Advances in Infectious Diseases, 2026, 16(1), 121-134
https://www.scirp.org/journal/aid
ISSN Online: 2164-2656
ISSN Print: 2164-2648

Antimicrobial Resistance in Senegal: Bacterial Ecology and Resistance Profiles from Cheikh Ahmadoul Khadim National Hospital of Touba

Ndeye Fatou Ngom[1], Abdou Niasse[1,2], Daouda Thioub[1,3], Aboubakar Sidikh Badiane[3], Sokhna Atta Diop[1], Fulgence Abdou Faye[1], Cheikh Seye[1], Ibrahima Konaté[4], Ousseynou Ka[1], Moussa Seydi[3]

[1]Faculty of Health and Sustainable Development, Alioune Diop University, Bambey, Senegal
[2]Cheikh Ahmadoul Khadim National Hospital, Touba, Senegal
[3]Department of Infectious and Tropical Diseases, University Hospital Center of Fann, Dakar, Senegal
[4]Faculty of Health Sciences, Gaston Berger University, Saint-Louis, Senegal
Email: ndeyefatou.ngom@uadb.edu.sn, niasseabdou30@gmail.com, daoudath05@yahoo.com, aboubakrbadiane@yahoo.fr, diopatta7@gmail.com, fulgenceabdou.faye@uadb.edu.sn, cheikh.seye@uadb.edu.sn, ibrahima.konate@ugb.edu.sn, seydi.moussa@gmail.com, ousseynou.ka@uadb.edu.sn

How to cite this paper: Ngom, N.F., Niasse, A., Thioub, D., Badiane, A.S., Diop, S.A., Faye, F.A., Seye, C., Konaté, I., Ka, O. and Seydi, M. (2026) Antimicrobial Resistance in Senegal: Bacterial Ecology and Resistance Profiles from Cheikh Ahmadoul Khadim National Hospital of Touba. *Advances in Infectious Diseases*, **16**, 121-134.
https://doi.org/10.4236/aid.2026.161009

Received: January 6, 2026
Accepted: February 1, 2026
Published: February 4, 2026

Abstract

Background: Antimicrobial resistance (AMR) is a growing concern in sub-Saharan Africa, where infectious diseases remain highly prevalent. In Senegal, available AMR data are limited and fragmented. **Methods:** We conducted a retrospective study at Cheikh Ahmadoul Khadim National Hospital, Touba (January-December 2024). All hospitalized patients with culture-confirmed bacterial infections were included. Bacterial identification and antimicrobial susceptibility testing followed CA-SFM/EUCAST 2024 guidelines. **Results:** Among 369 patients (median age 36 years; 59% male), 251 cultures were positive (68%). Gram-negative bacilli predominated (69.5%), mainly *Escherichia coli* (24.2%) and *Klebsiella spp.* (22.1%). Gram-positive cocci accounted for 30%, dominated by *Staphylococcus aureus* (20.4%). Resistance to first-line antibiotics was high: penicillins ≈ 50%, third-generation cephalosporins 20% - 36% in Enterobacterales, and trimethoprim-sulfamethoxazole ≥ 37%. Carbapenem resistance remained low (<12%), and amikacin, fosfomycin, and nitrofurantoin retained activity. MRSA prevalence was 14.3%. **Conclusion:** AMR is widespread in Senegal, with ESBL-producing Enterobacterales and MRSA circulation. Strengthened surveillance and stewardship are urgently required.

Keywords

Antimicrobial Resistance, Infection, Senegal, Touba

1. Introduction

Antimicrobial resistance (AMR) has emerged as a major threat to public health, with considerable clinical and economic consequences. In 2019, nearly 5 million deaths were estimated to be associated with antibiotic-resistant infections, of which 1.27 million were directly attributable to AMR [1]. The bacteria most commonly implicated include extended-spectrum beta-lactamase (ESBL)-producing Enterobacterales, carbapenem-resistant *Klebsiella pneumoniae*, and methicillin-resistant *Staphylococcus aureus* (MRSA), which are ranked among the priority pathogens by the World Health Organization [2] [3].

In sub-Saharan Africa, AMR is of particular concern due to the high burden of infectious diseases, the frequent reliance on empirical antibiotic therapy, and limited access to advanced microbiological diagnostic techniques [4]. The growing coexistence of infectious and non-communicable diseases further complicates clinical management. Several regional studies have documented high rates of Enterobacterales resistance to third-generation cephalosporins, as well as significant proportions of MRSA, reflecting both substantial antibiotic pressure and insufficient surveillance [5].

