

## Methicillin-resistant *Staphylococcus aureus* screening is important for surgeons

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**Backgrounds/Aims:** Perioperative surgical site infection (SSI) remains a morbid complication even in successful surgical procedures. We encountered an unusual experience of a methicillin-resistant *Staphylococcus aureus* (MRSA)-related SSI outbreak in our hospital; therefore, we conducted an epidemiologic analysis to determine the origin of SSIs due to MRSA. **Methods:** Among 102 consecutive patients who underwent hepatobiliopancreatic operations, SSIs occurred in eight cases. Infection surveillance regarding the operative environment was carried out. We analyzed the possible risk factors for this infectious outbreak in our institution. **Results:** Patients with SSI tended to be older ( $p=0.293$ ), had variable operation fields ( $p=0.020$ ), more cancer-related operation ( $p=0.003$ ), less laparoscopic surgery ( $p=0.007$ ), performed in operation room 1 ( $p=0.004$ ), prolonged operation time ( $p<0.001$ ) and had longer hospital stays ( $p=0.002$ ). After propensity score (PS) matching, there was the only significant difference in the participation of surgeon D as a second assistant ( $p=0.001$ ) between the SSI and non-SSI group. After PS matching, surgeon D as a second assistant was the only significant risk factor for MRSA SSI in the univariate ( $p=0.001$ ) and multivariate analysis ( $p=0.004$ , hazard ratio=25.088, 95% confidence interval=2.759-228.149). **Conclusions:** Outbreak of SSIs occurred due to transmission of MRSA from a surgeon to patients despite the standard regulation of infection control. These SSIs were associated with an excessive incidence of surgeon's nasal and hand carriage of the MRSA strain identified in the surgeon via cultures. We recommend the preoperative regular nasal and hand screening for MRSA among surgeons. ([Ann Hepatobiliary Pancreat Surg 2019;23:265-273](#))

**Key Words:** Surgical site infection; Methicillin-resistant *Staphylococcus aureus*; Screening

### INTRODUCTION

Perioperative surgical site infection (SSI) remains a morbid complication even in successful surgical procedures. *Staphylococcus aureus* is the most common causative pathogen in SSIs and is a common risk factor of healthcare worker-related morbidity and mortality.<sup>1</sup> Moreover, *S. aureus* accounts for a third of all SSIs according to the National Healthcare Safety Network report.<sup>2</sup> In particular, methicillin-resistant *S. aureus* (MRSA) has been an important causative pathogen of global healthcare and community-acquired infections.<sup>3,4</sup> The primary route of MRSA

transmission is from patients to patients, from the environment to the patient, or even contact with the healthcare workers' hands.<sup>5</sup> The most important transmission route usually involves contaminated hands. Microorganisms from the hands of the surgeon, organisms found in the operating room, or organisms from other surgical staff members are often causes of SSIs.<sup>6</sup>

Healthcare workers are expected to play an important role in MRSA transmission because the average rate of MRSA colonization among healthcare workers has been estimated at 4.6-6%.<sup>7,8</sup> A decrease in the incidence of SSI due to *S. aureus* screening and decolonization has directly

**Received:** March 7, 2019; **Revised:** April 22, 2019; **Accepted:** April 30, 2019

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Annals of Hepato-Biliary-Pancreatic Surgery • pISSN: 2508-5778 • eISSN: 2508-5859

attention towards preoperative *S. aureus* carriage.<sup>9</sup> Healthcare workers have been known as an important source of SSIs, such as SSIs originating from a pair of perforated surgical gloves of a surgeon harboring known colonies of *S. aureus* in his/her nose. Air-borne intraoperative infection is another common transmission pathway. A previous study reported a case of postoperative SSI due to *S. aureus* disseminated via droplets from an operating room staff member with eczema, who was later identified as the disperser of the outbreak strain.<sup>10</sup> A systematic review showed that 11 out of 191 nosocomial outbreaks of MRSA might have been caused by healthcare workers. Asymptomatic carriers were thought to be the cause in 3 of these SSI outbreaks.<sup>11</sup>

We encountered an unusual experience of a MRSA-related SSI outbreak in the hepatobiliopancreatic surgery division in our institution; we therefore performed an epidemiologic analysis to identify the origin of this outbreak. The aim of this study was to determine the origin of MRSA that was responsible for the SSI outbreaks.

