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Original article

Surveillance of MRSA, ESBL-producing *Klebsiella pneumoniae*, carbapenem-resistant Enterobacteriaceae, and *Clostridioides difficile* in Catalan Hospitals: Findings from the VINCat Program

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ABSTRACT

Introduction: This study aimed to describe the epidemiological trends of methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum beta-lactamase (ESBL)-producing *Klebsiella pneumoniae*, carbapenem-resistant Enterobacteriaceae (CRE), and *Clostridioides difficile* in Catalonia, Spain.
Methods: We analyzed data from hospitals participating in the VINCat Program from 2008 to 2022. The study analyzed antimicrobial susceptibility data from isolates collected in acute care hospital settings. Key metrics: annual MRSA rate, incidence density of new MRSA cases, MRSA bacteremia, and hospital-acquired MRSA cases. We assessed the rate of ESBL-producing *K. pneumoniae* and carbapenemase-resistant (CR)-*K. pneumoniae*, CR-*Enterobacter cloacae*, and CR-*Escherichia coli*. For *C. difficile* infections (CDI), the incidence density was determined.
Results: While MRSA rate slightly decreased over the study period, the incidence of MRSA bacteremia increased. Global hospital-acquired MRSA incidence decreased but increased in small hospitals. Among patients with bacteremia, the rate of ESBL-producing *K. pneumoniae* remained stable; in contrast, the rate of CR-*K. pneumoniae* rose in large centers as well as did the rates of CR-*E. cloacae* and CR-*E. coli*. CDI incidence rose substantially over the study period.
Conclusion: VINCat's hospital surveillance system has provided valuable insights into the evolving incidence of key multidrug-resistant organisms and CDI. These findings highlight the need for targeted interventions, particularly for MRSA in smaller hospitals and for CR-Enterobacteriaceae and CDI across all hospital sizes.

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◊ The members of this VINCat Programme appear in Appendix A.

Vigilancia de SAMR, *Klebsiella pneumoniae* productora de BLEE, *Enterobacteriaceae* resistentes a carbapenémicos y *Clostridioides difficile* en hospitales catalanes: resultados del programa VINCat

Palabras clave:
Microorganismos multirresistentes (MMR)
Staphylococcus aureus resistente a meticilina (SARM)
Enterobacteriaceae productoras de beta-lactamasas de espectro extendido (BLEE)
Enterobacteriaceae productoras de carbapenemasa
Clostridioides difficile

R E S U M E N

Introducción: Describir las tendencias de los principales patógenos asociados a la atención sanitaria en Cataluña, España.
Métodos: Se analizaron datos de hospitales participantes en el Programa VINCat. La población del estudio incluyó a pacientes tratados en áreas de agudos, y se basó en informes de susceptibilidad antimicrobiana. Indicadores: tasa anual de *Staphylococcus aureus* resistente a meticilina (SARM), densidad de incidencia de nuevos casos de SARM, de bacteriemia por SARM y de casos de SARM de adquisición hospitalaria.
Para *Klebsiella pneumoniae* productora de beta-lactamasa de espectro extendido (BLEE) y productoras de carbapenemasa (PC), *Enterobacter cloacae* y *Escherichia coli* PC: tasa de resistencia. Infecciones por *Clostridioides difficile* (ICD): densidad de incidencia.
Resultados: La tasa de SARM disminuyó del 23,73% al 21,34%, mientras que la incidencia de bacteriemia por SARM aumentó de 0,68 a 0,74 casos por 10.000 días-paciente (2015-2018 vs. 2019-2022). El SARM adquirido en el hospital disminuyó en los hospitales grandes de 0,77 a 0,66 casos por 10.000 días-paciente, pero aumentó en los hospitales pequeños de 0,58 a 0,81 casos (2012-2017 vs. 2018-2022). En pacientes con bacteriemia, la tasa de *K. pneumoniae*-BLEE se mantuvo estable por encima del 22%; en cambio, la tasa de *K. pneumoniae*-PC aumentó en centros grandes del 2,82% al 4,45%, al igual que las tasas de *E. cloacae*-PC (1,22% frente al 3,21%) y *E. coli* (0,07% frente al 0,26%) (2014-2017 vs. 2018-2022). La incidencia de ICD aumentó de 2,8 casos por 10.000 días-paciente a 4,19 casos (2008-2012 vs. 2018-2022).
Conclusión: El sistema de vigilancia de VINCat ha proporcionado información valiosa sobre la evolución de patógenos claves asociados a la atención sanitaria.

