

# Early and simple laboratory markers of poor outcome in children with inflammatory bowel disease

Katarzyna Zdanowicz\*, Aleksandra Czajkowska, Artur Rycyk, Dariusz M. Lebensztejn, Urszula Daniluk

Department of Pediatrics, Gastroenterology, Hepatology, Nutrition, Allergology and Pulmonology, Medical University of Białystok, Poland

**Submitted:** 26 March 2025; **Accepted:** 11 May 2025

**Online publication:** 23 June 2025

Arch Med Sci

DOI: <https://doi.org/10.5114/aoms/214618>

Copyright © 2025 Termedia & Banach

**\*Corresponding author:**

Katarzyna Zdanowicz  
Department of Pediatrics,  
Gastroenterology,  
Hepatology, Nutrition,  
Allergology and Pulmonology  
Medical University  
of Białystok, Poland  
E-mail: katarzyna.  
zdanowicz@umb.edu.pl

## Abstract

**Introduction:** Personalized medicine in inflammatory bowel disease (IBD) aims to achieve maximum effectiveness through rapid induction and maintenance of remission. To achieve this goal, reliable predictors of disease course are needed. The aim of this study was to identify early markers of IBD's poor course understood as the need for anti-tumor necrosis factor (anti-TNF- $\alpha$ ) treatment.

**Material and methods:** We analyzed the clinical, laboratory, radiological, and endoscopic data of children with IBD. These parameters were assessed at the time of diagnosis (T0) and 8–12 weeks (T1) after the start of induction therapy. The results of patients who did not require anti-TNF- $\alpha$  treatment were compared to children who needed such treatment during the 2-year observation time.

**Results:** 58.14% of patients with Crohn's disease (CD) and 31.71% of patients with ulcerative colitis (UC) required biological therapy. Patients with CD and UC receiving biological therapy, compared with those without, differed in selected clinical and laboratory parameters both at T0 and T1. In multivariate analysis, the risk of anti-TNF- $\alpha$  therapy in patients with CD was associated with the lack of normalization of mean corpuscular volume (MCV) and Pediatric Crohn's Disease Activity Index (PCDAI). In patients with UC, higher albumin levels reduced this risk.

**Conclusions:** In children with IBD, disease activity and concentrations of selected biochemical parameters assessed within 3 months after diagnosis may be helpful in predicting a poor outcome of CD and UC.

**Key words:** children, predictors, Crohn's disease, biological treatment, ulcerative colitis.

## Introduction

Crohn's disease (CD) and ulcerative colitis (UC) are idiopathic, inflammatory processes predominantly affecting the gastrointestinal tract, recognized as inflammatory bowel disease (IBD). In general, the course of IBD is chronic and lifelong, with episodes of exacerbations and remissions. Approximately 20–30% of children with CD already have complications at the time of initial diagnosis, i.e. structuring and/or penetrating disease [1]. Similarly, the course of UC in children is more severe compared to adult patients with more frequent exacerbations, hospitalizations and the need for colectomy [2]. 10% of all CD patients and 15–20% of all

UC cases are particularly at risk of an unfavorable outcome due to long-term exposure to pathogenic factors such as malnutrition, anorexia, and chronic inflammation [2, 3]. The goal of treating children with IBD is to achieve rapid and sustained remission, cure mucosal lesions, ensure quality of life, and avoid adverse drug reactions. For this reason, patients with pediatric IBD require an individualized approach based on reliable predictors of good and poor treatment outcomes. A number of clinical, laboratory, and endoscopic parameters are being analyzed for their usefulness in assessing the course of IBD in children. According to current guidelines, the combination of fecal calprotectin (fCal) and C-reactive protein (CRP) is better than fCal alone in the evaluation of children with CD [4]. What is more, fCal assessed at 14 weeks after initiation of biological treatment in children with CD was a predictor of clinical remission and endoscopic healing after 1 year of treatment with infliximab (IFX) [5]. The Pediatric Crohn's Disease Activity Index (PCDAI), as another marker studied, did not predict the need for steroid treatment at week 12 when assessed at disease onset [6].

Treatment regimens for IBD in children have changed significantly over the decades. First remission induction therapy in UC depends on disease activity and includes 5-aminosalicylic acid (5-ASA) or steroids. On the other hand, in patients with CD, until 2020, the type of treatment to induce remission also depended on the severity of the disease, and now relies on the presence of prognostic factors for poor disease outcome, and when these are absent, exclusive enteral nutrition (EEN) or steroids are used. When remission is achieved, then maintenance treatment is used as 5-ASA in UC or thiopurine in CD as monotherapy or in combination with partial enteral nutrition/exclusion diet. If treatment fails, escalation therapy with monoclonal antibody against tumor necrosis factor  $\alpha$  (anti-TNF- $\alpha$ ) is recommended as the first choice in children. Based on current guidelines, consideration of early anti-TNF- $\alpha$  therapy applies to CD patients with severe growth retardation, failure to achieve remission after induction therapy, deep colonic ulceration, stenotic and penetrating disease at diagnosis, and severe perianal disease. In pediatric patients with UC, biological therapy is dedicated to chronically active or steroid-dependent UC uncontrolled by 5-ASA and thiopurines and a second-line treatment for acute, severe UC [2, 7, 8]. Nowadays, there is a growing body of literature in both children and adults in which anti-TNF- $\alpha$  treatment is more effective when given earlier in the course of the disease ("top-down" strategy) [9–11]. In adult studies, the CALM and REACT trials, which enrolled patients with active CD, found that earlier escalation to anti-TNF- $\alpha$  therapy resulted in fewer major adverse

outcomes than treatment with conventional step-up strategies [12]. Moreover, recent data did not show biomarker utility (CRP and fCal) assessed at diagnosis in treatment choice, and top-down treatment was suggested as a standard of care for patients with newly diagnosed active CD [13]. Despite a growing amount of data on the benefits of a "top-down" strategy, no data on non-invasive prognostic markers for the early use of biological therapy in children with IBD are available.

The purpose of this study was to identify predictors of the progressive course of CD and UC requiring treatment escalation (anti-TNF- $\alpha$ ) at 2-year follow-up, based on clinical, biochemical, and endoscopic parameters assessed at initial diagnosis and during early follow-up. In this study, a progressive course of IBD was defined as one that required a stepwise approach with definitive use of anti-TNF- $\alpha$  during the first 2 consecutive years of disease.

## Material and methods

### Patients' characteristics and study design

We retrospectively analyzed the clinical, laboratory, radiological, and endoscopic data of children with IBD diagnosed and treated at our department between 2015 and 2021. Due to the need for 2-year follow-up of patients in our department, the maximum age of inclusion in the study was 16 years. The diagnosis of IBD was made based on European Society for Pediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) guidelines [14]. For the purpose of the study, two assessment time points were chosen: at the time of diagnosis (T0) and 8–12 weeks after diagnosis and remission-inducing treatment (T1).

Both the biochemical parameters and clinical disease activity were evaluated at two time points. Among laboratory parameters, complete blood count, CRP, erythrocyte sedimentation rate (ESR), albumin, ferritin, and fCal were assessed in all participants according to standard laboratory practice. Normal laboratory values for selected parameters were: WBC  $4\text{--}10 \times 10^9/\text{l}$ , neutrophil count  $1500\text{--}7000 \times 10^9/\text{l}$ , Hb  $12\text{--}15 \text{ g/dl}$ , MCV  $> 75 \text{ fl}$ , PLT  $150\text{--}450 \times 10^9/\text{l}$ , CRP  $< 5 \text{ mg/dl}$ , ESR  $< 20 \text{ mm/h}$ , albumin  $> 3.5 \text{ g/dl}$ , ferritin  $> 30 \text{ mg/dl}$  and fCal  $< 200 \mu\text{g/g}$ .

Disease activity was assessed according to the PCDAI in children with CD and defined as: remission  $< 10$  points, mild disease  $10\text{--}27.5$  points, moderate disease  $30\text{--}37.5$  points, and severe disease  $> 40$  points. The Pediatric Ulcerative Colitis Activity Index (PUCAI) was used in children with UC and rated as: remission ( $< 10$  points), mild ( $10\text{--}34$  points), moderate ( $35\text{--}64$  points) or severe ( $> 64$  points) [15–17].

Data obtained during colonoscopy, which was performed only at the time of diagnosis (T0), were also used for analysis. The phenotype of CD and UC was assessed using the Paris classification. In UC it was assessed as: E1 – proctitis, E2 – distal to splenic flexure colitis, E3 – extensive, distal to hepatic flexure and E4 – pancolitis [18]. CD type was evaluated as follows: age at diagnosis (A), disease location (L), disease behavior (B) and growth retardation (G) [9]. The Mayo Endoscopic Scale was used for UC children assessed as: 0 – normal colonic mucosa, 1 – erythema, decreased vascular pattern, mild friability, 2 – marked erythema, erosions, no vascular pattern, friability, 3 – ulceration, spontaneous bleeding [15, 19]. Endoscopic assessment of CD activity was performed using the Simple Endoscopic Scale for CD (SES-CD), which evaluates the size of ulcers, the ulcerated surface, the endoscopic extension, and stenosis, with each item being scored by segment on a scale from zero to three. Patients with active moderate to severe forms of the disease unresponsive to conventional treatment were eligible for biological therapy. Patients who developed side effects during conventional treatment were deemed eligible for biologic treatment after other therapeutic options were exhausted. Once the diagnosis was made, the patients were treated according to current recommendations for that time [2, 7, 8, 20, 21].

For the next 2 years, patients were followed up at the same medical center where the initial diagnosis was made. The entire cohort was then divided into two groups according to the course of the disease, i.e. Group I with stable disease without intensification of therapy for two-year follow-up and Group II with progressive complications requiring biological drugs (anti-TNF- $\alpha$ ) during 2-year follow-up. Children diagnosed with IBD received appropriate induction treatment, and in UC it was 5-ASA in combination ( $n = 32$ ) or without steroids, and in CD it was exclusive enteral nutrition (EEN) with ( $n = 10$ ) or without steroids. In Group II all outcomes analyzed at T1 were taken before the initiation of biological therapy. Exclusion criteria included other autoimmune comorbidities, perianal lesions (fistula or abscess) in CD cases at the time of diagnosis, as well as parental and patient noncompliance with medication, changing the residence, and significant data gaps (Supplementary Figure S1).