## MATERIALS AND METHODS

### Study design

This was an observational, retrospective, and epidemiologic study conducted at single center, Korea University Medical Center. Between January and February 2009, among 102 consecutive patients who underwent hepatobiliopancreas operations, SSIs occurred in 8 (7.8%) patients. An infection surveillance that involved patient characteristics, operative sterilization status, operation type, operation class, operation field, medical staff status, and in-hospital factors was carried out by a practitioner associated with the infectious disease division of the internal medicine department. Diagnosis of SSI was based on clinical findings, including redness, tenderness, and pus discharge of the operative wound, and identification of  $>10^5$  organisms in the surgical sites. Then, the SSIs were classified as a superficial wound infection, deep wound infection, or intra-abdominal organ/space infection according to criteria from the Centers for Disease Control and Prevention (CDC).<sup>12</sup> We compared the perioperative characteristics between the patients with the SSI and those without SSI. We then attempted to identify the possible risk factors of this infectious outbreak within our institution.

We divided hospital staff members into surgeons, first assistants, and second assistants according to the intraoperative role in the surgical field. Three surgeons (from A to C) or eight assistants (from B to I) participated in the operations and some operations were performed without an assistant. We then examined the proportion of participation of hospital staff members as a surgeon, first assistant, or second assistant in the operations.

### Microbiological surveillance

All faculty members and surgical residents who had direct contact with patients in the hepatobiliopancreas division were screened for *S. aureus* colonization via nasal and hand swabs. Methicillin-susceptible *Staphylococcus aureus* and MRSA were identified using standard methods.<sup>13</sup> Operative environments were also surveyed for infectious agents. We obtained test samples for culture from various sources, including different reusable surgical instruments, reusable laparoscopic instruments, disposable laparoscopic instruments, reusable surgical drapes, and reusable surgical gowns. In addition, we further examined the sterilization status of surgical instruments several hours after they were sterilized using a high-temperature sterilizer and ethylene oxide sterilizer.

We also reviewed the hospital infection management protocol of preoperative care, such as hair removal, skin preparation, and preoperative antibiotics.

### Statistical analysis

Each variable's distributional characteristics were assessed for normality. Continuous data were reported in terms of mean±standard deviation and/or median with interquartile range based on variance. The chi-squared test or Fisher's exact test was used to compare categorical variables, and independent t-test or Mann-Whitney test was used to compare continuous variables. The *p*-value was adjusted under Bonferroni correction after Mann-Whitney test. A 1:3 propensity score (PS) matching between cohorts with SSI and without SSI was applied for patients' age, sex, body mass index (BMI), co-morbid diseases, operation time, laparoscopic surgery, and operation field using the nearest-neighboring matching method with R software (version 3.4) "MatchIt" package.<sup>14</sup>

SSI risk factor analysis was performed in the univariate logistic regression analysis and variables with *p*-value  $<0.1$

were analyzed in the multivariate logistic regression method. Statistical analyses were performed using SPSS (version 20.0 for Mac, SPSS Inc., Chicago, IL, USA). The institutional review board of the ethics committees (IRB) of Korea University Ansan Hospital approved the study protocol. Written informed consent was waived by the IRB owing to the study's retrospective nature.

## RESULTS

### Clinical characteristics

Between January and February 2009, 102 patients underwent operations in the hepatobiliarypancreas surgery division. Among 102 patients, SSIs occurred in 8 patients, which demonstrated showed *S. aureus* with same antibiotic susceptibility in wound culture. Operation class in SSI group was all clean-contaminated. Six cases were superficial SSI and two cases were deep SSI. Deep SSI showed

**Table 1.** Comparison of clinical data between patients with and those without surgical site infection before and after propensity score matching

