RESEARCH ARTICLES

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SPECIES CHARACTERISTICS OF CAUSATIVE AGENTS OF ACUTE APPENDICITIS IN CHILDREN AND DETERMINATION OF THEIR SUSCEPTIBILITY TO ANTIBIOTICS

In pediatric surgery, acute appendicitis is considered one of the most common problems requiring surgical intervention. Among the causes of this disease, microorganisms are of primary importance. The specificity of postoperative treatment depends both on the degree of virulence of the pathogen and on the microbial load that caused the inflammatory process. The increase in the use of antimicrobial agents is of great concern because of the emergence of antibiotic-resistant bacteria. Therefore, the issue of rational postoperative antibiotic therapy remains relevant, as excessive, often unjustified use and incorrect dosage of drugs have become the cause of many medical problems. The aim of the research was to determine the species structure and analyze antibiotic resistance of microorganisms in biomaterial obtained from children after appendectomy for acute appendicitis.

Methods. We studied biomaterial obtained from 74 patients aged 2—18 years who were treated at the MNCE Ternopil Regional Children Clinical Hospital TRC in the period from September 2021 to March 2022. After appendectomy, the samples were placed in a transport medium for further laboratory research, which involved staining smears according to the Gram method, sowing microorganisms on nutrient media such as blood agar, salt agar, sugar broth and serum agar, and Endo medium for enterobacteria as well as for anaerobic pathogens — thioglycolic medium and Kitta-Tarozzi medium, and identifying by morphological, tinctorial, cultural and biochemical properties. The sensitivity of selected pathogenic microorganisms to antibiotics was determined using the Kirby-Bauer method. Statistical processing of digital data was carried out using Excel software (Microsoft, USA) and the Statistica 10.0 program.

Results. 74 children aged from 2 to 18 years were involved in the study. E. coli (28.4% of all examined), S. aureus (21.6%), and P. aeruginosa (14.9%) were found during the laboratory study of biomaterial. E. faecalis, Klebsiella spp., S. epidermidis, and S. viridans occurred much less often (from 9.4% to 4.5%). The study of antibiotic resistance showed that the isolated microorganisms differed significantly in their sensitivity both to different groups of antimicrobial agents and to generations of drugs within the same group. Ceftriaxone was
Species Characteristics of Causative Agents of Acute Appendicitis in Children and Determination

Appendicitis is one of the most common causes of intra-abdominal infections in children [1—4]. The causative agents of acute appendicitis (AA) can be various types of pathogenic and opportunistic microorganisms or their associations. The severity of this process depends both on the degree of virulence of the pathogen and on the number of associates causing the inflammatory process [5, 6].

To reduce the risk of postoperative complications in various forms of appendicitis, such as wound infections and intra-abdominal abscesses, treatment protocols include antibiotics. This is also important in interval appendectomy. However, there is no unified approach regarding the optimal choice of antibiotic therapy regimens [2, 7]. This problem remains complex and relevant due to the irrational use of antibacterial agents and the emergence of resistant strains of microorganisms.

Thus, it is important to objectively and comprehensively assess the etiology of appendicitis, in particular in children, and analyze the antibiotic sensitivity of its causative agents [2]. Identification of microorganisms and determination of their susceptibility to antibacterial agents will help to choose an effective treatment regimen and avoid postoperative complications and will be a guarantee of preventing the spread of antibiotic-resistant strains [5].

The aim of the research was to determine the species structure and analyze antibiotic resistance of microorganisms in biomaterial obtained from children after appendectomy for acute appendicitis.

Materials and methods. The study involved 74 patients aged from 2 to 18 years who were treated at the MNCE Ternopil Regional Children Clinical Hospital TRC in the period from September 2021 to March 2022. Patients were admitted with complaints of acute abdominal pain combined with signs and symptoms indicating appendicitis. After taking the anamnesis and evaluating the results of instrumental and laboratory research methods, the children were prescribed operative surgery to remove the appendix.

Immediately after appendectomy, biomaterial samples were taken from the perforation site or from the pelvic effusion. They were placed in a transport environment for further laboratory research.

