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ORIGINAL RESEARCH

Multidrug-Resistant Organism Infections of Inpatients in a Hospital in Eastern China from 2015 to 2021

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Background: The prevalence of multidrug-resistant organisms (MDRO) is gradually increasing in the global scope, causing serious burden to patients and society, which is an important public health problem.

Objective: To analyze the distribution and trend of MDROs and provide a reference for hospital infection control.

Methods: Collected data on MDROs infections among inpatients in a Grade III Level A hospital in Suzhou from 2015 to 2021, including drug-resistant bacteria strains and specimen sources, etc. Mantel-Haenszel χ^2 test was used to evaluate the trend of infection rates over the years and SPSS version 26.0 was used for statistics analysis.

Results: The hospital infection rate showed an overall downward trend across the seven-year period, ranging from 1.53% to 2.10%. According to the analysis of change of drug-resistant bacteria strains, the highest infection rate was *carbapenem-resistant Acinetobacter baumannii (CRABA)* (63.74%), followed by *methicillin-resistant Staphylococcus aureus (MRSA)* (46.37%), *carbapenem-resistant Pseudomonas aeruginosa (CRPAE)* (24.87%), *carbapenem-resistant Enterobacteriaceae (CRE)* (13.14%) and *vancomycin-resistant Enterococcus (VRE)* (0.42%). The results of Mantel-Haenszel χ^2 test showed that there was a linear relationship between the detection rate of *CRE* and *CRPAE* and the time ($P<0.001$), but the correlation was not strong (R = 0.136; R = 0.139). The overall detection rate of the five pathogens also increased ($P<0.001$). The majority of the specimens, mainly from sputum, airway secretions, and midstream urine, had a detection rate of over 70%.

Conclusion: Our data showed that the detection rate of MDROs generally increased from 2015 to 2021, although the hospital infection rate displayed a declining trend. Among the detection rate MDROs, the highest was *CRABA*, and the lowest was *VRE*. It is necessary to enhance the prevention, control, and management of MDROs infections in the clinical practice.

Keywords: MDRO, hospital infection, distribution characteristics

Introduction

Healthcare-associated Infection (HAI) is also known as hospital-acquired infection or nosocomial infection, refers to the infection acquired by patient in the hospital, including the infection occurring during hospitalization and the infection acquired in the hospital but occurring after discharge, excluding the infection that has started before admission or that were in the incubation period at the time of admission. Infections acquired by hospital staff in the hospital also belong to HAI. HAI prevention and control is an important part of medical work, which affects the safety and treatment effect of patients, is closely related to medical quality and safety, and is also an important indicator to evaluate the overall medical service level of the hospital.[1] As a negative event, HAI will significantly increase the medical costs of patients, prolong the hospitalization time and increase the burden of disease. It is estimated that 100,000 cases of HAI occur in the UK every year, resulting in 5000 deaths and an additional expenditure of 1.6 billion euros.[2] The annual economic burden caused by HAI in the United States is about 6.5 billion dollars every year.[3] The direct economic loss caused by HAI in China has already exceeded 10 billion yuan every year, resulting in a 70% increase in total medical expenses.[4] HAI is the key and difficult point of hospital management, and its high mortality and huge economic burden are gradually becoming the focus of clinical attention.

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Multidrug-resistant organism (MDRO) refers to bacteria that are resistant to three or more types of antimicrobial drugs at the same time. It is the main pathogenic bacteria of HAI, which significantly increases the difficulty of clinical treatment and brings great challenges to the prevention and control of HAI. The Scientific Advisory Committee of the Academia Europaea estimates that more than half of the deaths caused by HAI in the European Union every year are due to MDRO infections. Compared with non-MDRO infection, the mortality of MDRO infection is 1.3–2 times higher.[5] How to control and reduce MDRO infection has become the top priority in the management of medical institutions. In 2015, the National Health Commission of the People's Republic of China issued 13 indicators for the quality control of HAI, of which MDRO monitoring is the most important work in HAI management. MDRO is prone to hospital transmission and cluster events, so it is necessary to timely and accurately monitor relevant information, through which the type and severity of HAI in medical institutions can be monitored, and problems in infection prevention and control can be found in time. Long-term and systematic collection and analysis of MDRO infection data is of great significance for establishing preventive measures.[6] This study aims to provide reference for the implementation of infection control plans by analyzing MDRO surveillance data from a Grade III Level A hospital in eastern China from 2015 to 2021.