### Statistical analysis

Statistical tests, calculations and graphics were performed using Statistica software. Continuous variables were summarized as median (range) and compared using the Mann-Whitney  $U$  test; categorical variables were presented as number and

percentage and compared using the  $\chi^2$  test. Both tests involved comparing patients in Groups I and II at the same time point (T0 or T1). The paired Wilcoxon rank sum test was used to assess statistical differences within the same groups at T0 and T1. A paired Wilcoxon rank sum test was also used to compare the effect sizes ( $R$ ) of different variables. Interpretation values for  $R$  were 0.1 and  $< 0.3$  as a small effect,  $> 0.3$  and  $< 0.5$  as a moderate effect, and  $\geq 0.5$  as a large effect. The diagnostic value of biomarker concentrations was estimated using receiver operating characteristic (ROC) curve analysis. Cut-off values were selected to calculate sensitivity, specificity, and accuracy of indicators based on the maximization criterion of Youden's  $J$  statistic. Spearman's correlation test was used to analyze the correlations between variables assessed at T1. Odds ratio (OR) and 95% confidence intervals (95% CI) for factors associated with biological treatment were calculated using both univariate and multivariate logistic regression. Following the rule of 10 per factor in the multivariate regression analysis, power was sufficient to account for 2 variables in patients with UC and 2 variables in patients with CD. All candidate variables were initially evaluated using univariate logistic regression. Variables that demonstrated statistical significance were subsequently entered into a multivariable logistic regression model. A significant area under the curve (AUC) value for the model was  $> 0.7$ .  $p < 0.05$  was considered statistically significant.

### Ethical consideration

The study protocol was approved by the Local Ethics Committee under the registration number R-I-002/308/2014. All methods were carried out in accordance with relevant guidelines and regulations.

### Results

Between 2015 and 2021, the total number of IBD diagnoses in our department was 148, including 56 children with CD and 92 children with UC. Twelve patients did not meet the inclusion criteria for the study. The demographic and clinical characteristics of the study groups are summarized in Supplementary Table S1.

Ultimately, 54 children with CD (median age: 14 years, males: 59.26%) and 82 children with UC (median age: 14 years, males: 43.9%) were included in the study (Supplementary Figure S1). Almost half of children with CD (48.15%) received anti-TNF- $\alpha$  therapy including infliximab (IFX) or adalimumab (ADA) compared to one third of children with UC treated with IFX (31.71%). The median time from diagnosis to initiation of biolog-

ical treatment was 6 months in CD cases and 8 months in UC cases.

### Patients with CD

#### At the time of diagnosis (T0)

The demographic, clinical, laboratory, and endoscopic data of Groups I and II are shown in Table I. The groups did not differ in terms of BMI, while discrepancies in the values of clinical, laboratory, and endoscopic parameters were noted at T0. Group I consisted mainly of boys, and the patients were older than those in Group II. Mild CD activity assessed by PCDAI was more frequently observed in Group I (71.42% vs. 34.62%,  $p = 0.007$ ), while

severe activity was more frequently observed in the group of patients who received biologic treatment during the 2-year follow-up (50.00% vs. 14.29%,  $p = 0.005$ ). At the time of diagnosis, patients from Group II had higher ESR, PLT, PLT/albumin ratio, PCDAI, and SES-CD and lower Hb and MCV compared to Group I.  $PLT > 450 \times 10^9/l$ ,  $Hb < 12 \text{ g/dl}$  and  $MCV < 75 \text{ fl}$  were observed in more children in Group II than in Group I (Table I). In addition, children with ileocecal localization of disease (L3) significantly often required anti-TNF- $\alpha$  treatment during the 2 consecutive years (50.00% vs. 14.30%,  $p = 0.004$ ). Induction treatment and results of other laboratory and radiological findings were comparable in both groups (Table I).

**Table I.** Comparison of demographic parameters and selected clinical parameters at the time of diagnosis of CD between the group not requiring biological treatment (Group I) and the group requiring such treatment (Group II) during 2 years of follow-up

Parameter	Group I (n = 28)	Group II (n = 26)	P-value
T0			
Age [years] (median, range)	15 (9–16)	14 (6–16)	0.04
Male n (%)	21 (75.0)	11 (42.31)	0.01
BMI [pc] (median, range)	29 (1–80)	19 (1–87)	0.60
Growth G1/G0 n (%)	5 (17.90)/23 (82.1)	8 (30.77)/18 (69.23)	0.27
PCDAI (median, range)	22.5 (10.0–55.0)	40.0 (10.0–65.0)	0.01
IBD activity			
Remission n (%)	0 (0.0)	0 (0.0)	NA
Mild n (%)	20 (71.42)	9 (34.62)	0.007
Moderate n (%)	4 (14.29)	4 (15.38)	0.91
Severe n (%)	4 (14.29)	13 (50.00)	0.005
ESR [mm/h] (median, range)	36 (2–68)	46 (6–120)	0.03
ESR $\geq 20 \text{ mm/h}$ n (%)	22 (78.57)	23 (88.46)	0.33
CRP [mg/dl] (median, range)	15.6 (0.6–124.0)	24.5 (1.8–342.0)	0.08
CRP $> 5 \text{ mg/dl}$ n (%)	20 (71.43)	21 (80.77)	0.42
WBC [ $\times 10^9/l$ ] (median, range)	7.4 (4.0–14.1)	8.9 (5.8–14.9)	0.67
WBC $> 10 \times 10^9/l$ n (%)	10 (35.71)	10 (38.46)	0.83
Neutrophil count [ $\times 10^9/l$ ] (median, range)	4.9 (2.0–10.9)	5.7 (3.7–11.3)	0.79
Neutrophil count $> 7 \times 10^9/l$ n (%)	9 (32.14)	8 (30.77)	0.91
PLT [ $\times 10^9/l$ ] (median, range)	335 (160–624)	462 (309–756)	0.03
PLT $> 450 \times 10^9/l$ n (%)	6 (21.43)	14 (53.85)	0.01
Hb [g/dl] (median, range)	12.5 (9.6–15.0)	11.1 (8.5–14.2)	$< 0.001$
Hb $< 12 \text{ g/dl}$ n (%)	10 (35.71)	17 (65.38)	0.03
MCV [fl] (median, range)	78.6 (64.4–83.6)	69.4 (62.7–82.0)	0.001
MCV $< 75 \text{ fl}$ n (%)	8 (28.57)	17 (65.38)	0.007
Ferritin [ $\mu\text{g/l}$ ] (median, range)	45.2 (5.3–200.3)	47.9 (12.5–182.0)	0.45
Ferritin $< 30 \text{ mg/dl}$ n (%)	12 (42.86)	10 (38.46)	0.74
Albumin [g/dl] (median, range)	4.15 (3.35–5.07)	3.97 (3.05–4.50)	0.08
Albumin $< 3.5 \text{ g/dl}$ n (%)	3 (10.71)	7 (26.92)	0.13
PLT/albumin ratio (median, range)	81.77 (31.56–186.27)	117.97 (72.54–223.23)	0.02
fCal [ $\mu\text{g/g}$ ] (median, range)	1864 (693–3479)	2280 (366–3865)	0.92

Table I. Cont.

Parameter	Group I (n = 28)	Group II (n = 26)	P-value
fCal > 200 µg/g n (%)	28 (100.0)	26 (100.0)	NA
SES-CD (median, range)	7 (1–31)	12(4–25)	0.008
Location L1/L2/L3 n (%)	17 (60.7)/7 (25.0)/ 4 (14.30)	11 (42.31)/2 (7.69)/ 13 (50.00)	0.18/0.09/ 0.004
Behavior B1/B2 n (%)	16 (57.10)/12 (42.90)	13 (50.0)/13 (50.00)	0.60
Length of inflammatory lesions/stenosis on MRI [mm] (median, range)	50 (0–150)	70 (0–210)	0.31
Thickness of the small bowel wall on MRI [mm] (median, range)	5.5 (3–10)	7 (2–10)	0.06
Induction treatment:			
EEN only n (%)	25 (89.3)	19 (73.08)	0.13
Steroids (+/- EEN) n (%)	3 (10.7)	7 (26.92)	0.13
T1			
BMI [pc] (median, range)	21 (1–84)	30 (1–90)	0.60
PCDAI (median, range)	5 (0–25)	20 (0–55)	< 0.001
PCDAI ≥ 10 points n (%)	12 (42.86)	18 (26.23)	0.05
IBD activity			
Remission n (%)	16 (57.14)	8 (30.77)	0.05
Mild n (%)	12 (42.86)	15 (57.69)	0.28
Moderate n (%)	0 (0.0)	0 (0.0)	NA
Severe n (%)	0 (0.0)	3 (11.54)	NA
ESR [mm/h] (median, range)	10 (2–43)	25 (3–70)	< 0.001
ESR ≥ 20 mm/h n (%)	7 (25.00)	14 (53.85)	0.03
CRP [mg/dl] (median, range)	0.8 (0.1–28.0)	6.4 (0.3–43.9)	0.002
CRP > 5 mg/dl n (%)	6 (21.43)	15 (57.69)	0.006
WBC [ $\times 10^9/l$ ] (median, range)	6.7 (3.9–22.9)	8.39 (4.3–16.1)	0.1
WBC > $10 \times 10^9/l$ n (%)	5 (17.86)	6 (23.08)	0.63
Neutrophil count [ $\times 10^9/l$ ] (median, range)	4.2 (1.5–11.7)	5.0 (1.7–10.3)	0.05
Neutrophil count > $7 \times 10^9/l$ n (%)	4 (14.29)	5 (19.23)	0.63
PLT [ $\times 10^9/l$ ] (median, range)	329 (147–687)	399 (228–607)	0.14
PLT > $450 \times 10^9/l$ n (%)	5 (17.86)	10 (38.46)	0.09
Hb [g/dl] (median, range)	13.1 (10.5–15.2)	11.9 (10.1–14.6)	0.007
Hb < 12 g/dl n (%)	8 (28.57)	13 (50.00)	0.01
MCV [fl] (median, range)	77.6 (64.4–83.6)	72.6 (67.6–85.7)	0.005
MCV < 75 fl n (%)	7 (25.00)	16 (61.54)	0.007
Albumin [g/dl] (median, range)	4.64 (3.76–5.00)	4.15 (3.28–4.93)	< 0.001
Albumin < 3.5 g/dl n (%)	0 (0.0)	1 (3.85)	NA
PLT/albumin ratio (median, range)	67.09 (29.52–182.71)	97.95 (48.51–182.83)	0.02
fCal [µg/g] (median, range)	1391 (60–3288)	2281 (366–3865)	0.06
fCal > 200 µg/g n (%)	25 (89.29)	26 (100.0)	NA
PCDAI ≥ 10 + MCV < 75 fl	1 (3.57)	4 (15.38)	0.13
PCDAI ≥ 10 + CRP > 5 mg/dl	2 (7.14)	4 (15.38)	0.34
MCV < 75 fl + CRP > 5 mg/dl	1 (3.57)	1 (3.85)	0.96
PCDAI ≥ 10 + MCV < 75 fl + CRP > 5 mg/dl	1 (3.57)	9 (34.62)	0.003