In Senegal, available AMR data mainly derive from isolated hospital-based series, highlighting the increasing prevalence of ESBL-producing Enterobacterales and the circulation of MRSA in surgical, pediatric, and intensive care units [6] [7]. However, surveillance remains fragmented and poorly representative, while the country's participation in the WHO Global Antimicrobial Resistance Surveillance System (GLASS) underscores the need for consolidated and regularly updated local data.

The present study aimed to describe the bacterial ecology and antibiotic resistance profiles of clinical isolates from a referral hospital in Senegal.

2. Methods

2.1. Study Design and Setting

We conducted a retrospective, descriptive study at Cheikh Ahmadoul Khadim hospital (CAKH), a national referral hospital, located in Touba, approximately 200 kilometers east of Dakar, Senegal. The facility has a bed capacity of 300 patients and serves outpatients, drawn primarily from the central and northern regions of Senegal, with additional referrals from other parts of the country. CAKH provides tertiary-level care, including specialized surgical, pediatric, intensive care, and medical services, and receives referrals from across the country, establishing itself as a crucial healthcare facility in central Senegal and a major referral center for the region. The study covered the period from 01/01/2024 to 31/12/2024.

2.2. Study Population

All hospitalized patients, irrespective of age or sex, with a clinical diagnosis of bacterial infection and at least one positive bacteriological culture during the study period were included. Cases with incomplete clinical or laboratory records were excluded.

2.3. Data and Sample Collection

Demographic and clinical data, including age, sex, comorbidities, and hospital ward, were extracted from medical records using a standardized case report form. Clinical specimens—including urine, pus, blood cultures, respiratory samples, cerebrospinal fluid, and other sterile body fluids—were collected according to standard hospital procedures. Samples were transported to the microbiology laboratory under appropriate conditions (cold boxes at 2˚C - 8˚C for most specimens, room temperature for blood cultures).

2.4. Isolation, Identification, and Antimicrobial Susceptibility Testing

Clinical specimens (blood, urine, cerebrospinal fluid, respiratory samples, and wound swabs) were collected as part of routine patient care and processed at the bacteriology laboratory of Cheikh Ahmadoul Khadim National Hospital.

Samples were inoculated on appropriate culture media according to specimen type and incubated under standard conditions. Bacterial identification was performed using conventional phenotypic methods, including colony morphology, Gram staining, and standard biochemical tests.

Antimicrobial susceptibility testing (AST) was carried out using the disk diffusion method, in accordance with the European Committee on Antimicrobial Susceptibility Testing (EUCAST) recommendations. Zone diameters were interpreted using the EUCAST clinical breakpoints in force at the time of analysis.

Susceptibility results were categorized into Susceptible (S), Intermediate (I), and Resistant (R). Intermediate isolates were analyzed as resistant isolates. To avoid duplication and overestimation of resistance rates, only the first isolate per patient per bacterial species was included in the analysis.

Quality control: Internal quality control procedures were routinely performed using reference strains in accordance with standard laboratory practices. However, molecular resistance testing was available during the study period.

2.5. Statistical Analysis

Data were entered and analyzed using Epi Info version 7.2.5.0. Categorical variables were summarized as frequencies and percentages, whereas quantitative variables were expressed as mean (±standard deviation) or median with interquartile range (IQR), depending on their distribution.

3. Results

3.1. Sociodemographic Data

A total of 369 patients were included in this study. The median age was 36 years (IQR: 16 - 59). Sex distribution showed a male predominance (59%). Regarding comorbidities, the most frequent were diabetes (6.8%) and hypertension (6.0%).

Hospital ward distribution highlighted a strong representation of patients admitted to general surgery (24%) and pediatrics (24%), followed by intensive care (14%) and internal medicine (13%). Other wards most frequently involved were urology (7.9%), neurosurgery (3.0%), and orthopedics (2.7%). Pediatric surgery (1.6%), gynecology (1.6%), neurology (1.1%), ENT (0.3%), and oncology-radiotherapy (0.3%) were less represented.

3.2. Clinical Data

The distribution of suspected infections showed a predominance of deep-seated infections (59%), followed by superficial infections (17%); in 24% of cases, the type of infection was not specified. The most frequently suspected clinical diagnoses were urinary tract infections (26%), skin and soft tissue infections (22%), and bronchopulmonary infections (6.8%). Postoperative wound infections accounted for 4.3% of cases, while infected burns represented 4.1%. Osteoarticular infections (4.9%) and intra-abdominal infections (2.4%) were also reported.

