

Bacterial Isolates and Predictors of High-Risk Antimicrobial Resistance Among Pediatric Intensive Care Unit Patients in Ethiopia: A Hospital-Based Cross-Sectional Study

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Abstract

Background: Antimicrobial resistance (AMR) is a major threat in pediatric intensive care units (PICUs). Data on resistance patterns in non-neonatal pediatric cohorts in Ethiopia remain scarce. This study assessed Bacterial Isolates and Predictors of High-Risk Antimicrobial Resistance Among PICU at Asella Teaching and Referral Hospital.

Methods: A five-year (2020–2025) hospital-based cross-sectional study was conducted among patients aged 29 days to 14 years. Data were extracted from records using a structured checklist. Independent predictors of high-risk AMR were identified via multivariable logistic regression ($p < 0.05$).

Results:

Among 217 participants, 52.5% had positive microbial growth. Gram-negative bacteria accounted for 54.5% of isolates, slightly predominating over Gram-positive organisms. Among 66 isolates, high-risk AMR prevalence was 68.2%, including extended-spectrum beta-lactamase (ESBL) (19.7%) and extensively drug-resistant (XDR) (15.2%) strains. Multivariable analysis identified length of PICU stay (AOR 7.59, 95% CI: 1.10–52.60; $p = 0.040$) and adverse outcome at discharge (AOR 8.22, 95% CI: 1.39–48.63; $p = 0.020$) as independent predictors. Invasive device duration and Gram-negative status were significant only in bivariate models.

Conclusion: High-risk AMR (68.2%) is independently associated with prolonged hospitalization and adverse outcomes. These findings necessitate strengthened infection control, enhanced microbiological surveillance, and robust antimicrobial stewardship to mitigate multidrug-resistant pathogens in high-acuity settings.

Introduction

Background

Antimicrobial resistance (AMR) is a global public health crisis, particularly in low-resource settings where empirical antibiotic use is widespread (1). In 2021, AMR was directly responsible for an estimated 1.14 million deaths, with projections reaching 1.91 million by 2025(2). Pediatric intensive care units (PICUs) are high-risk environments for multidrug-resistant organisms (MDROs) due to invasive procedures, frequent broad-spectrum antibiotic use, and patient vulnerability (3).

Africa bears the highest AMR-associated mortality globally. In 2019, 1.05 million deaths were reported in the World Health Organization (WHO) African region, with MRSA and third-generation cephalosporin-resistant *Klebsiella pneumoniae* as leading contributors (4, 5). In Sub-Saharan Africa, AMR prevalence continues to rise, with MRSA and ESBL-producing Enterobacterales reaching 40%. Without intervention, AMR could cause 4.1 million annual deaths by 2050 (4, 6).

In Ethiopia, studies at University of Gondar and Nekemte hospitals reported multidrug resistance rates of 76% and 56.4%, respectively, with *E. coli*, *Klebsiella* spp., and *S. aureus* as predominant MDR pathogens (7–9). At Asella Teaching and Referral Hospital (ATRH), neonatal and surgical populations show high resistance rates to first-line antibiotics, highlighting a growing local AMR burden(10, 11).

Infectious diseases remain a leading cause of morbidity and mortality among children globally, particularly in low-resource settings (12, 13). PICU patients are especially vulnerable to MDR infections due to invasive procedures, being immunocompromised, and prolonged hospitalization (14, 15). AMR increases mortality, prolongs hospital stay, and raises healthcare costs (16–19).

In Ethiopia, retrospective data indicate alarming MDR rates, with *K. pneumoniae* and *Acinetobacter* spp. showing 80% to 84% resistance, and an overall MDR prevalence of 64.3% (20). The spread of drug-resistant bacteria challenges antibiotic treatments for widespread bacterial infections; infections from *Klebsiella pneumoniae*, *Escherichia coli*, *Staphylococcus aureus*, and *Enterobacteriaceae* resistant to last-resort carbapenem antibiotics have spread globally (21).

Limited data are available on microbial profiles, resistance patterns, and risk factors among non-neonatal PICU patients at ATRH. Local evidence is needed to guide therapy, strengthen antimicrobial stewardship, and improve infection prevention. This study aims to address these gaps.

