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# Analysis of the laboratory results of the patients enrolled in the Nutritional Therapy Program

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**Abstract. – OBJECTIVE: Nutritional treatment is an integral part of patient management, as meeting nutritional needs significantly contributes to improving treatment outcomes and reducing complications and length of hospitalization. The aim of this study was to analyze the laboratory results of the patients enrolled in the Nutritional Therapy Program.**

**PATIENTS AND METHODS: This study involved 103 subjects, aged 18-88. It was based on analysis of medical documentation of patients under the care of the Enteral Nutrition Clinic. Nutritional status was assessed by biochemical tests (urea, creatinine, AST, ALT, ALP, CRP, total cholesterol, triglycerides, INR, Na, K, Cl, Mg, Ca, P, Fe, total protein, albumin, and fasting glucose).**

**RESULTS: After six and twelve months, the groups with malnutrition and neurological diseases had higher levels of erythrocytes and albumin, and significantly lower CRP. The mean glucose level after six months was significantly lower compared to the first measurement, and a downward trend was observed. Calcium showed an upward trend. In cancer patients, a decline in erythrocytes was observed after six months compared to the initial measurement.**

**CONCLUSIONS: There were significant differences in the results of laboratory tests between patients with cancer and those with malnutrition and neurological diseases. These were mainly lower levels of lymphocytes and glucose, and higher levels of platelets and CRP. Furthermore, the greatest effect of nutritional treatment was observed in patients with malnutrition and neurological diseases.**

*Key Words:*
Nutritional therapy, Malnutrition, Neurological diseases, Cancer.

## Introduction

Malnutrition disorder has for several decades been one of the most important medical and social problems, both in Poland and in the world[1]. Malnutrition is a multifaceted issue, which may develop as a consequence of nutritional deficiencies or increased demands associated with a medical condition. It may also be a complication of the underlying disease, such as poor absorption or excessive nutrient loss, or may result from a compilation of the aforementioned factors[2]. According to the "Global nutrition report: action on equity to end malnutrition. Development Initiatives"[3] published in 2020, malnutrition is common in hospital settings, where 20-50% of patients are diagnosed as malnourished at the onset of hospitalization. A study by Kaiser et al[4] summarizing the results from 12 countries, showed that malnutrition affects about 23% of the elderly, with a higher incidence rate in rehabilitation facilities (about 50%). According to Keller et al[5] malnutrition has a significant clinical and socioeconomic impact, as it increases complications in hospitalized patients and raises the cost of health care. Its prevalence is estimated at 30-50% in hospitals of Western countries and at 85% in long-term care facilities, depending on the definition and the type of the studied population.

One of the problems associated with diagnosing malnutrition is the lack of a unified definition and a standard method for screening and diagnosis[5]. In the absence of a universally accepted definition of malnutrition and a gold standard for its diagnosis, screening and nutritional assessment tools have been developed. Many of them have been validated and recommended[6,7]. However, these tools use different criteria and cut-off points and have been designed for different purposes and populations. Therefore, they cannot be applied as universal tools in different clinical situations.

Because of the complexity of the aforementioned methods, physicians have sought rapid and


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effective laboratory methods to assess malnutrition. These usually included serum biochemical tests performed during routine blood analysis to identify patients at risk of this problem. In clinical practice, the advantage of blood testing is also that it allows immediate nutritional assessment and quick intervention in patients who are malnourished or at risk of malnutrition[7]. The most commonly determined parameters include peripheral blood count, lipid profile, and glucose. The levels of albumins and/or short half-life proteins (e.g. prealbumin, transferrin) as well as C-reactive protein (CRP), some vitamins and/or elements (potassium, magnesium, calcium, iron, phosphorus, zinc) should also be measured[8]. A deficit of 5-15% can be classified as mild, 15-30% as moderate, and over 30% as severe muscle mass deficiency[9,10]. Also the levels of liver enzymes, creatinine, urea, electrolytes, calcium, phosphate, and magnesium should be regularly tested and recorded in the test chart[8].

The European Society for Parenteral and Enteral Nutrition (ESPEN) and the American Society for Parenteral and Enteral Nutrition (ASPEN) propose three definitions of malnutrition: 1) starvation-related malnutrition-chronic starvation without inflammation, 2) chronic disease-related malnutrition-involves chronic mild/moderate inflammation, and 3) malnutrition related to acute illness or injury. The diagnostic criteria for the above definitions are energy intake, weight loss, body fat, muscle mass, and fluid accumulation. However, they do not include blood biomarkers[11,12].