Smears were made from the clinical material and stained by the Gram method. and bacteriologic examination was carried out. To identify aerobic microorganisms, the material was sown on the following nutrient media: blood agar, yolk-salt agar, sugar broth and serum agar, and Endo medium for enterobacteria (manufacturer
Violife Italiana S.r.I.) and incubated at 37 °C for 24 h. For the cultivation of fungi of the genus *Candida*, we used Saburo’s medium (FARMAK-TIV Ltd, Ukraine) with incubation of crops in a thermostat at 27—30 °C for up to 5 days. For anaerobic pathogens, a thioglycol medium and Kitta-Tarozzi medium were used. The material was incubated at a temperature of 37 °C for 48 h in anaerobic conditions in hermetic boxes GEN-box (VioMerieux, France), using gas-generating packages GENboxanaer (VioMerieux, France). Genus and species identification of microorganisms was carried out by morphological, tinctorial, cultural, and biochemical properties.

The susceptibility of isolated microorganisms to antibiotics was determined by the Kirby-Bauer method. Pure cultures of bacteria were cultivated on the Mueller-Hinton medium, and fungi were cultivated on Sabouraud’s medium. The results were evaluated by determining the diameters of growth retardation zones using standard tables [8].

Statistical processing of digital data was carried out using Excel software (Microsoft, USA) and the Statistica 10.0 program.

**Results.** During appendectomy, patients were diagnosed with various forms of acute appendicitis: catarrhal — in 7 (9.4%) patients, phlegmonous — in 14 (18.9%), gangrenous — in 37 (50%), and gangrenous-perforating — in 16 (21.6%) (Fig. 1).

Bacteriological examination of the peritoneal fluid contents revealed 10 strains of opportunistic and pathogenic microorganisms that were causative agents of the inflammatory process in AA (Fig. 2).

*E. coli*, *S. aureus*, and *P. aeruginosa* were the most common pathogenic representatives of the microbiota in the pelvic effusion contents. They occurred with varying frequency in all forms of AA (Fig. 2, Table 1).

In the clinical material taken from 21 (28.4%) patients, *E. coli* was found, which was in all patients examined. This enterobacterium was de-
Species Characteristics of Causative Agents of Acute Appendicitis in Children and Determination

Detected in all forms of AA, and most often it was the cause of gangrenous appendicitis — 57.1%. S. aureus was detected in 16 patients (21.6%) during the study of biomaterial. This causative agent occurred with a frequency from 12.5% to 43.7% in all forms of the inflammatory process.

A frequently isolated microorganism was P. aeruginosa. This pathogen was detected in biomaterial taken from 11 (14.9%) operated children. Most often, P. aeruginosa was the cause of gangrenous appendicitis — 54.5%, although it was cultured sporadically in other forms of AA.

Microorganisms such as E. faecalis, Klebsiella spp., S. epidermidis, and S. viridans were found much less frequently in the studied biomaterial (from 9.4% to 4.5%). They, in addition to S. epidermidis, were the cause of phlegmonous, gangrenous, and gangrenous-perforating forms of AA. S. epidermidis, in turn, was cultured in all forms of AA, except phlegmonous.

In catarrhal and phlegmonous appendicitis, S. saprophyticus was found in isolated cases — 2.7% of the total number of patients studied. In one patient, the cause of catarrhal appendicitis was Micrococcus spp. (1.3%). Fungi of the genus Candida were the causative agents of infection in 2 (2.7%) patients. They occurred in gangrenous and gangrenous-perforating appendicitis (Fig. 2).

When studying the antibiotic sensitivity of pathogenic microorganisms detected during appendectomy, we found that they differed significantly both in their susceptibility to different groups of antimicrobial agents and to different generations within the same group (Table 2).

Such common pathogens of AA as E. coli, S. aureus, and P. aeruginosa had different sensitivities to all tested antibiotics, with some exceptions, for example, E. coli and S. aureus are resistant to tobramycin, and P. aeruginosa — to cefuroxime and cefazolin.