Methods and Materials

Study Design and Setting

A hospital-based cross-sectional study was conducted from September to November 2025 at Asella Teaching and Referral Hospital (ATRH). ATRH is located in Asella town, 165 km southeast of Addis Ababa in the Arsi Zone of Oromia Regional State, Ethiopia. As a major referral center, it serves a catchment population of approximately 3.5 million with 284 inpatient beds. The hospital provides comprehensive services across departments including Pediatrics, Internal Medicine, Surgery, and Oncology, and serves as a teaching institution for medical training.

The Department of Pediatrics and Child Health contains 106 beds across emergency, outpatient, neonatal intensive care (NICU), and general wards. The Pediatric Intensive Care Unit (PICU), which shares space with the adult ICU, operates six beds for critically ill patients. It is staffed by 14 pediatricians, 23 residents, 4 general practitioners, and 15 dedicated PICU nurses.

Study Population and Eligibility

The **source population** included all pediatric patients aged 29 days to 14 years admitted to the ATRH PICU between July 1, 2020, and June 30, 2025. The **study population** consisted of those with complete medical records, including microbiological culture and antimicrobial susceptibility results. Patients were

excluded if they had incomplete records, if culture specimens were not collected, or if laboratory results were missing.

Variables of the Study

- **Dependent Variable:** Antimicrobial resistance.
- **Independent Variables:** Sociodemographic factors (age, sex, residence), clinical variables (admission diagnosis, comorbidities, prior antibiotic use, invasive procedures), microbiological data (pathogen type, specimen source), and health service variables (length of stay, empirical antibiotic use).

Operational Definitions

To ensure clarity in the analysis, the following definitions were applied:

- **Antimicrobial Resistance (AMR):** Resistance of bacterial isolates to one or more antibiotics tested using standard susceptibility testing.
- **High-risk AMR:** Resistance requiring special emphasis with limited or no treatment options, including MDR, extensively drug-resistant (XDR), pan-drug-resistant (PDR), carbapenem-resistant Enterobacterales (CRE), and ESBL-producing organisms (22, 23).
- **High AMR Prevalence:** Resistance to at least one first-line antimicrobial agent in $\geq 50\%$ of isolates, or the presence of MDR, XDR, or carbapenem-resistant organisms (CRO) regardless of prevalence (24).
- **Multidrug-resistant (MDR):** Resistance to at least one agent in three or more antimicrobial classes.
- **Hospital-acquired Infection (HAI):** Infection developing 48 hours after admission that was not present or incubating at the time of admission.
- **Invasive Procedures:** Medical procedures requiring entry into the body, such as central venous catheters, urinary catheterization, or mechanical ventilation.

Sample Size and Sampling Technique

A census of all eligible patients admitted during the five-year study period was performed. Out of 403 total PICU admissions recorded, 217 patients fulfilled the inclusion criteria and were included in the final analysis.

Data Collection and Quality Assurance

Data were extracted using a structured checklist adapted from the Global Antimicrobial Resistance and Use Surveillance System (GLASS) 2022 and African regional guidance (24). Four trained general

practitioners served as data collectors. To ensure tool clarity, a pre-test was conducted on 5% of the sample (20 children) at Adama Comprehensive Specialized Hospital. Data quality was maintained through daily supervision, the use of unique study codes for anonymity, and PI verification of all collected data.

Statistical Analysis

Data were cleaned and coded in Epi-Info version 7.2.7.0 before being exported to SPSS version 27 for analysis. Descriptive statistics summarized pathogen prevalence and susceptibility patterns. Binary logistic regression was used to assess associations between AMR and independent variables. Variables with $p < 0.25$ in bivariate analysis were entered into a multivariable model to control for confounders. Model fitness was verified using the Hosmer-Lemeshow test. Strength of association was measured via Adjusted Odds Ratios (AOR) with 95% Confidence Intervals (CI), with statistical significance set at $p \leq 0.05$.

Results

Socio-demographic and Clinical Characteristics

A total of 217 pediatric ICU patients were enrolled in the study. The median age of participants was 12 months (IQR: 6–36), with nearly half (48.8%, $n=106$) being infants under one year of age . Males comprised 52.5% ($n=114$) of the cohort, and a significant majority (84.8%, $n=184$) resided in rural areas.

