Infectious Medicine 3 (2024) 100103

Contents lists available at ScienceDirect

Infectious Medicine

journal homepage: www.elsevier.com/locate/imj

Original Article

Temporal patterns and clinical characteristics of healthcare-associated infections in surgery patients: A retrospective study in a major Chinese tertiary hospital

Tianyi Zhang[a,1], Li Yan[b,1], Shan Wang[c,1], Ming Chen[d,e], Yunda Jiao[a], Zhuoqi Sheng[a], Jianchao Liu[a,f,*], Lihua Liu[a,*]

[a] Institution of Hospital Management, Department of Medical Innovation and Research, Chinese PLA General Hospital, Beijing 100853, China
[b] Cadet Company One, Graduate School of Chinese PLA General Hospital, Beijing 100853, China
[c] Department of Medical Innovation and Research, Chinese PLA General Hospital, Beijing 100853, China
[d] Department of Orthopedics, Chinese PLA General Hospital, Beijing 100853, China
[e] National Clinical Research Center for Orthopedics, Sports Medicine & Rehabilitation, Beijing 100853, China
[f] School of Humanities and Social Sciences, North China Electric Power University, Beijing 102206, China

ARTICLE INFO

Keywords:
Healthcare-associated infections
Time series
Surgery
Public hospital

ABSTRACT

Background: Given the preventable nature of most healthcare-associated infections (HAIs), it is crucial to understand their characteristics and temporal patterns to reduce their occurrence.
Methods: A retrospective analysis of medical record cover pages from a Chinese hospital information system was conducted for surgery inpatients from 2010 to 2019. Association rules mining (ARM) was employed to explore the association between disease, procedure, and HAIs. Joinpoint models were used to estimate the annual HAI trend. The time series of each type of HAI was decomposed to analyze the temporal patterns of HAIs.
Results: The study included data from 623,290 surgery inpatients over 10 years, and a significant decline in the HAI rate was observed. Compared with patients without HAIs, those with HAIs had a longer length of stay (29 days vs. 9 days), higher medical costs (96226.57 CNY vs. 22351.98 CNY), and an increased risk of death (6.42% vs. 0.18%). The most common diseases for each type of HAI differed, although bone marrow and spleen operations were the most frequent procedures for most HAI types. ARM detected that some uncommon diagnoses could strongly associate with HAIs. The time series pattern varied for each type of HAI, with the peak occurring in January for respiratory system infections, and in August and July for surgical site and bloodstream infections, respectively.
Conclusions: Our findings demonstrate that HAIs impose a significant burden on surgery patients. The differing time series patterns for each type of HAI highlight the importance of tailored surveillance strategies for specific types of HAI.

1. Introduction

Healthcare-associated infections (HAIs) are a significant safety concern, particularly among hospitalized patients undergoing surgical procedures [1]. The impact of HAIs is profound, leading to prolonged hospitalization, increased healthcare costs, and elevated morbidity and mortality rates, placing a substantial burden on patients and public health [2]. On average, 7%–10% of patients acquire at least one HAI during their hospital stay, with

Abbreviations: HAIs, Healthcare-Associated Infections; ARM, Association Rules Mining; HIS, Hospital Information System; LOS, Length of Stay; RSI, Respiratory System Infection; CSI, Cardiovascular System Infection; BI, Bloodstream Infection; GI, Gastrointestinal Infection; CNSI, Central Nervous System Infection; UTI, Urinary Tract Infection; SSI, Surgical Site Infection; SSTI, Skin and Soft Tissue Infection; BJI, Bone and Joint Infection; RTI, Reproductive Tract Infection; OCI, Oral Cavity Infection; MI, Multisystem Infection; BJ/SSTI, Joint/Skin and Soft Tissue Infection; URSI, Urinary and Respiratory System Infection; APC, Annual Percent Change; AAPC, Average Annual Percent Change.

* Corresponding authors.
E-mail addresses: liujianchao@301hospital.com.cn (J.C. Liu), liulihua07@yeah.net (L.H. Liu).

[1] These authors contributed equally to this article.

https://doi.org/10.1016/j.imj.2024.100103
Received 1 August 2023; Received in revised form 29 December 2023; Accepted 15 March 2024

nearly 10% of these cases resulting in mortality and 6% dying directly from HAIs [3–5]. Given the preventable nature of most HAI cases, there is a need to understand their characteristics and temporal patterns to facilitate effective surveillance and reduce their incidence [5].

Several studies have explored the seasonal variation of HAIs, but the findings have been inconsistent [6–12]. Some studies have reported a peak in HAI incidence during the summer months [6,8], while others have detected peaks during the winter, or no distinct seasonal pattern [6,9,10]. These discrepancies may be attributed to differences in the regions, populations, and HAI types studied, as well as variations in the methods employed [11,12]. Some studies have divided the year into seasons or quarters and compared HAI rates between different periods. However, the occurrence of HAIs may vary significantly from month to month [11,12], and combining several months into one group may obscure the periodic pattern of HAI incidence.

Hitherto, previous studies on HAIs in China have primarily relied on point prevalence surveys and real-time surveillance systems [12,13] with few data on HAIs reported in the cover pages of medical records, which serve as the primary data source for assessing the performance of public hospitals in China. Thus, in this study, we aimed to: describe the features of HAIs; identify the most frequent diseases and surgical procedures among patients with HAIs; and explore the association between diagnosis, procedure, and HAI using association rules mining (ARM). We also aimed to estimate the incidence trend of HAIs and visualize the temporal pattern for each type of HAI, leveraging hospital information system data from a tertiary hospital in China between 2010 and 2019. By doing so, we hope to provide insights that will enable the development of targeted interventions to reduce the burden of HAIs and improve the quality of surgical care in China.

