Risk Stratification for Organ/Space Surgical Site Infection in Digestive System Cancer: A Prospective Cohort Study

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Abstract

Background: Organ/space surgical site infection (organ/space SSI) is one of the serious postoperative complications, closely related to a poor prognosis. Few studies have attempted to design risk scoring systems for patients with digestive system cancer. This study aimed to develop a simple and practical risk stratification score for these patients to identify a priori risk of organ/space SSI.

Methods: This prospective cohort study was based on two prospective studies (NCT02756910, ChiCTR-IPR-17011099), including patients undergoing elective radical resection of digestive system cancer. Logistic regression analysis was used to identify the determinant variables. The incidence of organ/space SSI stratified over perioperative factors was compared and compounded in a risk score.

Results: Among the 839 patients, 51 developed organ/space SSI (6.1%) within 30 days after surgery. Patients undergoing gastrectomy (OR=8.466, 95% CI: 2.728-26.270, P<0.001), colorectal resection (OR=11.180, 95% CI: 3.921-31.881, P<0.001) and pancreatoduodenectomy (OR=9.054, 95% CI: 3.329-24.624, P<0.001) with an anaesthesia time > 4 h (OR=2.335, 95% CI: 1.035-5.271, P=0.041) and prolonged intensive care unit (ICU) stays > 24 h (OR=4.243, 95% CI: 1.715-10.498, P=0.002) had a significantly higher risk of organ/space SSI. These risk factors (procedure type, anaesthesia time, prolonged ICU stays) were also associated with an increase in organ/space SSI rates based on a compounded score (P<0.001). Comparisons with the overall population revealed that patients with 0 or 1 risk factor (n=602) had an organ/space SSI rate of 2.8% (RR=0.197, 95% CI: 0.112-0.345), those with 2 risk factors (n=223) had an organ/space SSI rate of 13.0% (RR=3.641; 95% CI: 2.138-6.202), and those with 3 risk factors (n=14) had an organ/space SSI rate of 35.7% (RR=6.405, 95% CI: 3.005-13.653).

Conclusion: The risk stratification score in this study provides a simple and practical tool to stratify patients with digestive system cancer so that the relative risk of developing postoperative organ/space SSIs can be predicted.

Trial Registration: This study was based on one randomized controlled trial (NCT02756910) registered at ClinicalTrials.gov on April 29, 2016 and one prospective cohort study (ChiCTR-IPR-17011099) registered at the Chinese Clinical Trial Registry on April 9, 2017.

Introduction

Surgical site infection (SSI) is one of the most common complications in surgical patients and is closely related to unscheduled reoperation, unscheduled readmission, permanent disability and even death. The incidence of SSI in high-risk surgery can reach 10–20%[1−3]. In the United States, SSI causes more than 90,000 readmissions, extends the average length of hospital stay by 9.7 days, and increases medical costs by 700 million dollars each year[4]. SSI can be classified as superficial SSI, deep SSI and organ/space SSI[1]. Preventive methods such as hand hygiene, skin disinfection, perioperative prophylactic antibiotics, enhanced nutrition and the popularity of minimally invasive surgery[5−7] can effectively prevent approximately 50% of superficial SSIs[5]. However, the incidence of organ/space SSI has remained unchanged and has gradually become the major type of SSI[4].

Surgery for digestive system cancer is not an exception. Previous research has mainly focused on superficial SSI, with the primary goal of implementing increasingly complex and diverse protocols and preventive bundles to prevent wound infection[8]. However, only a few studies have investigated the risk factors for organ/space SSI in patients with digestive system cancer[9–12]. This study intends to develop a simple and practical risk stratification score for patients with digestive system cancer to identify a priori risks of organ/space SSI.

Methods

Study population

This single-centre prospective cohort study was based on one randomized controlled trial and one prospective cohort study (NCT02756910, ChiCTR-IPR-17011099), including patients undergoing elective radical resection of digestive system cancer in Peking Union Medical College Hospital (PUMCH) from February 1, 2016, to January 31, 2019. Patients who had a body mass index (BMI) ≥ 30 kg/m^2, suffered severe infection or had an axillary temperature > 37.3°C before surgery, or were treated with glucocorticoids more than 6 months before surgery were excluded from this study.

Data collection

A range of baseline characteristics were reviewed from the clinical databases of the 2 prospective studies above and the hospital information system in PUMCH to assess whether they were significantly associated with the incidence of organ/space SSI, including demographics, preoperative variables and operative variables. The thresholds for certain variables, such as age, American Society of Anesthesiologists (ASA) classification, intraoperative blood loss, intraoperative red blood cell transfusion, anaesthesia time and final core temperature, were selected according to the population median and previous research.

