Dong and Liu *BMC Infectious Diseases* (2025) 25:658
https://doi.org/10.1186/s12879-025-11046-7

BMC Infectious Diseases

RESEARCH Open Access

Point-prevalence surveys of hospital-acquired infections in 42 Chinese hospitals in Weifang, China: from 2015 to 2020

Yu Dong[1] and Hongqing Liu[1*]

Abstract

Background Hospital-acquired infections (HAIs) are a major health challenge, especially for developing countries. Therefore, this study investigated the prevalence of HAIs in 42 Chinese hospitals in Weifang, China.

Methods The definition of HAIs was identified using the Ministry of Health of the People's Republic of China. One-day cross-sectional surveys were annually performed from 2015 to 2020. The trained staff collected information on the prevalence of HAIs, isolated pathogens, and antibiotic use.

Results Among the surveyed inpatients, 1.66% developed HAIs, with a significant decline in HAI prevalence from 2015 (1.84%) to 2020 (1.55%) ($Z = -4.206$, $P < 0.001$). The ICU exhibited the highest prevalence of HAIs at 19.04%. Lower respiratory tract infections accounted for 46.32% of total cases. Moreover, a total of 1,297 bacterial isolates were identified, with *Pseudomonas aeruginosa* (218 isolates, 16.8%), *Klebsiella pneumoniae* (199 isolates, 15.3%), and *Escherichia coli* (133 isolates, 10.3%) being the most prevalent. The most frequently detected resistant pathogen was *Carbapenem-Resistant Enterobacteriaceae*(218 isolates,37.20%).Antimicrobial usage reached 35.19%, accompanied by a notable increase in pathogen testing submissions over the study period ($Z = 4.287$, $P < 0.001$).

Conclusions The overall prevalence of HAIs across 42 hospitals shows a declining trend. The prevention and control of healthcare-associated pathogens and multidrug-resistant organisms remain key priorities. Ensuring the rational use of antimicrobial agents is also a critical focus for future efforts.

Keywords Hospital-acquired infections, Point prevalence survey, Antimicrobial use, China

Introduction

Hospital-acquired infections (HAIs) are infections that develop in patients during their stay in healthcare facilities, typically emerging more than 48 h after admission and caused by various pathogens, including bacteria, viruses, and fungi [1–4]. HAIs are considered critical indicators of patient safety in healthcare settings [5]. According to the data reported by the World Health Organization (WHO), millions of patients worldwide experience complications or death due to HAIs annually, with an annual growth incidence of HAIs of approximately 0.06% [6]. HAIs place substantial financial burdens on healthcare systems due to prolonged hospital stays, additional treatments, and diagnostic tests [7–9]. Moreover, HAIs negatively affect patient outcomes and increase the economic burden on individuals [10]. When caused by multidrug-resistant organisms(MDROs), HAIs complicate treatment decisions and pose significant

*Correspondence:
Hongqing Liu
liuhq576@163.com
[1]School of Public Health, Shandong Second Medical University, Weifang, China

public health challenges [11]. Inappropriate antibiotic use and preventable HAIs requiring antibiotic treatment may accelerate the development of antimicrobial resistance, further restricting future treatment options.

In developing countries, the prevalence of HAIs is estimated at 15.5% [12]. While preventive measures have been implemented, research and management of HAIs in China began relatively late and remain in the early stages of development. Between 2018 and 2020, the prevalence of HAIs in Chinese hospitals showed a downward trend, with prevalence values of 1.91%, 1.86%, and 1.65%, respectively [13]. However, challenges persist, such as the improper use of antibiotics and the emergence of drug-resistant pathogens [14]. HAIs involving drug-resistant organisms have become a global crisis, exacerbated by the limited development of new antimicrobial drugs [15]. The implementation of two National Action Plans to Combat Antimicrobial Resistance (2016–2020, 2022–2025) has contributed to a significant reduction in antibiotic consumption, accompanied by a stabilization or decline in the prevalence of key resistant bacterial strains in China in recent years [16–19].

Importantly, studies suggest that restricting the inappropriate use of antimicrobial drugs may curb the emergence of antibiotic resistance [20]. Certain infections, such as bloodstream infections and respiratory tract infection, have been on the rise in recent years, indicating the need for continued research and targeted interventions [21]. Comprehensive, integrated intervention strategies have been shown to reduce the prevalence of HAIs by 35–55% [22]. Effective HAIs monitoring is crucial for assessing the effectiveness of preventive measures, identifying risk factors, and providing reliable data on disease occurrence. Such step is vital for improving healthcare quality and refining clinical services.

Therefore, this study conducted a retrospective analysis of targeted HAIs surveillance over six years in 42 hospitals in Weifang, Shandong Province, China. The objective was to provide a deeper understanding of the epidemiological characteristics, current trends, and antibiotic resistance patterns of HAIs. The findings are expected to contribute to policy formulation, enhance healthcare quality, and improve disease monitoring and early warning systems.

Methods

Study design and setting

The research population consisted of all inpatients from 42 secondary or higher-level hospitals in Weifang, Shandong Province, China. This included individuals discharged, transferred, or deceased on the survey day but excluded newly admitted patients. Each year, from 2015 to 2020, a single random day was selected for the survey. On that day, from 00:00 to 24:00, data were collected using a combination of medical record reviews and bedside investigations.

A cross-sectional survey was performed annually to collect clinical data from all hospitalized patients. This survey was executed by a dedicated team of infection control staff, attending physicians, infection control doctors, and nurses. Data collection was standardized using case registration and bedside survey forms designed by the National Hospital Infection Control Quality Control Center. Information was gathered through medical records and bedside consultations.

The collected data included patient demographics, infection status (hospital-acquired and community-acquired), antimicrobial usage, pathogen testing before antimicrobial administration, and bacterial resistance. HAIs were diagnosed based on the Hospital Infection Diagnostic Standards(Trial), which define HAIs as infections occurring 48 h or more after hospital admission that were neither present nor incubating at the time of admission [23]. Antimicrobial use was defined as (1) any systemic antibiotic or antifungal prophylaxis administered within 24 h prior to the survey, or (2) any systemic antibiotic or antifungal medication used on the survey date.All data were systematically entered into the hospital infection prevalence database and uploaded to the online hospital infections monitoring system in Weifang, Shandong Province, China.

Statistical analyses

Categorical variables were expressed as frequencies and percentages. The Cochran-Armitage trend test was applied to evaluate changes in the prevalence of HAIs, pathogen distribution, infection sites across different years, antimicrobial drug usage rate, and the rate of pathogen testing prior to antimicrobial therapy over time. All statistical analyses were conducted using R version 4.3.2. The two-tailed P-value of less than 0.05 was considered statistically significant.

Results

Prevalence of HAIs and infection episode rate across different years

As shown in Table 1, a total of 157,009 inpatients were monitored, with 2,605 developed HAIs, yielding an overall infection prevalence of 1.66%, of whom 2470 (94.80%) had 1 HAI, 120 (4.61%) had 2 HAIs, and 15 (0.58%) had 3 HAIs. The prevalence of HAIs declined from 1.84 to 1.55% (15.76% reduction), while the infection episode rate decreased from 1.92 to 1.59%. These trends were statistically significant (Cochran-Armitage Trend Test: Prevalence of HAIs: Z=-4.206, $P < 0.001$; Infection Episode rate: Z=-4.363, $P < 0.001$). The bed numbers for each hospital are included in Supplementary **Table S5**.

