

ORIGINAL ARTICLE

CONTENTS

Epidemiology of surgical site infection after abdominal surgery in Ukraine: results a multicenter study (2021-2023)

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ABSTRACT

Aim: To estimate the incidence, and to describe of antimicrobial resistance in responsible pathogens, and risk factors for surgical site infection (SSI) after abdominal surgery in Ukraine.

Materials and Methods: This were a multicenter, prospective cohort study performed in ten tertiary care hospitals from different regions of Ukraine. Definitions of SSIs after abdominal surgery were adapted from the European Centre for Disease Prevention and Control Surveillance of SSI. The incidence of SSI and predisposing risk factors were noted.

Results: Among 6,740 patients, 1,110 (16.5%) SSIs after abdominal surgery were observed. Of these cases, 45.8% superficial SSIs, 37.3% deep SSIs, and 16.9% was as organ/space SSIs. Of all SSI cases, 29.9% were detected after hospital discharge. The independent predictors of SSI were open surgical approach, emergency operation, and longed operation duration. The main pathogens of SSI were *Escherichia coli* (52%), followed by *Staphylococcus aureus* (9.1%), *Enterococcus* spp. (7.3%), *Pseudomonas aeruginosa* (7.1%), *Acinetobacter baumannii* (6.3%), *Stenotrophomonas maltophilia* (5.7%), *Serratia marcescens* (5.3%), and *Klebsiella pneumoniae* (5.1%). Meticillin resistance *S. aureus* (MRSA) and vancomycin resistance *Enterococcus* spp. (VRE) was found in 21.3% and 14.8% isolates, respectively.

Conclusions: This study found a high prevalence of SSI after abdominal surgery caused by multidrug-resistant organisms, varying widely depending on the bacterial species, and antimicrobial group in Ukraine. To minimise the risk of complications after abdominal surgery, it is essential to take several preventive measures before, during, and after the surgery.

KEY WORDS: abdominal surgery, open surgery, laparoscopic surgery, surgical site infection, risk factors, antimicrobial resistance, Ukraine

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INTRODUCTION

Surgical site infection (SSI) is a type of healthcare-associated infection (HAI) in which a wound infection occurs after an surgical procedure. SSIs are one of the most frequent complications in abdominal surgery and is associated with substantial morbidity and cost. SSIs have been shown to compose up to 20% of all healthcare-associated infections. At least 5% of patients undergoing a surgical procedure develop a surgical site infection [1]. The human and financial costs of treating SSIs are increasing [2]. According to the literature, SSIs command the highest economic toll, tallying an annual average cost of USD 3.3 billion [3].

To enhance patients' quality of life and reduce their total medical expenditures, it is vital to reduce the frequency of their SSI claims. This enduring issue is further compounded by the mounting challenge of antibiotic resistance, a surge in surgical interventions, and the presence of comorbidities among patients. Thus, a comprehensive exploration of all discernible risk factors, as well as proactive preventive and prophylactic strategies, becomes imperative [4].

Most SSIs are preventable. Measures can be taken in the pre-, intra- and postoperative phases of care to reduce the risk of infection [1]. However, the prevalence of multidrug-resistant microorganisms has reached alarming proportions [5, 6]. Many pathogens of SSIs may be implicated in these infections, especially multidrug-resistant organisms (MDROs), which have the ability to spread from patient to patient and to easily acquire antibiotic resistance [7-9]. Therefore, the identification of bacterial pathogens and their antibiotic susceptibility pattern is required for the successful treatment of SSI and curb antimicrobial resistance. Consequently, there is an acute need to investigate and scrutinize all potential therapeutic interventions to counter this burgeoning threat.

According to the literature, SSIs are more common in elderly patients, patients undergoing emergency surgeries, those with a longer preoperative hospital stay and longer surgical duration, and patients with a high American Society of Anesthesiologists (ASA) Index [10]. According to the literature, the ASA index has been recognized as a risk factor of SSI in many studies [11-13]. Consequently, there is an acute need to investigate and scrutinize all potential therapeutic interventions to counter these infections.