Outcomes

The primary outcome was organ/space SSI within 30 days after surgery. Organ/space SSI involves any part of the body (excluding the skin incision, fascia, or muscle layers) that is opened or manipulated during the operative procedure. In this study, patients who had at least 1 of the following were diagnosed with an organ/space SSI: a. purulent drainage from a drain placed through a surgical incision into the organ/space; b. organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space; c. an abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination; and d. diagnosis of an organ/space SSI by a surgeon or attending physician[1]. The diagnosis of organ/space SSI was first assessed by researchers. Suspected cases were confirmed after discussion with an expert panel composed of specialists in anaesthesiology, critical care medicine, surgery, and infectious diseases.

Secondary outcomes included superficial SSI within 30 days after surgery, unscheduled reoperation, unscheduled readmission and length of hospital stay. Unscheduled reoperation was defined as the need for unplanned second surgery for various reasons within 30 days after surgery. Unscheduled readmission was defined as an emergency admission after discharge for various reasons within 30 days after surgery.

Statistical analysis

All statistical analyses were performed using SPSS 25.0. Descriptive statistics illustrated the frequency of specific baseline characteristics; this was expressed in outcome percentages for dichotomous variables and means or medians with standard deviations and interquartile rates, respectively, for continuous variables. Binary logistic regression analysis was used in both the univariate and multivariate analyses. A 2-tailed *P* value of 0.05 or fewer was considered the threshold for statistical significance. Variable selection in multivariate analysis was based on the clinical experience, sample characteristics, the results of the univariate analysis, previous research and multicollinearity diagnosis. The correlation coefficient, variance inflation factor (VIF) and characteristic root system were chosen for multicollinearity diagnosis. Subsequently, to validate a stacked score based on the number of risk factors present, the rates of SSI and the relative risks of its occurrence compared with the remaining population were also assessed based on the number of high-risk baseline characteristics present. Associations between the number of high-risk characteristics and SSI rates were measured using Fisher's exact test.

Results

Baseline characteristics

A total of 839 patients receiving elective radical resection of digestive system cancer were included in this study, comprising 575 males (68.5%) and 264 females (31.5%). The average age was 62.9 ± 10.8 years, and 48.5% were ≥ 65 years. A total of 120 (14.3%) patients underwent oesophagectomy, 83 (9.9%) underwent gastrectomy, 236 (28.1%) underwent colorectal resection, 133 (5.9%) underwent pancreatoduodenectomy, 249 (29.7%) underwent hepatic resection and 26 (3.1%) underwent other procedure types (cholecystectomy, choledochotomy and distal pancreatectomy). Several patients received different procedure types at the same time. Among the 839 patients, 51 (6.1%) developed organ/space SSI within 30 days after surgery, almost all of whom had intra-abdominal infection, 17 (2.0%) developed superficial SSI, 19 (2.3%) underwent unscheduled reoperation, and 13 (1.5%) experienced unscheduled readmission. The median length of hospital stay was 14 days. Details are shown in Tables 1 and 2.

Table 1
Outcome Characteristics

	Overall (n = 839)
Primary outcome	
Organ/space SSI	51 (6.1)
Intra-abdominal infection	49 (5.8)
Other organ/space SSI	4 (0.5)
Secondary outcomes	
Superficial SSI	17 (2.0)
Unscheduled reoperation	19 (2.3)
Unscheduled readmission	13 (1.5)
Length of hospital stay (d)	14 (12, 19)

Notes: Results presented as median (P_{25}, P_{75}) or n (%).

Abbreviations: SSI surgical site infection.

Risk factors for SSI

Table 2 also lists the univariate analysis of all the risk factors for organ/space SSI. We selected 5 procedure types, intraoperative blood loss > 500 ml, anaesthesia time > 4 h and prolonged intensive care unit (ICU) stay in multivariate analysis, based on the clinical experience, sample characteristics, the results of univariate analysis, previous research and multicollinearity diagnosis. According to the results of logistic regression analysis, gastrectomy (OR = 8.466, 95% CI: 2.728–26.270, $P < 0.001$), colorectal resection (OR = 11.180, 95% CI: 3.921–31.881, $P < 0.001$), pancreatoduodenectomy (OR = 9.054, 95% CI: 3.329–24.624, $P < 0.001$), anaesthesia time > 4 h (OR = 2.335, 95% CI: 1.035–5.271, $P = 0.041$) and prolonged intensive care unit (ICU) stays (OR = 4.243, 95% CI: 1.715–10.498, $P = 0.002$) were significantly associated with a higher risk of organ/space SSI (Table 3).

