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Original article

Antibiotic Resistance Patterns and Multidrug-Resistant Bacteria in Pediatric Patients: A Retrospective Study

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Abstract
The increasing prevalence of antibiotic-resistant bacteria is a major public health concern worldwide. Pediatric patients are particularly vulnerable to infections caused by resistant bacteria, which can lead to increased morbidity, mortality, and healthcare costs. This study aimed to investigate the distribution of bacterial species, antibiotic resistance patterns, and multidrug-resistant (MDR) bacteria in pediatric patients admitted to the pediatric ward (PW), neonatal intensive care unit (NICU), and pediatric intensive care unit (PICU) of Tobruk Medical Center in 2024. A retrospective study was conducted on 164 pediatric patients (aged 0–18 years) who underwent blood culture tests at Tobruk Medical Center in 2024. Data were collected from the hospital's microbiology laboratory. The majority of patients were admitted to the PICU (n=75, 45.7%), followed by the PW (n=72, 43.9%). Most patients (86.6%) were under 5 years of age, with a mean age of 23.7 months. Sex distribution was relatively balanced, with a slight male predominance (n=84, 51.2%; M:F ratio 1.05:1). A total of 60 bacterial isolates were identified. Coagulase-negative Staphylococcus (CONS) and Staphylococcus aureus were the most common isolates (53.3% and 10%, respectively), followed by Klebsiella, E. coli, and Acinetobacter (each at 6.7%). Antibiotic resistance patterns revealed high resistance rates to: Beta-lactam antibiotics (16.7–20%), including ampicillin, ampicillin-sulbactam, amoxicillin-clavulanate, cefotaxime, and ceftriaxone. Fluoroquinolones (10–30%), including ciprofloxacin and levofloxacin. Carbapenems (11.7–15%), including imipenem, meropenem, and ertapenem. Penicillin and oxacillin (51.7% each). Low resistance rates were observed to Vancomycin (5%), linezolid (5%), and moxifloxacin (1.7%). Multidrug resistance (MDR) rate was alarmingly high: 68.3% (41/60) of isolates were resistant to one or more antibiotics across three or more classes. This study highlights alarming antibiotic resistance rates in pediatric patients, particularly to beta-lactams, fluoroquinolones, and carbapenems, with a high prevalence of MDR bacteria. However, vancomycin, linezolid, and moxifloxacin remain effective options due to their low resistance rates. The findings underscore the urgent need for judicious antibiotic use, enhanced infection control measures, and Continuous surveillance of resistance patterns to guide antibiotic stewardship programs and improve patient outcomes.

Keywords: Antibiotic Resistance, Pediatric Patients, Multidrug Resistance, Infection Control.

Introduction

The rise of antimicrobial-resistant bacteria (AMR) has become a pressing global health concern, with far-reaching consequences for patient outcomes and healthcare systems. It is estimated that bacterial AMR was directly responsible for 1.27 million global deaths in 2019 [1,2]. The overuse and misuse of antibiotics have accelerated the emergence of antibiotic-resistant bacteria, rendering infections increasingly difficult to treat and elevating the risk of complications and mortality [3,4]. Pediatric patients, particularly those in hospital settings, are disproportionately vulnerable to infections caused by resistant bacteria, which can lead to increased morbidity, mortality, and healthcare costs [5].

The spread of multidrug-resistant (MDR) bacteria has become a significant concern in pediatric healthcare, with MDR bacteria resistant to multiple antibiotics and posing a substantial challenge to treatment [6]. The World Health Organization (WHO) has identified antibiotic resistance as one of the most pressing threats to global health, with pediatric patients being particularly susceptible to the consequences of antibiotic resistance. High-risk areas for antibiotic-resistant infections include neonatal intensive care units (NICU) and pediatric intensive care units (PICU), where patients often undergo invasive procedures, require mechanical ventilation, and receive broad-spectrum antibiotics, increasing the risk of antibiotic resistance [7,8]. Furthermore, pediatric patients in these areas often have underlying medical conditions, such as premature birth, congenital anomalies, or chronic illnesses, which can elevate their susceptibility to infections and antibiotic-resistant bacteria [9].

