

## Bacterial profile and antibiotic resistance in pediatric appendicitis: retrospective analysis and associated laboratory and clinical findings

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### Abstract

**Introduction:** Identifying the bacterial profile in acute appendicitis, which is a common paediatric surgical emergency, can guide antibiotic therapy and improve outcomes. Therefore, the objective of this study is to evaluate the bacterial profile in paediatric appendicitis and its association with clinical and laboratory findings.

**Methodology:** A retrospective study was conducted on paediatric patients ( $\leq 14$  years) who underwent appendectomy at King Fahad Hospital, Al-Baha, from 1 January 2019 to 1 October 2023. Data collected included demographics, clinical presentation, laboratory results, intraoperative findings, bacterial cultures, antibiotic regimens, and outcomes. Kruskal–Wallis and Mann–Whitney tests were performed. The normality of the data was evaluated using the Kolmogorov–Smirnov and Shapiro–Wilk tests. A  $p < 0.05$  was considered statistically significant.

**Results:** In 170 patients (mean age of 10.02 years; 62.9% male), the prevalent symptoms were right lower quadrant pain (94.7%) and nausea or vomiting (80.6%). Preoperative antibiotics were administered in 91.8% of the patients. Peritoneal fluid cultures were positive in 28.8%, and *Escherichia coli* was the dominant isolate (60.2%). Antibiotic resistance was significantly associated with elevated white blood cell count ( $p = 0.003$ ), high polymorphonuclear granulocytes ( $p = 0.032$ ), abscess formation ( $p = 0.008$ ), and perforation ( $p = 0.016$ ). The mean hospital stay was 4.5 days, and postoperative complications occurred in 1.8% of patients.

**Conclusions:** *E. coli* is the predominant pathogen in paediatric appendicitis, with significant resistance in complicated cases. Tailored antibiotic therapy is crucial to reducing complications, but more studies are needed to refine empirical antibiotic selection.

**Key words:** pediatric patient; appendicitis; *Escherichia coli*; antibiotic resistance; bacterial profiling.

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### Introduction

Acute appendicitis is a prevalent condition that often necessitates emergency intervention, affecting pediatric and adult populations [1]. It is characterized by appendix inflammation, which can lead to serious complications if left untreated [2]. Epidemiological studies indicate that the risk of developing appendicitis during childhood is approximately 4%, and the lifetime risk in the Western world can be as high as 6%–8% [3]. The incidence of acute appendicitis varies geographically, and reported rates range from 100 cases to 151 cases per 100,000 people per year [4]. This variation underscores the significance of the condition and highlights the need for effective management strategies to mitigate complications [5].

Prompt intervention is crucial in cases of acute appendicitis because approximately one-third of patients may experience perforation of the appendix before undergoing appendectomy. This complication can increase morbidity and economic burden and

prolong hospital stay [3,6]. However, to optimize surgical outcomes and minimize the risk of postoperative complications, preoperative and postoperative antibiotic therapy is commonly employed [7,8].

Selecting the appropriate antibiotics for pediatric patients with appendicitis presents a challenge primarily because of the limited literature about bacterial profiles specific to this population. Understanding the predominant bacteria responsible for appendiceal infections is essential for tailoring effective antibiotic therapy [9,10].

The focus of our study is to shed light on the bacterial profile associated with acute appendicitis in pediatric patients at King Fahad Hospital, Al-Baha, Saudi Arabia. We aim to identify the predominant bacteria involved in this condition. The findings from this research will offer insights into the microbial landscape and facilitate the selection of appropriate preoperative and postoperative antibiotics. Ultimately,

this study seeks to reduce the risk of postoperative complications and optimize patient outcomes in pediatric appendicitis cases.

**Methodology**

*Study Design*

A retrospective study was conducted at King Fahad Hospital in the Al-Baha Region from 1 January 2019 to 1 October 2023. The inclusion criteria consisted of all patients aged 14 years or younger who underwent appendectomy through laparoscopy or open surgery. Patients were excluded if they were older than 14 years, underwent surgery at a facility other than King Fahd Hospital, or had incomplete data.

*Data Collection*

Medical records were reviewed retrospectively. The data collected included demographic information (e.g., age and gender), preoperative clinical presentation, laboratory investigations, imaging studies, and antibiotic administration. Operative details, such as surgical approach, intraoperative findings, fluid analysis and culture (if obtained), and intraoperative complications, were documented. The postoperative course was recorded, comprising management strategies, fluid analysis results, length of hospital stay, discharge medications, and the final follow-up.

