Surgical Site Infection After Emergency Abdominal Surgery in China: A Multicenter Prospective Study

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Abstract

Background There is still a lack of relevant studies on surgical site infection (SSI) after emergency abdominal surgery (EAS) in China. This study aims to understand the status of SSI after EAS in China and discuss its risk factors.

Materials and Methods All adult patients who underwent EAS in 47 hospitals in China from May 1 to 31, 2018, and from May 1 to June 7, 2019, were enrolled in this study. The basic information, perioperative data, and microbial culture results of infected incision were prospectively collected.The primary outcome measure was the incidence of SSI after EAS, and the secondary outcome variables were postoperative length of stay, ICU admission rate, ICU length of stay, 30-day postoperative mortality, and treatment costs. Univariate and multivariate logistic regression were used to analyze the risk factors.

Results A total of 953 patients (age 48.8 ± 17.9 years, male 51.9%) with EAS were included in this study: 71 patients (7.5%) developed SSI after surgery.The main pathogen of SSI was *Escherichia coli* (culture positive rate 29.6%). Patients with SSI had significantly longer overall hospital ($p < 0.001$) and ICU stays ($p < 0.001$), significantly higher ICU admissions ($p < 0.001$), and medical costs ($p < 0.001$) than patients without SSI.Multivariate logistic regression analysis showed that male ($P = 0.010$), high blood glucose level ($P < 0.001$), colorectal surgery ($P < 0.001$), intestinal obstruction ($P = 0.045$) and surgical duration ($P = 0.007$) were risk factors for SSI, whereas laparoscopic surgery ($P < 0.001 = 0.022$) was a protective factor.

Conclusion This study found a high incidence of SSI after EAS in China. The occurrence of SSI prolongs the patient's hospital stay and increases the medical burden. The study also revealed predictors of SSI after EAS and provides a basis for the development of norms for the prevention of surgical site infection after emergency abdominal surgery.

1. Introduction

The WHO ststes in the surgical site infection prevention guideline [1]: Surgical site infection (SSI) is among the most common health-care-associated infections in developing countries. The occurrence of SSI causes great pain to patients, prolongs the length of hospital stay, and causes expensive treatment costs [2, 3].

Current studies have found that the incidence of SSI after abdominal surgery ranges from 1.2% to 5.2% [4-6]. The incidence of SSI is much higher in patients undergoing emergency abdominal surgery (EAS) than in elective surgery [7, 8]. A cross-sectional study in the United States has shown that the incidence of incisional SSI in EAS patients is 6.7%, however, the respective incidence and proportion of drug-resistant bacteria in China are higher [9, 10]. In recent years, more patients undergo EAS with the rising number of emergency cases, patient management is more centralized, and the prevention of SSI has become more important [11]. However, there are limited studies on SSI after EAS in China. Therefore, it is important to obtain relevant data about SSI after EAS in China and provide a basis for its prevention.

In this study, prospective clinical data was collected from EAS patients in 47 hospitals in China, and the associated risk factors were analyzed. This study aims to provide the necessary evidence for the prevention of SSI after EAS.

2. Methods

We conducted a multicenter, prospective, observational study. The demographic and perioperative characteristics were collected to further evaluate the rate, risk factors and microbiological profile of SSI after EAS in China.

All adult patients who underwent EAS in 47 tertiary hospitals in China from May 1, 2018, to May 31, 2018, and from May 1, 2019, to June 7, 2019, were included. The follow-up period was 30 days postoperatively (patients with PP mesh had a 180 day postoperative follow-up). Patients who were participating in other clinical trials, pregnant, undergoing urologic, gynecologic, or transplant surgery were excluded.

