IMMUNOLOGICAL CRITERIA FOR PREDICTING THE EFFICACY OF THERAPY IN PATIENTS WITH BLASTOCYSTOSIS

Bodnia I.P.

Kharkiv National Medical University, Kharkiv, Ukraine

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ABSTRACT

Background. *Blastocystis* is one of the most common intestinal protists in humans; its clinical significance is controversial, and no generally accepted eradication strategy exists. Infection outcomes are thought to depend on parasite subtypes, gut microbiota, and host immunity.

Aim. To determine the prognostic value of immunological parameters for the efficacy of therapy in patients with blastocystosis and to develop a prognostic algorithm on this basis.

Materials and Methods. Pre-treatment immunological parameters of 300 patients with blastocystosis aged 15–54 years who received complex therapy were analyzed retrospectively. Based on the regression of clinical symptoms one month after the start of treatment, patients were divided into Group A with a good therapeutic effect (regression ≥31%; *n*=162) and Group B with an insufficient effect (≤30%; *n*=138). Prognostic coefficients for parameter gradations and informativeness (*J*) were calculated using the heterogeneous sequential Wald–Genkin procedure; the prognostic threshold at the 95% reliability level was ±13. The study was conducted using SPSS Statistics 29 (IBM, USA) within the author's dissertation (implementation period 2021–2026).

Research Ethics. The study was conducted in accordance with the World Medical Association Declaration of Helsinki (1964–2024). All patients (for minors, their parents or legal representatives) signed informed consent to participate in the study. The research design was approved by the Ethics and Bioethics Commission of Kharkiv National Medical University (Protocol No.5 of May 05, 2021).

Results. High prognostic informativeness was found for the levels of immunoglobulin G (IgG; *J*=3.50), immunoglobulin A (IgA; *J*=2.53) and immunoglobulin M (IgM; *J*=2.12) and the proportion of $CD8^+$ lymphocytes (*J*=1.50); moderate – for active T lymphocytes (*J*=0.87), $CD19^+$ lymphocytes (*J*=0.79) and circulating immune complexes (*J*=0.73); low – for immunoglobulin E (*J*=0.42) and $CD3^+$ lymphocytes (*J*=0.39). $CD4^+$ lymphocytes (*J*=0.22) and the immunoregulatory index (*J*=0.06) had no prognostic value. A good effect was predicted by IgG ≥21 g/L, IgA ≥8.1 g/L and IgM ≥1.7 g/L. On the training sample (*n*=300), the algorithm gave 78% correct, 18% indeterminate and 4% erroneous predictions.

Conclusions. The aim of the study was achieved: an algorithm for predicting the efficacy of therapy in blastocystosis based on immunological parameters was developed; humoral immunity parameters were the most informative. The proportion of erroneous predictions did not exceed the preset 5% level; the algorithm requires validation on an independent sample.

Keywords: *infectious and parasitic diseases, Blastocystis infections, immunoglobulins, T-lymphocyte subsets, treatment outcome.*

Abbreviations

CD3+ – lymphocytes expressing Cluster of Differentiation 3 (T lymphocytes).

CD4+ – lymphocytes expressing Cluster of Differentiation 4 (T helper cells).

CD8+ – lymphocytes expressing Cluster of Differentiation 8 (cytotoxic T lymphocytes).

CD19+ – lymphocytes expressing Cluster of Differentiation 19 (B lymphocytes).

CIC – Circulating Immune Complexes.

IgA – Immunoglobulin A.

IgE – Immunoglobulin E.

IgG – Immunoglobulin G.

IgM – Immunoglobulin M.

IRI – ImmunoRegulatory Index (CD4+/CD8+ ratio).

Corresponding Author:

Bodnia Igor P. – Candidate of Medical Sciences, Associate Professor of the Department of Infectious Diseases, Paediatric Infectious Diseases and Phthisiology, Kharkiv National Medical University, Ukraine.

✉ 4, Nauky ave., Kharkiv, 61022, Ukraine.

E-mail: bigor.bodnya@gmail.com

PC – Prognostic Coefficient.

ST – SubType.

