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The characteristics of surgical site infection with class I incision in neurosurgery

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Abstract

Objective Surgical site infections (SSIs) were recognized to be the most common complication of neurological surgery, with substantial life quality threats to patients and additional cost burdens to healthcare facilities. This study sought to expound the infection characteristics of class I incision and provide clinical indication for the prevention and treatment of SSIs.

Methods A 2-year retrospective analysis was conducted according to patients who performed neurological surgery with class I incision in a tertiary comprehensive hospital in Shaanxi Province, China. Case mix index (CMI)-adjusted and national nosocomial infection surveillance (NNIS) risk index-adjusted SSI rate were utilized for analytical standardization. The SSIs were specifically analyzed according to various departments, surgeons, and surgical classifications.

Findings 6046 surgical cases were finally included in our study. The majority of the American Society of Aneshesiologists (ASA) score and NNIS risk index of surgeries were allocated in level 2 and score 1. Our study found 121 SSI cases, with the crude infection rate of 2.00%. 95.04% were organ/space infection. The most of the infection were found in the surgeries with score 1 (68.60%) of the NNIS risk index. The main surgical classification was resection of space occupying lesions (61.96%). The highest crude and NNIS risk index adjusted infection were individually found in hybrid operation (11.67%) and endoscopy-assisted resection of space occupying lesions (13.33%). 21 of 54 surgeons were found to have SSIs. We found the main pathogenic bacteria was Staphylococcus epidermidis (22.81%), and the commonly prophylactic used antibiotics was Cefazolin (51.95%).

Conclusion Our study found the main infection was among surgeries with score 1 of NNIS risk index and the surgical classification of endoscopy-assisted resection of space occupying lesions. We indicated specific attention should be paid to the surgeon and surgical classification with highest infection rate to control and prevent SSIs.

Keywords Surgical site infection, Neurosurgery, CMI, NNIS risk index, Surgical classification

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Introduction

SSI is define as infection occurring in the surgical site within 30 days of surgery or one year of the use of implants [1]. The previous literature reported the SSIs were 0.2–16.3% [2–7]. The incidence of SSI could cause morbidity and mortality, which would also result in enormous medical burdens and economical costs for both patients and the healthcare institutions [8–11].

Surgical site infections occurring after clean-incision (class I) surgeries could severely affect the life quality of patients. Several studies have identified that earlier intervention for those controllable factors such as enhancing the immune level, controlling pre-existing comorbidities, and prophylactically using antibiotics could significantly reduce the incidence of SSIs in class I incisions [9–10]. Moreover, despite of the basic physical conditions of various patients, the SSIs caused by factors such as surgeons' technical deficiencies, substandard operating environments, and surgeons' non-compliant operations could be avoided in advance by taking appropriate infection control measures.

The Neurosurgery is a department with a significant portion of critically ill and emergent patients. The neurological surgery not only has complex procedures and surgical sites, but also has the long exposure of the surgical field in most neurosurgery types, which may increase the probability of the occurrence of SSI [12–13]. Previous literature showed the SSIs for neurosurgery were from 3.19 to 14.7%, which were affected by several factors such as patients' physical conditions, surgical procedures and duration, surgical environments, skin preparation, the surgeon's operation skills, and the prophylactic usages of antibiotics [14–17]. Although the advanced infection prevention awareness and the gradually matured neurosurgical techniques have been implemented in clinical practice, SSI still remains a substantial concern and a common complication in Neurosurgery worldwide [18–20]. However, the recent studies mainly focused on certain surgeries or specific surgical site, analysis such as the description of neurosurgical characteristics and the correlation between SSI and prophylactic usage of antibiotics were rarely found.

The medical informational software such as Diagnosis-Related Groups (DRGs) Operation Analysis System, Electronic Medical Record System (EMRS), Anesthesia Clinical Information System (ACIS), and Nosocomial Infection Surveillance (NIS) system are widely used in the healthcare institutions, which could obtain the relatively accurate and complete data about the patients and their infection related information. Utilizing data recorded in these software could comprehensively analyze SSIs in Neurosurgery. To date, research on the comprehensive analysis of SSIs using data from multiple informational systems was seldom. Meanwhile, the CMI and NNIS were regarded as essential indexes for the adjustment of SSIs, especially for the neurological surgeries, which had higher levels of surgical difficulties. Barely updated research was found to analyze the SSIs and surgeons or surgical classification by the adjustment of CMI or NNIS risk index in Neurosurgery, but the standardized SSIs by the adjustment of CMI and NNIS risk index may have more significance for clinical practice.

Our institution was a tertiary comprehensive hospital in Shaanxi province, China, which had 7 departments in the Neurosurgery with the approximately average annual surgical number of 3,000 cases. The Neurosurgery was at the leading position nationwide. We had skilled surgical professionals and well-equipped facilities and equipment, which enabled to perform complex and high-risk neurological surgeries. In order to obtain the current SSI trends in Neurosurgery, we conducted a 2-year retrospective analysis based on patients who performed neurological surgery with class I incision. Standardized adjustment measurements of CMI and NNIS risk index were used to detailed understand the distribution characteristics of neurological surgery. We expected our study could provide clinical recommendations for infection prevention and control of SSIs in Neurosurgery.

Methods

Data source

A 2-year (from 2022 to 2023) retrospective study was performed according to the data of patients with class I incision neurological surgery in a tertiary comprehensive hospital in Shaanxi province, China. SSIs are diagnosed according to the National Nosocomial Infections Surveillance system guidelines, which are divided into three categories based on CDC classification: superficial, deep and organ/space infection [21–22]. The diagnostic criteria include: (1) Drainage or puncture of pus, (2) purulent secretions from the incision or accompanied by fever, swelling, local pain, and tenderness, (3) relevant evidence of infection found by re-operation, imaging, or histopathology examination, or (4) infection of the superficial, deep or organ/space tissue diagnosed by clinicians [23].