The study showed that ceftriaxone, which belongs to the III generation of cephalosporins, had the highest effectiveness against all detected microorganisms. In particular, E. coli, S. aureus, P. aeruginosa, and S. epidermidis showed 100% susceptibility to this antimicrobial agent and the others — within 75—50%. Although ceftazidime also belongs to the III generation cephalosporins, the most frequent pathogens (E. coli, S. aureus, P. aeruginosa) showed sensitivity to it in the range from 38.1% to 27.3%. Since the frequency

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**Table 1. Frequency of detection of pathogenic microorganisms in various forms of appendicitis**

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Catarrhal appendicitis</th>
<th>Phlegmonous appendicitis</th>
<th>Gangrenous appendicitis</th>
<th>Gangrenous-perforating appendicitis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escherichia coli</td>
<td>4.7</td>
<td>23.8</td>
<td>57.1</td>
<td>14.3</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>12.5</td>
<td>25</td>
<td>43.8</td>
<td>18.8</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>9.1</td>
<td>18.2</td>
<td>54.5</td>
<td>18.2</td>
</tr>
<tr>
<td>Enterococcus faecalis</td>
<td>0</td>
<td>14.3</td>
<td>57.1</td>
<td>28.6</td>
</tr>
<tr>
<td>Klebsiella spp.</td>
<td>0</td>
<td>16.7</td>
<td>50</td>
<td>33.3</td>
</tr>
<tr>
<td>Staphylococcus epidermidis</td>
<td>20</td>
<td>0</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Streptococcus viridans</td>
<td>0</td>
<td>0</td>
<td>66.7</td>
<td>33.3</td>
</tr>
<tr>
<td>Streptococcus saprophyticus</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Micrococcus spp.</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Candida spp.</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>
of occurrence of \textit{S. epidermidis} is quite low (only 6.7\%) of the total number of isolated pathogens, the indicator of sensitivity to this antibiotic was quite high — 60\%. As for the other classes of different cephalosporins, the identified pathogens were significantly more resistant or not sensitive.

Among the tested aminoglycosides, amikacin turned out to be a very effective inhibitor of the tested microorganisms. 100\% of representatives of \textit{Klebsiella} spp. and \textit{S. epidermidis} were sensitive to this antibiotic, \textit{E. coli} — 90.5\%, \textit{P. aeruginosa}, and \textit{S. aureus} — 81.8\% and 81.2\%, respectively. Although tobramycin has a bactericidal effect against aerobic gram-negative and some gram-positive bacteria, only \textit{E. faecalis} (28.6\%) and \textit{P. aeruginosa} (18.2\%) were sensitive to it.

Gatifloxacin, an antimicrobial agent from the quinolone group, demonstrated good inhibition of the growth of almost all detected pathogenic microorganisms. From 100\% of \textit{S. epidermidis} to 61.9\% of \textit{E. coli} were sensitive to it. Almost all isolated microorganisms showed sensitivity to ofloxacin, however, in contrast to gatifloxacin, its inhibitory efficiency did not exceed 33.3\%.

Amoxiclav and ampisulbin (groups of penicillins) had weak inhibitory activity, except for 100\% of strains of \textit{Klebsiella} spp. and 75\% — of \textit{E. faecalis}, which were inhibited by amoxiclav. The sensitivity of \textit{E. coli}, \textit{S. aureus}, and \textit{P. aeruginosa} was approximately 45\%. The suppressive property of ampisulbin to the most frequent pathogens was from 9.1\% to 18.7\%.

Almost all studied microorganisms were partially susceptible to azithromycin, which belongs to the group of macrolides. The activity of this antibiotic ranged from 100—81.8\% for \textit{S. epidermidis} and \textit{S. aureus}, and up to 36.4\% for \textit{P. aeruginosa}.

Furagin, a nitrofuran antibacterial agent, turned out to be an effective drug for all pathogens in various forms of appendicitis. Among the main identified bacteria, \textit{E. faecalis} showed 100\%, \textit{E. coli} — 90.5\%, \textit{S. aureus} — 87.5\% sensitivity to this agent. The inhibitory effect of furagin against all other pathogens was in the range of 83.3—60.0\% (Table 2).

Due to the fact that \textit{S. viridans}, \textit{P. aeruginosa}, \textit{Micrococcus} spp., and \textit{Candida} spp. were detected with a low frequency, their indicators were not taken into account when analyzing the results for antibiotic susceptibility.