Table 1 Prevalence of HAIs and infection episodes rate (2015–2020)

Year	Total Patients Surveyed	Number of Infections	Prevalence of HAIs (%)	Number of Infection Episodes	Infection Episode Rate (%)
2015	20,871	385	1.84	400	1.92
2016	23,611	415	1.76	429	1.82
2017	26,211	490	1.87	536	2.04
2018	27,857	452	1.62	483	1.73
2019	29,192	409	1.40	443	1.52
2020	29,267	454	1.55	464	1.59
Total	157,009	2,605	1.66	2,755	1.75

The Cochran-Armitage Trend Test results for both the Prevalence of HAIs and the Infection Episode Rate are as follows: Prevalence of HAIs: Z=-4.206, $P<0.001$; Infection Episode Rate: Z=-4.363, $P<0.001$

Prevalence of HAIs by department

HAIs were identified across all 63 departments, with 8 reporting a prevalence exceeding 2%. The departments with the highest prevalence, in descending order, were: ICU (19.04%), Hematology (10.02%), Burn Unit (5.66%), Neurosurgery (5.58%), Neonatology (3.36%), Oncology (3.09%), Thoracic Surgery (2.94%), and Colorectal Surgery (2.22%). All of the above-listed department types had 36 departments involved in the study, except for neonatology, which had 42. The prevalence of HAIs for each department was calculated as the number of HAIs in that department divided by the number of patients assessed within that department. The annual prevalence of HAIs across the 63 departments is provided in Supplementary **Table S1**.

The ICU showed an initial increase in infection prevalence between 2015 and 2016, peaking slightly, followed by a gradual decline, though a secondary rise was noted in 2019. Despite this fluctuation, the overall trend remained downward (Z=-3.216, $P=0.001$). Neurosurgery consistently decreased infection prevalence throughout the study period (Z=-5.078, $P<0.001$). The Burn Unit experienced a marked decline between 2016 and 2017, with a minor rebound from 2018 to 2020, yet the overall trend was downward (Z=-2.545, $P=0.010$). Both Thoracic Surgery and Neonatology saw reductions in infection prevalence from 2015 to 2016, followed by minor peaks in 2017, and a continuation of the downward trend thereafter (Thoracic Surgery: Z=-2.601, $P=0.009$; Neonatology: Z=-2.196, $P=0.028$). Anorectal Surgery, after a decline from 2016 to 2017, showed a steady increase in infection prevalence ($Z=3.991$, $P<0.001$) (Fig. 1). Detailed results of the Cochran-Armitage Trend Test for departments are available in Supplementary **Table S4**.

Summary of HAIs sites and pathogen distribution

Table 2 presents the distribution of HAIs by infection site and their corresponding pathogens. Lower respiratory tract infections (LRTIs) were the most prevalent (46.32%), followed by upper respiratory tract infections(URTIs) (10.34%), urinary tract infections (UTIs) (10.78%), and surgical site infections (SSIs) (6.86%). Among the isolated pathogens ($n=1{,}297$), *Pseudomonas aeruginosa* (16.8%) and *Klebsiella pneumoniae* (15.3%) were the most common, while *Escherichia coli*, *Acinetobacter baumannii*, and *Staphylococcus aureus* also frequently detected.

Distribution of hospital-acquired infection sites

As illustrated in Fig. 2, from 2015 to 2020, the proportion of LRTIs showed a significant decline, dropping from 50.75 to 39.22% (Z=-4.289, $P<0.001$). Similarly, intracranial infections reduced from 1 to 0% over the same period (Z=-3.376, $P<0.001$). In contrast, gastrointestinal infections increased notably from 3.25% in 2015 to 8.62% in 2020 ($Z=3.229$, $P=0.001$). SSIs also showed a substantial rise, increasing from 2.75 to 7.54% ($Z=3.851$, $P<0.001$). Additionally, skin and soft tissue infections increased significantly, from 1.50 to 7.54% ($Z=3.796$, $P<0.001$),

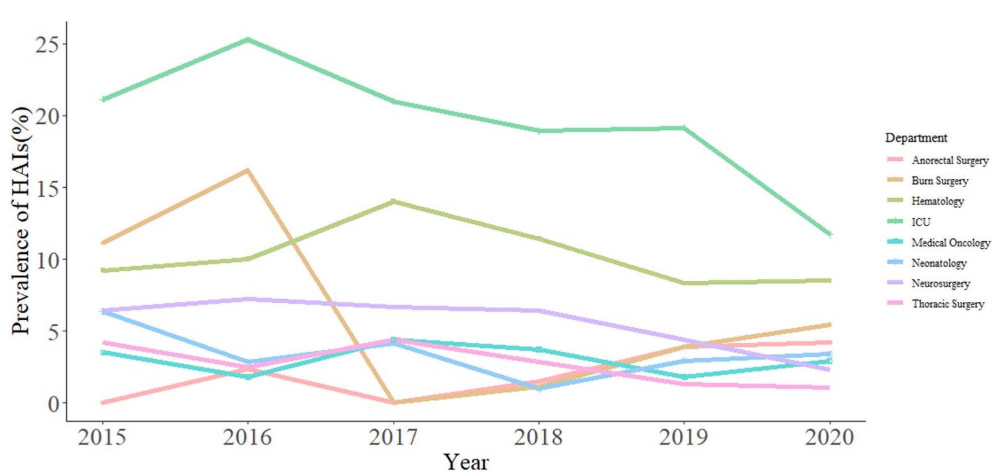

Fig. 1 Trends in HAI Prevalence by Department (2015–2020)

Table 2 Analysis of infection sites and pathogen distribution in HAIs (2015–2020)

	Total Infections	Upper Respiratory Tract	Lower Respiratory Tract	Intracranial	Urinary Tract	Gastrointestinal Tract	Intra-Abdominal Tissue	Surgical Site	Blood	Skin and Soft Tissue	Other sites[a]
Total HAIs Cases	2755	285	1276	23	297	143	88	189	132	116	171
Distribution of each HAIs type, % (95% CI)	…	10.34 (9.27-11.41%)	46.32 (44.46-48.18%)	0.83 (0.50-1.16%)	10.78 (9.64-11.92%)	5.19 (4.35-6.03%)	3.19 (2.54-3.84%)	6.86 (5.93-7.79%)	4.79 (3.98-5.60%)	4.21 (3.46-4.96%)	6.21 (5.30-7.12%)
Pathogen Counts	1297	44	824	5	127	38	49	75	46	37	38
Pseudomonas aeruginosa	218 (16.8%)	7 (15.9%)	176 (21.4%)	0 (0%)	8 (6.3%)	0 (0%)	7 (14.3%)	6 (8.0%)	1 (2.2%)	8 (21.6%)	5 (13.2%)
Klebsiella pneumoniae	199 (15.3%)	7 (15.9%)	156 (18.9%)	3 (60.0%)	5 (3.9%)	5 (13.2%)	4 (8.2%)	5 (6.7%)	9 (19.6%)	1 (2.7%)	4 (10.5%)
Escherichia coli	133 (10.3%)	2 (4.5%)	59 (7.2%)	0 (0%)	35 (27.6%)	4 (10.5%)	7 (14.3%)	9 (12.0%)	5 (10.9%)	4 (10.8%)	4 (10.5%)
Staphylococcus aureus	81 (6.2%)	4 (9.1%)	47 (5.7%)	0 (0%)	1 (0.8%)	2 (5.3%)	2 (4.1%)	13 (17.3%)	3 (6.5%)	7 (18.9%)	2 (5.3%)
Acinetobacter baumannii	141 (10.9%)	10 (22.7%)	111 (13.5%)	0 (0%)	4 (3.2%)	0 (0%)	0 (0%)	5 (6.7%)	6 (13.0%)	3 (8.1%)	1 (2.6%)
Enterococcus faecalis	14 (1.08%)	0 (0%)	3 (0.4%)	0 (0%)	6 (4.7%)	1 (2.6%)	0 (0%)	1 (1.3%)	1 (2.2%)	2 (5.4%)	0 (0%)
Enterococcus faecium	14 (1.08%)	0 (0%)	0 (0%)	0 (0%)	8 (6.3%)	0 (0%)	2 (4.1%)	1 (1.3%)	2 (4.3%)	0 (0%)	1 (2.6%)
Streptococcus pneumoniae	9 (0.7%)	2 (4.5%)	7 (0.8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Coagulase-Negative Staphylococci	15 (1.2%)	0 (0%)	4 (0.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (5.3%)	4 (8.7%)	0 (0%)	2 (5.3%)
Other pathogens[b]	473 (36.5%)	12 (27.3%)	261 (31.7%)	2 (40.0%)	60 (47.2%)	26 (68.4%)	27 (55.1%)	31 (41.3%)	15 (32.6%)	12 (32.4%)	19 (50.0%)

