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Original Article

Antimicrobial stewardship programs in acute-care hospitals: A multicenter assessment of structure, process, and outcome indicators in Italy and Spain

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ABSTRACT

Background: Antimicrobial stewardship (AMS) programs have been differently implemented across Europe. This study primarily aimed to compare AMS in two European regions. Secondarily, the study explored the COVID-19 pandemic impact on surrogate outcome indicators of AMS.
Methods: A retrospective observational study was conducted in Piedmont (Italy) and Catalonia (Spain). AMS programs were compared through structure and process indicators in 2021. Changes in surrogate outcome indicators (antimicrobial usage; alcohol-based sanitizer consumption; antimicrobial resistance, AMR) from 2017 to 2021 described the pandemic impact.
Results: Seventy-eight facilities provided structure and process indicators. Catalonia showed better structure scores ($p < 0.001$) and less dispersion in both indicators. The greatest areas to improve were accountability (Piedmont) and diversification of strategies (Catalonia). Overall, the regions reported consistent changes in outcome indicators. Antimicrobial usage decreased in 2020, returning to near-pre-pandemic levels in 2021. Alcohol-based sanitizer consumption surged in 2020, then dipped remaining above pre-pandemic levels. AMR trends were minimally affected.
Conclusions: The centralized approach of Catalonia ensured consistent attainment of quality objectives across all facilities, but it may limit facility-specific strategies. In Piedmont, accountability remain one of the most critical factors as in previous years. The pandemic did not substantially disrupt surrogate outcome measures of AMS. However, the data on AMR suggest that maintaining vigilance against this issue remains paramount.
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Introduction

Antibiotic-resistant infections are on the rise. The latest European data showed significantly rising trends in the number of infections caused by antibiotic-resistant pathogens, attributable deaths, and clinical burden in terms of disability-adjusted life years from 2016 to 2020. Approximately 70 % of infections with antibiotic-resistant bacteria are estimated to be healthcare-related [1].

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Although the trend of antimicrobial resistance (AMR) is increasing in most countries, there are substantial epidemiological differences among European countries, generally with a north-to-south and west-to-east gradient [1,2]. Italy is among the European countries with the greatest AMR burden, with over 19 estimated attributable deaths per 100,000 inhabitants in 2020, while other countries report a lower burden, such as Spain, which had 4 estimated attributable deaths per 100,000 inhabitants in the same year [1].

Antimicrobial stewardship (AMS) encompasses a comprehensive strategy and coordinated actions to promote responsible use of antimicrobials, including optimal selection, dosing, and duration [3,4]. Previous reports suggest the implementation of AMS initiatives can lead to decreases in infections and colonisations by antibiotic-resistant bacteria, as well as in the incidence of Clostridiodies *difficile* infections [5]. AMS can improve patient safety, as optimizing antibiotic use can reduce treatment failures and adverse events. Another measurable positive effect is the reduction of costs to hospitals, mainly due to reduced length of stay [6].

In Europe, each country has created programs for infection prevention and control, as well as AMS, based on its own health system and local epidemiological context [7]. However, despite a general decline in antimicrobial consumption, the most recent data indicate that there are relevant differences between countries in the utilization of antimicrobials, emphasizing the importance of prioritizing AMS efforts and highlighting the possibility of achieving even greater decreases in antimicrobial usage [2,8,9]. Moreover, along with a global rise in AMR [10], the COVID-19 pandemic has had an impact on AMS programs. The diversion of infection control resources during this unprecedented situation has generally resulted in challenges in implementing and sustaining AMS initiatives [11,12]. with an increase in certain healthcare-associated infections (HAIs) [13].

Given the above, it appears relevant to delve into AMS programs in countries with different approaches, to explore differences and areas for improvement. Therefore, this paper primarily aimed to compare key features of AMS programs implemented in Italy and Spain, which have different epidemiology and AMR burden [1] but similar health system structures. Secondarily, this study aimed to explore the disruption caused by the pandemic by describing changes in surrogate outcome indicators of AMS during and following the pandemic.

Methods

Study design

A multicenter retrospective observational study was conducted between February and May 2023 in Piedmont (Italy) and Catalonia (Spain). Participating centers were acute-care facilities enrolled in the surveillance programs. More detailed Methods are available in the Supplementary File.

In Piedmont, a regional program for surveillance and infection control of HAIs and AMR has been established since 2008. All acute-care hospitals in the Regional Health System adhere to the surveillance, as it is mandatory for hospitals to formulate a program for prevention and surveillance of HAIs and AMR based on European Centre for Disease Prevention and Control (ECDC) indicators. AMS program are developed by multidisciplinary teams within each hospital. Since 2017, surrogate outcome measures (i.e. the outcome indicators of this paper) relevant to AMS have been documented.

In Catalonia, the VINCat (Infection Control and Antimicrobial Stewardship Catalan Program) is a program of the Catalan Health System, instituted in 2006, which establishes a unified surveillance system for HAIs. The surveillance provides monitoring of several ECDC indicators through standardization and analysis enabled by a Coordinating Centre, which communicates with all participating hospitals. Acute hospitals are invited to participate and sign an annual contract with the Catalan Health System where they state the program goals they will pursue and the indicators monitored. Adherence to the surveillance is voluntary, but hospitals receive financial compensation upon goal attainment [14].

