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Implementation of infection prevention and control components in Italian hospitals based on a nationwide survey on behalf of INSIEME project

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We aim to assess the state-of-the-art of Infection Prevention and Control (IPC) practices and their results in Italian healthcare facilities 6 years after the kick-off of the new National Plan for the Control of Antibiotic Resistance (PNCAR). This was a multicenter, cross-sectional, observational study conducted between January 1st, and December 31st, 2023, among Italian hospitals. Survey questions were readapted from the WHO IPC assessment framework (IPCAF), PNCAR and INSIEME group proposals, resulting in 155 questions grouped into six sections: IPC program, surveillance, control activities for healthcare-associated infections, antimicrobial stewardship (AMS) strategies, IPC training and education, and monitoring indicators. Thirty-eight acute care Hospitals completed the survey (response rate: 30%): 26.3% of hospitals did not define an annual program and 34.2% an AMS task force. Periodic microbiology reports were available for 57.9%, hospital alcohol-based hand rubs consumption per 1000 bed-days in 42.1% and defined daily dose of antimicrobials per 100 bed-days in 55.3% hospitals with a significant difference between Northern and Southern regions (90.9% vs 22.2%; P = 0.006). Active monitoring of hand hygiene and contact isolation compliance was implemented in only half of the hospitals. Structured HAI surveillance systems were implemented in fewer than 20% of hospitals. Components on IPC implementation activity, such as no-touch sanitizing systems, checklist for environmental cleaning, informatic flags, bundles for pathogens revealed the lowest score. The appropriateness of antibiotic therapy prescribing was assessed in 73.7% of facilities. Only 42.1% of hospitals had budget goals. This survey provides a baseline assessment and identifies key barriers to the implementation of IPC programs across Italian acute care hospitals. The findings highlight priority areas for intervention and will inform the next phase of the INSIEME project, which aims to develop and implement tailored strategies that address the specific needs of healthcare workers and institutions nationwide.

Keywords Antimicrobial resistance, Infection prevention and control, Antimicrobial stewardship

Abbreviations

ABHRs	Alcohols-based hand rubs
AMR	Antimicrobial resistance
AMS	Antimicrobial stewardship
CAUTI	Catheter-associated urinary tract infections
CDC	Centers for disease control and prevention
DDD	Defined daily dose
HAI	Healthcare-associated infections
HHSAF	Hand hygiene self-assessment framework
ICU	Intensive Care Unit
INSIEME	Italian National project for contrast antibiotic resistance a cooperation between Simit (Italian society of infectious diseases) E (&) Ministry of hEalth
IPC	Infection prevention and control
IPCAF	Infection prevention and control assessment framework
MDRO	Multi drug resistant organisms
MRSA	Methicillin-resistant staphylococcus aureus
NNIS	National nosocomial infections surveillance
PNCAR	National plan for the control of antibiotic resistance
SIMIT	Italian society for infectious and tropical diseases
WHO	World health organization

In the twenty-first century antimicrobial Resistance (AMR), also known as "the silent pandemic", was considered by World Health Organization (WHO), the European Commission and the EU Member States one of the top three global priority health threat[1–3]. In this ongoing scenario, the COVID-19 pandemic has exacerbated the burden of antimicrobial resistance, posing a serious threat to global health[4,5]. Strong and coordinated global response is urgently needed, as the current pace of progress remains inadequate to effectively tackle AMR[6].

In 2016 WHO published the "Guidelines on core components of infection prevention and control programmes at the national and acute health care facility level", to prevent HAI and to combat AMR through infection prevention and control good practices[7]. To support those Guidelines, in 2018 WHO released the "Infection Prevention and Control Assessment Framework" (IPCAF) as a questionnaire to define a baseline self-assessment of IPC program[8]. Finally, in 2023 it was published the "Roadmap on antimicrobial resistance for the WHO European Region 2023–2030", aiming to support countries to identify, prioritize, implement and monitor important interventions to combat antimicrobial resistance[2]. Although global adherence to WHO minimum IPC requirements improved between 2017–18 and 2021–22, the pace of progress remains insufficient in many countries, only 4% met all minimum IPC requirements in place at the national level. Concrete actions at the facility level are urgently needed to drive behavioral change, raise awareness, and achieve sustained improvements[9].

The substantial variability in the implementation of IPC minimum requirements among countries worldwide highlighted the need to improve relevant national governance responses. In Italy the PNCAR 2022–2025 (National Plan for the Control of Antibiotic Resistance, first edition in 2017) aims to provide national strategic lines and operative indications to face antibiotic resistance in the next years, following a multidisciplinary approach and a One Health point of view, promoting an international comparison[10]. Nevertheless, Italy always ranks at the bottom of the league table for years of national silence about HAIs, for insufficient adherence to infection control practices, first and foremost hand hygiene, and for an antibiotic consumption that is among the highest in Europe. According to the third Point Prevalence Survey (PPS 2022–2023) conducted in 325 Italian acute care hospitals, the overall prevalence of healthcare-associated infections (HAIs), including SARS-CoV-2, was 8.8%, placing Italy among the five worst-performing countries in Europe. Recent data from the 2023 Italian Antimicrobial Resistance Surveillance System (AR-ISS) underscore the ongoing and substantial challenges of AMR in Italian hospitals, particularly the high rates of carbapenem resistance among Gram-negative pathogens. In response, the INSIEME project (Italian National Project to Combat Antibiotic Resistance), launched in 2022 in collaboration with SIMIT and the Ministry of Health, aims to strengthen infection prevention and control (IPC) and antimicrobial stewardship (AMS) through site visits, targeted training, and multidisciplinary audits. Only by tailoring interventions to local contexts and constraints, ensuring adequate time and resources for IPC and AMS, and fostering collaborative multidisciplinary approaches can evidence be effectively translated into practice[11].

The aim of this study is to assess the state-of-art of IPC practices in health-care facilities across Italy in the post-pandemic era and 6 years after the introduction of the National Plan for the Control of Antibiotic Resistance. We aimed to identify differences in implementation across regions, types of health-care facilities and case-mix complexity. This survey will be a starting point for the INSIEME project to develop a proactive plan to solve the long-standing problem of antibiotic resistance that places our country at the bottom rung in Europe.

Methods

Study design, setting and participants

This was a multicenter, cross-sectional, observational study conducted between January 1st, and December 31st, 2023, in Italian Hospitals from 21 Italian regions/autonomous provinces. The study was conducted and reported according to the STROBE guidelines for cross-sectional studies[12]. As the survey was a facility-based assessment and did not include individual patients or health workers data, ethical approval and informed consent were not required. All methods were carried out in accordance with relevant guidelines and regulations.

Survey structure and data collection

An anonymous survey assessing knowledge, behaviors, and practices was developed in Italy by the INSIEME project group, after the first workshop that took place in Modena University Hospital in 2022. As a result of the first workshop, the INSIEME project group produced a questionnaire to identify the barriers to implementation of IPC programs in Italian hospitals. The survey questions were readapted from the WHO IPC assessment framework (IPCAF) and according to the new PNCAR 2022–2025.

The survey was then reviewed and validated through a consensus of IPC project group (M. M, C. M, M. A, R. M, E. R, R. P) including all the AMS executive committees, which were formally appointed through an official vote by our national scientific society, the Italian Society of Infectious and Tropical Diseases (SIMIT). Although the survey was not piloted externally, its content and structure were the result of expert consensus and field-driven prioritization.

An online platform was created and a link to it was sent by SIMIT to all members. The link incorporated branching logic, where possible, to reduce response time. The survey was also promoted through the SIMIT website and social media campaigns. Two reminder emails were sent to encourage response. In cases where multiple responses were received from the same facility (n = 10), we retained the response submitted by the individual with a formal IPC role; if this was not specified, we selected the most complete dataset. The survey was specifically directed to acute care hospitals and did not include long-term care facilities. Respondents' professional roles primarily included infectious disease specialists and hygienists responsible for IPC and AMS programs.