Data are presented as No. (%) unless otherwise indicated

Abbreviations: CI, confidence interval

[a]Other sites included postoperative pneumonia, viral hepatitis, bacterial meningitis, transfusion-associated infections, intraspinal infections, cardiovascular infections, bone and joint infections, reproductive tract infections, oral infections, and burn site infections

[b]Other pathogens include Stenotrophomonas maltophilia, Anaerobes, Other Enterobacteriaceae, Haemophilus, Other Pseudomonas spp, Proteus, nonspecified gram-positive cocci, nonspecified gram-negative bacilli, fungi, and viruses

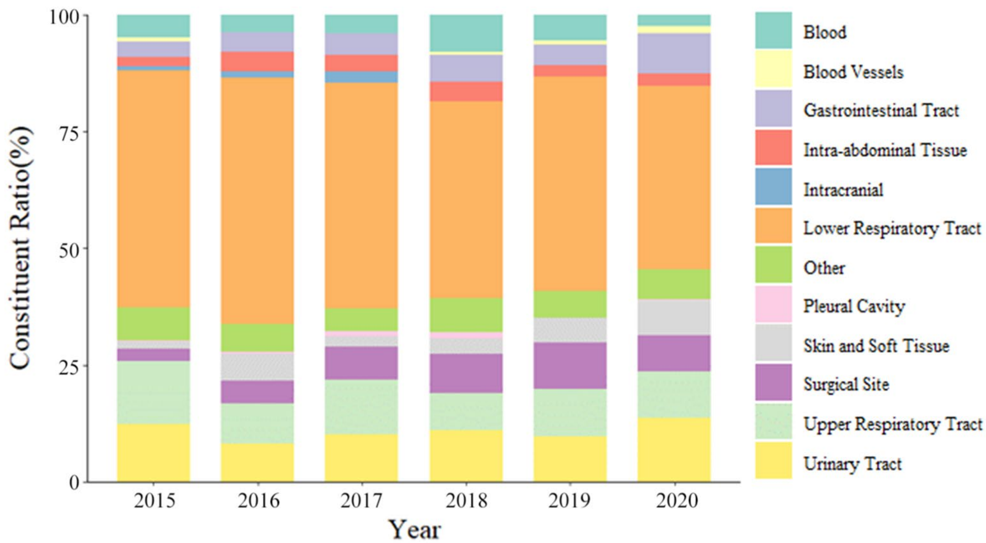

Fig. 2 Trend Analysis of Infection Proportions by Site in Hospitals (2015–2020)

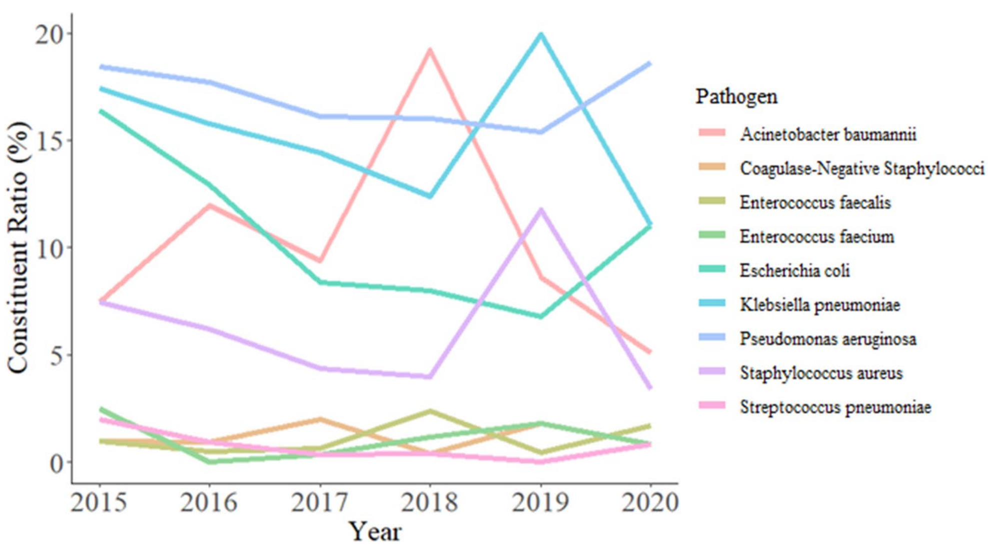

Fig. 3 Trends in the proportions of pathogens in HAIs (2015–2020)

while blood vessel-related infections experienced a modest increase from 0.75 to 1.72% ($Z = 2.702$, $P = 0.007$). Detailed results of the Cochran-Armitage Trend Test for infection sites are available in Supplementary **Table S4**,with the annual distribution of infection sites available in Supplementary **Table S2**.

Composition of pathogens in Hospital-Acquired infections

As detailed in Fig. 3, a total of 1,297 pathogenic strains were isolated from the 42 hospitals. *E. coli* showed a notable increase in cases between 2019 and 2020, despite an overall declining trend (Z=-2.856, $P = 0.004$). Similarly, *Streptococcus pneumoniae* exhibited a consistent decrease over time (Z=-2.856, $P = 0.004$). Detailed results of the Cochran-Armitage Trend Test for all bacterial pathogens are available in Supplementary **Table S4**, with the annual distribution of pathogens available in Supplementary **Table S3**.

