Risk Factors for Surgical Site Infections in Patients Undergoing Emergency Surgery: A Single-centre Experience

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Abstract. *Background/Aim:* Surgical site infections (SSI) are associated with increased morbidity and mortality, and they occur more frequently during unplanned emergency surgical (ES) procedures rather than elective. Our aim was to determine the incidence of SSI within our ES cohort and to identify risk factors for SSI. *Patients and Methods:* Data from consecutive patients undergoing ES in a single institution during a 5-year period were prospectively collected and analyzed. *Results:* A total of 838 consecutive patients were included. The median age was 52 (IQR=25-71) years and some 368 (44%) were female. 157 (18.7%) of those patients developed SSI. The most commonly isolated pathogen was *E. Coli* (55.4%) followed by *Staphylococcus Aureus* (40.1%). The 30-day mortality rate of patients who presented SSIs was 14.6% compared to 6.8% of patients without SSI ($p=0.002$). Multivariable analysis showed that the type of wound, American Society of Anesthesiology score, severity and duration of surgery >90 min were independent risk factors for the occurrence of SSI. *Conclusion:* Identification of modifiable causative factors for SSI within an ES unit is paramount as they can critically impact postoperative outcomes.

Surgical site infections (SSI) represent a major burden for surgical patients and are associated with increased morbidity, protracted hospital length of stay, higher intensive care unit

(ICU) admissions and hospital readmissions, as well as increased mortality and last but not least, increased economic costs (1). Over the past decades, prevention of SSIs has attracted substantial interest from surgeons, infection preventionists, and health care authorities (2). In particular, patients undergoing emergency surgery (ES) are at higher risk for developing SSIs compared to those undergoing elective surgery due to dirtier and more contaminated wounds. Notably, while SSIs in patients undergoing elective surgery may range from 1.5% to 5%, in patients undergoing ES, SSIs may account for 7-32% (3, 4). Patients undergoing ES have higher morbidity and mortality rates. In this context, predicting and preventing the occurrence of SSIs in these vulnerable patient groups are of cardinal importance.

A plethora of patient and procedure-related factors have been strongly associated with the occurrence of SSI over the past decades (5). Advanced age, poor nutritional status, increased body mass index (BMI), smoking, remote infections, and administration of immunosuppressive medication are amongst the most common patient-related risk factors for the occurrence of SSI. On the other hand, prolonged operative time, contaminated wound status, prophylactic administration of antibiotics, and emergency nature of surgery are among the most common procedure-related risk factors (5, 6).

Morbidity and mortality rates in these high-risk patients could be actively decreased by interventions focused on potentially modifiable risk factors for the development of SSI. For that reason, the objective of our study was to identify the incidence and risk factors of SSI within our ES cohort.

Patients and Methods

Study design. This study was a prospective, observational study, which was approved from the Institutional Review Board of “Agios Panteleimon” General Hospital of Nikea. A patient information sheet and an informed consent form were provided to patients eligible to be included in the study. Signed informed consent was

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	Mild	Moderate	Severe
Acute appendicitis	Appendectomy for inflammatory appendicitis	Appendectomy for suppurative appendicitis	Appendectomy±colectomy for perforated appendicitis / generalized peritonitis
Acute cholecystitis	Cholecystectomy for mild cholecystitis	Total/subtotal cholecystectomy for GB empyema	Total/subtotal cholecystectomy for GB perforation / biliary peritonitis
Acute diverticulitis	-	Primary repair/resection for perforated bowel/ local abscess	Resection for perforated bowel / generalized peritonitis
Gastrointestinal perforation	Primary repair for recent perforation / no abscess-peritonitis	Primary repair/resection for local abscess	Resection for generalized peritonitis
Obstructive ileus	Adhesiolysis (no ischaemia)	±Resection (ischaemia present)	Resection for perforation/ generalized peritonitis
Strangulated hernia	Simple repair (no ischaemia)	±Resection (ischaemia present)	Resection for perforated bowel
Trauma with haemorrhage	-	Repair/resection for single organ trauma	Resection for multiorgan trauma
Trauma with peritonitis	-	Primary repair/resection for localized peritonitis	Resection for generalized peritonitis
Upper gastrointestinal bleeding	-	Primary repair/short segment resection	Extended resection
Lower gastrointestinal bleeding	-	Short segment resection	Extended resection
Vascular ischaemia	-	Short segment resection	Extended resection

Figure 1. Study classification of severity of surgical procedures with examples.

obtained from each included patient. All patient data were de-identified, and the authors assumed written responsibility for the protection of patient data according to the regulations of the Hellenic Data Protection Authority.

Setting. The study took place at the “Agios Panteleimon” General Hospital of Nikea from January 1st, 2010 to December 31st, 2014. Data were collected with the use of a prospectively maintained Excel spreadsheet (Microsoft, Redmond, WA, USA), starting immediately after institutional review board (IRB) approval was obtained.

