy	30 days post-operation	4.41%	5.29% (12/227)	6.11% (8/131)	10.53% (2/19)	
Kim et al. [24]	Craniotomy	30 days post-operation	3.0%	3.1% (14/457)	3.3% (15/454)	1.8% (2/109)	-

NNIS, National Nosocomial Infections Surveillance; NS, not stated.

Table 6. A study by Ahn and Sohng [3] examined various inpatient surgeries and observed that 5.7% of patients with a clean wound had an SSI within 30 days post-operation. In comparison, the incidence of SSI was 29.4% among patients with wounds classified as dirty. Similar trends were observed in the other included studies, where the incidence of SSIs increased as wound conditions worsened.

Incidence by NNIS risk score

Four studies included in this review compared the incidence of SSI between NNIS risk categories (Table 7). Overall, the results showed that the higher the NNIS risk score, the greater the risk of SSI. In a study by Choi et al.

Table 8. Risk factors for surgical site infections

Source	Risk variable	Reference variable	Surgical procedure	Observation period	Analysis type	Risk estimate (95% CI)	P-value
Patient-associated risk factors							
Kim et al. [26]	48 hr mean blood glucose >200 mg/dL	48 hr mean blood glucose ≤200 mg/dL	Lumbar spine surgery	NS	Multivariate	OR >1	<0.05
Lee et al. [19]	Type 2 diabetes	No diabetes	Endoscopic gastrostomy	Mean of 26 days (range, 7 to 63 days)	Multivariate	OR 5.21 (1.94, 14.0)	0.001
Lee et al. [18]	Type 2 diabetes	No diabetes	Endoscopic gastrostomy	2 weeks post-operation	Multivariate	OR 3.80	0.035
Jeong et al. [21]	Co-morbidities present [a]	No co-morbidities	Abdominal surgery	30 days post-operation	Multivariate	OR 5.40 (1.48, 19.7)	0.011
Park et al. [23]	Co-morbidities present [b]	No co-morbidities	Laparoscopic gastrectomy	30 days post-operation	Multivariate	OR 2.38	0.018
Kim et al. [24]	CSF leaks	No CSF leaks	Craniotomy	30 days post-operation	Multivariate	OR 4.86 (4.54, 32.42)	NS
	GCS score ≤ 8	GCS > 8	Craniotomy	30 days post-operation	Multivariate	OR 2.35 (1.07, 5.18)	NS
Lee et al. [19]	Leukocytosis	No leukocytosis	Endoscopic gastrostomy	Mean of 26 days (range, 7 to 63 days)	Multivariate	OR 3.15 (1.19, 8.35)	0.021
Lee et al. [5]	Dirty infected wound	Clean wound	All surgical procedures	30 days post-operation	Multivariate	OR 6.51 (2.13, 19.90)	0.001
Procedure-associated risk factors							
Kim et al. [27]	Laparoscopy	Open surgery	Appendectomy	NS	Meta-analysis of 8 studies, fixed effects model	OR 0.33 (0.20, 0.55)	<0.05
Lee et al. [19]	No antibiotic prophylaxis	Antibiotic prophylaxis	Endoscopic gastrostomy	Mean of 26 days (range: 7-63 days)	Multivariate	OR 3.67 (1.01, 13.4)	0.048
Sakong et al. [7]	Antibiotics given >1 hr pre-operation	Antibiotics given <1 hr pre-operation	5 major surgeries [c]	30 days to 1 year, unless lost to follow-up	Multivariate	RR 8.20 (4.81, 13.99)	<0.05
Lee et al. [5]	Pre-operative stay (risk per additional day)		All surgical procedures	30 days post-operation	Multivariate	OR 1.038 (1.004, 1.073)	0.029
	No. of operations/patient		All surgical procedures	30 days post-operation	Multivariate	OR 3.27 (1.48, 7.27)	0.004
	Duration of operation (risk per hour increase)		All surgical procedures	30 days post-operation	Multivariate	OR 1.007 (1.004, 1.009)	<0.001

CI, confidence interval; CSF, cerebrospinal fluid; GCS, Glasgow Coma Scale; NS, not stated; OR, odds ratio.
[a]Includes hypertension, cancer and diabetes. [b]Includes diabetes, hypertension, heart/liver/renal disease. [c]Includes cardiac, colon and gastric surgery, hysterectomy, hip/knee replacement surgery.