Changes in the proportions of MDROs

Table 3 presents the annual counts and proportions of MDROs identified from 2015 to 2020. The most frequently detected were *carbapenem-resistant Enterobacteriaceae* (*CRE*, 11–79 per year, with substantial year-to-year fluctuation, accounting for 37.20%), followed by *carbapenem-resistant Acinetobacter baumannii* (*CRAB*, 11–44 per year, accounting for 20.65%), *methicillin-resistant Staphylococcus aureus* (*MRSA*, 5–25 per year, accounting for 18.26%), and *carbapenem-resistant Pseudomonas aeruginosa* (*CRPA*, 19–22 per year, accounting for 21.16%). *Vancomycin-resistant Enterococcus* (*VRE*,0–9 per year, accounting for 2.73%) was the

Table 3 Annual changes in the proportions of MDROs(2015–2020)

MDRO	Strains (%)						
	2015	2016	2017	2018	2019	2020	Total
Carbapenem-Resistant Enterobacteriaceae(CRE)	27 (34.18)	79 (60.77)	11 (15.07)	55 (38.73)	21 (27.92)	25(29.76)	218(37.20)
Methicillin-Resistant Staphylococcus aureus (MRSA)	9 (11.39)	9 (6.92)	25 (34.25)	20 (14.08)	21 (26.92)	23 (27.38)	107(18.26)
Carbapenem-Resistant Pseudomonas aeruginosa(CRPA)	20 (25.32)	22 (6.92)	21 (28.78)	22 (15.49)	19 (24.36)	20 (23.81)	124(21.16)
Carbapenem-Resistant Acinetobacter baumannii(CRAB)	22 (27.85)	11 (8.46)	12 (16.45)	44 (30.99)	17 (21.79)	15 (17.86)	121(20.65)
Vancomycin-Resistant Enterococcus (VRE)	1 (1.27)	9 (6.92)	4 (5.48)	1 (0.70)	0 (0.00)	1(1.19)	16(2.73)
Total	79 (23.09)	130 (100.00)	73 (100.00)	142 (100.00)	78 (100.00)	84 (100.00)	586(100.00)

least common, with no isolates detected in 2019. The years 2016 and 2018 represented peaks in MDROs detection, with totals of 130 and 142 isolates, respectively, making the highest numbers recorded during the study period.

Antimicrobial drug use and pathogen detection analysis

Between 2015 and 2020, a total of 156,009 hospitalized patients were included in this survey, among whom 54,907 received antimicrobial drugs, resulting in an average prevalence of 35.19%. Of those receiving antimicrobial treatment, 36,990 cases (67.37%) were prescribed for therapeutic purposes. Regarding combination therapy,39,090 patients (70.75%) received a single antimicrobial agent, 15,205 (27.52%) received dual combination therapy, and 818 (1.48%) were treated with three antimicrobial agents, whereas 144 (0.26%) received more than three antimicrobial agents. During the six-year study period, clinical specimens for pathogenic microorganisms testing were submitted for 1103 patients, resulting in a submission rate of 50.89%, which showed a significant upward trend over time ($Z = 4.287$, $P < 0.001$) (Table 4).

Discussion

This study analyzed data from 156,009 hospitalized patients across 42 hospitals in Weifang City, Shandong Province, China, from 2015 to 2020, focusing on antimicrobial use and HAIs. The overall prevalence of HAIs was 1.66%, showing a gradual decline over time. Compared to the reported prevalence in other countries—such as Singapore (11.9%) [24], Germany (4.6%) [25], Switzerland (5.6%) [26], Italy (5%) [27], and the United States (5%) [28]—the prevalence observed in our study is notably lower. This discrepancy is likely attributable to several methodological differences. First, diagnostic criteria differ significantly across countries. The Hospital Infection Diagnostic Standards (2001 edition) used in China do not explicitly define certain key HAIs, such as viral infections, catheter-related bloodstream infections, and ventilator-associated pneumonia. In contrast, the Centers for Disease Control and Prevention-National Healthcare Safety Network in the United States regularly updates and expands its definitions [29]. Consequently, the narrower diagnostic framework may lead to an underestimation of HAIs prevalence. Second, underreporting remains a substantial issue. In China, improving the identification and documentation of HAIs has been a central focus of infection control [30]. However, studies report underreporting of 5.97% in secondary hospitals and up to 7.19% in tertiary hospitals, particularly in the central region [13, 31]. Surveillance systems often rely heavily on case records and laboratory results, which may omit clinically significant cases. Similar underreporting patterns have been observed elsewhere. For instance, Romania reported the HAI prevalence of just 2.6% between 2015 and 2019, substantially below the European average (7.5%), likely due to deficiencies in reporting infrastructure [7]. Beyond methodological concerns, underreporting raises ethical issues. Missed or unreported HAIs can delay clinical intervention, directly compromising patient safety. Inaccurate documentation may also undermine patient confidentiality, reduce transparency, and weaken accountability. Therefore, accurate and timely reporting is crucial not only for effective infection surveillance but also for maintaining ethical standards in clinical practice and protecting patient rights. Transparency in HAI reporting is essential to ensure accuracy and uphold ethical care standards. Reporting practices should align with global patient safety frameworks, such as those outlined by the WHO, to enhance data integrity, promote accountability, and safeguard patient rights. Third, differences in data collection frequency and reporting practices further affect comparability. The European Centre for Disease Prevention and Control (ECDC) conducts a standardized point prevalence survey every five years, while our study uses an annual survey with random sampling [32]. The ECDC's one-day cross-sectional approach offers greater timeliness and consistency, whereas variations in our sampling period may reduce sensitivity to short-term trends. Although both systems employ electronic data collection tools, the ECDC applies more rigorous data validation procedures, resulting in higher data accuracy and reliability. These differences likely contribute to variability in HAI prevalence across studies. To facilitate clearer comparison, we have included **Table S6** in the supplementary materials, which outlines the key methodological differences between this study and the

Table 4 Analysis of antimicrobial drug use and clinical pathogen submission rates among hospitalized patients (2015–2020)

Year	Number of Patients Surveyed	Antimicrobial Drug Usage Rate (%)	Composition of Antimicrobial Drug Usage Purpose (%)			Composition of Antimicrobial Combination Therapy (%)				Rate of Pathogen Testing Prior to Antimicrobial Therapy (%)
			Therapeutic	Prophylactic	Therapeutic + Prophylactic	Single Drug	Dual Combination	Triple Combination	Quadruple or More Combination	
2015	20,871	36.22	63.65	30.57	5.78	66.82	32.00	1.12	0.05	42.77
2016	23,611	34.74	60.94	31.94	7.12	68.19	30.10	1.63	0.07	43.22
2017	26,211	38.22	65.83	27.44	6.73	68.19	30.10	1.63	0.07	45.17
2018	27,857	36.44	67.40	26.29	6.32	69.30	27.46	2.47	0.77	48.72
2019	29,192	33.86	73.90	23.02	3.08	71.31	27.33	1.26	0.09	51.51
2020	29,267	31.07	70.82	26.06	3.12	75.28	23.41	1.22	0.09	72.95
Total	157,009	35.19	67.37	27.31	5.33	70.75	27.52	1.48	0.26	50.89

The Cochran-Armitage Trend Test results for both the Antimicrobial Drug Usage Rate and the Rate of Pathogen Testing Prior to Antimicrobial Therapy are as follows: Antimicrobial Drug Usage Rate: Z=-0.756, P = 0.450; Rate of Pathogen Testing Prior to Antimicrobial Therapy: Z=-4.287, P < 0.001

ECDC protocol, particularly those that may affect data comparability. The ECDC's monitoring framework offers several valuable lessons for enhancing HAI surveillance in China, including the regular revision of standardized diagnostic criteria, the implementation of a structured and validated electronic data collection system, and the provision of comprehensive training programs to ensure data consistency and reliability. Adapting these practices could substantially improve the accuracy, comparability, and utility of HAI data in the Chinese healthcare context. Nevertheless, the implementation of real-time monitoring networks, intelligent early-warning systems, and enhanced governmental oversight has played a significant role in improving the detection of HAIs and mitigating underreporting [33, 34]. However, continued efforts are essential to standardize diagnostic criteria, enhance surveillance methodologies, and improve data comparability across regions. Future research should consider integrating such data with advanced data analytics and AI-driven tools to optimize infection control strategies, improve intervention effectiveness, and minimize reporting biases.