The finalized version of the questionnaire included 155 questions grouped into six sections:

1) Healthcare IPC program and organization (IPC steering committee, human resources full-time equivalent dedicated, health-care workers networks recruited in clinical areas);
2) Surveillance,
3) IPC-hospital activity,
4) Antimicrobial stewardship strategies (AMS),
5) IPC training and education,
6) Performance monitoring indicators.

Health-care-facilities characteristics were also collected: i) Geographical affiliation (North, Centre, South and Island regions); ii) Hospital type (university, public, private or territorial agency), iii) Hospital capacity expressed as the median number of hospital beds measured in terms of full hospitalization (number of beds) and partial hospitalization (Intensive Care Unit (ICU), Hematology or Transplant Unit); iv) Hospital case mix defined as the complexity of in-patients (see following session). To ensure the accuracy of data, each hospital involved had designated responsible for data collection and verification; any empty fields or fields with logical errors were double-checked with reference structures; some data were unknown. Hospitals with insufficient data were excluded from the survey.

Data management and outcomes

Regions were aggregated according to geographic distribution. To estimate the complexity of the patient case mix at each center, a dedicated score was developed based on expert consensus, using the following variables:

the number of hospitals beds, and the presence of ICU, Transplant Unit, or Hematology department. Centers received zero points for fewer than 200 beds, 1 point for 200–599 beds, 2 points for 600–999 beds, and 3 points for more than 1.000 beds. One additional point was awarded for the presence of each high-complexity department. The resulting case-mix complexity score ranged from 0 to 6 points. Hospitals scoring 0–2 points were classified as low complexity, those with 3–4 points as medium complexity, and those with 5–6 points as high complexity. To assess the associations between hospital characteristics and the presence of IPC strategies, we used a modified version of the six WHO core components for minimum requirements for IPC programs[11].

For each core component, we included the following endpoints:

i. IPC program and organization: the presence of a proactive group for antimicrobial stewardship and the development of an annual plan for IPC.
ii. Surveillance: the availability of a local microbiology report, an antibiotic consumption monitoring system based on DDD/100 days (Defined Daily Dose, meaning the average dose of a drug taken each day by an adult person, considering the main therapeutic indication of that drug) and a hand hygiene monitoring system following the five moments identified by the WHO.
iii. HAIs control activities: the presence of a monitoring system for adherence to contact isolation, a universal rectal screening strategy, and the implementation of pathogen-specific bundles.
iv. Antimicrobial stewardship: presence of a structured evaluation of antibiotic appropriateness, availability of local protocols for empirical therapy and presence of antibiotic restriction policies.
v. Training: implementation of structured training on HAI or AMS.
vi. Budget: explicit inclusion of IPC and/or AMS among hospital budget goals.

Statistical analysis

A descriptive analysis was conducted to outline the distribution of general characteristics and the presence of IPC and AMS strategies within our sample. Absolute frequencies and proportions were reported both overall and stratified by geographical area. For numerical variables, normality was assessed using the Shapiro–Wilk test. When the assumption of normality was not met; results were presented as medians with interquartile ranges (first and third quartiles). The case-mix complexity score demonstrated a Cronbach's alpha of 0.65, reflecting "good/acceptable" internal consistency.

To evaluate the association between hospital characteristics and the proportion of hospital meetings the IPC core components, we applied the chi-squared test, with Fisher's correction used in cases where the expected cell count was less than five. To evaluate the association between the presence of specific IPC/AMS strategies and hospital antibiotic consumption or the number of infectious diseases consultations, the Mann–Whitney U test was used. All statistical tests were two-tailed, with statistical significance set at a p-value of less than 0.05. Missing data were addressed by focusing on endpoints with no missing values to ensure robustness in the analysis. All statistical analyses were performed using R Studio software (*version 2024.04.2 + 764*).

Results

The survey was sent to 140 SIMIT-registered healthcare facilities (including all Italian hospitals with an infectious disease department), yielding a response rate of approximately 30%. Overall, 40 hospitals participated to this survey on a voluntary basis, but two hospitals were excluded from the study due to insufficient data provided. The 38 included Hospitals belonged to 15/21 regions/autonomous provinces of Italy. The hospital distribution was homogeneous among four geographical areas: 11 (28.9%) from Northern Italy, 9 (23.7%) from Centre, 9 (23.7%) from Southern and 9 (23.7%) from Islands. The median number of hospital beds ranging from 200–599 (18/38, 47.4%). ICU was present in 34/38 Hospitals (89.5%), Hematology ward in 23/38 Hospitals (60.5%); only 15/38 Hospitals had Transplant Unit (39.5%).

The general characteristics of the participating hospitals are shown in Table 1**.**

Regarding case-mix complexity (see Methods section for details), Hospitals were almost equally divided in high (13/38; 34.2%), medium (12/38; 31.6%) and low (13/38; 34.2%) complexity.

All detailed information regarding following items can be found in Supplementary Table 1.

IPC program and organization

Regarding IPC program and organization, 97.4% of hospitals (37/38) had a Strategic HAI Core, defined as a medical direction steering committee for risk management with key responsibilities in coordinating the IPC task force. In 78.4% of cases (29/37), this committee reported results annually. A defined working group for IPC and AMS was established in 92.1% and 65.8% of hospitals, respectively. The presence of an AMS working group was observed in 32% of hospitals in both Northern and Central Italy (8/25 in each area; $p = 0.228$), 60% of university hospitals (15/25; $p = 0.200$), 48% of facilities with 200–599 beds (12/25; $p = 0.338$), and 40% of those with medium case-mix complexity (10/25; $p = 0.323$); however, no statistically significant differences were observed across these categories. Eighteen hospitals (47.4%) had an established network of departmental facilitators to promote HAI control programs. All but one facility (97.4%) had an in-house microbiology laboratory; among them, 34.2% (13/38) provided a 24-h service, 47.4% (18/38) operated 12 h daily, and 52.6% (20/38) offered 24/7 coverage. An annual IPC plan was in place in 73.7% of facilities (28/38), with no significant differences by region or hospital characteristics: Northern Italy (9/28, 32.1%; $p = 0.698$), university hospitals (15/28, 53.6%; $p = 0.888$), and facilities with 200–599 beds (13/28, 46.4%; $p = 1$). Similarly, the presence of an annual plan did not vary significantly by case mix complexity: high (32.1%), medium (35.7%), and low (32.1%) complexity facilities ($p = 0.724$). Further details are provided in Table 2.

Surveillance

For antimicrobial resistance (AMR) surveillance, 73.7% of healthcare facilities (28/38) had an automated microorganism alert reporting system that connects the laboratory to the working groups. In 73.7% of cases (28/38), alerts were reported in real time, weekly (5.3%, 2/38), monthly (5.3%, 2/38), every three months (2.6%, 1/38), or annually (7.9%, 3/38).

Only 22 microbiology laboratories (57.9%) provided a local periodic microbiology report.

These reports were more common in facilities located on the Islands (7/22, 31.8%, p = 0.613) and were almost equally distributed between University Hospitals (11/22, 50%) and Public Hospitals (10/22, 45.5%, p = 0.696). They were predominantly found in hospitals with 200– 599 beds (10/22, 45.5%, p = 0.623) and were slightly more frequent in facilities with high case- mix complexity (8/22, 36.4%, p = 0.924). Details are provided in Table 3.

The frequency of reporting was semi-annual in 10 cases (26.3%), annual in 13 cases (34.2%), and on-demand or absent in 15 cases (39.5%).

The microbiology report provided data stratified for specimen types in 22 hospitals (57.9%), while cumulative antibiogram was available for 52.6% of facilities (20/38).

Based on data from participating hospitals, the median resistance rates were reported in Table 1 Supplementary materials.