Methods

Study Design and Data Collection

A retrospective study was conducted to select MDRO monitoring data of all inpatients in a hospital from January 1, 2015 to December 31, 2021. This hospital was established in December, 1988. It is a comprehensive "Grade III Level A" hospital which integrates medical treatment, teaching, scientific research, disease prevention and nuclear emergency treatment. It has first national nuclear emergency medical rescue technical support center, rescue unit and training base.

Surveillance of HAIs was performed with a real-time nosocomial infection surveillance system (RT-NISS). The algorithm of system screening considers the data of positive microbiological examinations, antibiotic administration, serological and molecular testing, imaging reports, temperature, invasive device usage, and inpatient transfer.[7] Clinicians and infection control practitioners then confirmed the suspected HAI cases pushed by the system. The determination of HAI cases was based on the Diagnostic Criteria for Healthcare-associated Infection (Trial) issued by the National Health Commission of the PRC in 2001.[8] For the same strains cultured from the same site in the same patient, only the first results were recorded, excluding repeated isolates.

Enter the time and bacterial species in the system for retrieval, and collect the number and type of target bacteria, the distribution of specimens submitted, and the proportion of MDRO in hospital infection of all hospitalized patients. For the confidentiality of patient information, all data collected in our study were de-identified, that is, they do not have individual identification and cannot be traced.

Target Detection of Bacterial Species

According to the Healthcare-associated Infection Quality Control Index (2015 edition), the type of MDRO monitored includes *Carbapenem-resistant Enterobacteriaceae (CRE), Vancomycin-resistant Enterococcus (VRE), Methicillin-resistant Staphylococcus aureus (MRSA), Carbapenem-resistant Pseudomonas aeruginosa (CRPAE)* and *Carbapenem-resistant Acinetobacter baumannii (CRABA)*. *CRE* includes *Carbapenem-resistant Klebsiella pneumoniae (CRKPN)* and *Carbapenem-resistant Escherichia coli (CRECO)*. *VRE* includes *Vancomycin-resistant Enterococcus faecium (VREfm)* and *Vancomycin resistant Enterococcus faecalis (VREfa)*.

Materials

BD Phoenix™ M50 automated microbiology system was used, and the results were determined according to the Clinical and Laboratory Standards Institute (CLSI) standards. The quality control strains were *Escherichia coli* (ATCC25922), *Klebsiella pneumoniae* (ATCC700603), *Staphylococcus aureus* (ATCC25923), *Acinetobacter baumannii* (ATCC19606), *Pseudomonas aeruginosa* (ATCC27853), *Enterococcus faecium* (ATCC35667) and *Enterococcus faecalis* (ATCC29212).

Statistical Analysis

SPSS 26.0 was used for data analysis, and Mantel-Haenszel χ^2 test was used to evaluate whether there was a linear trend of infection rate over the years. The significance was set at $P < 0.05$ and all statistical tests were two-tailed.

Results

HAI Situation Over the Years

From 2015 to 2021, a total of 542,754 inpatients were included, and the number of inpatients gradually increased. During this period, 9912 patients were infected in hospital, and the infection rate over the years was 2.10%, 1.62%, 1.58%, 2.09%, 2.07%, 1.85%, and 1.53%, respectively, which were basically maintained at a relatively stable level. The total incidence of HAI in the seven years was 1.83%. The detailed distribution is shown in Figure 1.

Detection of MDRO

From 2015 to 2021, a total of 7841 strains of five categories of pathogens were detected, of which 2127 strains were detected as MDRO, with a total detection rate of 27.13%. The detection rate of *CRABA* was the highest (958 strains, 63.74%), followed by *MRSA* 460 strains (46.37%), *CRPAE* 334 strains (24.87%), *CRE* 370 strains (13.14%) and *VRE* 5 strains (0.42%). Among the five pathogens, the detection rates of *CRPAE* and *CRE* showed an annual increase ($P < 0.001$), while the detection rates of the other three pathogens fluctuated slightly. In general, the total detection rate of five pathogens also showed an increasing trend ($P < 0.001$). The detection of each pathogen over the years is shown in Table 1, and the change in detection rate is shown in Figure 2.