Regarding clinical status, 78.8% ($n=171$) of the children had normal nutritional status, while 21.2% were affected by acute malnutrition (6.5% moderate and 14.7% severe). Immunization coverage was high, with 80.6% ($n=175$) fully vaccinated according to the national schedule. The primary indications for PICU admission were pneumonia (40.6%), meningitis (18.0%), and septic shock (10.6%).

The median length of PICU stay was 7 days (IQR: 4–11 days), ranging from 1 to 57 days. Approximately half of the patients (49.8%, $n=108$) required hospitalization for more than seven days. Complications developed in 17.5% ($n=38$) of patients during their stay, the most frequent being hospital-acquired infections (42.1% of complications) and ventilator-associated pneumonia (23.7%). The overall mortality rate during the PICU stay was 24.0% ($n=52$). The detailed socio-demographic and clinical profiles of the participants are summarized in Table 1.

Table 1: Socio-demographic and Clinical Characteristics of paediatrics ICU Patients at ARTH 2025 (N = 217)

Variable	Category	(n)	(%)
Sex	Male	114	52.5
	Female	103	47.5
Age	<1 year	106	48.8
	1–5 years	74	34.1
	5–14 years	37	17.1
Residence	Urban	33	15.2
	Rural	184	84.8
Nutritional status	Normal	171	78.8
	Moderate acute malnutrition	14	6.5
	Severe acute malnutrition	32	14.7
Immunization status	Fully vaccinated	175	80.6
	Unvaccinated	19	8.8
Primary reason for PICU admission	Pneumonia	88	40.6
	Meningitis	39	18.0
	Septic shock	23	10.6
Risk factor assessment	Recent hospitalization*	36	16.6
	Recent antibiotic use*	63	29.0
	Invasive device used in PICU	202	93.1
Length of stay in PICU	≤7 days	109	50.2
	>7 days	108	49.8
Outcome at discharge	Improved/Discharged	165	76.0
	Died	52	24.0
Complications in PICU	Yes	37	17.5

Microbiological Profiles

Positive microbial growth was observed in 52.5% (n=114) of the collected cultures. Gram-negative bacteria were the predominant isolates (54.5%), while Gram-positive bacteria accounted for 45.5%.

As detailed in **Table 2**, *Coagulase-negative staphylococci* (CoNS) were the most frequently isolated organisms (40.4%, n=46), followed by *Klebsiella* species (21.9%, n=25) and *Enterobacter* species (8.8%,

n=10) . Other pathogens identified included *Acinetobacter*, *Escherichia coli*, and *Pseudomonas* species, each representing 4.4% (n=5) of the total isolates.

Table 2: Distribution of Identified Pathogens, ARTH 2025 (N = 114)

Pathogen	(n)	(%)
<i>Coagulase-negative Staphylococci</i> (CoNS)	46	40.4
<i>Klebsiella</i> species	25	21.9
<i>Enterobacter</i>	10	8.8
<i>Escherichia coli</i>	5	4.4
<i>Acinetobacter</i>	5	4.4
<i>Pseudomonas</i>	5	4.4
<i>Serratia</i>	4	3.5
<i>Streptococcus pneumoniae</i>	3	2.6
<i>Citrobacter</i>	3	2.6
<i>Staphylococcus aureus</i>	2	1.8
<i>Shigella</i> species	2	1.8
<i>Haemophilus influenzae</i>	2	1.8
Fungal yeast	2	1.8

Antimicrobial Susceptibility and Resistance Patterns

Antibiotic susceptibility testing (AST) was performed for 66 (57.9%) of the 114 microbial isolates. An alarmingly high proportion of these isolates (92.4%) demonstrated resistance to at least one antibiotic, with only 7.6% remaining fully susceptible.

High-risk AMR phenotypes were identified in 68.2% (n=45) of the tested isolates, with the distribution comprising extended-spectrum β -lactamase (ESBL) production in 19.7% (n=13), extensively drug-resistant (XDR) strains in 15.2% (n=10), and both multidrug-resistant (MDR) and pan-drug-resistant (PDR) phenotypes occurring in 13.6% (n=9) each, while carbapenem-resistant Enterobacterales (CRE) accounted for 6.1% (n=4)

Resistance was notably high for commonly utilized β -lactam antibiotics, including ampicillin (91.3%), ceftazidime (92.3%), and ceftriaxone (81.0%). High resistance rates were also recorded for non- β -lactam agents such as gentamicin (76.9%) and cotrimoxazole (77.6%). Conversely, amikacin showed the most favorable susceptibility profile (83.0%).