[14], the incidence of SSI in those with a NNIS risk score of 0 and 1 following hip replacement was 1.2% and 1.6%, respectively. In the same study, the incidence of SSI for NNIS risk score 0 and 1 following knee replacement was 0.6% and 3.9%, respectively. A similar trend was observed in the studies by Kim et al. [15] and Kim et al. [24] that examined SSI following a variety of surgery types.

Risk factors associated with SSI in Korea

The risk factors for SSI are shown in Table 8. Nine studies included in this systematic review examined the association of specific risk factors with the incidence of SSI. Only factors which showed significant association with SSI through multivariate analysis were included, as univariate analysis does not take into account the possible confounding effects of other variables.

Patient-associated factors

Diabetes was identified as a patient-associated risk factor in three studies. Kim et al. [26] reported that following lumbar spine surgery, patients with a mean blood glucose level greater than 200 mg/dL at 48 hours post-surgery had a significantly higher incidence of SSI ($P < 0.05$, effect estimate not reported). Lee et al. [19] and Lee et al. [18] examined patients undergoing endoscopic gastrostomy. Type 2 diabetes was significantly associated with an increased risk of SSI in both studies (odds ratio [OR], 5.21; $P = 0.001$ and OR, 6.51; $P = 0.001$, respectively). Similarly, Jeong et al. [21] and Park et al. [23] both reported that co-morbidities (e.g., diabetes, hypertension, cancer) significantly increased the risk of SSI in patients undergoing abdominal surgery (OR, 5.4; $P = 0.011$) and laparoscopic gastrectomy (OR, 2.38; $P = 0.018$).

Lee et al. [5] showed that surgical patients with dirty infected wounds were at increased risk of developing SSIs, compared to surgical patients with clean wounds (OR, 6.51; $P = 0.001$). The incidence of SSI was associated with cerebrospinal fluid leaks (OR, 4.86; $P < 0.05$) and a Glasgow Coma score of >8 (OR, 6.51; $P < 0.05$) in patients undergoing craniotomy [24], while leukocytosis increased the risk of SSIs among patients undergoing endoscopic gastrostomy (OR, 3.15; $P = 0.021$), Lee et al. [19].

Procedure-associated factors

Kim et al. [27] conducted a meta-analysis of eight studies and found that the use of laparoscopy instead of open surgery for appendectomies reduced the risk of SSIs (OR, 0.33; 95% confidence interval, 0.20 to 0.55). Lee et al. [19] and Sakong et al. [7] showed that the absence of antibiotic prophylaxis and administration of antibiotics >1 hour before surgery significantly increased the risk of SSI (OR, 3.67; $P = 0.048$ and OR, 8.2; $P < 0.05$, respectively). A study by Lee et al. [5] identified several other procedure-associated risk factors that increased the risk of SSI. These included length of pre-operative stay (risk per additional day: OR, 1.038; $P = 0.029$), number of operations performed on the patient (risk per additional operation: OR, 3.27; $P = 0.004$) and duration of operation (risk per hour increase: OR, 1.007; $P < 0.001$).

SSI associated mortality

Only one study identified in this review examined the incidence of SSI-associated mortality. A study by Lee et al. [25] found no significant differences in the 5-year survival between patients with deep wound infections compared to patients with no infection following limb salvage surgery for osteosarcoma (88.9% vs. 82%, $P = 0.49$).

Pathogens associated with SSI in Korea

Ten of the included studies, comprising a range of surgical procedures, reported information on the pathogens present at the SSI (Table 9). The pathogens most commonly identified were *Staphylococcus aureus* (MRSA and MSSA), *Enterobacter* spp., *Enterococcus* spp. and *Klebsiella pneumonia*. The relative proportions of methicillin-resistant and methicillin-sensitive *S. aureus* varied between studies, but MRSA tended to be more common.

Economic burden data

Extended hospital stay

A substantial portion of the economic cost of SSI is attributable to increased length of hospital stay. As shown in Table 10, this review identified four studies that examined the association between hospital stay and SSI. Ahn and Shong [3] reported that following inpatient surgery,