In the ICU, which plays a critical role in managing severe cases, the prevalence of HAIs was markedly higher than in other departments, with notable year-to-year fluctuations. A global point prevalence study involving 1,150 ICUs in 88 countries found that the prevalence of ICU-acquired infections was 22.0% [35]. In this study, the ICU infection prevalence was recorded at 19.54%, which is slightly higher than prevalence observed in Wuhan City (19.09%) [36], Heilongjiang Province (12.87%) [37], and Anhui Province (10.64%) [38], but lower than those reported in Switzerland (26.2%) [26] and Singapore (37.0%) [24]. From 2015 to 2016, the ICU infection prevalence demonstrated an upward trend, subsequently stabilizing or declining (Z=-3.216, P = 0.001). This fluctuation may be attributed to increased patient volume and illness severity during that time, which likely strained infection control capacity. The subsequent decline in infection rates is plausibly linked to targeted interventions, including improved hand hygiene compliance, implementation of central line-associated bloodstream infection (CLABSI) prevention protocols, and enhanced staff training and surveillance. These context-specific strategies—particularly in high-risk units such as the ICU—appear to have played a key role in improving infection control outcomes and reducing nosocomial infection risks.

Departments performing complex and prolonged surgical procedures, such as gastrointestinal surgery, thoracic surgery, and neurosurgery, are particularly vulnerable to wound infections. Many patients may also be immunocompromised pre- and post- surgery, heightening their susceptibility to infections. The observed increase in infection prevalence within gastrointestinal surgery may be attributable to targeted monitoring initiatives introduced in 2018,which included strengthened surveillance and enhanced reporting practices specifically implemented in gastrointestinal surgery wards. Nonetheless, the neurosurgery department demonstrated an overall declining trend in the prevalence of HAIs, indicating effective infection control progress. The neonatology department reported an HAI prevalence of 3.36%, lower than 7.16% reported in Italy [39]. Given the vulnerability of newborns, particularly those who are extremely premature or low-birth-weight, strict infection control measures are imperative. These measures should include adherence to aseptic techniques, regular disinfection of medical equipment, infection prevention training for healthcare staff, enhanced environmental hygiene in wards, and timely monitoring and response mechanisms for infections.

Infection predominantly occurred in the lower respiratory tract, consistent with findings from relevant studies in China [40, 41] and Europe [42–45]. While LRTIs remained the most common type of infection, they exhibited a declining trend from 2015 to 2020, likely reflecting improved infection control measures and antibiotic stewardship. Notably, in 2020, the proportion of LRTIs reached the lowest level observed in our dataset, which may be attributed to the strict infection prevention and control measures implemented during the COVID-19 pandemic, including universal masking, enhanced use of personal protective equipment, and patient cohorts. These interventions likely reduced the cross-transmission of respiratory pathogens. However, this trend contrasts with findings from Africa [46, 47], where infections predominantly occurred in SSIs. Similarly, data from the National Healthcare Safety Network (NHSN) in the United States indicated that SSIs accounted for 42.4% of all HAIs, followed by catheter-associated UTIs (29.7%) and CLABSI (25.3%) [48]. In this study, SSIs exhibited a noticeable upward trend, which may be attributable to the implementation of more stringent control policies and enhanced institutional focus on surveillance. Specifically, the increased frequency of hospital-wide prevalence surveys, the establishment of dedicated surgical infection monitoring teams, and the introduction of standardized perioperative antibiotic prophylaxis protocols have likely improved the identification and reporting of SSIs. These changes reflect a shift from under-recognition to more active detection, thereby contributing to the observed increase.

The most frequently isolated pathogens were *P. aeruginosa*, *K. pneumoniae*, and *E. coli*, aligning with findings from other studies in China [40, 49]. These pathogens were predominantly associated with LRTIs (46.32%), UTIs (10.78%), and URTIs (10.34%), which were the most common infection sites observed. A nationwide study in China reported that respiratory infection constituted 52.22% of HAIs [50], a proportion substantially higher than those typically reported in Western countries, reflecting a greater burden of pneumonia among HAIs cases in China. In contrast, SSIs represent a larger proportion of HAIs in Western hospitals [51]. For example, data from the U.S. NHSN data indicate that *S. aureus* is the most common pathogen responsible for SSIs [48]. Consistent with this difference, our study found a relatively low proportion of SSIs (6.86% of HAIs), which corresponded with a lower prevalence of *S. aureus* (6.2% of isolates) compared to predominance of Gram-negative bacteria. This microbial distribution pattern may reflect underlying antibiotic usage practices within hospital settings. The predominance of Gram-negative pathogens, particularly *P. aeruginosa and K. pneumoniae*, is potentially associated with the widespread use of broad-spectrum antibiotics, including carbapenems. The overuse or inappropriate use of these agents can exert substantial selective pressure, facilitating the emergence and persistence of multidrug-resistant Gram-negative bacteria [52]. This underscores the importance of antimicrobial stewardship programs that aim to optimize antibiotic selection and reduce unnecessary use of last-line agents.

Additionally, *E. coli*, a major pathogen in UTIs, was predominantly isolated from UTIs (27.6%) and intra-abdominal infections (14.3%) in our study. The incidence of *E. coli* showed significant fluctuations, with a notable increase from 2019 to 2020 despite an overall declining trend (Z=-2.856, P = 0.004). Several factors may contribute to this variability, including advancements in infection control measures, shifts in antibiotic prescribing patterns, and changes in patient demographics. Understanding these trends is crucial for developing effective HAI control strategies. Overall, our findings underscore the importance of considering regional variations in infection epidemiology when designing prevention and control measures. Given the high burden of respiratory HAIs in China, targeted interventions—such as strengthened pneumonia prevention strategies and enhanced antimicrobial stewardship—are especially warranted to control Gram-negative bacterial infections.

Extensive research has established a strong correlation between the rise of antimicrobial resistance and the inappropriate use of antimicrobial agents. Minimizing irrational prescriptions is crucial for mitigating the spread of resistance [49, 53]. Our findings align with studies from other regions in China, confirming that *carbapenem-resistant bacteria* are the predominant MDROs in HAIs [54]. The widespread use of carbapenem antibiotics, particularly in Central Asia, has contributed to rising resistance rates [55]. However, unlike most Chinese regions where *CRAB* is typically the dominant MDRO, our study identified *CRE* as the most frequently isolated pathogen

[56, 57]. The highest MDROs counts were recorded in 2016 and 2018, with *CRE* being the most frequently isolated pathogen in both years. This surge underscores the need for targeted interventions to control *CRE* infections, particularly in healthcare settings where prevalence exhibit significant fluctuations. Such variations may be influenced by differences in antibiotic prescribing patterns and infection control measures, highlighting the importance of region-specific antimicrobial stewardship strategies.