Introduction

The rising prevalence of multidrug-resistant organisms (MDROs) poses a significant public health challenge worldwide, contributing to increased healthcare costs and morbidity. The prevalence of these microorganisms varies considerably by bacterial species and geographical region.[1,2] Among the most concerning MDROs are methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum beta-lactamase (ESBL) producing *Klebsiella pneumoniae*, and, more recently, carbapenem-resistant Enterobacteriaceae – all of which are associated with limited treatment options, healthcare-associated infections (HAIs), and potential outbreaks.[3] The European Antibiotic Resistance Surveillance System (EARSS) provides critical insights into multidrug-resistant organisms (MDROs).[1] Between 2018 and 2022, the percentage of MRSA in invasive isolates decreased from 17.8% to 15.2%. However, significant geographic variations were noted, ranging from less than 1% in northern Europe to over 25% in southern and eastern regions. During the same period, the incidence of bloodstream infections caused by MRSA declined from 5.80 to 4.94 cases per 100,000 population. In 2022, the prevalence of ESBL-producing *K. pneumoniae* in invasive isolates was 32.7%, with the highest rates observed in southern and eastern Europe (>25%), compared to northern Europe (>10%). Similarly, carbapenem-resistant *K. pneumoniae* accounted for 10.9% of invasive isolates in 2022, following a geographic distribution pattern comparable to that of ESBL-producing *K. pneumoniae*. In contrast, carbapenem-resistant isolates remained rare among invasive *Escherichia coli* isolates. *Clostridioides difficile*, the leading cause of healthcare-associated infectious diarrhea, has experienced a significant rise in incidence over the past decade. This increase is likely due to a growing number of at-risk patients and advances in diagnostic methods, including the identification of community-associated infections, particularly in developed countries.[4–6]

Effective surveillance is the cornerstone of infection prevention and control programs targeting MDROs and *C. difficile*.[7] A robust hospital surveillance system is essential for establishing baseline infection rates, monitoring trends over time, and evaluating the effectiveness of implemented control measures. Moreover, such surveillance enables institutions to benchmark their performance against similar organizations, promoting continuous improvement in infection prevention and control efforts. The VINCat is a program of the Catalan Health Service created to establish a unified surveillance system for HAIs in Catalonia, Spain, which had a population of eight million in 2024. Its objective is to reduce the incidence of HAIs through continuous, active epidemiological monitoring. The program relies on the expertise of multidisciplinary infection control teams across healthcare centers and has been systematically collecting data since 2008.

This study aims to describe the trends in MRSA, ESBL-producing *K. pneumoniae*, carbapenem-resistant Enterobacteriaceae, and *C. difficile* infections (CDI) recorded in hospitals participating in the VINCat Program from 2008 to 2022.

Methods

Study design and hospital participation

This longitudinal descriptive study was conducted over a 15-year period from 2008 to 2022. The study was conducted in acute care hospitals participating in the VINCat Program, all of which have an infection control team (ICT) and are structured based on hospital size. Hospitals were categorized into four groups: Group 1 (large) with over 500 beds, Group 2 (medium) with 200 to 500 beds, Group 3 (small) with fewer than 200 beds and Group 4, hospitals that did not fit into the size-based stratification and consisted of specialized centers (3 oncology centers and 1 urology center). All hospitals followed uniform surveillance protocols.

Data collection

The study population of MRSA, ESBL-producing *K. pneumoniae* and carbapenem-resistant Enterobacteriaceae (*K. pneumoniae*, *Enterobacter cloacae* and *E. coli*) were based on antimicrobial sus-

ceptibility reports provided by the microbiology laboratory during each period and consisted of isolates from patients treated in any acute care area of the hospital (hospitalization units, outpatient clinics, emergencies, etc.), regardless of their age. Data only included unduplicated strains from samples obtained for clinical purposes, regardless of their clinical value (colonization or infection) and the location of acquisition. Samples from active surveillance of carriers were not included. Bacteremia due to ESBL *K. pneumoniae*, carbapenem-resistant *K. pneumoniae*, *E. cloacae* and *E. coli* was defined as any episode of clinically significant bacteremia (one episode per patient), regardless of the source of infection and where it was acquired.

The study population for CDI surveillance consisted of adult patients (≥18 years) diagnosed with CDI during the surveillance period. Cases of CDI were defined as patients with acute diarrhea or toxic megacolon without another known cause, plus one of the following: (1) stool sample with a toxin A- or B-positive laboratory result for *C. difficile*, or detection of genes that encode toxin by molecular testing; (2) endoscopic, surgical or histological examination confirming the diagnosis of pseudomembranous colitis. Colonized and asymptomatic patients have not been included, even if they carry a toxin-producing strain. Patients with a previous history of CDI and those hospitalized in palliative care and convalescence units were excluded. CDI was classified according to the site of acquisition of diarrhea: (1) Hospital-acquired CDI: infection identified >48 h after admission to the hospital and before discharge. (2) Non-nosocomial healthcare-related CDI: infection starting in the community or within 48 h of admission, in patients admitted to a health center (hospital, nursing home or community healthcare center) in the 4 weeks prior to the onset of symptoms. (3) Community-acquired CDI: infection starting in the community or within 48 h of admission, with no admission to a healthcare center in the last 4 weeks.

Surveillance metrics

For methicillin-resistant *S. aureus:*

- MRSA rate
- Incidence density of MRSA bacteremia
- Incidence density of new cases of MRSA
- Hospital-acquired MRSA cases

For ESBL-producing *K. pneumoniae*:

- Rate of ESBL-producing *K. pneumoniae*:
- Rate of ESBL-producing *K. pneumoniae* bacteremia:

For carbapenem-resistant Enterobacteriaceae:

- Rate of carbapenem-resistant *K. pneumoniae*, *E. cloacae*, and *E. coli.*
- Rate of carbapenem-producing *K. pneumoniae*, *E. cloacae*, and *E. coli* bacteremia.

For *C. difficile*:

- Incidence density of *C. difficile* infections

Detailed definitions of metrics calculation have been provided in supplementary material (metrics definition and calculation).