	Before PS matching			After PS matching		
	SSI (n=8)	Non-SSI (n=94)	p-value	SSI (n=8)	Non-SSI (n=24)	p-value
Age (years)	55.5±11.2 57.5 [23.0]	48.6±18.3 52.0 [25.0]	0.293	55.5±11.2	54.2±18.6	0.674
Sex (male:female)	4:4	50:44	>0.99	4:4	13:11	>0.99
BMI (kg/m <sup>2</sup> )	25.0±3.4 24.8 [5.5]	24.2±4.0 24.4 [4.9]	0.520	25.0±3.4	24.9±2.9	0.948
Co-morbidity						
Hypertension	1 (12.5)	23 (24.5)	0.677	1 (12.5)	9 (37.5)	0.380
Diabetes	1 (12.5)	16 (17.2)	>0.99	1 (12.5)	3 (12.5)	>0.99
Pulmonary disease	2 (25.0)	5 (5.3)	0.093	2 (25.0)	1 (4.2)	0.147
Hepatitis	2 (25.0)	12 (12.8)	0.302	2 (25.0)	3 (12.5)	0.578
Cancer history	2 (25.0)	9 (9.6)	0.206	2 (25.0)	3 (12.5)	0.578
Smoking history	2 (25.0)	23 (24.5)	>0.99	2 (25.0)	6 (25.0)	>0.99
Operation class			>0.99			>0.99
Clean	0 (0)	4 (4.3)		0 (0)	0 (0)	
Clean-contaminated	8 (100)	84 (89.4)		8 (100)	22 (91.7)	
Contaminated	0 (0)	6 (6.4)		0 (0)	2 (8.3)	
Operation field			0.020*			0.601
Liver	2 (25.0)	13 (13.9)		2 (25.0)	5 (20.8)	
GB/bile duct	3 (37.5)	52 (55.3)		3 (37.5)	8 (33.3)	
Pancreas/duodenum	3 (37.5)	6 (6.4)		3 (37.5)	5 (20.8)	
Others	0 (0)	23 (24.5)		0 (0)	6 (25.0)	
Elective operation	8 (100)	69 (73.4)	0.194	8 (100)	17 (70.8)	0.150
General anesthesia	8 (100)	91 (96.8)	0.608	8 (100)	23 (95.8)	>0.99
Cancer-related Op	6 (75.0)	20 (21.3)	0.003*	6 (75.0)	11 (45.8)	0.229
Laparoscopy	1 (12.5)	60 (63.8)	0.007*	1 (12.5)	4 (16.7)	>0.99
Op Room			0.004*			0.414
1	6 (75.0)	18 (19.1)		6 (75.0)	11 (45.8)	
2	1 (12.5)	28 (29.8)		1 (12.5)	4 (16.7)	
Others	1 (12.5)	48 (51.1)		1 (12.5)	9 (37.5)	
Op time (minutes)	265±91 271 [193]	116±141 75 [80]	<0.001*	265±91 271 [193]	243±229 190 [271]	0.207
Hospital stay (days)	27.0±13.8 29.0 [16.0]	16.7±40.6 6.5 [13.0]	0.002*	27.0±13.8 29.0 [16.0]	21.5±16.5 16.0 [25.0]	0.214

Values are presented as mean±standard deviation, median [interquartile range], or n (%). BMI, body mass index; GB, gallbladder; MRSA, methicillin-resistant *Staphylococcus aureus*; Op, operation; PS, propensity score; SSI, surgical site infection  
\*Statistically significant

fascia defects in wound, which were repaired with re-operation.

We compared the clinical data between the group of pa-

tients with SSIs (SSI group) and the patients without SSIs (non-SSI group) before and after PS matching (Table 1).

SSI group tended to be older ( $p=0.293$ ), had variable op-

**Table 2.** Comparison of surgeons' factors between patients with and those without surgical site infection before and after propensity score matching