	Overall (n = 38)
Geographical area	
Central Italy	9/38 (23.7%)
Islands	9/38 (23.7%)
Northern Italy	11/38 (28.9%)
Southern Italy	9/38 (23.7%)
Hospital type	
Public hospital	15/38 (39.5%)
University hospital	20/38 (52.6%)
Private-public	2/38 (5.3%)
Other	1/38 (2.6%)
Number of beds	
< 200	4/38 (10.5%)
200–599	18/38 (47.4%)
600–999	6/38 (15.8%)
≥ 1000	10/38 (26.3%)
Presence of ICU	
Absent	4/38 (10.5%)
Present	34/38 (89.5%)
Number of ICU beds	
< 20	9/34 (23.7%)
≥ 40	10/34 (26.3%)
20–39	13/34 (34.2%)
Missing	2 (15.8%)
Presence of Hematology	
Absent	15/38 (39.5%)
Present	23/38 (60.5%)
Number of Hematology beds	
< 20	11/23 (28.9%)
≥ 40	2/23 (5.3%)
20–39	9/23 (23.7%)
Missing	1 (42.1%)
Presence of Transplant Unit	
Absent	23/38 (60.5%)
Present	15/38 (39.5%)
Case-mix complexity[a]	
high	13/38 (34.2%)
medium	12/38 (31.6%)
low	13/38 (34.2%)

Table 1. Characteristics of the participating hospitals. ICU: Intensive Care Unit.

Antimicrobial consumption was monitored by 30 hospitals (78.9%) and the standard DDDs/100 beds-days (Defined Daily Doses) were available in 21 facilities (55.3%): per total hospital consumption in 52.4%, per single Department in 71.4%, divided by antibiotic in 42.9% of cases.

The frequency of DDD data collection was annual in 57.1% of cases (12/21), monthly in 28.6% (6/21), and upon request in 33.3% (7/21). In some instances, data were available both monthly and annually. Monitoring of antibiotic consumption was significantly more prevalent in Northern Italy (p value 0.00671), in University Hospitals (11/21, 52.4%, p value 0.61), medium-sized Hospital with 200–599 beds (9/21, 42.9%, p value 0.777), without any variation for case-mix complexity (each 8/21, 38.1%, p value 0.313). Details in Table 3**.** Distribution of total antibiotic consumption and divided by class expressed as DDD/100 bed-days are shown in Fig. 1 and more details were reported in Supplementary Table 1.

Alcohols-based hand rubs (ABHRs) consumption expressed in litres per 1000 bed-days was tracked in 42.1% of participants (16/38), while only 31.6% of these provided data per department with differences per geographic area, hospital type and case-mix complexity. Details in Table 3.

The frequency of ABHRs monitoring was mainly annual (47.4%, vs 7.9% monthly). The median ABHRs total consumption in 2023 was 26.69 L per 1000 bed-days (IQR 15.35- 44.5), while median consumption in ICU was 60L/1000 bed-days (IQR 40–80).

Detection of hand hygiene compliance by a validated observer (direct observation) according to the WHO five moments for hand hygiene was performed in 63.2% of Hospitals (24/38), with an overall compliance average of 50% (IQR 22.5–75%).

Periodic HAIs surveillance was highly unattended: 15.8% of the hospitals included participated to the largest ICU networks (belonging to the Margherita-PROSAFE project), surgical site infections were monitored in 10.5% of facilities, central venous catheter-related infections in 5.3%, Catheter-Associated Urinary Tract Infections (CAUTI) in 2.6%.

HAI control activities

Most hospitals had recommendations or local Guidelines for Hand Hygiene Procedures (92%) and contact isolation precautions (97.4%). On the contrary, the presence of adherence monitoring systems was absent in most participants, without large differences among Italian regions (Table 4).

Active rectal screening for identifying patients colonised by MDRO (Multi Drug Resistant Organisms) was regularly performed in 86.8% of facilities (33/38): most of them targeted on patient risk factors (81.6%, 31/38). Hospitals in the North were more likely than those in the South or Centre Italy to implement universal screening in high-risk areas (48% vs 28% and 14%, respectively) (Table 4). Active rectal screening detected all carbapenem-resistant organisms in 71.1% of cases (27/38), carbapenem-resistant *Enterobacterales* in 21.2% (8/38), and carbapenem-producing *Enterobacterale*s in 5.3% (2/38). The screening strategy most often used for

Variable	Core component 1: IPC program and organization					
	AMS Working group			Annual plan for IPC		
	Absent (N = 13)	Present (N = 25)	p value[a]	Absent (N = 10)	Present (N = 28)	p value[a]
Geographical area						
Central Italy	1 (7.7%)	8 (32.0%)	0.228	2 (20.0%)	7 (25.0%)	0.698
Islands	4 (30.8%)	5 (20.0%)		2 (20.0%)	7 (25.0%)	
Northern Italy	3 (23.1%)	8 (32.0%)		2 (20.0%)	9 (32.1%)	
Southern Italy	5 (38.5%)	4 (16.0%)		4 (40.0%)	5 (17.9%)	
Hospital type						
Other	1 (7.7%)	0 (0%)	0.2	0 (0%)	1 (3.6%)	0.888
Private-public	0 (0%)	2 (8.0%)		0 (0%)	2 (7.1%)	
Public hospital	7 (53.8%)	8 (32.0%)		5 (50.0%)	10 (35.7%)	
University hospital	5 (38.5%)	15 (60.0%)		5 (50.0%)	15 (53.6%)	
Bed capacity						
< 200	1 (7.7%)	3 (12.0%)	0.338	1 (10.0%)	3 (10.7%)	1
200–599	6 (46.1%)	12 (48.0%)		5 (50.0%)	13 (46.4%)	
600–999	4 (30.8%)	2 (8.0%)		1 (10.0%)	5 (17.9%)	
≥ 1000	2 (15.4%)	8 (32.0%)		3 (30.0%)	7 (25.0%)	
Case-mix complexity[b]						
High	5 (38.5%)	8 (32.0%)	0.323	4 (40.0%)	9 (32.1%)	0.724
Medium	2 (15.4%)	10 (40.0%)		2 (20.0%)	10 (35.7%)	
Low	6 (46.1%)	7 (28.0%)		4 (40.0%)	9 (32.1%)	

Table 2. IPC program and organization. IPC: infection prevention and control; AMS: antimicrobial stewardship. [a]The p-value is derived from the chi-squared test or, when expected cell counts are less than 5, from Fisher's exact test. [b]See text for details.

Variable	Core component 2: Surveillance								
	Periodic local microbiology report			Antibiotic consumption monitoring system based on DDD/100 bed-days			Hand hygiene monitoring system[b]		
	Absent (N = 16)	Present (N = 22)	p value[a]	Absent (N = 17)	Present (N = 21)	p value[a]	Absent (N = 14)	Present (N = 24)	p value[a]
Geographical area									
Central Italy	4 (25.0%)	5 (22.7%)	0.613	3 (17.6%)	6 (28.6%)	**0.00671**	1 (7.1%)	8 (33.3%)	0.0916
Islands	2 (12.5%)	7 (31.8%)		6 (35.3%)	3 (14.3%)		4 (28.6%)	5 (20.8%)	
Northern Italy	6 (37.5%)	5 (22.7%)		1 (5.9%)	10 (47.6%)		3 (21.4%)	8 (33.3%)	
Southern Italy	4 (25.0%)	5 (22.7%)		7 (41.2%)	2 (9.5%)		6 (42.9%)	3 (12.5%)	
Hospital type									
Other	1 (62%)	0 (0%)	0.696	0 (0%)	1 (4.8%)	0.61	1 (7.1%)	0 (0%)	0.11
Private–public	1 (6.2%)	1 (4.5%)		0 (0%)	2 (9.5%)		8 (57.1%)	7 (29.2%)	
Public hospital	5 (31.3%)	10 (45.5%)		8 (47.1%)	7 (33.3%)		5 (35.7%)	15 (62.5%)	
University hospital	9 (56.3%)	11 (50.0%)		9 (52.9%)	11 (52.4%)		0 (0%)	2 (8.3%)	
Bed capacity									
< 200	2 (12.5%)	2 (9.1%)	0.623	2 (11.8%)	2 (9.5%)	0.777	2 (14.3%)	2 (8.3%)	0.686
≥ 1000	5 (31.2%)	5 (22.7%)		3 (17.6%)	7 (33.3%)		4 (28.6%)	6 (25.0%)	
200–599	8 (50.0%)	10 (45.5%)		9 (52.9%)	9 (42.9%)		5 (35.7%)	13 (54.2%)	
600–999	1 (6.3%)	5 (22.7%)		3 (17.6%)	3 (14.3%)		3 (21.4%)	3 (12.5%)	
Case-mix complexity[c]									
High	5 (31.25%)	8 (36.4%)	0.924	5 (29.4%)	8 (38.1%)	0.313	6 (42.9%)	7 (29.2%)	0.639
Low	6 (37.5%)	7 (31.8%)		8 (47.1%)	5 (23.8%)		5 (35.7%)	8 (33.3%)	
Medium	5 (31.25%)	7 (31.8%)		4 (23.5%)	8 (38.1%)		3 (21.4%)	9 (37.5%)	

Table 3. Surveillance. IPC: infection prevention and control; DDD: Defined Daily Dose. [a]The p-value is derived from the chi-squared test or, when expected cell counts are less than 5, from Fisher's exact test. [b]as per World Health Organization guidelines. [c]see text for details.