Data related to SSI was collected according to established study protocols. Patient baseline variables included: Age, sex, body mass index (BMI), admission diagnosis, American Society of Anesthesiologists (ASA) physical status score, hypertension, diabetes mellitus, chronic hepatic dysfunction (hepatitis, cirrhosis, and/or abnormal liver enzymes levels), chronic renal dysfunction (renal failure and/or dialysis), chronic cardiac dysfunction (heart failure, myocardial infarction, previous percutaneous coronary intervention, and/or previous cardiac surgery), immune suppression status, smoking status (current smoker, former smoker, or nonsmoker), and preoperative concentrations of hemoglobin, albumin, and fasting blood glucose. Surgery-related variables included type of surgery based on surgical site (colorectal or non-colorectal), surgical wound class (clean-contaminated, contaminated, or dirty), methods of bowel preparation (mechanical bowel preparation [MBP] or oral antibiotic bowel preparation [OABP]), hand preparation (disinfectant or scrubbing), use of laparoscopy or robotic surgery, use of incisional protection devices (gauze, adhesive drapes, wound edge protector, or something else), grade of lead surgeon (based on their title), duration of surgery (from incision to suture), and the national nosocomial infections surveillance (NNIS) risk index. The NNIS risk index ranged from 0 to 3 per the assessment of three variables: ASA score, surgical wound class, and duration of surgery; the cutoff values for each variable were an ASA score of 3, a contaminated surgical incision, and an operative time of 180 min, with 1 point assigned when each variable exceeded its respective cutoff value [12]. Antibiotic-related variables included the use of preoperative and postoperative antibiotics.

The data collected consisted of three validation steps. First, each hospital identified patients according to the study protocol, collected basic data, and followed up the patients. Second, three independent investigators (ZL, HL, and PW) collated all data to assess its accuracy. Third, team members discussed the problem data and qualitatively assessed the collection process and data.

The primary outcome was the rate of SSI at 30 or 180 days; patients discharged from the hospital were followed up at the clinic or by telephone. The secondary outcome variables were postoperative hospital stay, ICU admission rate, ICU length of stay, treatment costs, and 30-day mortality. Surgical site infections were classified according to the Centers for Disease Control and Prevention (CDC) criteria; superficial incisional, deep incisional, and organ or space infections [13]. The diagnosed of SSI was by the presence of the following: (1) Local pain or tenderness, local swelling, redness, heat, or several of these symptoms, combined with deliberate or spontaneous incision dehiscence; (2) drainage at the incision or drainage tube; (3) imaging diagnosis of intra-incision abscess or abdominal and pelvic infections (including anastomotic leak). The fluid from the drain or puncture where SSI occured were cultured according to the standards of each hospital.

3. Statistical Analysis

Data analysis was performed using SPSS 22.0 software. All patients were divided into the SSI or the non-SSI groups. Categorical variables between the two groups were compared using the $\chi 2$ test, adjusted $\chi 2$ test, or Fisher's exact test. Continuous variables that were not normally distributed were expressed as medians (interquartile range) and compared using the Mann-Whitney U test. Univariate and multivariate logistic regression analyses were used to identify predictors of SSI occurrence, in which continuous variables were substituted into the model by obtaining cut-off values through ROC curves. The signifificance level was set at the conventional level of $\alpha=0.05$. P values were two-sided, and $P < 0.05$ was considered statistically significant.

4. Result

The patient flow chart is provided in **Figure 1.** There were 986 subjects initially recruited into the study; 16 were lost to follow-up, 13 were excluded due to incomplete data, and 5 due to problematic data. The 953 cases (534 males and 419 females) that met the inclusion criteria were followed up and analyzed. The mean age of the patients was 48.8 ± 17.9 years, ranging from 18 to 88 years. Of the total, 216 patients had one or more co-morbidities, with hypertension and diabetes mellitus being the most common comorbidities (137, 57) (**Table 1)**.

Postoperative SSI was identified in 71 (7.5%) patients. The volume of patients with SSI, out of the total, in each participant hospital, is listed in Table S1. Among them, 23 patients (32.4%) had superficial incision infection, 27 (38.0%) had deep incision infection, and 21 (29.6%) had organ-space infection. Secretion and pus cultures were positive in 42 patients (59.2%); the pathogens were *Escherichia coli* in 21 patients (50.0%), *Klebsiella pneumoniae* in 7 patients (16.7%), *Staphylococcus aureus* in 6 patients (14.3%), *Enterococcus faecium* in 4 patients (9.5%), surface *staphylococci* in 2 patients (4.8%), and *Acinetobacter baumannii* and *Proteus mirabilis* in 1 patient each (2.4%). ICU admission and medical costs were significantly increased in the SSI group compared with the non-SSI group, and also, postoperative and ICU length of stay were significantly prolonged (**Table 2**). Four patients died within 30 days of surgery, but none was directly caused by SSI. The median duration from surgery to SSI was 5.2 d.