Our data were extracted through EMRS, ACIS and NIS system. Basic patient information data such as patient identity, gender (male/female), age, inpatient department (I to VI, Intensive Care Unit (ICU)), length of hospitalization (d), and incision class (class I) were extracted from EMRS. Surgical related information including ASA score (1–5), surgical time (min), surgeon, operative name, surgical type (selective/emergency), and prophylactic usage of antibiotics were obtained from ACIS. The perioperative prophylactic usage of antibiotics is defined as antibiotics prophylactically used for 24 h before and after surgery. The infection related data such as infection (yes/no), infection site (superficial incisional infection, deep incisional infection, organ/space incisional infection), pathogenic results, and length of SSI occurrence (d) were extracted from NIS system. The CMI value was obtained from DRGs Operation Analysis System.

Participants

The eligibility and exclusion criteria were as follows. Patients who performed class I incision surgeries in Neurosurgery with complete information about operations (involving ASA score and surgical time) were included in the analysis. Participants were excluded with incision misclassification ($n = 139$) and without ASA score/surgical time ($n = 266$). The original sample size extracted from NIS system was 6451. After exclusion, our final analytical sample size was 6046 (see Fig. 1).

Evaluation indexes

CMI is one of the indexes in DRGs, which represents the treatment difficulty levels. DRGs are groups categorized by the characteristics of patients such as main diagnosis, complications, age, gender, etc [24]. Higher CMI value means the institution has higher demand of treatment.

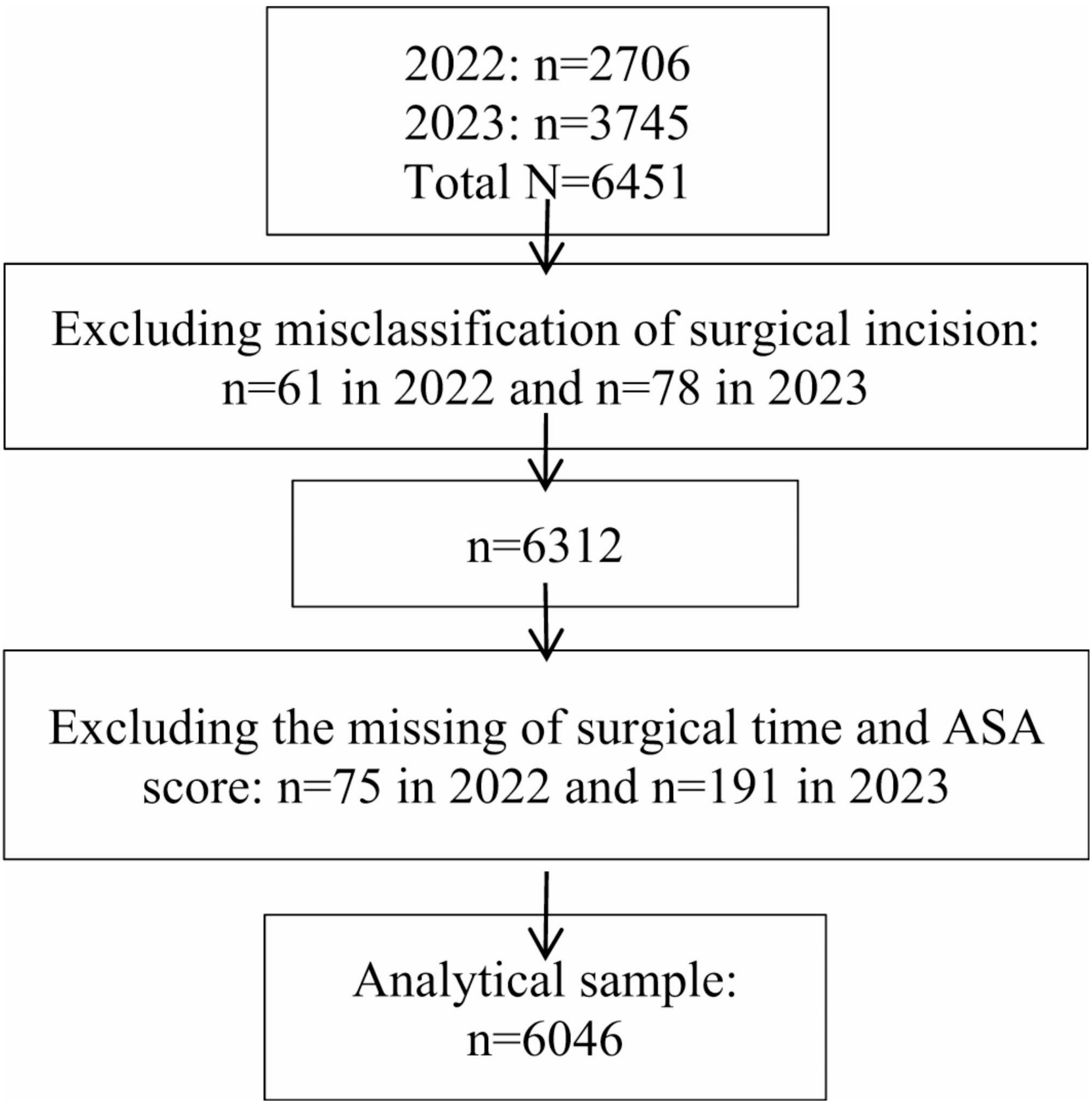

Fig. 1 Sampling flow chart

Therefore, to wave the differences of treatment difficulties, we use CMI to adjust the infection rate by various departments [25]. The calculation formula is: The CMI-adjusted SSI rate = Crude SSI rate/CMI value.