Factors Associated with Bacterial Isolates

The study evaluated several clinical and demographic variables for their association with bacterial isolates using both bivariate and multivariate logistic regression (**Table 3**).

- **Length of Stay and Device Use:** In the bivariate analysis, both the duration of invasive device use (COR 1.28, 95% CI: 1.05–1.55; p=0.012) and the length of stay in the PICU (COR 1.16, 95% CI: 1.01–1.34; p=0.033) were significantly associated with the presence of isolates. However, in the multivariate model, only the length of PICU stay remained a significant independent predictor (AOR 7.59, 95% CI: 1.10–52.60; p=0.040).
- **Microbiological and Clinical Outcomes:** The Gram reaction of bacterial isolates was significant in the crude analysis (COR 10.35, 95% CI: 1.07–99.37; p=0.043) but did not reach significance in the adjusted model (p=0.086). Notably, the outcome at discharge was strongly associated with isolates in both models; patients with specific outcomes were over eight times more likely to have bacterial isolates after adjusting for other variables (AOR 8.22, 95% CI: 1.39–48.63; p=0.020).
- **Complications:** While complications developed in the PICU showed a trend toward association, they did not reach statistical significance in either the bivariate (p=0.063) or multivariate (p=0.081) analyses.

Table 3: Logistic Regression Analysis of Factors Associated with Bacterial Isolates

Variables	COR (95% CI)	AOR (95% CI)
Duration of invasive devices (days)	1.28 (1.05–1.55)*	0.53 (0.09–3.33)
Length of stay in PICU (days)	1.16 (1.01–1.34)*	7.59 (1.10–52.60)*
Complication developed in PICU	3.64 (0.93–14.23)	5.27 (0.82–34.11)
Gram reaction of isolates	10.35 (1.07–99.37)*	22.37 (0.64–781.30)
Outcome at discharge	4.80 (1.23–18.63)*	8.22 (1.39–48.63)*

Abbreviations: COR, Crude Odds Ratio; AOR, Adjusted Odds Ratio; CI, Confidence Interval; PICU, Pediatric Intensive Care Unit.

Note: Statistical significance determined via binary logistic regression. * p<0.05.

Discussion

This hospital-based cross-sectional study demonstrates a substantial burden of antimicrobial resistance (AMR) among pediatric ICU patients beyond the neonatal period. Of the 217 participants, 52.5% had positive microbial growth, with Gram-negative bacteria (54.5%) slightly predominating over Gram-positive organisms (45.5%). *Coagulase-negative staphylococci* (CoNS) were the most frequently isolated pathogens, followed by *Klebsiella* species. Among Gram-negative isolates, *Klebsiella* and *Enterobacter*

species were predominant, while *Escherichia coli*, *Acinetobacter*, and *Pseudomonas* were less common. These findings are consistent with the WHO GLASS 2025 surveillance data (24), the WHO priority bacterial pathogens report (22), and data from the Ethiopian Public Health Institute (20), as well as other studies (3, 5, 8, 9, 11, 25-33), reinforcing the predominance of Gram-negative organisms in pediatric critical care settings.

Among tested isolates, 68.2% exhibited high-risk AMR (MDR, XDR, PDR, CRE, or ESBL-producing organisms). This prevalence is comparable to other Ethiopian reports (8, 11, 20) and aligns with WHO estimates indicating high regional resistance rates in Africa (24). However, it exceeds some Sub-Saharan African findings (4) and other studies (30, 31, 34-37), while remaining lower than reports from Egypt (5, 38).

Prolonged PICU stay (>7 days) was independently associated with high-risk AMR (AOR = 7.59; 95% CI: 1.10–52.60), consistent with findings from Ayder Hospital, Ethiopia (19), Minia University Children's Hospital, Egypt (5), and other studies (4, 16, 37, 39, 40). Extended hospitalization likely reflects severe illness, repeated antibiotic exposure, and increased environmental contact, facilitating resistant pathogen acquisition.