Central nervous system involvement was documented in 13 cases of meningoencephalitis (3.5%) and 5 cases of brain abscess (1.4%). Finally, 31 cases (8.4%) of sepsis were identified. The distribution of suspected infections is summarized in **Table 1**.

Table 1. Suspected infections (n = 369).

Suspected Infections	n (%)
Urinary tract infection	96 (26%)
Skin and soft tissue infections	83 (22%)
Bronchopulmonary infections	25 (6.8%)
Other infections (unspecified)	38 (10%)
Sepsis	31 (8.4%)
Osteoarticular infections	18 (4.9%)
Postoperative wound infections	16 (4.3%)
Infected burns	15 (4.1%)
Meningoencephalitis	13 (3.5%)
Intra-abdominal infections	9 (2.4%)
Gastroenteritis	8 (2.2%)
Brain abscess	5 (1.4%)
Ascitic fluid infection	4 (1.1%)
Genital infection	4 (1.1%)
Wound infections (other)	2 (0.5%)
Osteosynthesis material infection	1 (0.3%)
Chorioamnionitis	1 (0.3%)

3.3. Types of Specimens

The types of specimens collected were dominated by pus samples (46% of all fluids collected) followed by urine samples for cytobacteriological examination (26%), and blood cultures (11%). Respiratory specimens (bronchopulmonary aspiration, sputum, expectoration, bronchial secretions) accounted for a smaller proportion (4.9%), while sterile body fluids such as cerebrospinal fluid (3.5%), pleural fluid (1.4%), and peritoneal fluid (1.4%) were less frequently obtained. The distribution of collected specimen types is summarized in Table 2.

Table 2. Pathological specimens collected (n = 369).

Specimen type	n (%)
Pus	169 (46%)
Urine	94 (25%)
Blood	40 (11%)
Bronchopulmonary secretions	18 (4.9%)
Cerebrospinal fluid (CSF)	13 (3.5%)
Ascitic fluid	6 (1.6%)
Other fluids	6 (1.6%)
Pleural fluid	5 (1.4%)
Peritoneal fluid	5 (1.4%)
Articular/osteoarticular fluid	5 (1.4%)
Stool	4 (1.1%)
Catheter tip	2 (0.5%)
Necrotic or infected tissue	1 (0.3%)
Skin fluid	1 (0.3%)

3.4. Bacteriological Findings

Culture was positive in 251 patients (68%) out of the 369 specimens analyzed. The median time to reporting of results was 3 days [IQR: 2 - 4]. Most positive cultures were monomicrobial (87.2%, n = 219). Analysis of the 251 positive cultures revealed a predominance of Gram-negative bacilli (GNB), accounting for 69.5% of isolates. Among them, Enterobacterales were the most frequent (58.3%), led by *Escherichia coli* (24.2%) and *Klebsiella* spp. (22.1%). Non-fermenting GNB represented 11.3% of isolates, mainly *Pseudomonas* spp. (9.6%) and *Acinetobacter* spp. (1.7%). After exclusion of duplicate isolates per patient and species, a total of 240 bacterial isolates were included in the antimicrobial resistance analysis.

Gram-positive cocci accounted for 30% of the isolates, with a clear predominance of staphylococci (28.3%). *Staphylococcus aureus* (20.4%) was the most frequently isolated Gram-positive coccus. The distribution of bacterial isolates is presented in Table 3.

Table 3. Bacterial isolates identified.

Bacterial group		Species	n (%)
Gram-negative bacilli (n = 167; 69.58%)	Enterobacterales (n = 140; 58.33%)	*Escherichia coli*	58 (24.16)
		Klebsiella sp	53 (22.08)
		Citrobacter sp	15 (6.25)
		Proteus spp	9 (3.75)
		Enterobacter sp	5 (2.08)
	Non-fermenting GNB (n = 27; 11.25%)	*Pseudomonas sp*	23 (9.58)
		Acinetobacter sp	4 (1.66)
Gram-positive cocci (n = 72; 30%)	Staphylococcus (n = 68; 28.3%)	*Staphylococcus aureus*	49 (20.41)
		Coagulase-negative staphylococci (CoNS)	19 (7.91)
	Streptococcus (n = 4; 1.66%)	*Streptococcus pneumoniae*	4 (1.66)
Gram-negative coccobacilli (n = 1; 0.4%)	Gram-negative coccobacilli (n = 1; 0.4%)	*Pasteurella pneumotropica*	1 (0.4)

3.5. Antimicrobial Resistance Profiles

The study revealed high rates of resistance to first-line antibiotics, particularly penicillins. More than 40% of *E. coli* isolates (48.3%) were resistant to amoxicillin. Resistance to ticarcillin and piperacillin reached comparable levels (≈50%), with even higher values observed for *Enterobacter* spp. (80% - 100%) and *Proteus* spp. (55% - 78%).