Structure and process indicators were collected to compare the characteristics of AMS programs of Piedmont and Catalonia. Data on surrogate outcome indicators were gathered to explore the pandemic impact. The data collection was limited up to 2021. No ethical approval was required as no patient-level data were gathered.

Structure and process indicators

Structure and process indicators were assessed through scores previously developed by the Authors [15]. A modified version of the structure score was used as it was not possible to collect the item “microbiological laboratory quality management” in Catalonia. The modified structure score consisted of 4 items, whose scores ranged from 0 to 2 (overall score from 0 to 8). The process score was composed of 6 items, whose scores ranged from 0 to 1 or 2 (overall score from 0 to 10). A total score was calculated by adding the two scores. A higher score represented better quality in that domain. For both regions, these indicators referred to the year 2021.

For each center, data on ownership (public or private), number of beds, possible specialization of the hospital, and full time equivalent (FTE) dedicated infection control nurses per 100 beds were recorded.

Outcome indicators

Aggregated data were collected for the following outcome indicators from 2017 to 2021: antimicrobial usage (for adult patients); alcohol-based hand rub usage; percentage of methicillin-resistant *Staphylococcus aureus* (MRSA), carbapenem-resistant *Klebsiella pneumoniae* (CRKP), and carbapenem-resistant *Escherichia coli* (CREC) over invasive isolates. Data were available both total and stratified by groups of hospitals: > 500 beds (Group 1), 200–500 beds (Group 2), < 200 beds (Group 3), and specialized hospitals (Group 4). Antimicrobial usage represented an exception, being classified only using the first three groups until 2021.

In Piedmont, the data have been obtained from the same centers that participated in the collection of structure and process indicators. In Catalonia, the aggregated data were derived from a larger number of facilities, which could also include the centers participating in the collection of structure and process indicators, but was not restricted to them exclusively.

The number of facilities from which the data have been derived varied across indicators and years and were summarized through median and interquartile range (IQR).

Alcohol-based hand rub usage was quantified as liters/1000 patient-days in both regions.

Data collection concerning antimicrobial usage was different between the regions. In Piedmont, the usage was expressed in defined daily doses (DDD) per 1000 patient-days and facilities were requested to submit antimicrobial usage data for at least 4 antimicrobial categories, provided that the same classes were consistently monitored throughout the years. In Catalonia, the usage was expressed in DDD per 100 patient-days and included all antimicrobials belonging to the Anatomical Therapeutic Chemical code J01 “Antibacterials for systemic use”. Due to these differences, only the percentage changes could be described, precluding any descriptive analysis or comparison.

Considering AMR, in Piedmont the MRSA percentage was measured as the proportion of *S. aureus* isolates that were resistant to oxacillin and cefoxitin over all *S. aureus* invasive isolates. Similarly, CRKP and CREC were calculated considering the proportion of meropenem resistant isolates. In Catalonia, the MRSA percentage was measured as the proportion of *S. aureus* isolates that were resistant to methicillin over all *S. aureus* invasive isolates. The CRKP and CREC percentages were measured as the number of patients with a positive culture for K. pneumoniae or E. coli producing carbapenemase over the total number of patients with a positive culture for K. pneumoniae or E. coli.

Statistical analysis

Descriptive analyses were performed. Scalar variables did not have normal distributions (Shapiro-Wilk test) and were described with median and IQR. To compare the facilities' characteristics, chi-squared and Mann Whitney U tests were used.

Differences in the scores' distribution between the regions were assessed through the Mann Whitney U test. To explore scores' differences across the size groups, Kruskal Wallis tests were executed. Multiple linear regression models were run with structure, process, and total score as dependent variables to evaluate differences between Piedmont and Catalonia adjusting for ownership, beds, FTE dedicated nurses, and specialization. Additionally, for each item, the proportion of facilities achieving a high-quality score was compared through chi-squared tests. Having a high-quality score meant having the maximum score for that item.

To describe changes in outcome indicators, an average of the 2017–2019 period was calculated for all indicators, representing the pre-pandemic baseline. The following percentage changes were computed (overall and by size groups): from the mean 2017–2019 to 2020 to describe the situation during the most affected year of the pandemic compared with the baseline; from 2020 to 2021 to depict a potential return to normalcy, from the 2017–2019 period to 2021 to describe the trend of the most recent data compared with a baseline. Lastly, following the ECDC methods to describe changes in antimicrobial usage over a period [9], the compound annual growth rate (CAGR) from 2017 to 2021 was calculated for all outcome indicators. The CAGR represents the average yearly change as a percentage of the value of the first year of the observation period.

Results

Structure and process indicators

Structure and process indicators were available for 78 facilities (n = 23 from Piedmont, n = 55 from Catalonia). Table 1 shows the centers' characteristics stratified by region: they were different for ownership and size, while they had similar FTE dedicated nurses per 100 beds.

Regarding the structure score, the median was 6 (IQR=5–7) in Piedmont and 7 (IQR=7–7) in Catalonia ($p < 0.001$). The process score had a median of 9 (IQR=8–10) in Piedmont and 9 (IQR=9–10) in Catalonia (p = 0.420). The total score had a median of 15 (IQR=14–17) in Piedmont and 16 (IQR=16–17) in Catalonia (p = 0.077) (Fig. 1). There were no differences in the distribution of structure, process, and total scores across size groups in Piedmont (p = 0.126, p = 0.261, and p = 0.137) nor in Catalonia (p = 1, p = 0.064, and p = 0.064). Similarly, no significant differences were found considering single items (Supplementary File, Table S1).