Distribution of MDRO Specimens

The top five sources of MDRO specimens were sputum (1032, 96.63%), airway secretions (424, 95.71%), midstream urine (103, 45.78%), wound secretions (142, 88.20%) and drainage fluid (118, 83.69%).

Although the number of specimens was not large, the detection rate of lavage fluid, fiberscope brush specimens, ascites, nasal swabs, vaginal secretions, puncture fluid and peritoneal dialysis solution was 100%. The detection rate was above 70% in all specimens except midstream urine and faeces. All specimens were collected at the patient's visit for screening purposes. The distribution of specimens classified by pathogen type is shown in Table 2, and the distribution of specimens classified by year is shown in Table 3.

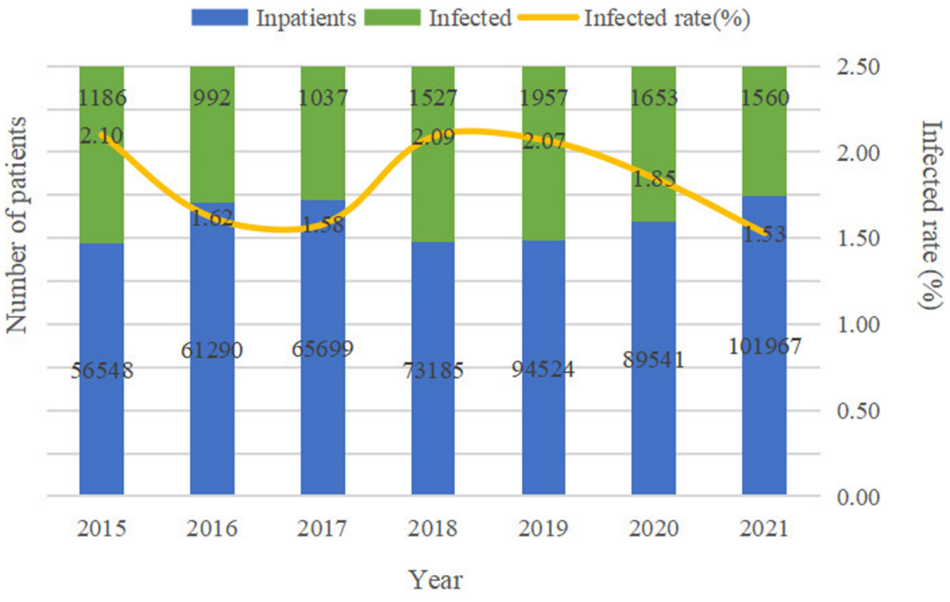

Figure 1 Healthcare-associated infection of inpatients in 2015–2021.

Table 1 Detection of Multidrug-Resistant Organisms from 2015 to 2021

Categories	2015		2016		2017		2018		2019		2020		2021		χ^2	*P*	*R*
	N	n (%)	N	n (%)	N	n (%)	N	n (%)	N	n (%)	N	n (%)	N	n (%)			
CRE	327	11 (3.36)	290	27 (9.31)	257	10 (3.89)	388	56 (14.43)	508	88 (17.32)	544	100 (18.38)	502	78 (15.54)	52.42	<0.001	0.136
VRE	142	1 (0.70)	97	0 (0.00)	105	0 (0.00)	174	1 (0.57)	240	1 (0.42)	211	1 (0.47)	218	1 (0.46)	0.01	0.907	0.003
MRSA	117	52 (44.44)	95	47 (49.47)	117	56 (47.86)	125	51 (40.80)	168	74 (44.05)	193	105 (54.40)	177	75 (42.37)	0.03	0.873	0.005
CRPAE	146	2 (1.37)	146	34 (23.29)	122	21 (17.21)	182	32 (17.58)	247	54 (21.86)	303	120 (39.60)	197	71 (36.04)	22.45	<0.001	0.139
CRABA	152	53 (34.87)	230	168 (73.04)	186	128 (68.82)	198	118 (59.60)	240	176 (73.33)	233	147 (63.09)	264	168 (63.64)	7.10	0.008	0.069
Total	884	119 (13.46)	858	276 (32.17)	787	215 (27.32)	1067	258 (24.18)	1403	393 (28.01)	1484	473 (31.87)	1358	393 (28.94)	41.91	<0.001	0.073

Notes: "N" represents the total number of such bacteria (both resistant and non-resistant), and "n" represents the number of multi-resistant bacteria in such bacteria.