**Discussion.** In surgical practice, it is generally accepted that AA is a non-specific infectious disease involving the inflammatory process of the submucosal and serous-muscular layers of the appendix, prone to spread to adjacent organs and tissues with necrosis of the appendix wall itself [6]. AA is one of the most common causes of acute abdomen. The incidence is high in Western countries, especially in Europe and America [9]. Appendicitis is more common in children, although it can occur in any age group [3, 5].

It is believed that the main pathogens of AA in children are pathogenic and conditionally pathogenic \textit{Escherichia} and \textit{Eacteroids} in association with aerobic enterobacteria (\textit{Protea}, \textit{Klebsiella}, \textit{Edwardsiella}, \textit{Pseudomonads}), \textit{Staphylococci} and \textit{Streptococci}, as well as anaerobic \textit{Peptococcus}, \textit{Peptostreptococcus}, and \textit{Clostridia} [3, 6].

However, there is no consensus regarding the specific causative agent of AA, the percentage ratio, and the frequency of its distribution among selected types of microorganisms. Some authors consider \textit{E. coli} and anaerobic \textit{Clostridium perfringens} to be the most common [10], others indicate \textit{E. coli}, \textit{Pseudomonas} spp., \textit{Klebsiella} spp., \textit{Streptococcus} spp., or \textit{Bacteroides fragilis}, \textit{P. aeruginosa}, \textit{Enterococcus} spp., and alpha- and gamma-hemolytic streptococci [2, 8].

According to scientists, it is suggested that the severity of the clinical course of AA in children may depend on the geographical distribution of types of pathogenic and opportunistic microorganisms, as well as their antibacterial resistance. Over the past decades, there has been a tendency to decrease the incidence rate of AA in the countries of North America and Eastern and Western
Europe, but in developing countries, on the contrary, it is increasing [10, 11].

It is necessary to pay attention to the pre- and postoperative periods, directly to the presence of toxic factors of bacterial origin, which even in minimal concentrations affect the course of the disease. Their excess or deficiency in the body leads to the formation of an immune response [2, 6, 10].

According to the treatment protocol MKH-10-K 35.0, approved by the Ministry of Health of Ukraine (Order No. 150 of February 18, 2010), II-III generation cephalosporins with aminoglycosides and metronidazole are used for destructive forms of AA with peritonitis [12]. However, antibacterial agents are often prescribed without prior determination of the antibiotic susceptibility of the selected microorganisms. In order to reduce postoperative complications, it is very important that all potential pathogens be included in the spectrum of the empiric regimen of antibiotic therapy. Besides, as scientists note [13], over the last decade, there has been an increase in the spread of resistant strains in AA in children. Therefore, systematic bacteriological cultures are of great importance for the detection of epidemiological changes in the resistance patterns of pathogens associated with AA. It is necessary to systematically carry out bacteriological examinations so that in the future it could be possible to adjust the antibiotic treatment scheme according to the sensitivity of the identified species [9, 14].

The results of scientific studies indicate that in most cases AA is caused by anaerobic bacteria in the digestive tract. Among them, E. coli occupies a leading place [3, 7, 10, 15, 16]. Thus, when studying the intraluminal and appendicular microbiome in children, Schulin et al [16] showed that E. coli dominates in all types