The regression models (Table 2) confirmed the relationships described by the above-mentioned Mann Whitney U tests, reporting the following adjusted coefficients for Catalonia compared with Piedmont: 0.851 (95 %CI 0.217; 1.485, p = 0.009) for structure score; 0.307 (95 %CI −0.468; 1.081, p = 0.433) for process score; 1.158 (95 %CI −0.120;2.435, p = 0.075) for total score. No other variable had a significant association with the scores.

For each item, Table 3 shows the comparison between regions considering the score distribution and the percentage of facilities with a high-quality score. Piedmont reported the lowest percentage of centers that reached a high-quality score considering accountability (whose high-quality score consisted of having identified an AMS program lead who is a clinician/infectious disease consultant); while Catalonia reported the lowest percentage concerning AMS strategies (whose high-quality score consisted of designing, implementing, and assessing at least two strategies to improve antimicrobial use). Overall, Catalonia scored significantly better in each item, except for AMS policies (whose high-quality score consisted of having both the availability of guidelines for common clinical conditions and the participation in the development of regional guidelines based on local epidemiology) among structure indicators and AMS strategies among process indicators. No significant differences were found for the process indicators: monitoring adherence to antimicrobial policy/treatment guidelines and AMR surveillance.

Table 1
Characteristics of the sample stratified by region (Piedmont and Catalonia), 2021.

Characteristic	Region		p-value
	Piedmont n = 23 N (%)	Catalonia n = 55 N (%)	
Ownership			**< 0.001**
Public	20 (87.0)	8 (14.5)	
Private	3 (13.0)	47 (85.5)*	
Number of beds†	439 (252-618)	186 (120-367)	**< 0.001**
Full time equivalent dedicated infection control nurses per 100 beds†	0.53 (0.41-0.67)	0.56 (0.37-0.76)	0.630
Size group			**0.002**
Group 1 (> 500 beds)	9 (39.1)	7 (12.7)	
Group 2 (200-500 beds)	9 (39.1)	16 (29.1)	
Group 3 (< 200 beds)	1 (4.3)	26 (47.3)	
Group 4 (specialized)‡	4 (17.4)	6 (10.9)	

Figures are expressed as number (N) and column percentages (%). P-value obtained via chi-squared tests.
* n = 43 privately managed state hospitals, n = 4 private.
†Figures expressed as median and interquartile range in bracket, p-value obtained via Mann Whitney U test.
‡Hospital size: Piedmont: n = 1 > 500 beds; n = 1 200-500 beds; n = 2 < 200 beds; Catalonia: n = 1 200-500 beds; n = 5 < 200 beds.

Outcome indicators

The median number of facilities from which the aggregated data have been derived was 21 (IQR=20–22) in Piedmont and 43 (IQR=34–59) in Catalonia.

From 2017 to 2021, alcohol-based hand rub usage ranged from 12.85 to 24.14 liters/1000 patient-days in Piedmont and from 22.5 to 35.95 liters/1000 patient-days in Catalonia. The percentages of resistant isolates over invasive isolates varied from 41.04 % to 34.53 % (MRSA), from 30.12 % to 21.64 % (CRKP), from 0.15 % to 0.34 % (CREC) in Piedmont and from 7.48 % to 9.58 % (MRSA), from 2.04 % to 3.19 % (CRKP), from 0.04 % to 0.18 % (CREC) in Catalonia.

Table 4 shows percentage changes and CAGRs for antimicrobial and alcohol-based sanitizer usage. Generally, in 2020, there was a reduction in antimicrobial usage both in Piedmont and Catalonia but in a different scale (−11.44 % and −0.06 %). In 2021, the antimicrobial usage grew in Piedmont (15.36 % compared with 2020 and 2.17 % compared with 2017–2019) while it kept decreasing in Catalonia (−2.24 % compared with 2020 and −2.29 % compared with 2017–2019), with different percentage changes across groups. The CAGR was 0.04 % in Piedmont and − 0.53 % in Catalonia.

Alcohol-based sanitizer usage greatly augmented in 2020, reaching a percentage increase higher than 100 % in Piedmont and Catalonia (except for Group 3 in Piedmont). In 2021, it decreased compared with 2020 but it remained higher than 2017–2019. The CAGR was 13.44 % in Piedmont and 9.83 % in Catalonia.

