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Incidence of Multidrug-Resistant *Klebsiella pneumoniae* Related to Nosocomial Infection in Pediatric Wards

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ABSTRACT

Multidrug-resistant *Klebsiella pneumoniae* is an important cause of healthcare-associated infections, particularly in pediatric settings, where environmental contamination may contribute to the transmission of resistant organisms. This study aimed to investigate environmental contamination with multidrug-resistant *K. pneumoniae* in pediatric wards at Benghazi Medical Center and to determine its antimicrobial susceptibility profile. A descriptive cross-sectional study was conducted using 166 environmental swab samples collected from high-touch surfaces and medical devices in pediatric departments between January 2024 and September 2025. Samples were cultured on blood agar and MacConkey agar, and bacterial isolates were identified using Gram staining and biochemical tests. Antimicrobial susceptibility was assessed using the Kirby-Bauer disk diffusion method. Bacterial growth was detected in 108/166 samples (65.1%), while 58/166 (34.9%) showed no growth. *K. pneumoniae* was the predominant isolate, detected in 67/166 (40.4%) of all samples and 67/108 (62.0%) of culture-positive samples. The medicine department showed the highest proportion of *K. pneumoniae* contamination (65.7%), followed by neurosurgery (10.4%), pediatric surgery (9.0%), and urology and orthopedic departments (7.5% each). The highest resistance was observed to amoxicillin/clavulanic acid (88.1%), followed by cefuroxime (71.6%), trimethoprim-sulfamethoxazole (62.7%), ceftazidime (58.2%), gentamicin (56.7%), and cefotaxime (52.2%). Colistin showed the highest susceptibility (95.5%). These findings demonstrate substantial environmental contamination by MDR *K. pneumoniae* and highlight the need for strengthened environmental cleaning, surveillance, infection-control practices, and antimicrobial stewardship in pediatric wards.

1. INTRODUCTION

Hospital-acquired infections (HAIs) remain a major public health problem worldwide and are associated with increased

morbidity, mortality, prolonged hospitalization, and healthcare costs. These infections are particularly serious among high-risk populations, including neonates, children, elderly patients, and immunocompromised individuals

Pediatric patients are especially vulnerable because of their immature immune systems, frequent contact with healthcare workers, and increased use of invasive medical devices. Prolonged hospitalization and the inappropriate use of broad-spectrum antibiotics may further contribute to the emergence and spread of multidrug-resistant (MDR) microorganisms. *Klebsiella pneumoniae* is an important Gram-negative opportunistic pathogen associated with healthcare-acquired infections, including pneumonia, bloodstream infections, urinary tract infections, and wound infections. Its ability to survive in the hospital environment, colonize medical devices and surfaces, form biofilms, and acquire antimicrobial-resistance mechanisms contributes to its persistence and transmission within healthcare settings. The emergence of MDR *K. pneumoniae* has become an important clinical concern because resistance to commonly used antimicrobial agents can limit available treatment options. Environmental contamination may contribute to the transmission of *K. pneumoniae*, particularly in pediatric wards where patients may have frequent contact with healthcare personnel, equipment, and high-touch surfaces. Environmental surveillance is therefore important for identifying potential reservoirs of resistant organisms and supporting effective infection-prevention and control measures. Local information concerning environmental contamination with MDR *K. pneumoniae* in pediatric wards in Benghazi remains limited. Therefore, this study aimed to investigate multidrug-resistant *K. pneumoniae* in the pediatric ward environment at Benghazi Medical Center by isolating and identifying *K. pneumoniae*, determining its distribution among pediatric departments and environmental sampling sites, and assessing its antimicrobial susceptibility pattern.