BMI – body mass index, pc – percentile, ESR – erythrocyte sedimentation rate, CRP – C-reactive protein, WBC – white blood count, PLT – platelet count, Hb – hemoglobin, MCV – mean corpuscular volume, fCal – fecal calprotectin, PCDAI – Pediatric Crohn's Disease Activity Index, SES-CD – simple endoscopic score for Crohn's disease, L1 – distal 1/3 ileum, L2 – colonic, L3 – ileocolonic, B1 – non-stricturing, non-penetrating, B2 – stricturing, GO – no evidence of growth delay, G1 – growth delay, MRI – magnetic resonance imaging, EEN – exclusive enteral nutrition, pc – percentile, T0 – at diagnosis, T1 – 8–12 weeks after diagnosis.



### At 8–12 weeks after diagnosis and remission-inducing treatment (T1)

Despite the trend toward normalization of clinical and laboratory parameters after the induction treatment in children with CD, significant differences were observed in several biochemical parameters between Groups I and II after 8–12 weeks of follow-up (Table I, Supplementary Table SII, Figure 1). Severe disease, based on PCDAI score, was noted in 3 (about 12%) children from Group II despite the treatment. Significantly higher ESR, CRP, PLT/albumin, PCDAI, and lower Hb, MCV, and albumin were observed in Group II compared to Group I. Moreover, significantly more children in Group II had CRP > 5 mg/dl (57.69% vs. 21.43%,  $p = 0.006$ ), ESR  $\geq 20$  mm/h (53.87 vs. 25.00%,  $p = 0.03$ ), Hb < 12 g/dl (50.00% vs. 28.57%,  $p = 0.01$ ) and MCV < 75 fl (61.54% vs. 25.00%,  $p = 0.007$ ) despite significant improvements of these outcomes based on calculated size effect (Supplementary Table SII). Only the results for fCal and neutrophil count showed no significant changes in Group II compared to Group I. However, the result for the neutrophil count was on the verge of statistical significance (Table I, Supplementary Table SII). We decided to evaluate whether abnormal results of more than one marker could be more often observed in Group II (Table I). For the analysis we choose PCDAI > 10, CRP > 5 mg/dl and MCV < 75 fl based on the results of regression analysis and AUC from ROC analysis presented below (due to the presence of ESR and albumin in the PCDAI, both parameters were not included in the regression analysis). It should be noted that the combination of two markers was not useful in differentiating patients who will require biologic treatment in the next 2 years. However, only 1 (3.57%) patient from Group I had abnormal results for the three markers simultaneously (PCDAI,

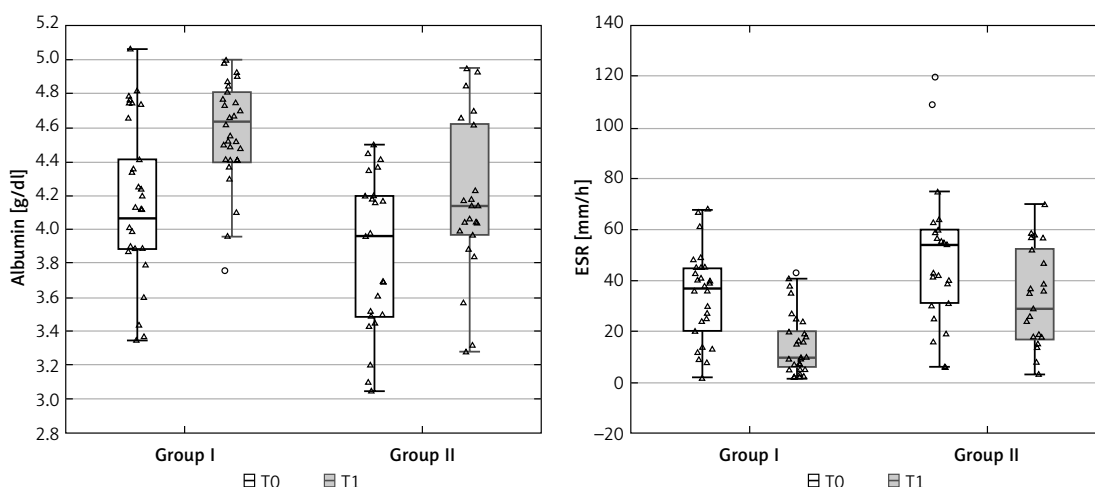
Hb, and MCV), in contrast to 9 patients from Group II (34.62%) ( $p = 0.003$ ) (Table I).

Due to the possible effect of steroids on WBC and neutrophil count values, patients receiving steroids from Groups I and II were compared, with no significant differences observed in the values of the parameters (data not shown).

Among patients who required anti-TNF- $\alpha$  treatment within 2-year follow-up, 14 (56.00%) children received it within the first 6 months of diagnosis. There were no significant differences in clinical presentation or additional test results between the groups receiving biological treatment within and after 6 months (data not shown).

### ROC analysis

ROC analysis was performed to select the best marker for predicting the need for treatment intensification in the next 2 years (Table II). At T0 the best diagnostic value with AUC > 0.7 was obtained for Hb (AUC = 0.773; sensitivity 87.0%; specificity 64.5% with a cut-off of 12.1 g/dl) and MCV (AUC = 0.763; sensitivity: 82.6%; specificity: 71.0% with a cut-off of 75.6 fl), PCDAI (AUC = 0.706, sensitivity 65.2%, specificity 66.7% with a cut-off 30 points) and SES-CD (AUC = 0.714; sensitivity = 73.9%; specificity = 67.7% with a cut-off of 11 points). At T1 the best differentiation markers were ESR (AUC = 0.794; sensitivity: 82.6%; specificity: 67.7% at a cutoff point of 17 mm/h), CRP (AUC = 0.754; sensitivity: 65.2%; specificity: 80.06% at a cutoff point of 5.08 mg/dl), Hb (AUC = 0.717; sensitivity: 87.0%; specificity: 51.6% at a cutoff point of 12.8 g/dl), MCV (AUC = 0.725; sensitivity: 78.3%; specificity: 74.2% at a cutoff point of 75.4 fl), albumin (AUC = 0.775; sensitivity: 73.9%; specificity: 90.3% at a cutoff point of 4.23 g/dl) and PCDAI (AUC = 0.788; sensitivity: 60.9%; specificity: 86.7% at a cutoff point of 17.5).



**Figure 1.** Biochemical and clinical parameters (median, range) assessed at T0 (white box) and T1 (green box), which showed significant diagnostic utility in differentiating CD patients in Group I from Group II

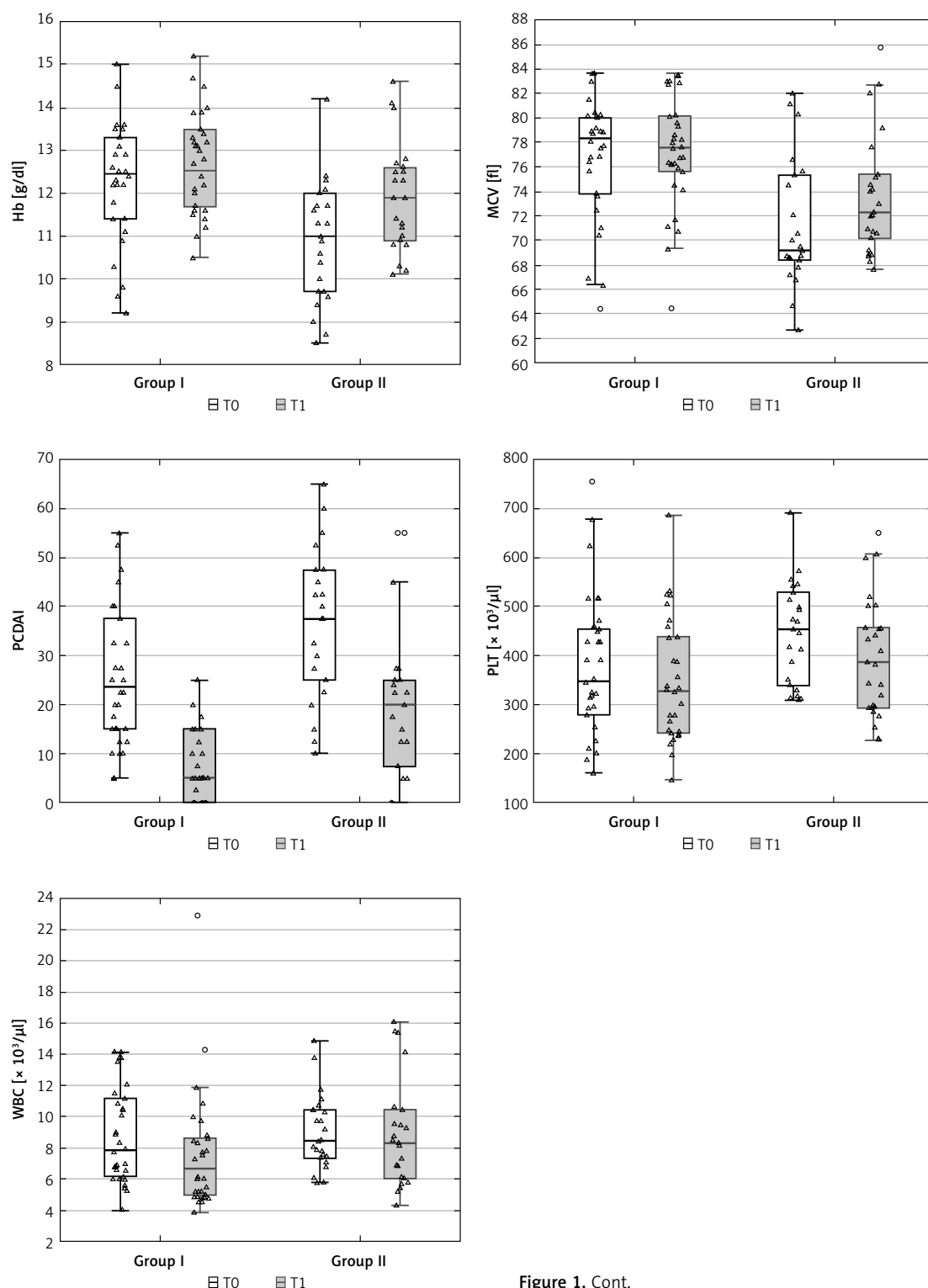


Figure 1. Cont.