Demographic characteristics: There was a higher incidence of SSI in male than in female patients ($p = 0.004$), and in patients with diabetes mellitus than in those without it ($p = 0.003$). There was a statistically significant difference between the two groups in preoperative hemoglobin, albumin, and blood glucose concentrations ($p = 0.012; 0.001; 0.000$) (**Table 1**).

Perioperative characteristics: Colorectal surgery patients had a higher rate of SSI than non-colorectal patients ($p < 0.001$); those with additional intestinal obstruction, had a higher rate of SSI ($p < 0.001$). The ASA score and NNIS risk index were significantly different between the two groups ($p < 0.001; 0.001$). The incidence of SSI was significantly lower in patients who underwent laparoscopic surgery than for those who underwent laparotomy. Adhesive drapes were the most commonly used wound protectors in EAS. Wound irrigation was significantly different between the groups ($p < 0.001$). The lead EAS surgeon was usually a senior surgeon. The duration of EAS was significantly longer in the SSI group than in the non-SSI group ($p < 0.001$) (**Table 3**).

For antibiotic administration, a total of 707 patients received preoperative antibiotic. Third-generation cephalosporins were the most commonly used antibiotic type (32.8%), followed by cephamycins and combination antibiotic. Antibiotic were used postoperatively in 872 patients, with the most patients receiving combination antibiotic (31.8%), followed by the third-generation cephalosporins in 200 patients. Postoperative antibiotic use was significantly longer in the SSI group than in the non-SSI group ($p < 0.001$) **(Table 4).**

Univariate logistic regression analysis risk factors results for SSI are shown in **Figure 2**. The factors significantly associated with the occurrence of SSI were age (> 47.5 years), male gender, preoperative albumin concentration (< 11 g/dL), preoperative blood glucose concentration (> 124 mg/dL), colorectal surgery, intestinal obstruction, ASA score greater than 2, NNIS risk index greater than 0, laparoscopic surgery, wound irrigation（povidone iodine solution）, and operation time (> 122 min). Multivariate logistic regression analysis confirmed that males, blood glucose concentration (> 124 mg/dL), colorectal surgery, intestinal obstruction, and surgical duration (> 122 min) were risk factors for SSI, while laparoscopic surgery was a protective factor.

5. Discussion

his study found that the incidence of postoperative SSI in EAS patients was 7.5%, with *Escherichia coli* infection being the most common, which is comparable to that reported worldwide [9, 14, 15]. The occurrence of SSI significantly prolonged the hospital stay of patients and increased medical costs. The incidence of SSI can be reduced by laparoscopic surgery and shorter operation time, whereas high blood glucose levels, intestinal obstruction, and colorectal surgery increase the risk.

It has been shown that older people are more likely to develop SSI [16] ; in this study, age was not a predictor as observed using multivariate logistic regression analysis. Male patients had a significantly higher risk of SSI after EAS than females (OR 2.204, 95% CI 1.178 – 8.985, $P = 0.010$); while this is partly debated, multiple studies have found significantly higher rates of SSI in male patients than in females [17, 18]. This may be related to male bushy hair; shaving increases the risk of skin trauma. Guidelines for

SSI prevention issued by the Surgical Infection Society strongly discourage the use of razors for hair removal and propose the use of clippers if necessary.

In our study, high blood glucose level (> 124mg/dL) was found to be a risk factor for SSI after EAS (OR 3.328, 95% CI 1.888 – 5.867, $P < 0.001$). Previous studies have shown that diabetes mellitus and preoperative hypergycemia are SSI risk factors [19]. Hyperglycemia can affect the function of white blood cells, which in turn reduces the body's defense. The EAS patients tend to be in an acute preoperative stress state, and the associated hyperglycemic levels can better predict SSI than diabetes. Decreased serum albumin is usually an indicator of malnutrition or combined chronic wasting disease. In the present study, low serum albumin levels did not significantly affect the occurrence of SSI after adjustment for other variables, which requires further investigation.