Table 9. Common pathogens associated with surgical site infection

Source	Surgical procedure	No. of cultures tested	Frequency of pathogens causing SSI (%)										
			Escherichia coli	*Pseudomonas aeruginosa*	MSSA	MRSA	*Staphylococcus epidermis*	*Enterobacter* spp.	*Enterococcus* spp.	*Streptococcus* spp.	*Candida albicans*	*Klebsiella pneumonia*	Others/not specified
Ahn and Sohng [3]	Any inpatient surgery	56	14.0	10.5	1.8	12.3	-	8.8	15.8	10.5	3.5	10.5	10.7
Jeong et al. [21]	Abdominal surgery	15	13.3	-	-	33.3	-	26.7	26.7	-	-	-	-
Kim et al. [15]	Hip/knee arthroplasty and gastrectomy	25	10.0	10.0	10.0	3.3	-	6.7	20.0	13.3	3.3	13.3	10.0
Kim et al. [24]	Craniotomy	13	-	6.7	-	20.0	-	20.0	-	26.7	-	13.3	13.3
Kim et al. [2]	Any surgical procedure	626	7.3	15.0	3.2	25.1	2.2	5.6	9.7	6.4	1.4	3.7	20.4
Lee et al. [19]	Endoscopic gastrostomy	33	7.0	33.0	2.0	38.0	-	-	-	-	-	11.0	9.0
Lee et al. [25]	Limb salvage surgery in osteosarcoma patients	17[a)]	-	5.9	41.2	29.4	11.8	-	5.9	5.9	-	-	-
Lee et al. [18]	Endoscopic gastrostomy	19	2.9	32.4	2.9	29.4	-	-	5.8	2.9	-	11.8	11.8
Lee et al. [19]	All surgical procedures	15	6.3	-	-	18.8	-	12.5	31.3	6.3	-	12.5	12.5
Lee et al. [5]	All surgical procedures	33	6.2	-	6.1	21.2	-	3.0	6.2	24.2	-	6.2	27.3

SSI, surgical site infection; MRSA, methicillin-resistant Staphylococcus aureus; MSSA, methicillin-susceptible Staphylococcus aureus; NS, not stated.
[a)]Cultures from deep infections only.

patients with SSIs experienced a significantly longer stay in hospital (31.8 days vs. 11.5 days, P < 0.001). Similarly, Park et al. [6] reported significantly longer post-operative stays in patients with SSIs (14.15 days vs. 8.96 days, P = 0.019). Chang et al. [8,9] reported that intensive care unit stay was longer in patients with SSI following sternotomy and open heart surgery, respectively.

Cost of surgical site infections

Hospitalisation cost associated with SSI for patients undergoing general surgery at Severance Hospital in Seoul was reported in a publication by Park et al. [6] (Table 11). The cost of hospitalisation was, on average, ₩2,153,964 higher in patients with SSI, compared to patients with no SSI (P = 0.045). A substantial portion of the increased cost was due to hospital room costs and the need for additional medication. The authors noted that the costs are likely an underestimation of the actual economic cost of SSI, as only hospital expenditure data were considered. In a study by Ahn and Shong [3], the cost of antibiotics in patients undergoing inpatient surgical procedures was ₩735,155 (SD, 526,336) among those who developed an SSI, compared to ₩174,087 (SD, 171,326) for patients without SSI. The increased cost of antibiotics among patients with SSI was found to be statistically significant (₩561,068 P < 0.001).

DISCUSSION

The overall incidence of SSI in Korea ranged between 2.0 to 9.7%. The wide range may be due to differences in the types of surgical procedures examined, or the levels of risk factors in the patients included in the studies. In particular, surgery involving the gastrointestinal system was generally associated with higher rates of SSI. Patient-associated risk factors such as diabetes, wound conditions and patient health were associated with a significantly greater risk of SSI. Similarly, procedure-associated factors such as antibiotic treatment and surgery duration were also found to influence the risk of SSI.

There are a number of limitations with this review. The inclusion of studies was assessed based on the information

Table 10. Extended hospital stay associated with surgical site infection

Source	Surgical procedure	Type of stay	Length of stay (days)			
			SSI	No SSI	Difference	P-value
Ahn and Sohng [3]	Any inpatient surgery	Post-operative	31.8 (SD, 27.9)	11.5 (SD, 9.3)	20.3	<0.001
Park et al. [6]	All surgical procedures	Post-operative	14.15 (SD, 8.02)	8.96 (SD, 7.19)	5.19	0.019
Chang et al. [9][a)]	Sternotomy	ICU	10.8 (SD, 10.1)	5.0 (SD, 4.6)	5.8	0.005
Chang et al. [8]	Open-heart surgery	ICU	14.5 (SE, 26.2)	3.1 (SE, 3.3)	11.4	<0.001

ICU, intensive care unit; SD, standard deviation; SE, standard error; SSI, surgical site infection.
[a)]Comparing patients with mediastinitis to those with no infection.