Statistical analysis

The data were summarized using frequencies and proportions for categorical variables. We presented medians and interquartile ranges (IQR) or means and standard deviations for continuous variables, depending on the distribution. Incidence rates were calculated by dividing the total number of cases by the total person-time at risk and adjusting for 10,000 patient-days, as appropriate. Analyses were stratified into relevant time periods. We conducted chi-square or Fisher's tests to assess differences in percentages, as deemed suitable. For continuous variables, comparisons were performed using *t*-Student or Wilcoxon tests, as appropriate. Odds ratios (OR) were calculated to quantify the magnitude and direction of these differences. We computed incidence rate ratios (IRR) to compare incidence rates. When comparing the two periods, we used the earlier period as the reference. In cases where three periods were compared, we evaluated the two most recent periods while taking the earliest of those two as the reference. To assess the degree of correlation and the direction of the relationship between incidence rates and years, we performed Spearman correlation (rho). LOESS smoothing was applied to the graphs to enhance the visualization of data trends. A significance level of 0.05 was applied to all statistical tests. Statistical tests were not explicitly adjusted for multiple comparisons. The results were analyzed using the R statistical software, version 4.2.2, developed by The R Foundation in Vienna, Austria.

Ethical aspects

Hospital participation in the VINCat Program is voluntary. The study complied with the principles of the Declaration of Helsinki, with international human rights, and with the legislation regulating biomedicine and personal data protection. All data were treated as confidential, and records were accessed anonymously. This study was approved by the Ethics Committee of Bellvitge Hospital (Ref. PR066/18). The Ethics Committee for Clinical Research waived the requirement for informed consent.

Results

Methicillin-resistant S. aureus

There were 67 participating hospitals collecting MRSA data. Table 1 and Fig. 1 provide data on MRSA metrics sorted by hospital size and study period (2011–2014, 2015–2018, 2019–2022). Overall, MRSA rate showed slight variability across the periods, with a minor decrease from 22.53% to 21.34%. This decrease was mainly observed in large and medium-sized hospitals, while specialized hospitals showed a notable increase from 23.01% to 32.07% and the small hospitals displayed relatively stable rates. The overall incidence rate of new cases of MRSA slightly increased from 5.05 per 10,000 patient-days in 2011–2014 to 5.19 in 2019–2022. Again, specialized hospitals had a marked increase, particularly in the 2019–2022 period. For MRSA bacteremia, the incidence rate varied over time from 0.63 to 0.74 per 10,000 patient-days in all hospital groups during the same periods. Characteristics of 3473 cases with hospital-acquired MRSA in clinical samples were collected across periods: period 1 (2012–2017:1889 cases) and period 2 (2018–2022:1584 cases), shown in Table S5. Key findings include a reduction in the median age in period 2. Additionally, there was a significant increase in the proportion of cases reported in small hospitals, rising from 15.6% to 23.5% between periods, particularly in medical wards. Finally, respiratory samples were the most common clinical source of MRSA in both periods, although their relative proportion decreased. The time from hospital admission to the first positive MRSA sample was less than 10 days in both periods.

ESBL-producing and carbapenem-resistant K. pneumoniae

Data was collected from 67 hospitals, 60 hospitals participating in the first period (2014–2017) and 66 in the second period

Table 1
Metrics for MRSA according to study period and type of hospital. (a) Rate of MRSA among *S. aureus* isolates. (b) Incidence rate of new cases of MRSA/10,000 patient-days. Incidence rate of MRSA bacteremia by hospital size.

Resistance profile and hospital size	Overall	Period 1 (2011–2014)	Period 2 (2015–2018)	Period 3 (2019–2022)	OR or IRR (95% CI)
Number of participating hospitals, n					
Total	67	56	63	66	
Large	9	9	9	9	
Medium	17	15	16	17	
Small	36	29	34	35	
Specialized	5	3	4	5	
% MRSA, cases/total S. aureus (%)					
Total	39,105/173,708 (22.51)	12,126/53,821 (22.53)	13,859/58,396 (23.73)	13,120/61,491 (21.34)	OR: 0.90 (0.88–0.92)
Large	17,421/79,656 (21.87)	5,932/26,271 (22.58)	6,202/27,047 (22.93)	5,287/26,338 (20.07)	OR: 0.88 (0.84–0.91)
Medium	12,483/56,586 (22.06)	3,438/16,090 (21.37)	4,397/18,308 (24.02)	4,648/22,188 (20.95)	OR: 0.87 (0.83–0.91)
Small	8,264/33,975 (24.32)	2,533/10,491 (24.14)	3,004/11,947 (25.14)	2,727/11,537 (23.64)	OR: 0.94 (0.89–1.00)
Specialized	937/3,491 (26.84)	223/969 (23.01)	256/1,094 (23.4)	458/1,428 (32.07)	OR: 1.37 (1.15–1.63)
New cases of MRSA/10,000 patient-days (IR)					
Total	24,961 (5.31)	7,359 (5.05)	9,180 (5.62)	8,422 (5.19)	IRR: 0.92 (0.90–0.95)
Large	11,871 (6.07)	3,487 (5.5)	4,501 (6.74)	3,883 (5.95)	IRR: 0.88 (0.85–0.92)
Medium	8,084 (5.08)	2,416 (5.04)	2,947 (5.3)	2,721 (4.9)	IRR: 0.93 (0.88–0.98)
Small	4,550 (4.39)	1,352 (4.32)	1,608 (4.44)	1,590 (4.26)	IRR: 0.96 (0.90–1.03)
Specialized	456 (3.81)	104 (3.37)	124 (2.68)	228 (5.37)	IRR: 2.00 (1.61–2.50)
MRSA bacteremia, cases/10,000 patient-days (IR)					
Total	3,233 (0.69)	912 (0.63)	1,117 (0.68)	1,204 (0.74)	IRR: 1.08 (1.00–1.18)
Large	1,728 (0.88)	566 (0.89)	566 (0.85)	596 (0.91)	IRR: 1.08 (0.96–1.21)
Medium	920 (0.58)	227 (0.47)	339 (0.61)	354 (0.64)	IRR: 1.05 (0.90–1.22)
Small	525 (0.51)	101 (0.32)	196 (0.54)	228 (0.61)	IRR: 1.13 (0.93–1.37)
Specialized	60 (0.5)	18 (0.58)	16 (0.35)	26 (0.61)	IRR: 1.76 (0.95–3.37)