Table 2
Baseline Characteristics and Risk Factors for Organ/Space Surgical Site Infection (Univariate Analysis)

Risk Factor	**Overall (n = 839)**	**Univariate analysis**	
		OR (95% CI)	**P value**
Sex			
Male	575 (68.5)	0.760 (0.422–1.367)	0.360
Female	264 (31.5)		
Age (y)	62.9 ± 10.8		
< 65	432 (51.5)		
≥ 65	407 (48.5)	1.208 (0.685–2.130)	0.514
BMI (kg/m^2)	23.5 ± 3.1	1.054 (0.963–1.154)	0.255
Current smoking	255 (30.4)	1.155 (0.633–2.109)	0.638
ASA classification			
□-□	709 (84.5)		
≥ □	130 (15.5)	1.016 (0.466–2.213)	0.969
Charlson comorbidity index			
0	0		
1	0		
2	80 (9.5)	/	0.983
3	137 (16.3)	0.808 (0.248–2.635)	0.723
4	282 (33.6)	0.962 (0.344–2.694)	0.942
5	255 (30.4)	1.004 (0.356–2.833)	0.994
6	85 (10.1)	1.139 (0.334–3.890)	0.835

Notes: Results presented as`x ± s or median (P_{25}, P_{75}) or n (%).

Abbreviations: OR odds ratio, CI confidence interval, BMI body mass index, COPD chronic obstructive pulmonary disease, ASA American Society of Anesthesiologists, PN parental nutrition, Hb haemoglobin, Hct haematocrit, Alb albumin, SCr serum creatinine, Glu glucose, RBC red blood cell, ICU intensive care unit.

* Cases in which a laparoscopic procedure was converted to an open procedure were considered open procedures.

** Other procedure types included cholecystectomy, choledochotomy and distal pancreatectomy.

Risk Factor	Overall (n = 839)	Univariate analysis	
		OR (95% CI)	P value
Comorbidities			
Hypertension	365 (43.5)	1.165 (0.661–2.055)	0.598
Diabetes	183 (21.8)	1.386 (0.732–2.623)	0.316
Coronary heart disease	97 (11.6)	0.822 (0.319–2.122)	0.686
COPD	14 (1.7)	0.947 (0.122–7.356)	0.958
Neoadjuvant chemotherapy	122 (14.5)	0.351 (0.108–1.146)	0.083
Neoadjuvant radiotherapy	57 (6.8)	0.544 (0.129–2.296)	0.407
PN	283 (33.7)	2.338(1.323–4.133)	0.003
Laboratory evaluation			
Hb (g/l)	133.0 ± 18.4	0.985 (0.970–0.999)	0.043
Hct (%)	39.6 ± 4.8	0.937 (0.885–0.991)	0.024
Alb (g/dl)	41.4 ± 4.2	0.948 (0.884–1.015)	0.127
SCr (μmol/l)	74.9 ± 30.8	0.996 (0.983–1.010)	0.589
Glu (mmol/l)	5.8 ± 1.7	0.992 (0.835–1.178)	0.924
Procedure approach			
Open*	468 (55.8)		
Laparoscopic	371 (44.2)	1.335 (0.758–2.354)	0.317
Procedure type			
Oesophagectomy	120 (14.3)	0.112 (0.015–0.822)	0.031
Gastrectomy	83 (9.9)	1.769 (0.802–3.902)	0.158
Colorectal resection	236 (28.1)	1.562 (0.867–2.815)	0.137

Notes: Results presented as`x ± s or median (P_{25}, P_{75}) or n (%).

Abbreviations: OR odds ratio, CI confidence interval, BMI body mass index, COPD chronic obstructive pulmonary disease, ASA American Society of Anesthesiologists, PN parental nutrition, Hb haemoglobin, Hct haematocrit, Alb albumin, SCr serum creatinine, Glu glucose, RBC red blood cell, ICU intensive care unit.

* Cases in which a laparoscopic procedure was converted to an open procedure were considered open procedures.