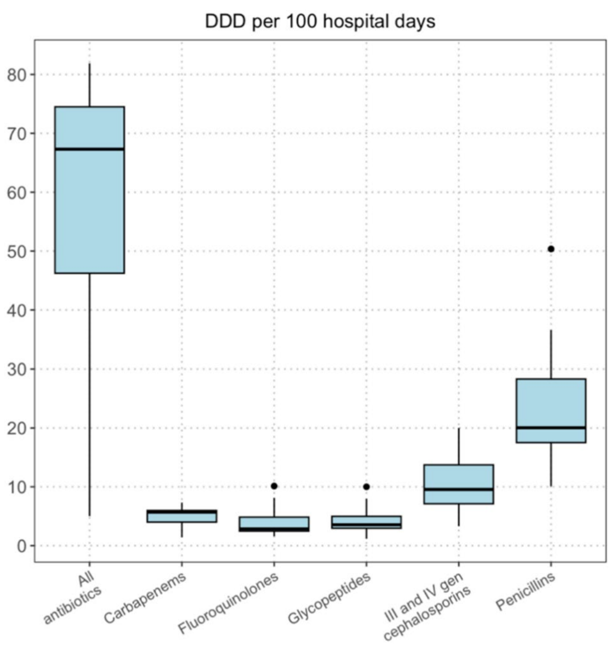

Fig. 1. Distribution of total antibiotic consumption and divided by class expressed as DDD/100 bed-days.

identifying microorganisms included molecular methods (52.6%, 20/38), meropenem disk on McConkey agar plates (39.5%, 15/38), and immunochromatography methods (5.3%, 2/38).

The "search and destroy" strategy for Methicillin-Resistant *Staphylococcus aureus* (MRSA) was implemented in 81.6% of healthcare facilities (31/38). This strategy was applied in 42% of ICUs and 37% of cases among patients undergoing elective surgery.

Only one facility (2.6%) performed nasal screening starting in the Emergency Unit.

Bundles for specific MDR-pathogens were available only in 35% of the Hospitals (34.2%), more implemented in Northern Italy comparing others geographic areas (5/13, 38.5%, p value 0.743) and more prevalent in University Hospitals (9/13, 69.2%, p value 0.291), Table 4.

Operating procedures and instructions for cleaning and disinfection were reported for 86.8% of facilities (33/38). However, only 44.7% (17/38) were equipped with no-touch sterilization systems, and only 42.1% (16/38) implemented a checklist to evaluate adherence to high-touch surface cleaning protocols. A graphical overview of HAI control activities was provided in Fig. 2.

Antimicrobial stewardship

Regarding the core elements of Antimicrobial Stewardship (AMS), many hospitals (73.7%) assessed the appropriateness of antibiotic prescriptions, though the interventions varied widely. These included: proactive consultations (85.7%), clinical case discussions (67.9%), prevalence surveys (57.1%), and clinical audits with feedback (53.6%). The evaluation of antibiotic prescriptive appropriateness was more frequent in Northern Italy (10/28, 35.7%, p = 0.327), in public–private hospitals (16/28, 57.1%, p = 0.489), in hospitals with over 1.000 beds (14/28, 50%, p = 0.113), and in facilities with low case-mix complexity (10/28, 35.7%, p = 1). Restrictive policy with preauthorization for specific antibiotic agents was performed in 68.4% of cases (26/38), most frequently for new cephalosporins including cefiderocol (20/26, 76.9%), new beta-lactamase inhibitors combinations (73.1%, 19/26) and carbapenems (57.7%, 15/26). Restrictions on antifungal drugs were present in 39.5% of cases (15/38): echinocandins (8/15, 53.3%), amphotericin B (11/15, 73.3%), other azoles except fluconazole (10/15, 66.7%).

Antibiotic restrictions were more often found in Central Italy (8/26, 30.8%, p value 0.192), public hospitals (15/26, 57.7%, p value 0.158), medium- bed capacity hospitals (14/26, 53.8%, p value 0.501) and case-mix complexity (10/26, 38.5%, p value 0.383). Further details shown in Table 5**.**

Figure 3 highlights a negative correlation between the presence of restrictive AMS policies and the total amount of antimicrobial consumption and by single antibiotic classes. All except one facility had an Infectious disease consultation service (97.4%). A computerized AMS consultation service was available in 76.3% of facilities (29/38), while teleconsultation services only in 44.7% (17/38). The median number of written infection consultations per year per 1,000 bed-days was 2.100 (IQR 1,136–4,917). During daytime hours (8:00 AM to 8:00 PM), infectious disease consultants received an average of 20 phone calls per day (IQR 10–30). In 55.3% (21/38) antimicrobial prescriptions were digitally recorded.

	Core component 3: HAI control activities								
	Monitoring system for contact isolation adherence			Rectal screening strategy			Pathogen specific bundles		
Variable	Absent (N = 20)	Present (N = 18)	p value[a]	Target (N = 31)	Universal (N = 7)	p value[a]	Absent (N = 25)	Present (N = 13)	p value[a]
Geographical area									
Central Italy	5 (25.0%)	4 (22.2%)	1	8 (25.8%)	1 (14.3%)	0.807	6 (24.0%)	3 (23.1%)	0.743
Islands	5 (25.0%)	4 (22.2%)		8 (25.8%)	1 (14.3%)		6 (24.0%)	3 (23.1%)	
Northern Italy	5 (25.0%)	6 (33.3%)		8 (25.8%)	3 (42.8%)		6 (24.0%)	5 (38.5%)	
Southern Italy	5 (25.0%)	4 (22.2%)		7 (22.6%)	2 (28.6%)		7 (28.0%)	2 (15.4%)	
Hospital type									
Other	7 (35.0%)	8 (44.4%)	0.146	2 (6.4%)	0 (0%)	0.12	1 (4.0%)	0 (0%)	0.291
Private-public	13 (65.0%)	7 (38.9%)		14 (45.2%)	1 (14.3%)		1 (4.0%)	1 (7.7%)	
Public hospital	0 (0%)	1 (5.6%)		15 (48.4%)	5 (71.4%)		12 (48.0%)	3 (23.1%)	
University hospital	0 (0%)	2 (11.1%)		0 (0%)	1 (14.3%)		11 (44.0%)	9 (69.2%)	
Bed capacity									
< 200	1 (5.0%)	3 (16.7%)	0.207	3 (9.7%)	1 (14.3%)	0.489	2 (8.0%)	2 (15.4%)	0.484
≥ 1000	8 (40.0%)	2 (11.1%)		7 (22.6%)	3 (42.85%)		5 (20.0%)	5 (38.5%)	
200–599	8 (40.0%)	10 (55.5%)		15 (48.4%)	3 (42.85%)		13 (52.0%)	5 (38.5%)	
600–999	3 (15.0%)	3 (16.7%)		6 (19.3%)	0 (0%)		5 (20.0%)	1 (7.7%)	
Case-mix complexity									
High	10 (50.0%)	3 (16.7%)	0.0952	10 (32.25%)	3 (42.85%)	0.661	8 (32.0%)	5 (38.5%)	1
Low	5 (25.0%)	8 (44.4%)		10 (32.25%)	3 (42.85%)		9 (36.0%)	4 (30.8%)	
Medium	5 (25.0%)	7 (38.9%)		11 (35.5%)	1 (14.3%)		8 (32.0%)	4 (30.8%)	

Table 4. HAI control activities. HAI: Healthcare-associated infections. [a]The p-value is derived from the chi-squared test or, when expected cell counts are less than 5, from Fisher's exact test. [b]see text for details.