Introduction

Blastocystis is one of the most common eukaryotic microorganisms of the human intestine. The number of people colonized with *Blastocystis* worldwide is estimated to exceed one billion, and the prevalence, as determined by DNA-based methods, ranges from about 50% in healthy adults in highly industrialized countries to 100% in Senegalese children [1]. The clinical significance of *Blastocystis* remains controversial: colonization is often asymptomatic, whereas in other cases it is associated with abdominal pain, diarrhea, irritable bowel syndrome, and urticaria [2].

Blastocystis is also detected in immunocompromised patients. In Tehran, it was the most frequent intestinal parasite in patients with cancer (22.3%) and with primary immunodeficiency (16.2%) [3]. In Italy, its prevalence among patients infected with the human immunodeficiency virus and receiving antiretroviral therapy was 25%, and colonization was not associated with CD4+ cell counts [4]. At the same time, Sarzhanov F. et al. (2021) [5] detected *Blastocystis* less often in immunodeficient than in immunocompetent patients with diarrhea (12.7% vs. 21.8%).

Blastocystis is genetically heterogeneous. Based on the small subunit ribosomal RNA gene, up to 44 subtypes (ST1–ST17, ST21, ST23–ST48) have been described; about 90% of human isolates belong to ST1–ST4 [6; 7], ten more subtypes (ST5–ST10, ST12, ST14, ST16, ST23) have been found in both humans and animals, and ST35 and ST41 only in humans [6]. The results of laboratory diagnosis depend on the method used. In a multicenter study in France, the prevalence determined by real-time polymerase chain reaction was 18.1%, whereas the sensitivity of direct light microscopy of fecal smears was only 45.8% [8]. In another study, the sensitivity of microscopy of permanently stained smears was 48%, and that of polymerase chain reaction was 94%; xenic culture was more sensitive than microscopy but required incubation for up to a week [9].

In pigs, *Blastocystis* is found mainly in the large intestine, in luminal material or near epithelial cells, without signs of attachment or invasion, which agrees with most observations in humans [10]. Nevertheless, the parasite interacts with the host immune system. Nagel R. et al. (2015) [11] found serum IgG antibodies to several *Blastocystis* proteins, which were detected more often in patients with irritable bowel syndrome, and lower serum IgA levels in *Blastocystis* carriers than in non-carriers. Cysteine proteases of *Blastocystis* induce interleukin-8 production by human colonic epithelial cells in a nuclear factor κB-dependent manner [12]. *Blastocystis* can degrade IgA and antimicrobial peptides and induce T helper type 1 and type 17 responses; and these effects differ among subtypes [13]. On the other hand, colonized individuals have lower fecal IgA and calprotectin levels, which suggests an anti-inflammatory effect of Blastocystis on the intestinal environment [14].

There is no known effective strategy for eradicating *Blastocystis*, and randomized controlled treatment trials are practically lacking [1]. Metronidazole remains the drug of first choice; however, treatment failures, resistance, reinfection, and adverse effects have been reported, and trimethoprim-sulfamethoxazole, paromomycin, and other nitroimidazoles are used as alternatives [2; 15]. The variability in the outcomes of *Blastocystis* infection is attributed to differences in subtypes, gut microbiota and the host immune response [2].

Previously, in the same cohort of patients, an algorithm for predicting the therapy efficacy on the basis of clinical symptoms was developed [16], and differences in the structure of correlations between immunological parameters in patients with different therapeutic effects were shown [17]. However, the prognostic value of individual immunological parameters for the efficacy of therapy in blastocystosis remains insufficiently studied.

The aim of the study was to determine the prognostic value of immunological parameters for the efficacy of therapy in patients with blastocystosis and to develop a prognostic algorithm based on this.

Materials and Methods

A retrospective analysis of immunological parameters was performed in 300 patients with blastocystosis aged 15–54 years who received complex therapy. The patients were examined and treated at the Department of Infectious Diseases, Pediatric Infectious Diseases and Phthisiology of Kharkiv National Medical University, the Laboratory of New and Poorly Studied Infectious Diseases of the I.I. Mechnikov Institute of Microbiology and Immunology of the National Academy of Medical Sciences of Ukraine, and the Private Office of Medical Parasitology. The diagnosis of blastocystosis was established by coproscopic examination. The complex therapy included co-trimoxazole, secnidazole, or nifuratel, administered

under a blind study design using a prognostic approach.

