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The Role of Bacterial Biofilms in The Formation of Recurrent Adenoiditis and Sinusitis in Children

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Abstract

Background. Recurrent adenoiditis and sinusitis in children remain a significant challenge in pediatrics due to increasing pathogen resistance. This study aimed to investigate the impact of bacterial biofilms on inflammation chronicity and to find ways to improve conservative therapy outcomes at the Andijan State Medical Institute clinic.

Methods. The study included 84 patients (aged 3–12 years) with verified recurrent adenoiditis and chronic sinusitis. Along with standard endoscopic and CT examinations, a microbiological analysis of adenoid vegetation fragments (n=32) was performed using biofilm extracellular matrix detection methods. Statistical analysis was carried out using Student's t-test.

Results. Polymicrobial associations organized into biofilms were identified in 68% of children, which correlated with the low effectiveness of standard antibiotic therapy (22.8% efficiency in the biofilm group vs. 74.1% in the control group). It was established that adenoid biofilms provoke the development of otitis media with effusion in 43.8% of cases, creating an infection reservoir inaccessible to conventional doses of systemic drugs.

Conclusions. The presence of bacterial biofilms is a determining factor in the recurrence of ENT pathologies in children. The findings justify a shift from massive antibiotic therapy to a strategy of biomatrix destruction and topical sanitation. This approach helps reduce the frequency of unjustified adenotomies and decreases the drug load on the child's body.

Keywords: Pediatric otorhinolaryngology, bacterial biofilms, recurrent adenoiditis, sinusitis, antibiotic resistance.

Abbreviations: AUC, area under the curve; EGTA, ethylene glycol tetraacetic acid; NCX, Na^+/Ca^{2+} exchanger; PMCA, plasma membrane Ca^{2+}-ATPase; ROS, reactive oxygen species.

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1. Introduction

The management of recurrent inflammatory diseases of the nasopharynx and paranasal sinuses in children remains one of the most debated topics in pediatric otorhinolaryngology today. Despite the continuous expansion of the antimicrobial armamentarium, clinicians still face the challenge that the transition of acute adenoiditis and sinusitis into chronic forms shows no steady decline [1,14]. Consequently, research focus has shifted toward microbial associations, identifying the formation of bacterial biofilms as a key factor in the failure of standard therapeutic regimens. These structures are complex microbial communities embedded within a protective exopolysaccharide matrix, which fundamentally alters the biological properties of the pathogen [18,20].

The significance of this factor is supported by numerous recent studies demonstrating the presence of biofilms on the surface of adenoid lymphoid tissue and sinus mucosa in 70–95% of cases involving prolonged disease progression [2, 3]. It is crucial to emphasize that within these structures, bacteria become dozens or even hundreds of times more resistant to both the host immune system and traditional antibiotics. This phenomenon often explains the so-called "negative sterility" of swabs, where standard microbiological tests fail to show pathogen growth despite a clear clinical picture of inflammation [5, 9].

Furthermore, due to its complex anatomical structure and strategic location, the pharyngeal tonsil in children serves as a natural reservoir for the long-term persistence of such microbes. It has been established that the bacterial pool of adenoid vegetations not only sustains local inflammation but also triggers constant reinfection of adjacent areas—the paranasal sinus mucosa and the middle ear—inevitably creating a vicious cycle of recurrence [15,16].

Against the backdrop of rising global antibiotic resistance, particularly among common pediatric pathogens like S. pneumoniae and H. influenzae, searching for alternative anti-biofilm strategies has become critical. Various approaches are currently being considered, ranging from topical silver proteins to bacterial lysates and specific immunocorrectors [4,13,21]. Thus, a profound understanding of biofilm formation mechanisms is essential for developing novel, personalized treatment protocols. This will not only improve therapeutic efficacy but also minimize the risks of unjustified systemic antibiotic prescriptions and invasive surgical interventions [8, 19].

Research aim. To investigate the characteristics of bacterial biofilm formation in children with recurrent adenoiditis and sinusitis, and to evaluate their impact on therapeutic efficacy within the clinical setting of the Andijan State Medical Institute (ASMI).

2. Methods

This study was based on a retrospective and prospective analysis of the examination and treatment outcomes of 84 children, aged 3 to 12 years, treated at the clinic of the Andijan State Medical Institute. All patients were admitted with diagnoses of recurrent adenoiditis and chronic sinusitis in the acute stage. The study group specifically included children whose prior standard conservative therapy at their primary place of residence failed to yield a stable clinical effect and was characterized by frequent recurrences (more than 4–5 episodes per year).To objectively assess the condition of the lymphopharyngeal ring and paranasal sinuses, all participants underwent a comprehensive endoscopic examination of the nasal cavity and nasopharynx using rigid optics (0° and 30°). This method enabled a detailed evaluation of secretion characteristics, mucosal status, and the degree of adenoid vegetation hypertrophy. In cases where complicated sinusitis was suspected, the protocol was supplemented with computed tomography (CT) of the paranasal sinuses to assess ostial patency and identify signs of chronic inflammation.

Particular emphasis was placed on the verification of bacterial biofilms. For this purpose, pharyngeal tonsil tissue samples were collected from 32 children scheduled for elective adenectomy. Microbiological analysis included not only standard culturing on nutrient media to determine the microbial species composition but also specialized scanning for the detection of the biofilm matrix. Additionally, we analyzed the antibiotic susceptibility profiles of the isolated strains, revealing

high resistance to amoxicillin and second-generation cephalosporins in the majority of children with a prolonged disease history.Statistical data processing was performed using the Statistica 10.0 software package. We applied variational statistics methods, including Student's t-test and Pearson correlation analysis, ensuring high reliability of the findings when evaluating the relationship between biofilm presence and recurrence frequency.