A decreasing number of ID consultations were reported in relation with the presence of audit and feedback strategies (p value 0.256), Fig. 4.

Only half of the hospitals had facility-specific treatment recommendations, based on national guidelines and local pathogen susceptibilities (empirical therapy protocols). The different prevalence of this empiric protocol was reported in Fig. 5: 50% for sepsis and septic shock, 60.5% for pneumonias, 26.3% for central nervous system infections, 36.8% for skin and soft tissue infections, 26.3% for osteomyelitis and diabetic foot infections, 31.6% for intra- abdominal infections, 15.8% for catheter-related bloodstream infections, 42.1% for urinary tract infections.

They were more commonly found in the Northern Italy (6/16, 37.5%, p value 0.146), in public hospitals (10/16, 62.5%, p value 0.13), in hospital with medium -bed capacity (7/16, 43.75%, p value 0.407) and low case-mix complexity hospitals (7/16, 43.75%, p value 0.323); details ***in*** Table 5.

Perioperative prophylaxis algorithms were available in all hospitals except two (36/38, 94.7%).

IPC training and education & Performance monitoring indicators

Training in infection control and AMS was formally authorized by the general Direction in 68.4% of cases (26/38), with higher representation in Northern Italy (9/26, 34.6%, p value 0.562), in private–public hospitals (14/26, 53.8%, p value 0.75), bed capacity 200–599 (10/26, 38.5%, p value 0.32) and high case-mix complexity (11/26, 42.3%, p value 0.323); details in Table 6.

A defined business plan for IPC and AMS program was available only among 42.1% of hospitals (16/38) with annual budget goals, more largely found in Northern Italy (6/16, 37.5%, p value 0.416), public hospitals (9/16, 56.25%, p value 0.696), bed capacity more than 1000 (7/16, 43.75%, p value 0.178), high case-mix complexity (8/16, 50%, p value 0.215); details in Table 6.

Results of IPC and AMS activities were periodically reported to clinicians and general direction or published in intranet site only in 42.1% of cases (16/38).

Stratification for geographical areas

Figure 5 illustrates the proportion of each measure implemented per core component stratified by geographical areas. Northern Italy exhibited the highest proportion of availability of an annual IPC plan (9/11, 81.8%; overall 25/38, 65.8%; p = 0.698), an antibiotic consumption monitoring system based on DDD/100 bed-days (10/11, 90.9%, p = 0.00671; overall 21/38, 55.3%), a monitoring system for contact isolation adherence (6/11, 54.5%; overall 18/38, 47.4%; p = 1). Northern Region implemented more often universal rectal screening strategy (3/11, 27.3%; overall 7/38, 18.4%; p = 0.807), pathogen-specific bundles (5/11, 45.5%; overall 13/38, 34.2%; p = 0.743), audit and feedback AMS strategies (10/11, 90.9%; overall 28/38, 73.7%; p = 0.327), and structured training on IPC and AMS (9/11, 81.8%; overall 26/38, 68.4%; p = 0.562).

Central Italy had a higher proportion of task forces dedicated to AMS (8/9, 88.9%; overall 25/38, 65.8%; p = 0.228), hand hygiene monitoring system (8/9, 88.9%; overall 22/38, 57.9%; p = 0.0515), empiric therapy protocols based on local epidemiology (5/9, 55.6%; overall 16/38,21 42.1%; p = 0.416), antibiotic restriction policies (8/9, 88.9%; overall 26/38, 68.4%; p = 0.192), and a defined budget for HAI and/or AMS (5/9, 55.6%; overall 16/38, 42.1%; p = 0.416).

Island regions most frequently provided microbiological reports based on local resistance, with a relatively high distribution over the territory (7/9, 77.8%; overall 22/38, 57.9%; p = 0.613).

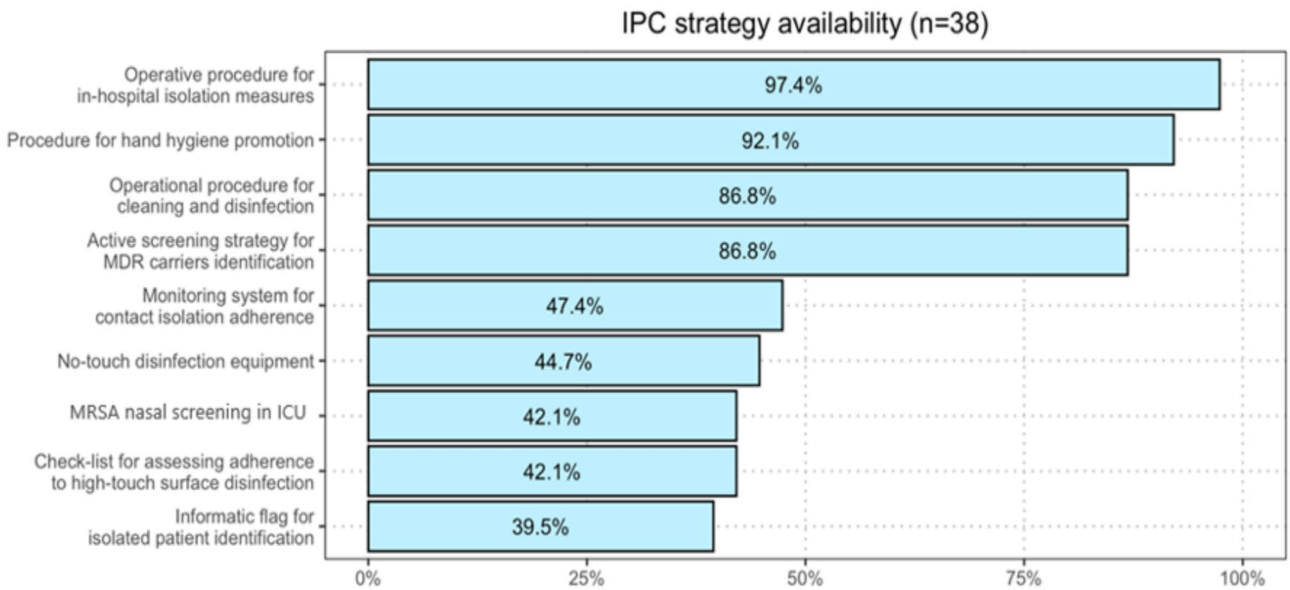

Fig. 2. Prevalence rates of HAI control activities implemented in the participant hospitals.