IR: incidence rate; OR: odds ratio; IRR: incidence rate ratio; MRSA: methicillin-resistant *Staphylococcus aureus*.

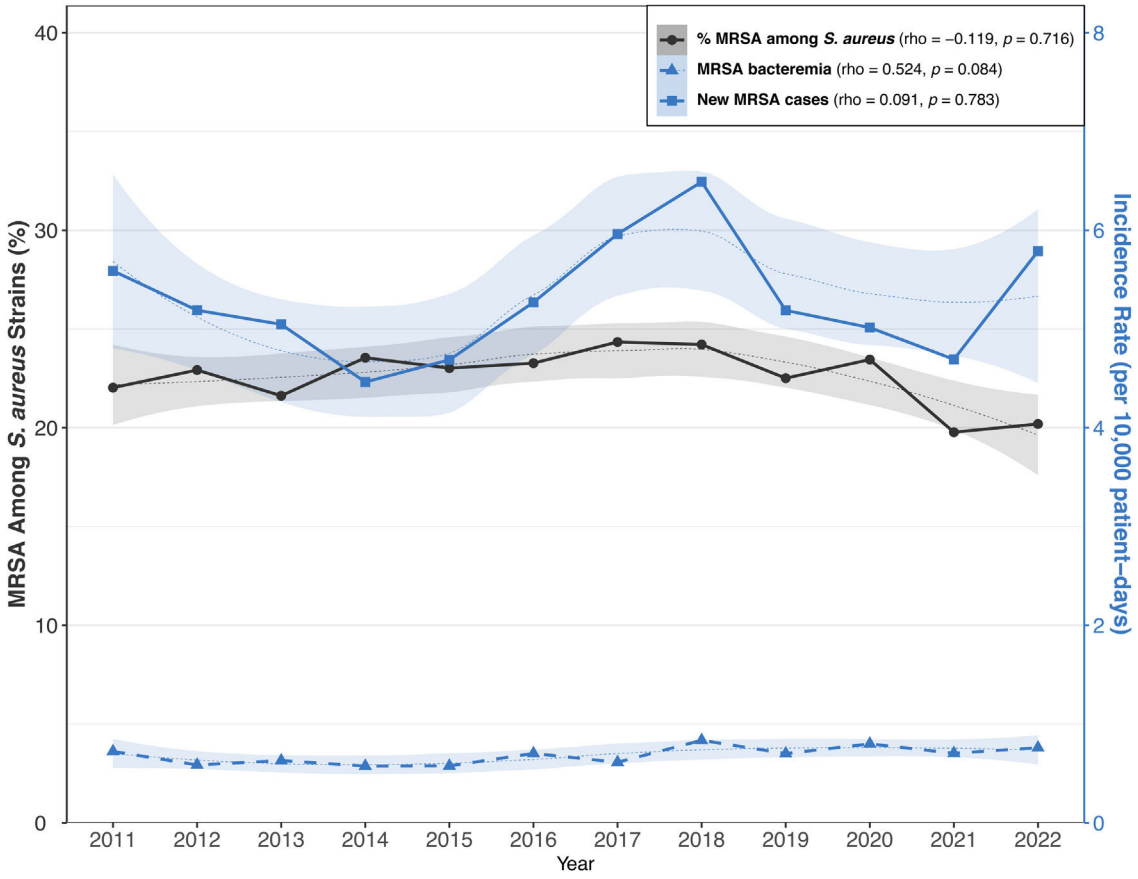

Fig. 1. Trends in (a) yearly rate of MRSA among *S. aureus* strains, (b) incidence rate per 10,000 patient-days of new cases of MRSA, (c) incidence of MRSA bacteremia per 10,000 patients-day. Shaded area represents the 95% confidence interval.

Table 2
Rates of ESBL-producing and carbapenemase producing *K. pneumoniae* according to hospital size and source of infection.