Resistance to third-generation cephalosporins remained a major concern: 20% - 24% for *E. coli*, 30% - 36% for *Klebsiella*, and up to 60% - 80% for *Enterobacter*. Carbapenems overall retained good activity, with low resistance rates in *E. coli* (<2%) and *Klebsiella* (<12%).

Fluoroquinolones showed intermediate to high resistance levels, particularly in *E. coli* (18% - 38%), *Klebsiella* (17% - 25%), and *Proteus* spp. (44% - 56%). Regarding aminoglycosides, amikacin remained generally active (<8% resistance), in contrast with gentamicin and tobramycin, which showed higher resistance levels (20% - 40%).

Finally, resistance rates were high for trimethoprim-sulfamethoxazole (≥50% for *E. coli* and 37% for *Klebsiella*). In contrast, fosfomycin (6% - 28%) and nitrofurantoin (3% - 13%) maintained promising activity (**Figure 1**).

For *Acinetobacter* spp., resistance was particularly noted against penicillins: 50% to piperacillin and 25% to ticarcillin. Resistance to imipenem (25%) and aztreonam (25%) was also observed.

For *Pseudomonas* spp., resistance rates appeared overall more moderate. The highest rates were observed for piperacillin (21.7%) and ticarcillin (17.4%). Resistance to antipseudomonal cephalosporins (ceftazidime, cefepime) and to piperacillin-tazobactam remained below 10%. Resistance to fluoroquinolones was also concerning, with rates of ciprofloxacin 8.7%, ofloxacin 13%, and levofloxacin 13%.