Variable	Core component 4: Antimicrobial stewardship								
	Antibiotic appropriateness evaluation			Empiric therapy protocols based on local epidemiology			Antibiotic restriction policy (any class)		
	Absent (N = 10)	Present (N = 28)	p value[a]	Absent (N = 22)	Present (N = 16)	p value[a]	Absent (N = 12)	Present (N = 26)	p value[a]
Geographical area									
Central Italy	2 (20.0%)	7 (25.0%)	0.327	4 (18.2%)	5 (31.25%)	0.416	1 (8.3%)	8 (30.8%)	0.192
Islands	3 (30.0%)	6 (21.4%)		7 (31.8%)	2 (12.5%)		2 (16.7%)	7 (26.9%)	
Northern Italy	1 (10.0%)	10 (35.7%)		5 (22.7%)	6 (37.5%)		6 (50.0%)	5 (19.2%)	
Southern Italy	4 (40.0%)	5 (17.9%)		6 (27.3%)	3 (18.75%)		3 (25.0%)	6 (23.1%)	
Hospital type									
Other	6 (60.0%)	9 (32.1%)	0.489	1 (4.5%)	0 (0%)	0.13	2 (16.7%)	0 (0%)	0.158
Private-public	4 (40.0%)	16 (57.1%)		11 (50.0%)	4 (25.0%)		5 (41.7%)	10 (38.5%)	
Public hospital	0 (0%)	1 (3.6%)		10 (45.5%)	10 (62.5%)		5 (41.7%)	15 (57.7%)	
University hospital	0 (0%)	2 (7.1%)		0 (0%)	2 (12.5%)		0 (0%)	1 (3.8%)	
Bed capacity									
< 200	2 (20.0%)	8 (28.6%)	0.113	2 (9.1%)	2 (12.5%)	0.407	1 (8.3%)	3 (11.5%)	0.501
≥ 1000	4 (40.0%)	14 (50.0%)		4 (18.2%)	6 (37.5%)		5 (41.7%)	5 (19.2%)	
200–599	4 (40.0%)	2 (7.1%)		11 (50.0%)	7 (43.75%)		4 (33.3%)	14 (53.8%)	
600–999	0 (0%)	4 (14.3%)		5 (22.7%)	1 (6.25%)		2 (16.7%)	4 (15.4%)	
Case-mix complexity[b]									
High	4 (40.0%)	9 (32.1%)	1	7 (31.8%)	6 (37.5%)	0.323	6 (50.0%)	7 (26.9%)	0.383
Low	3 (30.0%)	10 (35.7%)		6 (27.3%)	7 (43.75%)		4 (33.3%)	9 (34.6%)	
Medium	3 (30.0%)	9 (32.1%)		9 (40.9%)	3 (18.75%)		2 (16.7%)	10 (38.5%)	

Table 5. Antimicrobial stewardship strategies. [a]The p-value is derived from the chi-squared test or, when expected cell counts are less than 5, from Fisher's exact test. [b]see text for details.

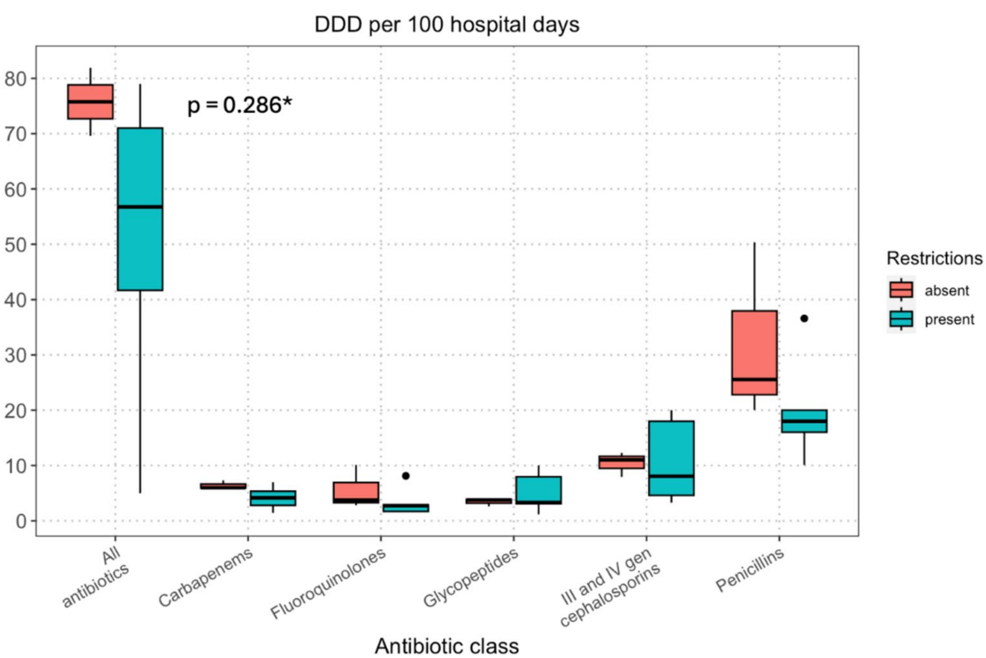

Fig. 3. Correlation between the presence of restrictive AMS policies and the total amount of antimicrobial consumption and by single antibiotic classes. *Mann–Whitney U test.

Discussion

This nationwide survey provides the first comprehensive assessment of IPC and AMS implementation across Italian hospitals, establishing a practical baseline aligned with WHO standards and tailored to the objectives of

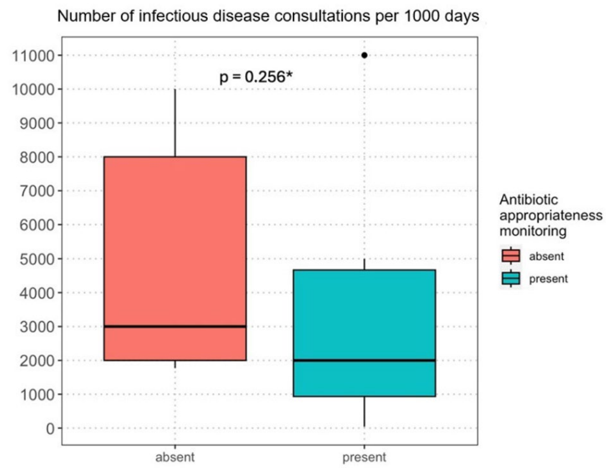

Fig. 4. Correlation between the total amount of Infectious disease consultations and the presence of audit and feedback AMS strategies. *Mann–Whitney U test.

the new PNCAR 2022–2025. With nearly equal geographic representation (11 hospitals in the North, 9 in the Centre, 9 in the South, and 9 in the Islands), our findings reflect national heterogeneity and help identify regional disparities and system-wide gaps. The primary aim of this survey was to inform the ongoing development and implementation of IPC programs on the field by identifying critical areas for improvement and acting as a tool to promote accountability, strengthen national commitments, and stimulate political action where gaps persist. Adjusted analysis of IPC and AMS components by hospitals based on size, location, ownership, and case-mix complexity further enhances the representativeness of the results. Significant differences emerged across regions. Northern and Central hospitals showed more advanced AMS teams, higher antibiotic consumption monitoring, and broader microbiology reporting, likely reflecting better funding, governance, academic support, and staffing. In contrast, hospitals in Southern regions and the Islands more frequently lacked basic surveillance and AMS functions, underlining structural and resource inequities.

In contrast to the recent study by Vincentini et al., which used IPC tools such as IPCAF to assess HAI prevalence in a single Northern region (Piemonte), our nationwide survey offers several distinct advantages. It included a broader range of hospitals, allowing for adjusted analyses by size, location, ownership, and case-mix complexity[13]. Importantly, our study captured facilities with varying levels of IPC program maturity, not only those with established structures. While Vincentini's approach was primarily descriptive, our analysis explored associations between IPC implementation and structural factors using cross-sectional data. Moreover, the multidisciplinary composition of the INSIEME working group—comprising public health experts, hospital administrators, infectious disease physicians, microbiologists, and IPC nurses—strengthened both clinical and operational applicability.

Comparing to the nationwide study by Moro et al. conducted in 2007, which used surveys targeting both hospital general managers and IPC strategic group leaders, our findings highlight several important advancements[14]. Notably, integration between risk management teams, IPC units, and clinical governance activities such as AMS improved from 54 to 70%. A key strength of our survey is the inclusion of infectious disease specialists actively involved in field implementation, providing a more pragmatic understanding of how IPC and AMS strategies must be considered complementary pillars in the fight against AMR. Progress was also observed in leadership accountability, with a significant increase in the allocation of dedicated IPC/AMS budgets compared to the period following the launch of the first PNCAR in 2017. However, only one-third of hospitals reported budget indicators disaggregated at the unit level, underscoring the need for context-specific financial planning. In contrast, surveillance activities remain limited, with no significant improvement from the previous rate of 45% observed by Moro et al. limiting to HAI surveillance based only on point prevalence studies carried out every three years. The absence of a national HAI surveillance system further hinders IPC program effectiveness. Building a structured network, modelled on international systems such as the CDC's NHSN, would allow timely feedback and benchmarking, reduce preventable infections, and inform national strategies. Microbiological tools such as cumulative antibiograms were underutilized, limiting data-driven empirical therapy and stewardship efforts. Similarly, limited access to antibiotic consumption data—especially in Southern regions—prevents benchmarking and targeted interventions. Real-time reporting cumulative antibiograms can significantly improve empirical therapy selection, enhance clinical outcomes, reduce mortality rates, and shorten hospital stays[15–17]. Similarly, limited access to antibiotic consumption data—especially in Southern regions—prevents benchmarking and targeted interventions.

