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## American Journal of Infection Control

journal homepage: [www.ajicjournal.org](http://www.ajicjournal.org)

## Major article

## Health care-associated infections and antimicrobial use: The third point prevalence survey on 42 acute care hospitals in Piedmont, Italy, 2022

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## Key Words:

Antimicrobial resistance  
Infection prevention control

**Background:** Health care-associated infections (HAIs), antibiotic use (AMU), and antimicrobial resistance (AMR) are critical indicators of health care quality and antimicrobial stewardship. Point prevalence surveys provide essential data for optimizing infection prevention and control strategies. We aimed to describe the prevalence of HAIs, AMU, and AMR in Piedmont, Italy, highlighting associations with hospital complexity and patient characteristics. **Methods:** Data included hospital characteristics, demographics, HAI, AMU, AMR, and clinical characteristics. Prevalence ratios were calculated to compare rates across subgroups.

**Results:** The prevalence of HAIs was 8%. AMU prevalence decreased to 40% from 42.8% in 2016. Trends in AMU aligned with the “Italian National Action Plan to contrast AMR” (PNCAR) goals, showing reduced fluoroquinolone use and increased amoxicillin prescriptions. AMR trends showed improvements in oxacillin-resistant *Staphylococcus aureus* and cephalosporin-resistant *Escherichia coli* and *Klebsiella pneumoniae*. **Conclusions:** The results highlight the critical importance of sustained investment in infection prevention and control measures and robust antimicrobial stewardship programs.

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## BACKGROUND

Hospital-acquired infections (HAIs) and antimicrobial resistance (AMR) are critical intertwining public health issues. Among the

factors contributing to AMR, there is the overuse and misuse of antimicrobials, particularly the inappropriate use of antibiotics.<sup>1</sup> Global burden estimates indicate that 1.14 million deaths were directly attributed to AMR in 2021, and this number could rise to approximately 1.91 million deaths per year by 2050 if effective actions are not taken to control it.<sup>2</sup>

AMR stands as a primary cause of death worldwide, with the most significant impacts observed in low-resource settings.<sup>3</sup> The 2024 World Health Organization “Bacterial Priority Pathogens List” includes 24 antibiotic-resistant bacterial pathogens from 15 families. Highlighted are gram-negative bacteria resistant to last-resort antibiotics, drug-resistant *Mycobacterium tuberculosis*, and other significant pathogens like *Salmonella*, *Shigella*, *Neisseria gonorrhoeae*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*. These pathogens are included due to their global burden, challenges in treatment, and transmission concerns, emphasizing the critical need for effective prevention strategies.<sup>4</sup>

An important proportion of AMR infections are health care-related. HAIs refer to infections that a patient does not have prior to hospital

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Ethics approval and consent to participate: The study protocol received ethical approval from the Bioethics Committee of the University of Turin (protocol number 0421518, July 29, 2022).

Conflicts of interest: None to report.

Funding/support: This study was funded by the Italian Ministry of Health within the CCM project “Sostegno alla Sorveglianza delle infezioni correlate all’assistenza anche a supporto del PNCAR.” This research was supported by EU funding within the MUR PNRR Extended Partnership initiative on Emerging Infectious Diseases (Project no. PE00000007, INF-ACT). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the paper.

<sup>1</sup> See Appendix working group.

admission but develop either upon arrival or within 48 to 72 hours after being admitted<sup>5</sup>; they represent some of the most common adverse events in health care settings and are associated with a significant burden on health systems, including increased costs.<sup>6</sup>

Since 2011, the European Center for Disease Prevention and Control (ECDC) has been promoting point prevalence surveys (PPS) of HAIs in acute care hospitals every 5 years. The third PPS, conducted in 2022 to 2023, revealed that every year, 4.3 million patients in EU/EEA hospitals acquire at least 1 HAI during their stay. Respiratory tract infections, including pneumonia and health care-associated Coronavirus disease 2019 (COVID-19), accounted for nearly one third of all reported HAIs, followed by urinary tract infections, surgical site infections, bloodstream infections (BSIs), and gastrointestinal infections.<sup>7</sup>

The Italian results of PPS3 revealed comparing results of the Italian PPS3 concerning non-COVID-19 patients with those of the previous edition of the PPS conducted in 2016, HAI prevalence remained stable around 8% in both editions, even though a higher proportion of BSIs was found in 2022 (21.3% of HAIs vs 18.3% in 2016). Antimicrobial use (AMU) prevalence decreased from 44.5% in 2016 to 41.5% in 2022. COVID-19 patients had a significantly higher crude HAI risk of 20% compared with non-COVID-19 patients, probably due to underlying clinical conditions and to the intensity of health care needs.<sup>8</sup>

The cumulative burden of 6 HAIs in EU/EEA was estimated at 501 DALYs per 100,000 people annually. Due to their severity, health care-associated pneumonia (HAP) and health care-associated primary bloodstream infections (HA primary BSI) covered more than 60% of this burden.<sup>9</sup> According to the estimates of a study evaluating the burden of HAIs in Italy, the yearly number of cases for the 5 considered ones (HA BSI; HA CDI, health care-associated *Clostridium difficile* infections; HA UTI, health care-associated urinary tract infections; HAP, health care-associated pneumonia) was of almost 641,065 HAIs and 29,375 deaths in 2016. BSI in the McCabe score 1 group had the highest burden, followed by HAP and SSI.<sup>10</sup>