Disease-related malnutrition is a common problem among cancer patients and affects more than 50% of people with certain types of cancers (e.g., pancreatic, esophageal, gastrointestinal, head and neck cancers). Increased lipolysis and proteolysis, which then occur, vary depending on the type of cancer, the anticancer therapy used, and the psychosocial response to treatment. In such cases, patients often grow thin due to the loss of muscle mass and adipose tissue, which is different from weight loss induced by starvation. Protein-calorie malnutrition is the main symptom of paraneoplastic syndrome characterized by metabolic disorders and skeletal muscle loss with or without fat loss[13].

Patients with neurological diseases are also particularly vulnerable to malnutrition. This is due to complaints that often accompany neurological disorders. These include impaired consciousness and cognitive function, neurogenic dysphagia, neurogenic vomiting, gastrointestinal dysfunction, motor deficits, and depression. Nutritional deficiency is an independent risk factor for poor prognosis in patients treated for neurological conditions[14]. Patients with neurological dysphagia in the course of stroke require nutritional support from the time of admission to hospital[15].

Medical nutrition treatment[16] is defined as the administration of oral food supplements, enteral nutrition, and parenteral nutrition. According to Regulation (EU) No. 609/2013 of the European Parliament and of the Council of 12 June 2013, nutritional products administered by the gastrointestinal (oral or enteral) route are defined as food for special medical purposes. It is specially processed or formulated for the dietary management of patients and used under medical supervision. Such food is used where proper nutrition cannot be achieved by modification of the normal diet alone.

The aim of this study was to analyze the laboratory results of the patients enrolled in the Nutritional Therapy Program. The results were analyzed on admission to hospital as well as after six and twelve months from the beginning of treatment in the Enteral Nutrition Clinic with regard to the underlying disease (cancer, neurological disorder, malnutrition).

## Patients and Methods

The study involved analysis of the medical records of the patients included in the Nutritional Therapy Program implemented by the Enteral Nutrition Clinic at the West Pomeranian Hospice for Children and Adults. The study sample consisted of 103 patients at the mean age of 60.67 years. The research material was pseudonymized by the data administrator – the West-Pomeranian Hospice. The study was approved by the Bioethics Committee of Pomeranian Medical University (KB-0012/40/01/19). Informed consent was obtained from the study participants.

The inclusion criteria for both the Nutritional Therapy Program and for our study were based on the standards developed by the Polish Society of Enteral and Parenteral Nutrition and Metabolism. Following the National Health Fund guidelines, patients referred to the Enteral Nutrition Clinic had: an ICD-10 diagnosis, had an artificial access percutaneous endoscopic gastrostomy (PEG), gastrostomy or jejunostomy, had a caregiver, and lived in the West-Pomeranian province. Each pa-

tient included in the program had vital signs measured, namely blood pressure [mmHg], saturation [$O_2$], heart rate [number of beats/min], and temperature [°C]. Additionally, blood for biochemical analysis was collected from each patient during scheduled visits at home once every three months. Blood was drawn on an empty stomach by nurses working at the Enteral Nutrition Clinic. Biochemical analysis was performed using commercial widely available diagnostic tests in the Diagnostyka Laboratories located in the West Pomeranian province **(Supplementary Table I)**.

### Statistical Analysis

The variables were characterized by the parameters of descriptive statistics, whose choice depended on the type of the measurement scale. For quantitative variables, the following parameters were determined: measures of central tendency (M – mean, Mdn – median), measures of variability (SD – standard deviation, CV – coefficient of variation), and measures of location (IQR – interquartile range, minimum and maximum values). For qualitative and ordinal variables, counts (N) and purity (%) were determined.

Statistical inference was based on null hypothesis testing. The choice of statistical tests was dictated by the type of research model (related and unrelated samples), the type of the dependent variable measurement scale, and the number of variants of the independent variable. Additionally, effect measures were determined to match the type of statistical test. The method of mathematical statistics used in the study was multivariate analysis of variance (MANOVA). The level of statistical significance was set as 0.05. All calculations were performed using the Statistica v. 13.3 software (TIBCO Software Inc., Palo Alto, CA, USA).