2. Methods

2.1. Data source and collection

Data were taken from the cover page of medical records in a hospital information system (HIS) in a hospital in Beijing that has over 3800 beds. Inpatients who underwent surgery and were discharged between January 1, 2009 and December 31, 2019 were included in our study. Data from inpatients' information were retrospectively reviewed and analyzed, including age, gender, length of stay (LOS), costs, primary discharge diagnosis, HAI, primary procedures, surgical wound class, and wound healing grade. The surgical wound class included: 1) aseptic wounds, such as thyroidectomy; 2) contaminated wounds, such as gastrectomy; and 3) dirty-infected wounds, such as the resection of tuberculous abscess of sinus [14,15]. Wound healing was classified into three grades: 1) well healed; 2) poorly healed but not purulent, such as a wound with hematoma; and 3) purulent. The terms used for diagnoses and procedures were coded based on the *International Classification of Diseases, Tenth Revision* (ICD10) and the *International Classification of Diseases, Ninth Revision, Clinical Modification, Third volume* (ICD9-CM3), respectively.

The information on inpatients was de-identified; therefore, institutional review board approval was waived.

2.2. HAI definition

HAIs were defined as an infection acquired by inpatients in the hospital, occurring either during hospitalization or after discharge from hospital, based on the Nosocomial Infection Diagnostic Criteria (2001) published by the National Health Commission of the People's Republic of China [16]. It includes the following situations: 1) infections occurring 48 hours after admission or the average incubation period; 2) infections related to the last hospitalization; 3) new infections occurring on the sites other than original infection, or the isolation of new pathogens on the original infection; 4) infections acquired by neonates during and after delivery; and 5) potential infections activated by diagnosis and treatment measures. Further, we incorporated the definition of surgical site infection based on the performance measurement for national tertiary public hospitals into the scope of HAIs, specifically classifying purulent aseptic surgical wounds as surgical site infections. The following cases were excluded from the scope of HAIs: 1) open wounds with bacterial colonization but without inflammation; 2) acute attacks of chorionic infection; 3) neonatal transplacental infection; and 4) inflammation caused by trauma or abiotic factors. According to the Nosocomial Infection Diagnostic Criteria (2001), we further classified HAIs into 13 categories: 1) respiratory system infection (RSI); 2) cardiovascular system infection (CSI); 3) bloodstream infection (BI); 4) gastrointestinal infection (GI); 5) central nervous system infection (CNSI); 6) urinary tract infection (UTI); 7) surgical site infection (SSI); 8) skin and soft tissue infection (SSTI); 9) bone and joint infection (BJI); 10) reproductive tract infection (RTI); 11) oral cavity infection (OCI); 12) others; and 13) multisystem infection (MI, if an inpatient had more than one infection) [16]. Given the limited number of patients with BJI and RTI, we incorporated BJI into SSTI to form the bone and joint/skin and soft tissue infection (BJ/SSTI) category and combined RTI with UTI to form the urinary and reproductive system infection (URSI) category.

2.3. Statistical analysis

First, we categorized the included inpatients as either patients with HAI or patients without HAI. The characteristics of the patients in the two groups were then described and compared. Continuous variables were expressed as mean ± standard deviation or median (first quartile, second quartile) and compared using the Student's t test or Wilcoxon's rank sum test based on the distribution of the data. Categorical variables were expressed as count (percentage) and compared using the chi-square test. Given the large sample size, p values were sufficient for most statistical tests to indicate significant differences; we also used effect size to estimate the difference between two groups, using Cramer's V and Cohen's d for nominal and continuous variables, respectively. Annual percent change (APC) and average annual percent change (AAPC) were calculated to test the temporal trend of the HAI rate from 2010 to 2019 using a Joinpoint model. Second, we described and compared the specific characteristics of various types of HAI. The most common primary disease diagnoses (based on three-digit ICD10-CM codes) and procedures (based on two-digit ICD9-CM3 codes) in each type of HAI were summarized. Furthermore, we identified the top 10 procedures with the highest HAI rates, to suggest the focus for monitoring the HAIs in surgical care. In addition, we used ARM to detect the association between diagnoses, procedures, and HAIs. Three parameters needed to be set to identify the association rules ($X \rightarrow Y$, in which X is the left-hand side and Y is the right-hand side):

- Support($X \rightarrow Y$) means the co-occurrence frequency of X and Y; for example, the co-occurrence frequency of the disease or procedure and HAI:

$$\text{support}(X \rightarrow Y) = P(X, Y), \tag{1}$$

- Confidence($X \rightarrow Y$) means the frequency of Y in the patients with X; for example, the frequency of HAI in the patients with X disease or procedure:

$$\text{confidence}(X \rightarrow Y) = P(Y|X) = \frac{P(X, Y)}{P(X)}, \tag{2}$$

- Lift($X \rightarrow Y$) means the ratio of $P(Y|X)$ to $P(Y)$:

$$\text{lift}(X \rightarrow Y) = \frac{P(Y|X)}{P(Y)} = \frac{P(X, Y)}{P(X)P(Y)}. \tag{3}$$

The thresholds for support, confidence, and lift were $3/N$ (where N is sample size), 0.05 and 1, respectively. Finally, to further explore the temporal pattern of each type of HAI, we decomposed the time series of each HAI type into three components: 1) overall trend; 2) seasonal trend, and 3) random fluctuation, using an additive model. All the components of the time series for each HAI type were visualized. Joinpoint 5.0.2 software was used to calculate APC and AAPC. Other statistical analyses were performed using R4.0.2 software.

3. Results

3.1. Temporal trend in HAI rate

Data were included from a total of 623,290 inpatients who underwent surgical procedures between 2010 and 2019. Of these, 2506 (4.02‰) patients developed HAIs. The HAI rate experienced a peak in 2013 (8.64‰) and dropped significantly after that. On average, the HAI rate decreased with a significant trend, from 5.05‰ in 2010 to 1.46‰ in 2019 (AAPC: −14.29%; 95% confidence interval (CI): −20.38%, −9.34%) (Fig. 1). Significant decreases were also observed in the rates of all types of HAI from 2010 to 2019, except for CNSI, SSI and OCI (Table 1).