In Ukraine few studies have evaluated the relative importance of surgical site infection risk factors in terms of consistency in abdominal surgery. Currently, antimicrobial resistance in responsible pathogens, and risk factors for SSIs after abdominal surgery in Ukraine for developing the condition remain largely unknown. Therefore, should be conducted to study the risk factors, pathogens, complications, and outcomes of surgical site infections in depth.

AIM

The aim this study to estimate the prevalence and incidence, and to describe of antimicrobial resistance in responsible pathogens, and risk factors for SSIs after abdominal surgery in Ukraine.

MATERIALS AND METHODS

DESIGN, SETTING AND PATIENTS

This were a multicenter, prospective cohort study performed in ten tertiary care hospitals from different regions (Kyiv, Zhytomyr, Vinnytsia, Lviv, Dnipro, Kharkiv, Odesa) of Ukraine. This study was performed partly as a cross-sectional study to estimate occurrence of SSI, partly as a case-control study to look for factors associated with SSIs. This study was conducted over a period of 36 months, from January 2021 to December 2023. The study included adult patients (male and female) aged ≥ 18 years who underwent abdominal surgery who stayed for more than 48 h in hospitals. In this study all patients were local residents. This study including patients undergoing abdominal surgery (vascular, gastrointestinal, colorectal, appendectomy, gynecological, urological or plastic indications). Liver resection, pancreatectomy, organ transplantation, pregnant women, and patients with urinary tract infection, and gastrointestinal infections were excluded from this study. Patients who left the operating theatre with an open packed wound or with a vacuum-assisted dressing were also excluded.

DEFINITIONS

The surgical procedure records included in the study were of patients and performed in accordance with the National Healthcare Safety Network (NHSN). An NHSN procedure is defined as that performed in an operating room where the surgeon makes at least one incision that is closed before leaving the operating room [14]. An SSI associated with abdominal surgery was defined as an infection arising >48 h after operative procedure and not present or incubating on admission, unless the patient had been discharged from hospital within a defined period. An incident of SSI after abdominal surgery was defined by microbiologically confirmed European Centre for Disease Prevention and Control (ECDC) surveillance of surgical site infections and prevention indicators [15]. The surgical wound classification is categorized by the degree of gross contamination (clean, clean-contaminated, contaminated, and dirty) [16]. Physical status classification developed by the American Society of Anesthesiologists (ASA) [17].

DATA COLLECTION

We collected data from medical records, including demographic, clinical, microbiological data, and radiographic investigations, and invasive procedures, smoking status, body mass index, and comorbid. Operative variables included operation performed, duration of surgery, use of prophylactic antibiotics, wound contamination class, surgical approach (open v. laparoscopic), urgency of surgery and drain use. In this study, data were collected for two types of surgical approaches used for abdominal surgery: (1) open surgery and (2) laparoscopic or endoscopic surgery. SSI was classified as superficial (involving the skin and subcutaneous tissue only), deep (involving deeper soft tissues such as fascia and muscle layers) or organ space (involving any part of the anatomy that was opened or manipulated during surgery) [15]. We used the American Society of Anesthesiologists (ASA) classification for categorization of a patient's physiological status that can help predict operative risk [16].

MICROBIOLOGICAL ANALYSIS

In this study pathogens identification was performed with standard microbial methods. Antibiotic suscepti-

Table 1. Distribution of surgical site infection by wound class after open and laparoscopic surgery in Ukraine, 2021-2023

Wound class	All surgical procedures (n=6,740)	Type of surgical approaches				Total SSI (n=1,110)	
		Open (n=2,760)		Laparoscopic (n=3,980)			
		Number of procedure	SSI n (%)	Number of procedure	SSI n (%)	n	%
Clean	4112	1628	237(5.8)	2484	73(1.8)	310	7.5
Clean-contaminated	1689	662	346(20.5)	1027	97(5.7)	443	24.1
Contaminated	712	299	197(27.7)	413	79(11.1)	276	35.8
Dirty or infected wounds	227	171	69(30.4)	56	12(5.3)	81	32.6
Total	6740	2760	849(12.6)	3980	261(3.8)	1,110	16.5