## Results

The study involved 103 patients, including 61 (59.2%) men and 42 (40.8%) women. The largest group of 50 (48.5%) respondents resided in a city with a population exceeding 100,000 inhabitants. The smallest number of respondents (26; 25.2%) were rural residents. 46 (44.7%) patients were married, 30 (29.1%) were single, and 27 (26.2%) were widowed. The most numerous patients enrolled in the Nutritional Therapy Program were those with cancer (46; 44.7%). There were 31 (30.1%) patients with ischemic disease, and 26 (25.2%) with neurological disease. The most common comorbidities were malnutrition (54; 52.4%) and neurological diseases (46; 44.7%), and the least common were malignant diseases (3; 2.9%).

The mean age of the participants was 60.67 years, the median was 62 years. Since the patients in the Nutritional Therapy Program had normal values of blood pressure, heart rate, and saturation, these parameters were not analyzed in the study.

Analysis of the data showed that the disease of the patients enrolled in the Nutritional Therapy Program was not a significant differentiating factor for the repeated blood count measurement results, except for the erythrocyte count ($p = 0.03$). The diagnosis had not statistically significant ($p > 0.05$) moderating effect on the potential change in the mean values of the other blood count parameters studied. In the groups of patients with malnutrition and neurological diseases there was an increase in the mean number of erythrocytes. In contrast, in the group of patients with cancer, there was a decrease in the mean erythrocyte count after six months compared to the initial measurement (Table I).

The disease entity was not a significant factor differentiating the results of repeated laboratory tests (phosphorus, total protein, urea, creatinine) ($p > 0.05$). It was found that in patients with neurological disease and malnutrition, the mean CRP concentration was significantly ($p = 0.003$) lower after six and twelve months compared to the initial measurement and showed a downward trend. In contrast, in the cancer group, the mean CRP concentration decreased after six months compared to the initial measurement, but it increased after twelve months. The mean albumin concentration in patients with malnutrition was significantly higher after twelve months compared to the initial measurement. In contrast, no significant change was observed in patients with cancer and neurological diseases (Table II).

The disease entity had not statistically significant ($p > 0.05$) moderating effect on the mean activity of liver enzymes in the blood of the patients upon admission, after six and after 12 months (Table III).

We found that glucose levels after six months were significantly lower compared to the first measurement in all the patients regardless of the disease entity ($p = 0.017$). The downward trend continued in patients diagnosed with malnutrition and neurological diseases. In contrast, glucose levels did not change significantly in patients with cancer after further six months.

**Table I.** Comparison of selected blood count parameters of the patients examined on admission, after six and twelve months depending on the disease entity.

| Parameter | Diagnosis | $T_0$ | | $T_{6M}$ | | $T_{12M}$ | | $F_{(4, 196)}$ | $p^*$ |
|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD | | |
| WBC (tys./µl) | neurological disease | 9.14 | 4.04 | 8.49 | 2.95 | 7.95 | 2.40 | 0.539 | 0.707 |
| | malnutrition | 8.80 | 3.63 | 8.10 | 2.70 | 8.32 | 2.33 | | |
| | neoplasma | 9.75 | 5.45 | 8.51 | 3.22 | 8.61 | 3.18 | | |
| LYM (tys./µl) | neurological disease | 1.28 | 0.50 | 7.13 | 28.34 | 1.92 | 1.19 | 0.802 | 0.525 |
| | malnutrition | 1.74 | 1.17 | 11.14 | 51.40 | 2.43 | 1.58 | | |
| | neoplasma | 1.14 | 0.74 | 1.22 | 0.52 | 1.22 | 0.54 | | |
| HB (g/dl) | neurological disease | 11.84 | 1.17 | 12.20 | 0.57 | 12.88 | 0.62 | 0.402 | 0.807 |
| | malnutrition | 10.98 | 1.36 | 11.82 | 0.97 | 12.94 | 0.77 | | |
| | neoplasma | 11.52 | 1.44 | 11.94 | 0.78 | 14.79 | 16.18 | | |
| E (mln/ul) | neurological disease | 3.85 | 0.64 | 3.92 | 0.40 | 4.26 | 0.38 | 2.736 | 0.030 |
| | malnutrition | 3.80 | 0.58 | 3.97 | 0.52 | 4.37 | 0.49 | | |
| | neoplasma | 3.86 | 0.55 | 3.83 | 0.42 | 4.04 | 0.50 | | |
| PLT (tys./µl) | neurological disease | 317.85 | 114.27 | 289.15 | 70.02 | 278.73 | 71.79 | 1.278 | 0.280 |
| | malnutrition | 274.42 | 101.92 | 281.55 | 84.67 | 255.19 | 57.52 | | |
| | neoplasma | 340.26 | 99.02 | 308.33 | 68.89 | 305.57 | 79.69 | | |