Studies have shown that the prevalence of MDR bacteria in pediatric patients is increasing, with significant implications for patient outcomes and healthcare systems. The development of effective infection control strategies and antibiotic stewardship programs is critical to reducing the spread of antibiotic-resistant bacteria in pediatric patients [10]. Therefore, this study aims to investigate the distribution of bacterial species, antibiotic resistance patterns, and multidrug-resistant (MDR) bacteria in pediatric patients admitted to the PW, NICU, and PICU of a Tobruk medical center in 2024.

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Methods

Study design and setting

This retrospective study was conducted at a Tobruk medical center in 2024. The study included 164 pediatric patients admitted to PW, NICU, and PICU between January 1, 2024, and December 31, 2024.

Data collection

Data were collected from the hospital's microbiology laboratory. Demographic data: age, sex, hospital unit (PW, NICU, or PICU), and bacterial culture results were obtained too. The laboratory used standard microbiological techniques to identify bacterial species and determine antibiotic susceptibility. MDR was defined as isolates that are resistant to one or more antibiotics in three (or more) different antibiotic classes.

Inclusion and exclusion criteria

Pediatric patients admitted to the PW, NICU, or PICU between January 1, 2024, and December 31, 2024, who had bacterial culture results available, we included in this study. While we excluded patients with incomplete or missing data, Patients with bacterial culture results that were not interpretable.

Statistical analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS) software version 25. Nominal or categorical data were presented as numbers and percentages, while numeric data were presented as means. The chi-square test was utilized to study the association between age group and bacterial isolation. A p-value < 0.05 was considered statistically significant.

Results

Table 1 shows that the majority of patients (86.5%) are under the age of 5 years, and the mean age range is 23.7 months. The sex distribution is relatively balanced, with a slight majority of male patients (51.2%).

Table 1. Patients' demographics

Categories	Frequency (n)	Percentage (%)
Age Group		
0-28 days (Neonates)	41	25%
29 days- 1 year (Infants)	64	39%
>1-2 years (Toddlers)	22	13.4%
>2-<5 years (Preschoolers)	15	9.1%
5-12 years (School-age children)	21	12.8%
>12-18 years	1	0.7%
Sex		
Male	84	51.2
Female	80	48.8

About 60 out of 164 patients (36.6%) had positive bacterial culture (Table 2). Staphylococcus coagulase-negative and Staphylococcus aureus were the most common bacterial species isolated from pediatric patients, followed by Klebsiella, E. coli, and Acinetobacter.

Table 2. Bacterial isolation and species distribution

Bacterial isolation and species	Frequency (n)	Percentage (%)
Bacterial Isolation		
Positive	60	36.6
Negative (no Growth)	104	63.4
Bacterial Species		
CONS	32	53.3
Staphylococcus aureus	6	10
Klebsiella	4	6.7
E. coli	4	6.7
Acinetobacter	4	6.7
Staph Saprophticus	3	5
Pseudomonas aeruginosa	2	3.3
Enterobacter	2	3.3
Pantoea	2	3.3
Burkholderia Cepacia	1	1.7

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Table 3 shows a statistically significant association between age group and bacterial isolation. This finding suggests that younger age group children (Neonates & Infants) are more susceptible to bacterial infections.

Table 3. The distribution of positive and negative culture to age groups

Age Group	Positive bacterial isolation	Negative bacterial isolation	Total
Neonates (0-28 days)	19	22	41
Infants (29 days-1 year)	26	38	64
Toddlers (>1-2 years)	4	18	22
Preschoolers (>2-<5 years)	6	9	15
School-age children (5-12 years)	5	16	21
Adolescents>12 years	0	1	1
Total	60	104	164

The data shows that PICU (Pediatric Intensive Care Unit) had the highest number of patients, 75 patients (45.7% of total patients), where the total patients are 164 as seen in Table 4:

Table 4. Hospital Unit distribution of Total patients.