NNIS risk index is used to adjust the SSI rates by various NNIS scores, which could improve the accuracy and comparability of SSI rates [26–27]. NNIS risk index is calculated by 3 main indexes: Class of surgical incision (class I to IV), ASA score (1 to 5), surgical time (> 3 h or ≤ 3 h), and finally divided into four levels (score 0 to 3). The scoring of NNIS risk index was shown in supplementary Table 1 (Table S1). The formula of average risk index is: The average risk index = Σ(Surgical cases*Infection cases by different categories)/Σ(Surgical cases). We conducted the NNIS risk index-adjusted SSI rate by surgical sites, surgical classifications, and surgeons. The formula is: The NNIS risk index-adjusted SSI rate = Crude SSI rate/Average risk index.

Statistical analysis

We firstly conducted the demographic characteristics analysis. Next, the crude SSI trends by month and perioperative prophylactic usage rate of antibiotics by month of class I incision surgeries, and the correlation between SSIs and prophylactic usage rate of antibiotics were summarized in our analysis. The CMI-adjusted SSI rate by department, and the NNIS risk index-adjusted SSI rate by surgical sites, surgical classifications, and surgeons were also calculated. Lastly, we displayed the distribution of pathogenic results of infection cases and types of prophylactic antibiotics.

The statistical software SPSS 26.0 was utilized for statistical analysis. Qualitative and quantitative data were presented as n(%) and x ± SD, separately. X^2 -test and correlation analysis were performed, $P < 0.05$ was regarded as statistically significant.

Results

Sample characteristics

A total of 6046 participants with the average age of 49.88 ± 16.99 year-old were included in our study. The average length of hospitalization and average surgical time were 12.35 ± 7.92d and 202.53 ± 99.19 min, the average length of SSI occurrence was 7.57 ± 6.50d. The ASA score and NNIS risk index of the majority of surgical patients were level 2 (69.35%) and score 2 (52.15%). Most of the surgeries were selective surgery (83.59%), and the main infection site was organ/space infection (95.04%). The overall SSI rate of class I incisional surgeries was 2.00. Significant difference of infection was only found in the infections with various NNIS risk indexes ($P = 0.000$). The details were in Table 1.

The analysis of SSI

The monthly SSI rates fluctuated from 0.30 to 4.49%, which were shown in Fig. 2. The crude and CMI-adjusted SSI rates in different departments were listed in Fig. 3. The crude SSI rates ranked from high to low by department were department I (4.44%), IV (3.01%), V (2.18%), II (1.78%), ICU (1.68%), VI (1.39%), and III (0.99%). And the CMI-adjusted SSI rates by department were department I (0.80%), IV (0.65%), V (%), VI (0.46%), II (0.34%),

Table 1 The demographic characteristics of participants

Variable		*n* (%) or X ± SD	Number of SSI infection	Infection rate (%)	*P*-value
N		6046	121	2.00	
Age (year-old)		49.88 ± 16.99			
Length of hospitalization (d)		12.35 ± 7.92			
Surgical time (min)		202.53 ± 99.19			
Length of SSI occurrence (d)		7.57 ± 6.50			
Gender	Male	3207 (53.00)	55	1.71	0.157
	Female	2839 (47.00)	66	2.32	
ASA score	1	151 (2.50)	2	1.32	0.890
	2	4193 (69.35)	87	2.07	
	3	1420 (23.49)	28	1.97	
	4	267 (4.42)	4	1.50	
	5	15 (0.25)	0	0.00	
NNIS risk index	0	2087 (34.52)	18	0.86	0.000
	1	3153 (52.15)	83	2.63	
	2	806 (13.33)	20	2.48	
Surgical type	Emergency surgery	993 (16.41)	16	1.61	0.337
	Selective surgery	5053 (83.59)	105	2.08	
Surgical infection site	Organ/Space infection	115 (95.04)			
	Deep incisional infection	2 (1.65)			
	Superficial incisional infection	4 (3.31)			