*Study Objectives*

The primary aim of the study was to evaluate the bacterial profile of peritoneal fluid after appendectomy. Additionally, we analyzed the relationship of the culture results with demographic data, preoperative investigations, and intraoperative findings.

*Data Analysis*

Data were summarized using descriptive statistics, including counts and percentages for categorical variables. For continuous variables, median, mean, and standard deviation (SD) values were reported. For categorical variables, the chi-square test or Fisher’s exact test was used. Continuous variables were analyzed using the independent t-test or Mann–Whitney U test. A  $p < 0.05$  was considered statistically significant.

Abscess, peritonitis, and perforation were analyzed using chi-square tests when expected cell frequencies were  $\geq 5$  and Fisher’s exact tests for smaller samples or expected frequencies were  $< 5$ , which were observed in some outcomes, such as abscess (7 cases) or perforation (9 cases). The normality of continuous variables (e.g., age, WBC count, and symptom duration) was assessed

using the Shapiro–Wilk test. Parametric tests (e.g., t-tests) were used for normally distributed variables, while non-parametric tests (e.g., Mann–Whitney U) were applied for non-normal data, such as symptom duration. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS), version 28, ensuring rigorous statistical interpretation.

*Ethical Considerations*

This study was conducted in accordance with the principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the Scientific Research Committee at King Fahd Hospital, Al-Baha, under approval number KFH/IRB23052023/7, dated 23 May 2023. All the data will be kept confidential. Given that this study is retrospective, the requirement for informed consent was waived by the scientific research committee.

**Results**

A total of 207 pediatric patients with appendicitis were initially evaluated, but 37 were excluded because of incomplete medical records. The analysis focused on 170 patients, of whom 107 (62.9%) were males, and 63 (37.1%) were females. The mean age was 10.02 years ( $\pm 2.74$ ). Co-morbidities were present in 12 patients (7.1%), and epilepsy was prevalent, alongside other conditions, such as asthma, cardiac issues, and cerebral palsy (Table 1).

Key clinical symptoms included right lower quadrant (RLQ) pain in 161 (94.7%), nausea or vomiting in 137 patients (80.6%), and fever was noted in 43 patients (25.3%). Laboratory investigations showed that 60.6% of the participants had leukocytosis with a mean WBC count of 13.10 (SD 505). However, only 35.3% of the participants had high PMN granulocyte counts. Imaging studies were conducted:

**Table 1.** Demographic and medical data of Study Patients.

Items	n	%
<b>Gender</b>		
Male	107	62.9%
Female	63	37.1%
<b>Age</b>		
Mean		10.02
Median		11.00
<b>Co morbidity</b>		
Yes	12	7.1%
No	158	92.9%
<b>If yes, please specify</b>		
Asthma	1	8.3%
Cardiac	3	25%
Cerebral Palsy	1	8.3%
Hypothyroidism	1	8.3%
epilepsy	2	16.7%
T1DM	1	8.3%
Others	3	25%

**Table 2.** Pre-operative data of Study Patients.

Items		<i>n</i>	%
<b>Clinical Picture</b>			
Nausea / Vomiting	Yes	137	80.6%
RLQ pain	Yes	161	94.7%
RLQ rebound pain	Yes	131	77.1%
Temperature	Fever	43	25.3%
<b>Laboratory Investigations</b>			
High WBC	No	67	39.4%
	Yes	103	60.6%
High PMN granulocytes	No	110	64.7%
	Yes	60	35.3%
<b>Imaging</b>			
US	Yes	93	54.7%
CT	Yes	19	11.2%
<b>Duration between beginning of symptoms and diagnosis (days)</b>		Mean	2.04
		Median	1.00
		Std. Deviation	3.854
<b>Antibiotics were given</b>		Yes	156
		No	14

ultrasound for 93 patients (54.7%) and CT scans for 19 (11.2%). The mean duration between the onset of symptoms and diagnosis was 2.04 days (median 1.00; SD 3.854). Preoperative antibiotics were administered to 156 patients (91.8%), and the common regimens were Augmentin (32 patients, 20.7%), Augmentin combined with Metronidazole (92 patients, 59.5%), and Ceftriaxone and Metronidazole (6 patients, 3.8%). The details of preoperative data are outlined in Table 2.