Hospital Unit	Number of patients	Percentage of Total Patients
PICU (Pediatric Intensive Care Unit)	75	45.7%
PW (Pediatric Ward)	72	43.9%
NICU (Neonatal Intensive Care Unit)	17	10.4%

PICU had the highest number of positive cultures and the highest diversity of bacterial species. Staphylococcus coagulase-negative (CONS): The most common bacterial species isolated in the PICU and PW. NICU: Had a higher proportion of Staphylococcus aureus, Klebsiella, and Enterobacter cloacae isolates as seen in Table 5

Table 5. Distribution of bacteria by hospital units.

Bacterial Species	PW (n=22)	NICU (n=9)	PICU (n=29)	Total (n=60)
CONS	16 (72.7%)	1 (11.1%)	15 (51.7%)	32 (53.3%)
Staph. aureus	1 (4.5%)	2 (22.2%)	3 (10.3%)	6 (10%)
Klebsiella	0	2 (22.2%)	2 (6.9%)	4 (6.7%)
E. coli	2 (9.1%)	0	2 (6.9%)	4 (6.7%)
Acinetobacter	1 (4.5%)	0	3 (10.3%)	4 (6.7%)
Staph Saprophyticus	2 (9.1%)	1 (11.1%)	0	3 (5%)
Pseudomonas aeruginosa	0	0	2 (6.9%)	2 (3.3%)
Enterobacter	0	2 (22.2%)	0	2 (3.3%)
Pantoea	0	1 (11.1%)	1 (3.4%)	2 (3.3%)
Burkholderia Cepacia	0	0	1 (3.4%)	1 (1.7%)

As shown in Table 6, there are high Multidrug resistance rates (MDR), where 68.3% (41/60) of isolates are resistant to ≥1 antibiotic in ≥3 different antibiotic classes. With high resistance rates to beta-lactam antibiotics, fluoroquinolones, and carbapenems. where the resistance rates to: Ampicillin, Salbactam-Ampicillin, Amoxicillin-Clavulanate, Cefotaxime, and Ceftriaxone ranged from 16.7 to 20%, the resistance rates to Ciprofloxacin (30%) and Levofloxacin (10%), the resistance rates to: Imipenem, Meropenem, and Ertapenem (11.7-15%), and rates to Penicillin and Oxacillin (51.7% each). But the data also show Low Resistance Rates to: Vancomycin (5%), Linezolid (5%), and Moxifloxacin (1.7%).

Table 6. Antibiotic resistance patterns

Antibiotic	Resistance Rate	
	Number	Percentage
Ampicillin	12	20%
Salbctam-Ampicillin	10	16.7%
Amoxicillin-Clavulanate	12	20%
Cefotaxime	11	18.3%
Ceftriaxone	10	16.7%
Ciprofloxacin	18	30%
Levofloxacin	6	10%

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Imipenem	9	15%
Meropenem	9	15%
Ertapenem	7	11.7%
Ceftazidim	10	16.7%
Cefoxitin	33	55%
Gentamycin	18	30%
Penicillin	31	51.7%
Oxacillin	31	51.7%
Erythromycin	30	50%
Trimethoprim-Sulfamethoxazole	11	18.3%
Vancomycin	3	5%
Amikacin	6	10%
Moxifloxacin	1	1.7%
Linezolid	3	5%
Tetracyclin	12	20%
Doxycycline	5	8.3%
Clindamycin	9	15%

Discussion

The increasing prevalence of antibiotic-resistant bacteria is a major public health concern worldwide. Pediatric patients are particularly vulnerable to infections caused by resistant bacteria, which can lead to increased morbidity, mortality, and healthcare costs [11]. This study aimed to investigate the distribution of bacterial species, antibiotic resistance patterns, and multidrug-resistant (MDR) bacteria in pediatric patients admitted to the pediatric ward (PW), neonatal intensive care unit (NICU), and pediatric intensive care unit (PICU) of Tobruk Medical Center in 2024. The results of this study show that the majority of patients (86.6%) are under the age of 5 years, with a mean age of 23.7 months, where 25% of patients (41 patients) accounted for Neonates, 39% of patients (64 patients) accounted for Infants, 13% of patients (22 patients) accounted for Toddlers and 9% of patients (15 patients) for Preschoolers (>2-<5 years). This is consistent with previous studies, which have reported that young children are more susceptible to bacterial infections due to their immature immune systems [12,13], highlighting the need for effective infection control practices and antibiotic stewardship programs in these populations.

