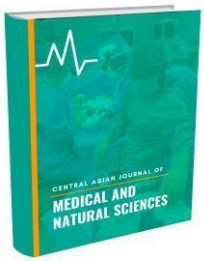

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Article

Integrated Inflammatory and Hematological Signatures in Pediatric Otitis Externa: Exploring the Diagnostic Role of CRP, ESR, and Blood Cell Indices

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Abstract: Pediatric otitis externa is an inflammatory disorder of the external ear canal, often related with bacterial infection and environmental exposures, and behavioral risk factors. The purpose of this study was to explore both inflammatory and hematological biomarkers of pediatric otitis externa and to determine the most common bacterial isolates in relation to the disease. A case–control study was conducted between March 2025 and February 2026 in Al-Nasiriyah Maternity and Children Hospitals and outpatient clinics in Nasiriyah, Iraq. There were 90 children participants (60 patients with otitis externa and 30 healthy controls). A clinical examination, hematological analysis, evaluation of inflammatory biomarkers and microbiological tests were conducted. Findings revealed no significant differences in age, sex, or BMI among groups ($P > 0.05$) and that swimming exposure and poor ear hygiene were significantly greater in patients ($P < 0.05$). Hematological examination showed that there is a substantial increase in white blood cell count and neutrophil percentage and a subsequent reduction in lymphocyte percentage in patients as compared to controls ($P < 0.001$). Patients had a higher inflammatory level, as evidenced by C-reactive protein (CRP), and erythrocyte sedimentation rate (ESR) ($P < 0.001$). The most common pathogens were *Pseudomonas aeruginosa* (35.0%) and *Staphylococcus aureus* (28.3%). Correlation analysis revealed that there were significant positive relationships between CRP and WBC as well as neutrophils but negative relationships with lymphocytes. In conclusion, pediatric otitis externa is characterized by significant inflammatory and hematological alterations, with distinct bacterial profiles. The integrated assessment of CRP, ESR, and blood cell indices provides valuable diagnostic insight and may improve clinical management strategies.

Keywords: Pediatric Otitis Externa, CRP, ESR, Hematological Indices, Bacterial Isolates

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1. Introduction

Pediatric otitis externa is an inflammatory disease of the external ear canal, especially among children and adolescents. The symptoms of the condition include ear pain, itching, discharge and tenderness which can be caused by bacterial infection, exposure to excessive moisture or mechanical trauma of the ear canal [1]. Environmental and behavioral factors, such as swimming, high humidity and poor ear hygiene are often linked to the condition. Although it can be considered to be a localized illness, otitis externa can greatly affect the quality of life of a pediatric patient and cause complications in case the illness is not timely diagnosed and treated [2].

Pathogenesis of otitis externa is multifactorial, and entails the breakdown of the normal protective barrier of the external auditory canal. Cerumen and a thin lining of the ear canal are lined with an epithelium that has antimicrobial protection as it keeps the environment acidic and prevents the colonization of microbes [3]. The appearance of opportunistic pathogens like *Pseudomonas aeruginosa* and *Staphylococcus aureus* could develop when this barrier is destroyed and provoke an inflammatory reaction. The consequent infection induces local and systemic immune responses, which are manifested in objective alterations in inflammatory and hematological parameters [4,5].

Inflammation is a key factor in the mechanism and pathogenesis of otitis externa. In response to pro-inflammatory cytokines, in particular interleukin-6 (IL-6), acute-phase reactants are produced at a high rate by the liver, especially C-reactive protein (CRP) [6]. CRP is a popular sensitive biomarker in the detection and monitoring of inflammatory diseases such as bacterial infections. Equally, erythrocyte sedimentation rate (ESR) is a non-specific inflammatory marker, which indicates elevated plasma protein levels, especially fibrinogen, in case of inflammatory conditions. High CRP and ESR levels have been documented in numerous infectious diseases and could be of useful diagnostic and prognostic data in childhood otitis externa [7].

Besides the biochemical markers, the hematological indices provide valuable information about the immune response of the host to infection. Alterations in the number and differential leukocyte analysis of white blood cell (WBC) are the typical shifts in the bacterial infections. Neutrophilia is normally linked to acute bacterial inflammation since neutrophils are the most important cellular defense against the pathogens entering the body [8]. On the other hand, relative lymphocyte depletion can be a result of redistribution of lymphocytes or a blockage of adaptive immune functions during acute inflammation. It is a hematological alteration that can be readily determined by routine complete blood count (CBC) analysis and is possibly a supportive diagnostic indicator [9].