The incidence of postoperative SSI is generally higher in patients undergoing colorectal than other gastrointestinal surgeries [20]. Our data shows that patients undergoing emergency colorectal surgery are at 7.017 times (95% CI 3.577-13.805, $P < 0.001$) higher risk of SSI than patients undergoing other emergency gastrointestinal surgeries. There is a high colorectal bacterial load, including a variety of gram-negative and anaerobic bacteria. Necessary bowel preparation is difficult to achieve for emergency surgery and intestinal contents are easily spilled, contaminating the surgical area. This explains the high risk of SSI in emergency colorectal surgery patients.

Our study found that intestinal obstruction was a risk factor for SSI (OR 1.973, 95% CI 1.014 – 3.838, $P = 0.045$). The intestinal barrier function is impaired due to fasting and dilatation of the bowel lumen regardless of whether the bowel is removed, and bacteria are easily translocated outside the bowel lumen, increasing the risk of SSI. In our study, gastrointestinal perforation was not an independent risk factor for SSI. Gastrointestinal perforation usually occurs in the upper gastrointestinal tract, which has a relatively less bacterial load. At the same time, more attention is often paid to SSI prevention during the treatment of patients with gastrointestinal perforation, including adequate irrigation of the surgical site and post-surgical application of high-grade antibiotics. There is need to pay attention to the prevention of SSI in patients with intestinal obstruction regardless of whether bowel resection is performed or not.

Our study also evaluated the relationship of ASA score, NNIS risk index, and wound irrigation with SSI. None of these were independent risk factors for SSI in EAS patients after adjustment for logistic regression analysis. The NNIS risk index included ASA score, duration of surgery, and surgical wound grade. The majority of patients had an ASA score of 1 or 2, and surgical wounds were classified as clean-contaminated. The incidence of SSI was higher in patients whose incisions were irrigated with saline and povidone-iodine solution. This may be due to more contaminated incisions being irrigated than clean incisions during surgery, therefore spreading the infective microbes. The World Society for Emergency Surgery (WSES) states in the Intraoperative Surgical Site Infection Control and Prevention that there is insufficient data to support the role of irrigation of the incision with saline or polyvidone before closure in preventing SSI [21].

Previous studies have shown that laparoscopic surgery can significantly reduce the incidence of SSI compared to open surgery [20, 22]. This study supports this view. Laparoscopic surgery uses a small incision, greatly reducing the chances of exposure with little damage to the surrounding tissues, which reduces the risk of SSI. However, laparoscopic surgery has some limitations, especially for emergency cases. Laparoscopy requires certain equipment base, operating space, and experienced surgeons. In the 2016 WSES consensus on the management of intra-abdominal infections, laparoscopic surgery was determined to be safe and preferred for procedures such as appendectomy, repair of perforated peptic ulcer, and cholecystectomy when contraindications are excluded [23]. However, if peritonitis episodes were > 24 h, laparotomy was recommended.

The duration of surgery is a risk factor for SSI [24, 25]. This study found that EAS patients who had longer surgery were more likely to have an SSI. Longer surgery not only aggravates the destruction of the microenvironment in the surgical area, but also greatly increases the chances of bacterial colonization due to the increased exposure time of the surgical incision to the air. Precautions against SSI can be appropriately instituted for operation time greater than 122 min.

We also analyzed patients' perioperative antibiotic use. The Infectious Diseases Society of America recommended administering prophylactic antibiotics only when indicated [26]. However, EAS patients are mostly treated for the primary disease in the emergency department before surgery; in our study 707 (74.2%) patients had received different classes of antibiotics, preoperatively. This shows that there is lack of perioperative antibiotic standards for use in emergency surgery in China. Further randomized controlled trials are needed to determine the type and timing of antibiotic therapy. The WHO and the Infectious Diseases Society of America recommend that the administration of antibiotics should not be prolonged after surgery [1, 26]. Interestingly, we found that the high incidence of SSI was associated with prolonged antibiotic administration; EAS patients who were on prophylactic antibiotics, are usually continued on antibiotics post surgically. The study shows that prolonged prophylactic antibiotics use is not beneficial in reducing the incidence of SSI, but leads to intestinal flora disturbances, drug-resistant bacteria, and increased medical burden [27, 28].