** Other procedure types included cholecystectomy, choledochotomy and distal pancreatectomy.

Risk Factor	Overall (n = 839)	Univariate analysis	
		OR (95% CI)	P value
Pancreatoduodenectomy	133 (15.9)	3.510 (1.924–6.405)	< 0.001
Hepatic resection	249 (29.7)	0.299 (0.126–0.710)	0.006
Others**	26 (3.1)	0.610 (0.081–4.598)	0.632
Intraoperative blood loss	152 (50, 390)		
≤ 500 ml	723 (86.2)		
> 500 ml	116 (13.8)	2.545 (1.330–4.871)	0.005
Intraoperative RBC transfusion	163 (19.4)		
≤ 2 U	75 (8.9)		
> 2 U	88 (10.5)	1.923 (0.903–4.098)	0.090
Anaesthesia time (h)	4 (3.1, 5.4)		
≤ 4 h	419 (49.9)		
> 4 h	420 (50.1)	2.083 (1.145–3.790)	0.016
Final core temperature (°C)	36.3 ± 0.8		
< 36.0	330 (39.3)	0.757 (0.416–1.379)	0.363
≥ 36.0	509 (60.7)		
Overnight ICU stay (≤ 24 h)	40 (4.8)		
Prolonged ICU stay (> 24 h)	166 (19.8)	4.395 (1.910-10.115)	< 0.001

Notes: Results presented as`x ± s or median (P_{25}, P_{75}) or n (%).

Abbreviations: OR odds ratio, CI confidence interval, BMI body mass index, COPD chronic obstructive pulmonary disease, ASA American Society of Anesthesiologists, PN parental nutrition, Hb haemoglobin, Hct haematocrit, Alb albumin, SCr serum creatinine, Glu glucose, RBC red blood cell, ICU intensive care unit.

* Cases in which a laparoscopic procedure was converted to an open procedure were considered open procedures.

** Other procedure types included cholecystectomy, choledochotomy and distal pancreatectomy.

Table 3
Risk Factors for Organ/Space Surgical Site Infection (Multivariate Analysis)

Risk Factor	Multivariate analysis	
	OR (95% CI)	P value
Procedure type		
Oesophagectomy		
Gastrectomy	8.466 (2.728–26.270)	< 0.001
Colorectal resection	11.180 (3.921–31.881)	< 0.001
Pancreatoduodenectomy	9.054 (3.329–24.624)	< 0.001
Hepatic resection		
Intraoperative blood loss		
> 500 ml		
Anaesthesia time (h)		
> 4 h	2.335 (1.035–5.271)	0.041
Prolonged ICU stay	4.243 (1.715–10.498)	0.002
Abbreviations: OR odds ratio, CI confidence interval, ICU intensive care unit.		

Risk score of SSI

The results showed that 3 risk factors (procedure type, anaesthesia time > 4 h, prolonged ICU stays) can be used to stratify patients according to risk. The number of risk factors was significantly associated with an increase in the rate of organ/space SSI ($P < 0.001$). Compared with the overall population, who had an organ/space SSI rate of 6.1%, patients with 1 or fewer risk factors had a lower risk, while patients with 2 or more risk factors had a significantly higher risk. Patients with 0 or 1 risk factor (n = 602) had an organ/space SSI rate of 2.8%, equivalent to a relative risk (RR) of 0.197 (95% CI: 0.112–0.345), whereas patients with 2 risk factors (n = 223) had an organ/space SSI rate of 13.0% (RR = 3.641; 95% CI: 2.138–6.202). Finally, 14 patients with all 3 risk factors (n = 14) had an organ/space SSI rate of 35.7% (RR = 6.405; 95% CI: 3.005–13.653). The association of the number of risk factors with the risk of organ/space SSI is shown in Table 4.

Table 4
Association of the Number of Risk Factors with the Risk of Organ/Space Surgical Site Infection

Risk factors	0–1	Overall	2	3	*P* value
No. of patients	602	839	223	14	NA
Rate of SSI (%)	2.8	6.1	13.0	35.7	< 0.001
Relative risk	0.197	1	3.641	6.405	NA

Abbreviations: NA: not applicable; SSI: surgical site infection.

Discussion

Organ/space SSI is one of the most serious postoperative complications and is closely related to poor prognosis. Although the incidence of superficial SSI has decreased as a result of many preventive methods, the incidence of organ/space SSI is still high in patients undergoing surgical treatment. In this study, the rate of postoperative organ/space SSI reached 6.1%, while the rate of superficial SSI was only 2.0%.

