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Original Article

Prevalence of nosocomial infections and their influencing factors in a tertiary general hospital in Qingdao

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Abstract

Introduction: The goals of this study were to analyze the situation and dynamic change trend of the prevalence of nosocomial infections among inpatients, to investigate the use of antibiotics, and to provide evidence-based support for the development of targeted prevention and control measures for nosocomial infections and rational use of antibiotics.

Methodology: The nosocomial infection surveillance system was utilized to conduct a cross-sectional survey of nosocomial infections of all inpatients, followed by a statistical evaluation of the 5-year survey results.

Results: The average prevalence of nosocomial infections over the 5-year period (2017 to 2021) was 2.28%, and the incidence rate per case was 2.42%. The lower respiratory tract was the primary site of infection, followed by the urinary tract. The most prevalent pathogens of nosocomial infections were Gram-negative bacteria (GNB), including *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and *Escherichia coli*; and the main strains of Gram-positive bacteria (GPB) included *Staphylococcus aureus* and *Enterococcus faecium*. The use of antibiotics accounted for 41.31% on average; and the proportion of antibiotics used for treatment was 84.99% on average. The average rate of pathogen examination was 51.09%, indicating an increasing trend ($\chi^2 = 44.196$, $p < 0.001$).

Conclusions: The average prevalence of nosocomial infections over the past five years was 2.28% in this tertiary general hospital. Although the prevalence rate of nosocomial infections in the hospital was relatively low, it is necessary to strengthen the measures for prevention and control of infections of the lower respiratory tract, urinary tract, and surgical incision.

Key words: antibiotics; pathogens; infection site; nosocomial infection; prevalence rate; healthcare-associated infections.

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Introduction

Nosocomial infection (NI), also known as hospital-acquired infection (HAI), can result in aggravated underlying diseases, prolonged length of hospital stay, decreased bed rotation rate, and an increase in the mortality rate of patients in clinical practice. It is also a leading cause of death in some developed Western countries [1,2]. In addition, it can result in conflicts between doctors and patients as a result of the additional difficulties it causes in patients; and it can easily lead to medical accidents among healthcare staff, thereby increasing the cost of treatment substantially. According to data from the National Health Commission of the People's Republic of China, the prevalence rate of nosocomial infections reported in China since 2014 is between 2.3–2.7%, compared to 3.2–4% in the United States, 1.7–3.06% in Italy [3], 5.9% in Europe, and 7.7% in Japan [4]. The incidence of nosocomial infections in China is comparable to, or slightly lower than, that in Europe and the US, but higher than in Japan.

According to the Standard for Nosocomial Infection Surveillance (WS/T312-2009) [5] issued on 1 April 2009, hospitals are required to conduct a nosocomial infection prevalence survey at least once a year. A tertiary general hospital in Qingdao conducted investigations and analyses on the prevalence of nosocomial infections for consecutive years. In this study, a cross-sectional investigation of nosocomial infections was conducted for all inpatients from 2017 to 2021 using a nosocomial infection monitoring system, followed by statistical analysis of the results of the 5-year survey. Our aim was to analyze the current situation and dynamic change trend of the prevalence of nosocomial infections and the use of antibiotics, and thereby provide evidence-based support for the

development of targeted prevention and control measures for nosocomial infection and rational use of antibiotics [6].

Methodology

Participants

The study population consisted of 3,692 inpatients at our hospital between 0:00 and 24:00 on 16 March 2017, 26 April 2018, 15 August 2019, 11 August 2020, and 16 September 2021; including patients discharged or transferred to another department, or who died on those days; but excluding patients admitted on those days. Our hospital was a tertiary hospital located in the central and urban-rural transition area of the northern part of Qingdao, China. This study was conducted after obtaining informed consent of the patients and their family members, and the approval of the hospital's ethics committee.

Survey methods

A total of 3,692 hospitalized patients were selected. The timing 0:00–24:00 was implemented according to the unified investigation plan of the national hospital infection monitoring network.