Table 11. Hospitalisation cost associated with surgical site infection in Korea [6]

Source of cost	Mean cost (SD)			
	SSI (₩)	No SSI (₩)	Mean difference (₩)	P-value
Doctor's fee	29,341 (34,765)	21,098 (24,718)	8,243	0.423
Operation	1,168,336 (708,235)	929,193 (337,490)	239,143	0.141
Room	1,513,334 (2,056,657)	790,220 (641,009)	723,114	0.105
Meal	197,036 (137,904)	124,785 (107,639)	72,251	0.047
Anaesthesia	455,783 (287,738)	400,555 (181,873)	55,228	0.428
Blood	176,440 (406,090)	68,594 (60,688)	107,846	0.468
Radiology tests	339,684 (783,692)	274,341 (759,276)	65,343	0.768
Laboratory tests	384,940 (401,864)	204,059 (211,755)	180,881	0.055
Medication	1,227,428 (1,366,122)	669,282 (721,234)	558,146	0.082
Dressings and injections	330,340 (288,759)	172,778 (159,859)	157,562	0.023
Others	26,638 (115,021)	28,740 (119,676)	-2,102	0.950
Total	6,316,895 (4,630,1866)	4,162,931 (2,266,829)	2,153,964	0.045

SD, standard deviation; SSI, surgical site infection.

presented in the title and abstract. As such, studies that reported the rates of SSI as a secondary outcome may not have been identified. However, expanding the search to include all publications assessing post-surgical outcomes in patients would have substantially increased the total number of publications identified in the literature search. This would have likely resulted in the identification of additional publications, generally related to case series of specific surgical techniques. Case series often have small sample sizes and would have only served to provide incidence rates of SSI over a broader range of surgeries than those reported here.

Differences in study designs made it difficult to combine the data and obtain summary estimates of the incidence of SSI. These include differences in follow-up duration, method of data collection, and consideration for the use of antibiotics in the estimates. Most of the studies identified in this systematic review assessed SSI during the hospitalisation (pre-discharge) period, as well as during the post-discharge period, typically for 30 days, according to the CDC definition for post-operative infection. However, some studies only assessed SSI prior to discharge [11], while others conducted follow-up over one year [25]. With a substantial portion of SSI often occurring after discharge from hospital, studies that do not conduct post-discharge surveillance are likely to underestimate the incidence of SSI. As shown in the studies by Lee et al. [5] and Choi et al. [13], approximately 20% of SSIs occurred post-discharge. The manner that data is collected (e.g., method of post-discharge surveillance) influences the accuracy of the estimates, which in turn compromises inter-study comparisons. For example, in the studies by Kim et al. [24] and Kim et al. [15], patients who did not return for outpatient checks after discharge were contacted by telephone by infection control nurses. In comparison, Jeong et al. [21] derived post-discharge information solely from the patients' medical records. The use of antibiotic prophylaxis has been shown to be significantly associated with risk of SSI [7]. Consequently, studies that do not consider or account for the use of antibiotic prophylaxis may result in biased estimates, making their comparison between studies inappropriate.

SSIs represent a substantial economic burden, mainly attributable to the extended length of stay in hospital. In Korea, the incremental cost of an SSI is estimated at ₩2,153,964 (approximately US$2,025) [6]. In comparison, the cost per case of SSI in Japan has been estimated at approximately US$1,600 in patients undergoing colorectal surgery [28], while in Australia, the cost per case of SSI is estimated at US$2,200 [29]. In addition, SSIs result in the loss of productivity in patients and carers. As reported by two studies in this review [5,13], a significant proportion (-20%) of SSIs was identified after discharge from hospital. Consequently, SSIs have the potential to further increase the burden on community healthcare services and the families of patients.

This review has shown that SSIs represent a significant clinical and economic burden in Korea. In particular, certain patient populations appear to be at increased risk of developing SSI, such as patients undergoing gastric surgery or patients with dirty/contaminated wounds. Consequently, strategies and interventions during surgery that reduce the incidence of SSIs would likely translate. For example, recent clinical trials [30-32] have shown that the use of anti-bacterial coated sutures may reduce the incidence of SSIs by up to 40%. The development of such interventions would reduce patient morbidity associated with the development of SSIs, in turn, this could potentially translate into cost-savings for the healthcare system.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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