Abbreviations: CRE, carbapenem-resistant E*nterobateriaceae*; VRE, vancomycin-resistant E*nterococcus*; MRSA, methicillin-resistant S*taphylococcus aureus*; CRPPAE, carbapenem-resistant P*seudomonas aeruginosa*; CRABA, carbapenem-resistant *Acinetobacter baumannii.*

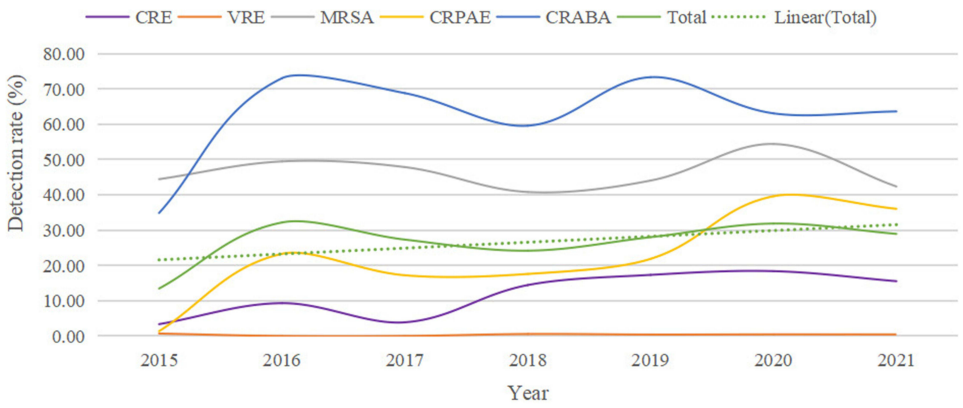

Figure 2 Distribution of the multidrug-resistant organisms detection rate.

Discussion

HAI surveillance is important for the implementation and follow-up evaluation of infection prevention and control measures. From 2014, the prevalence of HAI in China is 2.3–2.7%, which is lower than that of the United States (3.2–4%) and Europe (5.9%) during this period.[9] The present study showed that the seven-year average infection rate of the hospital was 1.83%, which met the relevant requirements of the National Health Commission (the prevalence rate of HAI in Grade III Level A hospitals ≤10%). The overall infection rate showed a downward trend, from 2.10% to 1.53%. Our data are similar to the infection rate of other tertiary hospitals in the region.[10] Compared with the results reported by comprehensive tertiary hospitals in other regions of the country, the data were slightly different, with higher or lower infection rates.[11–14] It may be related to the different disease types and severity of patients admitted by hospitals in different regions, as well as the different scale of hospitals, diagnosis and treatment conditions and the rate of examination. Compared with general hospitals in other countries, the infection rate in this study was significantly lower,[15–17] which is closely related to our country's efforts in HAI prevention and control. In recent years, the relevant laws and regulations on the management of HAI have been gradually improved, the allocation of HAI teams has been continuously optimized, the awareness of prevention and control of medical staff has been continuously strengthened, and the management of HAI has been carried out steadily, with certain achievements made. At the end of 2019, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection spread rapidly around the world and became a public health emergency of global concern.[18] The COVID-19 pandemic has improved people's awareness of infection prevention and control strategies, changed people's lifestyles and medical treatment behavior, and hospitals at all levels have strengthened infection control. The literature suggests that as the risk of COVID-19 has increased, health care professionals have comprehensively improved infection prevention and control behaviors.[19,20] The decrease in infection rates in 2020 and 2021 may be related to this reason. In 2018, due to the needs of business work, the study hospital added comprehensive intensive care unit and neurosurgery ward II, which are also prone to multidrug-resistant organism infection. The increase in infection rate in 2018 may be related to this reason.