Table 2. Demographic and preoperative characteristics of patients, who underwent abdominal surgeries in Ukraine (2021-2023)

Variable	SSI		p value
	No (n=5,640)	Yes (n=1,110)	
	n (%)	n (%)	
Age, yr, median	40 (31–52)	54 (43–61)	< 0.001
Gender			
Male	2,080 (36.9)	800 (73.0)	
Female	3,560 (63.1)	300 (27.0)	
Body mass index (median)	29 (25–36)	27 (25–31)	0.02
ASA score			< 0.001
1	2,860 (50.7)	320 (29.0)	
2	2,140 (37.9)	260 (24.0)	
3	620 (11.0)	360 (33.0)	
4	20 (0.4)	120 (11.0)	
5	0 (0.0)	40 (4.0)	
Diabetic	1,040 (18.4)	360 (33.0)	0.02
Smoking status			0.004
Current smoker	720 (12.8)	100 (9.0)	
Former smoker	160 (2.8)	100 (9.0)	
Nonsmoker	4,320 (76.6)	680 (62.0)	
Unknown	440 (7.8)	220 (20.0)	
Steroid use	220 (3.9)	80 (7.0)	0.3
Chemotherapy	120 (2.1)	80 (7.0)	0.04
Preoperative hemoglobin level, g/L, median	13 (12–14)	12 (11–14)	0.1
Preoperative albumin level, g/L, median	36 (33–38)	31 (26–35)	< 0.001
Benign disease	5,340 (94.7)	660 (60.0)	< 0.001

ASA, American Society of Anesthesiologists; SSI, surgical site infection

bility testing of isolates was determined according to the protocol of the European Committee on Antimicrobial Susceptibility Testing (EUCAST) (http://eucast.org). In this study an isolate is considered resistant to an antimicrobial agent when tested and interpreted as R in accordance with the EUCAST. When combining results for antimicrobial agents representing an antimicrobial group, the outcome is based on the most resistant result.

ETHICS

Approval for this study was obtained from the Institutional ethics committee, Shupyk National Healthcare University of Ukraine.

STATISTICAL ANALYSIS

In this study all clinical and microbiological data were recorded in the Microsoft excel sheets. Statisti-

Table 3. Operative and postoperative characteristics of patients, who underwent abdominal surgeries in Ukraine (2021-2023)

Variable	SSI		p value
	No	Yes	
	n (%)	n (%)	
Type of operative procedure			<0.001
Laparoscopic gynecologic surgery	2120 (37.6)	100 (9.0)	
Hernia repair	1220 (21.6)	120 (11.0)	
Gastric sleeve/bypass	1120 (19.8)	0 (0)	
Appendectomy	280 (5.0)	80 (7.0)	
Laparotomy	220 (3.9)	480 (44.0)	
Colectomy/abdominoperineal resection	120 (2.1)	100 (9.0)	
Cholecystectomy	80 (1.4)	160 (14.0)	
Other	480 (8.5)	60 (5.0)	
Wound class			<0.001
Clean	1,060 (18.8)	60 (5.0)	
Clean-contaminated	4,380 (77.6)	760 (69.0)	
Contaminated/dirty	200 (3.5)	280 (25.0)	
Urgency			<0.001
Emergent	1000 (17.7)	600 (54.0)	
Elective	4,640 (82.3)	500 (45.0)	
Approach			<0.001
Laparoscopic	3,840 (68.1)	140 (13.0)	
Laparoscopic converted to open	60 (1.1)	60 (5.0)	
Open midline	700 (12.4)	700 (64.0)	
Open nonmidline	1,040 (18.4)	200 (18.0)	
Length of operation, min, median	83 (110–155)	184 (113–292)	<0.001
Drains	1,560 (27.6)	540 (49.0)	0.007
Blood transfusion	280 (5.0)	440 (40.0)	<0.001
Postoperative stay, d, median	2 (1–3)	14 (6–25)	<0.001
Intensive care unit admission	440 (7.8)	560 (51.0)	<0.001
Death within 30 d	40 (0.7)	40 (4.0)	0.07