	Before PS matching			After PS matching		
	SSI (n=8)	Non-SSI (n=94)	<i>p</i> -value	SSI (n=8)	Non-SSI (n=24)	<i>p</i> -value
As an operator			0.037*			0.803
A	7 (87.5)	35 (37.2)		7 (87.5)	19 (79.2)	
B	1 (12.5)	41 (43.6)		1 (12.5)	2 (8.3)	
C	0 (0)	18 (19.1)		0 (0)	3 (12.5)	
As an operator			0.008*			>0.99
A	7 (87.5)	35 (37.2)		7 (87.5)	19 (79.2)	
Others	1 (12.5)	59 (62.8)		1 (12.5)	5 (20.8)	
As a first assistant			0.279			0.544
B	0 (0)	2 (2.2)		0 (0)	2 (8.7)	
C	7 (87.5)	27 (29.7)		7 (87.5)	12 (52.2)	
D	0 (0)	12 (13.2)		0 (0)	0 (0)	
E	0 (0)	17 (18.7)		0 (0)	5 (21.7)	
F	0 (0)	7 (7.7)		0 (0)	1 (4.3)	
G	0 (0)	8 (8.8)		0 (0)	0 (0)	
H	0 (0)	1 (1.1)		0 (0)	1 (4.3)	
I	0 (0)	6 (6.6)		0 (0)	1 (4.3)	
Others	1 (12.5)	11 (12.1)		1 (12.5)	1 (4.3)	
As a first assistant			0.002*			0.101
C	7 (87.5)	27 (28.7)		7 (87.5)	12 (50.0)	
Others	1 (12.5)	67 (71.3)		1 (12.5)	12 (50.0)	
As a second assistant			<0.001*			0.002*
D	6 (75.0)	8 (8.5)		6 (75.0)	2 (8.3)	
E	1 (12.5)	3 (3.2)		1 (12.5)	1 (4.2)	
F	0 (0)	15 (16.0)		0 (0)	6 (25.0)	
G	0 (0)	3 (3.2)		0 (0)	1 (4.2)	
H	0 (0)	3 (3.2)		0 (0)	0 (0)	
I	0 (0)	0 (0)		0 (0)	2 (8.3)	
Others	1 (12.5)	62 (66.0)		1 (12.5)	12 (50.0)	
As a second assistant			<0.001*			0.001*
D	6 (75.0)	8 (8.5)		6 (75.0)	2 (8.3)	
Others	2 (25.0)	86 (91.5)		2 (25.0)	22 (91.7)	
All surgeon						
MRSA nasal carrier	0.75±0.46 1.0 [0.75]	0.54±0.50 1.0 [1.0]	0.259	0.75±0.46 1.0 [0.75]	0.54±0.51 1.0 [1.0]	0.510
MRSA hand carrier	0.75±0.46 1.0 [0.8]	0.66±0.50 1.0 [1.0]	0.600	0.75±0.46 1.0 [0.75]	0.63±0.58 1.0 [1.0]	0.306
As a first assistant						
MRSA nasal carrier	0 (0)	25 (26.6)	0.194	0 (0)	5 (20.8)	0.296
MRSA hand carrier	0 (0)	33 (35.1)	0.051	0 (0)	2 (8.3)	>0.99
As a second assistant						
MRSA nasal carrier	6 (75.0)	26 (27.7)	0.011*	6 (75.0)	11 (45.8)	0.229
MRSA hand carrier	6 (75.0)	29 (30.9)	0.019*	6 (75.0)	10 (41.7)	0.220

Values are presented as mean±standard deviation, median [interquartile range], or n (%)

Surgeons were identified as A, B, C, D, E, F, G, H, and I

MRSA, methicillin-resistant *Staphylococcus aureus*; PS, propensity score; SSI, surgical site infection

\*Statistically significant

eration fields ( $p=0.020$ ), more cancer-related operation ( $p=0.003$ ), less laparoscopic surgery ( $p=0.007$ ), performed in operation room 1 ( $p=0.004$ ), prolonged operation time ( $p<0.001$ ) and had longer hospital stays ( $p=0.002$ ). After PS matching, there were no statistically significant differences between two groups.

We compared surgeons' factors between the SSI and non-SSI groups (Table 2). In the SSI group, surgeon A performed operation significantly ( $p=0.008$ ), surgeon C participated operation as a first assistant significantly ( $p=0.002$ ), and surgeon D participated operation as a second assistant significantly ( $p<0.001$ ). The MRSA nasal and hand carriage of second assistant was found to be significantly higher in the SSI group ( $p=0.011$  and  $p=0.019$ ). After PS matching, there was the only significant difference in the participation of surgeon D as a second assistant ( $p=0.001$ ).