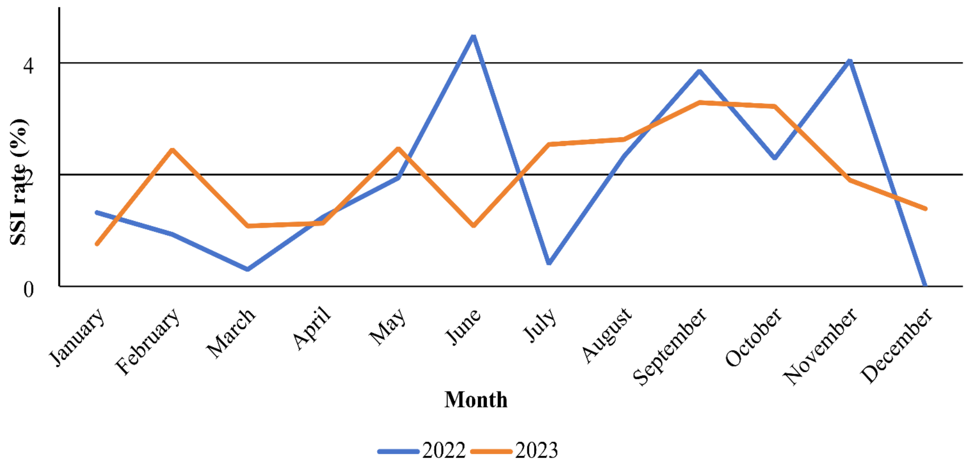

Fig. 2 Surgical site infection rate of class I incision by month

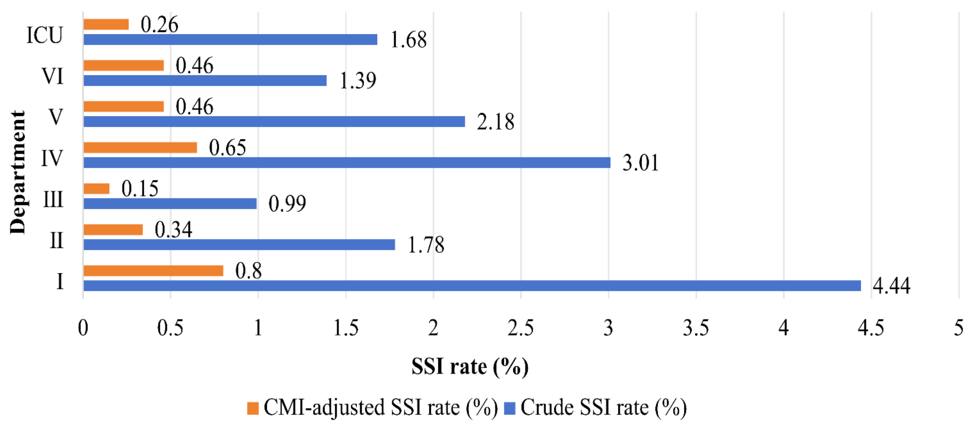

Fig. 3 The crude SSI rate and CMI-adjusted SSI rate of different departments

Table 2 The SSI rate of different infection site with different NNIS risk indexes

Surgical infection site	NNIS risk index (*n* (%))			
	0	1	2	In total
Organ/Space infection	16(13.91)	80 (69.57)	19 (16.52)	115
Deep incisional infection	1 (50.00)	1 (50.00)	0	2
Superficial incisional infection	1 (25.00)	2 (50.00)	1 (25.00)	4
In total	18 (14.88)	83 (68.60)	20 (16.53)	121

ICU (0.26%), and III (0.15%). The ranking differences mainly observed in department II, VI and ICU. To be specific, department IV had the relatively lower difficulty of medical treatment and economic expenses, so its CMI-adjusted SSI rate was relatively high compared with the crude rate. On the contrary, department II had higher crude SSI rate, but its CMI-adjusted SSI rate was relatively low, implicating the higher treatment difficulty and economic expenses in this department. The detailed data of SSI adjustment by CMI values could be found at Table S2.

A total of 121 infection cases were summarized in our study. We firstly analyzed the infection sites stratified by NNIS risk indexes (see Table 2). Of the 121 infections, 115 cases were organ/space infection, and 83 cases (68.60%) belonged to score 1 of the NNIS risk index. Most of the organ/space infections occurred in score 1 of the NNIS risk index ($n=80$, 69.57%), 2 cases of deep incisional infections were located in score 0 and score 1 of the NNIS risk index, and 4 cases of superficial incisional infection were individually located in score 0 ($n=1$), score 1 ($n=2$), and score 2 ($n=1$) of the NNIS risk index.

Our analysis confirmed the overall crude and NNIS risk index-adjusted SSI rate were 2.00% and 0.04%. We also evaluated the SSI rate of different surgical classifications and various surgeons. We firstly classified all surgeries into 17 categorizations. The most common surgery classification was resection of space occupying lesions ($n=3746$, 61.96%), followed by skull/dural repair surgery ($n=370$, 6.12%) and electrical stimulation electrode replacement surgery ($n=273$, 4.52%). The highest and lowest crude infection rates were found in hybrid operation (11.67%) and bone graft fusion and internal fixation surgery (0.46%). Similarly, the highest and lowest NNIS risk index-adjusted SSI rates were observed in resection of space occupying lesions (0.06%) and endoscopy-assisted resection of space occupying lesions (13.33%). No SSI was found in electrical stimulation electrode replacement surgery (n = 273, 4.52%), craniotomy/spinal canal decompression surgery (n = 143, 2.37%), endoscopy-assisted craniotomy evacuation of hematoma (n = 122, 2.02%), endoscopy-assisted craniotomy decompression surgery (n = 108, 1.79%), arteriosynagiosis surgery (n = 73, 1.21%), neurolysis surgery (34, 0.56%), and internal fixation device implantation/removal surgery (n = 17, 0.28). Detailed information were shown in Table 3. We secondly analyzed the SSI rate by surgeons, the detailed statistics were exported in Table S3. A total of 54 surgeons were summarized, of which 21 surgeons had SSI after surgery. The highest and lowest crude infection rates were found in surgeon 34 (50.00%) and surgeon 13 (0.58%). Similarly, the highest NNIS risk index-adjusted SSI rate was observed in surgeon 30 and 34 (50.00%), and the lowest NNIS risk index-adjusted SSI rate was found in surgeon 1 (0.21%) (Fig. 4).

Pathogenic results

Additional analysis of the distribution characteristics of pathogenic results was listed in our study (see Table 4). 44 of 121 SSI cases had confirmed pathogenic results from the cerebrospinal fluid examination for the evidence of SSI. A total of 57 types of pathogens were detected, the most common pathogenic bacterium were Staphylococcus epidermidis (n = 13, 22.81%), Staphylococcus capitis (n = 10, 17.54%) and Staphylococcus hominis (n = 9, 15.79%).