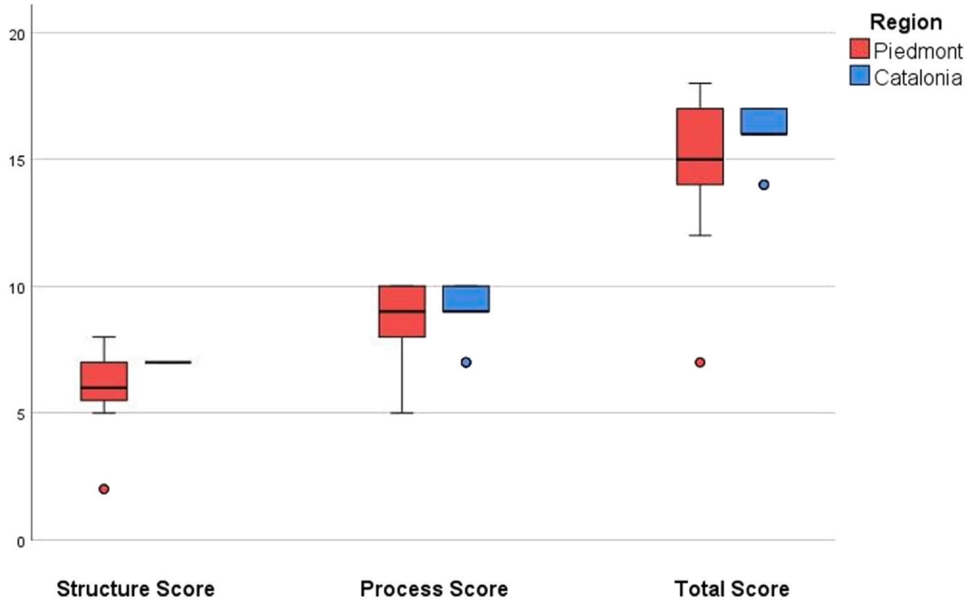

Fig. 1. Structure, process, and total score in acute-care facilities in Piedmont (n = 23) and Catalonia (n = 55), 2021.

About AMR, Table 5 describes percentage changes and CAGRs.

In 2020, the MRSA percentage generally decreased, with substantial differences across size groups. Overall, in 2021 it kept decreasing in Piedmont (−4.24 % compared with 2020 and −7.64 % compared with 2017–2019), while it slightly increased in Catalonia (0.76 % compared with 2020 and 0.48 % compared with 2017–2019). The CAGR was − 3.40 % in Piedmont and 5.06 % in Catalonia.

Considering the CRKP percentage, in 2020 it increased in Piedmont (18.79 %) while it decreased in Catalonia (−5.36 %). This pattern reversed in 2021, compared both with 2020 and 2017–2019. The CAGR was − 6.40 % in Piedmont and 9.35 % in Catalonia.

The CREC percentage increased by 46.74 % in Piedmont and decreased of − 87.50 % in Catalonia in 2020, while in 2021 it showed a great increase in both regions compared with 2020. Compared with 2017–2019, in 2021 it increased in Piedmont and decreased in Catalonia. The CAGR was 18.10 % in Piedmont and 35.10 % in Catalonia.

Discussion

This research primarily aimed to compare the essential characteristics of AMS programs of two regions of Italy and Spain, which have distinct epidemiological situations and face different AMR-related challenges [1] while sharing a comparable healthcare system. Secondarily, this work sought to investigate the pandemic impact by documenting potential alterations in AMS outcome indicators.

Overall, our findings highlighted a significant difference in structure indicators, with higher scores in Catalonia. Remarkably, Spanish facilities reported less dispersion in both the structure (identical in all facilities) and the process score, although the distribution of the latter was not significantly different from that of Italian facilities. Financial incentives may play a role in increasing quality standards: in Catalonia participation in the surveillance system is voluntary, but hospitals that participate and achieve the desired goals receive a compensation. However, there is conflicting evidence about the effect of financial incentives on AMS programs [16–18] and the weight of this feature on the success of indicators should be further examined. On the other hand, despite the surveillance system is at regional level in both cases, these results could be attributed to the difference in how AMS programs are implemented. In Piedmont, the programs are developed within each hospital, whereas in Catalonia, the strategies are shared across the entire network, ensuring that all facilities reach standards. Although there is currently no conclusive evidence to determine the most effective approach, a centrally-led approach has been reported as the most common AMS model [19] and our results suggest that a central superstructure may ensure the development of shared programs that guide each facility to high-quality standards.

Table 2
Multiple linear regression models for structure, process, and total score.

	Structure score		**Process score**		**Total score**	
	adjCoef. (95 % CI)	**p**	**adjCoef. (95 % CI)**	**p**	**adjCoef. (95 % CI)**	**p**
Region						
Piedmont	Ref.		Ref.		Ref.	
Catalonia	0.851 (0.217;1.485)	**0.009**	0.307 (−0.468;1.081)	0.433	1.158 (−0.12;2.435)	0.075
Ownership						
Public	Ref.		Ref.		Ref.	
Private	0.189 (−0.475;0.854)	0.571	0.12 (−0.691;0.931)	0.769	0.309 (−1.029;1.648)	0.646
Number of beds	0.001 (−0.0004;0.001)	0.236	0 (−0.001;0.001)	0.756	0 (−0.001;0.002)	0.687
FTE dedicated nurses per 100 beds	-0.071 (−0.52;0.379)	0.755	-0.157 (−0.706;0.392)	0.571	-0.227 (−1.133;0.678)	0.618
Specialized hospital						
No	Ref.		Ref.		Ref.	
Yes	0.264 (−0.42;0.949)	0.444	-0.55 (−1.387;0.286)	0.194	-0.286 (−1.665;1.094)	0.681

Abbreviations: CI confidence interval; FTE full time equivalent.

Table 3
Items of the structure and process scores: description and comparison between Piedmont (Italy) and Catalonia (Spain), 2021.