SSI, surgical site infection.

cal analysis was carried out using a computer based statistical analysis program Microsoft Excel 2019 and statistical packages, SPSS version16 (IBM Corp, Armonk, NY, USA). Frequencies and percentages were calculated for categorical variables. Mean and standard deviation (SD) were calculated for continuous variables. The overall incidence of SSI was calculated and correlated with predisposing risk factors. We used the Pearson and Wilcoxon univariable tests to guide the multivariable models for discrete and continuous variables, respectively. We used multivariable logistic regression models to identify preoperative and operative variables independently associated with SSI. The results are presented using tables. P-value ≤0.05 was taken as significant.

RESULTS

INCIDENCE OF SSI

A total of 6,740 patients, who underwent abdominal surgeries from January 2021 to December 2023 in Ukrainian tertiary care hospitals, were including in this cohort study. Among these patients, 1,110 (16.5%, 95% CI: 16.2-16.6) after surgery procedures were found to have SSIs. Of these cases, 45.8% superficial SSIs, 37.3% deep SSIs, and 16.9% was as organ/space SSIs. Of the total SSI, 29.9% were detected after hospital discharge. SSIs after abdominal surgery were the most common in contaminated wounds (35.8%) followed by dirty (32.6%), clean-contaminated (24.1%), and clean wounds (7.5%) (Table 1). However, the results were not

Table 4. Multivariate logistic regression analysis of factors associated with surgical site infection after abdominal surgery in Ukraine, 2021-2023

Risk factor	OR (95% CI)
Male sex	2.6 (1.02–6.6)
Length of operation (86 min v. 181 min [25th v. 75th percentile])	2.1 (1.23–3.6)
Urgency (emergent v. elective)	4.7 (1.58–14.4)
Approach (open vs. laparoscopic)	6.5 (2.16–19.6)
Age	1.09 (0.57–2.1)
Body mass index	1.20 (0.68–2.1)
Smoking	0.55 (0.15–2.1)
Diabetic	1.52 (0.52–4.5)
ASA score	1.27 (0.75–2.2)
Blood transfusion	0.93 (0.28–3.2)
Preoperative albumin level	0.91 (0.63–1.3)
Malignant disease	2.35 (0.65–8.5)
Preoperative antibiotic	2.32 (0.71–7.6)
Wound type (contaminated/dirty vs. clean-contaminated)	1.59 (0.48–5.3)

ASA, American Society of Anesthesiologists; CI, confidence interval; OR, odds ratio.

statistically significant. Open and laparoscopic types of surgical approaches for abdominal surgery were, 40.9% (2,760/6,740) and 59.1% (3980/6740), respectively. The incidence of SSI depended on the microbial contamination of wounds and was discrepant between open and laparoscopic types of surgical approaches surgeries. Incidence rate of SSIs were, 12.6% (open surgery) and 3.8% (laparoscopic surgery), respectively. The distribution of SSI by wound classes after open and laparoscopic surgeries is presented in Table 1.

Of the 6,740 abdominal surgical procedures, 2,880 (42.7%) were performed on males and 3,860 (57.3%) on females. The mean age of the study patients was 43.7 ± 5.9 years. In this study SSI was more common in male gender than in female (14.5% vs. 4.5%). The mean body mass index was 31±5.7. In this study 20.8% patients, who underwent abdominal surgeries were diabetic, and 12.2% were current smokers, and 82.8% had an ASA score less than 3. Demographic and preoperative characteristics of patients, who underwent abdominal surgeries are presented in Table 2.