VRE was the least frequently detected pathogen, a trend consistent with findings from other regions in China, with occasional years of zero detection [58]. Nevertheless, its occasional presence highlights the importance of continued monitoring. The variability observed in absolute MDROs counts emphasizes the importance of continuous evaluation and adaptive improvements in infection control strategies and antimicrobial stewardship programs, which are essential for effectively managing resistance and reducing the burdens of associated infections.

The average prevalence of antibiotic use among hospitalized patients in Weifang was 35.19%, which complies with the threshold recommended by the National Health Commission of China, stating that antibiotic utilization among inpatients should remain below 60.0% [59]. However, this level exceeds the World Health Organization's recommendation of less than 20% [60]. Compared to European nations, where antibiotic usage rates range from 14.5–22.3% [61–63], this rate reflects a persistent reliance on antimicrobial agents in Chinese hospitals. To mitigate this, comprehensive measures should be adopted, including enhanced antibiotic management, clinical training, improved diagnostic capabilities, and multidisciplinary collaboration with continuous monitoring and feedback. These strategies aim to improve HAI control, enhance patient safety, and reduce inappropriate antibiotic use. A notable shift in antimicrobial prescribing patterns was observed over the six-year study period. The use of single-agent therapy increased from 5,051 patients (66.82%) in 2015 to 6,805 patients (75.28%) in 2020, while dual combination therapy declined from 2,419 patients (32.00%) to 2,116 patients (23.41%) over the same period. Furthermore, the number of patients receiving exactly three antimicrobial agents remained relatively stable, increasing slightly from 85 (1.12%) in 2015 to 110 (1.22%) in 2020, while the number of patients receiving more than three agents also remained relatively stable, increasing from 4 (0.05%) to 8 (0.09%). Although the proportion of patients receiving three or more antibiotics remained relatively low, this pattern warrants attention, as it may reflect the presence of complex infections, empirical overtreatment, or gaps in diagnostic confidence, all of which could undermine stewardship efforts if not carefully monitored. This shift toward single-agent therapy likely reflects improved adherence to antimicrobial stewardship principles aimed at minimizing unnecessary combination therapy. The rate of pathogen testing before antibiotic administration significantly increased from 42.77% in 2015 to 72.85% in 2020 ($Z = 4.287$, $P < 0.001$), exceeding the recommended threshold of ≥ 50% set by national guidelines. This increase highlights a growing emphasis on pathogen identification in the hospital setting, which contributes to more accurate diagnoses and supports rational antibiotic use, thereby reducing reliance on empirical broad-spectrum therapies and mitigating the risk of antimicrobial resistance.

These findings provide a robust foundation for the development of evidence-based guidelines on rational antibiotic use, the enhancement of infection surveillance systems, and the improvement of healthcare quality. However, several limitations must be acknowledged. First, the study's focus on a single city constrains the generalizability of the findings to other regions or national contexts.Second, the retrospective design may have introduced potential biases or inconsistencies in data collection and recording.Third, we lacked data on the total number of tested isolates for each bacterial species, which limited our ability to calculate resistance rates and conduct trend analyses.Future research should expand the scope of monitoring to include diverse geographical regions, employ prospective study designs to mitigate biases, and incorporate complete isolate data to enable more accurate and standardized analysis of antimicrobial resistance trends.

Conclusions

This study provides key insights into the prevention and control of HAIs, highlighting the importance of strengthening infection control measures, responsible antimicrobial use, and improved pathogen detection. While limited to one city, the findings suggest that expanding future research to broader regions is essential to obtain more representative conclusions. Future studies should focus on in-depth analysis of specific infection types and more detailed data collection to enhance the applicability of the findings. Furthermore, enhanced multidisciplinary collaboration, continuous monitoring, and policy development are essentialcto further reduce infection prevalence and antimicrobial resistance, ensuring better patient outcomes.

Abbreviations

HAIs	Hospital-acquired infections
MDRO	Multidrug-resistant organism
WHO	World Health Organization
NHSN	National Healthcare Safety Network
ECDC	European Centre for Disease Prevention and Control
CLABSI	Central line-associated bloodstream infection
CRE	Carbapenem-resistant Enterobacteriaceae

CRAB	Carbapenem-resistant Acinetobacter baumannii
MRSA	Methicillin-resistant Staphylococcus aureus
CRPA	Carbapenem-resistant Pseudomonas aeruginosa
VRE	Vancomycin-resistant Enterococcus
LRTIs	Lower respiratory tract infections
URTIs	Upper respiratory tract infections
UTIs	Urinary tract infections
SSIs	Surgical site infections

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-025-11046-7.

Supplementary Material 1

Acknowledgements
Not applicable.

Author contributions
YD: Software, Validation, Formal analysis, Resources, Data curation, Writing-original draft, Writing-review & editing, and Visualization. HL: Conceptualization, Methodology, Writing-review & editing, Supervision, and Project administration.

Funding
No financial support was received for this study.

Data availability
This can be obtained by contacting the corresponding author.

Declarations

Ethics approval and consent to participate
This survey was conducted as part of a mandated quality improvement initiative and did not require ethical approval. As the study did not involve any interventions or the collection of personally identifiable information, the requirement for informed consent was waived. The research adhered to ethical principles consistent with the Declaration of Helsinki.

Consent for publication
None.

Competing interests
The authors declare no competing interests.

Received: 16 December 2024 / Accepted: 25 April 2025
Published online: 05 May 2025