Inclusion and exclusion criteria. Consecutive patients who underwent ES at the First Surgical Department of “Agios Panteleimon” General Hospital of Nikea were considered eligible for inclusion. We have excluded patients which underwent ES for skin and soft tissue infections, as there is no standard definition of SSI for these operations, given the difficulty to assess the presence of SSI in soft tissue infections.

Definitions. We have used the Centers for Disease Control and Prevention/National Healthcare Safety Network (CDC/NHSN) criteria of SSI (7). For surgical wound class we have used the standard definitions of American College of Surgeons Committee on Control of Surgical Infections (8).

Recorded variables. The following variables were recorded: a) Patient information (demographics and personal history): gender, age, body mass index (BMI), smoking status, presence of diabetes mellitus, coronary heart disease, heart failure, chronic respiratory failure and chronic renal failure, administration of anticoagulants,

and American Society of Anesthesiology score (9). b) Data of the surgery: surgical wound class, severity and duration of operation, perioperative red blood cell unit (RBCU) transfusions, antimicrobials before surgery, other remote infection, chemoprophylaxis or antimicrobial treatment, and intensive care unit (ICU) admission. c) SSI Data: SSI classification, pathogenic cause of SSI, antimicrobial treatment administered, other postoperative infections, postoperative complications (graded according to Clavien-Dindo classification) (8) d) Outcomes: length of hospital stay, readmission, and 30-day mortality. The severity of the surgical procedure performed was independently assessed by two surgeons (AP and CV) based on predetermined criteria (Figure 1). The grading of the surgical wound class in each patient was similarly independently assessed by the same two surgeons (10).

Statistical analysis. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM, Armonk, NY, USA). Chi-square test and Fisher’s exact test were used for comparisons among groups with categorical variables. Logistic regression analysis was used for multivariable analysis of risk factors for SSI. All the tests were two-tailed. Results were considered statistically significant if the *p*-value was less than 0.05.

Results

Patient characteristics. A total of 838 patients who underwent ES during the study period were included. The mean age was 50.9 years (SD=23.0) and 368 (44%) of them were female. One hundred and fifty-five (18.7%) of these patients developed SSI. Characteristics of patients with and

Table I. Patient characteristics.

		Presence of SSI			p-Value [§]
		Total (n=835)	No (n=678)	Yes (n=157)	
Gender	Female	368 (44)	306 (45.1)	62 (39.5)	0.210
Age	Years (mean - SD)	50.1 (23.0)	48.1 (23.0)	63.2 (18.6)	<0.001*
BMI	Kg/m ² (mean - SD)	26.1 (5.2)	25.7 (4.8)	27.9 (6.2)	<0.001*
Smoking	Current smoker	337 (40.3)	263 (38.8)	74 (47.1)	0.239
	Ex-smoker	75 (9)	61 (9.1)	14 (8.9)	
	Non-smoker	424 (50.7)	355 (52.3)	69 (43.9)	
	Unknown	1 (0.1)	1 (0.1)	0 (0)	
Comorbidities	Diabetes	116 (13.9)	73 (10.8)	43 (27.4)	<0.0001
	CHD - CHF	121 (14.5)	84 (12.4)	37 (23.6)	<0.0001
	CKD	29 (3.5)	22 (3.2)	7 (4.5)	0.445
	COPD	59 (7.1)	38 (5.6)	21 (13.4)	0.001
Medication	Anticoagulants	42 (5)	29 (4.3)	13 (8.3)	0.038
	Antiplatelets	71 (8.5)	48 (7.1)	23 (14.6)	0.002
	Steroids	37 (4.4)	23 (3.4)	14 (8.9)	0.002
ASA	1	223 (26.6)	216 (31.8)	7 (4.5)	<0.0001
	2	443 (52.9)	357 (52.5)	86 (54.8)	
	3	146 (17.4)	85 (12.5)	61 (38.9)	
	4	22 (2.6)	19 (2.8)	3 (1.9)	
	5	3 (0.4)	3 (0.4)	0 (0)	
Preop LOS >1 day		254 (30.3)	175 (25.7)	79 (50.3)	<0.0001

SSI: Surgical site infection; BMI: body mass index; CHD: coronary heart disease; CHF: Congestive heart failure; CKD: chronic kidney disease; COPD: chronic obstructive pulmonary disease; ASA: American society of anesthesiology score, [§]p-Value for Chi-square test, *p-Value for Mann-Whitney U-test.

without SSI are shown in detail in Table I. Characteristics associated with the presence of SSI were older age, higher BMI, presence of diabetes, coronary heart disease or congestive heart failure, and chronic obstructive pulmonary disease. Patients with SSI were more frequently receiving anticoagulants, aspirin, and steroids compared to the non-SSI group, confirming the higher comorbid state of these patients. Finally, patients with SSI had significantly higher ASA score and were more frequently admitted to our hospital >1 day before undergoing ES.