6. Limitations Of The Study

This study has several limitations. The study period is short and only includes patients who underwent EAS from May 1 to May 31, 2018, and May 1, June 7, 2019, which may have some bias. The study included different types of patients, which may be a confounding factor. Also, the results of bacterial culture of samples may be biased due to different standards and technical levels of culturing in each hospital. The multicenter study will be refined in the coming years.

7. Conclusions

This study found a high incidence of SSI after EAS in China. The occurrence of SSI prolongs the patient's hospital stay and increases the medical burden. We suggest that SSI monitoring should be performed according to the patient's gender, preoperative blood glucose level, disease, type and duration of surgery. Our study provides a basis for the development of norms for the prevention of SSI after EAS.

8. Abbreviations

ASA:

American Society of Anesthesiologists

CDC:

Center for Disease Control and Prevention

EAS:

Center for Disease Control and Prevention

ICU:

Intensive Care Unit

NNIS:

National Healthcare Safety Network

PP mesh:

Polypropyleneps mesh

SPSS:

Statistical Package for Social Sciences

SSI:

Surgical site infections

WHO:

World Health Organization

WSES:

World Society for Emergency Surgery

9. Declarations

Ethics approval and consent to participate

The institutional ethics committees of all participating hospitals approved this study. Written informed consent was obtained from all study participants

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available. Because they are archived in the clinical databases of all participating hospital and the Affiliated Hospital of Qingdao University, they are only used for scientific purposes. Datasets are available from the corresponding author upon request.

Competing interests

The authors declared no potential Competing interest with respect to the research, authorship, and/or publication of this article.

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Authors' contributions

Peige Wang, Jianan Ren and Ze Li designed and originated the study; Ze Li,Hui Li and Changliang Wu were responsible for the collection of clinical data; Ze Li and Pin Lv analyzed the data; Ze Li, Hui Li and Xingang Peng wrote the paper. All authors read and approved the final manuscript.

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Tables

Table1 Demographics of included patients

es	SSI group (n=71)	Non-SSI group (n=882)	Statistic	P value
ars（median (IQR)	56（48-70）	47（33-63）	U=39918	<0.001
:(%)			χ^2=8.173	0.004
	51（9.6）	483（90.4）		
le	20（4.8）	399（95.2）		
;/m^2（median (IQR)	23.0（22.0-26.0）	23.0（22.0-24.4)	U=20738.5	0.695
oidity (%)				
etes mellitus	10（17.5）	47（82.5）	χ^2=8.958	0.003
rtension	14（10.2）	123（89.8）	χ^2=1.779	0.182
nic liver disease	1(5.9)	16(94.1)	χ^2=0.021	0.885
nic kidney disease	3(13.6)	19(86.4)	χ^2=0.500	0.479
nic heart disease	3(9.4)	29(90.6)	χ^2=0.006	0.937
rculosis	1(12.5)	7(87.5)		0.463
id use	0	6(100)		1.000
ınosuppressive medication	0	2(100)		1.000
ıg history (%)			χ^2=3.036	0.219
	58（7.2）	747（92.8）		
er	3（18.8）	13(81.2)		
nt	10（7.6）	122（92.4）		
lobin, g/dL, median (IQR)	12.5（9.8-14.5）	13.1（12.0-14.4）	U=25430.5	0.012
n, g/dL, median (IQR)	3.6（3.0-4.3）	4.0(3.6-4.5)	U=22932.5	0.001
;lucose, mg/dL , median	144（106-199）	108(93-128)	U=43743	<0.001

Outcomes of included patients

es	SSI group (n=71)	Non-SSI group (n=882)	Statistic	P value
erative delivery of icu, n(%)	36（18.2）	195（91.8）	χ^2=29.259	<0.001
of ICU stay, day, median (IQR)	0(0-2)	0(0-0)	U=41004	<0.001
of postoperative stay, day, ı (IQR)	13（8-19）	6（4-9）	U=49486	<0.001
l cost, thousand dollar, median	6.9（3.7-9.7）	2.3(1.7-3.8)	U=51318	<0.001
ortality, n (%)	2（50%）	2（50%）		0.030