Prophylactic usage of antibiotics

Finally, we analyzed the characteristics of perioperative prophylactic usage of antibiotics. The monthly usage rates of prophylactic antibiotics were displayed in Fig. 5. Due to the relatively high risk of infections after surgery, the fairly high rate of perioperative prophylactic usage of antibiotics fluctuated from 76.96 to 96.95% by month was observed in our study. A sum of 17 kinds and 36 types of antibiotics were listed (see Table 5). The most commonly used antibiotics was Cefazolin (n = 4170, 51.95%) and Cefuroxime (n = 1060, 13.21%), which indicated the first generation cephalosporins were routinely used for perioperative prophylaxis. Besides, the analysis of correlation between SSI and prophylactic usage of antibiotics by month was performed (as shown in Fig. 6). We found no significant associations for SSI and prophylactic usage of antibiotics (r = 0.157, P = 0.464).

Discussion

This study analyzed the SSI distribution characteristics utilizing a 2-year neurological class I incision surgery data of a tertiary comprehensive hospital from 2022 to 2023. 6046 participants and 121 SSI cases were included in the analysis. We confirmed the overall crude and NNIS risk index-adjusted SSI rate were 2.00% and 0.04%. The main infection site in our study was organ/space infection (95.04%). Additionally, the study pointed out the resection of space occupying lesions (40.34%) and the surgeon 30 and 34 (50.00%) had the topmost NNIS risk index-adjusted SSI rate. Meanwhile, the largest proportion of pathogens detected in the surgical site infected cases was Staphylococcus epidermidis (22.81%). We finally stated the most commonly used antibiotics for perioperative prophylaxis was Cefazolin (51.95%), and no significant association was found in the correlation between SSI and prophylactic usage of antibiotics (P = 0.464).

CMI represents the average DRG relative weight for the certain medical institution or department, which is capable to compare the targeted medical indicators in various healthcare institutions or departments [28]. Using CMI value could adjust the differences of medical treatment and economic expenses of different diseases and make the evaluated indicators be more scientific and comparable [29–31]. We calculated the SSI rate in 7 departments and adjusted by their CMI values. The crude and CMI-adjusted ranking differences of SSI rates mainly existed in department II, VI and ICU, indicating the true comparison of the SSI differences among departments should depend on the CMI-adjusted statistics, which had already balanced the effects of the differences of medical treatment and economic expenses in those departments.

We dissected the 121 infection case by surgical classifications and adjusted the crude SSI rate by NNIS risk index. NNIS risk index is a generously utilized tool for the assessment of SSI risk, which could comprehensively evaluate the surgical difficulty and predict the potential risk of SSI [26–27, 32]. Our analysis showed the endoscopy-assisted resection of space occupying lesions had the topmost NNIS risk index-adjusted SSI rate (13.33%) but not the highest crude SSI rate, which implied this kind of surgeries should have lower risk of infection, and more attention should be paid for the management of perioperation of such surgeries for infection control. Significantly, the highest crude SSI rate was found in hybrid operation (11.67%). Previous studies had already illustrated that hybrid operations in Neurosurgery was surgeries performed in the hybrid operating room equipped with a digital subtraction angiography system which could simultaneous conduct interventional procedures and craniotomy surgery [33–34]. Such a striking crude SSI rate could be understood because the surgical time, surgical incision, and exposure of ventricular system of

Table 3 The SSI rate of different surgical classifications stratified by NNIS risk index

Surgical classification	Total surgical cases (*n* (%))	NNIS risk index									Crude infection rate (%)	Average risk index	NNIS risk index-adjusted SSI rate (%)
		0			1			2					
		Surgical cases	Infection cases	Infection rate (%)	Surgical cases	Infection cases	Infection rate (%)	Surgical cases	Infection cases	Infection rate (%)			
Resection of space occupying lesions	3746 (61.96)	1289	16	1.24	2084	61	2.93	373	9	2.41	2.30	40.34	0.06
Skull/dural repair surgery	370 (6.12)	181	0	0.00	149	2	1.34	40	1	2.50	0.81	0.91	0.89
Electrical stimulation electrode replacement surgery	273 (4.52)	119	0	0.00	121	0	0.00	33	0	0.00	0.00	0.00	/
Craniotomy evacuation of hematoma	269 (4.45)	21	0	0.00	99	0	0.00	149	2	1.34	0.74	1.11	0.67
Arterial and venous embolization	217 (3.59)	104	0	0.00	92	3	3.26	21	2	9.52	2.30	1.47	1.57
Bone graft fusion and internal fixation surgery	216 (3.57)	81	0	0.00	119	1	0.84	16	0	0.00	0.46	0.55	0.84
Lumboperitoneal/ventricular -peritoneal shunt	145 (2.40)	83	1	1.20	58	2	3.45	4	0	0.00	2.07	1.37	1.51
Craniotomy/spinal canal decompression surgery	143 (2.37)	27	0	0.00	73	0	0.00	43	0	0.00	0.00	0.00	/
Intraventricular trepanation and drainage surgery	133 (2.20)	41	1	2.44	84	2	2.38	8	0	0.00	2.26	1.57	1.44
Endoscopy-assisted craniotomy evacuation of hematoma	122 (2.02)	11	0	0.00	77	0	0.00	34	0	0.00	0.00	0.00	/
Endoscopy-assisted craniotomy decompression surgery	108 (1.79)	53	0	0.00	51	0	0.00	4	0	0.00	0.00	0.00	/
Incarceration of aneurysm	94 (1.55)	9	0	0.00	46	5	10.87	39	4	10.26	9.57	4.11	2.33
Arterio-synagiosis surgery	73 (1.21)	20	0	0.00	34	0	0.00	19	0	0.00	0.00	0.00	/
Hybrid operation	60 (0.99)	5	0	0.00	38	6	15.79	17	1	5.88	11.67	4.08	2.86
Neurolysis surgery	34 (0.56)	19	0	0.00	14	0	0.00	1	0	0.00	0.00	0.00	/
Endoscopy-assisted resection of space occupying lesions	26 (0.43)	11	0	0.00	10	1	10.00	5	1	20.00	7.69	0.58	13.33
Internal fixation device implantation/removal surgery	17 (0.28)	13	0	0.00	4	0	0.00	0	0	/	0.00	0.00	/
In total	6046 (100)	2087	18	0.86	3153	83	2.63	806	20	2.48	2.00	52.16	0.04