The infection management department of the hospital was responsible for organizing and implementing the survey in strict accordance with the survey plan which was uniformly developed by the National Nosocomial Infection Training Base [5]. The investigators included personnel from the department of infection management and part-time nosocomial infection monitoring physicians from various departments. Prior to the survey, the investigators received a combined training, and the clinical departments were informed of the relevant contents and objectives of the survey. The various examinations related to the diagnosis of infectious diseases were conducted in a timely manner to ensure accuracy of the survey. On the day of the survey, the investigators conducted bedside patient interviews, inpatient medical record reviews, and physician interviews, and completed the unified individual questionnaire. After an individual completed the questionnaire, the nosocomial infection control staff verified its compliance and accuracy. If there were any intractable cases, the investigation team and the physician-in-charge discussed them mutually.

Diagnostic criteria

Nosocomial infections were diagnosed according to the previously published diagnostic criteria for nosocomial infection, issued by the Ministry of Health in 2005 [7]. Inpatients with nosocomial infections on the day of survey, including both newly infected cases and the infections that had previously occurred but not cured, were referred to as patients diagnosed with nosocomial infections. The prevalence rate of nosocomial infections (case infection rate) was calculated as:

$$\text{Case infection rate (\%)} = \frac{PAT_{TOT}}{PAT_{SUR}} \times 100$$

Where: PAT_{TOT} = No. of patients with new and old nosocomial infections during the observation period; PAT_{SUR} = No. of inpatients surveyed during the observation period.

Statistical analysis

SPSS 25.0 software (IBM Corp, Armonk, NY, USA) was used to analyze statistical data. The enumeration data were expressed as a rate or constituent ratio and compared using the Chi square test; $p < 0.05$ indicated that the difference was statistically significant.

Results

Prevalence of nosocomial infections in different survey stages

A total of 3,692 inpatients were chosen as participants for the survey of the prevalence of nosocomial infections from 2017 to 2021, and 3,677 of them were surveyed, with an actual survey rate of 99.59%. There were 84 patients with nosocomial infections (89 infections), and the average prevalence rate in the 5 years was 2.28% (case infection rate

Table 1. Comparison of prevalence rate of nosocomial infections from 2017 to 2021.

Year	Number of cases to be surveyed	Number of cases actually surveyed	Actual survey rate (%)	Number of cases with infection	Prevalence rate (%)	Number of infections	Case infection rate (%)
2017	861	859	99.80	26	3.00	26	3.00
2018	868	856	98.62	18	2.10	19	2.22
2019	868	868	100.00	11	1.30	11	1.30
2020	605	604	99.83	16	2.65	19	3.15
2021	490	490	100.00	13	2.65	14	2.86
Total	3692	3677	99.59	84	2.28	89	2.42
χ^2					0.197		< 0.001
p					0.657		0.988

Table 2. Comparison of prevalence rate of nosocomial infections in different departments from 2017 to 2021.

Clinical Departments	2017			2018			2019			2020			2021			Total			χ^2	p
	Number of cases actually surveyed	Number of cases with infection	Prevalence rate (%)	Number of cases actually surveyed	Number of cases with infection	Prevalence rate (%)	Number of cases actually surveyed	Number of cases with infection	Prevalence rate (%)	Number of cases actually surveyed	Number of cases with infection	Prevalence rate (%)	Number of cases actually surveyed	Number of cases with infection	Prevalence rate (%)	Number of cases actually surveyed	Number of cases with infection	Prevalence rate (%)		
Internal Medicine Department	411	11	2.7	424	10	2.36	425	3	0.71	304	2	0.66	238	2	0.84	1802	28	1.55	8.776	0.057
Surgery Department	210	5	2.4	199	3	1.51	199	3	1.51	153	5	3.27	114	5	4.39	875	21	2.40	3.713	0.431
Gynecology Department	43	0	0	37	0	0	35	0	0	16	0	0	19	0	0	150	0	0	-	-
Obstetrics Department	65	0	0	24	0	0	38	0	0	19	0	0	12	0	0	158	0	0	-	-
Pediatrics Department	50	1	2.0	55	0	0	68	0	0	20	0	0	49	0	0	242	1	0.40	4.237	0.492
ENT Department	18	0	0	21	0	0	13	0	0	11	1	9.09	11	0	0	74	1	1.35	4.740	0.297
ICU	13	8	61.5	20	5	25	11	4	36.4	20	6	30.00	20	5	25.00	84	28	33.33	5.664	0.224
Other Departments	49	1	2.04	76	0	0	79	1	1.27	61	2	3.28	27	1	3.70	292	5	1.71	3.650	0.363
Total	859	26	3.03	856	18	2.10	868	11	1.27	604	16	2.65	490	13	2.65	3677	84	2.28	6.928	0.140

ENT: ear nose; throat; ICU: intensive care unit.