References

1. Friedman ND, Kaye KS, Stout JE, McGarry SA, Trivette SL, Briggs JP, Lamm W, Clark C, MacFarquhar J, Walton AL, et al. Health care–associated bloodstream infections in adults: a reason to change the accepted definition of community-acquired infections. Ann Intern Med. 2002;137(10):791–7.
2. Šuljagić V, Bajčetić M, Mioljević V, Dragovac G, Mijović B, Janićijević I, Đorđević Z, Krtinić G, Rakić V, Ćirković I, et al. A nationwide assessment of the burden of healthcare-associated infections and antimicrobial use among surgical patients: results from Serbian point prevalence survey, 2017. Antimicrob Resist Infect Control. 2021;10(1):47.
3. König E, Medwed M, Pux C, Uhlmann M, Schippinger W, Krause R, Zollner-Schwetz I. Prospective surveillance of Healthcare-Associated infections in residents in four Long-Term care facilities in Graz, Austria. Antibiot (Basel) 2021, 10(5).
4. Cardoso T, Almeida M, Friedman ND, Aragão I, Costa-Pereira A, Sarmento AE, Azevedo L. Classification of healthcare-associated infection: a systematic review 10 years after the first proposal. BMC Med. 2014;12:40.
5. Gardam MA, Lemieux C, Reason P, van Dijk M, Goel V. Healthcare-associated infections as patient safety indicators. Healthc Pap. 2009;9(3):8–24.
6. Raoofi S, Pashazadeh Kan F, Rafiei S, Hosseinipalangi Z, Noorani Mejareh Z, Khani S, Abdollahi B, Seyghalani Talab F, Sanaei M, Zarabi F, et al. Global prevalence of nosocomial infection: A systematic review and meta-analysis. PLoS ONE. 2023;18(1):e0274248.
7. Szabó S, Feier B, Capatina D, Tertis M, Cristea C, Popa A. An overview of healthcare associated infections and their detection methods caused by pathogen Bacteria in Romania and Europe. J Clin Med 2022, 11(11).
8. Manoukian S, Stewart S, Graves N, Mason H, Robertson C, Kennedy S, Pan J, Kavanagh K, Haahr L, Adil M, et al. Bed-days and costs associated with the inpatient burden of healthcare-associated infection in the UK. J Hosp Infect. 2021;114:43–50.
9. Puro V, Coppola N, Frasca A, Gentile I, Luzzaro F, Peghetti A, Sganga G. Pillars for prevention and control of healthcare-associated infections: an Italian expert opinion statement. Antimicrob Resist Infect Control. 2022;11(1):87.
10. Barrasa-Villar JI, Aibar-Remón C, Prieto-Andrés P, Mareca-Doñate R, Moliner-Lahoz J. Impact on morbidity, mortality, and length of stay of Hospital-Acquired infections by resistant microorganisms. Clin Infect Dis. 2017;65(4):644–52.
11. Medina E, Pieper DH. Tackling threats and future problems of Multidrug-Resistant Bacteria. Curr Top Microbiol Immunol. 2016;398:3–33.
12. Allegranzi B, Bagheri Nejad S, Combescure C, Graafmans W, Attar H, Donaldson L, Pittet D. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. Lancet. 2011;377(9761):228–41.
13. Zhao JH, Qin B, Yan RN, Ma J, Hu LL, Liu YL. Analysis of the current status and trends of major hospital-acquired infection indicators in tertiary public hospitals in China (2018–2020). Chin J Infect Control. 2022;21(06):524–31.
14. Aggarwal R, Mahajan P, Pandiya S, Bajaj A, Verma SK, Yadav P, Kharat AS, Khan AU, Dua M, Johri AK. Antibiotic resistance: a global crisis, problems and solutions. Crit Rev Microbiol 2024:1–26.
15. Boucher HW, Talbot GH, Bradley JS, Edwards JE, Gilbert D, Rice LB, Scheld M, Spellberg B, Bartlett J. Bad Bugs, no drugs: no ESKAPE! An update from the infectious diseases society of America. Clin Infect Dis. 2009;48(1):1–12.
16. Xiao Y, Li L. A National action plan to contain antimicrobial resistance in China: contents, actions and expectations. AMR Control. 2017;15(3):17–20.
17. Ding L, Hu F. China's new National action plan to combat antimicrobial resistance (2022-25). J Antimicrob Chemother. 2023;78(2):558–60.
18. Zong Z, Wu A, Hu B. Infection control in the era of antimicrobial resistance in China: progress, challenges, and opportunities. Clin Infect Dis. 2020;71(Suppl 4):S372–8.
19. Hu F, Zhu D, Wang F, Wang M. Current status and trends of antibacterial resistance in China. Clin Infect Dis. 2018;67(suppl2):S128–34.
20. Willemsen I, Bogaers-Hofman D, Winters M, Kluytmans J. Correlation between antibiotic use and resistance in a hospital: temporary and ward-specific observations. Infection. 2009;37(5):432–7.
21. Luthander J, Bennet R, Giske CG, Eriksson M, Nilsson A. Trends of pediatric bloodstream infections in Stockholm, Sweden: A 20-year retrospective study. Pediatr Infect Dis J. 2020;39(12):1069–74.
22. Gozel MG, Hekimoglu CH, Gozel EY, Batir E, McLaws ML, Mese EA. National infection control program in Turkey: the healthcare associated infection rate experiences over 10 years. Am J Infect Control. 2021;49(7):885–92.
23. Notice on Issuing the Diagnostic Criteria for Nosocomial Infections. (Trial) [http://www.nhc.gov.cn/yzygj/s3593/200804/e19e4448378643a09913ccf2a055c79d.shtml].
24. Cai Y, Venkatachalam I, Tee NW, Tan TY, Kurup A, Wong SY, Low CY, Wang Y, Lee W, Liew YX, et al. Prevalence of Healthcare-Associated infections and antimicrobial use among adult inpatients in Singapore Acute-Care hospitals: results from the first National point prevalence survey. Clin Infect Dis. 2017;64(suppl2):S61–7.
25. Behnke M, Aghdassi SJ, Hansen S, Diaz LAP, Gastmeier P, Piening B. The prevalence of nosocomial infection and antibiotic use in German hospitals. Dtsch Arztebl Int. 2017;114(50):851–7.
26. Metsini A, Vazquez M, Sommerstein R, Marschall J, Voide C, Troillet N, Gardiol C, Pittet D, Zingg W. The Swissnoso N: point prevalence of healthcare-associated infections and antibiotic use in three large Swiss acute-care hospitals. Swiss Med Wkly. 2018;148:w14617.
27. Quattrocolo F, D'Ambrosio A, Corcione S, Stillo M, Blanco V, Gualano M, Villa G, Voglino G, Clemente S, Camussi E. Studio di Prevalenza Italiano Sulle Infezioni Correlate All'Assistenza e Sull'uso di Antibiotici Negli Ospedali per Acuti-Protocollo ECDC. Dipartimento Scienze della Salute Pubblica e Pediatriche, Università di Torino: Turin, Italy. 2018.