Recent research has highlighted the significance of combining inflammatory biomarkers with hematological parameters in enhancing the diagnostic accuracy of infectious diseases. A combination of CRP, ESR, and blood cell indexes gives a more detailed picture of the inflammatory status and immune reaction in the case of the affected persons [10]. This combined strategy is especially useful in pediatric patients, as the clinical presentation can be unspecific, and the lab findings can help to detect and treat the illness in time. In addition, the relationship between these biomarkers and microbial etiology can be used to inform specific antimicrobial treatment and decrease the use of antibiotics which may be unnecessary [11].

Microbiological profiling still forms an important part of the assessment of otitis externa. Determination of the causative organisms does not only validate the diagnosis but also gives information about the local epidemiology trends and trends in antibiotic resistance [12]. Most commonly involved bacteria include Pseudomonas aeruginosa and Staphylococcus aureus, but other Gram-negative and Gram-positive bacteria can also be causative agents. These pathogens may be distributed differently according to geographic location, environmental factors, and patient-specific factors, which require geographic studies [13].

Thus, the current research paper seeks to explore the combined inflammatory and hematologic signatures of pediatric otitis externa through assessing CRP, ESR, and blood cell indices in children with the condition and in the healthy population. Moreover, the research aims to determine the most common bacterial isolates that are related to the condition. Through the integration of clinical, biochemical, hematological, and microbiological evaluations, the study will offer in-depth insights into the disease, and also discuss the possible diagnostic usefulness of these indicators in enhancing the treatment of the pediatric otitis externa.

2. Materials and Methods

This case-control study was carried out March 3, 2025 and February 10, 2026 in Al-Habbobi Teaching Hospitals and at the selected outpatient pediatric clinics in Nasiriyah, Iraq. A total of 90 children were recruited, and separated into two groups in which 60 patients were clinically diagnosed to have otitis externa, and 30 children who were apparently healthy and served as controls. Specialist physicians diagnosed otitis externa using clinical features such as ear pain, itching, discharge and tenderness of the external auditory canal as well as otoscopic observation. The study did not include children who had chronic systemic diseases, immunodeficiency, had undergone an antibiotic treatment in the near past, and those with other ear pathologies like otitis media.

About 5 mL of venous blood was taken under aseptic conditions out of an individual. The blood samples were separated into two tubes, one with EDTA tube to perform hematological analysis and another plain tube to separate the serum. Complete blood count (CBC) was performed on the EDTA samples, including white blood cells (WBC), neutrophils, lymphocytes, hemoglobin and platelet counts, with an automated hematology analyzer. Plain tubes were left to clot at room temperature and centrifugation at 3000 rpm in 10 min to get serum that was isolated and stored at −20 °C until biochemical analysis.

The level of serum C-reactive protein (CRP) was measured by a high-sensitivity immunoturbidimetric technique, and the erythrocyte sedimentation rate (ESR) was measured by the standard Westergren technique. All assays were carried out as per the instructions of the manufacturers and standard laboratory procedures.

In order to perform the microbiological analysis, sterile cotton swabs were used to collect ear swab samples aseptically at the external auditory canal of the patients. The samples were then directly taken to the laboratory and cultured on blood agar plate, MacConkey agar plate, and chocolate agar plate. The plates inoculated were incubated at 37 o C, aerobically over 24-48 hours. The identification of the bacterial isolates was through colony morphology, Gram staining and the standard biochemical tests. Mixed growth was registered in cases where two or more bacterial species were seen to be isolated on the same sample.

Statistical analysis:

The Statistical Package of the Social Sciences (SPSS), version 26 (IBM Corp., Armonk, NY, USA) was used to conduct statistical analysis. Data were presented in the form of mean and standard deviation (SD). Continuous variables between groups were compared using independent samples t-test, and categorical variables were compared using the chi-square test. Pearson correlation coefficient was used to assess relationships between inflammatory and hematological parameters. A p-value of less than 0.05 was considered statistically significant.

Ethical approval:

Parents or guardians of all the participants gave informed consent in writing and the study was carried out in line with the Declaration of Helsinki.