Table3 Perioperative characteristics of included patients

es	SSI group (n=71)	Non-SSI group(n=882)	Statistic	P value
surgery(%)			χ^2=72.133	<0.001
ectal surgery	22(34.3)	42(65.7)		
olorectal surgery	49(5.5)	840(94.5)		
preparation (%)				0.528
	62(7.4)	778(92.6)		
only	4(12.9)	27(87.1)		
only	5(6.3)	75(93.7)		
-OABP	0	2(100.0)		
nal obstruction(%)			χ^2=29.526	<0.001
	20(21.5)	73(78.5)		
	51(5.9)	809(94.1)		
ntestinal perforation(%)			χ^2=0.031	0.861
	6(7.0)	80(93.0)		
	65(7.5)	802(92.5)		
ore(%)			χ^2=31.630	<0.001
	15(4.2)	340(95.8)		
	28(6.5)	406(93.5)		
	20(15.2)	112(84.8)		
	8(25.0)	24(75.0)		
isk index			χ^2=91.767	<0.001
	17(3.0)	551(97.0)		
	27(9.7)	252(90.3)		
	19(20.7)	73(79.3)		
	8(57.1)	6(42.9)		
ch			χ^2=53.600	<0.001
	61(14.4)	362(85.6)		
oscopic	10(1.9)	520(98.1)		
al wound class(%)			χ^2=0.766	0.381
n-contaminated	48(7.0)	639(93.0)		
aminated or dirty	23(8.6)	243(91.4)		
nal protection (%)			χ^2=23.051	<0.001
	29(5.1)	537(94.9)		
e	14(9.4)	135(90.6)		
sive drapes	12(7.6)	145(92.4)		
d edge protector	16(19.8)	65(80.2)		
irrigation(%)			χ^2=23.442	<0.001
	12(2.9)	406(97.1)		
e	35(10.3)	306(89.7)		
one iodine solution	24(12.4)	170(87.6)		
of lead surgeon (%)			χ^2=12.356	0.002
	0	71(100.0)		
e	22(5.6)	371(94.4)		
r	49(10.0)	440(90.0)		
al duration, min, median	130.0(83.0-205.0)	75.0(53.0-114.3)	U=45556.5	<0.001

Antibiotics use

Variables	SSI group (n=71)	Non-SSI group (n=882)	Statistic	P value
erative prophylactic tic(%)				0.005
	14(5.7)	232(94.3)		
phalosporin	14(9.6)	70(90.4)		
phalosporin	21(4.8)	211(95.2)		
mycin	6(2.4)	137(4.0)		
phem	1(93.0)	23(4.0)		
llin	2(93.0)	70(4.0)		
oglycoside	0(17.5)	3(82.5)		
lones	1(6.8)	22(93.2)		
penem	5(93.0)	14(93.2)		
nidazole	2(10.2)	13(89.8)		
	0(7.0)	4(93.0)		
ined antibiotic	5(93.0)	83(93.0)		
erative antibiotic(%)				0.002
	2(7.6)	79(92.4)		
phalosporin	6(47.0)	81(24.0)		
phalosporin	17(12.2)	183(8.6)		
mycin	9(5.2)	123(1.9)		
phem	2(92.4)	16(92.4)		
llin	5(34.3)	68(92.4)		
oglycoside	1(5.5)	2(65.7)		
lones	1(92.4)	23(94.5)		
penem	9(7.4)	30(92.4)		
nidazole	1(12.9)	0(87.1)		
	3(6.3)	15(93.7)		
ined antibiotic	15(6.3)	262(100.0)		
n of postoperative antibiotic(%)			χ^2 =19.359	<0.001
	3(9.1)	30(90.9)		
	15(5.1)	278(94.9)		
	23(6.0)	360(94.0)		
	28(17.2)	135(82.8)		
.(IQR)	7.0(4.0-9.0)	5.0(3.0-7.0)	U =41725	<0.001

ble5 Results of Multivariate logistic regression analysis

riables	B	OR	95%CI	Statistic	P value
nder （male）	0.790	2.204	1.178~8.985	6.576	0.010
od glucose（>124mg/dL）	1.202	3.328	1.888~5.867	17.286	<0.001
orectal surgery	1.950	7.027	3.577~13.805	32.031	<0.001
proach(Laparoscopic)	-1.579	0.206	0.099~0.430	17.700	<0.001
estinal obstruction	0.680	1.973	1.014~3.838	4.009	0.045
rgical duration(>122 min)	1.073	2.923	1.673~5.106	14.204	<0.001