28. Huerta-Gutiérrez R, Braga L, Camacho-Ortiz A, Díaz-Ponce H, García-Mollinedo L, Guzmán-Blanco M, Valderrama-Beltrán S, Landaeta-Nezer E, Moreno-Espinosa S, Morfín-Otero R, et al. One-day point prevalence of healthcare-associated infections and antimicrobial use in four countries in Latin America. Int J Infect Dis. 2019;86:157–66.
29. Yang X, Liu Z, Zeng S, Zhou P. The diagnostic criteria for healthcare-associated infections in China should be urgently upgraded. Infect Control Hosp Epidemiol. 2024;45(6):795–6.
30. Liqian J. Application effect of root cause analysis in the management of underreported hospital infection cases. J Tradit Chin Med Manag:2020. 2014;2038:2225–6.
31. Song Xiaochao JJ, Qiao Meizhen J, Meijuan Z, Junji ZS. Analysis of regional hospital infection surveillance platform data from 41 hospitals in Suzhou. Chin J Nosocomiol. 2023;33(09):1413–6.
32. Point prevalence survey of healthcare-associated. infections and antimicrobial use in European acute care hospitals– protocol version 6.1 [https://www.ecdc.europa.eu/en/publications-data/point-prevalence-survey-healthcare-associated-infections-and-antimicrobial-use-vs-6].
33. Sips ME, Bonten MJM, van Mourik MSM. Automated surveillance of healthcare-associated infections: state of the Art. Curr Opin Infect Dis. 2017;30(4):425–31.
34. Wen R, Li X, Liu T, Lin G. Effect of a real-time automatic nosocomial infection surveillance system on hospital-acquired infection prevention and control. BMC Infect Dis. 2022;22(1):857.
35. Vincent JL, Sakr Y, Singer M, Martin-Loeches I, Machado FR, Marshall JC, Finfer S, Pelosi P, Brazzi L, Aditianingsih D, et al. Prevalence and outcomes of infection among patients in intensive care units in 2017. JAMA. 2020;323(15):1478–87.
36. Liu XL, Song Y, Gong L, Wang YM. A trend study of cross-sectional survey results on hospital infections in Wuhan from 2016 to 2020. Chin J Infect Control. 2024;23(02):175–81.
37. Xiao JQ, Lin L, Ren H, Li J, Zhang XX. Survey of prevalence rates of nosocomial infections in 74 hospitals of Heilongjiang Province in 2018. Chin J Nosocomiol. 2020;30(10):1569–73.
38. Peng H, Tao XB, Li Y, Hu Q, Qian LH, Wu Q, Ruan JJ, Cai DZ. Health care-associated infections surveillance in an intensive care unit of a university hospital in China, 2010–2014: findings of international nosocomial infection control consortium. Am J Infect Control. 2015;43(12):e83–85.
39. Ceparano M, Sciurti A, Isonne C, Baccolini V, Migliara G, Marzuillo C, Natale F, Terrin G, Villari P, The Collaborating G. Incidence of Healthcare-Associated infections in a neonatal intensive care unit before and during the COVID-19 pandemic: A Four-Year retrospective cohort study. J Clin Med 2023, 12(7).
40. Tao XB, Qian LH, Li Y, Wu Q, Ruan JJ, Cai DZ, Peng H. Hospital-acquired infection rate in a tertiary care teaching hospital in China: a cross-sectional survey involving 2434 inpatients. Int J Infect Dis. 2014;27:7–9.
41. Chen Y, Zhao JY, Shan X, Han XL, Tian SG, Chen FY, Su XT, Sun YS, Huang LY, Han L. A point-prevalence survey of healthcare-associated infection in fifty-two Chinese hospitals. J Hosp Infect. 2017;95(1):105–11.
42. Palaiopanos K, Krystallaki D, Mellou K, Kotoulas P, Kavakioti CA, Vorre S, Vertsioti G, Gkova M, Maragkos A, Tryfinopoulou K, et al. Healthcare-associated infections and antimicrobial use in acute care hospitals in Greece, 2022; results of the third point prevalence survey. Antimicrob Resist Infect Control. 2024;13(1):11.
43. Antonelli A, Ales ME, Chiecca G, Dalla Valle Z, De Ponti E, Cereda D, Crottogini L, Renzi C, Signorelli C, Moro M. Healthcare-associated infections and antimicrobial use in acute care hospitals: a point prevalence survey in Lombardy, Italy, in 2022. BMC Infect Dis. 2024;24(1):632.
44. Vandael E, Latour K, Goossens H, Magerman K, Drapier N, Catry B, Versporten A. Point prevalence survey of antimicrobial use and healthcare-associated infections in Belgian acute care hospitals: results of the Global-PPS and ECDC-PPS 2017. Antimicrob Resist Infect Control. 2020;9(1):13.
45. Zarb P, Coignard B, Griskeviciene J, Muller A, Vankerckhoven V, Weist K, Goossens M, Vaerenberg S, Hopkins S, Catry B et al. The European Centre for Disease Prevention and Control (ECDC) pilot point prevalence survey of healthcare-associated infections and antimicrobial use. Euro Surveill. 2012;17(46).
46. Abubakar U, Amir O, Rodríguez-Baño J. Healthcare-associated infections in Africa: a systematic review and meta-analysis of point prevalence studies. J Pharm Policy Pract. 2022;15(1):99.
47. Alemu AY, Endalamaw A, Bayih WA. The burden of healthcare-associated infection in Ethiopia: a systematic review and meta-analysis. Trop Med Health. 2020;48:77.
48. Weiner-Lastinger LM, Abner S, Edwards JR, Kallen AJ, Karlsson M, Magill SS, Pollock D, See I, Soe MM, Walters MS, et al. Antimicrobial-resistant pathogens associated with adult healthcare-associated infections: summary of data reported to the National healthcare safety network, 2015–2017. Infect Control Hosp Epidemiol. 2020;41(1):1–18.
49. Zhang Y, Chen XL, Huang AW, Liu SL, Liu WJ, Zhang N, Lu XZ. Mortality attributable to carbapenem-resistant Pseudomonas aeruginosa bacteremia: a meta-analysis of cohort studies. Emerg Microbes Infect. 2016;5(3):e27.
50. Wang Z, Du M, Cao H, Yao H, Liu B, Bai Y, Geng H, Jia Z, Liu Y. Epidemiology and risk factors of nosocomial infections in a Chinese tertiary-care hospital: a 10-year retrospective case-control study. Infect Dis (Lond). 2024;56(4):320–9.
51. Surgical site infection (SSI) event. Centers for Disease Control and Prevention (CDC) website. [https://www.cdc.gov/nhsn/PDFs/pscManual/9pscSSIcurrent.pdf]
52. Jean SS, Harnod D, Hsueh PR. Global threat of Carbapenem-Resistant Gram-Negative Bacteria. Front Cell Infect Microbiol. 2022;12:823684.
53. Davido B, Bouchand F, Calin R, Makhloufi S, Lagrange A, Senard O, Perronne C, Villart M, Salomon J, Dinh A. High rates of off-label use in antibiotic prescriptions in a context of dramatic resistance increase: a prospective study in a tertiary hospital. Int J Antimicrob Agents. 2016;47(6):490–4.
54. Fan ZY, You SJ, Li LB, Bian J, Tan FL. Multidrug-Resistant organism infections of inpatients in a hospital in Eastern China from 2015 to 2021. Infect Drug Resist. 2023;16:4387–95.
55. Versporten A, Zarb P, Caniaux I, Gros MF, Drapier N, Miller M, Jarlier V, Nathwani D, Goossens H. Antimicrobial consumption and resistance in adult hospital inpatients in 53 countries: results of an internet-based global point prevalence survey. Lancet Glob Health. 2018;6(6):e619–29.
56. Zhang Y, Zhong ZF, Chen SX, Zhou DR, Li ZK, Meng Y, Zhou JF, Hou TY. Prevalence of healthcare-associated infections and antimicrobial use in China: results from the 2018 point prevalence survey in 189 hospitals in Guangdong Province. Int J Infect Dis. 2019;89:179–84.
57. Xu Peng LY, Miaomiao C, Linna T, Yang W, Lixiang Z, Fang Z. Targeted surveillance analysis of Multidrug-Resistant Bacteria in Healthcare-Associated infections in a general hospital from 2018 to 2020. Chin J Nosocomiol. 2022;32(24):3779–82.
58. Yu J, Wang J, Fang X, Huang F. Investigation and Analysis of Infection among Inpatients in a Tertiary Hospital in Shanghai. Comput Math Methods Med. 2022;2022:1157083.
59. Notice on the Issuance of the National Action Plan for Combating Microbial Resistance. (2022–2025) [http://www.nhc.gov.cn/yzygj/s7659/202210/2875ad7e2b2e46a2a672240ed9ee750f.shtml]
60. Finn J. Application of SBDD to the discovery of new antibacterial drugs. Methods Mol Biol. 2012;841:291–319.
61. Dumpis U, Balode A, Vigante D, Narbute I, Valinteliene R, Pirags V, Martinsons A, Vingre I. Prevalence of nosocomial infections in two Latvian hospitals. Euro Surveill. 2003;8(3):73–8.
62. Lemmen SW, Becker G, Frank U, Daschner FD. Influence of an infectious disease consulting service on quality and costs of antibiotic prescriptions in a university hospital. Scand J Infect Dis. 2001;33(3):219–21.
63. Pavia M, Bianco A, Viggiani NM, Angelillo IF. Prevalence of hospital-acquired infections in Italy. J Hosp Infect. 2000;44(2):135–9.

Publisher's note