**Results of infectious surveillance**

Nasal swab culture and hand culture of samples ob-

tained from the surgical team were carried out (Table 3). Nasal swab cultures yielded three cases of MRSA infection (D, F, I) and one case of methicillin-susceptible *Staphylococcus aureus* infection (E). Three cases of MRSA infection (D, F, I) were detected via hand cultures. Quality control and cultures from the surgical environment, including surgical instruments, surgical drapes, and high temperature and ethylene oxide gas disinfection sterilizers, yielded no growths. The hospital infection management protocol of preoperative care, such as hair removal, skin preparation, and preoperative antibiotics has been well controlled according to the infection protocol.

**Outbreak control measures**

Lectures for infection prevention education were provided in the hepatobiliopancreas division between May and July 2009. During these lectures, routine practices (Standard Precautions) with an emphasis on hand hygiene were prioritized. Proper intervals for preoperative antimicrobial prophylaxis and avoidable movement in and out of the op-

**Table 3.** Culture results of samples obtained from surgical staffs

Surgeon	Culture	Organism	Antibiotic susceptibility								Organism after treatment <sup>†</sup>
			PG	OX	VA	TC	EM	CI	GM	ST	
A	Wound*	<i>S. aureus</i>	R	R	S	S	S	S	S	S	
	Nasal swab										
B	Hand										
	Nasal swab										
C	Hand										
	Nasal swab										
D	Hand	<i>S. aureus</i>	R	R	S	S	S	S	S	S	-
	Nasal swab	<i>S. aureus</i>	R	R	S	S	S	S	S	S	<i>S. aureus</i>
E	Hand	<i>S. aureus</i>	R	S	S	S	S	S	S	S	-
	Nasal swab										
F	Hand	<i>S. aureus</i>	R	R	S	S	S	S	S	S	-
	Nasal swab	<i>S. aureus</i>	R	R	S	S	S	S	S	S	-
G	Hand	<i>S. aureus</i>	R	R	S	S	S	S	S	S	-
	Nasal swab										
H	Hand										
	Nasal swab										
I	Hand	<i>S. aureus</i>	R	R	S	S	S	S	S	S	-
	Nasal swab	<i>S. aureus</i>	R	R	S	S	S	S	S	S	-

Surgeons were identified as A, B, C, D, E, F, G, H, and I

CI, ciprofloxacin; EM, erythromycin; GM, gentamicin; OX, oxacillin; PG, penicillin G; R, resistant; S, susceptible; ST, sulfamethoxazole/trimethoprim; TC, teicoplanin; VA, vancomycin

\*Surgical site showed *S. aureus* with same antibiotic susceptibility

<sup>†</sup>Mupirocin ointment and rifampin medication

**Table 4.** Regression analysis of significant risk factors for surgical site infections in the univariate and multivariate analysis before and after propensity score matching

	Univariate analysis		Multivariate analysis	
	<i>p</i> -value	HR (95% CI)	<i>p</i> -value	HR (95% CI)
Before PS matching				
Age	0.298	1.025 (0.979-1.072)		
Male sex	0.862	1.136 (0.268-4.815)		
A as an operator	0.054	0.122 (0.014-1.040)	0.354	0.233 (0.011-5.062)
C as a first assistant	0.009*	17.370 (2.039-147.992)	0.230	3.519 (0.115-108.096)
D as a second assistant	<0.001*	32.250 (5.567-186.824)	0.998	0.161 (0.008-3.180)
Open surgery	0.021*	12.353 (1.458-104.690)	0.429	3.127 (0.186-52.607)
Cancer-related operation	0.005*	11.100 (2.080-59.249)	0.447	0.393 (0.035-4.396)
Operation time	0.034*	1.004 (1.000-1.008)	0.441	1.002 (0.997-1.008)
Nasal MRSA carrier <sup>†</sup>	0.015*	0.127 (0.024-0.672)	>0.99	
Hand MRSA carrier <sup>†</sup>	0.024*	0.149 (0.028-0.781)	>0.99	
After PS matching				
Age	0.663	1.010 (0.965-1.058)		
Male sex	0.838	1.182 (0.238-5.864)		
A as an operator	0.605	1.842 (0.182-18.657)		
C as a first assistant	0.089	7.000 (0.743-65.943)	0.361	3.423 (0.244-47.977)
D as a second assistant	0.001*	33.000 (3.814-285.533)	0.004*	25.088 (2.759-228.149)
Open surgery	0.779	1.400 (0.133-14.743)		
Cancer-related operation	0.166	3.545 (0.592-21.245)		
Operation time	0.707	1.001 (0.997-1.005)		
Nasal MRSA carrier <sup>†</sup>	0.117	4.200 (0.698-25.264)		
Hand MRSA carrier <sup>†</sup>	0.166	0.282 (0.047-1.690)		