### Spearman correlation

Spearman correlation was used to evaluate collinearity of the PCDAI and laboratory parameters assessed in T1. The following significant correlations were observed: CRP and ESR ( $R = 0.57$ ,  $p = 0.002$ ), CRP and neutrophil count ( $R = 0.47$ ,

$p = 0.001$ ), CRP and PCDAI ( $R = 0.54$ ,  $p = 0.004$ ), ESR and PLT ( $R = 0.52$ ,  $p = 0.007$ ), ESR and albumin ( $R = -0.66$ ,  $p < 0.001$ ), ESR and PCDAI ( $R = 0.48$ ,  $p = 0.01$ ), Hb and albumin ( $R = 0.44$ ,  $p = 0.02$ ), PLT and WBC ( $R = 0.63$ ,  $p < 0.001$ ), PLT and fCal ( $R = 0.50$ ,  $p = 0.02$ ), WBC and neutrophil count ( $R = 0.82$ ,  $p < 0.001$ ).

**Table II.** Analysis of diagnostic performance of selected parameters (significantly differentiating Groups I and II) as predictors of anti-TNF- $\alpha$  treatment within 2 years of CD diagnosis

Parameter	AUC	SE	95% CI (AUC)	P-value	Cut-off	Sensitivity	Specificity
CD at T0							
ESR [mm/h]	0.670	0.075	(0.523–0.818)	0.02	54	52.2%	83.9%
CRP [mg/dl]	0.639	0.076	(0.490–0.788)	0.07	138	100.0%	0.0%
WBC [ $\times 10^9/l$ ]	0.535	0.08	(0.379–0.691)	0.66	7.12	82.6%	45.2%
Neutrophil count [ $\times 10^9/l$ ]	0.522	0.08	(0.365–0.679)	0.79	3.7	100.0%	28.8%
PLT [ $\times 10^9/l$ ]	0.676	0.073	(0.533–0.819)	0.02	309	100.0%	32.3%
Hb [g/dl]	0.773	0.064	(0.648–0.899)	< 0.001	12.1	87.0%	64.5%
MCV [fl]	0.763	0.071	(0.625–0.901)	< 0.001	75.6	82.6%	71.0%
Albumin [g/dl]	0.640	0.077	(0.489–0.790)	0.07	3.7	47.8%	83.9%
PLT/albumin ratio	0.684	0.072	(0.542–0.825)	0.01	72.54	100.0%	35.5%
fCal [ $\mu g/g$ ]	0.492	0.081	(0.333–0.650)	0.97	1989	65.2%	48.4%
PCDAI	0.706	0.072	(0.565–0.847)	0.004	30	65.2%	66.7%
SES-CD	0.714	0.071	(0.575–0.853)	0.003	11	73.9%	67.7%
CD at T1							
ESR [mm/h]	0.794	0.062	(0.673–0.914)	< 0.001	17	82.6%	67.7%
CRP [mg/dl]	0.754	0.069	(0.619–0.889)	< 0.001	5.08	65.2%	80.06%
WBC [ $\times 10^9/l$ ]	0.634	0.076	(0.485–0.783)	0.08	5.26	95.7%	35.5%
Neutrophil count [ $\times 10^9/l$ ]	0.661	0.075	(0.514–0.807)	0.04	5.23	52.2%	77.4%
PLT [ $\times 10^9/l$ ]	0.616	0.077	(0.466–0.767)	0.13	286	82.6%	41.9%
Hb [g/dl]	0.717	0.073	(0.573–0.861)	0.003	12.8	87.0%	51.6%
MCV [fl]	0.725	0.074	(0.581–0.869)	0.001	75.4	78.3%	74.2%
Albumin [g/dl]	0.775	0.070	(0.637–0.913)	< 0.001	4.23	73.9%	90.3%
PLT/albumin ratio	0.698	0.072	(0.557–0.838)	0.006	68.89	78.3%	56.7%
fCal [ $\mu g/g$ ]	0.663	0.082	(0.503–0.823)	0.05	1864	63.2%	70.4%
PCDAI	0.783	0.064	(0.657–0.908)	< 0.001	17.5	60.9%	87.1%

AUC – area under the curve, SE – standard error, C.I. – confidence interval, ESR – erythrocyte sedimentation rate, CRP – C-reactive protein, PLT – platelet count, Hb – hemoglobin, MCV – mean corpuscular volume, fCal – fecal calprotectin, PCDAI – Pediatric Crohn's Disease Activity Index, SES-CD – simple endoscopic score for Crohn's disease, T0 – at diagnosis, T1 – 8–12 weeks after diagnosis.

### Univariate and multivariate analysis

Parameters that were significantly associated with the need for anti-TNF- $\alpha$  therapy in CD patients shown in the univariate regression model are listed in Table III. The best multivariate regression model, with an AUC = 0.86, was noted for PCDAI and MCV (Table III). Considering the components of PCDAI, ESR, CRP, and albumin were not analyzed. PCDAI had a stimulating effect on the risk of treatment intensification (OR = 1.122, 95% CI: 1.034–1.217), while an increase in MCV levels reduced this risk (OR = 0.803, 95% CI: 0.671–0.960) (Table III).

### Patients with UC

#### At the time of diagnosis (T0)

Demographic parameters, PUCAI, and endoscopic findings revealed no significant differences

between Groups I and II (Table IV). Analysis of serum and stool markers determined at T0 showed only significant higher ESR levels in children requiring anti-TNF- $\alpha$  treatment. In addition, more children in Group II had CRP > 5 mg/dl (46.15% vs. 19.64%,  $p = 0.01$ ), PLT >  $450 \times 10^9/l$  (30.77% vs. 14.29%,  $p = 0.03$ ) and Hb < 12 g/dl (61.54% vs. 32.14%,  $p = 0.01$ ). Induction treatment was comparable in both groups.

#### At 8–12 weeks after diagnosis and remission-inducing treatment (T1)

In contrast to T0, more differences between Group I and II in clinical and laboratory parameters were observed at T1 (Table IV, Supplementary Table SIII, Figure 2). Significant differences in ESR, WBC, neutrophil count, PLT, Hb, MCV, albumin, PLT/albumin ratio, fCal, and PUCAI were noted. Because of the effect of systemically administered



steroids on WBC and neutrophil counts, patients receiving steroids in Groups I and II were compared; no significant differences in WBC or neutrophil counts were observed between the two groups ( $p > 0.05$ ) (data not shown). In Group I, significant improvements of most serum markers (CRP, WBC, neutrophil count, albumin) and fCal and PUCAI with a large  $R$  ( $\geq 0.5$ ) were noted. In contrast, in Group II, significant improvements in results at moderate  $R$  were observed only for PLT, ESR, and PLT/albumin ratio, while no significant normalization was observed for CRP, WBC, neutrophil count, Hb, MCV, albumin, and fCal. In Group II, significantly more children had  $WBC > 10 \times 10^9/l$  (30.77% vs. 8.93%,  $p = 0.02$ ),  $Hb < 12$  g/dl (61.54% vs. 17.86%,  $p < 0.001$ ),  $MCV < 75$  fl (23.08% vs. 7.14%,  $p = 0.04$ ) and  $fCal > 200$   $\mu g/g$  (84.62% vs. 57.14%,  $p = 0.02$ ). PLT count  $> 450 \times 10^9/l$  was noted in 30.77% of patients in Group II, while this abnormality was not found in Group I. Moreover, clinical remission was achieved by 67.86% of children in Group I ( $p = 0.005$ ). Severe disease according PUCAI was noted in 15.38% of children requiring biological treatment over the following 2 years. It is worth noting that no patient in Group I had a severe course of disease at T1. We then performed a combination analysis of the best parameters based on AUC value (PUCAI  $> 10$ , PLT/albumin ratio  $\geq 83.22$  and  $Hb < 12$  g/dl) to see how many patients had more than one abnormal marker result. In contrast to patients in the CD group, only ROC analysis was relied on due to the borderline statistical significance obtained in the regression model. Then, among the parameters with the highest AUC, those whose cut-off point was not within the normal laboratory range were selected. The presence of three abnormal (PUCAI  $> 10$  + PLT/albumin ratio  $\geq 83.22$  +  $Hb < 12$  g/dl) markers was significantly more frequent in children with progressive disease ( $p = 0.002$ ). Other clinical and laboratory findings were comparable between groups (Table IV).

Twelve (46.15%) children with UC were treated with biological therapy within the first 6 months of diagnosis. The only parameter differentiating the group with early (within the first 6 months after diagnosis) and late (within 7–24 months after diagnosis) induction of anti-TNF- $\alpha$  treatment was a lower albumin concentration at T0 in the first subgroup (4.18 vs. 4.36,  $p = 0.04$ ; data not shown).