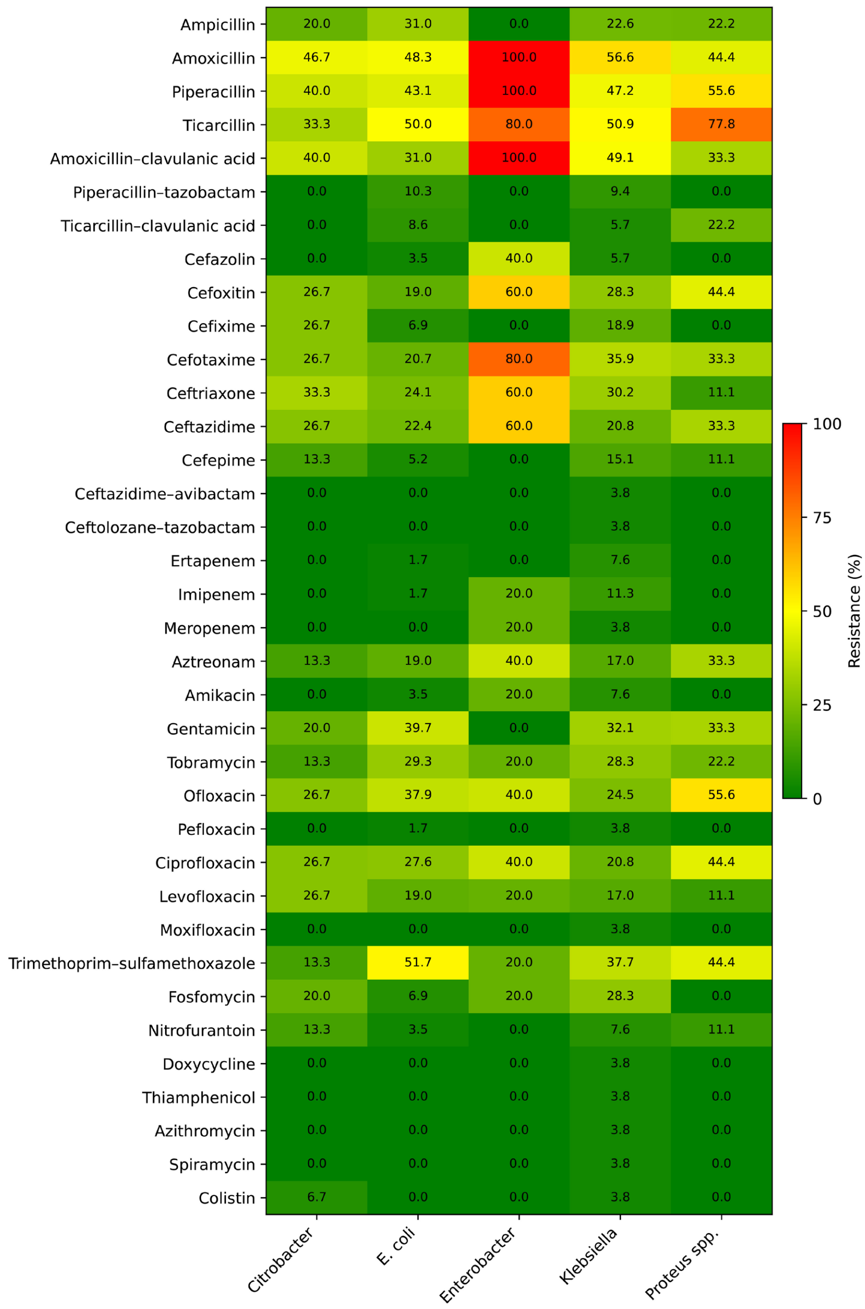

Figure 1. Resistance patterns of Enterobacterales.

Aminoglycosides (tobramycin, gentamicin, amikacin) retained good activity, with resistance rates ≤ 8.7% in *Pseudomonas* and absent in *Acinetobacter* (**Figure 2**).

For *Streptococcus pneumoniae*, although the sample size was limited, no resistance was observed to reference β-lactams (amoxicillin, third-generation cephalosporins). However, high resistance rates were recorded to gentamicin (75%) and to doxycycline/erythromycin (25%).

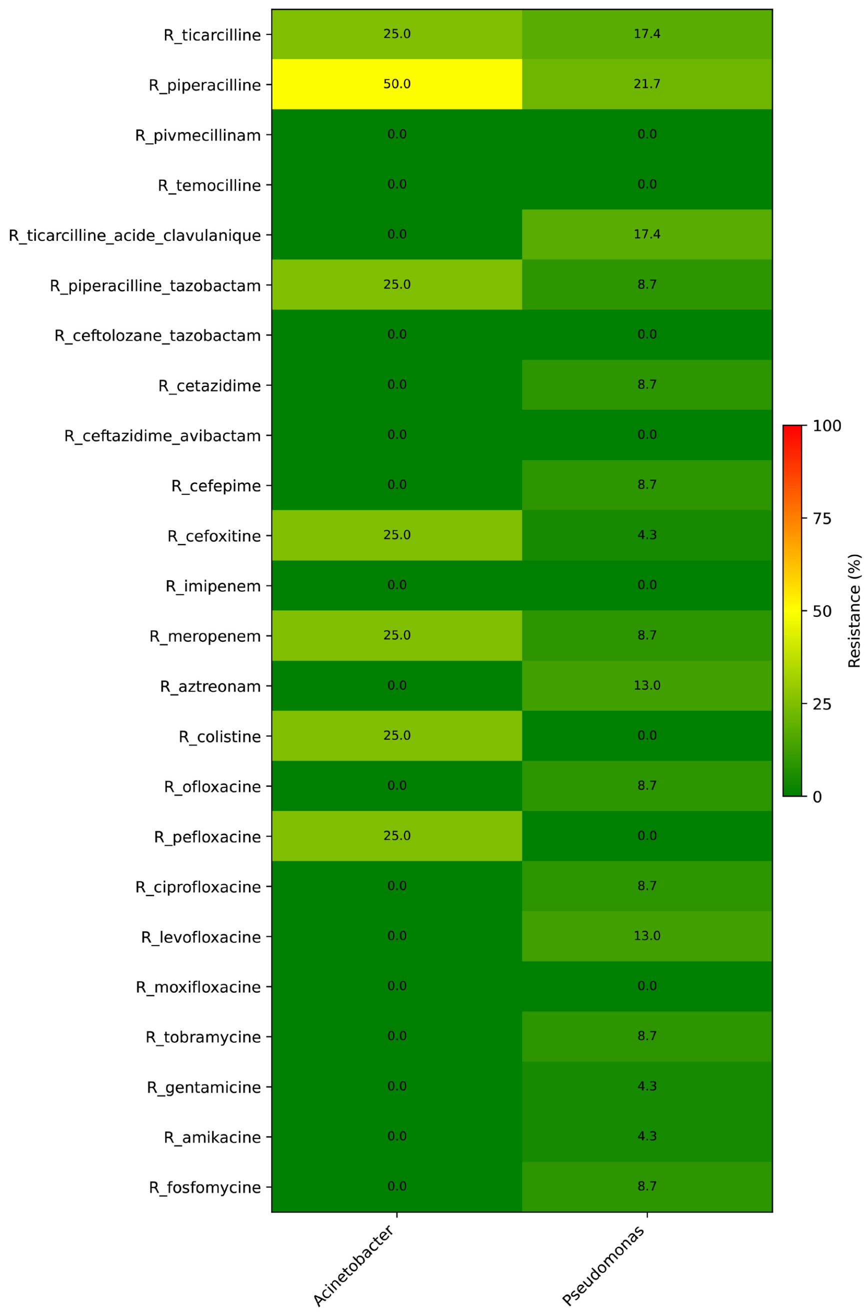

Figure 2. Resistance patterns of non-fermenting Gram-negative bacilli.