Key IPC practices such as hand hygiene and isolation precautions—already in place since 2007—still lack systematic monitoring and implementation: only half of hospitals currently perform regular audits and feedback. Hand hygiene compliance in Italy was significantly lower than the European average, with a median compliance rate of 50% (IQR 22.5–75%)[18]. Alcohol-based hand rub (ABHR) monitoring and departmental stratification were rare, and compliance indicators for isolation precautions, environmental cleaning, and MDR

	Overall (N=38)	Nord (N=11)	Centre (N=9)	South (N=9)	Islands (N=9)	P value
Core component 1: IPC program and organization						
Proactive group for antimicrobial stewardship	65,80%	72,70%	88,90%	44,40%	55,60%	0.228
Annual plan for IPC	73,70%	81,80%	77,80%	55,60%	77,80%	0.698
Core component 2: surveillance						
Periodic local microbiology report	57,9%	45,5%	55,6%	55,6%	77,8%	0.613
Antibiotic consumption monitoring system based on DDD/100 bed-days	55,3%	90,9%	66,7%	22,2%	33,3%	**0.00671**
Hand hygiene monitoring system	57,9%	72,7%	88,9%	22,2%	44,4%	0.0515
Structured surveillance system for HAI	15,8%	27,3%	11,1%	11,1%	11,1%	0.686
Core component 3: HAI control activities						
Monitoring system for contact isolation adherence	47,4%	54,5%	44,4%	44,4%	44,4%	1
Universal rectal screening strategy	18,4%	27,3%	11,1%	22,2%	11,1%	0.807
Pathogen specific bundles	34,2%	45,5%	33,3%	22,2%	33,3%	0.743
Core component 4: antimicrobial stewardship						
Antibiotic appropriateness evaluation	73,7%	90,9%	77,8%	55,6%	66,7%	0.327
Empiric therapy protocols based on local epidemiology	42,1%	54,5%	55,6%	33,3%	22,2%	0.416
Antibiotic restriction policy (any class)	68,4%	45,5%	88,9%	66,7%	77,8%	0.192
Core component 5 and 6: training and budget						
Structured training on HAI and AMS	68,4%	81,8%	77,8%	55,6%	55,6%	0.562
Defined budget for HAI and/or AMS	42,1%	54,5%	55,6%	22,2%	33,3%	0.416

Fig. 5. Heatmap showing IPC core components adoption rates, stratified for geographical area.

carrier identification were low. More structured, behaviourally informed interventions, supported by leadership engagement and real-time monitoring tools, are needed to close these gaps.

A particularly concerning finding was the limited adoption of active screening strategies for multidrug-resistant organisms (MDROs). Targeted or universal screening was inconsistently implemented, especially outside intensive care units. This may allow silent MDRO colonization and facilitate intra- and inter-hospital transmission, particularly in regions with high patient mobility. Without systematic identification of carriers, adherence to isolation precautions and environmental cleaning protocols becomes ineffective. Strengthening regional networks and introducing standardized screening protocols—backed by national guidance—should be prioritized. More evidence is urgently needed to support targeted screening strategies that are tailored to MDR pathogen risk, specific clinical contexts, and local hospital epidemiology[19–21].

According to a systematic review by Zings et al., infection prevention cannot rely only on a functional infection-control team, but also depends on hospital organization, bed occupancy, staff and workload[22]. Knighton SC et al. emphasized the importance of identifying strategies ensuring the long-term sustainability of routine ICPs, tailored to the specific settings in which they were implemented[23].

Although strategic and IPC working groups were reported in all hospitals except one, structured job descriptions and standard staffing recommendations were lacking. Only 65% of facilities had an AMS team, quite heterogenous in size and composition, ranging from one infectious disease physician to large teams with more than ten members, larger represented in Northern and Central Italy (each 32%), in University Hospitals

Variable	Core component 5: Training			Core component 6: Budget		
	Structured training on IPC and/or AMS			Defined budget for IPC and/or AMS		
	Absent (N = 12)	Present (N = 26)	p value[a]	Absent (N = 22)	Present (N = 16)	p value[a]
Geographical area						
Central Italy	2 (16.7%)	7 (26.9%)	0.562	4 (18.2%)	5 (31.25%)	0.416
Islands	4 (33.3%)	5 (19.2%)		6 (27.3%)	3 (18.75%)	
Northern Italy	2 (16.7%)	9 (34.6%)		5 (22.7%)	6 (37.5%)	
Southern Italy	4 (33.3%)	5 (19.2%)		7 (31.8%)	2 (12.5%)	
Hospital type						
Other	6 (50.0%)	9 (34.6%)	0.75	1 (4.5%)	1 (6.25%)	0.696
Private-public	6 (50.0%)	14 (53.8%)		10 (45.5%)	5 (31.25%)	
Public hospital	0 (0%)	1 (3.8%)		11 (50.0%)	9 (56.25%)	
University hospital	0 (0%)	2 (7.7%)		0 (0%)	1 (6.25%)	
Bed capacity						
< 200	1 (8.3%)	3 (11.5%)	0.32	2 (9.1%)	2 (12.5%)	0.178
≥ 1000	1 (8.3%)	9 (34.6%)		3 (13.6%)	7 (43.75%)	
200–599	8 (66.7%)	10 (38.5%)		13 (59.1%)	5 (31.25%)	
600–999	2 (16.7%)	4 (15.4%)		4 (18.2%)	2 (12.5%)	
Case-mix complexity[b]						
High	2 (16.7%)	11 (42.3%)	0.323	5 (22.7%)	8 (50.0%)	0.215
Low	5 (41.7%)	8 (30.8%)		9 (40.9%)	4 (25.0%)	
Medium	5 (41.7%)	7 (26.9%)		8 (36.4%)	4 (25.0%)	

Table 6. IPC training and education & Performance monitoring indicators. AMS: antimicrobial stewardship; HAI: healthcare-associated infection; IPC: infection prevention and control. [a]The p-value is derived from the chi-squared test or, when expected cell counts are less than 5, from Fisher's exact test.

(60%), and in medium case-mix complexity facilities (40%). IPC stakeholders and "department facilitators" were appointed in 47.4% of hospitals. A possible solution was suggested by Bartles et al.[24]: an online survey-based calculator (The Association for Professionals in Infection Control and Epidemiology's staffing calculator), created using risk and complexity factors specific for each facility, could help identifying individualized IPC staffing ratios.

Further evidence-based recommendations on human resource needs for IPC and AMS program in Italian facilities, adapted to local health-care system contexts are urgently required.

This study has several limitations. First, the study was conducted on a voluntary basis, therefore not all Italian regions/autonomous provinces participated. Selection bias may have occurred, as participating facilities were possibly more committed to IPC, while non-responders—likely including smaller private clinics with limited resources—may be under-represented, limiting generalizability. However, the INSIEME project was designed with a constructive intent, and hospitals participated with a collaborative mindset. Missing variable for lack of available data, may have influenced the statistical significance. Lastly, as the answers to the questionnaire were self-administered, data from each Hospital were not verified by and external checker.

Conclusions

This national survey provides an overview of the country's heterogeneous situation with a practical approach readapted from the WHO IPC assessment framework (IPCAF) and according to the new PNCAR 2022–2025. Stratifying by geographical areas, larger differences were found in antibiotic consumption and microbiology surveillance, implementation of hand hygiene and contact isolation precaution, active screening strategy methods, pathogen specific bundles, antibiotic appropriateness evaluation and antibiotic restriction policy, structure IPC training and defined business plan with dedicated budget. Strengthening continuous, ward-level surveillance and routine performance monitoring is essential to translating policy into practice. Despite the limitations, this study is the first national survey assessing the baseline IPC program in Italy, representing a starting point to develop a proactive implementation plan. To ensure consistency and sustainability, this plan will be adapted to local contexts by integrating best practices, which constitutes the primary objective of the second phase of the INSIEME project.