* MANOVA - multivariate analysis of variance, M - mean, SD - standard deviation,
WBC - leukocytes, LYM - lymphocytes, Hb - hemoglobin, E - Erythrocytes, PLT - platelets

There were no statistically significant differences in the mean levels of total cholesterol and triglycerides depending on the disease entity ($p$ = 0.529) (Table IV).

Statistically significant differences were noted between the results of initial and consecutive measurements of iron ($p < 0.0001$) and calcium ($p = 0.025$) depending on the disease entity. In the group of patients with neurological disease and malnutrition, the mean levels of iron were systematically increasing up to the last measurement. In contrast, in the group of patients diagnosed with cancer, an increase in the mean iron level was observed after six months. However, this trend

**Table II.** Comparison of blood laboratory results on admission, after six and twelve months depending on the disease entity.

| Parameter | Diagnosis | $T_0$ | | $T_{6M}$ | | $T_{12M}$ | | $F_{(4, 196)}$ | $p^*$ |
|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD | | |
| Phosphorus (mmol/l) | neurological disease | 1.51 | 0.99 | 1.72 | 0.68 | 1.80 | 0.79 | 1.662 | 0.160 |
| | malnutrition | 1.01 | 0.42 | 1.77 | 1.98 | 1.48 | 0.67 | | |
| | neoplasma | 1.47 | 0.75 | 1.75 | 0.61 | 1.53 | 0.61 | | |
| Albumin (g/dl) | neurological disease | 3.18 | 0.43 | 3.28 | 0.29 | 3.46 | 0.45 | 2.715 | 0.031 |
| | malnutrition | 3.19 | 0.74 | 3.39 | 0.73 | 7.96 | 16.83 | | |
| | neoplasma | 3.19 | 0.46 | 3.21 | 0.42 | 3.32 | 0.52 | | |
| Total protein (g/dl) | neurological disease | 6.00 | 0.58 | 6.12 | 0.36 | 6.41 | 0.43 | 1.264 | 0.286 |
| | malnutrition | 5.86 | 0.59 | 6.00 | 0.66 | 7.39 | 6.27 | | |
| | neoplasma | 6.14 | 0.45 | 6.17 | 0.38 | 6.28 | 0.55 | | |
| CRP (mg/l) | neurological disease | 12.63 | 10.69 | 6.92 | 4.20 | 5.68 | 4.00 | 4.156 | 0.003 |
| | malnutrition | 20.13 | 22.93 | 7.82 | 5.41 | 4.86 | 3.20 | | |
| | neoplasma | 41.99 | 31.69 | 19.86 | 13.68 | 22.49 | 17.48 | | |
| urea (mg/dl) | neurological disease | 36.50 | 15.25 | 34.63 | 9.34 | 36.77 | 12.42 | 1.406 | 0.233 |
| | malnutrition | 36.03 | 15.48 | 33.15 | 9.54 | 33.09 | 13.81 | | |
| | neoplasma | 37.91 | 19.88 | 35.15 | 10.89 | 40.99 | 15.08 | | |
| creatinine (mg/dl) | neurological disease | 0.69 | 0.40 | 0.57 | 0.26 | 0.64 | 0.25 | 2.300 | 0.060 |
| | malnutrition | 0.64 | 0.31 | 2.73 | 8.58 | 0.68 | 0.21 | | |
| | neoplasma | 0.70 | 0.23 | 0.62 | 0.23 | 0.75 | 0.27 | | |

* MANOVA - multivariate analysis of variance, M - mean, SD - standard deviation, CRP - C-reactive protein

**Table III.** Comparison of selected parameters of liver enzymes in blood on admission, after six and twelve months depending on the disease entity.