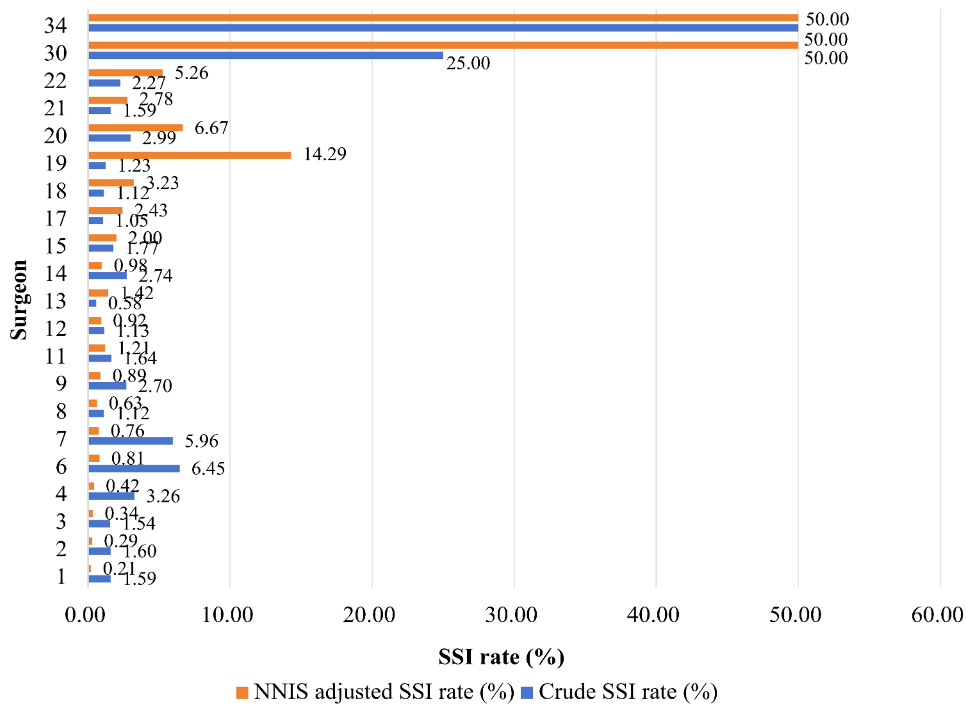

Fig. 4 The crude SSI rate and NNIS risk index-adjusted SSI rate of surgeons

Table 4 The distribution of pathogens

Pathogen		*n* (%)
Gram-positive bacteria	Staphylococcus epidermidis	13 (22.81)
	Staphylococcus capitis	10 (17.54)
	Staphylococcus hominis	9 (15.79)
	Staphylococcus cohnii	2 (3.51)
	Corynebacterium	1 (1.75)
	Staphylococcus caprae	1 (1.75)
	Micrococcus luteus	1 (1.75)
	Micrococcus lylae	1 (1.75)
	Microbacterium	1 (1.75)
	Staphylococcus haemolyticus	3 (5.26)
	Acinetobacter baumannii	3 (5.26)
Gram-negative bacteria	Klebsiella pneumoniae	3 (5.26)
	Pantoea agglomerans	1 (1.75)
	Klebsiella aerogenes	1 (1.75)
	Chryseobacterium gleum	1 (1.75)
	Adhesive sphingomonas	1 (1.75)
	Serratia marcescens	1 (1.75)
	Sphingomonas paucimobilis	1 (1.75)
	Enterobacter cloacae	1 (1.75)
	Rothia mucilaginosa	1 (1.75)
Fungus	Fusarium	1 (1.75)
In total		57 (100)

such surgeries would be relatively long [34]. Our study also found the higher proportion of these surgeries was categorized into score 1 (38 of 60) and score 2 (17 of 60) of the NNIS risk index categories, indicating the quite high level of surgical complexity of hybrid operations. Therefore, it was reasonable that the adjusted SSI rate would soon see a decrease after the NNIS risk index adjustment. However, the further infection control measurement should be implemented for both endoscopy-assisted resection of space occupying lesions and hybrid operations to reduce the overall high SSI.

The analysis also classified the 121 infections by surgeons, and adjusted the SSI rates by NNIS risk index. Our results showed 21 of 54 surgeons had SSI occurred after surgery. The highest crude and NNIS risk index-adjusted SSI rates were both observed in surgeon 34 (50.00%), who had a total of 2 cases of Intraventricular trepanation and drainage surgery (NNIS risk index = score 1), with 1 case of infection occurred. The highest NNIS risk index-adjusted SSI rate was also seen in surgeon 30 (50%), who totally performed 3 cases of Arterial and venous embolization surgery (NNIS risk index of 2 cases = score 1,NNIS risk index of 1 cases = score 0)and 1 case of intraventricular trepanation and drainage surgery (infected, NNIS risk index = score 0). The above statistics implicated the necessity of infection surveillance should be proceeded on these 2 surgeons to decline the high NNIS risk index-adjusted SSI rate. The further SSI surveillance of the entire procedures of surgeries operated by surgeon 30 and 34 would be conducted consecutively to identify potential risk factors for infection and intervene accordingly. The surveillance indicators should include but not limit to surgical follow-up, reviewing surgical videos, surgical hand hygiene monitoring, etc.