Perioperative outcomes. The indications for ES as well as perioperative outcomes are shown in Table II. The primary wounds of patients who developed SSI were more commonly dirty or contaminated, compared to the non-SSI groups of patients ($p<0.0001$), whilst they also underwent more severe procedures compared to the latter ($p<0.0001$). Surgical procedures lasted more frequently longer than 90 minutes in patients who eventually developed SSI ($p<0.0001$), whilst these patients were more frequently transfused with >2 RBC units. The most common type of infection was superficial (60.5%), followed by deep incisional (21.7%), and organ/space infections (17.8%). The most commonly isolated pathogen was *E. Coli* (55.4%) followed by *Staphylococcus aureus* (40.1%), *Enterococcus spp.* (21.6%), *Pseudomonas*

aeruginosa (19.7%), *Klebsiella spp.* (15.4%), *coagulase-negative staphylococci* (12.7%), and *Acinetobacter spp.* (6.4%). Patients who developed SSI had significantly higher CD complications (>grade II) ($p<0.0001$), and were more frequently reoperated ($p<0.0001$) and readmitted ($p<0.0001$), compared to non-SSI patients. Patients not developing SSI had a median length of hospital stay of 5 days (IQR=5-6), while those who developed SSI had a median stay of 17 (IQR=14-23) days. The 30-day mortality rate of patients who presented SSIs was higher (23/157, 14.6%) compared to (47/681, 6.8%) that of patients without SSI ($p=0.002$).

Multivariable analysis. All variables associated with SSI in univariate analysis were entered into a multivariable logistic regression model in which the outcome was the presence of SSI. Ordinal variables were transformed into binary: ASA score 1 vs. 2-5, severity mild vs. moderate and severe, wound category clean vs. non-clean categories. Logistic regression analysis showed that non-clean wound class [odds ratio (OR)=3.312, 95% confidence intervals (CI)=1.266-8.663], $p=0.015$], ASA score ≥ 2 (OR=3.895, 95%CI=1.702-8.914, $p=0.001$), moderate or higher severity (OR=4.735, 95%CI=2.501-8.963, $p<0.0001$) and duration of surgery >90 min (OR=1.876, 95%CI=1.186-2.969, $p=0.007$) were independent risk factors for the occurrence of SSI (Figure 2).

Table II. Perioperative characteristics.

		Presence of SSI			p-Value
		Total n (%)	No n (%)	Yes n (%)	
Indication for surgery	GI bleeding	14 (1.7)	5 (0.7)	9 (5.7)	<0.0001
	Obstructive Ileus	189 (22.6)	147 (21.6)	42 (26.8)	
	Intra-abdominal infection*	564 (67.4)	465 (68.4)	99 (63.1)	
	Other	17 (2)	17 (2.5)	0 (0)	
	Trauma with bleeding	40 (4.8)	36 (5.3)	4 (2.5)	
	Trauma with peritonitis	5 (0.6)	5 (0.7)	0 (0)	
	Vascular ischemia	8 (1)	5 (0.7)	3 (1.9)	
Wound category	Clean	116 (13.9)	111 (16.3)	5 (3.2)	<0.0001
	Clean-contaminated	382 (45.6)	342 (50.3)	40 (25.5)	
	Contaminated	297 (35.5)	212 (31.2)	85 (54.1)	
	Dirty	42 (5)	15 (2.2)	27 (17.2)	
Severity	Mild	388 (46.4)	374 (55)	14 (8.9)	<0.0001
	Moderate	259 (30.9)	206 (30.2)	53 (33.8)	
	Severe	190 (22.7)	100 (14.7)	90 (57.3)	
Duration >90 min		370 (44.2)	253 (37.2)	117 (74.5)	<0.0001
Transfusion of >2 RBCU		73 (8.7)	43 (6.3)	30 (19.1)	<0.0001
Pre-operative antimicrobials	Prophylaxis	205 (24.5)	179 (26.3)	26 (16.6)	<0.0001
	Treatment for remote infection	25 (3)	11 (1.6)	14 (8.9)	
	Treatment for surgical infection	606 (72.4)	489 (71.9)	117 (74.5)	
	Treatment for surgical infection, Prophylaxis	1 (0.1)	1 (0.1)	0 (0)	
SSI classification	Deep incisional	34 (4.1)	0 (0)	34 (21.7)	<0.0001
	No SSI	680 (81.2)	680 (100)	0 (0)	
	Organ/space	28 (3.3)	0 (0)	28 (17.8)	
	Superficial incisional	95 (11.4)	0 (0)	95 (60.5)	
Clavien-Dindo Classification	Grade I	92 (11)	86 (12.6)	6 (3.8)	
	Grade II	133 (15.9)	72 (10.6)	61 (38.9)	
	Grade III	48 (5.7)	8 (1.2)	40 (25.5)	
	Grade IV	45 (5.4)	19 (2.8)	26 (16.6)	
	Grade V	69 (8.2)	46 (6.8)	23 (14.6)	
	None	450 (53.8)	449 (66)	1 (0.6)	
Reoperation		80 (9.6)	19 (2.8)	61 (38.9)	<0.0001
Readmission		45 (5.4)	18 (2.7)	27 (17.2)	<0.0001
30-day mortality		70 (8.4)	47 (6.9)	23 (14.6)	0.002