Evidence indicates that scaling up effective infection prevention and control (IPC) interventions could prevent up to 70% of HAIs.<sup>11</sup> Investing in IPC is highly effective and cost-saving, particularly through measures like hand hygiene and environmental disinfection, which can reduce the risk of death from infections with AMR pathogens by over 50% and decrease long-term complications and health burdens by at least 40%. Improving hand hygiene alone could save approximately US\$16.50 in reduced health care costs for every dollar invested.<sup>6</sup>

Globally, numerous initiatives are being implemented to contrast AMR and HAIs. In Italy, the National Action Plan to contrast AMR (“Piano Nazionale di Contrasto all’Antimicrobico resistenza, PNCAR 2022-2025”) aims to provide the country with strategic guidelines and operational directions to address AMR. The approach is multidisciplinary, following a One Health vision, promoting ongoing international collaboration. The focus is on key interventions for the prevention and control of antibiotic resistance in human, animal, and environmental sectors such as surveillance and monitoring of AMR, AMU, and environmental monitoring, prevention of HAIs in both hospital and community settings, as well as infectious diseases and zoonoses, promoting the appropriate use of antibiotics in human and veterinary medicine, and proper management and disposal of antibiotics and contaminated materials.<sup>12</sup>

In accordance with the PNCAR, the Northern Italian Piedmont region (4,253,778 inhabitants as of August 31, 2024) also implements several initiatives to combat AMR and HAIs, including adherence to specific indicators within health care facilities, surveillance and control of HAIs (surgical site infections, BSIs, and pneumonias in intensive care), implementation of prevention programs, activities related to diagnostic and antimicrobial stewardship, and improving hand hygiene practices. Training on HAIs, AMR, and prevention and control measures is also emphasized.<sup>13,14</sup>

In November 2022, Italy participated in the third edition of the ECDC PPS.<sup>7</sup> Piedmont participated in the latest and previous editions of the national PPS, allowing to monitor trends in HAI prevalence.<sup>15,16</sup>

During PPS 2 in 2016 to 2017, 42 hospitals were involved and data on 7,525 patients were collected in Piedmont. The prevalence of patients with at least 1 HAI was 7.26%. The prevalence of patients receiving at least 1 antibiotic treatment was 42.8%.<sup>15</sup> The objective of Piedmont’s participation in the third edition of the PPS was to provide updated data on the prevalence of HAIs, antibiotic consumption, and AMR in the region, analyzing associated factors and estimating their risk. Within nationally coordinated surveillance efforts, it is important to monitor and interpret local results in light of implemented interventions, to identify strengths and areas for improvement, and to guide the implementation of effective interventions.

## METHODS

### *Study design, protocol, and definitions*

This study, focusing on HAIs, antibiotic consumption, and microbial resistance in acute care hospitals in the Piedmont region, was structured as a regional analysis derived from a national PPS conducted in November 2022. The national PPS followed the ECDC guidelines, adapting the ECDC PPS protocol version 6.0. This protocol employs European case definitions for HAIs as defined by the Hospitals in Europe Link for Infection Control through Surveillance and the National Healthcare Safety Network (NHSN).<sup>7</sup>

### *Sampling of hospitals*

The sampling strategy for the national survey aimed to ensure comprehensive coverage and regional representativeness across Italy. The ECDC-recommended sample size was calculated to estimate an HAI prevalence of 6% ( $\pm 1\%$ ), considering the average size of acute care hospitals in Italy. Each Italian region was assigned a minimum number of hospitals to enroll based on their population, number of acute care hospital bed-days, and discharges from acute care facilities. Beyond this minimum, regions were encouraged to participate more extensively.

In the Piedmont region, a total of 42 acute care hospitals (including all public and some private facilities) participated in the PPS. This approach not only adhered to the minimum hospital requirement but also enhanced the representativeness and diversity of the data by including hospitals of various sizes and types.

### *Data collection*

Trained local hospital personnel, including physicians, infection control nurses, and other nursing staff, carried out data collection. Each ward within participating hospitals was assessed over a single day, and the entire data collection process for each hospital was completed within a voluntary 3-week period. Patients included in the study were those who had been admitted to the ward before 8 AM on the day of the survey and were still present at the time of data collection. Accident and emergency departments, as well as day hospitals and day surgery, were not included in the survey.

Data were collected at 3 levels:

- Hospital level: Information gathered included hospital characteristics, structure, and IPC practices.
- Ward level: Detailed ward-specific information, including the type of ward and its capacity, was collected.

– Patient level: Demographic and clinical data were recorded, including the presence of invasive devices, the severity of underlying conditions (assessed through the McCabe score), AMU, and the presence of active HAIs. For patients receiving antimicrobial treatment, additional data included the antimicrobial agent, route of administration, dosage, indication, anatomical site of infection, and whether the reason for antimicrobial use was documented in the patient's chart. For active HAIs, data collected included the date of onset, origin of infection, microbiological test results, and susceptibility to selected AMR markers when available.