Immunological parameters were determined before the start of therapy They included the serum levels of IgG, IgA, and IgM (g/L), IgE (IU/mL), and CIC (IU/mL), the proportions of CD3+, CD4+, CD8+, and CD19+ lymphocytes and active T lymphocytes (%), and IRI. The parameters were determined by the medical laboratory "Analityka" (license No.554074 dated May 20, 2010, attestation certificate No.100–4203/2011 dated October 14, 2011).

The criterion of therapeutic efficacy was the overall degree of regression of clinical symptoms one month after the start of treatment, calculated as the percentage reduction in the total clinical symptom score from baseline to the follow-up assessment. To substantiate the division of patients into groups with a good and an insufficient therapeutic effect, the distribution of patients by the degree of regression of clinical symptoms was analyzed beforehand. The distribution was not normal and was bimodal: the mode of its first part was at 0% regression, and that of the second part was shifted to the right (40–60%). The dividing point between the two parts was 30–31% regression. Therefore, Group A (good therapeutic effect) included 162 patients with regression of clinical symptoms ≥31%, and Group B (insufficient therapeutic effect) included 138 patients with regression ≤30%.

The prognostic algorithm was developed using the heterogeneous sequential Wald–Genkin procedure described by Gubler E.V. (1978) [18]. For each gradation of a parameter, the prognostic coefficient was calculated using the following formula:

$$PC = 10 \times \lg\left[\frac{P\left(\frac{x_i}{A}\right)}{P\left(\frac{x_i}{B}\right)}\right] \quad (1),$$

where: PC – prognostic coefficient of gradation x_i; $P(x_i/A)$ and $P(x_i/B)$ – frequencies of gradation x_i in Group A and Group B, respectively. Positive PC values indicate a good therapeutic effect; negative values indicate an insufficient effect.

The informativeness of a gradation was assessed with the Kullback measure, and the overall informativeness of a parameter was the sum of the informativeness of its gradations:

$$I(x_i) = 0.5 \times PC \times \left[P\left(\frac{x_i}{A}\right) - P\left(\frac{x_i}{B}\right)\right] \quad (2);$$

$$J = \sum I(x_i) \quad (3),$$

where: $I(x_i)$ – informativeness of gradation xi; J – overall informativeness of the parameter.

Parameters with $J \geq 1.00$ were considered highly informative, with J=[0.50–0.99] moderately informative, and with J=[0.25–0.49] low-informative; parameters with J<0.25 were considered to have no prognostic value.

The prognosis was determined by algebraic summation of the PC values for a patient's parameters, in descending order of their informativeness, until the prognostic threshold was reached. For the 95% reliability level ($\alpha=\beta=0.05$), the threshold was calculated using the following formula:

$$\pm 10 \times \lg\left[\frac{1-\beta}{\alpha}\right] = \pm 10 \times \lg\left(\frac{0.95}{0.05}\right) \approx \pm 13 \quad (4),$$

where: α and β – permissible probabilities of erroneous predictions.

A sum of PC values ≥+13 predicted a good therapeutic effect, and a sum ≤−13 predicted an insufficient effect; if the threshold was not reached after all parameters had been summed, the prediction was considered indeterminate. The algorithm was tested on the same 300-patient sample (training set). The calculations were performed using SPSS Statistics 29 (IBM, USA).

Research Ethics

The study was conducted in accordance with the principles of the World Medical Association Declaration of Helsinki (1964–2024), Article 28 of the Constitution of Ukraine, Article 43 of the Law of Ukraine "Fundamentals of the Legislation of Ukraine on Health Care" (1992) and the Order of the Ministry of Health of Ukraine No.690 of September 23, 2009. All patients (and parents or legal representatives of patients under 18 years of age) signed informed consent to participate in the study. The study protocol was approved by the Ethics and Bioethics Commission of Kharkiv National Medical University (Protocol No.5 dated May 05, 2021).