SSI: Surgical site infection; LOS: length of stay; GI: gastrointestinal; RBCU: red blood cell unit; *including appendicitis, cholecystitis & diverticulitis.

Discussion

Our study demonstrated that the incidence of SSI in patients who underwent ES in a single unit during a 5-year period was 18.7%, with *E. coli* being the most frequently isolated pathogen. Patients who developed SSI were, in accordance to what has been reported in the literature, older, had higher BMI, had more comorbidities, and underwent more severe surgical procedures, which lasted longer and had contaminated wounds more frequently compared to those who did not develop SSIs.

American Society of Anesthesiology performance status scoring was an independent predictor for the occurrence of SSI. Van Walraven *et al.* demonstrated a similar outcome in a study, which investigated risk factors of SSI using the

National Surgical Quality Improvement Program (11), while Mezemir *et al.* showed that patients with ASA class I had decreased likelihood of developing SSI (OR=0.3) compared to ASA class III patients (12). Khan *et al.* demonstrated a similarly strong association of ASA score and SSI rates in clean and clean-contaminated wounds of surgical patients (13). A large international prospective multicenter study, which included a total of 12,539 patients who underwent gastrointestinal surgery, 1,538 (12.2%) of whom developed SSI also demonstrated that ASA scores II and III were independently associated with SSI (14).

Operative time is a potentially modifiable risk factor, in contrast to other inherent or acquired risk factors such as chronic kidney dysfunction, pulmonary obstructive diseases,

OR: Odds ratio; CI: confidence intervals; ASA: American society of anesthesiology score; RBC: red blood cells; CHD: coronary heart disease; CHF: congestive heart failure; CKD: chronic kidney disease.

Figure 2. Multivariable logistic regression analysis for the presence of surgical site infections.

or diabetes mellitus. In addition, it is also influenced by several other factors such as surgical experience and operative planning. Our analysis confirmed the detrimental role of prolonged operative time in causing SSIs. Such outcome is in line with the findings of several prospective and retrospective studies throughout multiple surgical disciplines and different types of procedures (15-17). A recently published systematic review and meta-analysis demonstrated a statistically significant association between operative time and occurrence of SSI (16). Although the included studies covered a wide range of surgical procedures, based on their pooled analysis, the authors showed that the likelihood of developing SSI was twice as high among individuals who underwent surgical procedures with protracted operative times. Lastly, Li *et al.* also showed that surgical duration >120 minutes was independently associated with development of SSI in patients undergoing emergency abdominal surgery (18). Therefore, the adoption of measures such as improved operative planning, whenever possible, is of paramount importance.

Several inherent limitations to our study should be acknowledged. In particular, there was significant heterogeneity among the surgical procedures undertaken. Furthermore, there is no widely accepted international classification of severity of ES procedures, thus our classification may be subject to bias. Nevertheless, these criteria were predetermined and all patients were independently assessed by two surgeons to ensure adherence to our criteria. Moreover, our study evaluated only a certain number of risk factors, which however have been previously validated in the

literature, thus other potential risk factors, patient-, procedure- or perioperative care-associated, may remain elusive.

Identification of patients at risk for developing SSI is critical, because reduction of SSI can reduce the associated morbidity and mortality. Interdisciplinary cooperation between surgeons, anesthesiologists, infectious diseases specialists, operative theater and nursing staff is crucial for achieving the best possible outcomes in this high-risk group of patients. As patient safety is of utmost importance in the practice of surgery nowadays and as patients undergoing ES are more vulnerable and at higher risk of developing SSI, every surgical unit should audit their outcomes in order to pinpoint modifiable risk factors.

Conflicts of Interest

The Authors declare that they have no competing interests in relation to this study.

Authors' Contributions

Conception and design: AP, MS, CV, GLD; Acquisition of data: AP, CC, EM, DB; Analysis and interpretation: MS, NM, GT; Drafting the manuscript: AP, NM, SK, CC, DB; Revising the manuscript: NM, MS, GT, CV, GLD; Final approval for submission: all Authors.

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