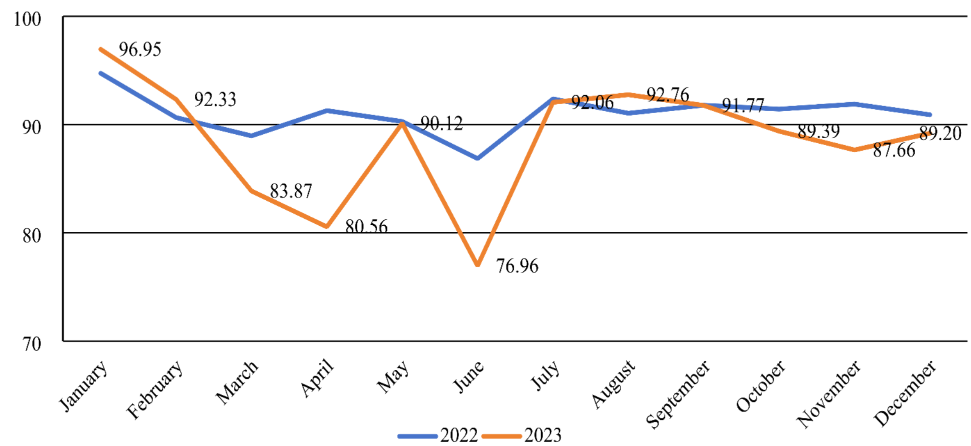

Fig. 5 Perioperative prophylactic usage rate of antibiotics of class I incision surgery

Our study confirmed 2.00% of the crude SSI, the majority of infection sites were organ/space infection. Such a result was similar to other previous studies [14, 15, 16, 17, 35–36]. We calculated 0.04% of the NNIS risk index-adjusted SSI rate, but seldom NNIS risk index-adjusted SSI rate of neurological surgery was found in recently historical research. In addition, the main pathogenic results of this study were staphylococcus epidermidis ($n=13$, 22.81%). The dissimilar result was found in former research, which found the staphylococcus aureus were the major pathogen in SSI of neurological surgery [37–38]. Similar distribution was found in a former study, which illustrated the staphylococcus epidermidis mainly existed in the healthcare-associated infection (HAI) of Neurosurgery (23.00%) [39]. As a conditional pathogen for HAI, the staphylococcus epidermidis is the most commonly seen coagulase-negative staphylococcusclinical in clinical practice [40–41]. The invasive procedures such as craniotomy, drainage, and intubation in neurological surgeries would create favorable conditions for the infection of Staphylococcus epidermidis [42–43]. We suggested the strict management of surgical hand hygiene, the monitoring of the environment in operating rooms and wards, and the rigorous aseptic operation techniques should be processed to prevent and control the infection of Staphylococcus epidermidis.

Meanwhile, the analysis of distribution of perioperative prophypactic usage of antibiotics revealed the most commonly used antibiotics was Cefazolin ($n=4170$, 51.95%), whic was in line with the Guidelines for clinical application of antibacterial drugs in China [44]. We also performed the correlation analysis of SSI and perioperative prophypactic usage rate of antibiotics and no significant association was found ($r=0.157$, $P=0.464$). The statistical significance did not mean practical significance, more statistics should be involved for the next-step correlation analysis.

This study had a relatively large sample size. The data were extracted from a large comprehensive tertiary hospital, which had a plenty of neurological surgeries in the past decades for research. The Neurosurgery in our institution was an advantageous discipline with the great medical reputation and prominent surgical techniques reaching the leading level in China. Besides, our institution had the excellent construction of informational systems, which could allow us to extract the relatively accurate and complete information of surgical data. Due to the substantial sample sizes, the well developed informational systems, as well as the matured and diverse neurological surgeries conducted in our institution, our analysis of SSI characteristics could be generalized and provide certain reference in this field to some extent. However, our study had several limitations. Firstly, we did not conduct surveillance of SSI after discharge, the SSI rate might be underestimated result from the infection bias of the partly lost data. Secondly, this study only analyzed the distribution of antibiotics used within 48 h of surgery. Neither the duration of prophylactic use of antibiotics nor the duration and type of therapeutic use of antibiotics was monitored in our study. Those were also vital indicators for the evaluation of infection, which should be further analyzed in the next research. Additionally, at the beginning of sampling, we excluded 6.28% (405 of 6451) of the participants due to the misclassification of surgical incisional class and the missing of the surgical time and ASA score. Although no infection was found in this proportion of participants, possible impacts of overestimation or underestimation might exist for the evaluation of SSI rate. Meanwhile, the sampling rule of our study was set as extracting surgeries by class I incision. Despite of the relatively cautious systems, the selection bias might occurred and potentially leading to high or low infection rates because of the misclassification of surgical incisions such as misclassified class I into class 0, or leaving the column blank. More quality control of data