| Parameter | Diagnosis | $T_0$ | | $T_{6M}$ | | $T_{12M}$ | | $F_{(4, 196)}$ | p* |
|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD | | |
| ALT(U/l) | neurological disease | 31.23 | 16.86 | 26.04 | 8.71 | 24.81 | 10.98 | 0.952 | 0.435 |
| | malnutrition | 31.13 | 19.19 | 27.39 | 14.78 | 22.84 | 9.92 | | |
| | neoplasma | 28.33 | 19.10 | 24.13 | 8.88 | 24.76 | 10.02 | | |
| AST(U/l) | neurological disease | 27.92 | 15.70 | 23.08 | 8.98 | 22.04 | 9.51 | 0.562 | 0.691 |
| | malnutrition | 24.06 | 14.17 | 22.26 | 12.46 | 19.42 | 8.76 | | |
| | neoplasma | 24.70 | 16.58 | 21.76 | 9.68 | 21.57 | 9.01 | | |
| ALP(U/l) | neurological disease | 105.38 | 37.19 | 87.04 | 22.89 | 82.73 | 21.55 | 1.738 | 0.143 |
| | malnutrition | 96.03 | 41.88 | 92.97 | 40.42 | 98.13 | 59.45 | | |
| | neoplasma | 105.83 | 71.45 | 86.07 | 31.14 | 92.98 | 43.48 | | |

* MANOVA – multivariate analysis of variance; M – mean; SD - standard deviation, ALT – Alanine Aminotransferase, AST – Aspartate Aminotransferase, ALP – Alkaline Phosphatase.

weakened over the next six months, and only a minimal increase was recorded at the last measurement. The mean level of calcium, on the other hand, showed an upward trend over six months in the group of patients with neurological diseases and malnutrition, and a downward trend both after six and twelve months in the group of cancer patients. For the mean electrolyte and magnesium levels, no statistically significant differences were found between the results of measurements after six and twelve months depending on the disease entity (Table V).

## Discussion

Nutritional treatment is an integral part of modern patient management. It has been proven that meeting nutritional needs significantly contributes to improving treatment outcomes, to reducing complications and length of hospitalization, and ultimately to lowering treatment costs. Therefore, proper identification of malnourished patients is extremely important.

Blood biomarkers, especially albumin, are often used to diagnose malnutrition in clinical settings. Unfortunately, neither the evidence-based literature nor clinical guidelines indicate what levels of blood biomarkers are an indication for nutritional intervention, and how it can be tailored to the patient's specific situation (clinical status, diagnosis, comorbidities)[7]. The results of a meta-analysis by Hickson[17] show that several blood biomarkers, including albumin, prealbumin, hemoglobin, total cholesterol, and total protein are useful biochemical indicators of malnutrition, even in cases of chronic inflammation. Inflammation caused by disease or aging is an important etiological factor in the development of malnutrition.

Our study, which involved analysis of laboratory results (including the composition and qual-

**Table IV.** Comparison of blood laboratory test results (glucose, total cholesterol, and triglycerides) on admission, after six and twelve months depending on the disease entity.

| Parametr | Diagnosis | $T_0$ | | $T_{6M}$ | | $T_{12M}$ | | $F_{(4. 196)}$ | *p** |
|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD | | |
| Glukose (mg/dl) | neurological disease | 119.13 | 32.91 | 101.85 | 19.76 | 96.58 | 12.52 | 3.076 | 0.017 |
| | malnutrition | 113.63 | 34.36 | 99.58 | 17.79 | 95.37 | 10.82 | | |
| | neoplasma | 102.09 | 21.16 | 93.61 | 9.79 | 94.54 | 10.51 | | |
| Total Cholesterol (mg/dl) | neurological disease | 152.38 | 48.68 | 138.62 | 28.11 | 148.01 | 25.21 | 0.796 | 0.529 |
| | malnutrition | 158.35 | 57.77 | 147.81 | 36.48 | 143.85 | 32.42 | | |
| | neoplasma | 157.83 | 42.83 | 1415.7 | 31.40 | 146.65 | 27.43 | | |
| Trigliceryds (mg/dl) | neurological disease | 97.02 | 38.07 | 97.81 | 22.11 | 104.93 | 23.59 | 0.808 | 0.521 |
| | malnutrition | 115.28 | 60.46 | 111.11 | 44.36 | 109.03 | 30.50 | | |
| | neoplasma | 123.25 | 76.81 | 116.57 | 51.28 | 117.35 | 43.07 | | |

* MANOVA – multivariate analysis of variance; M – mean; SD – standard deviation.