2.42%). Neither the difference in prevalence rate of nosocomial infections between 2017 and 2021 (χ^2 = 0.197, $p > 0.05$); nor the difference in the case infection rate ($\chi^2 < 0.001$, $p > 0.05$) were statistically significant. (Table 1).

Prevalence of nosocomial infections in different departments

The survey on the prevalence of nosocomial infections from 2017 to 2021 included a total of 34 departments (12 internal medicine, 11 surgery, 3 ear nose throat [ENT], 1 gynecology, 1 obstetrics, 1 pediatrics, 1 intensive care unit [ICU], and 4 other departments), and the results indicated that the ICU had the highest prevalence rate of nosocomial infections (33.33%). The annual prevalence rate in the internal medicine, ICU, and pediatric wards showed a decreasing trend, with the differences not being statistically significant ($p > 0.05$). The prevalence rate in the surgery department showed an increasing trend; but the difference was not statistically significant ($p > 0.05$). The prevalence rate in the hospital from 2017 to 2021 showed an overall decreasing trend, but the difference was not statistically significant ($p > 0.05$; Table 2).

Distribution of nosocomial infection sites

In terms of the infection site, nosocomial infections from 2017 to 2021 mainly involved respiratory tract infection, followed by urinary tract infection, superficial incision infection, and upper respiratory infection (Table 3).

Pathogens and distribution of nosocomial infections

During the 5 surveys conducted on inpatients from 2017 to 2021, the number of isolated pathogenic bacterial strains from specimens of nosocomial infection patients were 14, 5, 8, 21, and 14, respectively. The predominant pathogens of nosocomial infections over the past 5 years were Gram-negative bacteria (GNB); and *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and *Escherichia coli* were the most prevalent strains. *Staphylococcus aureus* and *Enterococcus faecium* were the most prevalent Gram-positive bacteria (GPB) in the 5 surveys (Table 4).

Use of antibiotics and pathogenic examination

The average rate of antibiotics use in inpatients was 41.31% from 2017 to 2021, with an increasing trend from 2017 to 2019. The lowest level was in 2020, with a rebound in 2021; however, the differences were not statistically significant (χ^2 = 3.152, $p > 0.05$). The proportion of antibiotics used for treatment increased over the past 5 years, but the differences were not statistically significant (χ^2 = 1.456, $p > 0.05$).

Table 3. Distribution of nosocomial infection sites from 2017 to 2021, n (%).

Infection site	2017	2018	2019	2020	2021
Upper respiratory tract	15.38	5.26	9.09	0	0
Lower respiratory tract	61.54	63.16	27.27	42.10	57.14
Gastrointestinal tract	3.85	0	9.09	0	0
Urinary tract	0	21.05	36.37	21.05	0
Superficial incision	7.69	10.53	0	10.53	28.57
Deep wound	3.85	0	0	0	7.15
Skin and soft tissue	0	0	9.09	0	7.14
Intraperitoneal tissue	0	0	0	10.53	0
Blood flow	0	0	0	10.53	0
Others	7.69	0	9.09	5.26	0
Total	100.00	100.00	100.00	100.00	100.00

Table 4. Pathogens of nosocomial infections and their constituent ratio from 2017 to 2021.