Hospital size	Other sources				Bacteremia			
	Overall	Period 1 2014–2017	Period 2 2018–2022	*p*-Value[a]	Overall	Period 1 2014–2017	Period 2 2014–2017	*p*-Value[a]
% ESBL K. pneumoniae, cases/total K. pneumoniae								
Total	22,642/118,182	6,142/32,785	16,500/85,397	0.059	2,481/11,257	678/3,031	1,803/8,226	0.701
	19.16%	18.73%	19.32%		22.04%	22.37%	21.92%	
Large	22.96%	24.89%	22.16%	<0.001	23.52%	25.21%	22.81%	0.134
Medium	16.68%	13.69%	17.82%	<0.001	20.13%	15.53%	21.67%	0.002
Small	17.44%	17.39%	17.45%	0.940	19.73%	22.22%	19.06%	0.304
Specialized	16.12%	13.36%	17.63%	<0.001	28.81%	34.02%	26.34%	0.377
% CP K. pneumoniae, cases/total K. pneumoniae (%)								
Total	2,326/118,182	511/32,785	1,815/85,397	<0.001	335/11,257	75/3,031	260/8,226	0.074
	1.97%	1.56%	2.13%		2.98%	2.47%	3.16%	
Large	3.17	2.08	3.62	<0.001	3.97	2.82%	4.45%	0.007
Medium	1.43	1.55	1.38	0.221	1.91	1.97%	1.89%	0.997
Small	1.02	0.75	1.11	0.024	1.62	1.63%	1.62%	1.000
Specialized	0.95	0.74	1.07	0.216	3.97	4.12%	3.9%	1.000

Period 1 (2014–2017) included 60 hospitals.
Period 2 (2018–2022) included 66 hospitals.
ESBL: extended-spectrum β-lactamase; CP: carbapenemase-producing.
[a] Pearson Chi-squared test.

(2018–2022). Rates of ESBL-producing and CR-*K. pneumoniae* isolates by hospital group and infection source are shown in Table 2. The overall rate of ESBL isolates from bloodstream and other sources remained stable between both periods. However, there was notable differences by hospital group: large hospitals showed a decrease, while medium and specialized hospitals observed increases. The CR-*K. pneumoniae* isolates rate from bloodstream infections and from other sources increased significantly from period 1 (2014–2017) to period 2 (2018–2022). The increase was most pronounced in large and small hospitals, while medium sized and specialized hospitals had lower and more stable rates.

Carbapenem-resistant E. cloacae *and* E. coli

Data was collected from 67 hospitals, with 60 hospitals participating in the first period (2014–2017) and 66 in the second (2018–2022) is shown in Table 3. Across the entire study period, 765 out of 31,880 of *E. cloacae* isolates were CR, resulting in an overall rate of 2.4%. The rate of CR-*E. cloacae* isolates from patients with bacteremia was 2.66%, with a statistically significant increase from 1.22% in the first period to 3.21% in the second period, mainly in large hospitals. The overall rate of CR-*E. coli* was 0.08%, increasing from 0.08% in period 1 to 0.18% in period 2 for bloodstream infections and from 0.06 to 0.09% for other sources.

Types of carbapenemase

Table S6 presents the distribution of type of carbapenemases among *K. pneumoniae*, *E. cloacae*, and *E. coli*, comparing period 1 (2014–2017) and period 2 (2018–2022). The OXA48 was the most common, accounting for 67.2% overall, slightly increasing from 66.3% in period 1 to 67.5% in period 2. The VIM also rose from 13% to 19.3% between periods, NDM remained stable at around 6.9%, and KPC rose from 4.6% to 13.3%. There were significant differences in carbapenemase distribution between the two periods for most organisms, especially for *K. pneumoniae* and *E. cloacae*.

Clostridioides difficile *infections*

The characteristics of 15,047 CDI reported by 62 hospitals across the three periods, period 1 (2008–2012), period 2 (2013–2017), and period 3 (2018–2022) are shown in Table S7. The median age of patients with CDI decreased from 75 years in period 1 to 72 years in period 3. Large hospitals reported 49.3% of cases, medium-sized hospitals 34.2%, and smaller hospitals 13.7%, while the percentage in specialized hospitals group was 2.9%. The proportion of cases reported by larger hospitals fell from 55.6% to 45.7% across periods, while smaller hospitals saw an increase from 6.2% to 16.8%.

The acquisition of CDI was hospital-acquired in 41.6% of cases, non-nosocomial healthcare-associated in 32% and community-acquired in 26.4%. Community-acquired cases rose from 19.4% in period 1 to 29.6% in period 3; hospital-acquired CDI increased from 30.3% to 42.1%, and non-nosocomial healthcare-related decreases from 50.3% to 28.3% across periods. Fig. 2 and Table 4 demonstrate a significant increase in CDI incidence from 2.28 cases per 10,000 patient-days in period 1 (2008–2012) to 4.19 in period 3 (2018–2022). The trend was maintained across nosocomial CDI (from 0.46 in 2010 to 1.94 in 2022) and community CDI (from 0.44 to 1.46). Table S7 shows that the CDI incidence rate rose from 3.33 cases per 10,000 patient-days (2013–2017) to 4.19 cases (2018–2022), regardless of hospital size or CDI origin.

Discussion

This study, which examines the trends in the incidence of major MDROs and CDIs across more than 60 hospitals in Catalonia, highlights the value of robust, long-term surveillance systems. The findings provide insights into baseline rates, their evolution over time, and the effectiveness of infection control measures. Moreover, hospitals can use these data to benchmark their performance and adapt infection prevention strategies accordingly.