Figures

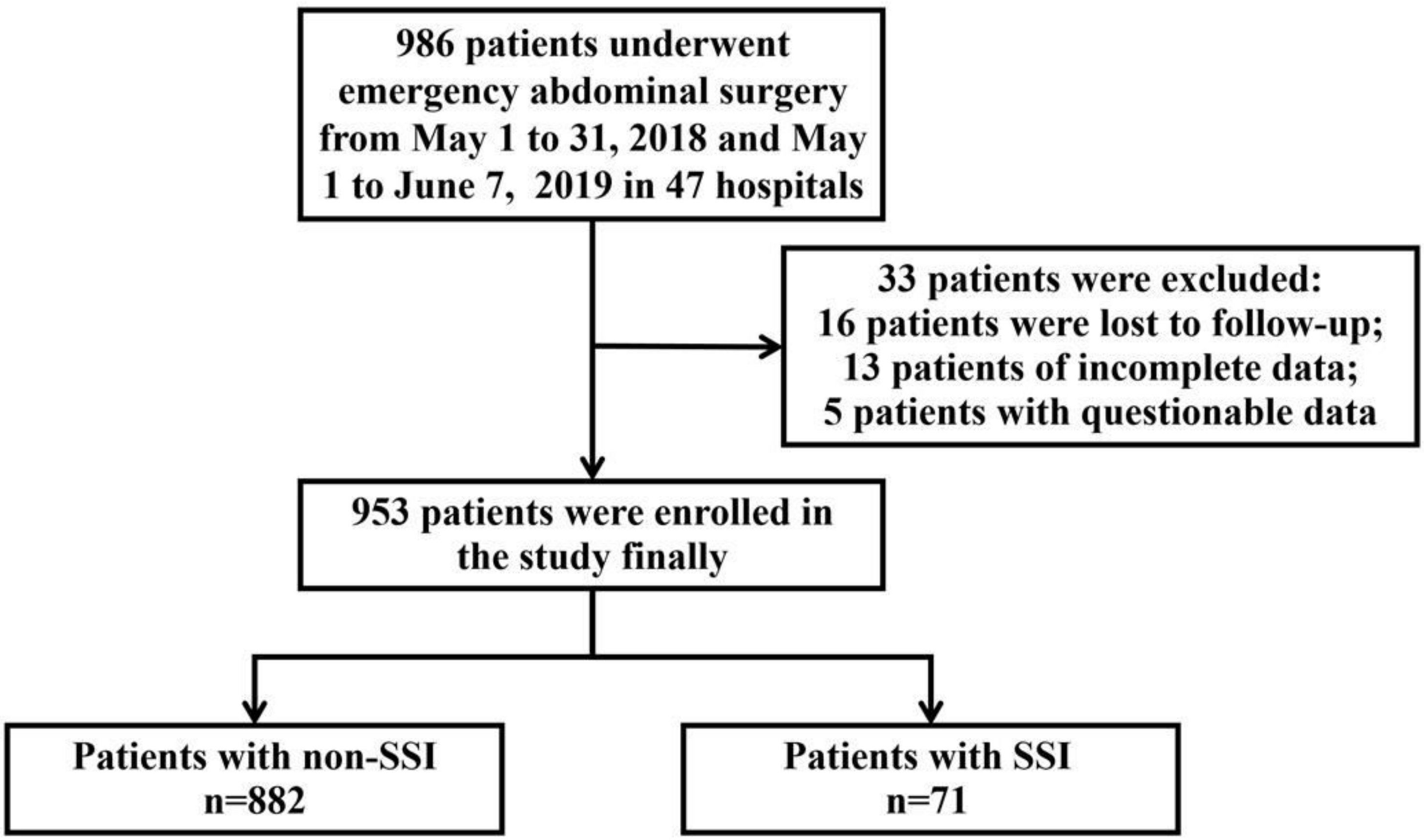

Figure 1

Patient flow chart

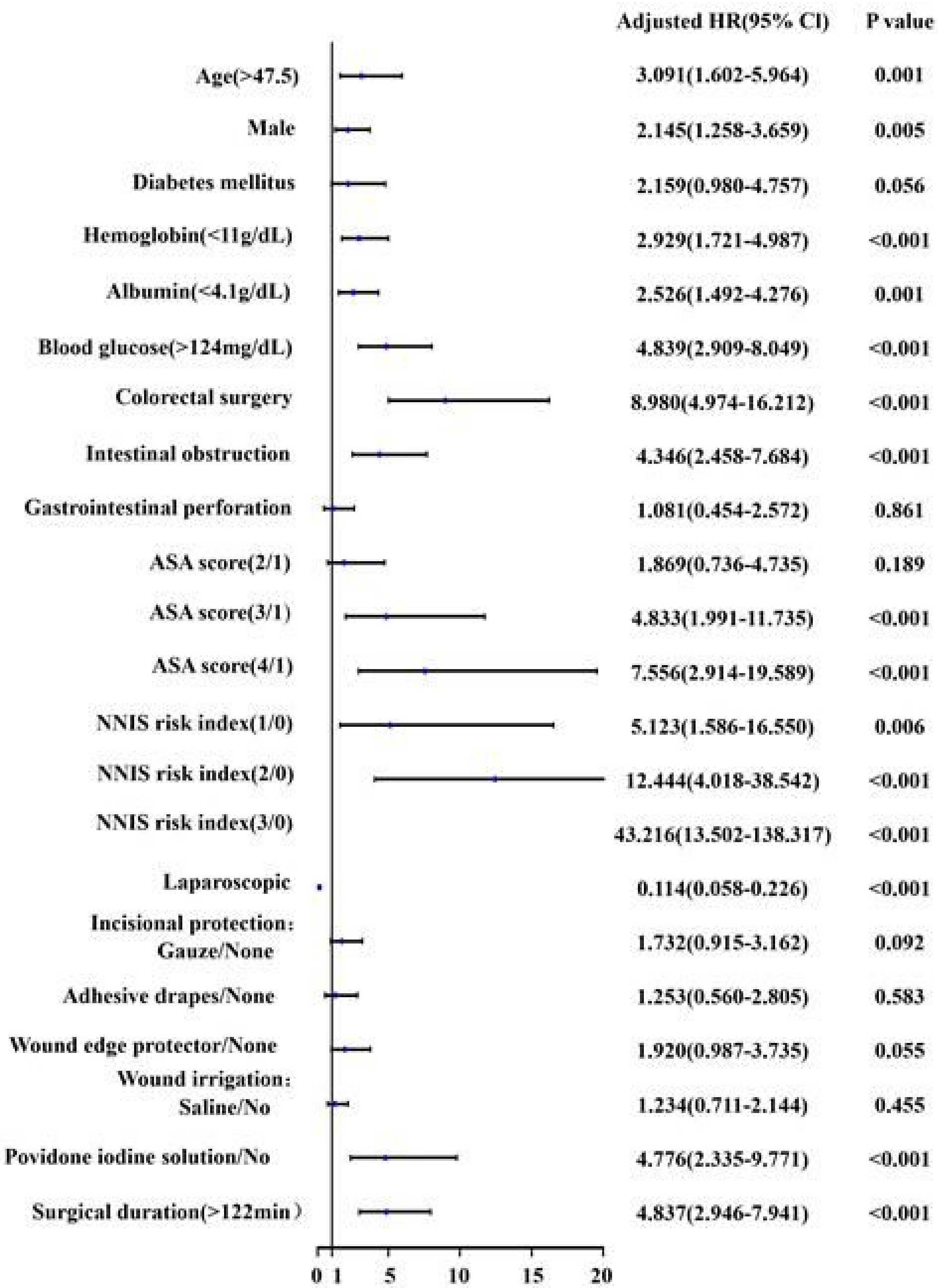

Figure 2

Results of univariate logistic regression analysis

Supplementary Files

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- supplement1.docx