It is important to understand the composition, distribution and infection characteristics of clinical MDRO in order to control and reduce HAI. In our study, the total detection rate of MDRO was 27.13%, and the detection rate of *CRABA* ranked first for six consecutive years since 2016. In terms of specimen types, the isolates were mainly derived from lower respiratory tract, and sputum specimens were the main source (1032, 48.52%), which was consistent with other reports in China and other countries.[20,21] It is worth noting that the collection of respiratory specimens is susceptible to contamination, and it is recommended to collect as far as possible not easily contaminated, meaningful specimens. The qualified rate of respiratory tract specimens was as follows: bronchoalveolar lavage fluid > aspiration secretion > induced sputum > deep sputum. Although sputum specimens have limited clinical significance, they are the specimens with the highest rate of examination. The key to their reliability lies in the standard collection and examination of specimens in clinical work, which is also the focus of infection managers. *CRABA* is an important opportunistic pathogen of HAI in critically ill and immunocompromised patients, mainly causing respiratory infections. In recent two years,

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Table 2 Specimen Sources of Multidrug-Resistant Organisms from 2015 to 2021

Variables	CRE		VRE		MRSA		CRPAE		CRABA		Total	
	N	n (%)	N	n (%)	N	n (%)	N	n (%)	N	n (%)	N	n (%)
Sputum	147	146 (99.32)	21	0 (0.00)	269	268 (99.63)	180	176 (97.78)	451	442 (98.00)	1068	1032 (96.63)
Airway secretion	63	61 (96.83)	8	0 (0.00)	50	49 (98.00)	67	61 (91.04)	255	253 (99.22)	443	424 (95.71)
Midstream urine	91	51 (56.04)	62	2 (3.23)	5	3 (60.00)	30	17 (56.67)	37	30 (81.08)	225	103 (45.78)
Wound secretion	23	21 (91.30)	17	1 (5.88)	41	41 (100.00)	26	26 (100.00)	54	53 (98.15)	161	142 (88.20)
Drainage fluid	22	22 (100.00)	24	2 (8.33)	16	16 (100.00)	25	24 (96.00)	54	54 (100.00)	141	118 (83.69)
Blood	42	41 (97.62)	8	0 (0.00)	11	11 (100.00)	10	10 (100.00)	41	40 (97.56)	112	102 (91.07)
Pharyngeal swab	11	11 (100.00)	5	0 (0.00)	51	50 (98.04)	10	10 (100.00)	34	33 (97.06)	111	104 (93.69)
Faeces	0	0 (NA)	43	0 (0.00)	2	0 (0.00)	9	0 (0.00)	0	0 (NA)	54	0 (0.00)
Cerebrospinal fluid	2	2 (100.00)	0	0 (NA)	3	3 (100.00)	1	1 (100.00)	19	18 (94.74)	25	24 (96.00)
Lavage fluid	1	1 (100.00)	0	0 (NA)	4	4 (100.00)	5	5 (100.00)	12	12 (100.00)	22	22 (100.00)
Catheter	10	10 (100.00)	3	0 (0.00)	4	4 (100.00)	0	0 (NA)	6	6 (100.00)	23	20 (86.96)
Pleural fluid	1	1 (100.00)	3	0 (0.00)	1	1 (100.00)	1	1 (100.00)	8	8 (100.00)	14	11 (78.57)
Fiberscope brush specimen	1	1 (100.00)	0	0 (NA)	0	0 (NA)	2	2 (100.00)	8	8 (100.00)	11	11 (100.00)
Ascites	2	2 (100.00)	0	0 (NA)	1	1 (100.00)	1	1 (100.00)	1	1 (100.00)	5	5 (100.00)
Nasal swab	0	0 (NA)	0	0 (NA)	5	5 (100.00)	0	0 (NA)	0	0 (NA)	5	5 (100.00)
Vaginal secretion	0	0 (NA)	0	0 (NA)	2	2 (100.00)	0	0 (NA)	0	0 (NA)	2	2 (100.00)
Punctate	0	0 (NA)	0	0 (NA)	1	1 (100.00)	0	0 (NA)	0	0 (NA)	1	1 (100.00)
Peritoneal dialysis solution	0	0 (NA)	0	0 (NA)	0	0 (NA)	0	0 (NA)	1	1 (100.00)	1	1 (100.00)
Total	416	370 (88.94)	194	5 (2.58)	466	459 (98.50)	367	334 (91.01)	981	959 (97.76)	2424	2127 (87.75)

Notes: "N" represents the total number of such bacteria (both resistant and non-resistant), and "n" represents the number of multi-resistant bacteria in such bacteria. These specimens were collected according to different types of infection at the patient's first visit in order to detect pathogens.