Our study focused on organ/space SSI after surgery, which has become the major type of postoperative SSI with the development of endoscopic surgery but has always been neglected. We analysed a broad range of preoperative and operative factors to determine whether the compounding effect of these factors is associated with the incidence of organ/space SSI. The risk score identifies patients for whom frequent monitoring and more aggressive preventive efforts would be the most useful. The analysis of risk factors demonstrated that certain procedure types (gastrectomy, colorectal resection and pancreatoduodenectomy), anaesthesia time and prolonged ICU stays were associated with the risk of organ/space SSI. Due to the prevalence of bloodless surgery, intraoperative blood loss has become less associated with postoperative SSI. When these factors were included in the risk scoring system, patients with 1 risk factor or fewer were found to be 5 times less likely than the remainder of the population to develop organ/space SSI. Conversely, patients with all 3 risk factors were more than 6 times more likely to develop organ/space SSI. This method provides an easy and practical way to stratify risk and selectively focus preventive efforts and postoperative methods on those patients who have significantly greater risk. Using this approach, higher-risk patients could be selected to benefit from additional preventive measures and more frequent monitoring of the organ/space surgical site to ascertain a timely response when the first symptoms of infection appear. There are some similar risk stratification methods for superficial SSI in digestive system cancer, but only a few are available for organ/space SSI[13]. Compared with similar risk scores in previous research, our study focused on postoperative organ/space SSI, which has become the major type of SSI after surgery. Another advantage of our study was the inclusion of various types of cancer of the digestive organs.

Previous studies have reported that diabetes or perioperative hyperglycaemia, obesity, low preoperative albumin and immunosuppressive status were associated with a high risk of SSI[4,6,14–17], but in our study, they did not show a significant correlation with postoperative organ/space SSI. On the one hand, diabetes and obesity may be more related to superficial SSI than organ/space SSI. On the other hand, the population included in our study came from two prospective studies, leading to consistency in terms of demographics, comorbidities, preoperative nutritional status and so on. According to the exclusion criteria, patients with a BMI ≥ 30 kg/m^2 and those who were treated with glucocorticoids more than 6 months before surgery were not included in our study, which eliminated the potential influence of obesity and immunosuppressive status. In addition, patients undergoing elective surgery in PUMCH usually receive comprehensive consultation and treatment before surgery as a result of a normal range of preoperative Glu and Alb levels for most patients in our study. A final core temperature < 36°C also did not have a significant association with organ/space SSI, which was in accordance with previous research[18, 19].

This study also had several limitations. First, the sample size in this study was not large enough. Some potential risk factors for organ/space SSI may be neglected because of the limited population. Patients for each procedure type were not sufficient to perform subgroup analysis. Second, this was a single-centre study based on two prospective studies. Thus, some results may not be representative or applicable to other centres.

Conclusions

The risk score developed in this study provides a simple and practical tool to stratify patients with digestive system cancer to predict the relative risk of developing postoperative organ/space SSI based on operative factors. It offers a method to focus preventive efforts on high-risk patients using readily available characteristics that do not require any additional effort to verify. Using this score, more targeted efforts can be implemented to prevent or detect organ/space SSI in a timely manner.

Abbreviations

SSI: Surgical site infection; PUMCH: Peking Union Medical College Hospital; BMI: Body mass index; ASA classification: American Society of Anesthesiologists classification; VIF: Variance inflation factor; ICU: Intensive care unit; RR: Relative risk; OR: Odds ratio; CI: Confidence interval.

Declarations

Ethics approval and consent to participate

The study was based on two prospective studies (NCT02756910, ChiCTR-IPR-17011099), both approved by the ethics committee of Peking Union Medical College Hospital (HS-1019, HS-1121). Written informed consent was obtained from all subjects involved. All methods were carried out in accordance with the institutional guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated during and analyzed during the current study are not available because they came from the hospital information system in our institution which was not open accessed to the public. Furthermore, according to our limited knowledge, there has not been relevant national database in China. However, the datasets in this study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Chen Sun, Lijian Pei, and Yuguang Huang contributed to the study design. Chen Sun, Lijian Pei and Hui Gao contributed to data acquisition. Chen Sun, Lijian Pei and Yuelun Zhang contributed to the data analysis. Chen Sun and Lijian Pei wrote the report. All authors reviewed the report and approved it for publication.