Methicillin-resistant *S. aureus* continues to be a significant public health concern due to its association with high morbidity and mortality, especially in patients with bacteremia. Our study observed a slight decline in the rate of MRSA across the study period. This trend aligns with broader European data, which shows a reduction in MRSA prevalence in several countries.[1] While MRSA rates in larger hospitals decreased, specialized hospitals experienced an increase, possibly due to the higher admission rates of high-risk or colonized patients, such as those with frequent hospitalizations or chronic condicitions.[8] The rise in bacteremia cases between the two study periods suggests a need for further investigation into infection sources and control strategies.[9] Despite overall improvements in infection control, such as decolonization protocols, the figure of MRSA bacteremia underscores the necessity

Table 3
Rates of carbapenemase-producing *E. cloacae* and *E. coli* according to source of infection and hospital group.

Resistance profile and hospital size	Other sources				Bacteremia			
	Overall	Period 1 2014–2017	Period 2 2018–2022	*p*-Value[a]	Overall	Period 1 2014–2017	Period 2 2018–2022	*p*-Value[a]
% CR E. cloacae, cases/total E. cloacae								
Total	765/31,880	252/9,601	513/22,279	0.101	71/2,672	9/738	62/1,934	0.008
	2.4%	2.62%	2.3%		2.66%	1.22%	3.21%	
Large	3.39%	1.65%	4.11%	<0.001	3.78%	0.91%	4.93%	<0.001
Medium	2.1%	4.25%	0.85%	<0.001	0.78%	0.94%	0.72%	1.000
Small	0.83%	0.34%	0.95%	0.163	1.37%	4.55%	0.44%	0.061
Specialized	0.61%	0.23%	0.74%	0.613	4.11%	0%	5.56%	0.734
% CR E. coli, cases/total E. coli								
Total	371/450,410	77/135,081	294/315,329	<0.001	58/37,992	9/11,195	49/26,797	0.029
	0.08%	0.06%	0.09%		0.15%	0.08%	0.18%	
Large	0.15%	0.08%	0.18%	<0.001	0.2%	0.07%	0.26%	0.012
Medium	0.05%	0.06%	0.05%	0.250	0.13%	0.15%	0.12%	0.845
Small	0.05%	0.01%	0.06%	0.007	0.08%	0%	0.11%	0.346
Specialized	0.04%	0.03%	0.05%	0.810	0.36%	0%	0.64%	0.605

Overall period (2014–2022) included 67 hospitals: 9 large hospitals, 17 small hospitals, 36 medium-sized hospitals and 5 specialized hospitals.
Period 1 (2014–2017) included 60 hospitals: 9 large hospitals, 16 small hospitals, 31 medium-sized hospitals and 4 specialized hospitals.
Period 2 (2018–2022) included 66 hospitals: 9 large hospitals, 17 small hospitals, 35 medium-sized hospitals and 5 specialized hospitals.
ESBL: extended-spectrum β-lactamase; CP: carbapenemase-producing.
[a] Pearson Chi-squared test.