In 170 participants with elevated WBC counts, a significant association was observed with abscess formation ( $p = 0.014$ ; 6 patients vs. 1 patient), but no significant links were found for peritonitis ( $p = 0.165$ ) or perforation ( $p = 0.278$ ). Conversely, an elevated PMN granulocyte count was significantly associated only with perforation ( $p = 0.043$ ; 6 patients vs. 3 patients), and no significant differences in peritonitis ( $p = 0.217$ ) or abscess formation were found ( $p = 0.807$ ; Table 3). Most patients underwent an open appendectomy (155 patients, 91.2%), and 15 patients (8.8%) had a laparoscopic procedure. The mean duration between diagnosis and operation was 14.02

hours (SD 12.38). Intraoperative findings revealed that simple appendicitis was present in 149 patients (87.6%). Other findings included peritonitis in 7 patients (4.1%), abscess in 24 (14.1%), appendicular mass in 4 (2.4%), and perforation in 9 (5.3%). Additionally, peritoneal fluid sampling was performed in 49 patients (28.8%).

Various postoperative antibiotic regimens were used. The Augmentin–Metronidazole combination was the most common, which was administered to 102 patients (60%), followed by the Augmentin–Metronidazole–Gentamicin combination, which was administered to 18 patients (10.59%). Augmentin was administered to 17 patients (10%). The mean duration of antibiotic treatment was 4.58 days, with a median of 5.00 days (SD 1.284). Complications were reported in three patients (1.8%), and specific issues included adhesive intestinal obstruction, allergy treated with cetirizine, and surgical wound infection. Intraoperative peritoneal fluid sampling for culture and sensitivity assessment was not performed routinely, but it was performed on 49 patients (28.8%) when deemed

**Table 3.** Association between intraoperative events, WBC and PMN.

High WBC		No = 67		Yes = 103		<i>p</i>
Items		<i>n</i>	%	<i>n</i>	%	
Peritonitis	Yes	1	1.5%	6	5.8%	0.165
	No	66	98.5%	97	94.2%	
Abscess	Yes	4	6.0%	20	19.4%	0.014
	No	63	94.0%	83	80.6%	
Perforation	Yes	2	3.0%	7	6.8%	0.278
	No	65	97.0%	96	93.2%	
High PMN granulocytes		No = 110		Yes = 60		<i>p</i>
Items		<i>n</i>	%	<i>n</i>	%	
Peritonitis	Yes	3	2.7%	4	6.7%	0.217
	No	107	97.3%	56	93.3%	
Abscess	Yes	15	13.6%	9	15.0%	0.807
	No	95	86.4%	51	85.0%	
Perforation	Yes	3	2.7%	6	10.0%	0.043
	No	107	97.3%	54	90.0%	

necessary. A total of 30 patients (61.2%) had positive cultures, and *E. coli* was the most frequently detected organism, either alone or in combination with other bacteria (24 cases, 80%). Antibiotic resistance was observed in 17 patients. A significant correlation was found between antibiotic resistance and elevated WBC count ( $p = 0.003$ ), and 16 resistant cases exhibited higher WBC counts than a single case with normal counts. A significant association was also found between antibiotic resistance and elevated PMN granulocyte counts ( $p = 0.032$ ), with 10 resistant cases showing high PMN granulocyte counts and 7 with normal counts. Additionally, resistance was significantly linked to the presence of abscesses ( $p = 0.008$ ): 11 patients with resistance had abscesses, and 6 without. Perforation similarly demonstrated a significant association with antibiotic resistance ( $p = 0.016$ ): 14 resistant cases in patients with perforation and 3 without. The average hospital stay was approximately 4.5 days. After discharge, 150 patients (88.2%) were prescribed take-home antibiotics, particularly a combination of Augmentin and Metronidazole (118 patients, 42.9%; Table 4).

The re-admission data revealed that six patients (3.5%) were re-admitted for various causes necessitating further medical attention, but only one of them was readmitted because of a post-operative abscess. The last follow-up data indicated that 109 patients (64.1%) attended their follow-up appointments. The mean duration until the last follow-up was 1.11 weeks, with a median of 1 week (SD = 0.39). Complications during the last follow-up were rare, occurring in only 1 patient (0.6%), who

experienced deterioration of diabetes. Histopathological examinations were conducted for all 170 patients (100%), with all results being negative for malignancy.