Data collection was facilitated using a secure, web-based platform designed and tested through a pilot study.<sup>17</sup> This platform ensured compliance with the EU General Data Protection Regulation by restricting access to authorized users only. The national coordinating center received anonymized data between December 2022 and March 2023, which were then subjected to quality assessment, compilation, and analysis.

#### Ethical considerations

This study was conducted within an infectious disease surveillance and a national quality improvement network supported by the Italian National Health Institute, the Ministry of Health, and the Italian Centre for Disease Control. Consequently, the requirement for written patient consent was waived. However, patients were informed about their participation in the study through an information sheet detailing the study's objectives and methodology. The study protocol received ethical approval from the Bioethics Committee of the University of Turin (protocol number 0421518, July 29, 2022).

#### Statistical analysis

Descriptive statistics were employed to summarize the characteristics of hospitals and patients. Due to the non-normal distribution of quantitative variables (as determined by Shapiro-Wilk tests), these variables were summarized using medians and interquartile ranges. The prevalence of HAIs and AMU was calculated as the percentage of patients with at least 1 HAI or prescribed at least 1 antimicrobial, respectively, out of the total number of included patients.

To compare HAI and AMU rates among different subgroups, prevalence ratios (PRs) were used, calculated through binomial analysis with 95% confidence intervals (CIs) obtained via the Taylor

Series method. Unlike odds ratio, which estimates the odds of an outcome occurring relative to its nonoccurrence, PR directly quantifies the relative probability of an event occurring in 1 group compared with the sum of cases in the other categories. This approach could be more conservative, consistent, and interpretable in cross-sectional studies.<sup>18</sup> Additionally, differences in AMR rates among microorganisms were evaluated. Mantel-Haenszel's  $\chi^2$  test was applied to assess the significance of observed differences, and *P* values < .05 were considered statistically significant.

## RESULTS

### Hospital characteristics

For this study, 42 acute care hospitals in the region of Piedmont were involved on a voluntary basis. Hospital characteristics are summarized in Table 1.

The majority of included hospitals were public (92.86%, *n* = 39), of small-medium size, and providing primary-level care (45.23%, *n* = 19). The majority of patients (*n* = 3,292, 45.26%) were treated in a primary care hospital.

On the day of the survey, 622 HAIs were recorded among 7,274 patients. The highest number of HAIs (56.50%, *n* = 352) was recorded in medium-sized hospitals (200–500 beds), where more than half of the total antibiotics were prescribed (55.78%, *n* = 2,083). Furthermore, based on the levels of care, a significantly higher number of HAIs was recorded in secondary care hospitals (45.91%, *n* = 286), despite a lower number of patients admitted compared with primary care hospitals (HAIs = 258, 41.40%).

In terms of AMU, the highest prevalence was observed in primary care hospitals, where 47.03% (*n* = 1,756) of the total antibiotics were prescribed. Secondary care hospitals, despite having a higher number of HAIs (45.91%, *n* = 286), accounted for a slightly lower percentage of total AMU (37.55%, *n* = 1,402).

### Patient characteristics

The study sample included 7,274 patients. Patients' characteristics are described in Table 2.

The median age was 72 years (interquartile range: 56–81). The majority of patients (*n* = 4395) were over 65 years old (60.45%). HAI prevalence was 8.0% (*n* = 582) and 39.96% (*n* = 2,907) of patients received an antibiotic on the day of the survey.

**Table 1**  
Characteristics and distribution of HAI and AMU prevalence in participant hospitals, Piedmont, 2022

Characteristic	Hospital, N (%)	Patients, n (%)	Patients with HAI, n (%)	Prevalence ratio, % (95% CI)	Patients with AMU, n (%)	Prevalence ratio, % (95% CI)	Total HAIs, n (%)	Total AMU, n (%)
Hospital beds								
< 200	19 (45.23)	1,331 (18.30)	72 (5.41)	0.63 (0.50–0.80)**	538 (40.42)	NS	73 (11.72)	675 (18.08)
200–500	19 (45.23)	4,061 (55.83)	336 (8.27)	NS	1,637 (40.31)	NS	352 (56.50)	2,083 (55.78)
> 500	4 (9.52)	1,882 (25.87)	174 (9.25)	1.22 (1.03–1.45)*	732 (38.89)	NS	197 (31.62)	976 (26.14)
Hospital type								
Public	39 (92.86)	7,016 (96.45)	573 (8.17)	2.34 (1.23–4.47)*	2,841 (40.49)	1.58 (1.28–1.95)**	612 (98.71)	3,644 (97.59)
Not-for-profit	3 (7.14)	258 (3.55)	9 (3.49)	0.43 (0.22–0.82)*	66 (25.58)	0.63 (0.51–0.78)**	10 (1.61)	90 (2.41)
Level of care								
Basic care	9 (21.43)	469 (6.45)	25 (5.33)	0.65 (0.44–0.96)*	190 (40.51)	NS	25 (4.01)	232 (6.21)
Primary care	19 (45.23)	3,292 (45.26)	248 (7.53)	NS	1,407 (42.74)	1.14 (1.07–1.2)**	258 (41.41)	1,756 (47.03)
Secondary care	8 (19.05)	2,742 (37.70)	259 (9.45)	1.32 (1.13–1.55)**	1,055 (38.48)	0.94 (0.89–0.99)*	286 (45.91)	1,402 (37.55)
Specialized care	6 (14.29)	771 (10.60)	50 (6.49)	NS	255 (33.07)	0.81 (0.73–0.9)**	53 (8.51)	344 (9.21)
Total	42	7,274	582		2,907		622	3,734

ATB, antibiotic; CI, confidence interval; HAI, health care-associated infections; NS, not significant.