Pathogen	2017		2018		2019		2020		2021	
	Detected number of strains	Constituent ratio (%)	Detected number of strains	Constituent ratio (%)	Detected number of strains	Constituent ratio (%)	Detected number of strains	Constituent ratio (%)	Detected number of strains	Constituent ratio (%)
Gram positive bacteria	1	7.10	1	20.00	1	12.50	8	38.09	5	35.72
Staphylococcus aureus	1	7.10	1	20.00	0	0	1	4.76	2	14.29
Staphylococcus epidermidis	0	0	0	0	0	0	0	0	3	21.43
Other coagulase negative staphylococcus	0	0	0	0	0	0	1	4.76	0	0
Enterococcus faecium	0	0	0	0	1	12.50	4	19.05	0	0
Other Gram positive bacteria	0	0	0	0	0	0	2	9.52	0	0
Gram negative bacteria	13	92.90	4	80.00	7	87.50	10	47.61	9	64.28
Escherichia coli	1	7.10	0	0	2	25.00	3	14.29	1	7.14
Klebsiella pneumoniae	4	28.60	3	60.00	2	25.00	2	9.52	1	7.14
Proteus	0	0	0	0	2	25.00	2	9.52	1	7.14
Pseudomonas aeruginosa	4	28.60	1	20.00	0	0	0	0	3	21.43
Acinetobacter baumannii	4	28.60	0	0	1	12.50	1	4.76	3	21.43
Stenotrophomonas maltophilia	0	0	0	0	0	0	2	9.52	0	0
Fungi	0	0	0	0	0	0	3	14.3	0	0
Other fungi	0	0	0	0	0	0	3	14.30	0	0
Total	14	100.00	5	100.00	8	100.00	21	100.00	14	100.00

Table 5. Use of antibiotics and pathogenic examination for nosocomial infections from 2017 to 2021.

Year	Number of cases monitored	Antimicrobial agents		Purpose of medication (%)			Combination of antibiotics (%)				Bacterial culture	
		Number of cases	Use rate (%)	Treatment	Prevention	Treatment + prevention	Monotherapy	Dual therapy	Triple therapy	Quadruple therapy or above	Number of cases examined	Examination rate (%)
2017	859	317	36.90	267 (84.23)	42 (13.25)	8 (2.52)	184 (58.05)	131 (41.32)	2 (0.63)	0	144	45.43
2018	856	362	42.29	304 (83.98)	56 (15.47)	2 (0.55)	252 (69.62)	103 (28.45)	5 (1.38)	2 (0.55)	154	42.54
2019	868	409	47.12	346 (84.60)	60 (14.67)	3 (0.73)	203 (49.63)	192 (46.94)	12 (2.93)	2 (0.50)	206	50.37
2020	604	204	33.77	175 (85.78)	28 (13.73)	1 (0.49)	140 (68.63)	61 (29.90)	3 (1.47)	0 (0.00)	103	50.49
2021	490	227	46.33	199 (87.67)	26 (11.45)	2 (0.88)	154 (67.84)	69 (30.40)	3 (1.32)	1 (0.44)	169	74.45
Total	3677	1519	41.31	1291 (84.99)	212 (13.96)	16 (1.05)	933 (61.42)	556 (36.60)	25 (1.65)	5 (0.33)	776	51.09
χ^2			3.152	1.456	1.527	3.204	2.005	2.887	0.716	0.141		44.196
p			0.076	0.227	0.217	0.073	0.157	0.089	0.397	0.707		<0.001

The Chi-square value in Table 5 is from trend Chi-square test, and the "linear correlation" in the Chi-square test and the corresponding p value were taken.

Table 6. Antibiotic resistance of pathogenic bacteria in nosocomial infections.