Table 5 The distribution of perioperative prophylactic antibiotics type

Antibiotics type		n (%)
First generation cephalosporins	Cefazolin	4170 (51.95)
Second generation cephalosporins	Cefuroxime	1060 (13.21)
	Cefoxitin	3 (0.04)
Third generation cephalosporins	Cefoperazone sulbactam	633 (7.89)
	Ceftriaxone	233 (2.90)
	Ceftazidime	143 (1.78)
	Cefdinir	9 (0.11)
	Cefixime	7 (0.09)
	Cefotaxime	1 (0.01)
Glycopeptides	Vancomycin	553 (6.89)
	Norvancomycin	31 (0.39)
Carbapenems	Meropenem	326 (4.06)
	Biapenem	89 (1.11)
	Imipenem cilastatin	43 (0.54)
Penicillins	Oxacillin	255 (3.18)
	Penicillin	4 (0.05)
	Amoxicillin	1 (0.01)
Quinolones	Levofloxacin	136 (1.69)
	Moxifloxacin	80 (1.00)
	Piperacillin tazobactam	55 (0.69)
Penicillin compound preparation	Amoxicilin sodium and clavulanate potassium	33 (0.41)
	Sitafloxacin	5 (0.06)
Oxazolidinones	Linezolid	66 (0.82)
Aminoglycosides	Amikacin	15 (0.19)
	Gentamicin	5 (0.06)
Tetracyclines	Tigecycline	16 (0.20)
Lincosamides	Clindamycin	16 (0.20)
Antifungal agents	Voriconazole	8 (0.10)
	Fluconazole	5 (0.06)
	Caspofungin	2 (0.02)
Imidazole derivatives	Ornidazole	8 (0.10)
	Metronidazole	3 (0.04)
	Levononidazole	2 (0.02)
Oxacephems	Moxalactam	5 (0.06)
Polymyxins	Polymyxin B	3 (0.04)
Macrolides	Azithromycin	3 (0.04)
In total		8027 (100)

accuracy was required in the next step research. Moreover, our study was a retrospective descriptive analysis for the distribution characteristics of SSIs, we did not refer to causal analysis or any risk assessment. Subsequent prospective cohort study or clinical trail would be preferred for the further exploration of causality of SSIs and any risk indicators. Lastly, forward in-depth research should be performed to consecutively monitor the environments of operating rooms and wards, and more attention should be paid on the process indicators of perioperation including but not limited to the qualification rate of preoperative skin preparation, the incidence rate of postoperative pneumonia, and the use rate of antibiotics 0.5–1 h before surgery.

Conclusions

SSIs of neurological surgery had substantial medical burdens and economic costs for both patients and healthcare institutions. This study illustrated the infection characteristics of class I incision in neurological surgery using a 2-year retrospective data. The adjusted tools of CMI value and NNIS risk index were utilized for the comparison of SSIs by different departments, various surgical classifications, and multiple surgeons. We confirmed 2.00% of the overall crude SSI rate and 0.04% of the overall NNIS risk index-adjusted SSI rate in our study. The main infection were found among surgeries with score 1 of NNIS risk index and the surgical classification of endoscopy-assisted resection of space occupying lesions. The main pathogenic result was found to be staphylococcus epidermidis, and the most commonly used antibiotics for perioperative prophylaxis was Cefazolin. Further surveillance of surgeons and surgeries with high SSI rates should be conducted to detect potential risk factors and intervene consecutively. We expected our study could provide clinical indications and infection control guidance for the purpose of control and prevention of SSIs in Neurosurgery.

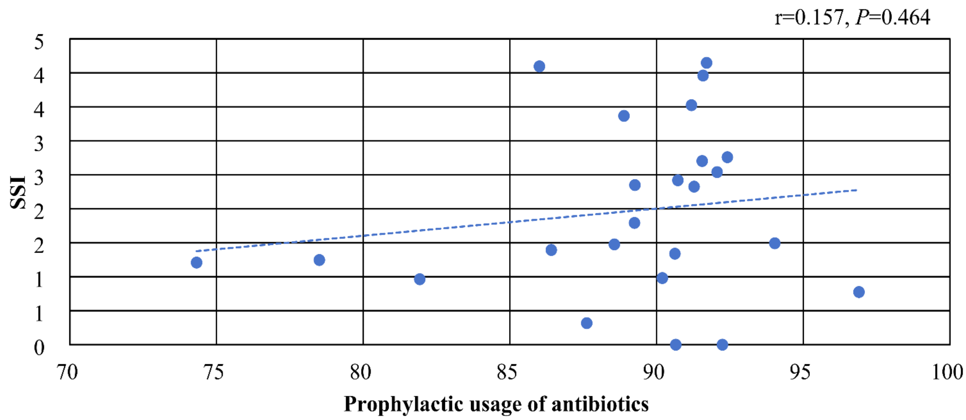

Fig. 6 The correlation between SSI and prophylactic usage of antibiotics

Supplementary Information

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Supplementary Material 1

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Not applicable.

Author contributions

Y.L. (Yifei Li) and L.G. contributed equally to this work. Y.L. (Yifei Li), L.G. and S.F. (Shanhong Fan) conceptualized and designed the study. Y.L. (Yifei Li) and L.G. performed the data analysis and have full access to all the data in this study, taking responsibility for the integrity of the data and the accuracy of the data analysis. Y.L. (Yifei Li) and L.G. drafted the manuscript and were the major contributors in writing the manuscript. S.F. (Shanhong Fan) provided supervision of the project. Y.L. (Yifei Li), L.G. and S.F. (Shanhong Fan) contributed to the data interpretation and revision of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The ethic committee of our institution (IEC of Institution for National Drug Clinical Trials, Tangdu Hospital, Fourth Military Medical University) approved the study, and all participants signed the informed consent at the time of participation.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trail number

Not applicable.

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