Results

The prognostic informativeness of immunological parameters and the PC values of their gradations are presented in the *Table*. High prognostic informativeness was found for the levels of IgG (J=3.50), IgA (J=2.53), and IgM (J=2.12), and for the proportion of CD8+ lymphocytes (J=1.50). The proportions of active T lymphocytes (J=0.87), and CD19+ lymphocytes (J=0.79) and the CIC

Table. Prognostic value of immunological parameters

Parameter	Gradation	PC	*J*
IgG, g/L	≤20	−3.4	3.50
	≥21	+11.1	
IgA, g/L	≤4.0	−5.1	2.53
	4.1–8.0	−2.3	
	8.1–12.0	+7.0	
	≥12.1	+8.6	
IgM, g/L	≤1.2	−2.0	2.12
	1.3–1.6	−4.0	
	1.7–2.0	+2.8	
	≥2.1	+9.0	
$CD8^+$ lymphocytes, %	≤19	+1.8	1.50
	20–25	−5.2	
	≥26	+3.8	
Active T lymphocytes, %	≤15	+2.0	0.87
	≥16	−4.0	
$CD19^+$ lymphocytes, %	≤30	+3.2	0.79
	≥31	−2.3	
CIC, IU/mL	≤70	+3.8	0.73
	≥71	−1.5	
IgE, IU/mL	≤200	−1.0	0.42
	≥201	+4.6	
$CD3^+$ lymphocytes, %	≤30	−8.0	0.39
	31–40	+1.8	
	41–50	+2.6	
	≥51	−0.7	
$CD4^+$ lymphocytes, %	≤30	−2.3	0.22
	≥31	+1.0	
IRI	≤1.5	−0.3	0.06
	≥1.6	+1.8	

Notes: PC – prognostic coefficient; *J* – informativeness of the parameter; "+" – PC values indicating a good therapeutic effect; "−" – PC values indicating an insufficient therapeutic effect; $CD3^+$, $CD4^+$, $CD8^+$, $CD19^+$ – lymphocytes expressing Cluster of Differentiation 3, 4, 8, 19; CIC – circulating immune complexes; IgA, IgE, IgG, IgM – immunoglobulins A, E, G, M; IRI – immunoregulatory index ($CD4^+/CD8^+$ ratio).

level (*J*=0.73) had moderate informativeness, whereas the IgE level (*J*=0.42) and the proportion of CD3+ lymphocytes (*J*=0.39) had low informativeness. The proportion of CD4+ lymphocytes (*J*=0.22) and IRI (*J*=0.06) had no prognostic value.

According to the PC values, the strongest predictors of a good therapeutic effect were IgG ≥21 g/L (PC=+11.1), IgM ≥2.1 g/L (PC=+9.0) and IgA ≥12.1 g/L (PC=+8.6), and those of an insufficient effect were a proportion of CD3+ lymphocytes ≤30% (PC=−8.0), a proportion of CD8+ lymphocytes of 20–25% (PC=−5.2) and IgA ≤4.0 g/L (PC=−5.1). The association between the proportion of CD8+ lymphocytes and the therapeutic effect was non-linear: both values ≤19% and ≥26% indicated a good effect.

For example, in a patient with IgG of 22 g/L (PC=+11.1) and IgA of 9.0 g/L (PC=+7.0), the sum after two steps is +18.1, which exceeds the threshold, and a good therapeutic effect is predicted. In a patient with IgG of 18 g/L (PC=−3.4), IgA of 3.5 g/L (PC=−5.1), IgM of 1.4 g/L (PC=−4.0) and a proportion of CD8+ lymphocytes of 22% (PC=−5.2), the threshold is reached at the

fourth step (−17.7), and an insufficient effect is predicted.

Testing the algorithm on the training sample (*n*=300) showed that correct predictions were obtained in 78% of cases, indeterminate in 18%, and erroneous in 4%. Thus, the proportion of erroneous predictions did not exceed the preset 5% level.

Discussion

In this study, humoral immunity parameters had the highest prognostic informativeness: higher levels of IgG, IgA and IgM were associated with a favorable effect of therapy. This agrees with the results of the analysis of the same cohort, in which patients with a good therapeutic effect showed more pronounced antibody production of all classes [17].