The mean operative time in surgical procedures was 145.2 minutes. Of all surgical procedures, 59.1% were performed laparoscopically. Most patients (76.3%) underwent elective abdominal surgery. In this study, the most frequent type of abdominal surgery was laparoscopic gynecologic procedure (32.9%), followed by hernia repair (19.9%) and gastrointestinal surgery (16.6%). Operative and postoperative characteristics of patients, who underwent abdominal surgeries are presented in Table 3.

The highest SSI rate among patients, who underwent abdominal surgeries was detected in laparotomy procedures: In our study, postoperative SSI developed in 69% of the 700 patients in this group. The incidence rate of SSI after abdominal surgery was 12.6% following open operations, compared to 3.8% following laparoscopic procedures ($p < 0.001$). Postoperative SSI developed in 61% of the 720 patients with malignant disease, compared to 11.0% of the 6,000 patients with benign disease ($p < 0.001$). In this study, the 30-day mortality rate was 0.7% among non-infected patients and 3.6% among infected patients.

RISK FACTORS

In present study, patients with postoperative SSI were older than noninfected patients (73% vs. 36.9%, respectively, $p < 0.001$). Almost half (47.2%) of all patients with SSI had an ASA physical status classification score >2. The most patients (54.1%) of patients with postoperative SSI underwent emergency surgery, and most (87%) had an open surgical approach. Use of steroids, preoperative hemoglobin level, prophylactic antibiotic therapy and death within 30 days were not associated with SSI on univariable analysis. In this study, SSI after abdominal surgery was more likely to develop in patients who underwent emergent operations than those who underwent elective procedures. Surgical procedure duration (operation time) also are predictors of SSI, with odds ratios (OR) of 2.1 (95% CI 1.23–3.6). We found that length of hospital stay was predicted to increase with open versus laparoscopic procedures, long operative times. Multivariate logistic regression analysis of factors associated with SSI after abdominal surgery is presented in Table 4.

RESPONSIBLE PATHOGENS AND ANTIMICROBIAL RESISTANCE

In this study microbiological cultures were available for all patients with SSI. In total, 1,487 pathogens (Gram-negative and -positive bacteria) were isolated from 1,110 patients with postoperative SSI. The most commonly implicated pathogens were *Escherichia coli* (52%), followed *Staphylococcus aureus* (9.1%), *Enterococcus* spp. (7.3%), *Pseudomonas aeruginosa* (7.1%), *Acinetobacter baumannii* (6.3%), *Stenotrophomonas maltophilia* (5.7%), *Serratia marcescens* (5.3%), and *Klebsiella pneumoniae* (5.1%). Among responsible pathogens, meticillin resistance *S. aureus* (MRSA) and vancomycin resistance *Enterococcus* spp. (VRE) was found in 21.3% and 14.8% isolates, respectively. Resistance to third-generation cephalosporins was detected in *K. pneumoniae* (61.2%) and *E. coli* (36.1%). Carbapenem resistance was found in 22.1% of all Enterobacterales In present study, all of our patients were given the antibiotic prophylaxis according to our standard hospital protocols. However, only 24.5% of responsible pathogens of SSIs were sensitive to the prophylactic antibiotic given preoperatively.

DISCUSSION

The results presented in this study are based on multicentre, prospective surveillance data. The primary objectives of this study were to describe the incidence and risk factors associated with SSI in patients undergoing abdominal surgery. The secondary objectives were to study the microbiological pattern of SSI in our population and their antibiotic resistance in responsible pathogens in Ukrainian tertiary care hospitals. We found a high incidence of SSI cases caused by MDROs. These pathogens varying depending on the bacterial species, and antimicrobial group in Ukraine. This study expands upon the previous reports and is the first study to publish frequent pathogens and/or characterization of the antimicrobial resistance of responsible pathogens of SSI after abdominal surgery in Ukraine [5, 6].