3. Results

Sociodemographic and Clinical Characteristics of Pediatric Otitis Externa Patients and Controls

The comparisons revealed that there were no significant differences between the patients and controls in terms of age (P = 0.641), sex distribution (P = 0.768), and BMI (P = 0.412), thus showing similar baseline characteristics of the two groups. On the other hand, swimming exposure was also much more among patients than among controls (65.0% vs. 36.7, P = 0.012). On the same note, poor ear hygiene was higher among patients than

controls (46.7% vs. 23.3, P = 0.031) indicating that these factors play a significant role in the development of otitis externa as shown in the table 1.

Table 1. Baseline comparison of demographic variables and risk factors between study groups

Variable	Patients (n=60)	Control (n=30)	P-value
Age (years)	8.2 ± 2.9	7.9 ± 2.7	0.641
Male (%)	34 (56.7%)	16 (53.3%)	0.768
BMI (kg/m²)	17.8 ± 2.4	17.3 ± 2.1	0.412
Swimming exposure (%)	39 (65.0%)	11 (36.7%)	0.012*
Ear hygiene (poor) (%)	28 (46.7%)	7 (23.3%)	0.031*

Hematological Parameters in Pediatric Otitis Externa Patients and Controls

These findings indicated that the total white blood cell count and neutrophil percentage in patients increased significantly as compared to controls (P < 0.001) whereas lymphocyte percentage was significantly reduced in patients (P < 0.001). Conversely, there were no significant differences in the level of hemoglobin (P = 0.118) or the number of platelets (P = 0.089) suggesting that hematological changes were more a result of inflammatory response than overall hematopoietic changes (Table 2).

Table 2. Comparative analysis of complete blood count indices between study groups

Parameter	Patients (n=60)	Control (n=30)	P-value
WBC (×10⁹/L)	9.8 ± 2.6	7.4 ± 1.9	<0.001*
Neutrophils (%)	64.2 ± 8.7	55.6 ± 7.9	<0.001*
Lymphocytes (%)	27.3 ± 6.5	34.8 ± 7.2	<0.001*
Hemoglobin (g/dL)	12.1 ± 1.2	12.5 ± 1.1	0.118
Platelets (×10⁹/L)	312 ± 74	285 ± 68	0.089

Inflammatory Biomarkers in Pediatric Otitis Externa Patients and Controls

The results in the table 3, showed that the levels of inflammatory biomarkers were significantly higher in patients than in controls. CRP and ESR levels were also significantly increased in patients (P < 0.001), indicating an active inflammatory process related to otitis externa and justifying their diagnostic usefulness as a factor distinguishing between infected and healthy patients.

Table 3. Assessment of CRP and ESR levels as indicators of systemic inflammation

Parameter	Patients (n=60)	Control (n=30)	P-value
CRP (mg/L)	9.6 ± 3.8	3.2 ± 1.5	<0.001*
ESR (mm/hr)	22.4 ± 8.1	10.6 ± 4.3	<0.001*

Distribution of Bacterial Isolates in Pediatric Otitis Externa Patients

Microbiological investigation revealed that Pseudomonas aeruginosa was the commonest organism to be isolated (35.0%), and the second most common was Staphylococcus aureus (28.3%). Proteus spp. were also other isolates. Klebsiella pneumoniae (10.0%), Escherichia coli (8.3%), and Klebsiella pneumoniae (13.3%), with mixed growth exhibited a low percentage (5.0%). These results suggest the major role of Gram-negative microorganisms, especially P. aeruginosa, in pediatric otitis externa (Table 4).

Table 4. Frequency and percentage of microorganisms isolated from ear swabs

Bacterial Isolate	Frequency (n)	Percentage (%)
Pseudomonas aeruginosa	21	35.0%
Staphylococcus aureus	17	28.3%
Proteus spp.	8	13.3%
Klebsiella pneumoniae	6	10.0%
Escherichia coli	5	8.3%
Mixed growth	3	5.0%

Correlation Between Inflammatory and Hematological Parameters in Patients

A correlation analysis in the table 5, revealed that CRP has significant positive correlations with WBC count and neutrophil percentage ($P < 0.01$) and ESR and these hematological parameters. CRP on the other hand showed a negative correlation with lymphocyte percentage ($P < 0.05$) which is an indication of a tendency towards the innate immune response during infection. These findings indicate that there is a significant association between inflammatory indicators and hematological indicators in pediatric otitis externa.