### ROC analysis

To assess the discriminatory diagnostic ability of the markers, the AUC value was calculated for T0 and T1 (Table V). The only parameter that achieved statistical significance at T0 was ESR (AUC = 0.640; sensitivity = 96.2%; specificity =

**Table III.** Univariate and multivariate analyses yielding independently significant predictors of eventual anti-TNF- $\alpha$  use during the first 2 consecutive years of CD

Variable	Odds ratio (95% CI)	P-value
Univariate		
ESR T0	1.036 (1.005–1.068)	0.02
MCV T0	0.817 (0.723–0.923)	0.001
Hb T0	0.498 (0.316–0.786)	0.003
Albumin T0	0.252 (0.070–0.917)	0.04
PLT/albumin ratio T0	1.015 (1.001–1.030)	0.04
PCDAI T0	1.053 (1.010–1.097)	0.01
SES-CD T0	1.093 (1.007–1.188)	0.03
CRP T1	1.133 (1.019–1.260)	0.02
ESR T1	1.076 (1.029–1.125)	0.001
Hb T1	0.528 (0.319–0.875)	0.01
MCV T1	0.854 (0.751–0.970)	0.02
Albumin T1	0.052 (0.009–0.318)	0.001
PLT/albumin ratio T1	1.020 (1.001–1.039)	0.04
PCDAI T1	1.122 (1.044–1.206)	0.002
Multivariate		
PCDAI T1	1.122 (1.034–1.217)	0.006
MCV T1	0.803 (0.671–0.960)	0.02

CI – confidence interval, ESR – erythrocyte sedimentation rate, CRP – C-reactive protein, PLT – platelet count, Hb – hemoglobin, MCV – mean corpuscular volume, PCDAI – Pediatric Crohn's Disease Activity Index, T0 – at diagnosis, T1 – 8–12 weeks after diagnosis (T1).

30.4% with a cut-off point of 8 mm/h). At T1, the best diagnostic markers with AUC  $> 0.7$  were albumin (AUC = 0.769; sensitivity = 88.5%; specificity = 60.7% with a cut-off point of 4.58 g/dl), Hb (AUC = 0.761; sensitivity = 57.7%; specificity = 89.3% with a cut-off point of 11.3 g/dl) and PUCAI (AUC = 0.739; sensitivity = 57.7%; specificity = 83.9% with a cut-off of 15 points).

### Spearman correlation

Spearman correlation was used to evaluate collinearity of the PUCAI and laboratory parameters assessed in T1. The following significant correlations were observed: WBC and PLT ( $R = 0.66$ ,  $p < 0.001$ ), WBC and Hb ( $R = -0.47$ ,  $p = 0.02$ ), WBC and neutrophil count ( $R = 0.85$ ,  $p < 0.001$ ), WBC and albumin ( $R = -0.47$ ,  $p = 0.02$ ), PLT and Hb ( $R = -0.60$ ,  $p = 0.001$ ), PLT and MCV ( $R = -0.49$ ,  $p = 0.01$ ), PLT and neutrophil count ( $R = 0.65$ ,  $p < 0.001$ ), PLT and albumin ( $R = -0.41$ ,  $p = 0.04$ ), PLT and ESR ( $R = 0.50$ ,  $p = 0.009$ ), Hb and MCV ( $R = 0.43$ ,  $p = 0.03$ ), Hb and neutrophil count ( $R = -0.41$ ,  $p = 0.04$ ), Hb and albumin ( $R = 0.64$ ,  $p < 0.001$ ), neutrophil count and albumin ( $R = -0.45$ ,  $p = 0.02$ ), CRP and ESR ( $R = 0.47$ ,  $p = 0.02$ ), CRP and PUCAI ( $R = 0.55$ ,  $p = 0.003$ ), ESR and fCal

**Table IV.** Comparison of demographic parameters and selected clinical parameters at the time of diagnosis of UC between the group not requiring biological treatment (Group I) and the group requiring such treatment (Group II) during 2 years of follow-up

Parameter	Group I (n = 56)	Group II (n = 26)	P-value
T0			
Age [years] (median, range)	14 (4–16)	13 (8–16)	0.80
Male n (%)	26 (46.4)	10 (38.5)	0.50
BMI [pc] (median, range)	39 (1–98)	66 (1–98)	0.08
PUCAI (median, range)	45 (10–75)	40 (10–75)	0.34
Remission n (%)	0 (0.0)	(0.0)	NA
Mild n (%)	23 (41.07)	6 (23.08)	0.11
Moderate n (%)	23 (41.07)	14 (53.85)	0.28
Severe n (%)	10 (17.86)	6 (23.08)	0.58
ESR [mm/h] (median, range)	16 (2–87)	20 (2–113)	0.04
ESR $\geq$ 20 mm/h n (%)	20 (35.71)	13 (50.0)	0.22
CRP [mg/dl] (median, range)	1.1 (0.1–94.9)	3.5 (0.3–18.9)	0.25
CRP $>$ 5 mg/dl n (%)	11 (19.64)	12 (46.15)	0.01
WBC $\times 10^9/l$ (median, range)	7.47 (3.71–14.53)	7.77 (4.82–11.22)	0.69
WBC $> 10 \times 10^9/l$ n (%)	11 (19.64)	6 (23.08)	0.72
Neutrophil [ $\times 10^9/l$ ] (median, range)	2.34 (0.62–5.76)	2.33 (1.26–4.73)	0.17
Neutrophil $> 7 \times 10^9/l$ n (%)	5 (8.93)	1 (3.85)	0.41
PLT [ $\times 10^9/l$ ] (median, range)	334 (148–609)	374 (197–827)	0.30
PLT $> 450 \times 10^9/l$ n (%)	8 (14.29)	8 (30.77)	0.03
Hb [g/dl] (median, range)	12.6 (5.8–14.9)	11.3 (6.4–16.5)	0.08
Hb $<$ 12 g/dl n (%)	18 (32.14)	16 (61.54)	0.01
MCV [fl] (median, range)	80.8 (61.9–90.1)	80.9 (63.0–91.9)	0.57
MCV $<$ 75 fl n (%)	5 (8.93)	5 (19.23)	0.20
Ferritin [ $\mu g/l$ ] (median, range)	22.3 (2.0–184.5)	19.7 (2.1–122.4)	0.33
Ferritin $<$ 30 mg/dl n (%)	31 (55.36)	18 (69.23)	0.23
Albumin [g/dl] (median, range)	4.2 (3.2–5.2)	4.3 (3.0–5.0)	0.10
Albumin $<$ 3.5 g/dl n (%)	3 (5.36)	1 (3.85)	0.77
PLT/Alb ratio (median, range)	74.88 (30.27–159.77)	86.12 (43.78–187.95)	0.17
fCal [ $\mu g/g$ ] median, range	2405 (100–3975)	2147 (136–3635)	0.33
fCal $>$ 200 $\mu g/g$ n (%)	55 (98.21)	25 (96.15)	0.57
Mayo endoscopic score I/II/III n (%)	10 (17.8)/26 (46.4)/ 20 (35.7)	5 (19.2)/8 (30.8)/ 13 (50.0)	0.43
Mayo total score (median, range)	8 (4–11)	8 (4–11)	0.89
Extent – E1/E2/E3/E4 n (%)	17 (30.4)/16 (28.6)/ 4 (7.1)/19 (33.9)	4 (15.4)/10 (38.5)/ 4 (15.4)/8 (30.8)	0.14/0.37/ 0.24/0.78
Induction treatment			
5-ASA n (%)	36 (64.29)	14 (53.8)	0.37
Steroids n (%)	20 (35.71)	12 (46.2)	0.37
T1			
BMI [pc] (median, range)	46 (2–99)	60 (3–99)	0.39
PUCAI (median, range)	5 (0–65)	15 (0–80)	$<$ 0.001
PUCAI $\geq$ 10 points n (%)	18 (32.14)	17 (65.38)	0.005
IBD activity:			
Remission n (%)	38 (67.86)	9 (34.62)	0.005
Mild n (%)	14 (25.0)	11 (42.31)	0.11

Table IV. Cont.

Parameter	Group I (n = 56)	Group II (n = 26)	P-value
Moderate n (%)	4 (7.14)	2 (7.69)	0.93
Severe n (%)	0 (0.0)	4 (15.38)	NA
ESR [mm/h] (median, range)	7 (2–66)	13 (2–107)	0.03
ESR $\geq$ 20 mm/h n (%)	11 (19.64)	10 (38.5)	0.07
CRP [mg/dl] (median, range)	0.6 (0.3–26.2)	0.6 (0.3–125.6)	0.80
CRP > 5 mg/dl n (%)	4 (7.14)	5 (19.23)	0.05
WBC [ $\times 10^9/l$ ] (median, range)	6.25 (3.44–12.27)	8.88 (3.75–24.09)	0.009
WBC > $10 \times 10^9/l$ n (%)	5 (8.93)	8 (30.77)	0.02
Neutrophil [ $\times 10^9/l$ ] (median, range)	1.57 (0.52–7.83)	4.35 (1.44–13.7)	0.009
Neutrophil > $7 \times 10^9/l$ n (%)	1 (1.79)	2 (7.69)	0.18
PLT [ $\times 10^9/l$ ] (median, range)	280 (161–447)	349 (178–794)	0.04
PLT > $450 \times 10^9/l$ n (%)	0 (0.0)	8 (30.77)	NA
Hb [g/dl] (median, range)	13.1 (9.9–15.7)	11.1 (8.6–17.5)	< 0.001
Hb < 12 g/dl n (%)	10 (17.86)	16 (61.54)	< 0.001
MCV [fl] (median, range)	81.3 (66.4–92.3)	79.5 (69.0–91.2)	0.10
MCV < 75 fl n (%)	4 (7.14)	6 (23.08)	0.04
Albumin [g/dl] (median, range)	4.64 (3.91–5.12)	4.3 (3.4–4.8)	< 0.001
Albumin < 3.5 g/dl n (%)	0 (0.0)	1 (3.85)	NA
PLT/albumin ratio (median, range)	61.97 (35.08–102.88)	80.64 (38.44–188.15)	0.04
fCal [ $\mu g/g$ ] (median, range)	219 (10–3697)	1143 (18–3620)	0.02
fCal > 200 $\mu g/g$ n (%)	32 (57.14)	22 (84.62)	0.02
PUCAI > 10 + PLT/ albumin ratio $\geq$ 83.22	1 (1.79)	1 (3.85)	0.57
PUCAI > 10 + Hb < 12 g/dl	0 (0.0)	1 (3.85)	NA
PLT/albumin ratio $\geq$ 83.22 + Hb < 12 g/dl	2 (3.57)	3 (11.54)	0.16
PUCAI > 10 + PLT/ albumin ratio $\geq$ 83.22 + Hb < 12 g/dl	3 (5.36)	8 (30.77)	0.002

BMI – body mass index, ESR – erythrocyte sedimentation rate, CRP – C-reactive protein, WBC – white blood count, PLT – platelet count, Hb – hemoglobin, MCV – mean corpuscular volume, fCal – fecal calprotectin, PUCAI – Pediatric Ulcerative Colitis Activity Index, 5-ASA-5 – aminosalicylic acid, pc – percentile, T0 – at diagnosis, T1 – 8–12 weeks after diagnosis.