\**P* value < .05.

\*\**P* value < .001.

**Table 2**  
Characteristics and distribution of HAI and AMU prevalence among patients recruited, Piedmont, 2022

Characteristic	Patients, N (%)	Patients with HAI, n (%)	Prevalence ratio, % (95% CI)	Patients with ATB, n (%)	Prevalence ratio, % (95% CI)
<b>Age group</b>					
< 2 y	401 (5.52)	4 (1)	0.12 (0.05-0.32)**	58 (14.46)	0.35 (0.27-0.44)**
2-18 y	236 (3.25)	5 (2.12)	0.26 (0.11-0.62)**	99 (41.95)	NS
19-64 y	2,238 (30.78)	167 (7.46)	NS	854 (38.16)	0.94 (0.88-0.99)*
+ 65 y	4,395 (60.45)	406 (9.24)	1.51 (1.27-1.79)**	1,895 (43.12)	1.22 (1.16-1.30)**
<b>Sex</b>					
Female	3,642 (50.08)	259 (7.11)	0.80 (0.68-0.94)*	1,342 (36.85)	0.85 (0.81-0.90)**
Male	3,631 (49.92)	323 (8.9)	1.25 (1.07-1.46)*	1,565 (43.10)	1.17 (1.11-1.24)**
<b>McCabe score</b>					
Nonfatal	5,020 (69.01)	295 (5.88)	0.46 (0.40-0.54)**	1,779 (35.44)	0.71 (0.67-0.75)**
Ultimately fatal	1,473 (20.25)	186 (12.63)	1.85 (1.57-2.18)**	727 (49.36)	1.31 (1.24-1.40)**
Rapidly fatal	644 (8.85)	86 (13.35)	1.79 (1.44-2.21)**	344 (53.42)	1.38 (1.28-1.49)**
Unknown	137 (1.88)	15 (10.95)	NS	57 (41.61)	NS
<b>Invasive device use</b>					
Central vascular catheter	1,264 (17.38)	244 (19.30)	3.43 (2.95-4)**	729 (57.67)	1.59 (1.50-1.69)**
Urinary catheter	2,295 (31.55)	316 (13.77)	2.58 (2.21-3.01)**	1,283 (55.90)	1.71 (1.62-1.81)**
Intubation	254 (3.49)	67 (26.38)	3.60 (2.88-4.49)**	172 (67.71)	1.74 (1.59-1.90)**
≥ One device	2,876 (39.54)	395 (13.73)	3.23 (2.73-3.82)**	1,578 (54.87)	1.82 (1.72-1.92)**
<b>Surgery since admission</b>					
No	4,990 (68.60)	346 (6.94)	0.67 (0.57-0.79)**	1,930 (38.68)	0.90 (0.85-0.96)**
Yes, non-NHSN	630 (8.66)	56 (8.89)	NS	274 (43.49)	NS
Yes, NHSN	1,654 (22.74)	180 (10.88)	1.52 (1.29-1.80)**	703 (42.5)	1.08 (1.02-1.16)*
<b>Specialty ward type</b>					
Medical specialties	2,927 (40.24)	258 (8.81)	1.18 (1.01-1.38)*	1,362 (46.55)	1.31 (1.24-1.38)**
Surgical specialties	1,918 (26.37)	156 (8.13)	NS	783 (40.84)	NS
Gynecology and obstetrics	512 (7.04)	2 (0.39)	0.05 (0.01-0.18)**	120 (23.44)	0.57 (0.49-0.67)**
Intensive care	320 (4.40)	69 (21.56)	2.92 (2.33-3.66)**	173 (54.06)	1.38 (1.24-1.53)**
Pediatrics	256 (3.52)	1 (0.39)	0.05 (0.01-0.33)**	96 (37.5)	NS
Neonatology	248 (3.41)	2 (0.81)	0.10 (0.02-0.39)**	22 (8.87)	0.22 (0.15-0.32)**
Psychiatry	203 (2.79)	5 (2.46)	0.30 (0.13-0.72)*	10 (4.93)	0.12 (0.07-0.22)**
Rehabilitation	181 (2.49)	23 (12.71)	1.61 (1.09-2.38)*	29 (16.02)	0.39 (0.28-0.55)**
Geriatrics	140 (1.92)	21 (15)	1.90 (1.28-2.85)*	68 (48.57)	1.22 (1.03-1.45)*
Long-term care	9 (0.12)	3 (33.33)	NS	4 (44.44)	NS
Combination of specialties	330 (4.54)	30 (9.09)	NS	146 (44.24)	NS
Other	10 (0.14)	0	NA	1 (10)	NS
COVID medicine	220 (3.02)	12 (5.45)	NS	93 (42.27)	NS
<b>Total</b>	<b>7,274</b>	<b>582</b>		<b>2,907</b>	

NOTE. Four patients for the age variable and 1 patient for the sex variable were not considered due to missing data.