3.2. Patient characteristics and outcomes by HAI status

Compared with patients without HAI, the proportion of males was relatively higher among patients who developed HAI (Table 2). HAI was associated with poorly healed and purulent wounds, and higher mortality rates (Table 2). The costs and LOS were much larger and longer, respectively, in patients with HAI than those without HAI

Table 1
The rate and average annual percent change of each kind of HAIs from 2010 to 2019.

	Rate (‰)										APCC (%, 95% CI)
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
ALL HAIs	5.05	6.41	4.98	8.64	5.86	4.15	2.43	1.88	1.98	1.46	−14.3 (−20.4, −9.3)
RSI	2.61	3.37	2.06	4.07	2.65	1.58	0.95	0.72	0.64	0.39	−19.7 (−26.9, −14.4)
BI	0.21	0.45	0.47	0.48	0.45	0.33	0.21	0.06	0.05	0.08	−16.0 (−31.4, −5.6)
GI	0.28	0.38	0.58	0.77	0.43	0.35	0.21	0.07	0.07	0.08	−16.8 (−23.2, −12.0)
CNSI	0.21	0.21	0.09	0.25	0.10	0.09	0.06	0.01	0.12	0.09	−10.0 (−23.6, 2.1)
URSI	0.23	0.37	0.10	0.40	0.31	0.24	0.15	0.03	0.05	0.07	−18.2 (−35.5, −6.5)
SSI	0.76	0.42	0.61	0.71	0.40	0.50	0.42	0.55	0.55	0.47	−3.0 (−9.1, 3.8)
BJ/SSTI	0.06	0.19	0.03	0.15	0.19	0.06	0.03	0.01	0.00	0.01	−29.14 (−55.52, −14.55)
OCI	0.02	0.12	0.03	0.19	0.14	0.14	0.00	0.00	0.00	0.00	−47.1 (−90.5, 3.7)
MI	0.15	0.19	0.05	0.13	0.12	0.06	0.04	0.01	0.03	0.01	−21.54 (−38.00, −9.60)
Others	0.51	0.70	0.94	1.49	1.07	0.80	0.37	0.41	0.46	0.24	−6.95 (−12.78, −0.82)

Abbreviation: HAIs, Healthcare-associated infections; RSI, Respiratory system infection; BI, Bloodstream infection; GI, Gastrointestinal infection; CNSI, Central nervous system infection; URSI, Urinary and reproductive infection; SSI, Surgical site infection; BJ/SSTI, Bone and joint/Skin and soft tissue infection; OCI, Oral cavity infection; MI, Multiple infection; APCC, Average annual percent change.

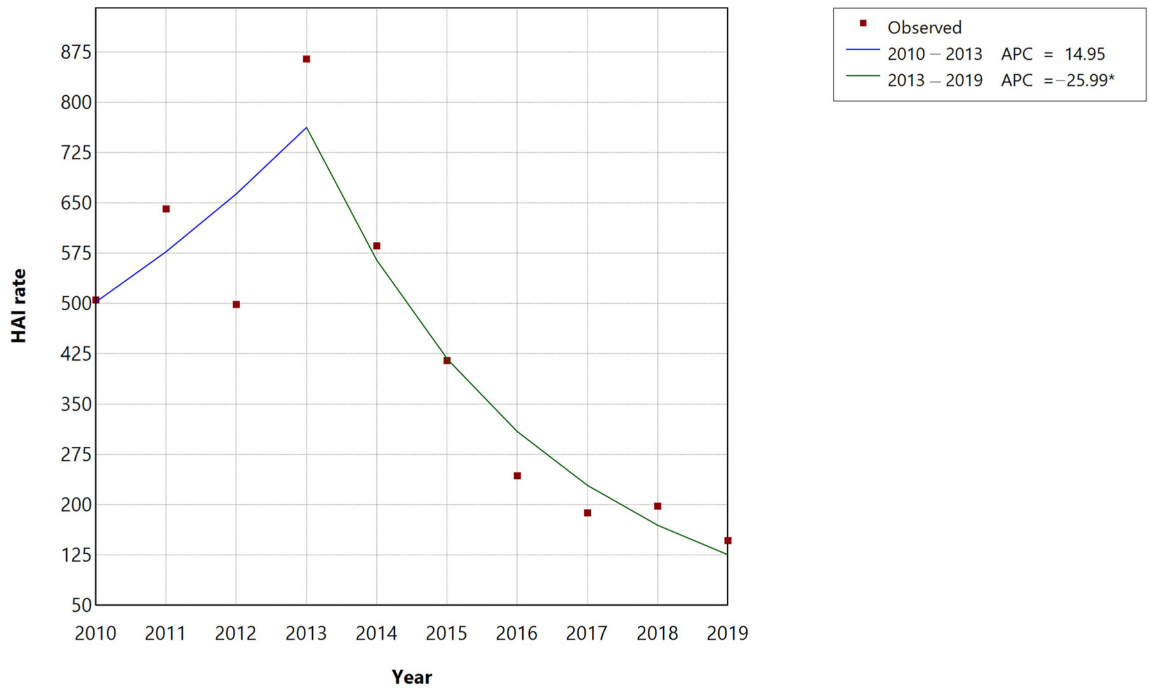

Fig. 1. Temporal rate of HAIs in patients who underwent surgical procedures from 2010 to 2019. The trend of HAI rate can be group into two segments, joined at 2013. The overall HAI rate experienced a peak in the 2013. After 2013, the HAI rate dropped significantly with an APC of −25.99% (95% CI: −36.23%, −20.79%). On average, the HAI rate had a significant decreasing trend from 2010 to 2019 with an AAPC of −14.29% (95% CI: −20.38%, −9.34%). AAPC, average annual percentage change; CI, confidence interval; HAI, healthcare-associated infection. * Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level. Test statistic and *p*-value not available for the Empirical Quantile method. Final Selected Model: 1Joinpoint.