( $R = 0.40$ ,  $p = 0.04$ ), PUCAI and fCal ( $R = 0.52$ ,  $p = 0.007$ ), PUCAI and albumin ( $R = -0.43$ ,  $p = 0.03$ ).

#### Univariate and multivariate analysis

We observed that certain parameters were significant in univariate analyses, as shown in Table VI. The best multivariate regression model, with an AUC = 0.86, was noted for albumin and neutrophil count (Table VI). In a multivariate logistic regression model, predictors of treatment intensification with biological therapy were higher neutrophil count (OR = 1.38, 95% CI: 1.017–1.873) and lower albumin concentration (OR = 0.117, 95% CI: 0.016–0.862) assessed after remission-inducing treatment.

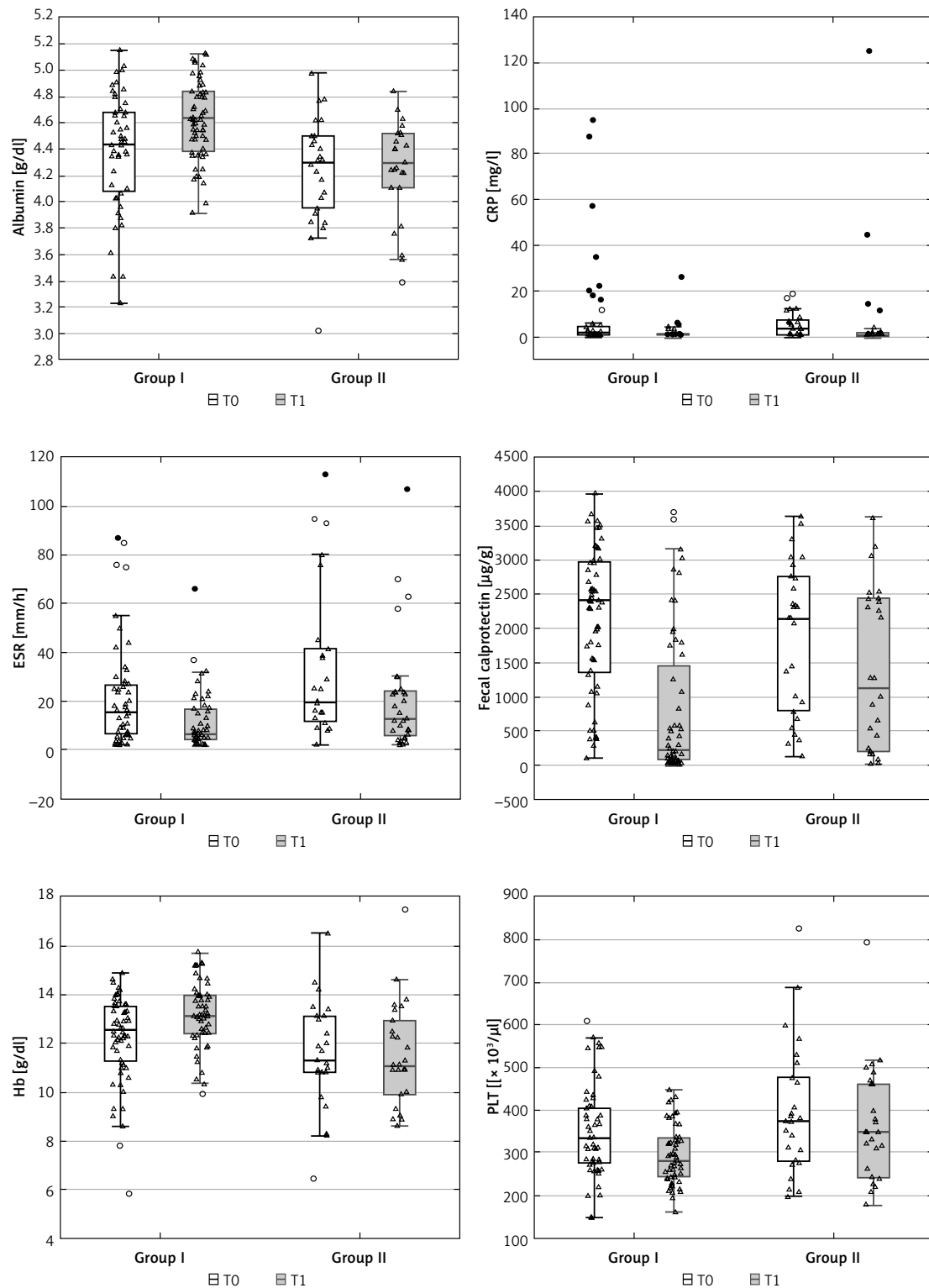
#### Discussion

Our study showed that evaluation of commonly used clinical and laboratory parameters within

the first 8–12 weeks of diagnosis could be helpful to select patients with progressive IBD who will require close monitoring of the course of the disease and early escalation of therapy with anti-TNF- $\alpha$  monoclonal antibody. To the best of our knowledge, there are only a few published studies dedicated to analyzing markers useful in predicting the progressive course of IBD requiring anti-TNF- $\alpha$  treatment in pediatric patients at the time of diagnosis and after treatment initiation [6, 22–25]. We compared children with CD as well as UC separately. In addition, patients in other studies were evaluated at different time points (3–20 months assessed during the use of various therapeutic regimens, including biological treatment). In our study, the time of follow-up was clearly defined as 8–12 weeks from the moment of diagnosis, after remission-inducing treatment, but before the initiation of anti-TNF- $\alpha$  therapy. We observed that assessment of readily available biochemical

parameters used in daily clinical practice in the first few weeks of treatment can predict which patients will require close monitoring in subsequent months of disease and earlier escalation of treatment.

Considering the studies involving children with CD, we found anti-TNF- $\alpha$  treatment in almost 50% of patients, similar to the observation by Olbjørn *et al.* [22]. Olbjørn *et al.* evaluated ESR, CRP, and fCal at diagnosis and after 12–24 months



**Figure 2.** Biochemical and clinical parameters (median, range) assessed at (T0) and (T1), which showed significant diagnostic utility in differentiating UC patients in Group I from Group II

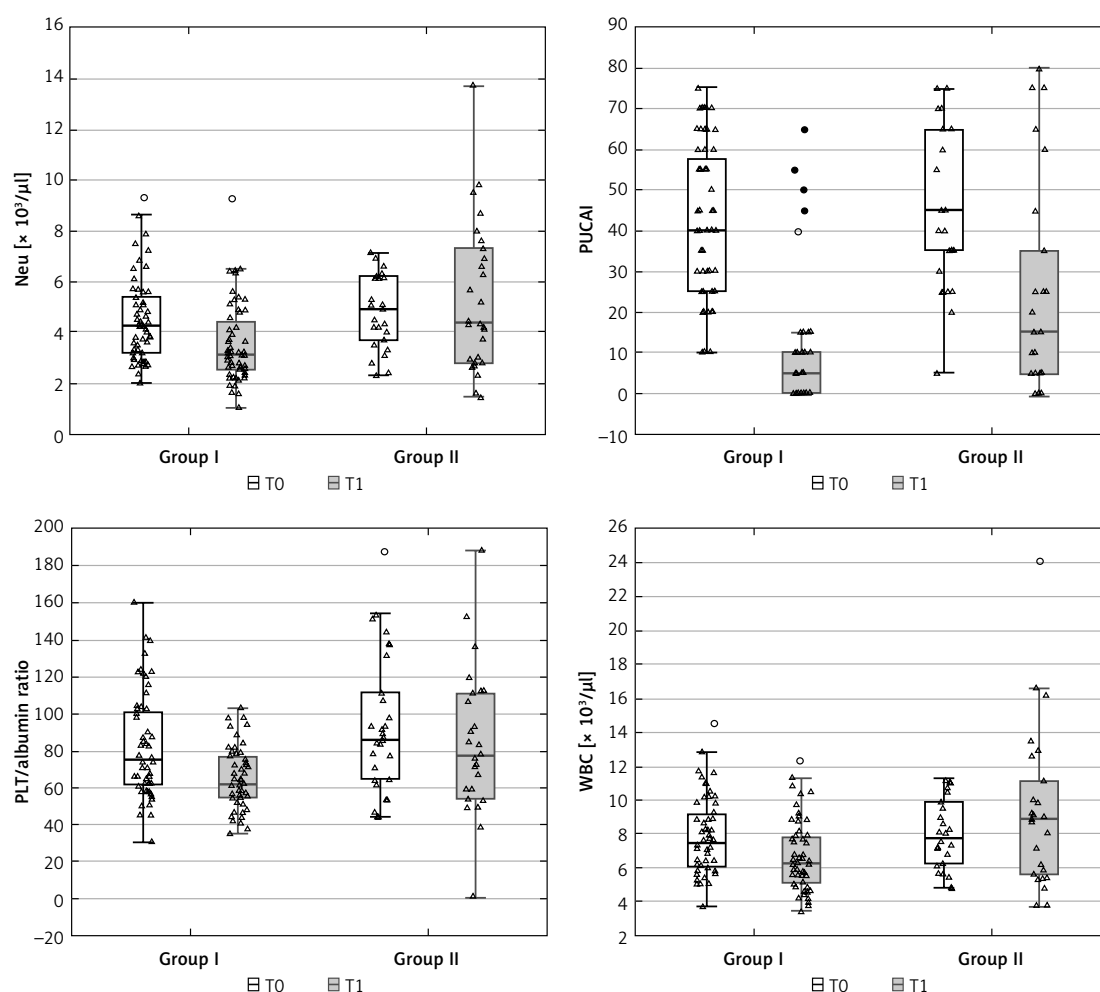


Figure 2. Cont.