The sex distribution is relatively balanced, with a slight majority of male patients (51.2%). The bacterial species distribution shows that Staphylococcus coagulase-negative (CONS) and Staphylococcus aureus are the most common bacterial species isolated from pediatric patients, accounting for 53.3% and 10% of isolates, respectively. This is consistent with previous studies, which have reported that Staphylococcus species are common causes of bacterial infections in pediatric patients [14]. The antibiotic resistance patterns show high resistance rates to beta-lactam antibiotics, fluoroquinolones, and carbapenems. This is consistent with previous studies, which have reported high rates of antibiotic resistance among bacterial isolates from pediatric patients [15-17].

The widespread resistance to Penicillin and Oxacillin is also alarming, as these antibiotics are commonly used to treat bacterial infections in pediatric patients; this result is consistent with Maria Singer et al., 2024 [17]. The high Multidrug Resistance (MDR) Rate of 68.3% observed in this study is concerning, as MDR bacteria are resistant to multiple antibiotics, making treatment challenging. This highlights the need for effective antibiotic stewardship programs and infection control practices to reduce the spread of MDR bacteria in pediatric patients.

The results show Low Resistance Rates to Vancomycin 5%, Linezolid 5%, and MXF Moxifloxacin 1.7%, which can be options for managing resistant infections. This is consistent with the findings of Maria Madalina Singer et al. [17], who found that Linezolid, Ertapenem, and Teicoplanin were emergent antibiotics for MDR bacteria. The results of this study show that the PICU had the highest number of patients (75 patients, 45.7% of total patients), followed by the PW (72 patients, 43.9% of total patients). This is consistent with previous studies, which have reported that PICU patients are at higher risk of developing antibiotic-resistant infections due to the use of invasive devices and broad-spectrum antibiotics [18]. The findings of this study emphasize the need for judicious antibiotic use, enhanced infection control practices, and continuous monitoring of bacterial resistance patterns to inform antibiotic stewardship programs and improve patient outcomes. This is consistent with previous studies, which have reported that antibiotic stewardship programs and infection control practices such as hand hygiene, proper use of personal protective equipment, and environmental cleaning can reduce the spread of antibiotic-resistant bacteria in pediatric patients [19-21].

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Conclusion

This retrospective study investigated the distribution of bacterial species, antibiotic resistance patterns and multidrug-resistant (MDR) bacteria in pediatric patients admitted to a Tobruk medical center in 2024 by use of blood culture results of the patients. The results show high resistance rates to beta-lactam antibiotics, fluoroquinolones, and carbapenems, with 68.3% of isolates exhibiting MDR. However, low resistance rates were observed for Vancomycin, Linezolid, and Moxifloxacin, making them potential options for managing resistant infections. Staphylococcus coagulase-negative and Staphylococcus aureus are the most common bacterial species isolated from pediatric patients, then Klebsiella and E. coli are the commonly gram-negative bacteria which isolated. The majority of patients (86.6%) were under the age of 5 years, highlighting the need for effective infection control practices and antibiotic stewardship programs in these populations the findings emphasize the importance of addressing antibiotic resistance in pediatric patients, particularly in the PICU, where patients are at higher risk of developing antibiotic-resistant infections. The study's results are consistent with previous studies and highlight the need for ongoing efforts to combat antibiotic resistance and improve patient outcomes.