### Table 2. Antibiotic sensitivity of pathogenic microorganisms detected in acute appendicitis (AA) among children

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Ceftriaxone</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>75</td>
<td>66.7</td>
<td>100</td>
<td>100</td>
<td>50</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Cefazidime</td>
<td>38.1</td>
<td>37.5</td>
<td>27.3</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>66.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cefoperazone</td>
<td>33.3</td>
<td>31.2</td>
<td>27.3</td>
<td>57.1</td>
<td>33.3</td>
<td>60</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Sulperazone</td>
<td>23.8</td>
<td>18.7</td>
<td>18.2</td>
<td>28.6</td>
<td>0</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cefuroxime</td>
<td>9.5</td>
<td>12.5</td>
<td>0</td>
<td>0</td>
<td>33.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Cefazolin</td>
<td>9.5</td>
<td>12.5</td>
<td>0</td>
<td>0</td>
<td>33.3</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Amikacin</td>
<td>90.5</td>
<td>81.2</td>
<td>81.9</td>
<td>57.1</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>100</td>
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</tr>
<tr>
<td>Tobramycin</td>
<td>0</td>
<td>0</td>
<td>18.2</td>
<td>28.6</td>
<td>0</td>
<td>0</td>
<td>66.7</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>Gatifloxacin</td>
<td>61.9</td>
<td>87.5</td>
<td>81.8</td>
<td>75</td>
<td>66.7</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Ofloxacin</td>
<td>14.3</td>
<td>12.5</td>
<td>27.3</td>
<td>28.6</td>
<td>33.3</td>
<td>0</td>
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<td>100</td>
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<tr>
<td>Amoxiclav</td>
<td>42.8</td>
<td>43.7</td>
<td>45.4</td>
<td>75</td>
<td>100</td>
<td>0</td>
<td>66.6</td>
<td>0</td>
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<td>0</td>
</tr>
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<td>Ampisulbin</td>
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<td>18.7</td>
<td>9.1</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>50</td>
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<td>0</td>
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<tr>
<td>Azithromycin</td>
<td>38.1</td>
<td>81.8</td>
<td>36.4</td>
<td>57.1</td>
<td>66.7</td>
<td>100</td>
<td>33.3</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Furagin</td>
<td>90.5</td>
<td>87.5</td>
<td>63.6</td>
<td>100</td>
<td>83.3</td>
<td>60</td>
<td>66.7</td>
<td>100</td>
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<td>50</td>
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</table>

ISSN 1028-0987. Microbiological Journal. 2023. (3)
of appendicitis (catarrhal — 43%, phlegmonous — 41%, gangrenous — 50%). A similar trend is observed in Ukraine: *E. coli* was cultured in 56% of all positive results [7]. Song and co-authors described that out of 16 detected pathogens, this pathogen occurred in 64.6% of cases [15]. According to other scientists, in the clinical material of operated children, *E. coli* was cultured in 81.4% of cases [10].

Our data are consistent with the results of the studies analyzed. As a result of the study of clinical material, it was established that in children aged 2 to 18 years, the most frequent causative agent of AA was *E. coli* (28.4% of all patients). The isolated strains showed antibiotic susceptibility to almost all tested antibiotics except for tobramycin.

*S. aureus* is commonly found as a commensal microorganism of the skin and upper respiratory tract. Isolation of methicillin-resistant *S. aureus* in various abdominal infections such as diverticulitis, spontaneous bacterial peritonitis, and infected peritoneal dialysis catheters has been described in [14]. The fecal carriage of *S. aureus* is reported in the literature to be 26%, but it is rarely detected in isolates obtained after appendectomy. The presence of *S. aureus* in the appendix lumen, serous membrane, or intra-abdominal fluid was recorded in only 0.7—3.7% of cases [17, 18]. Contrary to these statements, we found that *S. aureus* was cultured most often in various forms of AA in children (21.6% of all examined).

It was shown that *P. aeruginosa* in gangrenous appendicitis accounts for 13% of all pathogens of AA, which is consistent with other results that showed that *P. aeruginosa* occurred in 16.7% of gangrenous and 27.8% of perforated appendicitis [16]. It showed resistance to cephalosporin, tetracycline, and sulfonamide antibiotics, respectively: cefotaxime — 93.2%, cotrimoxazole — 93.2%, tetracycline — 93.2% [19]. During the laboratory analysis of the pathological material, we established that this microorganism was the cause of various forms of AA. In a single case (9.1%), *P. aeruginosa* was found in catarrhal, 18.2% in phlegmonous and gangrenous-perforating, and 54.5% in gangrenous appendicitis.

*Klebsiella* spp. is a well-known pathogen that causes infections of the upper respiratory tract and is one of the main causative agents of diseases of the gastrointestinal tract. A new problem associated with infection caused by *Klebsiella* spp. is the increase in the number of resistant strains [18]. According to the literature, *Klebsiella pneumonia* is the causative agent of GA in 15% of cases [5], and *Klebsiella oxytoca* — in 11.1% [2]. Upon examining the microbial landscape of AA in children of the Ternopil region, similar results were obtained, namely: 8.1% of the detected microorganisms were *Klebsiella* spp.

The conducted studies were aimed not only at establishing the microbial diversity in AA but also at analyzing the effectiveness of the use of antibacterial agents (cephalosporins, aminoglycosides, fluoroquinolones, penicillins, macrolides, and nitrofuran derivatives) for a specific isolated pathogen.