of biologic treatment. A high ESR at diagnosis was identified as a predictor of further biologic treatment, as in our study. Moreover, we noted higher PLT and PCDAI and lower Hb and MCV in this group of patients. In our study, results after 8–12 weeks showed that more than half of the patients who required biologic therapy at 2-year follow-up had elevated CRP and ESR, compared to only a quarter of patients in the other group. Abnormal results for PCDAI (including ESR and albumin), MCV, and CRP were noted in about 35% of patients who received intensified treatment, compared to about 4% of patients who did not require intensified treatment. In addition, the multivariable regression analysis showed the significant value of PCDAI and MCV as predictors of risk of intensification of treatment in the next 2 years. The low MCV is related to deficiency anemia, often seen in children with IBD [26, 27]. To the best of our knowledge, MCV has not been evaluated in published studies in the first months of disease as a predictor of poor outcome of IBD. In addition, low Hb (< 12 g/dl) at time T1 was found in less than 4% of children in the group without CD

progression in the next 2 years and no concomitant abnormal PCDAI, CRP, and Hb values were observed in this group. As mentioned previously, the combination of fCal and CRP is better than fCal alone in the evaluation of children with CD [7]. In our study, we did not include fCal in the analysis due to its lack of normalization after 8–12 weeks of treatment. Turner *et al.* found that fCal decreases irrespective of treatment (steroids or exclusive enteral nutrition) within 8 weeks of starting treatment in both CD and UC, indicating that assessing fCal over a shorter period may not be helpful in clinical practice [28]. Furthermore, Levine *et al.* observed a reduction in fCal in 23–50% of children with CD regardless of the type of initial therapy (steroids, EEN, 5-ASA) [6]. Similarly, Matuszczyk *et al.* reported a reduction in fCal < 250 μg/g in less than one-third of children with CD after 12 weeks of treatment of CD with an exclusion diet combined with partial enteral nutrition [29]. Our results suggest that finding still abnormal PCDAI (> 10), CRP (> 5 mg/dl) and MCV < 75 fl results at the follow-up time point is more useful in predicting which patients will require close monitoring.

**Table V.** Analysis of diagnostic performance of selected parameters (significantly differentiating Groups I and II) as predictors of anti-TNF- $\alpha$  treatment within 2 years of UC diagnosis

Parameter	AUC	SE	95% CI (AUC)	P-value	Cut-off	Sensitivity	Specificity
UC at T0							
ESR [mm/h]	0.640	0.064	(0.541–0.766)	0.03	8	96.2%	30.4%
CRP [mg/dl]	0.580	0.071	(0.441–0.720)	0.26	3	69.6%	30.4%
WBC [ $\times 10^9/l$ ]	0.527	0.069	(0.391–0.664)	0.69	9.01	34.65%	75.0%
Neutrophil [ $\times 10^9/l$ ]	0.595	0.068	(0.462–0.728)	0.16	6.1	38.5%	83.9%
PLT [ $\times 10^9/l$ ]	0.572	0.071	(0.432–0.712)	0.31	339	61.5%	55.4%
Hb [g/dl]	0.621	0.069	(0.486–0.756)	0.08	12.0	65.4%	64.3%
MCV [fl]	0.539	0.072	(0.399–0.680)	0.59	75.9	26.9%	89.3%
Albumin [g/dl]	0.613	0.065	(0.486–0.740)	0.08	4.32	57.7%	66.1%
PLT/albumin ratio	0.595	0.070	(0.459–0.731)	0.17	77.17	69.2%	51.8%
fCal [ $\mu g/g$ ]	0.432	0.069	(0.296–0.568)	0.33	136	100.0%	1.8%
PUCAI	0.566	0.068	(0.433–0.699)	0.33	35	76.9%	37.5%
UC at T1							
ESR [mm/h]	0.648	0.067	(0.516–0.780)	0.03	8	73.1%	53.6%
CRP [mg/dl]	0.482	0.078	(0.330–0.634)	0.82	11.21	19.2%	98.2%
WBC [ $\times 10^9/l$ ]	0.681	0.070	(0.545–0.818)	0.009	8.07	61.5%	78.6%
Neutrophil [ $\times 10^9/l$ ]	0.681	0.069	(0.545–0.816)	0.009	5.7	42.3%	92.9%
PLT [ $\times 10^9/l$ ]	0.643	0.073	(0.499–0.786)	0.05	459	30.8%	100.0%
Hb [g/dl]	0.761	0.063	(0.638–0.884)	< 0.001	11.3	57.7%	89.3%
MCV [fl]	0.613	0.068	(0.480–0.746)	0.10	76.8	38.5%	83.9%
Albumin [g/dl]	0.769	0.053	(0.666–0.872)	< 0.01	4.58	88.5%	60.7%
PLT/albumin ratio	0.692	0.069	(0.556–0.827)	0.006	83.22	50.0%	85.7%
fCal [ $\mu g/g$ ]	0.667	0.064	(0.541–0.793)	0.009	540	65.4%	66.1%
PUCAI	0.739	0.061	(0.619–0.860)	< 0.001	15	57.7%	83.9%

AUC – area under the curve, SE – standard error, CI – confidence interval, ESR – erythrocyte sedimentation rate, WBC – white blood count, PLT – platelet count, Hb – hemoglobin, fCal – fecal calprotectin, PUCAI – Pediatric Ulcerative Colitis Activity Index, T0 – at diagnosis, T1 – 8–12 weeks after diagnosis.

**Table VI.** Univariate and multivariate analyses yielding independently significant predictors of eventual anti-TNF use during the first 2 consecutive years of UC

Variable	Odds ratio (95% CI)	P-value
Univariate		
Hb T1	0.543 (0.386–0.764)	0.004
Albumin T1	0.041 (0.007–0.234)	< 0.001
Neutrophil count T1	1.505 (1.162–1.950)	0.002
WBC T1	1.354 (1.119–1.639)	0.002
PLT T1	1.008 (1.002–1.013)	0.007
ESR T1	1.047 (1.006–1.090)	0.02
PUCAI T1	1.041 (1.014–1.069)	0.003
Multivariate		
Albumin T1	0.117 (0.016–0.862)	0.04
Neutrophil count T1	1.38 (1.017–1.873)	0.04

CI – confidence interval, Hb – hemoglobin, WBC – white blood count, PLT – platelet count, ESR – erythrocyte sedimentation rate, PUCAI – Pediatric Ulcerative Colitis Activity Index, T0 – at diagnosis, T1 – 8–12 weeks after diagnosis.

More studies are needed to assess the usefulness of the combinations of different factors in daily clinical practice

Regarding children with UC, only a few publications are available that focus on early markers of poor prognosis of the disease and the need for biological therapy [24, 25]. Among our patients, nearly 32% required biological treatment within two consecutive years. At the time of diagnosis, only ESR values significantly differentiated the study groups. Hyams *et al.* noted that factors leading to escalation of therapy included low levels of Hb, vitamin D<sub>3</sub>, and eosinophil counts in rectal biopsy specimens at the time of diagnosis [24]. On the other hand, Gasparetto *et al.* noted that children with severe UC (requiring biologic treatment and/or major surgery within 18 months) had lower albumin and Hb values at diagnosis compared to mild disease [25]. In contrast, ESR values did not differ significantly between patient groups [25].

Interestingly, in our study, more differences in assessed parameters between the groups requir-



ing and not requiring biological treatment were found after 8–12 weeks of remission-inducing treatment. The group with UC progressing despite treatment had significantly higher values of PUCAI and most inflammatory parameters (ESR, PLT, fCal) and lower levels of albumin, Hb, and MCV after 8–12 weeks compared to the group not requiring biological treatment. Although PUCAI scores decreased over 8–12 weeks of follow-up in both groups, clinical remission (PUCAI < 10) was achieved by the majority of children in the group without biological treatment, while there were a few cases with severe disease in the other group. Similar results were obtained by Gasparetto *et al.*, who noted that the clinical assessment with PUCAI of patients 3 months after diagnosis is important for predicting the severity of the disease [25]. They observed that clinical remission without steroids, as well as PUCAI assessed at month 3 of the disease, are the most reliable clinical predictors of long-term remission in children in subsequent years. However, no laboratory parameter was evaluated during follow-up in this study, making it impossible to compare most of our results. In our study, significantly lower fCal values at T1 were observed in children not requiring biological treatment. However, it should be noted that less than half of the patients had fCal < 200 µg/g. Perhaps the reasons for the lack of normalization of fCal in our study were the measurement of fCal too soon after the inclusion of remission-inducing treatment and the more severe form of the disease at the time of diagnosis. It is now emphasized that the goal of treating patients with IBD is not only to achieve clinical remission, but also mucosal healing, which is a long-term process [30]. Therefore, monitoring fCal over a longer period seems to be more important. The use of multivariate regression analysis in our study revealed that the high predictive value of weak improvement in albumin levels after 2–3 months may be associated with a higher risk of a more severe disease course requiring treatment with TNF- $\alpha$  inhibitors. However, it should be noted that in the ROC analysis, the cut-off point for albumin differentiating both study groups was 4.58 g/dl, which is within the normal laboratory range. Moreover, the albumin values were within normal laboratory limits in the majority of patients at the follow-up time point. Perhaps in the group of children with UC, different normal values of albumin should be considered. To the best of our knowledge, published studies have not assessed the usefulness of albumin assessed 8–12 weeks after diagnosis of UC to the need for treatment intensification. The only study, by Hyams *et al.*, reported that a higher baseline albumin level of 1 g/dl in the < 12 age group could indicate remission without

CS 12 weeks after diagnosis in children with UC [31]. In adults, the positive value of the neutrophil-to-albumin ratio in determining the response to IFX treatment and long-term maintenance of remission has been observed. Higher peripheral neutrophil counts compared to healthy controls were positively correlated with the severity of endoscopic lesions according to the Mayo score [32, 33]. However, in both studies, the neutrophil to albumin ratio was assessed just before IFX was included (up to 1 week earlier). Finally, we determined the usefulness of a combination of two or three selected clinical and laboratory markers (PUCAI, Hb and PLT/albumin ratio) in predicting which UC patients would require anti-TNF- $\alpha$  treatment, and the results were comparable to the CD group (PCDAI, MCV, and CRP).