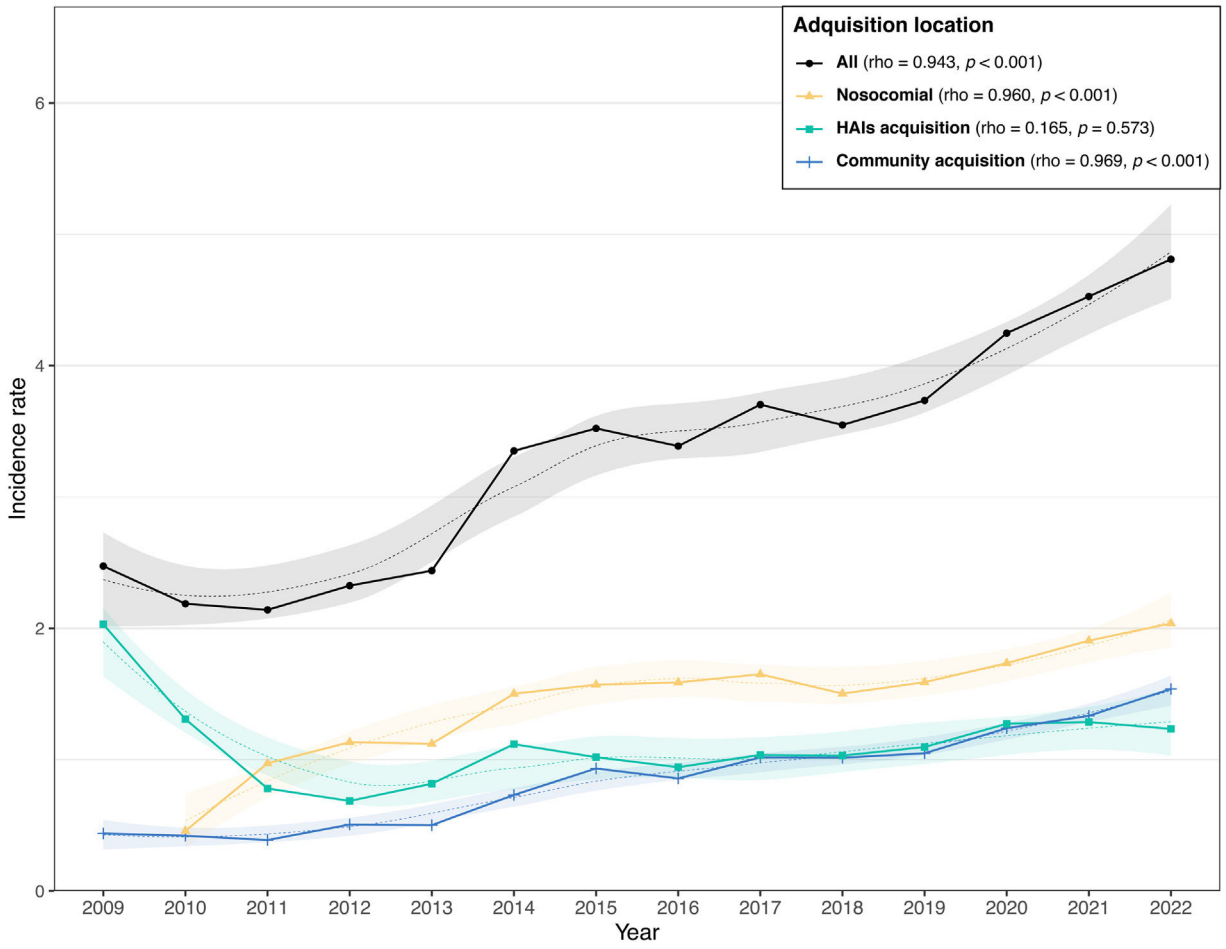

Fig. 2. Trends in the incidence rate per 10,000 patient-days of *Clostridioides difficile* infections diagnosed at VINCat hospitals stratifying by acquisition location.

for ongoing surveillance and tailored interventions, particularly in smaller hospitals and specialized centers.[10]

The stability of ESBL-producing *K. pneumoniae* rates at around 22% of cases of bacteremia is consistent with other European data, where rates vary significantly by region.[1] However, the rise in carbapenem-resistant Enterobacteriaceae, though still relatively low, is alarming. The increase in carbapenem-resistant *K. pneumoniae*, *E. coli*, and *E. cloacae* reflects global and broader European

Table 4
Incidence rate per 10,000 patient-days of *Clostridioides difficile* infections diagnosed at VINCat hospitals by acquisition and hospital size.

Source of infection and hospital group	Overall			Period 1 2008–2012			Period 2 2013–2017			Period 3 2018–2022			IRR (95% CI)
	Ep.	PD	IR	Ep.	PD	IR	Ep.	PD	IR	Ep.	PD	IR	
All	15,047	43,356,304	3.47	2,088	9,147,358	2.28	5,522	16,566,202	3.33	7,437	17,741,097	4.19	1.26 (1.21–1.30)
Large	7,413	18,510,540	0.40	1,16	4,026,062	0.29	2,853	7,327,253	0.39	3,4	7,255,578	0.47	1.20 (1.15–1.26)
Medium	5,141	16,819,670	0.31	727	4,160,278	0.17	1,869	6,086,765	0.31	2,545	6,572,627	0.39	1.26 (1.19–1.34)
Small	2,059	7,116,239	0.29	130	843,182	0.15	680	2,776,152	0.24	1,249	3,496,905	0.36	1.46 (1.33–1.60)
Specialized	434	909,855	0.48	71	117,836	0.60	120	376,032	0.32	243	415,987	0.58	1.83 (1.47–2.28)
Nosocomial	6,262	43,356,304	1.44	633	9,147,358	0.69	2,501	16,566,202	1.51	3,128	17,741,097	1.76	1.17 (1.11–1.23)
Large	3,565	18,510,540	0.19	397	4,026,062	0.10	1,458	7,327,253	0.20	1,71	7,255,578	0.24	1.18 (1.10–1.27)
Medium	1,773	16,819,670	0.11	149	4,160,278	0.04	729	6,086,765	0.12	895	6,572,627	0.14	1.14 (1.03–1.25)
Small	697	7,116,239	0.10	53	843,182	0.06	241	2,776,152	0.09	403	3,496,905	0.12	1.33 (1.13–1.56)
Specialized	227	909,855	0.25	34	117,836	0.29	73	376,032	0.19	120	415,987	0.29	1.48 (1.11–1.99)
HAIs acquisition	4,808	43,356,304	1.11	1,05	9,147,358	1.15	1,651	16,566,202	1.00	2,107	17,741,097	1.19	1.19 (1.12–1.27)
Large	2,199	18,510,540	0.12	573	4,026,062	0.14	764	7,327,253	0.10	862	7,255,578	0.12	1.14 (1.03–1.26)
Medium	1,817	16,819,670	0.11	411	4,160,278	0.10	639	6,086,765	0.10	767	6,572,627	0.12	1.11 (1.00–1.23)
Small	613	7,116,239	0.09	32	843,182	0.04	210	2,776,152	0.08	371	3,496,905	0.11	1.40 (1.19–1.66)
Specialized	179	909,855	0.20	34	117,836	0.29	38	376,032	0.10	107	415,987	0.26	2.54 (1.77–3.72)
Community acquisition	3,977	43,356,304	0.92	405	9,147,358	0.44	1,37	16,566,202	0.83	2,202	17,741,097	1.24	1.50 (1.40–1.61)
Large	1,649	18,510,540	0.09	190	4,026,062	0.05	631	7,327,253	0.09	828	7,255,578	0.11	1.33 (1.19–1.47)
Medium	1,551	16,819,670	0.09	167	4,160,278	0.04	501	6,086,765	0.08	883	6,572,627	0.13	1.63 (1.46–1.82)
Small	749	7,116,239	0.11	45	843,182	0.05	229	2,776,152	0.08	475	3,496,905	0.14	1.65 (1.41–1.93)
Specialized	28	909,855	0.03	3	117,836	0.03	9	376,032	0.02	16	415,987	0.04	1.59 (0.71–3.81)