For *Staphylococcus aureus*, resistance rates remained relatively moderate: oxacillin (14.3%), ampicillin (22.5%). Resistance to macrolides (erythromycin 4%, clindamycin 4%) and to fluoroquinolones (≈2%) was present but at low levels, suggesting maintained clinical efficacy. Resistance to glycopeptides (vancomycin, teicoplanin ≈ 2%) remained marginal, which is reassuring given their status as last-resort agents.

In contrast, coagulase-negative staphylococci (CoNS) displayed more concerning resistance patterns, with elevated rates: Gentamicin (21%), Clindamycin

(21%), Oxacillin (15.8%), Fluoroquinolones (ofloxacin 15.8%, levofloxacin 15.8%) (see Figure 3).

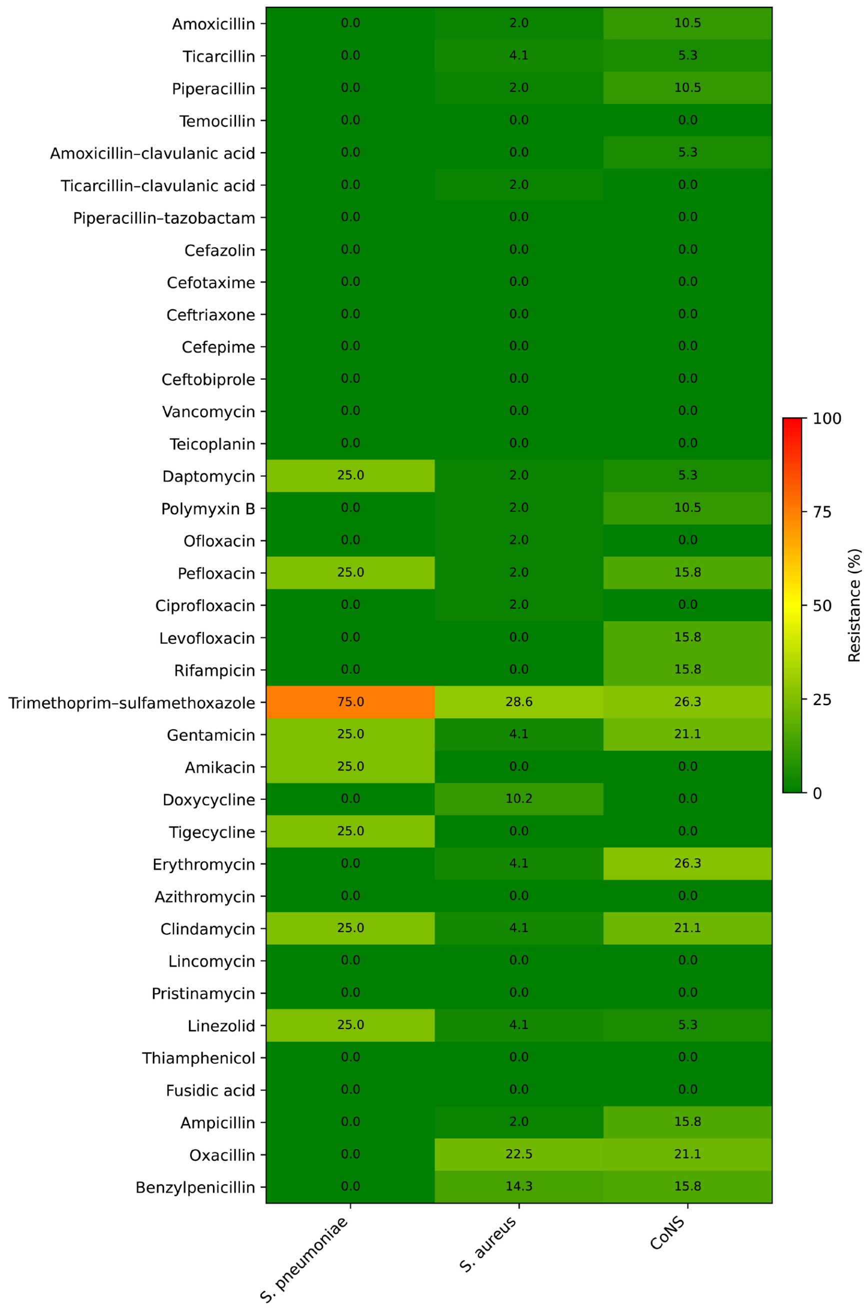

Figure 3. Resistance patterns of Gram-positive cocci.