The most important outcome of our study was to demonstrate the usefulness of common biochemical parameters assessed after 8–12 weeks of remission-inducing treatment in predicting which patients with CD or UC will require close monitoring in subsequent years of disease and more rapid intensification of treatment. To date, only a few studies in the pediatric population have focused on outcomes not only at the time of diagnosis, but also at specific time points. Another strength of this study is that our department was the main pediatric endoscopy center with histopathological examination in northeastern Poland, diagnosing all IBD in children in recent years, and all patients remained under monitoring until the age of 18. It should be noted that the markers we are analyzing are readily available and inexpensive. The present study also has some limitations. First, the small number of participants does not allow us to generalize our results and reduces statistical power. The number of patients included in the study was low due to the time frame and monocentric nature of the study. We recognize that our results may be subject to errors of omission (type II error) and did not interpret non-significant results as underlying a true null difference. Another limitation is the retrospective analysis, which involves potential errors. Further research without these limitations would be useful.

In conclusion, our results suggest that the assessment of patients' clinical and routine biochemical parameters, not only at the time of diagnosis, but also shortly after initial remission-inducing treatment, is a promising benchmark for predicting the course of the disease over the next 2 years. In a multivariate regression model, the risk of anti-TNF- $\alpha$  therapy in patients with CD was associated with failure to normalize MCV and PCDAI after remission-inducing treatment. In contrast, in patients with UC, higher albumin levels reduced this risk of such therapy. Further studies

in a larger group of patients are needed to confirm the usefulness of the markers we analyzed. Perhaps long-term studies of new genetic, serological, or microbiological markers would provide more information about the course of the disease [34, 35].

## Funding

This study was financially supported by grants from the Medical University of Białystok, Poland. Grant No: B.SUB.24.437.

## Ethical approval

Approval number: R-I-002/308/2014.

## Conflict of interest

The authors declare no conflict of interest.

## References

- Thia KT, Sandborn WJ, Harmsen WS, Zinsmeister AR, Loftus EV. Risk factors associated with progression to intestinal complications of Crohn's disease in a population-based cohort. *Gastroenterology* 2010; 139: 1147-55.
- Turner D, Ruemmele FM, Orlanski-Meyer E, et al. Management of paediatric ulcerative colitis, part 1: ambulatory care-an evidence-based guideline from European Crohn's and Colitis Organization and European Society of Paediatric Gastroenterology, Hepatology and Nutrition. *J Pediatr Gastroenterol Nutr* 2018; 67: 257-91.
- Ezri J, Marques-Vidal P, Nydegger A. Impact of disease and treatments on growth and puberty of pediatric patients with inflammatory bowel disease. *Digestion* 2012; 85: 308-19.
- de Laffolie J, Zimmer KP, Sohrabi K, Hauer AC. Running behind "POPO" - Impact of predictors of poor outcome for treatment stratification in pediatric crohn's disease. *Front Med* 2021; 8: 644003.
- Lee YM, Kim ES, Choi S, et al. Fecal calprotectin at postinduction is capable of predicting persistent remission and endoscopic healing after 1 year of treatment with infliximab in pediatric patients with Crohn's disease. *Gut Liver* 2024; 18: 498-508.
- Levine A, Turner D, Pfeffer Gik T, et al. Comparison of outcomes parameters for induction of remission in new onset pediatric Crohn's disease: evaluation of the porto IBD group "growth relapse and outcomes with therapy" (GROWTH CD) study. *Inflamm Bowel Dis* 2014; 20: 278-85.
- van Rheenen PF, Aloï M, Assa A, et al. The medical management of paediatric Crohn's disease: an ECCO-ESPGHAN guideline update. *J Crohns Colitis* 2021; 15: jjaa161.
- Turner D, Ruemmele FM, Orlanski-Meyer E, et al. Management of paediatric ulcerative colitis, part 2: acute severe colitis-an evidence-based consensus guideline from the European Crohn's and Colitis Organization and the European Society of Paediatric Gastroenterology, Hepatology and Nutrition. *J Pediatr Gastroenterol Nutr* 2018; 67: 292-310.
- Guariso G, Gasparetto M. Treating children with inflammatory bowel disease: current and new perspectives. *World J Gastroenterol* 2017; 23: 5469-85.
- Claßen M, de Laffolie J, Schnell A, Sohrabi K, Hoerning A. Significant advantages for first line treatment with TNF-alpha inhibitors in pediatric patients with inflammatory bowel disease – data from the multicenter CEDATA-GPGE registry study. *Front Pediatr* 2022; 10: 903677.
- Kim HJ, Oh SH, Lee SH, et al. risk factors for disease behavior evolution and efficacy of biologics in reducing progression in pediatric patients with nonstricturing, non-penetrating Crohn's disease at diagnosis: a single-center experience in Korea. *Gut Liver* 2021; 15: 851-7.
- Khanna R, Bressler B, Levesque BG, et al. Early combined immunosuppression for the management of Crohn's disease (REACT): a cluster randomised controlled trial. *Lancet* 2015; 386: 1825-34.
- Noor NM, Lee JC, Bond S, et al. A biomarker-stratified comparison of top-down versus accelerated step-up treatment strategies for patients with newly diagnosed Crohn's disease (PROFILE): a multicentre, open-label randomised controlled trial. *Lancet Gastroenterol Hepatol* 2024; 9: 415-27.
- Levine A, Koletzko S, Turner D, et al. ESPGHAN revised porto criteria for the diagnosis of inflammatory bowel disease in children and adolescents. *J Pediatr Gastroenterol Nutr* 2014; 58: 795-806.
- Turner D, Griffiths AM, Mack D, et al. Assessing disease activity in ulcerative colitis: patients or their physicians? *Inflamm Bowel Dis* 2010; 16: 651-6.
- Turner D, Otley AR, Mack D, et al. Development, validation, and evaluation of a pediatric ulcerative colitis activity index: a prospective multicenter study. *Gastroenterology* 2007; 133: 423-32.
- Lewis JD, Chuai S, Nessel L, Lichtenstein GR, Aberra FN, Ellenberg JH. Use of the noninvasive components of the Mayo score to assess clinical response in ulcerative colitis. *Inflamm Bowel Dis* 2008; 14: 1660-6.
- Levine A, Griffiths A, Markowitz J, et al. Pediatric modification of the Montreal classification for inflammatory bowel disease: the Paris classification. *Inflamm Bowel Dis* 2011; 17: 1314-21.
- Daperno M, D'Haens G, Van Assche G, et al. Development and validation of a new, simplified endoscopic activity score for Crohn's disease: the SES-CD. *Gastrointest Endosc* 2004; 60: 505-12.
- Ruemmele FM, Veres G, Kolho KL, et al. Consensus guidelines of ECCO/ESPGHAN on the medical management of pediatric Crohn's disease. *J Crohns Colitis* 2014; 8: 1179-207.
- Turner D, Travis SP, Griffiths AM, et al. Consensus for managing acute severe ulcerative colitis in children: a systematic review and joint statement from ECCO, ESPGHAN, and the Porto IBD Working Group of ESPGHAN. *Am J Gastroenterol* 2011; 106: 574-88.
- Olbjørn C, Nakstad B, Småstuen MC, Thiis-Evensen E, Vatn MH, Perminow G. Early anti-TNF treatment in pediatric Crohn's disease. Predictors of clinical outcome in a population-based cohort of newly diagnosed patients. *Scand J Gastroenterol* 2014; 49: 1425-31.
- Olbjørn C, Cvancarova Småstuen M, Thiis-Evensen E, Nakstad B, Vatn MH, Perminow G. Serological markers in diagnosis of pediatric inflammatory bowel disease and as predictors for early tumor necrosis factor blocker therapy. *Scand J Gastroenterol* 2017; 52: 414-9.
- Hyams JS, Davis Thomas S, Gotman N, et al. Clinical and biological predictors of response to standardised paediatric colitis therapy (PROTECT): a multicentre inception cohort study. *Lancet* 2019; 393: 1708-20.

25. Gasparetto M, Wong-Spracklen V, Torrente F, et al. Early treatment response predicts outcome in paediatric ulcerative colitis: gastroenterology: inflammatory bowel disease. *J Pediatr Gastroenterol Nutr* 2018; 67: 217-20.
26. Krawiec P, Pac-Kożuchowska E. Biomarkers and hematological indices in the diagnosis of iron deficiency in children with inflammatory bowel disease. *Nutrients* 2020; 12: 1358.
27. Daniluk U, Daniluk J, Krasnodebska M, Lotowska JM, Sobaniec-Lotowska ME, Lebensztejn DM. The combination of fecal calprotectin with ESR, CRP and albumin discriminates more accurately children with Crohn's disease. *Adv Med Sci* 2019; 64: 9-14.
28. Turner D, Ricciuto A, Lewis A, et al. STRIDE-II: An Update on the Selecting Therapeutic Targets in Inflammatory Bowel Disease (STRIDE) Initiative of the International Organization for the Study of IBD (IOIBD): determining therapeutic goals for treat-to-target strategies in IBD. *Gastroenterology* 2021; 160: 1570-83.
29. Matuszczyk M, Meglicka M, Wiernicka A, et al. Effect of the Crohn's Disease Exclusion Diet (CDED) on the fecal calprotectin level in children with active Crohn's disease. *J Clin Med* 2022; 11: 4146.
30. Vaughn BP, Shah S, Cheifetz AS. The role of mucosal healing in the treatment of patients with inflammatory bowel disease. *Curr Treat Options Gastroenterol* 2014; 12: 103-17.
31. Hyams JS, Davis S, Mack DR, et al. Factors associated with early outcomes following standardised therapy in children with ulcerative colitis (PROTECT): a multicentre inception cohort study. *Lancet Gastroenterol Hepatol* 2017; 2: 855-68.
32. Zhang Y, Xu F, Li Y, Chen B. C-reactive protein-to-albumin ratio and neutrophil-to-albumin ratio for predicting response and prognosis to infliximab in ulcerative colitis. *Front Med* 2024; 11: 1349070.
33. Zhou Z, Zhang Y, Pan Y, et al. A novel neutrophil-based biomarker to monitor disease activity and predict response to infliximab therapy in patients with ulcerative colitis. *Front Med* 2022; 9: 872831.
34. Zdanowicz K, Pietrowska K, Lebensztejn DM, et al. Evaluation of microbiome composition combined with serum untargeted metabolomic profiling in newly diagnosed children with inflammatory bowel disease. *Arch Med Sci* 2025; 21: 416-24.
35. Yasuda R, Arai K, Kudo T, et al. Serum leucine-rich alpha-2 glycoprotein and calprotectin in children with inflammatory bowel disease: a multicenter study in Japan. *J Gastroenterol Hepatol* 2023; 38: 1131-9.