Mortality was strongly and independently associated with high-risk AMR (AOR = 8.22; 95% CI: 1.39–48.63). This is in agreement with global data identifying AMR as a major contributor to death in low-resource settings (24, 41). Our results align with studies linking mortality to highly resistant pathogens, such as XDR *Klebsiella pneumoniae* (5, 26, 31, 34, 37, 42-44), although one specific study noted no significant difference in mortality rates (45). This discrepancy may be attributed to variations in sample sizes and the specific resistance profiles of the bacterial isolates studied.

Strengths and Limitations

Strengths Despite its limitations, this study has several notable strengths. It provides critical, site-specific data on antimicrobial resistance patterns in a Pediatric Intensive Care Unit (PICU) setting, which is essential for tailoring local empirical therapy. The use of both bivariate and multivariate logistic regression allowed for a robust attempt to control for confounding variables, ensuring that the identified associations—such as the link between length of stay and bacterial isolates—are internally valid within this cohort. Furthermore, the inclusion of specific resistance profiles (ESBL, CRE, MDR) offers a detailed microbiological map that can inform future infection control strategies.

Limitations Several limitations should be considered when interpreting these findings. First, this study was conducted at a single center using a cross-sectional design, which limits the generalizability of the results and precludes the establishment of causal relationships. Second, antimicrobial susceptibility testing was not performed for coagulase-negative Staphylococci (CoNS), as these were laboratory-classified as contaminants in this specific clinical context.

Furthermore, the relatively small sample size resulted in statistical instability for certain variables in the multivariable logistic regression model. Specifically, variables such as Gram reaction exhibited wide confidence intervals, indicating a lack of precision. While these factors did not reach statistical significance in the adjusted model, these wide intervals suggest the study may have been underpowered to detect these specific associations independently. This instability likely reflects the distribution of isolates within specific clinical sub-categories.

Conclusion and Recommendations

This study highlights a substantial burden of high-risk antimicrobial resistance (68.2%) among pediatric ICU patients. The multivariable logistic regression analysis identified **length of PICU stay** and **outcome at discharge** as the primary independent predictors of bacterial isolation. While prolonged use of invasive devices and Gram-negative status showed significant associations in bivariate models, these effects were largely secondary to the duration of hospitalization. These findings emphasize the importance of strengthening national AMR surveillance systems and expanding access to routine antimicrobial susceptibility testing (24).

Targeted interventions are urgently needed to mitigate the spread of resistant pathogens. Specifically, it is recommended that:

- **Enhanced IPC Strategies:** Infection prevention and control measures should be prioritized to reduce the transmission of high-risk profiles like ESBL and CRE.
- **Antimicrobial Stewardship:** Site-specific empirical therapy protocols should be developed, focusing on the high prevalence of multidrug-resistant organisms identified in this cohort.
- **Hospitalization Management:** Strategies aimed at reducing the length of PICU stay may serve as a critical leverage point in decreasing the incidence of healthcare-associated infections.

Abbreviations

AOR
Adjusted odds ratio
AMR
Antimicrobial Resistance
ATRH
Asella Teaching and Referral Hospital
BSI
Blood Stream Infections
CAI
Community Acquired Infection
CI
Confidence Interval

CoNS
Coagulase-negative staphylococci (CoNS)
CRE
Carbapenem-Resistant Enterobacteriaceae
ESBL
Extended-Spectrum β -lactamase
HAI
Hospital Acquired Infection
KPCs
Klebsiella Pneumoniae-associated Carbapenemases
MDR
Multidrug-Resistant
MRSA
Methicillin-Resistant Staphylococcus Aureus
OR
Odds Ratio
PICU
Pediatric Intensive Care Unit
SPSS
Statistical Package for the Social Sciences

Declarations

Ethics approval and consent to participate

Ethical clearance was obtained from the Arsi University, College of Health Sciences Ethical Review Committee (Protocol No. CoHS/R/222/2025). A formal letter of cooperation was submitted to the management of Asella Referral and Teaching Hospital to obtain permission for access to pediatric ICU medical records. As the study utilized anonymized secondary data, the requirement for obtaining individual informed consent was not mandated by the Ethical Review Committee. To ensure confidentiality, all data were anonymized and assigned unique identification codes in accordance with the principles of the World Medical Association Declaration of Helsinki.

Trial registration: Not applicable. This study was not a clinical trial.

Consent for publication

Not applicable.