Pathogen		*Staphylococcus aureus*	*Coagulase-negative Staphylococcus*	*Enterococcus faecalis*	*Enterococcus faecium*	*Streptococcus pneumoniae*	*Escherichia coli*	*Klebsiella pneumoniae*	*Pseudomonas aeruginosa*	*Acinetobacter baumannii*	Total
Number		5	0	0	5	0	9	10	9	9	47
Benzathioprine	Resistant strains	3	0	0	0	0	0	0	0	0	3
	Sensitive strains	2	0	0	0	0	0	0	0	0	2
	Not performed	0	0	0	0	0	0	0	0	0	0
Cefoxitin	Resistant strains	2	0	0	0	0	0	0	0	0	2
	Sensitive strains	3	0	0	0	0	0	0	0	0	3
	Not performed	0	0	0	0	0	0	0	0	0	0
Ampicillin	Resistant strains	0	0	0	4	0	0	0	0	0	4
	Sensitive strains	0	0	0	1	0	0	0	0	0	1
	Not performed	0	0	0	0	0	0	0	0	0	0
Vancomycin	Resistant strains	0	0	0	1	0	0	0	0	0	1
	Sensitive strains	0	0	0	4	0	0	0	0	0	4
	Not performed	0	0	0	0	0	0	0	0	0	0
Penicillin	Resistant strains	0	0	0	0	0	0	0	0	0	0
	Sensitive strains	0	0	0	0	0	0	0	0	0	0
	Not performed	0	0	0	0	0	0	0	0	0	0
Ceftazidime	Resistant strains	0	0	0	0	0	0	0	7	0	7
	Sensitive strains	0	0	0	0	0	8	8	3	0	19
	Not performed	0	0	0	0	0	0	0	0	0	0
Imipenem	Resistant strains	0	0	0	0	0	8	9	9	9	35
	Sensitive strains	0	0	0	0	0	0	0	3	0	3
	Not performed	0	0	0	0	0	0	0	0	0	0
Levofloxacin	Resistant strains	0	0	0	0	0	6	6	0	0	12
	Sensitive strains	0	0	0	0	0	3	4	0	0	7
	Not performed	0	0	0	0	0	0	0	0	0	0
Piperacillin / Tazobactam	Resistant strains	0	0	0	0	0	0	0	8	0	8
	Sensitive strains	0	0	0	0	0	0	0	4	0	4
	Not performed	0	0	0	0	0	0	0	0	0	0
Cefepime	Resistant strains	0	0	0	0	0	0	0	7	0	7
	Sensitive strains	0	0	0	0	0	0	0	3	0	3
	Not performed	0	0	0	0	0	0	0	0	0	0
Amikacin	Resistant strains	0	0	0	0	0	0	0	5	0	5
	Sensitive strains	0	0	0	0	0	0	0	3	0	3
	Not performed	0	0	0	0	0	0	0	0	0	0
Cefoperazone / Sulbactam	Resistant strains	0	0	0	0	0	0	0	0	4	4
	Sensitive strains	0	0	0	0	0	0	0	0	5	5
	Not performed	0	0	0	0	0	0	0	0	0	0
Ciprofloxacin	Resistant strains	0	0	0	0	0	0	0	8	0	8
	Sensitive strains	0	0	0	0	0	0	0	0	0	0
	Not performed	0	0	0	0	0	0	0	0	0	0

The proportion of preventive drugs decreased, but the differences were not statistically significant (χ^2 = 1.527, $p > 0.05$); and the proportion of drug combinations decreased, but again the difference were not statistically significant (χ^2 = 2.887, $p > 0.05$). The average submission rate of bacterial specimens from inpatients was 51.09% during the period from 2017 to 2021, showing a statistically significant increasing trend (χ^2 = 44.196, $p < 0.001$; Table 5)

Antibiotic resistance of pathogenic bacteria in nosocomial infections

A resistance analysis was conducted on 47 strains of pathogenic bacteria causing nosocomial infections from 2017 to 2021, including 5 strains of *Staphylococcus aureus*, 5 strains of *Enterococcus faecalis*, 9 strains of *Escherichia coli*, 10 strains of *Klebsiella pneumoniae*, 9 strains of *Pseudomonas aeruginosa*, and 9 strains of *Acinetobacter baumannii*. The results showed that vancomycin was most effective against *Enterococcus faecalis*, and it had an 80% resistance rate to ampicillin. *Acinetobacter baumannii*, *Klebsiella pneumoniae*, and *Escherichia coli* were 100% resistant to imipenem; and *Pseudomonas aeruginosa* exhibited a 75% resistance rate to meropenem. *Staphylococcus aureus* had resistance rates of 60% to benzylpenicillin and 40% to cefotaxime (Table 6).

Discussion

Trend analysis of prevalence of nosocomial infections

According to the results of this survey, the actual rate of prevalence of nosocomial infections was 99.59% in this general tertiary hospital between 2017 and 2021. The data used for this study were comprehensive and reliable, and the observations can be used as a reference for guiding measures for prevention and control of infections in this hospital. The average prevalence rate of nosocomial infections was 2.28%, and the average case infection rate was 2.42% in this hospital, which was lower than the national average level, and met the national maximum requirements for the incidence of nosocomial infections to be approximately 3%. The 5-year prevalence rate of nosocomial infections in this hospital satisfied the former Ministry of Health requirement of less than 10% [5] and was lower than the European prevalence rate of nosocomial infections, which is 7.1% [6].

The lower occurrence rate of hospital infections in China compared to Europe since 2014 can be attributed to several factors. Firstly, the underreporting of hospital infection cases in clinical settings may lead to a lower official count of infections. This could be due to a lack of standardized reporting procedures, inadequate training on infection control practices, or a reluctance to report cases for fear of repercussions.