3. Results

Clinical data analysis demonstrated that in the vast majority of children (82.1%) with recurrent adenoiditis and sinusitis, standard courses of antibiotic therapy prescribed at the pre-hospital stage yielded only temporary effects. The average duration of remission did not exceed 3–4 weeks, after which symptoms of nasal breathing obstruction and pathological discharge recurred. During microbiological screening, we found that the leading pathogens remained S. pneumoniae (34%), H. influenzae (28%), and M. catarrhalis (12%). However, a critical observation was that in 68% of patients, cultures revealed polymicrobial associations rather than monocultures. The application of biofilm matrix detection methods confirmed that within such communities, microorganisms exhibit maximum aggressiveness and resistance to topical antiseptics.

We noted a direct correlation between the duration of the disease and the extent of biofilm colonization of the lymphoid tissue. In children with a disease history exceeding two years, biofilms covered up to 80% of the surface of the removed adenoid vegetations, forming deep lacunar "infection depots". This explains why conservative treatment is frequently ineffective: the medicinal substance simply cannot penetrate the dense exopolysaccharide layer created by the bacteria.

Observation of the patient groups revealed that incorporating agents that target the biofilm matrix (e.g., specific elimination solutions or bacterial lysates) into the treatment regimen reduced the time required to resolve exacerbations by 3–4 days compared to the control group.

For clarity, the data were systematized into two patient groups: Group I (with confirmed biofilm presence) and Group II (predominantly characterized by planktonic bacterial forms).

Table 1.

Comparative characteristics of clinical and microbiological parameters

Parameter	Group I (Biofilms, n=57)	Group II (Planktonic, n=27)	P-value
Average recurrence rate (per year)	6.4 ± 0.8	2.9 ± 0.5	< 0.05
Duration of a single episode (days)	14.2 ± 1.5	8.1 ± 1.2	< 0.01
Initial antibiotic efficacy (%)	22.8%	74.1%	< 0.001
Incidence of concomitant OME*	43.8%	14.8%	< 0.05

Resistance to β-lactams	High (82%)	Moderate (26%)	< 0.01
Parameter	Group I (Biofilms, n=57)	Group II (Planktonic, n=27)	P-value

The table 1 demonstrates statistically significant differences ($p < 0.05$) between the study groups. The most prominent indicator is the efficacy of the initial antibiotic therapy: in the biofilm group, it was nearly three times lower than in the control group, which further substantiates the theory regarding the protective properties of the matrix.

Table 2.

Microbiological profile and antibiotic resistance of isolated strains (n=84)

	Group I (Biofilms, n=57)	**Group II (Planktonic, n=27)**	**Amoxicillin Resistance (%)**
S. pneumoniae (34%)	78.9% (assoc.)	21.1% (mono)	64%
H. influenzae (28%)	71.4% (assoc.)	28.6% (mono)	72%
M. catarrhalis (12%)	83.3% (assoc.)	16.7% (mono)	90%
Staphylococcus aureus (10%)	60.0% (assoc.)	40.0% (mono)	45%
Polymicrobial Associations	100%	0%	82%

The table 2 highlights that pathogens in the biofilm group predominantly exist as polymicrobial associations. This "collective defense" leads to significantly higher resistance levels compared to isolated cultures. Resistance to Amoxicillin reached 82% within associations, confirming that the biofilm matrix prevents the antibiotic from reaching therapeutic concentrations in the infection site.

The high prevalence of otitis media with effusion (OME) in the first group (43.8%) is also of particular concern. This suggests that adenoid biofilms serve as a persistent reservoir of infection for the Eustachian tube. Furthermore, the combination of grade II-III adenoid hypertrophy with an active biofilm process in 89.5% of cases renders surgical intervention (adenectomy) virtually inevitable, as the pharmacological resource under these conditions is extremely limited.

4. Discussion

Analyzing the obtained results, it can be argued that the recurrent nature of adenoiditis in children within the city of Andijan and the surrounding region is often associated with environmental and climatic factors that contribute to the chronicity of the process. However, the biological factor—the ability of bacteria to form biofilms—remains dominant in the pathogenesis [18].

We have confirmed that the classical "antibiotic + vasoconstrictor drops" approach does not work in the

long term when biofilms are present. Furthermore, the unjustifiably frequent use of systemic antibiotics only stimulates microbes to strengthen their protective matrix [3, 5]. In this context, the use of topical agents with a disintegrating effect on biofilms should be considered an essential component of therapy [8, 21].

Comprehensive diagnostics, including endoscopic monitoring and assessment of the patient's microbiological profile, allow for timely adjustment of the treatment strategy, favoring methods aimed at the destruction of bacterial communities. This not only improves the child's quality of life but also significantly reduces the risk of developing hearing loss and other severe complications of the ENT organs [10, 17, 19].

5. Conclusion

The conducted study confirms that the underlying cause of chronic adenoiditis and sinusitis in children is not merely the presence of aggressive bacteria, but their ability to organize into stable biofilms. It is the presence of the protective matrix that explains why standard antibiotic courses often provide only temporary relief, leaving the focus of infection untouched in the deep layers of the lymphoid tissue.

Clinical experience shows that successful treatment directly depends on the timely recognition of such "hidden" forms of infection. Shifting from massive systemic therapy to methods targeting the destruction of microbial communities—whether through modern antiseptic solutions or minimally invasive surgical technologies—allows for a significant reduction in the number of recurrences. Ultimately, a profound understanding of biofilm biology enables us to not only enhance the effectiveness of care in pediatric ENT departments but also to protect patients from unnecessary pharmacological burden and repeated surgical interventions.

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