Surgeons were identified as A, B, C, D, E, F, G, H, and I

PSM, propensity score matching; HR, hazard ratio; CI, confidence interval

\*Statistically significant

<sup>†</sup>Participation as a second assistant

erating room was also reinforced. The staffs were made aware of the constant transmission of MRSA.

Hospital members with nasal MRSA colonization were decolonized with mupirocin ointment (2 times per day) and rifampin 600 mg (once a day) for 5 days. Hospital members with hand MRSA colonization were decolonized via a 4% chlorhexidine shower twice. Surveillance for *Staphylococcus* infections was followed up 4 weeks after the *S. aureus* decolonization, and only one case of *Staphylococcus* colonization detected via a hand culture was found during the process (surgeon D, Table 3).

#### Analysis of risk factors affecting the outbreak of MRSA-related SSI

In univariate analysis before PS matching, surgeon C as a first assistant C ( $p=0.009$ ), surgeon D as a second assistant ( $p<0.001$ ), open surgery ( $p=0.021$ ), cancer-re-

lated operation ( $p=0.005$ ), longer operation time ( $p=0.034$ ), MRSA nasal carriage ( $p=0.015$ ), and MRSA hand carriage ( $p=0.024$ ) were significant factors for SSI in our study (Table 4). In the multivariate analysis before PS matching, there was no significant risk factor for MRSA-related SSI. After propensity score matching, surgeon D as a second assistant was the only significant risk factor for MRSA SSI in univariate ( $p=0.001$ ) and multivariate analysis ( $p=0.004$ , hazard ratio=25.088, 95% confidence interval=2.759-228.149).

## DISCUSSION

This observational, retrospective, and epidemiologic study was conducted to establish the origin of a *S. aureus* outbreak, which was eventually identified via detection of nasal and hand MRSA carriage in a healthcare worker,

a surgeon in particular. The exact position where the dissemination occurred was, however, not recognized. While some reports propose that healthcare workers with MRSA carriage are infection targets rather than offenders of outbreaks,<sup>15</sup> other reports have focused on the significance of MRSA carriage in healthcare workers in SSI outbreaks.<sup>16,17</sup> In our study, surgeon D had hand and nose MRSA carriage, and the colonies could not be completely eradicated even after the medication. This indicates the possibility of suboptimal treatment compliance of surgeon D in terms of the prevention of SSI, which intensified the degree of SSIs.

Devenish and Miles<sup>18</sup> have proposed that the operators' or assistants' hand *S. aureus* carriage could infect the surgical site via breaks in surgical gloves. Another study demonstrated that nasal and hand *S. aureus* colonies played a significant role in surgical site infection outbreak. A high proportion of the surgeons in the operating environment with MRSA carriage could indicate dispersion among healthcare workers.<sup>19</sup> In our study, the mean operation time in SSI group was 265±91 minutes, which meant that the probability of defects to the surgical gloves became increased. Makama et al.<sup>20</sup> have demonstrated that the longer the duration of operation, the greater the risk of surgical glove perforation in the randomized controlled study. They also reported that second assistant had a higher perforation rate of surgical glove. At the end of the operation, fascia closure suturing was mainly performed by the first and second assistant, and skin suturing was performed primarily by the second assistant in our institute. A high rate of colonization found in healthcare staff during a *S. aureus* outbreak was reported by Weber et al.,<sup>19</sup> and the outbreak was thought to have occurred because of the presence of virulent colonizing considerations in the outbreak strains and the spread of the strain due to diffusion from people (not recognized in our study). In our study, suboptimal compliance under standard regulations of infection control was a liable causative source in the spread of the outbreak strains, which could be deduced via the positive hand culture for MRSA after treatment in surgeon D.