Data availability

The data collected and analyzed in this study are available as Supplementary Materials.

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References

1. Christaki, E., Marcou, M. & Tofarides, A. Antimicrobial Resistance in Bacteria: Mechanisms, Evolution, and Persistence. *J. Mol. Evol.* **88**(1), 26–40. https://doi.org/10.1007/s00239-019-09914-3 (2020) (**Epub 2019 Oct 28 PMID: 31659373**).
2. Geneva: World Health Organization; Antimicrobial resistance. [Online]. Disponibile su: https://www.who.int/health-topics/antimicrobial-resistance. (2022).
3. WHO/Newsroom/Spotlight. Geneva: World Health Organization; Ten threats to global health in 2019. [Online]. Disponibile su: https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019. (2019).
4. Meschiari, M. et al. Long-Term Impact of the COVID-19 Pandemic on In-Hospital Antibiotic Consumption and Antibiotic Resistance: A Time Series Analysis (2015–2021). *Antibiot (Basel).* **11**(6), 826. https://doi.org/10.3390/antibiotics11060826.PMID:35740232;PMCID:PMC9219712 (2022).
5. Meschiari, M., López Lozano, J. M., Medioli, F., Bacca, E., Sarti, M., Cancian, L et al. A time-series analysis approach to quantify change in antibiotic resistance and antibiotic consumption during COVID-19 Epidemics: a multicenter cross-national ecological study on behalf of QUARANTINE (QUantifying change in Antibiotic Resistance ANTibiotic use and INfection control during COVID-19 Epidemics) study project. Clin Microbiol Infect. S1198–743X (25)00296–4. (2025).
6. Naghavi, M. et al. GBD 2021 Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance 1990-2021: a systematic analysis with forecasts to. *Lancet* **404**(10459), 1199–1226 (2024).
7. WHO Guidelines Approved by the Guidelines Review Committee. Geneva: World Health Organization, Guidelines on Core Components of Infection Prevention and Control Programmes at the National and Acute Health Care Facility Level. [Online]. Disponibile su: http://www.ncbi.nlm.nih.gov/books/NBK401773/. (2016).
8. WHO. Infection prevention and control assessment framework at the facility level. https://www.who.int/publications/i/item/WHO-HIS-SDS-2018.9. (2018).
9. Tartari, E. et al. Evaluating national infection prevention and control minimum requirements: evidence from global cross-sectional surveys, 2017–22. *Lancet Glob. Health.* **12**(10), e1620–e1628. https://doi.org/10.1016/S2214-109X(24)00277-8.PMID:39304235;PMCID:PMC11420467 (2024).
10. Ministero della Salute. Piano Nazionale di Contrasto all'Antibiotico-Resistenza (PNCAR) 2022–2025. Disponibile su: https://www.salute.gov.it/portale/antibioticoresistenza/dettaglioPubblicazioniAntibioticoResistenza.jsp?id=3294
11. Glowicz, J. B. et al. SHEA/IDSA/APIC Practice Recommendation: Strategies to prevent healthcare-associated infections through hand hygiene: 2022 Update. *Infect Control Hosp. Epidemiol.* **44**(3), 355–376. https://doi.org/10.1017/ice.2022.304 (2023) (**Epub 2023 Feb 8. PMID: 36751708; PMCID: PMC10015275**).
12. Von Elm, E. et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J. Clin. Epidemiol.* **61**(4), 344–349. https://doi.org/10.1016/j.jclinepi.2007.11.008 (2008) (**PMID: 18313558**).
13. Vicentini, C. et al. Level of implementation of multimodal strategies for infection prevention and control interventions and prevalence of healthcare-associated infections in Northern Italy. *Antimicrob. Resist. Infect. Control* **13**, 39 (2024).
14. Moro, M. L. et al. Progress in infection prevention and control in Italy: a nationwide survey. *J. Hospital Infec.* **77**, 52e57 (2011).
15. Truong, W. R., Hidayat, L., Bolaris, M. A., Nguyen, L. & Yamaki, J. The antibiogram: key considerations for its development and utilization. *JAC Antimicrob. Resist.* **3**(2), 060. https://doi.org/10.1093/jacamr/dlab060 (2021) (**PMID: 34223122; PMCID: PMC8210055**).
16. WHO; The WHO AWaRe (Access, Watch, Reserve) Antibiotic. [Online]. Disponibile su: https://www.who.int/publications/i/item/WHO-MHP-HPS-EML-2023.04. (2022).
17. Geneva: World Health Organization; The Global Health Observatory. Disability-adjusted life years (DALYs). [Online]. Disponibile su: https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158. (2015).
18. De Kraker, M. E. A. et al. Implementation of hand hygiene in health-care facilities: results from the WHO Hand Hygiene Self-Assessment Framework global survey 2019. *Lancet Infect. Dis.* **22**(6), 835–844. https://doi.org/10.1016/S1473-3099(21)00618-6 (2022) (**Epub 2022 Feb 23. PMID: 35202600; PMCID: PMC9132778**).
19. Arzilli, G. et al. Screening for antimicrobial-resistant Gram-negative bacteria in hospitalised patients, and risk of progression from colonisation to infection: Systematic review. *J. Infect.* **84**(2), 119–130 (2022).
20. Recanatini, C. et al. Impact of Pseudomonas aeruginosa carriage on intensive care unit-acquired pneumonia: a European multicentre prospective cohort study. *Clin. Microbiol. Infect.* **31**(3), 433–440 (2025).
21. Ben-David, D. et al. Contribution of active surveillance cultures to the control of hospital-acquired carbapenem-resistant Acinetobacter baumannii in an endemic hospital setting. *Infect. Control. Hosp. Epidemiol.* **45**(2), 188–195 (2024).
22. Zingg, W. et al. Systematic review and evidence-based guidance on organization of hospital infection control programmes (SIGHT) study group. Hospital organisation, management, and structure for prevention of health-care-associated infection: a systematic review and expert consensus. *Lancet Infect. Dis.* **15**(2), 212–224. https://doi.org/10.1016/S1473-3099(14)70854-0 (2015).
23. Knighton, S. C., Engle, J., Berkson, J. & Bartles, R. A narrative review of how infection preventionist (IP) staffing and outcome metrics are assessed by health care organizations and factors to consider. *Am. J. Infect. Control.* **52**(1), 91–106. https://doi.org/10.1016/j.ajic.2023.06.017 (2024) (**Epub 2023 Nov 16 PMID: 37978984**).
24. Bartles, R., Reese, S. & Gumbar, A. Closing the gap on infection prevention staffing recommendations: Results from the beta version of the APIC staffing calculator. *Am. J. Infect. Control.* **52**(12), 1345–1350. https://doi.org/10.1016/j.ajic.2024.09.004 (2024) (**Epub 2024 Oct 10 PMID: 39387792**).

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Author contributions

MM, conceived the original idea, designed the study and administered the study questionnaire. MM and AG wrote the original draft of the manuscript. M. M, C. M, M. A, R. M, E. R, R. P participated in the questionnaire development and data collection. F.V.S. and MM designed the analysis. M.M., C.M, E.R. reviewed the work critically for important intellectual content. MM, AG, CM, MA, RM, ER, RP, FVS, NE, DCC, CDB, GCM, LO, NC, GP, OC, DF, IS, LS, SDB, RFDV read, edited, and approved the final version of the manuscript. All authors contributed to the study.

Declarations

Competing interests
The authors declare no competing interests.

Ethical statement
This study did not use any individual or patient data, and there was no involvement of members of the public or patients in its design or analysis. According to Italian law, ethics approval was not necessary for this research. This study was performed under the auspices of SIMIT.

Additional information
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