(Table 2). Patients with SSIs had the highest proportion of poorly healed and purulent wounds. Patients with MIs had the longest LOS and the highest medical costs and mortality rates (Table S1).

3.3. Diseases and surgical procedures associated with HAIs

As shown in Table 3, RSIs (43.74%) were the most common HAIs. For RSIs, the most frequently reported disease diagnosis and surgical procedure were acute upper respiratory infection of multiple and unspecified sites, and operations on bone marrow and spleen, respectively. The top three surgical procedures with the highest HAI rate were: operations on bone marrow and spleen (7.67%); operations on larynx and trachea (3.23%); and operations on chest wall, pleura, mediastinum, and diaphragm (1.22%) (Table S2). RSI was also found to be the most common type of HAI for these top three procedures (Table S2). Eight association rules were found by ARM (Table 4 and Fig. S1) which showed that some less-frequent diagnoses were strongly associated with HAIs. For example, patients with acute tonsillitis who underwent operations on bone marrow and spleen had a high probability of suffering from RSIs.

3.4. Time series of HAIs

The time series plot showed a seasonal trend for the rate of RSI, BI, and SSI. The temporal pattern of each type of HAI was different: RSI peaked in January of each year; for BI the peak was reached in July, and for SSI the peak was in August (Fig. 2).

4. Discussion

This study described and analyzed the pattern of HAIs in patients who underwent surgery during a 10-year period. Our findings revealed a significant downward trend in the HAI rate between 2010 and 2019, with the exception of a peak in 2013. The peak in 2013 may be related to the outbreak of avian influenza in China in the same year [17]. The overall decline in HAI rates was consistent with the previous study by Zhang et al. [12]. The effective implementation of an infection surveillance system in this hospital since 2010 may have contributed to this significant downward trend. As reported by Haley et al., an intensive infection surveillance and control program is strongly associated with a reduction in the rate of HAIs [18].

Our study highlights the substantial medical burden of HAIs, with surgical patients experiencing almost three times the LOS and five times the cost of hospitalization compared with general inpatients [19–21]. The longer LOS and higher medical costs associated with HAIs in surgical patients suggest a significant impact on patients who are already sensitized by surgery. Patients with MIs, had the longest LOS and highest medical costs. Mortality rates were also much higher among patients with HAIs

Table 2
Characteristics according to HAI status.

	Non-HAI (N = 620,784)	HAI (N = 2506)	Effect size	p value
Male, n (%)	320,184 (51.58)	1509 (60.22)	0.01	<0.0001
Age (median, IQR)	51 (37, 62)	52 (34, 65)	0.01	0.0977
Year, n (%)				
2010	46,877 (7.55)	238 (9.50)	0.03	<0.0001
2011	56,894 (9.16)	367 (14.64)		
2012	56,919 (9.17)	285 (11.37)		
2013	51,835 (8.35)	452 (18.04)		
2014	57,708 (9.30)	340 (13.57)		
2015	65,752 (10.59)	274 (10.93)		
2016	67,273 (10.84)	164 (6.54)		
2017	70,679 (11.39)	133 (5.31)		
2018	73,142 (11.78)	145 (5.79)		
2019	73,705 (11.87)	108 (4.31)		
Surgical wound class, n (%)				
Aseptic	308,295 (49.66)	1584 (63.21)	0.03	<0.0001
Contaminated	218,548 (35.21)	390 (15.56)		
Dirty-infected	14,676 (2.36)	50 (2.00)		
No incision or not reported	79,265 (12.77)	482 (19.23)		
Wound healing grade, n (%)				
Well	485,316 (78.18)	1594 (63.61)	0.20	<0.0001
Poor but not purulent	2555 (0.41)	108 (4.31)		
Purulent	386 (0.06)	255 (10.18)		
Others or not reported	132,527 (21.35)	549 (21.91)		
Death, n (%)	1138 (0.18)	161 (6.42)	0.09	<0.0001
Costs (median, IQR, CNY)	22,351.98 (10,476.56, 57,287.17)	96,226.57 (50,362.02, 178,540.31)	2.37	<0.0001
Length of stay (median, IQR, Days)	9 (5, 14)	29 (19, 43)	2.54	<0.0001

Abbreviation: HAIs, Healthcare-associated infections.
Note: Effect size: Cramér's V and Cohen's d were used to estimate the effect size for the nominal and continuous variables, respectively. The cut offs for effect size were small (0.2), medium (0.5) and large (0.8).

than those without, with the highest risk of death also observed in patients with MIs. These findings underscore the importance of effective prevention and management strategies, particularly for MIs.

Consistent with previous studies, RSI accounted for the majority of HAIs, while the proportions of URTI and BI were lower than in other reports [12,13,22]. This discrepancy may be due to the uncoded names of HAIs in the medical records, resulting in some being categorized vaguely as "Others". The most common diagnoses among patients with RSI were respiratory system diseases, with bone marrow and spleen operations being the most frequent surgical procedures. These diagnoses and procedures may impair the immune system, putting patients at greater risk of infection. Our use of ARM revealed strong associations between some infrequent diseases and HAIs. For example, patients with acute tonsillitis who underwent bone marrow and spleen operations were more likely to suffer from RSI, possibly due to the combined immune-impairing effects of both conditions.