2. METHOD

I carried out a study in the pediatric wards of Benghazi Medical Center (BMC), Benghazi, Libya. I collected a total of 166 swab samples between January 2024 and September 2025 from the medicine, pediatric surgery, neurosurgery, orthopedic, and urology departments. I obtained samples from high-touch surfaces and medical devices such as bed rails, venous lines (CVLs), endotracheal tubes (ETTs), catheters, sinks, ventilators, incubators, suction bottles and machines, monitors, door handles, floors, files, chairs, basins, trolleys, patient zones, and other contact surfaces. I used cotton swabs that were moistened with saline, handled them under aseptic conditions, labeled them properly, and transported them to the microbiology laboratory within one hour for processing. I cultured the samples on blood agar and MacConkey agar under appropriate conditions. I identified isolates by examining colony morphology, performing Gram staining, and running tests such as oxidase, urease, citrate utilization, indole, Triple Sugar Iron (TSI), catalase, and string tests. I tested the susceptibility of Klebsiella pneumoniae isolates using the Kirby–Bauer disk diffusion method on Mueller–Hinton agar for the chosen agents and interpreted the results according to CLSI guidelines. I determined colistin susceptibility separately with the microdilution (BMD) method. Interpreted it according to the recommended criteria. The antimicrobial agents I evaluated were imipenem, amikacin, ceftazidime, ciprofloxacin, gentamicin, ceftriaxone, cefotaxime, levofloxacin, meropenem, colistin, amoxicillin/clavulanic acid, piperacillin/tazobactam, cefuroxime, and trimethoprim/sulfamethoxazole. I analyzed the data using SPSS.

3. ETHICAL APPROVAL

Ethical approval for this study was obtained from the relevant authorities at Benghazi Medical Center before sample collection. The study involved environmental sampling from surfaces and medical equipment in pediatric wards and did not involve direct intervention with patients or collection of human biological samples. All samples and study data were handled confidentially and used exclusively for scientific research purposes.

4. RESULT

4.1 Distribution of samples collected

Bacterial Growth and Prevalence of *Klebsiella pneumoniae.* A total of 166 environmental swab samples were collected from different sites within the pediatric wards at Benghazi Medical Center. Of these, 108 samples (65.1%) showed positive bacterial growth, whereas 58 samples (34.9%) showed no bacterial growth. *Klebsiella pneumoniae* was the predominant bacterial isolate, detected in 67 of the 166 environmental samples (40.4%) and representing 62.0% of the culture-positive samples.

4.2 Distribution of *Klebsiella pneumoniae* among Pediatric Departments

The distribution of *K. pneumoniae* isolates varied among the pediatric departments. The Medicine Department showed the highest proportion of isolates (65.7%), followed by Neurosurgery (10.4%) and Pediatric Surgery (9.0%). The Orthopedic and Urology departments each accounted for 7.5% of the isolates, as illustrated in Table1.

Table 1. Distribution of *Klebsiella pneumoniae* isolates in pediatric ward departments.

Department	Frequency	Percentage (%)
Medicine Department	44	65.7
Neurosurgery Department	7	10.4
Pediatric Surgery Department	6	9.0
Pediatric Orthopedic Department	5	7.5
Pediatric Urology Department	5	7.5
Total	**67**	**100.0**