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References

1. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. *Am J Infect Control*. 2008;36(5):309–332. doi:10.1016/j.ajic.2008.03.002.
2. Ban KA, Minei JP, Laronga C, et al. American College of Surgeons and Surgical Infection Society: Surgical Site Infection Guidelines, 2016 Update. *J Am Coll Surg*. 2017;224(1):59–74. doi:10.1016/j.jamcollsurg.2016.10.029.
3. Legesse Laloto T, Hiko Gemeda D, Abdella SH. Incidence and predictors of surgical site infection in Ethiopia: prospective cohort. *BMC Infect Dis*. 2017;17(1):119. doi:10.1186/s12879-016-2167-x.
4. Babazade R, Yilmaz HO, Zimmerman NM, et al. Association Between Intraoperative Low Blood Pressure and Development of Surgical Site Infection After Colorectal Surgery: A Retrospective Cohort Study. *Ann Surg*. 2016;264(6):1058–1064. doi:10.1097/SLA.0000000000001607.

5. National Healthcare Safety Network, Centers for Disease Control and Prevention. Surgical site infection (SSI) event. http://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf. (Accessed January 25, 2017).
6. Berríos-Torres SI, Umscheid CA, Bratzler DW, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. *JAMA Surg*. 2017;152(8):784–791. doi:10.1001/jamasurg.2017.0904.
7. Liu Z, Dumville JC, Norman G, et al. Intraoperative interventions for preventing surgical site infection: an overview of Cochrane Reviews. *Cochrane Database Syst Rev*. 2018;2(2):CD012653. doi:10.1002/14651858.CD012653.pub2.
8. Tanner J, Padley W, Assadian O, et al. Do surgical care bundles reduce the risk of surgical site infections in patients undergoing colorectal surgery? A systematic review and cohort meta-analysis of 8,515 patients. *Surgery*. 2015;158(1):66–77. doi:10.1016/j.surg.2015.03.009.
9. de Campos-Lobato LF, Wells B, Wick E, et al. Predicting organ space surgical site infection with a nomogram. *J Gastrointest Surg*. 2009;13(11):1986–1992. doi:10.1007/s11605-009-0968-6.
10. Tu RH, Huang CM, Lin JX, et al. A scoring system to predict the risk of organ/space surgical site infections after laparoscopic gastrectomy for gastric cancer based on a large-scale retrospective study. *Surg Endosc*. 2016;30(7):3026–3034. doi:10.1007/s00464-015-4594-y.
11. Yuwen P, Chen W, Lv H, et al. Albumin and surgical site infection risk in orthopaedics: a meta-analysis. *BMC Surg*. 2017;17(1):7. doi:10.1186/s12893-016-0186-6.
12. Toiyama Y, Okugawa Y, Shimura T, et al. Neutrophil priming as a risk factor for surgical site infection in patients with colon cancer treated by laparoscopic surgery. *BMC Surg*. 2020;20(1):5. doi:10.1186/s12893-019-0674-6.
13. Amri R, Dinaux AM, Kunitake H, et al. Risk Stratification for Surgical Site Infections in Colon Cancer. *JAMA Surg*. 2017;152(7):686–690. doi:10.1001/jamasurg.2017.0505.
14. Nasser H, Ivanics T, Leonard-Murali S, et al. Risk Factors for Surgical Site Infection After Laparoscopic Colectomy: An NSQIP Database Analysis. *J Surg Res*. 2020;249:25–33. doi:10.1016/j.jss.2019.12.021.
15. Endo S, Tsujinaka T, Fujitani K, et al. Risk factors for superficial incisional surgical site infection after gastrectomy: analysis of patients enrolled in a prospective randomized trial comparing skin closure methods. *Gastric Cancer*. 2016;19(2):639–644. doi:10.1007/s10120-015-0494-z.
16. Janssen DMC, van Kuijk SMJ, d'Aumerie B, et al. A prediction model of surgical site infection after instrumented thoracolumbar spine surgery in adults. *Eur Spine J*. 2019;28(4):775–782. doi:10.1007/s00586-018-05877-z.
17. Kim JH, Kim J, Lee WJ, et al. A High Visceral-To-Subcutaneous Fat Ratio is an Independent Predictor of Surgical Site Infection after Gastrectomy. *J Clin Med*. 2019;8(4):494. doi:10.3390/jcm8040494.
18. Geiger TM, Horst S, Muldoon R, et al. Perioperative core body temperatures effect on outcome after colorectal resections. *Am Surg*. 2012;78(5):607–612.

19. Baucom RB, Phillips SE, Ehrenfeld JM, et al. Association of Perioperative Hypothermia During Colectomy with Surgical Site Infection. *JAMA Surg*. 2015;150(6):570–575. doi:10.1001/jamasurg.2015.77.