ATB, antibiotic; CI, confidence interval; HAI, health care-associated infections; NA, not applicable; NHSN, National Healthcare Safety Network; NS, not significant.

\*P value < .05.

\*\*P value < .001.

Among the patients, 5.62% (n = 409) were COVID-19 patients, of these, 29 (7.09%) were affected by an HAI and 44.45% (n = 182) were undergoing antibiotic therapy.

Considering patients aged over 65 years, a significantly higher proportion acquired an HAI (PR 1.51, 95% CI 1.27-1.79,  $P < .001$ ) and were receiving at least 1 antibiotic (PR 1.22, 95% CI 1.16-1.30,  $P < .001$ ) compared with patients aged <65 years. Female patients had a significantly lower HAI prevalence (PR 0.80, 95% CI 0.68-0.94,  $P < .05$ ) compared with male patients (PR 1.25, 95% CI 1.07-1.46,  $P < .05$ ).

Based on the estimated clinical severity assessed using the McCabe score, 69.01% (n = 5,020) of patients had a nonfatal disease (expected survival > 5 years), 20.25% (n = 1,473) had an ultimately fatal disease, and 8.85% (n = 644) had been diagnosed with rapidly fatal disease. In patients with a nonfatal score, both the prevalence of HAI (n = 295, 4.05%, PR 0.46, 95% CI 0.40-0.54,  $P < .001$ ) and the administration of antibiotic therapy (24.46%, PR 0.71, 95% CI 0.67-0.75,  $P < .001$ ) were lower compared with patients with more severe McCabe scores.

Regarding invasive devices, 39.54% of patients (n = 2,876) had at least 1 medical device in place (central vascular catheter, urinary catheter, or intubation), with the urinary catheter being the most common (n = 2,295, 31.55%), followed by central vascular catheters (n = 1,264, 17.38%) and intubation (n = 254, 3.49%). Among patients with at least 1 device, 13.73% (n = 395) had an HAI, and more than half (54.87%) were receiving antibiotic therapy. Patients affected by HAI included 244 (19.30%) with a central vascular catheter, 316 (13.77%) with a urinary catheter, and 67 who were intubated

(26.38%). Notably, patients with central vascular catheters had a higher prevalence of HAI (PR: 3.43, 95% CI: 2.95-4.00,  $P < .001$ ). A similar increase was observed for those with a urinary catheter (PR: 2.58, 95% CI: 2.21-3.01,  $P < .001$ ) and for patients undergoing intubation (PR: 3.60, 95% CI: 2.88-4.49,  $P < .001$ ), highlighting the substantial risk of HAI associated with invasive devices.

Regarding surgical procedures, 22.74% (n = 1,654) of the sample underwent an NHSN-defined surgery, 8.66% (n = 630) underwent a non-NHSN procedure, and 68.60% (n = 4,990) had no surgical procedure. Patients undergoing NHSN surgery were at significantly higher HAI risk (PR 1.52, 95% CI 1.29-1.80,  $P < .001$ ).

The majority of patients were hospitalized in medical wards (40.24%, n = 2,927), followed by surgical wards (26.37%, n = 1,918). In medical wards, 3.55% (n = 258) were affected by HAI (PR 1.18, 95% CI 1.01-1.38,  $P < .05$ ), while 18.72% (n = 1,362) were receiving antibiotics (PR 1.31, 95% CI 1.24-1.38,  $P < .001$ ). Intensive care was the ward with the highest prevalence of HAIs (21.56%, n = 69), relative to the number of hospitalized patients (n = 320), followed by geriatrics (15%) and rehabilitation (12.71%). Furthermore, over half of the patients hospitalized in intensive care (54.06%, n = 173) were prescribed antibiotics.

#### Isolated microorganisms and AMR

The most commonly prescribed antibiotics in the study were beta-lactams combined with enzyme inhibitors and cephalosporins. Piperacillin with enzyme inhibitors was the most frequently used,

accounting for 663 prescriptions (17.76%), followed by ceftriaxone, a third-generation cephalosporin, with 559 prescriptions (14.97%). Amoxicillin combined with enzyme inhibitors represented 301 prescriptions (8.06%), while cefazolin, a first-generation cephalosporin, accounted for 261 prescriptions (6.99%). Meropenem, a carbapenem, constituted 234 prescriptions (6.27%). Among fluoroquinolones, levofloxacin was the most frequently prescribed (113 prescriptions, 3.03%), followed by ciprofloxacin (75 prescriptions, 2.01%).