Secondly, incomplete participation of hospitals in the national hospital infection monitoring network may result in a lack of comprehensive data on the prevalence and trends of hospital infections. Hospitals that are not part of the network may not have access to best practices, guidelines, and support for infection prevention and control measures.

Furthermore, the focus of hospital infection research in China on small-scale studies, analysis of influencing factors, and management of quality evaluation indicates a need for more extensive and continuous cross-sectional studies on a national level. A broader research scope could provide insights into regional variations, emerging trends, and long-term patterns of hospital infections across different healthcare settings.

In conclusion, while the current data suggests a slightly lower occurrence rate of hospital infections in China compared to Europe since 2014, addressing issues such as underreporting, incomplete monitoring network participation, and limited research scope is crucial for effectively managing and preventing hospital-acquired infections in the country.

Analysis of the distribution of nosocomial infection departments

ICU, hematology, oncology, breast surgery, and interventional surgery were among the departments with infection rates above 10% over the past 5 years. There were a large number of critically ill patients in the aforementioned departments, and their low body resistance and prolonged length of hospital stay; as well as invasive operations, the use of immunosuppressive agents, antitumor drugs, and other high-risk factors, could all lead to the development of nosocomial infections. According to a study, the prevalence of nosocomial infections in most departments, except the ICU, decreased between 2019 and 2020, before and after the outbreak of coronavirus disease 2019 (COVID-19) [7]. The departments with the highest nosocomial infection rates were reported to be neurosurgery and ICU, with infection rates of 9.92% and 9.38%, respectively.[8] There were also international reports that the ICU had the highest rate of nosocomial infections [9]. Thus, it is clear that the ICU is the primary department for nosocomial infections.

Analysis of nosocomial infection sites

Consistent with relevant reports, the top 3 infection sites over the 5 years were the lower respiratory tract, the urinary tract, and the surgical incision [10–12]. This indicated that all departments should increase their efforts to prevent and control infections of the lower respiratory tract, urinary tract, and surgical incision. Patients should be guided in various breathing techniques, including effective deep breathing and coughing exercises. Hospitals should strictly adhere to the indications for urinary catheterization and mechanical ventilation, ensuring proper care of the tubes, daily assessment, and timely removal [13]. For long-term bedridden patients, enhanced turning and back patting should be implemented to prevent accumulation-related pneumonia. In addition, hospitals should provide thorough basic care for critically ill patients to prevent aspiration in critical, comatose, and nasogastric tube-fed patients; and maintain good oral hygiene. The staff should clean and disinfect preoperative skin preparation, minimize clinic visit duration, enhance the implementation of aseptic procedures, strictly perform surgical hand disinfection, and control the number of surgical personnel. Healthcare workers should minimize surgical time for patients with extensive trauma or significant bleeding. Rational use of antibiotics based on sensitivity test results is essential [14]. Hospital staff should adjust clothing in a timely manner to prevent chilling, ensure adequate nutritional intake, and enhance the patients' resistance to illness. They should regularly ventilate patient rooms to maintain air circulation. All staff should strictly adhere to aseptic techniques, hand hygiene standards, and various disinfection and isolation protocols to further reduce the occurrence of hospital infections.

Pathogens of nosocomial infections

Pathogens of nosocomial infections in the 5 surveys were predominantly GNB, with the most commonly found strains being *K. pneumoniae*, *P. aeruginosa, A. baumannii*, and *E. coli*; which differed from the findings of some previous studies which reported that *E. coli* was the main pathogen, and was caused by the different disease spectrum distribution of patients in the hospital [15,16]. According to some studies, *K. pneumoniae* was the leading cause of nosocomial infection, and some studies even demonstrated an increase in the proportion of *K. pneumoniae*. Additionally, it was reported that detectable *A. baumannii* is more prevalent. It was speculated that the different distribution of pathogenic bacteria in nosocomial infections in different hospitals may be related to the different distributions of the disease spectrum [17,18]. *S. aureus* and *E. faecium* were the predominant GPB strains found in the five surveys, which is consistent with the disease distribution in the departments with infection rates exceeding 10%.