Data availability statement

Findings from this study are based on hospital medical records from ARTH. The raw data set is attached to this submission; further inquiries regarding data usage may be directed to the corresponding author, subject to Arsi University guidelines.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AH conceived the study, collected the data, performed the analysis, and drafted the manuscript. TG and ST supervised the study, TG and ST validation, contributed to interpretation of results, and critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Figures

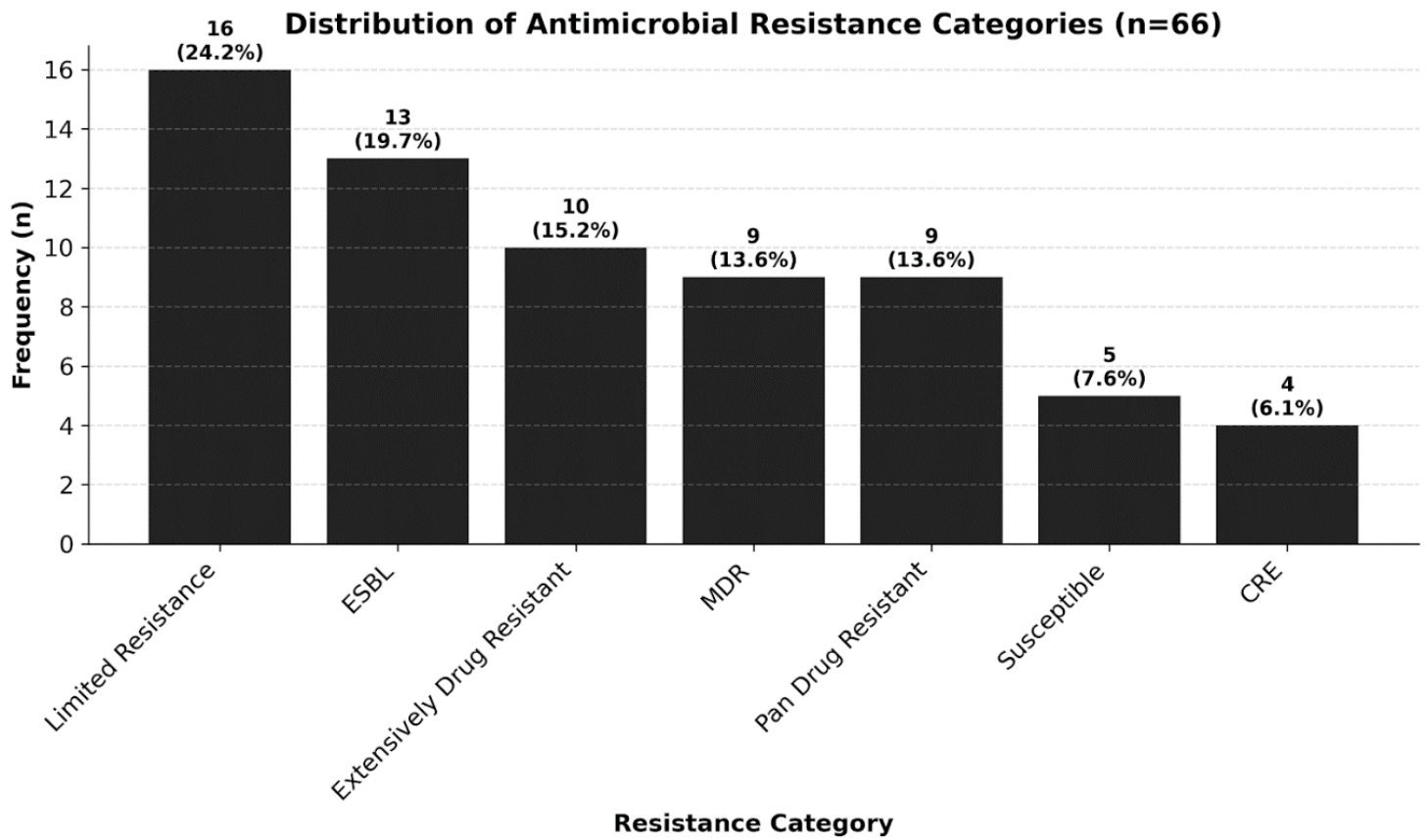


Figure 1

Distribution of antimicrobial resistance patterns among isolated pathogens of pediatric ICU Patients, ARTH (n = 217)