4. Discussion

4.1. Epidemiological and Clinical Aspects

These results suggest that the hospitalized population studied was relatively young, with a median age of 36 years (IQR: 16 - 59). This profile contrasts with European series, where patients hospitalized for bacterial infections generally have a mean age above 60 years, reflecting the high burden of chronic comorbidities [8]. In sub-Saharan Africa, several studies similarly report a younger patient population, consistent with the demographic structure of the region and the continued weight of infectious diseases in hospital admissions [4] [9]. The male predominance observed in our cohort is consistent with findings from several African studies, where men are often more exposed to certain risk factors (trauma, surgical interventions, self-medication with antibiotics) and more frequently utilize hospital services [5] [6].

The relatively low frequency of comorbidities can be explained by the young age of patients. However, diabetes (6.8%) and hypertension (6.0%) were the most frequent conditions, confirming the epidemiological transition occurring in sub-Saharan Africa: non-communicable diseases are increasingly coexisting with infectious diseases [10] [11]. This finding is particularly important since these comorbidities are recognized as aggravating factors for infectious outcomes and the risk of antimicrobial resistance.

Finally, the high proportion of cases from general surgery (24%) and pediatrics (24%) likely reflects the substantial burden of surgical activity and pediatric admissions in our hospital, as reported in other Senegalese studies [7] [12]. The notable contributions of intensive care (14%) and internal medicine (13%) also highlight the severity of cases managed, which is consistent with international literature identifying these wards as major hotspots for infections due to multidrug-resistant bacteria [3].

In our study urinary tract infections (26%) and skin and soft tissue infections (22%) were the main clinical suspicions. These findings are consistent with data reported in Senegal and West Africa, where community-acquired urinary tract infections and skin/wound infections are among the most frequent indications for antibiotic prescriptions [6] [7]. Globally, urinary tract infections also represent one of the leading causes of bacterial infections in hospitals [8], but with a higher prevalence among older patients, in contrast with our younger study population.

The proportion of suspected respiratory infections (6.8%), although moderate, highlights the continued burden of these conditions in hospital morbidity. These figures are in line with the findings of Sow *et al.* (2018) in Senegalese pediatric hospitals, which reported a high frequency of bronchopulmonary infections, often associated with multidrug-resistant bacteria. In other African series (Nigeria, Ghana), respiratory infections account for between 5% and 15% of suspicions, reflecting a persistent burden despite advances in vaccination [5].

Severe forms were also noteworthy: sepsis (8.4%), meningoencephalitis (3.5%), and brain abscess (1.4%). These proportions are comparable to those observed in African intensive care cohorts, where sepsis may account for 8% - 12% of admissions [4]. At the global level, the burden of sepsis remains considerable, estimated at 48.9 million cases annually, with a predominance in low- and middle-income countries [13].

With regard to specimen types, pus (46%) and urine samples (26%) were the most common, followed by blood cultures (11%). This distribution reflects a high burden of superficial and urinary infections but also an under-representation of invasive specimens. The limited use of respiratory samples (≈10%) and sterile body fluids (CSF, pleural, peritoneal <5%) is concerning, as these infections are often severe and associated with high mortality [3]. Similar observations have been reported in other African hospitals, where logistical and technical constraints limit the performance and preservation of invasive samples [4].

Another important finding is that 57% of specimens were transported by patients' attendants, compared with 43% by healthcare staff. This non-standardized mode of transport exposes samples to risks of poor preservation and contamination, potentially compromising microbiological quality. This problem, also reported in other African contexts [5], underscores the need to strengthen hospital logistics and harmonize specimen transport procedures in order to improve the reliability of bacteriological results.

4.2. Bacteriological Aspects and Resistance Profiles

In this study, Gram-negative bacilli (GNB) accounted for nearly 70% of bacterial isolates, dominated by Enterobacterales (58.3%), mainly *Escherichia coli* (24.1%) and *Klebsiella* spp. (22.1%). This predominance is consistent with findings from other Senegalese [6] [7] and African series [5], where Enterobacterales are the main agents responsible for urinary tract infections, intra-abdominal infections, and bacteremia. At the global level, *E. coli* and *Klebsiella pneumoniae* rank among the pathogens most frequently implicated in antibiotic-resistant infections according to the GRAM report [1].