Item	Median (IQR) score*			Proportion of facilities with a high-quality score† N (%)		
	Region			Region		
	Piedmont n = 23	Catalonia n = 55	p-value	Piedmont n = 23	Catalonia n = 55	p-value
Structure indicators						
AMS team	2 (2-2)	2 (2-2)	**0.028**	21 (91.3)	55 (100.0)	**0.027**
Accountability	1 (1-2)	2 (2-2)	**< 0.001**	6 (26.1)	55 (100.0)	**< 0.001**
Mission statement	2 (1-2)	2 (2-2)	**< 0.001**	17 (73.9)	55 (100.0)	**< 0.001**
AMS policies	1 (1-2)	1 (1-1)	**0.002**	11 (47.8)	0 (0.0)	**< 0.001**
Process indicators						
AMS strategies	2 (1-2)	1 (1-2)	**0.042**	15 (65.2)	20 (36.4)	**0.019**
Monitoring of adherence to antimicrobial policy/treatment guidelines	1 (1-1)	1 (1-1)	0.130	18 (78.3)	50 (90.9)	0.128
Monitoring of antimicrobial usage	2 (2-2)	2 (2-2)	**0.028**	21 (91.3)	55 (100.0)	**0.027**
Surveillance of antimicrobial resistance	2 (2-2)	2 (2-2)	1.000	23 (100.0)	55 (100.0)	1.000
Regular feedback to clinicians	2 (1-2)	2 (2-2)	**< 0.001**	15 (65.2)	55 (100.0)	**< 0.001**
Education on AMS	1 (1-1)	1 (1-1)	**0.028**	21 (91.3)	55 (100.0)	**0.027**

*Figures are expressed as median and interquartile range in brackets. P-value obtained via Mann Whitney U test. The scores could range from 0 to 2 (except for monitoring adherence and education on AMS: range from 0 to 1).
† Figures are expressed as number (N) and column percentages (%). Only N and % of high-quality facilities are presented in the table. P-value obtained via Chi-Squared test.
Abbreviations: AMS antimicrobial stewardship; IQR interquartile range.

Considering the single item analysis, Piedmont and Catalonia reported different improvement opportunities. The main weakness in Piedmont concerned accountability. Unfortunately, already in 2017, the ECDC reported issues in accountability among the main determinants influencing the alarming Italian AMR situation [20], indicating this remains among the most relevant challenges for Italian hospitals. Regarding Catalonia, while the centralized approach ensures that all facilities achieve quality goals within the same timeframe a few at a time, this type of approach could hinder the implementation of diverse and multiple strategies within each facility, tailored to the local context.

Additionally, the centralized approach influenced data collection: the existence of the VINCat Coordinating Centre database, where facilities directly upload their data, has accelerated the collection, enabling immediate information extraction. The ease of centrally managing and processing data facilitates benchmarking between organizations and sharing of best practices [21].

It should be acknowledged that, despite similar health systems from an organizational perspective, the samples revealed variations in hospital size and ownership. However, these characteristics appeared to have no impact on the indicators. It has been reported that small hospitals may face more obstacles when implementing AMS programs [22], although a lack of data makes it challenging to compare findings with smaller medical centers or larger hospitals [6]. Our study suggests the centralized approach may serve as a means to overcome potential challenges faced by smaller facilities that may otherwise struggle without belonging to a robust network. Considering ownership, consistently with the results of our regression models, several studies reported no conclusive evidence regarding the overall performance and quality of care of public and private hospitals [23–25].

Lastly, this work provided a glimpse on the pandemic impact on outcomes relevant to AMS. Italy and Spain were similarly impacted by the pandemic, experiencing COVID-19 death rates above the European average. Both Piedmont and Catalonia were among the most affected regions within their countries [26].

Overall, the regions reported changes in the outcome indicators that went in the same direction.

Considering antimicrobial usage, both regions reported a decrease in 2020 (a very slight reduction in Catalonia) compared with the 2017–2019 period, with a return to values close to the pre-pandemic ones in 2021 and small changes across the whole period. These results are consistent with European data that showed a general decreasing trend in 2020 (although not significant), including in Italy and Spain [27]. Interestingly, the ECDC report on 2021 data revealed an overall significant decreasing trend over the past 10-year period, while this trend was not significant for Italy and Spain [9]. Globally, conflicting results on antimicrobial consumption trends across the pandemic have been reported, depicting several contrasting reasons, such as interruption of AMS programs on the

Table 4
Antimicrobial usage and alcohol-based hand rub usage: percentage changes and compound annual growth rate from 2017 to 2021, Piedmont (Italy) and Catalonia (Spain).

	Overall		Group 1		Group 2		Group 3		Group 4	
	Pied.	Cat.	Pied.	Cat.	Pied.	Cat.	Pied.	Cat.	Pied.	Cat.
Median number of centers (IQR)	21 (20-22)	43 (34-59)	9 (8-9)	8 (6-9)	8 (8-9)	14 (13-17)	1 (0-1)	20 (14-31)	4 (3-4)	2 (2-4)
Antimicrobial usage										
% change:										
Mean 2017-2019 to 2020	-11.44	-0.06	-0.11	-3.78	-26.33	6.68	32.14	-2.58	.	.
2020 to 2021	15.36	-2.24	13.92	0.75	15.44	-8.30	-20.60	1.13	.	.
Mean 2017-2019 to 2021	2.17	-2.29	13.79	-3.06	-14.95	-2.17	4.91	-1.48	.	.
CAGR (%) from 2017 to 2021	0.04	-0.53	2.25	-0.55	-3.50	-0.48	1.50	-0.63	.	.
Alcohol-based hand rub usage										
% change:										
Mean 2017-2019 to 2020	137.25	136.04	122.65	128.12	157.51	150.52	20.33	127.92	173.21	114.08
2020 to 2021	-29.19	-40.12	-16.71	-50.13	-32.46	-38.12	-12.64	-12.75	-47.32	-32.72
Mean 2017-2019 to 2021	67.99	41.33	85.45	13.75	73.93	55.02	5.12	98.86	43.94	44.02
CAGR (%) from 2017 to 2021	13.44	9.83	15.67	7.72	14.91	8.47	4.29	17.73	8.33	7.48

Abbreviations: CAGR Compound annual growth rate, Cat. Catalonia, IQR interquartile range, Pied. Piedmont.