4.3 I carried out a study in the pediatric wards of Benghazi Medical Center (BMC), Benghazi, Libya. I collected a total of 166 swab samples between January 2024 and September 2025 from the medicine, pediatric surgery, neurosurgery, orthopedic and urology departments. I obtained samples from high-touch surfaces and medical devices such as bed rails, venous lines (CVLs), endotracheal tubes (ETTs), catheters, sinks, ventilators, incubators, suction bottles and machines, monitors, door handles, floors, files, chairs, basins, trolleys, patient zones, and other contact surfaces. I used cotton swabs that were moistened with saline, handled them under aseptic conditions, labeled them properly, and transported them to the microbiology laboratory within one hour for processing. I cultured the samples on blood agar and MacConkey agar under appropriate conditions. I identified isolates by examining colony morphology, performing Gram staining, and running tests such as oxidase, urease, citrate utilization, indole, Triple Sugar Iron (TSI), catalase, and string tests. I tested the susceptibility of Klebsiella pneumoniae isolates using the Kirby–Bauer disk diffusion method on Mueller–Hinton agar for the chosen agents and interpreted the results according to CLSI guidelines. I determined colistin susceptibility separately with the microdilution (BMD) method. Interpreted it according to the recommended criteria. The antimicrobial agents I evaluated were imipenem, amikacin, ceftazidime, ciprofloxacin, gentamicin, ceftriaxone, cefotaxime, levofloxacin, meropenem, colistin, amoxicillin/clavulanic acid, piperacillin/tazobactam, cefuroxime and trimethoprim/sulfamethoxazole. I analyzed the data using SPSS for *K. pneumoniae* isolates according to the sample sites within the Medicine Department

The distribution of *Klebsiella pneumoniae* according to sampling sources within the Medicine Department showed that central venous lines (CVL) had the highest recorded percentage (6.6%). Catheters, endotracheal tubes (ETT), and trolleys each accounted for 6.0%, followed by TIP (4.2%) and basins (3.0%). Lower percentages (1.5% each) were recorded for sinks, suction bottles, beds, suction machines, and monitors. No *K. pneumoniae* was detected from floors, patient zones, ventilators, or incubators as illustrated in Table 2.

Table 2. Distribution of *Klebsiella pneumoniae* isolates according to sample sites within the Medicine Department.

	catheter	CVL	ETT	TIP	Basin	floor	sink	Suction bottle
Medicine department	6.0%	6.6%	6.0%	4.2%	3.0%	0.0%	1.5%	**1.5%**
	bed	Trolley	Patient zone	Suction machine	monitor	ventilator	Incubator	
	1.5%	**6.0%**	**0.0%**	**1.5%**	**1.5%**	**0.0%**	**0.0%**	

4.4 Distribution of *K. pneumoniae* isolates according to the sample sites within the Neurosurgery Department

In the Neurosurgery Department, the highest percentage of *K. pneumoniae* was detected from suction machines (4.5%). CVL, ETT, basins, and beds each showed a percentage of 1.5%. No *K. pneumoniae* was detected from catheters, TIP, floors, sinks, suction bottles, trolleys, patient zones, monitors, ventilators, or incubators, as illustrated in Table 3.

Table 3. Distribution of *Klebsiella pneumoniae* isolates according to sample sites within the Neurosurgery Department.

	Catheter	CVL	ETT	TIP	Basin	Floor	Sink	Suction bottle
Neurosurgery department	0.0%	1.5%	1.5%	0.0%	1.5%	0.0%	0.0%	0.0%
	Bed	Trolley	Patient zone	Section machine	Monitor	Ventilator	Incubator	
	1.5%	**0.0%**	**0.0%**	**4.5%**	**0.0%**	**0.0%**	**.0%**	

4.5 Distribution of *K. pneumoniae* isolates according to the sample sites within the Pediatric Surgery Department
In the Pediatric Surgery Department, *K. pneumoniae* was most frequently detected from CVLs and floors, with each accounting for 3.0%. Trolleys and ventilators each accounted for 1.5%. No *K. pneumoniae* was detected from the other sampling sources investigated, as illustrated in Table 4.

Table 4. Distribution of *Klebsiella pneumoniae* isolates according to sample sites within the Pediatric Surgery Department.

	catheter	CVL	ETT	TIP	Basin	floor	sink	Suction bottle
Pediatric surgery department	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	bed	trolley	Patient zone	Suction machine	monitor	ventilator	Incubator	
	0.0%	**1.5%**	**0.0%**	**0.0%**	**0.0%**	**1.5%**	**0.0%**	

4.6 Distribution of *K. pneumoniae* isolates according the sample sites within the Pediatric Orthopedic Department
Within the Pediatric Orthopedic Department, incubators showed the highest percentage of *K. pneumoniae* (3.0%). Catheters, patient zones, and ventilators each accounted for 1.5%. No isolates were detected from the remaining investigated sampling sources, as illustrated in Table 5.