### Discussion

Antibiotic-resistant bacteria have become an important concern in modern healthcare settings because of the high incidence of infections associated with surgical conditions [11]. Appendicitis is one of the most common causes of infection and a leading indication for surgical intervention in pediatric and adult populations [12]. Hence, understanding the local bacterial ecology is crucial for selecting effective preoperative and postoperative antibiotic regimens. In our study, bacterial cultures were positive in 61.22% of cases ( $n = 30$ ), consistent with findings from the literature. The multisite study of Bhaskar in London hospitals reported a similar positivity rate of 61.3% in cultured fluid [13]. Kitahara *et al.* observed a higher rate in Japan (90%) [14], and Naji *et al.* reported a lower rate for swab cultures (48%) [15]. These results consistently show high culture positivity rates, which highlight the importance of intraoperative fluid sampling as a crucial step in postoperative antibiotic therapy. By identifying causative pathogens, this approach supports targeted antimicrobial treatment, reduces unnecessary use of broad-spectrum antibiotics, and helps to mitigate the risk of antibiotic resistance. In our study, postoperative antibiotic regimens were modified in 12 cases (7.1%) based on culture results, particularly for cases with *Pseudomonas* species, and most preoperative antibiotics (e.g., Augmentin and Aetronidazole) do not

**Table 4.** Post-operative data of Study Patients.

Items	n	%	
Specify (Type of antibiotics):	Augmentin, Metronidazole	102	60.0%
	Augmentin, Metronidazole, Gentamicin	18	10.59%
	Augmentin	17	10.0%
	Augmentin, Metronidazole, Amikacin	9	5.29%
	Ceftriaxone, Metronidazole, Gentamycin	6	3.52%
	Ceftriaxone, Metronidazole	5	2.94%
	Others	13	7.64%
Duration of antibiotic (day)	Mean	4.58	
	Median	5.00	
	Std. Deviation	1.284	
Culture Results	Positive	30	61.22%
	Negative	18	36.73%
Culture Growth	<i>E. Coli</i>	24	80%
	<i>Pseudomonas Aeruginosa</i>	3	10%
	<i>Klebsiella Pneumoniae</i>	1	3.3%
	other	5	16.6%
	Resistance	6	20%
Length of stay (day)	4.50	4.50	4.50
	4.00	4.00	4.00
	3.065	3.065	3.065
Take home antibiotic	Yes	150	88.2%
	No	20	11.8%

adequately cover this bacterium. Adjustments included switching to antibiotics, such as piperacillin–tazobactam, to target *Pseudomonas* and resistant *Escherichia coli*.

The prevalent organism identified in our study was *E. coli*, which accounted for 80% of positive cultures ( $n = 24$ ). This finding aligns with the literature. For instance, Naji *et al.* reported *E. coli* as the predominant bacterium, which was detected in 85% of cases [15]. Similarly, Cimpean *et al.* and Coccolini *et al.* identified *E. coli* as the most prevalent pathogen, as did Chen *et al.* [16–18]. Regarding the second most commonly identified pathogen, *Pseudomonas* species accounted for 10% of positive cultures. This result is in line with the findings of Aiyoshi *et al.*, who reported *Pseudomonas aeruginosa* in 18% of positive cultures [2]. Furthermore, Kakar *et al.* and Bhaskar *et al.* highlighted *P. aeruginosa* as the second most commonly isolated pathogen in cases of acute complicated appendicitis [10,13], further supporting the consistency of our results with the literature.

In our study, antimicrobial resistance was predominantly observed in *E. coli*, accounting for 24.4% of all culture-positive cases. No resistance was identified among *P. aeruginosa* isolates. These findings are in line with those of Garzon-González *et al.*, who reported that 26.99% of *E. coli* isolates exhibited resistance [19]. Similarly, no antibiotic resistance was detected in *P. aeruginosa* in their study. Regarding extended-spectrum beta-lactamase (ESBL) production, only 10% ( $n = 3$ ) of the resistant *E. coli* isolates in our study were identified as ESBL producers. By contrast, Garzón-González *et al.* reported an ESBL prevalence of 5.31% in *E. coli* isolates [19]. The prevalence of ESBL-producing *E. coli* in acute appendicitis cases ranges from 3.5% to 16.6%, including data from the SMART study and a study conducted by Tse *et al.* [20,21]. These figures place our findings well within the reported range, supporting their consistency with the literature.

Our findings revealed a significant association between elevated WBC count and the intraoperative discovery of an appendicular abscess ( $p = 0.014$ ). Similarly, an increased level of neutrophils was significantly linked to the intraoperative identification of perforated appendicitis ( $p = 0.043$ ). These results are consistent with those of Şahbaz *et al.* [22], who demonstrated that the neutrophil ratio provides high sensitivity and specificity in diagnosing appendicitis. Additionally, elevated leukocyte count and male gender were identified as significant risk factors for complicated appendicitis. Spampinato *et al.* found that CRP ( $p < 0.001$ ) and neutrophil percentage ( $p = 0.02$ )

were associated with complicated appendicitis [23]. These findings highlight the clinical importance of inflammatory markers, such as WBC count and neutrophil levels, in predicting complications, such as appendicular abscess and perforated appendicitis. Incorporating these markers into clinical practice can improve the early diagnosis and management of acute appendicitis.