Our study also examined the time series patterns for each type of HAI, revealing differing trends among them. In the case of RSI, the peak of infection occurred in January during the winter season, which could be attributed to the cold and dry weather prevalent in northern China during this period. These environmental conditions may enhance the stability and transmission of respiratory viruses while weakening the host immune system, thereby rendering patients more susceptible to RSI [23]. Conversely, for BI and SSI, the peak was in the summer season. The higher ambient temperature and relative humidity during summer may facilitate the colonization and transmission of pathogens such as *Acinetobacter, E. coli*, and *Staphylococcus aureus*, thereby increasing the risk of acquiring BI and SSI [24–27]. These diverse time series patterns observed among different types of HAIs may help explain the inconsistencies found in previous studies regarding the seasonal peaks of HAIs [10,12]. Geographical regional differences may also contribute to such discrepancies. For instance, our findings on the SSI peak in the summer are consistent with those of a previous study conducted in northern China [12]whereas a study in the US reported a winter peak [6], and another study in southern China observed no seasonal variation [10]. These results suggest that surveillance efforts should focus on specific types of HAI during different time periods, based on the infection peak of each HAI type. This approach would enable the effective allocation of resources and the development of tailored prevention strategies. Furthermore, clinicians should be aware of the risk of seasonal variability in HAIs, which can guide the administration of potentially specific antibiotic treatments.

There are several limitations in our study. First, the information about HAIs in the cover pages of medical records was spontaneously reported by physicians, leading to a lower HAI rate compared with data from point prevalence surveys [22] or real-time surveillance systems [12]. However, the characteristics of HAIs in this study were similar to those reported in other studies for the most common types of HAI. Second, as mentioned above,

Table 3
Most frequent disease and procedures associated with each type of HAI.

	N (%)	Most frequent procedure	Most frequent disease
Respiratory System Infection (RSI)	1096 (43.74)	Operations on bone marrow and spleen (484); Operations on vessels of heart (71); Incision and excision of skull, brain, and cerebral meninges (53); Operations on esophagus (43); Repair and plastic operations on joint structure (40); Operations on chest wall, pleura, mediastinum, and diaphragm (39); Other operations on larynx and trachea (275); Incision and excision of stomach (21); Incision, excision, and anastomosis of intestine (20); Excision of lung and bronchus (18)	Acute upper respiratory infections of multiple and unspecified sites (95); Transplanted organ and tissue status (68); Choronic ischaemic heart disease (63); Bacterial pneumonia, not elsewhere classified (55); Pneumonia, unspecified organism (51); Essential (primary) hypertension (47); Lymphoid leukaemia (28); Non-insulin-dependent diabetes mellitus (23); Other respiratory disorders (20); Candidiasis (16)
Bloodstream Infection (BI)	164 (6.54)	Operations on bone marrow and spleen (77); Operations on gallbladder and biliary tract (17); Operations on liver (9); Other incision and excision of uterus (8); Operations on vessels of heart (7); Incision, excision, and anastomosis of intestine (5); Operations on pancreas (5); Operations on esophagus (5); Other operations on larynx and trachea (4); Incision, excision, and occulsion of vessels (4)	Other septicaemia (14); Transplanted organ and tissue status (9); Bacterial infection of unspecified site (7); Myeloid leukaemia (6); Monocytic leukaemia (5); Cholelithiasis (5); Other postsurgical states (5); Non-insulin-dependent diabetes mellitus (4); Fibrosis and cirrhosis of liver (5); Pneumonia, unspecified organism (4)
Gastrointestinal Infection (GI)	186 (7.42)	Operations on bone marrow and spleen (60); Operations on liver (26); Operations on gallbladder and biliary tract (24); Operations on pancreas (16); Incision, excision, and anastomosis of intestine (11); Other operations on stomach (9); Other operations on abdominal region (8); Operations on vessels of heart (7); Operations on esophagus (6); Incision and excision of stomach (4)	Other diseases of biliary tract (19); Other postsurgical states (11); Secondary maliganat neoplasm of respiratory and digestive organs (10); Chronic ischaemic heart diseases (7); Other postsurgical states (7); Gastritis and duodenitis (6); Cholelithiasis (5); Pneumonia, unspecified organism (5); Noninfective enteritis and colitis (5); Infectious gastroenteritis and colitis, unspecified (5); Essential (primary) hypertension (5)