Table 5. Distribution of *Klebsiella pneumoniae* isolates according to sample sites within the Pediatric Orthopedic Department.

	catheter	CVL	ETT	TIP	Basin	floor	sink	Suction bottle
Orthopedic surgery department	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.0%**
	bed	Trolley	Patient zone	Suction machine	monitor	ventilator	Incubator	
	0.0%	**0.0%**	**1.5%**	**0.0%**	**0.0%**	**1.5%**	**3.0%**	

4.7 Distribution of *K. pneumoniae* isolates according to the sample sites within the Pediatric Urology Department
In the Pediatric Urology Department, floors showed the highest percentage of *K. pneumoniae* (3.0%). CVL, ETT, and monitors each accounted for 1.5%, whereas no *K. pneumoniae* was detected from the other sampling sources investigated, as illustrated in Table 6.

Table 6. Distribution *of Klebsiella pneumoniae* isolates according to sample sites within the Pediatric Urology Department.

	catheter	CVL	ETT	TIP	Basin	floor	sink	Suction bottle
Urology surgery department	0.0%	1.5%	1.5%	0.0%	0.0%	3.0%	0.0%	**0.0%**
	bed	trolley	Patient zone	Suction machine	monitor	ventilator	Incubator	
	0.0%	**0.0%**	**0.0%**	**0.0%**	**1.5%**	**0.0%**	**0.0%**	

4.8 Antimicrobial Susceptibility of *Klebsiella pneumoniae*

The antimicrobial susceptibility profile demonstrated multidrug resistance among the *K. pneumoniae* isolates. The highest resistance rate was observed to amoxicillin/clavulanic acid (88.1%), followed by cefuroxime (71.6%), trimethoprim/sulfamethoxazole (62.7%), ceftazidime (58.2%), gentamicin (56.7%), and cefotaxime (52.2%). In contrast, colistin demonstrated the highest susceptibility rate (95.5%), followed by amikacin (85.1%). The complete antimicrobial susceptibility profile of the isolates was presented in Figure 1.

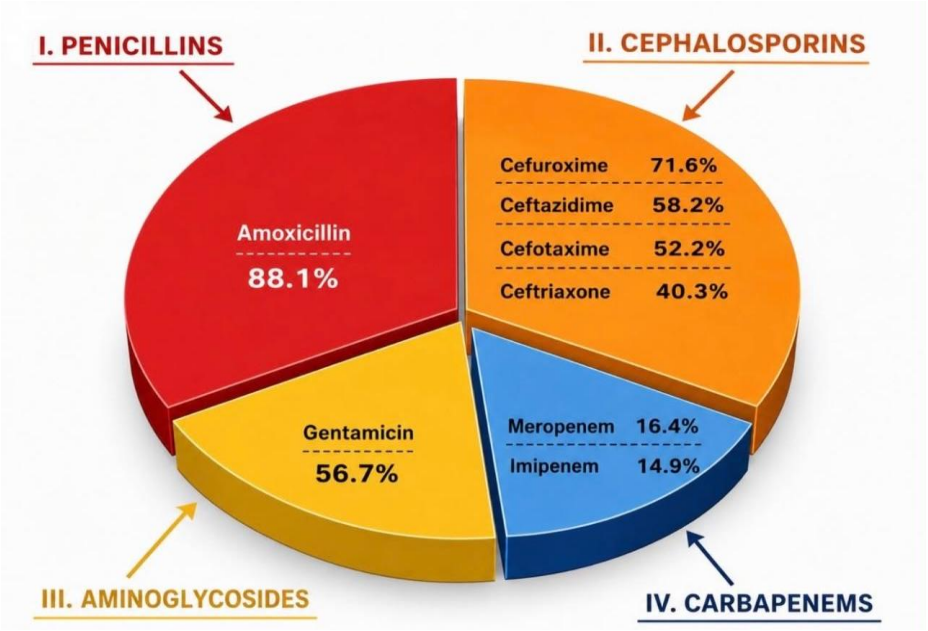

Figure (1). Antimicrobial susceptibility pattern of *Klebsiella pneumoniae* isolates.