The majority of antibiotic prescriptions were for the treatment of community-acquired infections, with 1,749 prescriptions (46.84%). Hospital-acquired infections accounted for 736 prescriptions (19.71%), while infections acquired in long-term care or residential facilities were less common, with 102 prescriptions (2.73%). Prophylaxis represented a significant proportion of AMU, including medical prophylaxis with 353 prescriptions (9.45%) and surgical prophylaxis, which was categorized into single-dose administration (216 prescriptions, 5.78%), 1-day regimens (96 prescriptions, 2.57%), and prolonged courses lasting more than 1 day (235 prescriptions, 6.29%). Additionally, 247 prescriptions (6.61%) were classified under other indications. Of the antibiotic prescriptions analyzed, 3,365 (90.12%) had a documented indication in the patient's medical records.

Laboratory detection was performed for 413 HAIs (66.40% of total HAIs). Among 661 isolated microorganisms, 117 (17.70%) were resistant to at least 1 tested antibiotic. Regarding the use of devices, intubated patients had the highest rate of resistance (35.82%) among tested HAIs compared with patients with CVC and UC (31.50% and 29.17%, respectively). Almost all HAIs in intensive care were tested (88.75%,  $n = 71$ ), of which 35.21% ( $n = 25$ ) were resistant.

Among the positive microbiological tests, the most frequently identified microorganisms were Enterobacteriaceae (45.08%,  $n = 206$ ), gram-positive cocci (26.26%,  $n = 120$ ), gram-negative bacilli (13.57%,  $n = 62$ ), fungi (7.44%,  $n = 34$ ), anaerobic bacilli (6.56%,  $n = 30$ ), gram-negative coccobacilli (0.88,  $n = 4$ ), and viruses (0.22%,  $n = 1$ ). The AMR profile of the main microorganisms tested is represented in Figure 1.

Among *Staphylococcus aureus*, resistance to oxacillin was observed in 14 out of 42 isolates (33.33%), while susceptibility to glycopeptides was nearly universal, with only 1 resistant isolate (2.38%) reported. Regarding *Enterococcus* species, *E. faecalis* exhibited low resistance to glycopeptides, with 2 resistant isolates (11.76%), whereas *E. faecium* demonstrated a high resistance profile, with 11 out of 15 isolates (73.33%) resistant.

For third-generation cephalosporins, resistance was notably higher in *Klebsiella pneumoniae* (27 out of 70 isolates, 38.57%) and *Escherichia coli* (18 out of 65 isolates, 27.69%) compared with *Proteus mirabilis* (4 out of 22 isolates, 18.18%).

In the carbapenem group, *Escherichia coli* showed a low resistance level, with 2 out of 65 isolates (3.08%) resistant, while *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* showed 18 out of 70 isolates (25.71%) and 20 out of 41 isolates (48.78%) resistant, respectively. *Acinetobacter baumannii* displayed near-total resistance, with 14 out of 15 isolates (93.33%) resistant.

There was also 1 possible case of pan-drug-resistant microorganisms, resistant to all tested antibiotics.

A significant reduction in the use of fluoroquinolones, such as levofloxacin (PR: 0.36, 95% CI: 0.29–0.44,  $P < .001$ ) and ciprofloxacin (PR: 0.40, 95% CI: 0.31–0.52,  $P < .001$ ), was observed compared with the previous survey. Additionally, an increase in the use of amoxicillin (PR: 2.47, 95% CI: 1.54–3.97,  $P < .001$ ) was noted, along with a concurrent reduction in the use of amoxicillin combined with beta-lactamase inhibitors (PR: 0.80, 95% CI: 0.69–0.92,  $P < .001$ ). No significant change was observed in the use of carbapenems. An increase in the use of piperacillin and beta-lactamase inhibitors (PR: 1.29, 95% CI: 1.16–1.42,  $P < .001$ ) and ceftriaxone (PR: 1.20, 95% CI: 1.08–1.34,  $P < .001$ ) was also detected. Lastly, a reduction in medical prophylaxis (PR: 0.59, 95% CI: 0.53–0.67,  $P < .001$ ) was observed, whereas no improvement was seen in the use of surgical prophylaxis for more than 1 day.

## DISCUSSION

This study aimed to provide a comprehensive analysis of HAIs, AMU, and AMR in acute care hospitals across the Piedmont region of Italy, utilizing data collected during the 2022 to 2023 PPS.<sup>7</sup>

In total, 622 HAIs were recorded across 7,274 patients, yielding an overall prevalence of 8%. Excluding COVID-19 patients, HAIs prevalence was 8.1%, slightly higher than the previous study in 2016 (7.26%).<sup>15</sup> The prevalence of AMU was recorded globally at 40% and 39.6%, excluding COVID-19 patients, indicating a reduction from 42.8% in the previous survey but still highlighting a significant use of antibiotics. These figures highlight a slight improvement, in line with other recently published Italian studies, while underlining the persistent challenge posed by HAIs and AMUs in the health care sector.<sup>19,20</sup> Furthermore, it should be taken into consideration that the worsening of the hospital case mix over the years could lead to a physiological slowdown in the improvement process. In this sense, compared to the previous national survey, we recorded a higher proportion of elderly patients (PR: 1.08, 95% CI: 1.05–1.10,  $P < .001$ ) and a greater prevalence of patients with rapidly or ultimately fatal McCabe scores (PR: 1.10, 95% CI: 1.06–1.15,  $P < .001$ ).<sup>16</sup>