Conflicts of Interest

There are no conflicts of interest

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الملخص

يُعدّ الانتشار المتزايد للبكتيريا المقاومة للمضادات الحيوية مصدر قلق كبير على الصحة العامة في جميع أنحاء العالم. ويُعدّ الأطفال أكثر عُرضةً للإصابة بالعدوى التي تُسببها هذه البكتيريا، مما قد يؤدي إلى زيادة معدلات الاعتلال والوفيات وتكاليف الرعاية الصحية. هدفت هذه الدراسة إلى دراسة توزيع الأنواع البكتيرية، وأنماط مقاومة المضادات الحيوية، والبكتيريا المقاومة للأدوية المتعددة (MDR) لدى الأطفال الذين تم إدخالهم إلى قسم الأطفال، ووحدة العناية المركزة لحديثي الولادة، ووحدة العناية المركزة للأطفال في مركز طبرق الطبي عام 2024. أُجريت دراسة استعادية على 164 طفلاً (تتراوح أعمارهم بين 0 و18 عامًا) خضعوا لفحوصات مزرعه الدم في مركز طبرق الطبي عام 2024. جُمعت البيانات من مختبر الأحياء الدقيقة بالمستشفى. أُدخلت غالبية المرضى إلى وحدة العناية المركزة للأطفال (ن = 75، بنسبة 45.7%)، يليهم الأطفال (ن = 72، بنسبة 43.9%). كان معظم المرضى (86.6%) دون سن الخامسة، بمتوسط عمر 23.7 شهرًا. كان توزيع الجنسين متوازنًا نسبيًا، مع غلبة طفيفة للذكور (ن = 84، 51.2%؛ نسبة الذكور إلى الإناث 1.05:1). تم تحديد 60 عزلة بكتيرية. كانت المكورات العنقودية الذهبية (CONS) والمكورات العنقودية السلبية للتخثر (النوعان الأكثر شيوعًا) (53.3% و10% على التوالي)، تليهما الكلبسيلة، والإشريكية القولونية، والأسينيتوباكتر (6.7%) لكل منهما. أظهرت أنماط مقاومة المضادات الحيوية معدلات مقاومة عالية لمضادات بيتا لاكتام (16.7-20%)، بما في ذلك الأمبيسلين، والأمبيسلين-سولباكتام، والأموكسيسيلين-كلافولانات، والسيفوتاكسيم، والسيفترياكسون. الفلوروكينولونات (10-30%)، بما في ذلك سيبروفلوكساسين وليفوفلوكساسين. الكاربابينيمات (11.7-15%)، بما في ذلك إيميبينيم وميروبينيم وإرتابينيم. البنسلين والأوكساسيلين (51.7% لكل منهما). لوحظت معدلات مقاومة منخفضة للفانكومايسين (5%)، واللينيزوليد (5%)، والموكسيفلوكساسين (1.7%). كان معدل مقاومة الأدوية المتعددة (MDR) مرتفعًا بشكل مثير للقلق: 68.3% (41/60) من العزلات كانت مقاومة لمضاد حيوي واحد أو أكثر في ثلاث فئات أو أكثر. تسلط هذه الدراسة الضوء على معدلات مقاومة المضادات الحيوية المثيرة للقلق لدى المرضى الأطفال، وخاصةً لبيتا لاكتامز والفلوروكينولونات والكاربابينيمات، مع انتشار واسع للبكتيريا المقاومة للأدوية المتعددة. ومع ذلك، لا تزال الفانكومايسين واللينيزوليد والموكسيفلوكساسين خيارات فعالة نظرًا لمعدلات مقاومتها المنخفضة. تُؤكد النتائج على الحاجة المُلحة لاستخدام المضادات الحيوية بحذر، وتعزيز إجراءات مكافحة العدوى، والمراقبة المُستمرة لأنماط المقاومة لتوجيه برامج إدارة المضادات الحيوية وتحسين نتائج المرضى. الكلمات المفتاحية: مقاومة المضادات الحيوية، مرضى الأطفال، مقاومة الأدوية المُتعددة، مكافحة العدوى.

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