Central Nervous System Infection (CNSI)	73 (2.91)	Incision and excision of skull, brain, and cerebral meninges (43); Operations on other endocrine glands (16); Other operations on skull, brain, and cerebral meninges (4); Operations on spinal cord and spinal canal structures (3); Incision, excision, and occulsion of vessels (2); Other operations on vessels (2); Repair and plastic operations on joint structure (1); Operations on cranial and peripheral nerves (1); Incision, excision, and division of other bones (1)	Complications of procedures, not elsewhere classified (14); Encephalitis, myelitis and encephalomyelitis (6); Essential (primary) hypertension (4); Hypofunction and other disorders of the pituitary gland (3); Epilepsy (3); Postprocedural disorders of nervous system (2)
Urinary and Reproductive System Infection (URSI)	114 (4.55)	Operations on bone marrow and spleen (15); Other incision and excision of uterus (15); Operations on vessels of heart (9); Other operations on larynx and trachea (8); Operations on urinary bladder (5); Incision and excision of skull, brain, and cerebral meninges (5); Operations on chest wall, pleura, mediastinum, and diaphragm (5); Incision, excision, and anastomosis of intestine (4); Other operaions on lung and bronchus (4); Operations on spinal cord and spinal canal structures (4)	Choronic ischaemic heart disease (8); Other disorders of urinary system (8); Leiomyoma of uterus (6); Complications of procedures, not elsewhere classified (4); Other postsurgical states (4); Non-insulin-dependent diabetes mellitus (3); Respiratory failure, not elsewhere classified (3); Candidiasis (3); Bacterial pneumonia, not elsewhere classified (3); Hydrocephalus (2)
Surgical Site Infection (SSI)	330 (13.17)	Repair and plastic operations on joint structure (60); Incision and excision of joint structures (34); Operations on gallbladder and biliary tract (21); Incision, excision, and division of other bones (18); Operations on pancreas (13); Incision, excision, and anastomosis of intestine (12); Incision and excision of skull, brain, and cerebral meninges (12); Operations on thyroid and parathyroid glands (11); Operations on liver (10); Operations on skin and subcutaneous tissue (10)	Complications of procedures, not elsewhere classified (14); Other postsurgical states (12); Non-insulin-dependent diabetes mellitus (11); Essential (primary) hypertension (10); Choronic ischaemic heart disease (9); Cholelithiasis (7); Other diseases of biliary tract (5); Presence of other functional implants (5); Secondary and unspecified malignant neoplasm of lymph nodes (5); Other intervertebral disc disorders (4)
Bone and Joint/Skin and Soft Tissue Infection ((BJ/SSTI))	43 (1.72)	Operations on bone marrow and spleen (25); Repair and plastic operations on joint structures (3); Operations on skin and subcutaneous tissue (3); Incision, excision, and anastomosis of intestine (2); Operations on muscle, tendon, fascia, and bursa, except hand (2)	Other local infections of skin and subcutaneous tissue (4); Transplanted organ and tissue status (3); Monocytic leukaemia (2); Non-insulin-dependent diabetes mellitus (2); Cellulitis (2); Abscess of anal and rectal regions (2); Fissure and fistula of anal and rectal regions (2); Other septicaemia (2); Essential (primary) hypertension (2)
Oral Cavity Infection (OCI)	37 (1.48)	Operations on bone marrow and spleen (33); Operations on facial bones and joints (1); Operations on esophagus (1); Operations on chest wall, pleura, mediastinum, and diaphragm (1); Other incision and excision of uterus (1)	Transplanted organ and tissue status (5); Stomatitis and related lesions (4); Lymphoid leukaemia (3); Essential (primary) hypertension (3); Other neoplasms of uncertain behavior of lymphoid, hematopoietic and related tissue (2); Other postsurgical states (2); Gingivitis and periodontal diseases (2)
Multisystem Infection (MI)	46 (1.84)	Operations on gallbladder and biliary tract (6); Incision, excision, and anastomosis of intestine (4); Incision and excision of skull, brain, and cerebral meninges (4); Operations on bone marrow and spleen (3); Operations on pancreas (3); Operations on urinary bladder (2); Operations on muscle, tendon, fascia, and bursa, except hand (2); Operations on other endocrine glands (2); Operations on chest wall, pleura, mediastinum, and diaphragm (2)	Cholelithiasis (3); Choronic ischaemic heart disease (3); Secondary malignant neoplasm of respiratory and digestive organs (2); Paralytic ileus and intestinal obstruction without hernia (2); Other septicaemia (2)
Others	417 (16.64)	Operations on bone marrow and spleen (134); Operations on valves and septa of heart (24); Operations on gallbladder and biliary tract (20); Operations on vessels of heart (19); Operations on liver (17); Incision and excision of skull, brain, and cerebral meninges (15); Operations on chest wall, pleura, mediastinum, and diaphragm (14); Operations on pancreas (14); Operations on skin and subsutaneous tissue (13); Operations on spinal cord and spinal canal structures (13)	Agranulocytosis (24); Transplanted organ and tissue status (22); Other diseases of biliary tract (18); Choronic ischaemic heart disease (16); Complications of procedures, not elsewhere classified (14); Bacterial pneumonia, not elsewhere classified (12); Essential (primary) hypertension (10); Stomatitis and related lesions (8); Pneumonia, unspecified organism (7),Myeloid leukaemia (7)