Interestingly, the study revealed notable differences in the prevalence of HAIs and AMU across hospital characteristics. PRs for HAIs and AMU

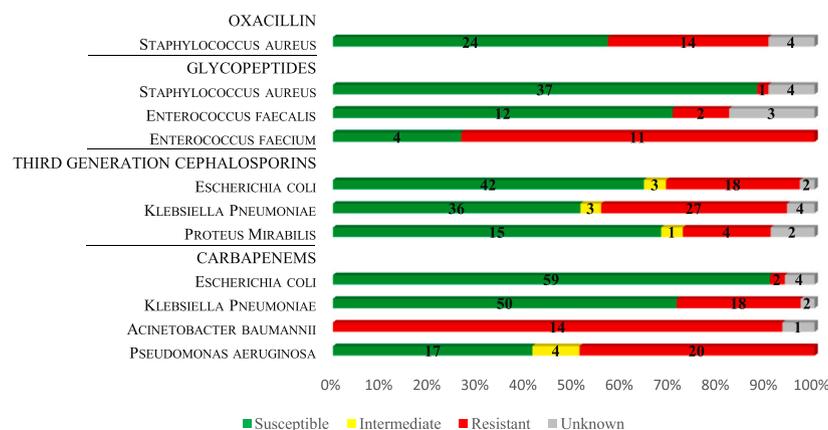


Fig. 1. AMR profiles of main microorganisms tested, grouped by antibiotic type.

show an almost inverse trend across different levels of hospital beds and type of care. This trend is noteworthy and could be linked to the different roles and functions of hospitals, as outlined in the Italian Ministry of Health's Decree 70/2015, which classifies hospitals into basic hospitals, first-level emergency departments (DEA I), and second-level emergency departments (DEA II).<sup>21</sup> Basic hospitals typically handle lower-acuity cases and a broader range of nonspecialized conditions. These hospitals may have a lower rate of HAIs (PR 0.65, 95% CI 0.44–0.96,  $P$  value < .05) due to simpler procedures and fewer complex cases. On the other hand, second-level hospitals (DEA II), being specialized centers with more advanced infrastructure and expertise, typically handle higher-acuity cases. The higher PR for HAIs (PR 1.32, 95% CI 1.13–1.55,  $P$  value < .001) in these hospitals could be explained by the increased complexity of procedures, the higher risk of infections related to intensive care, and the presence of immunocompromised patients. However, these hospitals could tend to be more judicious in their use of antibiotics due to more stringent antimicrobial stewardship programs and better diagnostic capabilities (PR 0.94, 95% CI 0.89–0.99,  $P$  value < .05).<sup>22</sup>

Regarding antibiotic consumption, several notable findings emerged compared with the previous survey.<sup>15</sup> These findings align with the objectives of the PNCAR, which aimed for a reduction of over 10% in fluoroquinolone use and a 30% increase in the prescription ratio of amoxicillin.<sup>12</sup> Additionally,<sup>12</sup> the observed increase in piperacillin/beta-lactamase inhibitors and ceftriaxone could potentially be explained by a worsening of the hospital-type patient as discussed before. Lastly, while the reduction in medical prophylaxis is a positive trend, the persistent inappropriate use of surgical prophylaxis beyond 1 day remains an area of concern, as it is generally discouraged by guidelines.<sup>23</sup>

Notable improvements were observed in the resistance profiles of *Staphylococcus aureus* to oxacillin, as well as *Escherichia coli* and *Klebsiella pneumoniae* to third-generation cephalosporins, compared with the previous survey.<sup>15</sup> *Klebsiella pneumoniae* also showed a reduction in resistance to carbapenems. Unfortunately, no significant improvement was observed for *Acinetobacter baumannii* and *Pseudomonas aeruginosa* in their carbapenem resistance profiles. Additionally, *Enterococcus faecium* exhibited a worsening trend in its resistance to glycopeptides, a concerning development compared with the 2016 data.<sup>15</sup>

In Piedmont, IPC efforts have been systematically strengthened since 2008 through regional policies, quality-driven strategies, and an indicator-based performance evaluation system aligned with the PNCAR.<sup>12</sup> A recent study reported a high level of implementation of multimodal IPC strategies among hospitals in the region, with a median Infection Prevention and Control Assessment Framework score of 11/14.<sup>24</sup> Unlike previous surveys, which did not incorporate Infection Prevention and Control Assessment Framework, this inclusion in the current study marks a significant step forward in evaluating the quality and scope of IPC measures. Particularly, participation in regional surveillance networks for surgical site infections, AMR, AMU, and alcohol-based handrub consumption has significantly increased. Areas for improvement include safety climate, culture of change, and accountability among health care professionals.<sup>24</sup> However, the impact of COVID-19, which has likely elevated awareness and attention toward IPC, must be considered in relation to IPC practices and AMR. As the emergency phase subsides, it is crucial to ensure that the heightened focus on IPC does not regress. Vigilance and sustained commitment will be necessary to maintain the advances achieved during the pandemic.<sup>25,26</sup>