**Table V.** Comparison of blood laboratory test results (electrolytes, iron, calcium, and magnesium) on admission, after six and twelve months depending on the disease entity.

| Parametr | Diagnosis | $T_0$ | | $T_{6M}$ | | $T_{12M}$ | | $F_{(4, 196)}$ | $p^*$ |
|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD | | |
| Sodium (mmol/l) | neurological disease | 135.46 | 5.36 | 136.50 | 3.44 | 138.65 | 2.91 | 0.602 | 0.662 |
| | malnutrition | 133.97 | 3.83 | 134.94 | 2.74 | 136.90 | 5.40 | | |
| | neoplasma | 136.48 | 5.52 | 157.41 | 147.82 | 136.91 | 3.40 | | |
| Potassium (mmol/l) | neurological disease | 4.43 | 0.60 | 4.17 | 0.50 | 4.30 | 0.44 | 1.159 | 0.330 |
| | malnutrition | 4.47 | 0.52 | 4.23 | 0.51 | 8.79 | 24.73 | | |
| | neoplasma | 4.58 | 0.64 | 4.27 | 0.55 | 4.44 | 0.59 | | |
| Chlorides (mmol/l) | neurological disease | 97.31 | 4.84 | 97.54 | 2.67 | 99.27 | 2.09 | 0.200 | 0.938 |
| | malnutrition | 96.58 | 3,64 | 96.68 | 2.61 | 97.14 | 17.39 | | |
| | neoplasma | 96.50 | 4.92 | 95.78 | 2.50 | 97.20 | 2.49 | | |
| Iron (ug/dl) | neurological disease | 36.04 | 15.61 | 45.92 | 10.24 | 53.58 | 13.78 | 5.490 | <0.0001 |
| | malnutrition | 32.97 | 13.03 | 41.23 | 10.67 | 56.61 | 14.28 | | |
| | neoplasma | 26.15 | 12.27 | 39.83 | 10.11 | 41.54 | 12.67 | | |
| Calcium (mmol/l) | neurological disease | 2.15 | 0.26 | 2.26 | 0.08 | 2.26 | 0.06 | 2.860 | 0.025 |
| | malnutrition | 2.19 | 0.15 | 2.28 | 0.08 | 2.26 | 0.07 | | |
| | neoplasma | 2.26 | 0.28 | 2.25 | 0.09 | 2.23 | 0.14 | | |
| Magnesium (mmol/l) | neurological disease | 0.96 | 0.39 | 1.03 | 0.31 | 1.16 | 0.44 | 1.107 | 0.354 |
| | malnutrition | 0.87 | 0.40 | 0.95 | 0.29 | 1.11 | 0.39 | | |
| | neoplasma | 0.93 | 0.43 | 0.94 | 0.26 | 1.01 | 0.37 | | |

* MANOVA – multivariate analysis of variance; M – mean; SD – standard deviation.

ity of morphotic elements of blood) on admission to the Enteral Nutrition Clinic, showed that all elements were within normal limits, except for hemoglobin and erythrocytes, whose mean levels were below normal. After six months the mean values of hemoglobin and erythrocytes slightly increased but were still below normal, and after twelve months they reached the reference values. In addition, in our study, the mean total cholesterol and triglyceride levels were within the reference values, both at enrollment and after six and twelve months of treatment. An etiology-based approach to the diagnosis of adult malnutrition recognizes the importance of inflammation[18]. An increase in the ratio of CRP to prealbumin in intensive care unit patients has been associated with higher mortality[19]. Routine measurement of pre-albumin is considered to be a useful nutritional and prognostic indicator in the pathophysiology of malnutrition[20]. In our study, all the subgroups had the mean CRP values above and the mean leukocyte levels within the reference values at the initial measurement. In patients with neurological diseases and malnutrition, a significant decrease in the mean CRP levels was observed both after six and after twelve months. In cancer patients, the mean CRP level was lower after six months, but there was an increase after twelve months.

In a study by Hickson et al[17] inflammation among patients was confirmed by elevated CRP levels (> 10 mg/dL). However, the authors claim that CRP, TLC, and WBC can only serve as indicators of inflammation, and are not good indicators of malnutrition. As for other blood biomarkers (i.e., transferrin, creatinine, triglycerides, iron, and hematocrit), the authors believe that there is no sufficient evidence to support using them as indicators of malnutrition. In our study, plasma creatinine levels were also determined and found to be slightly below normal. After six months, an upward trend in the mean creatinine level was observed, but it was still slightly below normal. Ultimately, it reached the lower limit of the reference values after twelve months. Despite an upward trend, also the levels of iron were below the reference values both after six and twelve months.