Table 5. Association between CRP, ESR, and blood cell indices in pediatric otitis externa

Variables	r-value	P-value
CRP vs WBC	0.42	0.001*
CRP vs Neutrophils	0.38	0.003*
ESR vs WBC	0.36	0.005*
ESR vs Neutrophils	0.34	0.007*
CRP vs Lymphocytes	-0.31	0.012*

4. Discussion

The current research showed no significant differences in the baseline features of age, sex ratio and BMI of patients with pediatric otitis externa and healthy controls which means that there is an appropriate matching of the two groups and reducing the chances of confounding factors. Nevertheless, an even greater percentage of patients reported a history of exposure to swimming and poor ear hygiene, which are already well-known risk factors of otitis externa because of higher levels of moisture and disturbed ear canal barrier [14]. These results are in line with other prior epidemiological studies which have found exposure to water and poor hygiene as significant factors in causing external ear infections among children [15].

Hematologic testing showed that patients had high leukocytosis with an increase in total white blood cell (WBC) count and neutrophil percentage and a decrease in lymphocyte percentage. This trend is a symptom of severe bacterial inflammation reaction, with neutrophils being the first line of defense against pathogenic invaders [16]. The fact that there is no significant variation in the number of hemoglobin and platelets indicates that the infection is localized and it is not linked with the system-wide changes in hematology. These results are consistent with those studies that have reported elevated neutrophil dominance during acute bacterial infections, such as in otitis externa [17]. Nonetheless, other studies have indicated slight alterations in the hematological parameters of mild cases of otitis externa [18], which can be explained by the variation in the severity of the disease, duration of infection, or the time of sample collection.

An active inflammatory process was also observed with significant elevation of inflammatory biomarkers (CRP and ESR) in patients relative to controls. CRP is a sensitive protein of acute-phase synthesis in the liver in reaction to cytokines like IL-6, whereas ESR shows the existence of systemic inflammation and raised fibrinogen [19]. The significant

increase in these markers justifies their diagnostic usefulness in the differentiation of infected and non-infected people. These results are in line with the past reports of high levels of CRP and ESR in bacterial infections of the ear and upper respiratory tract [20]. Other studies on the other hand have proposed that CRP may not necessarily be high in localized infections [21], which might be attributed to differences in host immune reaction or early infection.

The microbiological results showed that the most common pathogen was Pseudomonas aeruginosa, and then Staphylococcus aureus, and this is in line with the known etiology of otitis externa [22]. Majority of P. aeruginosa is explained by its capacity to grow in wet conditions and adherent properties to epithelial lining of the external auditory canal. S. aureus also is a frequent colonizer of the skin and may lead to infection in the case of the protection barrier being weakened. The identification of other bacteria, including Proteus spp., Klebsiella pneumoniae, and Escherichia coli, indicates that there might be contamination or lack of hygiene in the environment. This observation agrees with various microbiological studies that documented similar distributions of bacteria in pediatric otitis externa [23]. Nevertheless, there are also studies that identified a greater presence of fungal pathogens [24], which can be attributed to the climate conditions, abuse of antibiotics, or extended contact with moisture.

The correlation analysis also revealed substantial correlations between inflammatory and hematological markers. The positive relationships between CRP and WBC along with the neutrophil percentage suggest that the systemic inflammatory markers are strongly associated with cellular immune responses [25]. Correspondingly, ESR was positively correlated with WBC and neutrophils, which underlines its effectiveness as a measure of the inflammatory burden. Conversely, the negative correlation between CRP and lymphocytes indicates that it becomes activated (shifted) toward innate immune activation and away of the adaptive immune response in case of acute infection [26]. These results are in agreement with earlier research that has shown that integrated inflammatory and hematological markers can be used to evaluate the severity of infection [27].

Limitations:

This may be explained by differences in sample size, age distribution, severity of infection, and environmental conditions like humidity and water exposure among the present findings and some of the past reports. Moreover, methodological discrepancies, such as laboratory procedures and diagnostic criteria can also result in differences in reported outcomes. Even with these differences, the general trend in this study is towards the use of integrated inflammatory and hematological profiling as an effective method in the diagnosis and assessment of pediatric otitis externa.

5. Conclusion

In conclusion, the current paper illustrates that pediatric otitis externa is related to critical changes in inflammatory and hematological indicators, as well as to typical bacterial profiles. The combination of CRP, ESR and blood cell indexes gives a dependable as well as clinically useful model to enhance diagnostic accuracy and management.

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