Table 5
Percentage of methicillin-resistant Staphylococcus aureus (MRSA), carbapenem-resistant Klebsiella pneumoniae (CRKP), and carbapenem-resistant Escherichia coli (CREC) over invasive isolates: percentage changes and compound annual growth rate from 2017 to 2021, Piedmont (Italy) and Catalonia (Spain).

	Overall		Group 1		Group 2		Group 3		Group 4	
	Pied.	Cat.	Pied.	Cat.	Pied.	Cat.	Pied.*	Cat.	Pied.	Cat.
Median number of centers (IQR)	21 (20-22)	43 (34-59)	9 (8-9)	8 (6-9)	8 (8-9)	14 (13-17)	1 (0-1)	20 (14-31)	4 (3-4)	2 (2-4)
Percentage of MRSA over invasive isolates										
% change:										
Mean 2017-2019 to 2020	-3.53	-0.28	-13.12	17.39	18.80	-7.52	-	-29.75	-5.46	-58.77
2020 to 2021	-4.26	0.76	5.06	6.90	-25.34	-6.40	-	63.91	-7.13	3.77
Mean 2017-2019 to 2021	-7.64	0.48	-8.73	25.50	-11.30	-13.43	-	15.15	-12.20	-57.21
CAGR (%) from 2017 to 2021	-3.40	5.06	-4.18	13.26	-2.24	1.67	-	5.88	-3.46	-6.94
Percentage of CRKP over invasive isolates										
% change:										
Mean 2017-2019 to 2020	18.79	-5.36	15.88	0.33	18.41	-34.55	-	-78.47	103.93	127.17
2020 to 2021	-33.05	23.17	-31.91	3.96	-24.83	4.17	-	711.36	-49.26	-65.72
Mean 2017-2019 to 2021	-20.47	16.57	-21.10	4.30	-10.99	-31.82	-	74.71	3.48	-22.13
CAGR (%) from 2017 to 2021	-6.40	9.35	-7.02	14.22	-2.91	-2.92	-	20.42	-6.80	-13.41
Percentage of CREC over invasive isolates										
% change:										
Mean 2017-2019 to 2020	46.74	-87.50	-50.89	-85.95	1395.97	-100.00‡	-	-100.00§	-°	100°°
2020 to 2021	24.72	50.00	153.24	34.78	-88.64	100‡	-	100§	100°	-100°°
Mean 2017-2019 to 2021	83.01	-81.25	24.36	-81.06	69.96	-57.14	-	7415.79	100°	-°°
CAGR (%) from 2017 to 2021	18.10	35.10	5.07	28.06	-0.05†	-36.60‡	-	193§	-°	-°°

*Pied., Group 3: no available data about 2019, 2020, 2021.
†Pied., Group 2: in 2017 CREC% over invasive isolates was 0 % CAGR calculated from 2018 to 2021.
‡Cat., Group 2: in 2017 and 2020 the CREC% over invasive isolates was 0 %; CAGR calculated from 2018 to 2021.
§Cat., Group 3: in 2017, 2018, 2020 the CREC% over invasive isolates was 0 %: CAGR calculated from 2019 to 2021.
°Pied., Group 4: from 2017 to 2020, the CREC% over invasive isolates was 0 %, while it was 6 % in 2021.
°°Cat., Group 4: in 2017, 2018, 2019, 2021 the CREC% over invasive isolates was 0 %, while it was 3.45 % in 2020.
Abbreviations: CAGR Compound annual growth rate, Cat. Catalonia, IQR interquartile range, Pied. Piedmont.

one side and enhanced hand hygiene and cleaning, lower people-people contact, and adjustment of AMS programs due to the health crisis on the other [28]. Therefore, although our results do not indicate that the pandemic disrupted consumption rates, our findings highlight the need of keeping working on this matter.

Regarding alcohol-based hand rub, the pandemic impact was clearer: a great increase in 2020, with a consequent reduction in 2021, during which, however, the levels of consumption remained higher than pre-pandemic levels. The role of hand hygiene has gained extreme relevance during the pandemic, but it should be noted that the consumption of hand sanitizer can vary among different departments. For example, there may be greater increases in departments with COVID-19 patients [29]. Thus, these potential differences should be further explored.

For both regions, our results on AMR in 2020 reflected the European trends that revealed a reduction in MRSA [2]. In 2020, only Piedmont followed the increasing European trend in CRKP and CREC [2]. However, it should be noted that the CRKP reduction in Catalonia was small and CREC results may be biased by few total isolates.

Considering 2021 and the overall CAGR, Piedmont kept following the European decreasing trend of MRSA; however, it remained at a substantially higher level compared with the overall MRSA percentage in Europe (i.e. 15.8 %). Catalonia showed a small increase but it remained below 10 % [30]. As for CRKP and CREC, Catalonia was in line with the increasing rates reported by ECDC in 2017–2021. However, while it reported a comparable CREC percentage (Europe: 0.2 %), Catalonia presented a CRKP percentage considerably lower than the 2021 European data (i.e. 11.7 %) [30]. Piedmont changes resulted consistent with ECDC trend for CREC, with a slightly higher value compared with Europe. On the other hand, Piedmont improved in CRKP rates, although it remained at higher levels compared with Europe [30].