Albumin has been determined for decades as an indicator of malnutrition in clinically stable patients. Serum albumin levels decrease with age by approximately 0.1 g/L per year. However, age alone is not the cause of marked hypoalbuminemia. A study by Cabrerizo et al[18] indicated that albumin is the best tested protein used in the diagnosis of malnutrition. The above study also provides evidence suggesting that the use of a cut-off point of 3.5 g/dl for serum albumin as an

indicator of malnutrition may not be appropriate for the elderly. Hypoalbuminemia, often defined as serum albumin < 3.5 g/dl, has traditionally been considered a standard indicator of malnutrition. According to Shenkin et al[21] measuring albumin levels is a useful tool for identifying malnutrition in individuals with vague clinical conditions. At the same time, they claim that only a small proportion of high-risk individuals have prealbumin levels below 20 mg/dl, which may lead to underdiagnosis of malnutrition. In our study, plasma total protein and albumin levels were also measured. Both on admission and after six months, the patients' mean total protein levels were below reference values, while after twelve months they were within the normal range. Similarly, on admission to and after six months in the Enteral Nutrition Clinic the mean plasma albumin levels were also below normal. After twelve months, the mean albumin level was within the normal range.

Cederholm et al[22] found that hemoglobin, total cholesterol, and total protein levels are useful markers of adult malnutrition. More importantly, they observed that the above-mentioned biochemical parameters were insensitive to acute stress induced by the disease. The estimated hemoglobin level in the population analyzed by Smith was relatively low, even in individuals who were not at risk of malnutrition (< 14.2 g/dl). The value of < 13 g/dl was accepted as a cut-off point for malnutrition, which is consistent with the lower limit of the adult hemoglobin standard proposed by WHO: 13 g/dl for men; 12 g/dl for women)[23]. Furthermore, Omran et al[24] provided evidence that cholesterol levels below 160 mg/dl, defined as 'hypocholesterolemia', should be considered as an effect of malnutrition.

In our study, selected laboratory parameters were evaluated with regard to the disease entity: cancer, neurological disease, and malnutrition. Depending on the disease, statistically significant differences in the mean values of six parameters were observed. These parameters were lymphocyte, platelet, inorganic phosphorus, CRP, glucose, and iron. The mean lymphocyte count was highest in the malnutrition group. The mean platelet count was highest in the cancer group. The mean level of inorganic phosphorus was lowest in the malnutrition group. The mean CRP level was highest and above reference values in the cancer group. The mean glucose level was highest and above reference values in the group with neurological disease. The mean iron level was highest, although still below reference values, in the group with neurological diseases.

### *Malnutrition and Cancer*

The results of meta-analysis by Blackwood et al[25] indicate the need for further research on nutritional support for patients with cancer. Key questions regarding the optimal time for starting nutritional treatment (for example, stage of disease), and the basis on which the decision to terminate such therapy should be made remain unanswered.

This circumstance also justifies addressing this topic in this paper. Indeed, there is evidence to support the need for greater attention to nutritional support for patients with incurable cancer. Our study revealed statistically significant differences between the results of the first, second, and third blood count measurement. All blood count parameters, except for lymphocytes, changed over the six-month and twelve-month intervals. The strongest effect of enteral nutrition was observed for erythrocytes. The mean erythrocyte count on admission to the Enteral Nutrition Clinic was statistically significantly lower than after twelve months but did not differ from the mean count recorded after six months. The mean hemoglobin level was statistically significantly lower on admission compared to that observed after twelve months, but the same as after six months. Gangadharan et al[26] provided a comprehensive review of factors affecting nutrient intake in cancer patients. These authors put particular emphasis on nutritional support available to malnourished patients and promising biomarkers for identifying patients who are likely to develop serious nutritional complications. Our study showed that the mean albumin and total protein levels in cancer patients did not change significantly from the initial measurement.

As cancer progresses, the activity of pro-inflammatory cytokines increases. Systemic inflammation is a hallmark of cancer cachexia indicated by the production of acute phase proteins (APRs), such as CRP and fibrinogen. Increased APR production may result in a higher demand for amino acids, compensated by an increase in muscle catabolism[27]. Our study showed that in patients diagnosed with cancer, mean CRP levels decreased after six months compared to the initial measurement, however, after twelve months an increase in the mean values was observed. Hypermetabolism in malnourished patients contributes to a negative energy balance that manifests as weight loss.