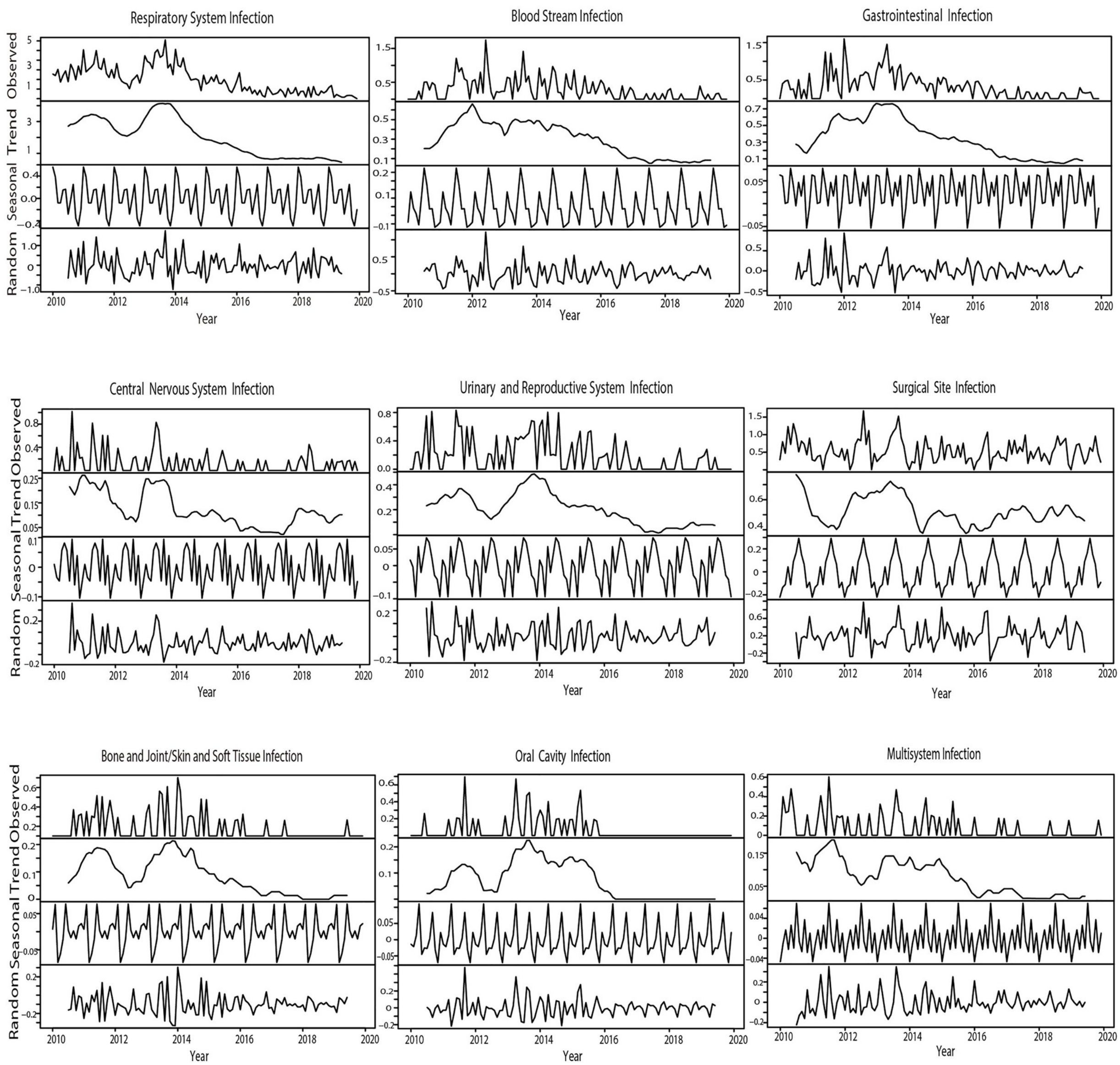

Fig. 2. Time series pattern for each type of HAI. The first row from the top of each HAI represents the observed trend, which can be decomposed into overall trend (second row), seasonal trend (third row), and random fluctuations (bottom row). An evident seasonal pattern can be seen in RSI, BI, and SSI, with fluctuations exceeding 20%. RSI reaches its peak in January, BI in July, and SSI in August. BI, bloodstream infection, HAI, healthcare-associated infection; RSI, respiratory system infection; SSI, surgical site infection.

Table 4
The association rules between disease, procedure and HAI detected among surgery inpatients.

Rules			Count	Confidence	Lift
Complications of procedures, not elsewhere classified & Operations on other endocrine glands	=>	Central nervous system infection	8	0.57	4878.98
Encephalitis,myelitis and encephalomyelitis & Incision and excision of skull, brain, and cerebral meninges	=>	Central nervous system infection	6	0.86	7318.47
Other gastroenteritis and colitis of infectious and unspecified origin & Operations on bone marrow and spleen	=>	Gastrointestinal infection	5	0.56	1861.68
Acute tonsillitis & Operations on bone marrow and spleen	=>	Respiratory system infection	4	0.50	284.35
Other sepsis & Other incision and excision of uterus	=>	Bloodstream infection	3	1.00	3800.55
Candidiasis & Incision and excision of stomach	=>	Respiratory system infection	3	0.75	426.52
Bacterial pneumonia, not elsewhere classified & Incision, excision, and division of other bones	=>	Respiratory system infection	3	0.75	426.52
Acute upper respiratory infections of multiple and unspecified sites & Operations on liver	=>	Respiratory system infection	3	0.50	284.35

the terms used for HAIs in the cover pages were uncoded, resulting in some HAIs being categorized vaguely as "Others". Finally, the information about the infectious organism and the antibiotics for treatment cannot be obtained from the data in the cover page. As the information in the cover page of medical records is the main data source for evaluating the performance of public hospitals in China, HAI reporting rates and information on HAI should be improved and standardized.

In summary, this study demonstrates a significant trend of decline in HAI rates over the last 10 years in a large Chinese tertiary hospital, which may be attributed to the development of the real-time surveillance system in this hospital. The occurrence of HAIs is a significant burden to inpatients, prolonging LOS and increasing both medical costs and the risk of death. HAIs are most common in patients undergoing operations on bone marrow and spleen. Furthermore, each type of HAI shows a different time series pattern. There should be particular emphasis placed on surveillance regarding specific types of HAI in the different time period based on the infection peak of each HAI type. In addition, reporting rates of HAIs and information about HAIs in the cover page of medical record should be improved and standardized.

Funding

This work was supported by the National Key Research and Development Program of China (No. 2020YFC2003402) and the Key Health Service Research Projects (HSR010007000). The funders had no role in the design and conduct of the study.

Author contributions

L.H.L., J.C.L. and T.Y.Z. make contributions to the conception and design of the study. T.Y.Z., L.Y., J.C.L. and S.W. wrote the paper and collected the data. J.C.L., Y.D.J. and Z.Q.S. cleaned the data. T.Y.Z., L.Y. and J.C.L. analyzed the data. T.Y.Z., L.Y., S.W., M.C. and L.H.L. interpreted the data. L.H.L. and T.Y.Z. revised and edited the paper. All authors read and approved the final manuscript.

Acknowledgments

We would like to thank Mr Lin Wei and Ms Boya Zhang for their helpful advice and technical guidance for this study. Furthermore, we would like to express our sincere gratitude to Director Hongyan Zhai from the Department of Disease Prevention and Control at the Fifth Medical Center of the Chinese PLA General Hospital for her invaluable expertise in the field of nosocomial infections and her valuable insights during the process of revising this paper.

Declaration of competing interest

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

Data available statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics statement

The information on inpatients was de-identified; therefore, institutional review board approval was waived.

Informed consent

Not applicable.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.imj.2024.100103.