The importance of IgA is consistent with published data on the interaction between *Blastocystis* and mucosal immunity. Serum IgA levels in *Blastocystis* carriers were lower than in non-carriers, regardless of symptoms [11]; colonized individuals had lower fecal IgA levels [14]; and *Blastocystis* can degrade IgA [13]. It can therefore be assumed that patients with a high level of IgA production better respond to therapy; in this study, an IgA level ≤8.0 g/L predicted an insufficientresponse, and a level ≥8.1 g/L predicted a good response. However, total serum immunoglobulins rather than *Blastocystis*-specific antibodies were determined, so this assumption requires verification.

Among cellular parameters, the proportion of CD8+ lymphocytes was the most informative, and its association with the therapeutic effect was nonlinear: both low (≤19%) and high (≥26%) values indicated a good effect, whereas intermediate values (20–25%) indicated an insufficient one. This pattern has no clear explanation and needs to be confirmed in an independent sample. The proportion of CD4+ lymphocytes and IRI had no prognostic value. Similarly, *Blastocystis* colonization was not associated with CD4+ cell counts in patients infected with the human immunodeficiency virus [4] or in patients with chronic leukemia; in the latter, gastrointestinal symptoms in infected patients were also not associated with CD4+ cell counts, *Blastocystis*-specific IgA and IgG antibodies or interleukin-8 levels [19].

A high IgE level (≥201 IU/mL) indicated a good therapeutic effect, although this parameter was not very informative. Blastocystis infection is associated with urticaria [2; 15]. Yegit O.O. et al. (2025) [20] found higher total IgE levels in patients with chronic spontaneous urticaria and *Blastocystis* than in healthy carriers; after parasite eradication, remission was more frequent in patients with ST3, who had lower baseline IgE levels than patients with other subtypes. Thus, the association between IgE and the outcome of therapy may depend on the clinical form of the disease and the parasite subtype, which were not assessed in this study.

The heterogeneous sequential Wald–Genkin procedure combines parameters of different types and yields an individual prediction at a preset error level, leaving cases with insufficient information indeterminate. In the same cohort, the algorithm based on clinical symptoms yielded 77% correct, 20% indeterminate, and 3% erroneous predictions [16], which is comparable to the results of the immunological algorithm (78%, 18%, and 4%, respectively). Therefore, combining clinical and immunological predictors into a single algorithm seems promising.

The study has ***limitations***. It was retrospective, and the algorithm was developed and tested on the same sample, which overestimates its accuracy; the proportions of correct and erroneous predictions should be verified on an independent sample. Blastocystis subtypes, which may determine the course of infection and the host immune response [2; 13], were not identified. The efficacy criterion was clinical (symptom regression) and did not take into account the parasitological outcome of therapy.

Conclusions

Using the heterogeneous sequential Wald–Genkin procedure, an algorithm for predicting the efficacy of therapy in patients with blastocystosis based on immunological parameters was developed, thereby achieving the aim of the study.

The levels of immunoglobulins G, A and M and the proportion of cytotoxic T lymphocytes had the highest prognostic informativeness. In contrast, the proportion of T helper cells and the immunoregulatory index had no prognostic value.

On the training sample, the algorithm made correct predictions in most cases, and the proportion of erroneous predictions did not exceed the preset 5% threshold; before clinical use, the algorithm should be validated on an independent patient sample.

Prospects for Further Research

Further research should validate the algorithm on an independent sample of patients, integrate immunological and clinical predictors into a single algorithm, and take into account *Blastocystis* subtypes and the parasitological outcome of therapy.

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Declarations

Conflict of interest is absent.

The author has agreed to the publication of the article under the terms of the Creative Commons BY-NC-SA 4.0 license and the public agreement with publisher of the journal, and to the processing and publication of his personal data.

The author of the manuscript declares that in the process of conducting research, preparing, and editing this manuscript, he did not use any generative artificial intelligence tools or services to perform any of the tasks listed in the Generative Artificial Intelligence Delegation Taxonomy (GAIDeT, 2025).

All stages of the work (from the development of the research concept to the final editing) were performed exclusively by the author, without the involvement of generative artificial intelligence.

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