Among Gram-positive cocci, *Staphylococcus aureus* represented 20.4% of isolates, with a notable proportion of coagulase-negative staphylococci (7.9%). These results are in line with Senegalese data, which identify *S. aureus* as a major pathogen in skin infections, postoperative wound infections, and bacteremia [12]. Internationally, *S. aureus* remains a central contributor to the global burden of resistance, particularly due to MRSA [8].

Regarding resistance, our results showed high levels of non-susceptibility to first-line *β*-lactams: nearly 50% of *E. coli* and *Klebsiella* isolates were resistant to amoxicillin, and 20% - 35% to third-generation cephalosporins. These proportions are comparable to Senegalese and West African data, where ESBL-producing Enterobacterales account for 25% - 40% of isolates in hospital series [4] [6]. At the global level, resistance to third-generation cephalosporins is estimated at 36% for *K. pneumoniae* and 18% for *E. coli* in GLASS reports [2], placing our findings at the higher end of African observations.

Resistance to carbapenems remained relatively low in our series (≤10%), although some *Enterobacter* and *Klebsiella* strains were already resistant to imipenem and meropenem. This is concerning, as the spread of carbapenemases is considered a critical threat in West Africa [3] [5].

Among non-fermenting GNB, *Pseudomonas* spp. (9.6%) and *Acinetobacter* spp. (1.6%) exhibited heterogeneous resistance profiles, including non-susceptibility to antipseudomonal *β*-lactams and, for *Acinetobacter*, resistance to imipenem. Although limited by the small sample size, these findings echo international alerts regarding the growing role of these pathogens in severe nosocomial infections [3].

For Gram-positive cocci, *S. aureus* resistance to oxacillin (14%) suggests the presence of MRSA strains. This rate is slightly lower than those reported in some African series (20% - 30%) but confirms the local circulation of MRSA [5]. In addition, the high resistance to trimethoprim-sulfamethoxazole (28% in Gram-positive cocci and >50% in *E. coli*) reflects the widespread use of this agent in Africa, particularly in HIV prophylaxis, thereby promoting the selection of resistant strains [12].

Finally, resistance to fluoroquinolones was worrisome: 27.6% in *E. coli*, 20.8% in *Klebsiella*, and 44% in *Proteus*. These levels are consistent with African trends (20% - 40%) and in some cases exceed global estimates [1], illustrating the massive and often inappropriate use of this antibiotic class in the region.

4.3. Study Limitations

The findings of this study provide valuable insight into local antimicrobial resistance patterns in central Senegal and may contribute to guiding empirical antibiotic therapy in a context where surveillance data remain limited.

However, several important limitations must be considered when interpreting these results. First, the retrospective and single-center design limits generalizability. Second, missing clinical information, particularly regarding infection type in nearly one quarter of cases, reduced the ability to establish robust clinicomicrobiological correlations.

Importantly, specimen transport conditions represent a major limitation. In many cases, specimens were transported by patients without standardized timelines or temperature control, which may have compromised bacterial viability and culture quality, particularly for fastidious organisms. This limitation may have influenced both culture positivity rates and the observed bacterial ecology.

Finally, the absence of molecular characterization of resistance mechanisms and external quality assurance limits deeper interpretation of resistance patterns. Future studies incorporating standardized specimen transport, molecular diagnostics, and national reference laboratory collaboration are needed to strengthen antimicrobial resistance surveillance in Senegal.

5. Conclusions

This study highlights the predominance of Enterobacterales (*E. coli*, *Klebsiella*). However, the high levels of resistance to *β*-lactams and fluoroquinolones illustrate the considerable antibiotic pressure in our setting. The presence of carbapenem-resistant strains, although limited, represents a major warning given the critical importance of these agents. Among Gram-positive cocci, the circulation of MRSA underscores the urgent need for stricter regulation of antibiotic use and strengthened surveillance.

These findings have several implications:

- empirical prescribing must be re-evaluated in light of observed resistance profiles;
- improving specimen collection and transport procedures is essential to ensure reliable microbiological diagnosis;
- the establishment and reinforcement of surveillance programs (GLASS, national networks) and antimicrobial stewardship initiatives are crucial to curb the progression of AMR in Senegal and across the region.

Ethics Approval Statement

The study was approved by the ethics committee of the Thiès Health Directorate and Mame Abdou Sy Dabakh Hospital.

Conflicts of Interest

The authors have no competing interests to declare.

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