References

[1] B. Allegranzi, S. Bagheri Nejad, C. Combescure, et al., Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis, Lancet 377 (9761) (2011) 228–241, doi:10.1016/S0140-6736(10)61458-4.
[2] WHO, The burden of health care-associated infection worldwide, 2010. Available at: https://www.who.int/news-room/feature-stories/detail/the-burden-of-health-care-associated-infection-worldwide. Accessed August 1, 2023.
[3] A. El-Saed, H.H. Balkhy, D.J. Weber, Benchmarking local healthcare-associated infections: available benchmarks and interpretation challenges, J. Infect. Public Health 6 (5) (2013) 323–330, doi:10.1016/j.jiph.2013.05.001.
[4] R.M. Klevens, J.R. Edwards, C.L. Richards Jr, et al., Estimating health care-associated infections and deaths in U.S. hospitals, 2002, Public Health Rep. 122 (2) (2007) 160–166, doi:10.1177/003335490712200205.
[5] M. Haque, M. Sartelli, J. McKimm, et al., Health care-associated infections—an overview, Infect. Drug Resist. 11 (2018) 2321–2333, doi:10.2147/IDR.S177247.
[6] H. Richet, Seasonality in Gram-negative and healthcare-associated infections, Clin. Microbiol. Infect. 18 (10) (2012) 934–940, doi:10.1111/j.1469-0691.2012.03954.x.
[7] C. Schröder, F. Schwab, M. Behnke, et al., Epidemiology of healthcare associated infections in Germany: nearly 20 years of surveillance, Int. J. Med. Microbiol. 305 (7) (2015) 799–806, doi:10.1016/j.ijmm.2015.08.034.
[8] K. Kobayashi, K. Ando, F. Kato, et al., Seasonal variation in incidence and causal organism of surgical site infection after PLIF/TLIF surgery: a multicenter study, J. Orthop. Sci. 26 (4) (2021) 555–559, doi:10.1016/j.jos.2020.05.015.
[9] A.C. Maestri, P.K. Ando, G. Sarot, et al., Prevalence and seasonality of clostridiodes difficile over 12 years at a tertiary hospital in Brazil, Curr. Microbiol. 79 (12) (2022) 354, doi:10.1007/s00284-022-03062-6.
[10] Y. Chen, X. Xu, J. Liang, et al., Relationship between climate conditions and nosocomial infection rates, Afr. Health Sci. 13 (2) (2013) 339–343, doi:10.4314/ahs.v13i2.20.
[11] P.S. Shah, W. Yoon, Z. Kalapesi, et al., Seasonal variations in healthcare-associated infection in neonates in Canada, Arch. Dis. Child. Fetal Neonatal Ed. 98 (1) (2013) F65–F69, doi:10.1136/fetalneonatal-2011-301276.
[12] Y. Zhang, M. Du, J.M. Johnston, et al., Incidence of healthcare-associated infections in a tertiary hospital in Beijing, China: results from a real-time surveillance system, Antimicrob. Resist. Infect. Control 8 (2019) 145, doi:10.1186/s13756-019-0582-7.
[13] J. Wang, F. Liu, E. Tartari, et al., The prevalence of healthcare-associated infections in mainland China: a systematic review and meta-analysis, Infect. Control Hosp. Epidemiol. 39 (6) (2018) 701–709, doi:10.1017/ice.2018.60.

[14] C.D. Owens, K. Stoessel, Surgical site infections: epidemiology, microbiology and prevention, J. Hosp. Infect. 70 (Suppl 2) (2008) 3–10, doi:10.1016/S0195-6701(08)60017-1.
[15] M. Askarian, N.R. Gooran, National nosocomial infection surveillance system-based study in Iran: additional hospital stay attributable to nosocomial infections, Am. J. Infect. Contr. 31 (8) (2003) 465–468, doi:10.1016/s0196-6553(03)00673-4.
[16] National Health Commission, Diagnostic criteria for nosocomial infection (in Chinese), Chin. Med. J. 81 (2001) 314.
[17] N. Zhou, H. Dai, W. Zha, et al., The development trend of influenza in China from 2010 to 2019, Hum. Vaccines Immunother. 18 (5) (2022) 2071558, doi:10.1080/21645515.2022.2071558.
[18] R.W. Haley, D.H. Culver, J.W. White, et al., The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals, Am. J. Epidemiol. 121 (2) (1985) 182–205, doi:10.1093/oxfordjournals.aje.a113990.
[19] Q. Zhou, L. Fan, X. Lai, et al., Estimating extra length of stay and risk factors of mortality attributable to healthcare-associated infection at a Chinese university hospital: a multi-state model, BMC Infect. Dis. 19 (1) (2019) 975, doi:10.1186/s12879-019-4474-5.
[20] H. Jia, W. Li, T. Hou, et al., The attributable direct medical cost of healthcare associated infection caused by multidrug resistance organisms in 68 hospitals of China, Biomed Res. Int. 2019 (2019) 7634528, doi:10.1155/2019/7634528.
[21] H. Jia, L. Li, W. Li, et al., Impact of healthcare-associated infections on length of stay: a study in 68 hospitals in China, Biomed Res. Int. 2019 (2019) 2590563, doi:10.1155/2019/2590563.
[22] Y. Zhang, J. Zhang, D. Wei, et al., Annual surveys for point-prevalence of healthcare-associated infection in a tertiary hospital in Beijing, China, 2012–2014, BMC Infect. Dis. 16 (1) (2016) 161, doi:10.1186/s12879-016-1504-4.
[23] A. Audi, M. AlIbrahim, M. Kaddoura, et al., Seasonality of respiratory viral infections: will COVID-19 follow suit? Front. Public Health 8 (2020) 567184, doi:10.3389/fpubh.2020.567184.
[24] F. Schwab, P. Gastmeier, P. Hoffmann, et al., Summer, sun and sepsis-the influence of outside temperature on nosocomial bloodstream infections: a cohort study and review of the literature, PLoS One 15 (6) (2020) e0234656, doi:10.1371/journal.pone.0234656.
[25] M.J. Durkin, K.V. Dicks, A.W. Baker, et al., Seasonal variation of common surgical site infections: does season matter? Infect. Control Hosp. Epidemiol. 36 (9) (2015) 1011–1016, doi:10.1017/ice.2015.121.
[26] K. Blot, N. Hammami, S. Blot, et al., Gram-negative central line-associated bloodstream infection incidence peak during the summer: a national seasonality cohort study, Sci. Rep. 12 (1) (2022) 5202, doi:10.1038/s41598-022-08973-9.
[27] A.P.H. Sahtoe, L.S. Duraku, M.J.W. van der Oest, et al., Warm weather and surgical site infections: a meta-analysis, Plast. Reconstr. Surg. Glob. Open 9 (7) (2021) e3705, doi:10.1097/GOX.0000000000003705.