According to the literature, the incidence of SSI after abdominal surgery ranges from 1.2 to 7.5% [18-20]. However, our rate of SSI is slightly higher than those reported in these studies. In our study, SSI developed in 16.5% undergoing abdominal surgery, compatible with reported in the literature [21, 22]. A higher incidence rate (21.8% and 24.2%) of SSI after abdominal surgery was found in too studies [23, 24].

In present study, multivariable analysis identified open surgical approach, emergency operation, length of the operation and male sex as independent predictors of SSI after abdominal surgery. According to the literature, open surgical approach and emergency surgery were documented as risk factors for SSI in previous reports [19-21, 25]. We found that patients who had open surgery were 6.5 times more likely to get SSI than those who had laparoscopic surgery. Emergency surgery increased the risk of SSI fivefold compared to elective surgery. The duration of surgery procedure was an independent predictor for SSI. A patient who had an operation lasting longer than the 75th percentile (> 3 h in our cohort) had double the risk of SSI in contrast to an operation lasting less than the 25th percentile (86 min). This finding is in keeping with previous study [22].

According to the literature, longer operative time reflects the complexity of the surgery. It would also increase the wound susceptibility to infection by increasing the exposure to potential contamination and decreasing the tissue concentration of antibiotic [26].

The ASA score and wound class were not significant predictors of SSI after abdominal surgery in the multivariable model in our study. Certain other known risk factors for SSI such as body mass index, diabetes and smoking were also not found to be statistically significant.

In this study, the commonest organisms isolated from patients with SSI after abdominal surgery were gram-negative bacteria. The most commonly implicated responsible pathogens of SSIs were *E. coli*, followed *S. aureus, Enterococcus* spp., *P. aeruginosa, A. baumannii, S. maltophilia, S. marcescens,* and *K. pneumoniae.* The most authors reported findings similar to ours, with more common gram-negative bacteria isolated from the infected abdominal wounds [4-6]. We also found that most of the pathogens were multidrug-resistant organisms to the commonly prescribed prophylactic antibiotics. This might explain why we found a high rate of deep SSI after abdominal surgery. Therefore, further consideration regarding the selection of appropriate prophylactic antibiotics will be needed, especially in patients at high risk.

Knowing the risk factors can help us in earlier risk stratification, prevention as well as diagnosis of the SSI after abdominal surgery. The relative importance of these causes of SSI after abdominal surgery may differ from country to country. Understanding the magnitude of SSI after abdominal surgery is critical for interventions, for monitoring access to quality medical care, and for mitigating risk factors for and consequences of SSI in worldwide.

STRENGTH AND LIMITATIONS

This work may be considered the first of more-detailed epidemiological studies of SSI after abdominal surgery in Ukraine. The primary objective of this study is to meticulously assess the origins and risk elements intertwined with surgical site infections across a diverse spectrum of surgical procedures. As the medical landscape continues to evolve, this critical analysis seeks to provide a nuanced understanding of the multi-faceted factors contributing to surgical site infections, with the overarching aim of facilitating more effective management and mitigation strategies. By exploring these dimensions comprehensively, we endeavor to enhance patient safety and the quality of surgical care in this era of evolving healthcare challenges. No other reports in the literature based on nationwide data collection describe the proportion of SSI after abdominal surgery. This study was some limitations. Limitations include conducting the study only in 29.2% regions (7 out of 24) of Ukraine. Therefore, the results may not be representative of other regions of Ukraine.

CONCLUSIONS

This study found a high incidence rate of SSI after abdominal surgery caused by MDROs, varying widely depending on the bacterial species, and antimicrobial group in Ukraine. To minimise the risk of complications after abdominal surgery, it is essential to take several preventive measures before, during, and after the surgery. Preoperative skin preparation should be conducted and, whenever possible, laparoscope or robot-assisted surgery. Duration of surgery should be as short as possible while maintaining surgery quality and improving patient care. These steps can help ensure a safe and successful procedure, as well as a smooth recovery process.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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