5. DISCUSSION

The present study demonstrated a considerable level of bacterial contamination in the pediatric ward environment at Benghazi Medical Center, with bacterial growth detected in 65.1% of the collected environmental samples. *Klebsiella pneumoniae* was the predominant isolate, representing 40.4% of all collected samples and 62.0% of culture-positive samples. The predominance of *K. pneumoniae* in the pediatric environment is of particular concern because this organism is an important opportunistic pathogen associated with healthcare-associated infections and has the ability to persist on hospital surfaces and medical equipment. The highest proportion of *K. pneumoniae* contamination was observed in the Medicine Department (65.7%), whereas lower proportions were recorded in Neurosurgery, Pediatric Surgery, Orthopedic, and Urology departments. The detection of *K. pneumoniae* on high-touch surfaces and medical devices, including central venous lines, catheters, endotracheal tubes, suction equipment, and basins, indicates that the hospital environment may

represent an important reservoir for transmission and highlights the importance of effective environmental cleaning, disinfection, and adherence to infection-control practices.

The antimicrobial susceptibility findings revealed a concerning multidrug-resistant pattern among the isolated *K. pneumoniae*. The highest resistance was observed against amoxicillin/clavulanic acid (88.1%), followed by cefuroxime (71.6%), trimethoprim/sulfamethoxazole (62.7%), ceftazidime (58.2%), gentamicin (56.7%), and cefotaxime (52.2%). In contrast, considerably lower resistance was observed against carbapenems, including imipenem and meropenem, suggesting that these antimicrobial agents retained greater activity against the isolates compared with several commonly used β-lactam antibiotics. Amikacin also demonstrated relatively good activity. Importantly, colistin showed the highest susceptibility rate (95.5%), indicating strong in-vitro activity against the investigated isolates. Nevertheless, the detection of colistin-resistant isolates, although at a low rate (3.0%), remains clinically important because colistin is considered an important therapeutic option against highly resistant Gram-negative bacteria.
Overall, the high prevalence of MDR *K. pneumoniae* observed in the pediatric environment emphasizes the need for continuous antimicrobial-resistance surveillance, strict infection-prevention and control measures, appropriate environmental decontamination, and rational antimicrobial use to reduce the potential transmission of resistant organisms within pediatric wards.

6. CONCLUSION

This study demonstrated substantial environmental contamination with multidrug-resistant *Klebsiella pneumoniae* in the pediatric words of Benghazi Medical Center. *K. pneumoniae* was the predominant bacterial isolate and was detected on different environmental surfaces and medical devices, with the highest proportion recorded in the Medicine Department. The isolates exhibited high resistance to several commonly used antimicrobial agents, particularly amoxicillin/clavulanic acid, cefuroxime, trimethoprim/sulfamethoxazole, ceftazidime, gentamicin, and cefotaxime. In contrast, lower resistance rates were observed to be carbapenems and amikacin, while colistin demonstrated the highest susceptibility rate (95.5%). These findings highlight the importance of strengthening infection-prevention and control measures, particularly effective cleaning and disinfection of frequently touched surfaces and medical equipment. Continuous environmental surveillance and antimicrobial-resistance monitoring, together with appropriate antimicrobial stewardship, are recommended to reduce the spread of multidrug-resistant *K. pneumoniae* within pediatric wards. Further studies involving larger sample sizes and additional healthcare settings are recommended to provide a broader understanding of environmental contamination.

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