Ceftiraxone (III-generation cephalosporins) has a special antibacterial spectrum of action: *S. aureus* (sensitive to methicillin), coagulase-negative *Staphylococci*, *S. pneumoniae* (sensitive to penicillin), *Streptococcus* spp., *H. influenzae*, *M. catarrhalis*, *N. meningitidis*, *N. cereae*, and *E. gonorrhea* [10]. The results of the study confirmed that ceftiraxone is a highly effective antimicrobial with a broad spectrum of action. Its inhibitory ability to most pathogens of AA was 100%. According to other scientists, the use of ceftiraxone in combination with metronidazole reduces the frequency of abscesses and complications in various forms of appendicitis in children. Treatment with these antibacterial agents is believed to shorten the time of postoperative therapy and also provide significant savings in antibiotic costs [20].

Despite the fact that *Escherichia coli* is generally sensitive to II, III-generation cephalosporins (approximately 97%), which are most often used for empiric antibiotic treatment, its sensitivity is still decreasing (Table 2) [21].
The obtained results indicate that such isolated pathogens of AA as *E. faecalis* and *Klebsiella* spp. were resistant to cefazidime, *S. viridans* — to cefoperazone, and *Klebsiella* spp. and *S. viridans* — to sulperazone, although they belong to III-generation cephalosporins as well.

When determining antibiotic sensitivity, it was established that amikacin has a good inhibitory effect on the vast majority of pathogenic microorganisms (from 100% to 57.1%) (Table 1). However, simplified regimens of broad-spectrum antibiotics, namely ceftriaxone, in the postoperative period are more effective and cost-saving than the triple regimen of ampicillin, gentamicin, and clindamycin for appendicitis [20].

Furagin belongs to the main nitrofuran agents. It has a wide spectrum of inhibitory activity against gram-positive and gram-negative bacteria and protozoa. Nitrofurans are effective against strains that are resistant to some antibiotics since resistance to it develops rarely [22]. The conducted research also confirms the effectiveness of this antibiotic. All detected microorganisms were highly sensitive to this agent (from 100% to 60%).

### Conclusions

1. In children with a diagnosis of AA, such microorganisms as *E. coli*, *S. aureus*, *P. aeruginosa*, and sporadically *S. saprophiticus*, *Micrococcus* spp., *S. viridans*, and *Candida* spp. are most often isolated.

2. The most effective inhibitors of the selected strains were ceftriaxone, which belongs to the group of cephalosporins of the III generation (100—66.7%), amikacin from the group of aminoglycosides (100—57.1%), and furagin (100—60%). The microorganisms studied were the most resistant to penicillins and antibiotics of the II generation fluoroquinolone group.

3. In order to avoid the risk of postoperative complications and the development of antibiotic resistance, antibiotics with different mechanisms of action should be used during empiric antibacterial therapy of various forms of appendicitis, taking into account the sensitivity of a specific pathogen to a specific antimicrobial agent.

4. Therefore, in all appendectomies, the sensitivity of isolated microorganisms to antibiotic susceptibility should be determined.

### REFERENCES


Received 17.02.2023

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ВИДОВА ХАРАКТЕРИСТИКА ЗБУДНИКІВ ГОСТРОГО АПЕНДИЦИТУ
В ДІТЕЙ ТА ВИЗНАЧЕННЯ ЇХНЬОЇ АНТИБІОТИКОЧУТЛИВОСТІ

Апендицит є одним із найпоширеніших гострих хірургічних захворювань органів черевної порожнини, яке характерне як для дітей, так і для дорослих. Загальновідомо, що в більшості випадків це захворювання спричинено аеробними бактеріями травного тракту, зокрема Escherichia coli або Klebsiella pneumoniae, а також грамнегативними — Bacteroides fragilis. Таким чином, саме патогенні мікроорганізми або їх асоціації є ключовим фактором запалення апендикса. Найхарактернішими післяопераційними ускладненнями при гострому апендициті вважаються ранова інфекція, внутрішньочеревний абсцес і кишкова непрохідність. З метою зниження частоти їх розвитку під час лікування застосовують антибактеріальні препарати. Стійкість хвороботворних мікроорганізмів до антибіотиків (антимікробна резистентність), поява мультирезистентних бактеріальних штамів є вагомою проблемою сьогодення. Швидкість, з якою вона формується і розповсюджується, збільшується з кожним роком. Препарати, які ще декілька років тому були ефективними, сьогодні втрачають свою ефективність, а їх використання вимушено обмежується. Основними причинами формування резистентності у патогенних бактерій є активне використання антимікробних препара-
тів у тваринництві і невиправдане їх використання в клінічній медицині. З огляду на зазначене вище, дол
слідження стійкості патогенних мікроорганізмів до антибіотиків є надзвичайно актуальною проблемою.