Generally, the AMR trends were not substantially influenced by the pandemic, as they showed growth or reduction patterns consistent with the previous years. Relevant reviews on the pandemic impact on AMR reported increased rates of MRSA, CRKP, and CREC; nevertheless, these changes were not significant [10,31]. However, more time could be required for the pandemic impact to manifest. Furthermore, although our data confirm a more favorable epidemiological profile in Catalonia, the trends and values we have observed indicate that AMR should continue to be a priority in both regions.

An additional consideration arises when examining the division of groups: except for alcohol-based sanitizer, a different direction of changes has generally been observed among groups within the same region. As there is no significant difference in structure and process indicators concerning AMS, it would be desirable to delve deeper into the distinctive characteristics that account for these results in future investigations.

This study had several limitations. First, our results cannot be generalized to Italy and Spain due to regional differences within the countries. About the structure and process indicators, the reliability of AMS scores depends on self-reported responses, which may not be completely accurate. Regarding the outcome indicators, the opportunity to perform detailed analyses on trends was precluded by the availability of only aggregated data, which also limited the assessment of the size of the underlying data that generated the reported information. Moreover, certain groups were composed by very few hospitals, participation changed across the years, and there were differences in measurement and collection between Piedmont and Catalonia, making the results not completely comparable. Although in a previous study we found associations between the chosen surrogate outcomes and AMS activities [15], these outcomes, by definition, cannot directly describe changes in AMS activities. The findings regarding surrogate outcomes to depict the pandemic's impact on AMS activities should be approached with caution, yet they may suggest hypotheses requiring confirmation through studies with other designs. Lastly, outcome indicators may have been influenced by numerous factors, and robust conclusions about the pandemic impact cannot be drawn.

Conclusions

Examining healthcare facilities in different regions provided valuable insights into international variations in AMS programs. Catalonia achieved higher and less variable scores, likely due to a centralized approach ensuring consistent quality objectives across facilities. However, this centralized approach may limit strategies' flexibility. In Piedmont, addressing accountability issues remains crucial for enhancing AMS programs. In both regions, existing trends in outcome measures were not disrupted by the pandemic, emphasizing the value of well-established, centralized AMS programs, albeit with different approaches. While outcome indicators may not conclusively demonstrate the pandemic impact, it is clear that maintaining a high level of attention in combating AMR and sustaining efforts in implementing AMS strategies remains paramount.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jiph.2024.05.045.