The most commonly used antibiotic regimen in our patient population was the combination of Augmentin (amoxicillin-clavulanate) and Metronidazole, which was used in 60% of the cases, followed by a triple therapy regimen consisting of Augmentin, Metronidazole, and Gentamicin, which was administered to 10.5% of cases. Notably, Elrod *et al.* in Hamburg recommended the use of an aminopenicillin combined with a beta-lactamase inhibitor for all cases of uncomplicated appendicitis [24]. Furthermore, a study conducted in Hong Kong showed that piperacillin–tazobactam provided optimal antimicrobial coverage (69.8%) against ESBL-producing *E. coli* and *P. aeruginosa* in patients with complicated appendicitis [25]. A U.S.-based study compared operative and non-operative management strategies for appendicitis. Patients received at least 24 hours of intravenous antibiotics, either piperacillin–tazobactam or a combination of ciprofloxacin and Metronidazole in cases of penicillin allergy. The study found a 67.1% success rate for non-operative management [26].

Postoperative complications were reported in four cases (2.3%) in our study, including adhesive intestinal obstruction, intra-abdominal abscess, and surgical wound infection. By contrast, a study conducted in the UK reported a postoperative complication rate of 7% in children, and most were infective in nature and managed with antibiotics [27]. Similarly, a study from the Netherlands reported higher complication rates; 25% of patients experienced at least one postoperative complication. Specifically, 12% of patients with simple appendicitis and 38% of those with complicated appendicitis developed complications, and intra-abdominal abscesses were prevalent [28]. The relatively low complication rate observed in our series is likely attributable to under-documentation of wound infections in patients.

Regarding readmission, six cases (3.5%) in our study required hospital readmission for various reasons, and no complications were documented in five of these cases. Only one patient was readmitted because of an intra-abdominal abscess, which was successfully treated with interventional radiology. The patient was

discharged in good condition. This readmission rate is comparable to findings from a Swedish study, which reported a rate of 1.9%. In that study, readmissions were frequently associated with complicated appendicitis [29]. However, a study from the Netherlands reported a significantly higher readmission rate (12%). The most common causes included intra-abdominal abscess, incisional hernia, and urinary tract infection. Additionally, one patient was readmitted for ileostomy reversal following a prior appendiceal stump leak managed during the initial admission with a diverting ileostomy [28].

Our study is the first in our region to investigate the bacterial profile associated with pediatric appendicitis and to evaluate antibiotic selection. As such, it provides valuable insights into the local bacterial ecology, contributes to the literature, and supports evidence-based decision-making for appropriate antibiotic use. These contributions are particularly important for optimising management, improving patient outcomes, and reducing the incidence of complications in pediatric appendicitis. However, several limitations should be acknowledged. The retrospective design and relatively small sample size, given that the study was conducted at a single centre, may have limited the strength of the conclusions. Consequently, the findings may not be generalisable to other hospitals or regions.

## Conclusions

This study explores the bacterial profile and antibiotic management of pediatric appendicitis within our region. Among patients for whom cultures were obtained, 61.22% yielded positive results, and *E. coli* and *P. aeruginosa* were the dominant pathogens. Antibiotic resistance was identified in 24.4% of positive cultures and was significantly associated with elevated WBC and PMN granulocyte counts, indicating their potential utility as markers for complicated appendicitis. The most frequently administered antibiotic regimen was a combination of Augmentin and Metronidazole. Postoperative outcomes were generally favourable, with a low complication rate and minimal readmissions. Despite its retrospective single-centre design and limited sample size, the study provides important regional data and underscores the need for larger, multi-centre investigations to guide clinical practice.

## Authors contributions

Conception and design: Khalid Alzahrani / Tayyaba Batool; Administrative support: Mohammad Barnawi; Collection

and assembly of data: Abdullah H. Alghamdi / Meshal M. Alzahrani / Sarah I Alghamdi; Data analysis and interpretation: Ahmed A. Hussein / Mohammad Barnawi; Manuscript writing: Norah S Alharthi / Ahmed A. Hussein; Manuscript Editing: Khalid Alzahrani / Tayyaba Batool; Final approval of manuscript: All authors

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## Conflict of interest

No conflict of interest is declared.

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