On the other hand, many studies have focused on the MRSA nasal carriage of patients as the source of SSIs. The most widely described risk factor specific to SSI due to *S. aureus* is nasal colonization in patients.<sup>21</sup> The risk of *S. aureus* nosocomial infections is greater in preopera-

tive carriers than in non-carriers, and almost patients who develop SSIs already have an MRSA colonization. Patients with nasal MRSA carriage are at greater risk for nosocomial *S. aureus* bacteremia than control groups.<sup>22</sup> However, this is additionally understandable from the previous documented data, wherein preoperative nasal or hand carriage does not explain all of the SSIs.<sup>23</sup> Given that routine preoperative screening for *S. aureus* in patients was not conducted in our study, we could not assess this risk factor. However, the potential benefits and harms of using decontamination for the prevention of SSI remain uncertain.<sup>24</sup>

Our study confirmed that nasal colonization of MRSA in a surgeon is an important factor for the development of MRSA SSI in the perioperative period of hepatobiliary-pancreatic surgery. The specific strain of MRSA found in both the patients and surgeon D demonstrated identical result of antibiotic susceptibilities. After extermination of the strain obtained from the surgeon with MRSA carriage, we could manage the SSI outbreak and no additional SSIs were detected. There is some evidence to suggest that the screening of healthcare workers, in principle, acceptable to both patients and healthcare workers. However, evidence regarding its effectiveness in the prevention and control of MRSA in the endemic setting is limited.<sup>11</sup>

The optimal antibiotic prophylactic regimen for MRSA-related SSI prevention has not been identified thus far. We currently have no evidence to confirm that preoperative administration of multiple antibiotics or long-term antibiotics administration is beneficial for controlling and preventing MRSA-related SSIs.<sup>25</sup>

We also analyzed other risk factors for SSIs due to MRSA. Longer operation duration is a well-known perioperative risk factor for SSI<sup>26</sup> and for *S. aureus*-related SSIs.<sup>21</sup> Cancer-related surgery was also identified as a significant risk factor for SSI.<sup>26</sup> However, in this study, longer operation duration and cancer-related surgery showed no significant differences in terms of incidence of SSI, despite the fact that those factors were significant in the univariate analysis before propensity score matching. This difference could be associated with a difference in patient populations, surgical field, as well as our somewhat smaller population size.

Such outbreaks can be prevented by a combination of infection control practices: isolation of affected patients;

importance on hand hygiene; improved environmental disinfection with a hypochlorite agent; and screening for MRSA colonization via nasal and hand cultures. Supplementary education and teaching were also provided in the surgery department after the outbreak of MRSA.

This study has some limitations. We could not confirm preoperative *S. aureus* colonization status in our patients, because this study was retrospective in nature. The relatively small number of infection cases might have decreased our capacity to identify significant risk factors despite of PS matching statistical analysis. Moreover, we did not perform genetic testing of the *S. aureus* strains isolated during the outbreak and that obtained from surgeon D. We believe that the outbreak strain was originated from surgeon D because of the same antibiotic susceptibility. This study was conducted in the hepatobiliarypancreas surgery division of a single university hospital, and the SSI outbreak epidemiological study results might be applicable to in-hospital patients undergoing hepatobiliarypancreas surgeries elsewhere as well. Furthermore, the feasibility of preoperative additive screening for *S. aureus* and decolonizing surgeons is being explored within the hepatobiliarypancreas surgery division.

In conclusion, the SSI outbreak in the hepatobiliarypancreas surgery division occurred due to transmission of MRSA from a surgeon to patients in the setting of standard perioperative infection control measures, which did not include preoperative screening of MRSA for surgeons. The outbreak was associated with a high prevalence of nasal and hand carriage of the outbreak MRSA strain among the surgeons, especially who participated in surgery as a second assistant. We recommend the preoperative regular nasal and hand screening of surgeons to prevent the spread of MRSA.

## ACKNOWLEDGEMENTS

The work was supported by the research seed fund from the Korea University Research and Business Foundation.

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