Abbreviations: CRE, carbapenem-resistant *Enterobateriaceae*; VRE, vancomycin-resistant *Enterococcus*; MRSA, methicillin-resistant *Staphylococcus aureus*; CRPPAE, carbapenem-resistant *Pseudomonas aeruginosa*; CRABA, carbapenem-resistant *Acinetobacter baumannii*.

Table 3 Distribution of Major Specimen Sources of Multidrug-Resistant Organisms from 2015–2021

Variables	2015		2016		2017		2018		2019		2020		2021	
	N	n (%)	N	n (%)	N	n (%)	N	n (%)	N	n (%)	N	n (%)	N	n (%)
Sputum	68	53 (77.94)	133	133 (100.00)	112	112 (100.00)	137	132 (96.35)	210	206 (98.10)	245	238 (97.14)	163	158 (96.93)
Airway secretion	36	25 (69.44)	55	55 (100.00)	2	2 (100.00)	45	43 (95.56)	78	76 (97.44)	109	107 (98.17)	84	82 (97.62)
Midstream urine	15	2 (13.33)	23	8 (34.78)	17	5 (29.41)	23	14 (60.87)	50	21 (42.00)	51	24 (47.06)	46	29 (63.04)
Wound secretion	12	11 (91.67)	33	33 (100.00)	19	17 (89.47)	18	16 (88.89)	25	23 (92.00)	20	17 (85.00)	34	25 (73.53)
Drainage fluid	15	11 (73.33)	14	14 (100.00)	11	10 (90.91)	16	14 (87.50)	19	15 (78.95)	26	24 (92.31)	40	30 (75.00)
Total	146	102 (69.86)	258	243 (94.19)	161	146 (90.68)	239	219 (91.63)	382	341 (89.27)	451	410 (90.91)	367	324 (88.28)

Notes: "N" represents the total number of such bacteria (both resistant and non-resistant), and "n" represents the number of multi-resistant bacteria in such bacteria. These specimens were collected according to different types of infection at the patient's first visit in order to detect pathogens.

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there have been increasing reports of *CRABA* associated with hospital-acquired pneumonia, especially ventilator-associated pneumonia.[22–26] The infection is difficult to treat may be related to the following reasons: First, once A. baumannii exhibits carbapenem resistance, resistance to most other antibiotics expected to be active against wild-type A. baumannii usually develops, leaving few therapeutic options. Second, there is no clear "gold standard" for evaluating the effectiveness of various treatment regimens for *CRABA* infection, and studies on the effectiveness of commonly used drug treatments are limited. Third, the data on whether specific drugs have an advantage in *CRABA* treatment or whether combination regimens have additive benefit in treating *CRABA* infection are still incomplete.[27]

Limitations

There are also limitations in our study. First, the data collected were all from one hospital, and sample representation may be insufficient. So, we tried to extend the research time to overcome this limitation. Second, the identification and classification of our cases are based on clinical microbiology results and the judgment of professional staff. Despite the existence of official guidelines, variations may exist among individuals in identifying the occurrence of HAI. Third, the sensitivity of colistin is an important part of MDRO. Due to the limitations of conditions, we did not conduct colistin sensitivity tests, but it may be involved in our following research.

Conclusion

This study analyzed the HAI situation, especially the MDROs, in a Grade III Level A hospital. Our data indicated a general increase in the detection rate of MDROs, despite the declining trend observed in the hospital infection rate. The *CRABA* ranked first in detection rate for six years in a row. Lower respiratory tract infection was the main infection site, and sputum was the main specimen source. The increasing detection rate of MDRO hinders the clinical anti-infection treatment. Starting from the changeable influencing factors such as improving the hand hygiene compliance of medical staff, strict environmental disinfection, implementation of contact isolation, standardized use of antibiotics and appropriate administrative support, and take timely and effective control measures is imperative.

Data Sharing Statement

The raw data supporting the conclusions of this article will be made available from the corresponding author by request.

Ethics Approval

Ethical approval was not necessary for this study because our study has not affected participants directly. This study was retrospective and did not involve any prospective observation or intervention. The data were derived from biological samples from previous medical records, which had been collected before this study. All the data used in this study have been de-identified, that is, they do not have individual identification and cannot be traced. The information obtained is only used for this study to effectively protect the privacy of participants. The research project does not involve commercial interests, and the privacy and identity information of participants are protected.

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Disclosure

The authors report no conflicts of interest in this work.

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