Period 1: 2008–2012; period 2: 2013–2017; period 3: 2018–2022; Ep.: episodes; PD: patient-days; IR: incidence rate; IRR: incidence rate ratio.

trends, where carbapenem resistance has steadily increased, especially in Southern and Eastern European countries. This increase signals the need for more aggressive infection control strategies, including stricter antibiotic stewardship and enhanced isolation procedures for affected patients.[11] The widespread presence of OXA-48 carbapenemase, the most prevalent in our study, further underscores the necessity of surveillance to track the spread of specific resistance mechanisms.

Our findings reveal a significant increase in CDI incidence from 2009 to 2022, with a consistent rise across nosocomial and community-acquired cases. This trend contrasts with reports from other regions where CDI incidence has stabilized or decreased.[12] Improved diagnostic tools, introduced in 2011, may partly explain the rise, but other factors, including increased antibiotic use and an aging patient population, are likely to contribute to the higher rates.[13,14] The relative increase in the burden of CDI cases diagnosed in smaller hospitals makes it necessary to improve preventive measures, including antibiotic stewardship programmmes, in such centers. The increase in community-acquired CDI is particularly concerning, suggesting the need for more comprehensive preventive strategies beyond the hospital setting. This could involve enhanced antimicrobial stewardship programs, better hygiene practices in community healthcare environments, and public education about CDI transmission and prevention.[14]

The results from the VINCat Program offer critical insights into the evolution of MDROs and CDI in Catalonia's hospitals. However, the rise in carbapenemase-producing organisms and the persistence of MRSA and CDI in certain settings indicate that current infection control measures must be adapted and intensified, especially in smaller and specialized hospitals. Tailored interventions focusing on high-risk patient populations, more effective decolonization strategies, and comprehensive antibiotic stewardship programs are essential.

Further research should explore the long-term impact of COVID-19 on MDRO and CDI incidence. The pandemic likely influenced infection control practices and antibiotic usage in ways that are not yet fully understood. Changes in infection control practices and supply shortages were identified in facilities with eMDRO outbreaks during the SARS-CoV-2 pandemic and might have contributed to eMDRO transmission. Jeon et al. observed an increase in the prevalence of infections caused by MDRO isolates associated with a higher antibiotic consumption.[15] Other authors observed a reduction in the incidence density in the health-care associated CDI because a strict infection control measures including reinforced cleansing procedures.[16,17] Ongoing surveillance will be crucial in identifying whether trends observed during the pandemic will persist.

Our study has several strengths that contribute to its robustness and relevance. First, the longitudinal design spanning 15 years provides a comprehensive analysis of trends in MDROs and CDI. This extended timeframe allows for the identification of meaningful changes and long-term patterns. Second, the inclusion of data from 67 hospitals, representing diverse settings in terms of size and specialization, enhances the generalizability of the findings. By stratifying results based on hospital size, the study captures variability across different healthcare environments. Third, the use of standardized surveillance protocols across all participating centers ensures consistency in data collection and reporting, minimizing methodological bias and enabling reliable comparisons over time. Fourth, the study covers multiple key MDROs and CDI, providing a holistic view of antimicrobial resistance and healthcare-associated infections. This comprehensive approach makes the findings particularly valuable for guiding infection control strategies. Finally, as part of the VINCat Program, the study contributes valuable regional data on antimicrobial resistance trends in Catalonia, offering insights that can inform both local and broader infection control policies. Our study has several limitations that should be considered when interpreting the results. While grouping hospitals by size reduces the impact of outliers, we did not perform adjusted analyses to account for potential center-specific surveillance variations. This may have introduced bias, particularly if certain hospitals had significantly higher or lower infection rates. The study does not explore in detail the underlying factors driving the observed trends, such as the implementation of antibiotic stewardship programs or specific infection control measures. This limits our ability to directly attribute changes in incidence to particular interventions. Finally, the potential impact of the COVID-19 pandemic on antimicrobial resistance trends and hospital-acquired infections is not fully addressed. Changes in infection control practices, resource allocation, and antibiotic usage during the pandemic may have

influenced the results, and further investigation is needed to assess these effects comprehensively.

In conclusion, the VINCat Program's surveillance system has provided invaluable data on MDROs and CDI in Catalonia. These insights should guide future infection control efforts within individual hospitals and the broader healthcare system.

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Conflicts of interest

All authors declare no conflict of interest relevant to this article.

Data availability

Restrictions apply to the availability of these data, which belong to a national database and are not publicly available. Data was obtained from VINCat and are only available with the permission of the VINCat Technical Committee.

Appendix A. Members of the VINCat Program and the infection control teams participating in the program, and external microbiologists from the centers

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Appendix B. Supplementary data

Supplementary data associated with this article can be found in the online version available at https://doi.org/10.1016/j.eimce.2025.02.013.

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