**Мета роботи.** Визначити видову структуру та проаналізувати антибіотикорезистентність хвороботворних мікроорганізмів у біоматеріалі, отриманому від дітей, хворих на гострий апендицит, після апендектомії.

**Методи.** Досліджували біоматеріал, отриманий від 74 хворих віком 2—18 років, які перебували на лікуванні в КНП «Тернопільська обласна дитяча клінічна лікарня» ТОР у період з вересня 2021 до березня 2022 року. Після апендектомії зразки поміщаля в транспортне середовище для подальшого лабораторного до
слідження, яке передбачало фарбування мазків за методом Г рама, посів мікроорганізмів на живильні се
редовища: кров'яний агар, сольовий агар, цукровий бульйон та сироватковий агар, середовище Ендо для ентеробактерій; для анаеробних збудників — тіогліколеве середовище та середовище Кітта-Тароцці, а також ідентифікацію за морфологічними, тинкторіальними, культуральними та біохімічними властивостями. Чутливість виділених патогенних мікроорганізмів до антибіотиків визначали за допомогою метода Кірбі-Бауера. Статистичну обробку цифрових даних здійснювали за допомогою програмного забезпечення Excel (Microsoft, США) та програми Statistica 10.0.

**Результати.** Під час лабораторного дослідження біоматеріалу виявлено E. coli (28.4% від усіх обстежених), S. aureus (21.6%) та P. aeruginosa (14.9%). E. faecalis, Klebsiella spp., S. epidermidis, S. viridans зустрічалися значно рідше (від 9.4% до 4.5%). Дослідження антибіотикорезистентності показало, що виділені мікроорганізми значно відрізнялись за чутливістю як до різних груп антимікробних засобів, так і до покоління в межах однієї групи. Цефтріаксон, який належить до III покоління цефалоспоринів, був найефективнішим інгібітором усіх виявлених мікроорганізмів. Зокрема, E. coli, S. aureus, P. aeruginosa, S. epidermidis проявляли 100% чутливість до цього антимікробного засобу, а всі інші — в межах 75—50%. Всі представники Klebsiella spp. та S. epidermidis проявили чутливість до амікацину (гру
па аміноглікозидів): E. coli — 90.5%, P. Aeruginosa та S. aureus — відповідно 81.8% та 81.2%. Амоксиклав та ампісульбін, які належать до пеницилів, мали слабку інгібуючу активність, за винятком 100% для штамів Klebsiella spp. та 75% — E. faecalis, які інгібувалися амоксиклавом. До азитроміцину, що належить до групп макролідів, частково чутливими були майже всі досліджувані мікроорганізми. Активність цього антибіотика була в діапазоні від 81.8 до 100% (S. epidermidis, S. aureus) та до 36.4% (P. aeruginosa). Висновки. Найчастіше збудниками гострого апендициту у пацієнтів дитячого віку є такі мікроорганізми: E. coli, S. aureus, P. aeruginosa та спорадично — S. saprophiticus, Micrococcus spp., S. viridans, Candida spp. Серед антибіотиків, які застосовуються для лікування післяопераційних ускладнень при різних формах апендициту, найефективнішим виявився цефтріаксон, який належить до цефалоспоринів III покоління (100—66.7%), амікацин (аміноглікозиди) (100—57.1%) та фурагін (похідні нітрофурану) (100—60%). Досліджувані мікроорганізми були найменш чутливими до пеницилінів та антибіотиків групи фторхінолонів II покоління.

**Ключові слова:** гострий апендицит, хвороботворні мікроорганізми, антибіотики, антибіотикочутливість, апендектомія.