As regards the influence of patient characteristics, age was one of the most significant factors, with older adults ( $\geq 65$  years) experiencing a higher prevalence of both HAIs (PR 1.51, 95% CI 1.27–1.79,  $P$  value < .001) and AMU (PR 1.22, 95% CI 1.16–1.30,  $P$  value < .001) compared with the other groups. Elderly patients are more susceptible to infections due to age-related immune system decline and comorbidities.<sup>27,28</sup>

This is supported by the fact that in terms of underlying health conditions, patients with more severe conditions, as indicated by the McCabe score, were more likely to acquire HAIs. Particularly, patients classified as “rapidly fatal” had the highest rates of HAIs and AMU. Moreover, invasive device use emerged as a strong predictor for both HAIs and AMU. Patients with central vascular catheters, urinary catheters, or those who were intubated had significantly higher rates of both infections and antimicrobial treatment. Unfortunately, an increased presence of patients with more than 1 invasive device was observed compared with the previous national PPS (PR: 1.71, 95% CI: 1.64–1.78,  $P$  < .001), which likely contributes to the region's HAI prevalence.<sup>16</sup> This finding aligns with the broader context of Italy being among the worst-performing countries in Europe regarding the frequency of catheter-related HAIs, underscoring the crucial need for targeted IPC measures to protect this high-risk group.<sup>7</sup>

The study also revealed differences in HAI rates across different types of hospital wards. Intensive care units recorded the highest risk of HAIs (PR 2.92, 95% CI 2.33–3.66,  $P$  value < .001) and were associated with more frequent AMU (PR 1.38, 95% CI 1.24–1.53,  $P$  value < .001). This is consistent with the well-established higher risk of infections and AMU in intensive care unit settings due to the invasive treatments and critical nature of the patients.<sup>28</sup> At the same time, patients not undergoing surgical interventions are comparatively at reduced risk of HAIs and AMU, while those who do, particularly NHSN, experience increased risks. At the ward level, however, this pattern does not entirely replicate. This discrepancy may arise from the practice of transferring postsurgical patients who develop infections to specialized wards, such as medical or infectious disease units, for targeted treatment. These findings underscore the importance of implementing progressive IPC practices according to the specific infective risk levels associated with different hospital wards and departments. Furthermore, these results support the reinforcement and potential expansion of surveillance programs already in place at regional and national levels.<sup>12</sup>

This study has several limitations that should be acknowledged. First, data were collected as part of a PPS, which provides a snapshot of HAIs, AMU, and AMR at a specific time. While valuable for identifying patterns, this approach does not allow for temporal trends or causality to be assessed. Second, the study relied on clinical and microbiological data available at the time of the survey, which might lead to underreporting or misclassification of HAIs due to variations in diagnostic practices or delays in microbiological confirmation. Similarly, the completeness and accuracy of data on AMR depend on the proportion of HAIs tested for microorganisms, which may vary across patient groups and settings. Moreover, the voluntary selection of the surveillance period within the study window may have influenced the results, as seasonality could affect the prevalence of HAIs. Finally, the results reflect the specific characteristics of the participating hospitals and health care regional systems.

The strengths of the study lie in its extensive regional representativeness, achieved by including almost all hospitals within the area. This comprehensive approach provides valuable insights across different health care settings, reflecting variations in patient populations and clinical practices, and offering a robust foundation for identifying emerging trends and challenges in patient care. For instance, the increasing use of invasive devices and changes in AMU and AMR have been captured, enabling timely responses to new threats in future iterations. Additionally, the implementation of a dedicated digital platform represents a key innovation, simplifying data collection and analysis.<sup>17</sup> This system not only ensures the reproducibility of the study but also facilitates its potential repetition over time. Such periodic surveillance would enable more frequent monitoring, allowing for the evaluation of temporal trends and the effectiveness of IPC measures, ultimately supporting targeted interventions.

## CONCLUSIONS

This study provides an important overview of HAIs and AMU in the Piedmont region, highlighting the ongoing challenges in hospital settings. The findings underscore the need for continued investment in IPC and antimicrobial stewardship programs. By addressing these issues, it is possible to reduce the incidence of HAIs, optimize AMU, and ultimately improve patient outcomes in the region.

## CONSENT FOR PUBLICATION

This study was conducted within an infectious disease surveillance and a national quality improvement network supported by the Italian National Health Institute, the Ministry of Health, and the Italian Centre for Disease Control. Consequently, the requirement for written patient consent was waived. However, patients were informed about their participation in the study through an information sheet detailing the study's objectives and methodology.

## AVAILABILITY OF DATA AND MATERIALS

All data collected within the CCM project “Sostegno alla Sorveglianza delle infezioni correlate all'assistenza anche a supporto del PNCAR,” including those reported in this study, are owned by the Italian Ministry of Health. The datasets used and analyzed during the current study will be made available from the corresponding author on reasonable request.

## Acknowledgments

We gratefully acknowledge the regional coordination of the study: Valentina Blengini, Edoardo Rolfini, Heba Safwat Mhmoued Abdo Elhadidy, Irene Gintoli, and Giulia Libero. A sincere thank you also goes to all the infection risk specialist nurses (ISRI) of the participating hospitals and everyone who contributed to the data collection.

## APPENDIX

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