Klebsiella pneumoniae mainly originates from the lower respiratory tract and the urinary tract [19]. Drug resistance analysis indicates resistance to imipenem, significant resistance to levofloxacin, and sensitivity to cephalothin; making it a clinically recommended medication. *Pseudomonas aeruginosa* primarily comes from the lower respiratory tract and its resistance rates to most antibiotics are relatively high, suggesting the need for more stringent clinical protocols to restrict the use of related antibiotics and further delay the development of resistance [20]. *Acinetobacter baumannii* primarily stems from respiratory diseases and exhibits high antibiotic resistance. Resistance analysis shows a 100% resistance rate to imipenem, with sensitivity to ceftazidime/sulbactam sodium exceeding 50%, making it a possible choice for clinical use. *Escherichia coli* is a common pathogen causing nosocomial infections and is most likely to trigger urinary tract infections [21]. Complete resistance to imipenem, sensitivity to levofloxacin in only one-third of cases, and sensitivity to cephalothin make it a viable clinical option. Methicillin-resistant *Staphylococcus aureus* (MRSA) has a high resistance rate in clinical practice, and vancomycin is considered the most effective antibiotic against MRSA. Careful consideration should be given to its use to reduce the development of resistant strains [22]. Resistance analysis in our hospital shows a sensitivity rate of 40% to benzylpenicillin and 60% to cephalothin, highlighting the necessity of resistance analysis for correct drug selection. *E. faecalis* mainly originates from urinary tract infections or the feces of patients with disrupted intestinal flora [23]. In recent years, the resistance rate has gradually increased, making it an important nosocomial pathogen. Inherent and acquired resistance were observed during resistance analysis, with an 80% resistance rate to ampicillin and 80% sensitivity to vancomycin.

Use of antibiotics for nosocomial infections, examination and analysis

Based on our findings, the use rate of antibiotics in the 5 surveys was less than 50%, which met the requirements for the use rate of antibiotics for inpatients in general hospitals [24] and the use rate of antibiotics demonstrated a decreasing trend under the assumption

of maintaining basic stability. The majority of medications in the 5-year surveys were antibiotics, and the use of antibiotics did not decrease significantly, while the proportion of preventive drugs was relatively low. This could be related to the small number of operations, fewer complex operations, short duration of operations, and a limited use of antibiotics in the perioperative period. Meanwhile, an increasing number of elderly patients were admitted to this hospital, wherein respiratory and urinary tract infections were common and antibiotics were frequently prescribed. The most common antibiotic treatment was monotherapy, followed by double combinations. From 2017 to 2021, the average submission rate of bacterial specimens from inpatients was 51.09%, showing an increasing trend (χ^2 = 44.196, p < 0.001), but the examination rate was still low. Studies indicate that similar situations exist in other countries [25]. The examination rate for the use of antibiotics in the hospital's surgical departments was low, which also reflected the extensive empirical drug use.

Conclusions

Nosocomial infections management is essential for both hospitals and patients. Monitoring nosocomial infections is facilitated through prevalence rate surveys. In this tertiary general hospital, the average prevalence rate of nosocomial infections over the past five years was 2.28%. Although the prevalence rate of nosocomial infections in the hospital was relatively low, it is necessary to further strengthen the prevention and control of infections of the lower respiratory tract, the urinary tract, and the surgical incision. Special attention is required in the ICU, hematology, oncology, breast surgery, interventional surgery, and other departments to actively implement prevention and control measures and reduce nosocomial infections. It is necessary to focus on the prevention and control of *K. pneumoniae*, *P. aeruginosa*, *A. baumannii*, and *E. coli* as pathogenic microorganisms of nosocomial infections.

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Ethics approval and consent to participate

This study was conducted with approval from the Ethics Committee of Qingdao The Eighth People's Hospital. This study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request. The materials described in the manuscript, including all relevant raw data, will be freely available to any scientist wishing to use them for non-commercial purposes, without breaching participant confidentiality.

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Authors' contributions

Conception and design of the research: H-FD, CL, M-XL; data acquisition: CL, M-XL, Y-XX; analysis and interpretation of the data: CL, M-XL, H-FD; statistical analysis: H-FD, FW, FL; obtaining funding: FL; manuscript writing, H-FD, FW; critical revision of the manuscript for intellectual content: H-FD, FL, Y-XX. All authors read and approved the final draft.

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