References

[1] European Centre for Disease Prevention and Control (ECDC). Assessing the health burden of infections with antibiotic-resistant bacteria in the EU/EEA, 2016–2020. Stockholm: 2022.
[2] European Centre for Disease Prevention and Control (ECDC). Antimicrobial resistance in the EU/EEA (EARS-Net) - Annual Epidemiological Report for 2020. Stockholm: 2022.
[3] Dyar OJ, Huttner B, Schouten J, Pulcini C. What is antimicrobial stewardship? Clin Microbiol Infect 2017;23:793–8. https://doi.org/10.1016/j.cmi.2017.08.026
[4] Shrestha J, Zahra F, Cannady JP. Antimicrobial Stewardship. StatPearls. StatPearls Publishing,; 2023.
[5] Baur D, Gladstone BP, Burkert F, Carrara E, Foschi F, Döbele S, et al. Effect of antibiotic stewardship on the incidence of infection and colonisation with antibiotic-resistant bacteria and Clostridium difficile infection: a systematic review and meta-analysis. Lancet Infect Dis 2017;17:990–1001. https://doi.org/10.1016/S1473-3099(17)30325-0
[6] Nathwani D, Varghese D, Stephens J, Ansari W, Martin S, Charbonneau C. Value of hospital antimicrobial stewardship programs [ASPs]: a systematic review. Antimicrob Resist Infect Control 2019;8:35. https://doi.org/10.1186/s13756-019-0471-0
[7] Organisation for Economic Co-operation and Development (OECD). Antimicrobial Resistance Tackling the Burden in the European Union. 2019.
[8] Organisation for Economic Co-operation and Development (OECD). Antimicrobial Resistance in the EU/EEA. A One Health Response,; 2022.
[9] European Centre for Disease Prevention and Control (ECDC). Antimicrobial consumption in the EU/EEA (ESAC-Net) - Annual Epidemiological Report 2021. Stockholm: 2022.
[10] Abubakar U, Al-Anazi M, Alanazi Z, Rodríguez-Baño J. Impact of COVID-19 pandemic on multidrug resistant gram positive and gram negative pathogens: A systematic review. J Infect Public Health 2023;16:320–31. https://doi.org/10.1016/j.jiph.2022.12.022
[11] Ashiru-Oredope D, Kerr F, Hughes S, Urch J, Lanzman M, Yau T, et al. Assessing the impact of COVID-19 on Antimicrobial Stewardship Activities/Programs in the United Kingdom. Antibiotics 2021;10:110. https://doi.org/10.3390/antibiotics10020110
[12] Subramanya SH, Czyż DM, Acharya KP, Humphreys H. The potential impact of the COVID-19 pandemic on antimicrobial resistance and antibiotic stewardship. Virusdisease 2021;32:330–7. https://doi.org/10.1007/s13337-021-00695-2
[13] Baccolini V, Migliara G, Isonne C, Dorelli B, Barone LC, Giannini D, et al. The impact of the COVID-19 pandemic on healthcare-associated infections in intensive care unit patients: a retrospective cohort study. Antimicrob Resist Infect Control 2021;10:87. https://doi.org/10.1186/s13756-021-00959-y
[14] Badia J., Barrufet P., Campins M., Calbo E., Casas I., Cots J., et al. Programa de vigilància de les infeccions relacionades amb l'atenció sanitària de Catalunya (VINCat): manual VINCat. 5a. ed. 2023.
[15] Vicentini C, Blengini V, Libero G, Raso R, Zotti CM. Working Group "Unità Prevenzione Rischio Infettivo (UPRI), Regione Piemonte". Antimicrobial stewardship experiences in acute-care hospitals of Northern Italy: Assessment of structure, process and outcome indicators, 2017-2019. Am J Infect Control 2023;51(3):282–8. https://doi.org/10.1016/j.ajic.2022.06.006
[16] Balinskaite V, Johnson AP, Holmes A, Aylin P. The impact of a national antimicrobial stewardship program on antibiotic prescribing in primary care: an interrupted time series analysis. Clin Infect Dis 2019;69:227–32. https://doi.org/10.1093/cid/ciy902
[17] Okubo Y, Nishi A, Michels KB, Nariai H, Kim-Farley RJ, Arah OA, et al. The consequence of financial incentives for not prescribing antibiotics: a Japan's nationwide quasi-experiment. Int J Epidemiol 2022;51:1645–55. https://doi.org/10.1093/ije/dyac057
[18] Okubo Y, Nishi A, Uda K, Miyairi I, Michihata N, Kumazawa R, et al. Financial incentives for infection prevention and antimicrobial stewardship to reduce antibiotic use: Japan's nationwide observational study. J Hosp Infect 2023;131:89–98. https://doi.org/10.1016/j.jhin.2022.09.027
[19] Buckel WR, Stenehjem EA, Hersh AL, Hyun DY, Zetts RM. Harnessing the power of health systems and networks for antimicrobial stewardship. Clin Infect Dis 2022;75:2038–44. https://doi.org/10.1093/cid/ciac515
[20] European Centre for Disease Prevention and Control (ECDC). ECDC Country Visit to Italy to Discuss Antimicrobial Resistance Issues. Stockholm: 2017.
[21] Ashiru-Oredope D, Budd EL, Doble A, Cramp E, Hendrick A, Hopkins S. Development and implementation of a national antimicrobial stewardship surveillance system, with open access data sharing. J Hosp Infect 2021;107:16–22. https://doi.org/10.1016/j.jhin.2020.10.015
[22] Stenehjem E, Hyun DY, Septimus E, Yu KC, Meyer M, Raj D, et al. Antibiotic stewardship in small hospitals: barriers and potential solutions. Clin Infect Dis 2017;65:691–6. https://doi.org/10.1093/cid/cix407
[23] Kruse FM, Stadhouders NW, Adang EM, Groenewoud S, Jeurissen PPT. Do private hospitals outperform public hospitals regarding efficiency, accessibility, and quality of care in the European Union? A literature review. Int J Health Plann Manag 2018;33:e434–53. https://doi.org/10.1002/hpm.2502
[24] Moscone F, Siciliani L, Tosetti E, Vittadini G. Do public and private hospitals differ in quality? Evidence from Italy. Reg Sci Urban Econ 2020;83:103523. https://doi.org/10.1016/j.regsciurbeco.2020.103523
[25] Tynkkynen L-K, Vrangbæk K. Comparing public and private providers: a scoping review of hospital services in Europe. BMC Health Serv Res 2018;18:141. https://doi.org/10.1186/s12913-018-2953-9
[26] The Institute for Health Metrics and Evaluation. COVID-19 Projections. 〈Https://Covid19HealthdataOrg/〉 2023.
[27] European Centre for Disease Prevention and Control (ECDC). Antimicrobial consumption in the EU/EEA (ESAC-Net) - Annual Epidemiological Report 2020. Stockholm: 2021.
[28] Fukushige M, Ngo N-H, Lukmanto D, Fukuda S, Ohneda O. Effect of the COVID-19 pandemic on antibiotic consumption: a systematic review comparing 2019 and 2020 data. Front Public Health 2022;10:946077. https://doi.org/10.3389/fpubh.2022.946077
[29] Si Ali A, Cherel O, Brehaut P, Garrait V, Lombardin C, Schortgen F, et al. Impact of COVID-19 pandemic waves on health-care worker hand hygiene activity in department of medicine and ICU as measured by an automated monitoring system. Infect Dis Health 2023;28:95–101. https://doi.org/10.1016/j.idh.2022.11.003
[30] European Centre for Disease Prevention and Control (ECDC). Antimicrobial resistance in the EU/EEA (EARS-Net) - Annual Epidemiological Report 2021. Stockholm: 2022.
[31] Langford BJ, Soucy J-PR, Leung V, So M, Kwan ATH, Portnoff JS, et al. Antibiotic resistance associated with the COVID-19 pandemic: a systematic review and meta-analysis. Clin Microbiol Infect 2023;29:302–9. https://doi.org/10.1016/j.cmi.2022.12.006