Resting energy consumption has been shown to vary depending on the type of tumor. Patients with gastric and colorectal cancer usually have normal resting energy expenditure, whereas in patients with pancreatic and lung cancer, it is increased[28]. Higher energy expenditure in patients with lung cancer is usually the result of systemic inflammatory response[29]. Patients with cancer and/or receiving anticancer therapy experience a variety of physiological symptoms that negatively affect appetite and disrupt diet. These side effects can lead to reduced food intake, improper digestion, and poor absorption of nutrients, the consequence of which may be the development of anorexia. The toxicity of chemotherapy causes many complications in cancer patients, including nausea, vomiting, anorexia, changes in taste and smell, early satiety, mucositis, esophagitis, diarrhea, and constipation. The most common complications of chemotherapy include nausea, affecting 84% of patients. In addition to the reduced intake of nutrients, metabolic abnormalities such as hyperglycemia and hypercalcemia also occur after chemotherapy[30].

Our study showed that the mean glucose level was significantly lower after six months compared to the first measurement but did not substantially change during the next six months. At the same time, a downward trend was observed in the mean calcium level after six and twelve months.

Alkylating agents, such as Cyclophosphamide, Ifosfamide or Methotrexate, may contribute to malabsorption by stimulating the direct mucosa and altering metabolism[31]. Moreover, due to changes associated with mucositis, erosive changes may develop in the gastrointestinal tract[30]. Taste changes are common – they occur in 45-84% of cancer patients receiving chemotherapy[32,33]. Chemosensory dysfunction influences food intake and appetite[34], leading to the development of food aversions and weight loss[35]. In moderately and severely malnourished cancer patients who are at risk of not receiving adequate nutrition for 7 to 14 days after surgery, enteral nutrition (EN) appears to be beneficial. This especially applies to the administration of an immune-boosting formula containing arginine and ω-3 oil. In a study by Braga et al[36] acids and nucleotides were shown to reduce the incidence of surgical complications in patients.

Cancer patients suffer from nutritional deficiencies (mainly protein and caloric deficits). In patients with nutritional deficits at the time of diagnosis, therapy is likely to exacerbate this problem, which may result in the necessity of suspension or reduction of medication management. Therefore, the nutritional status of oncology patients should be monitored from the time of diagnosis throughout treatment. It has been recently shown[37] that nutritional interventions improve the quality of life of such patients but have little effect on their mortality.

### Malnutrition and Neurological Diseases

In a study by Sorgun et al[38] the prevalence of chronic malnutrition, based on serum albumin levels < 3.5 mg/dL, was 11.8% in patients with multiple sclerosis and only 2% in patients with other chronic neurological diseases.

Salemi et al[39] found that patients with clinically stable multiple sclerosis had higher levels of homocysteine and HDL cholesterol, and lower levels of vitamin E in the whole blood, as well as a lower ratio of vitamin E to cholesterol.

Workinger et al[40] and Volpe[41] assert that magnesium is an important mineral in the human body. It regulates the activity of hundreds of enzymes and is engaged in approximately 80% of known metabolic functions. Maintaining balance in the body requires a daily intake of 3.6 mg/kg magnesium in humans under typical physiological conditions. The average daily intake of this element for an adult is estimated to be 320 to 420 mg/day (13-17 mmol/day). Unlike other minerals, magnesium can be absorbed throughout the gastrointestinal tract. The total serum magnesium concentration ranges from 0.65 mmol/l to 1.0 mmol/l, the rest is distributed in soft tissues (19%), muscles (27%) and bones (53%)[42,43]. Analysis of our results demonstrated that the mean level of magnesium was statistically significantly lower on admission than twelve months later but did not significantly differ from that noted after six months. In spite of medical and diagnostic progress, the nutritional status of patients is still a topical issue that attracts the attention of many researchers. The data available in the literature clearly indicate the need for further research in this field.

The study presented here has some limitations. The first of them is that the number of participants was limited to those under the care of one outpatient clinic for enteral feeding. Secondly, we did not find any publications that would compare laboratory and anthropometric parameters measured in six-month intervals in patients included in a nutritional therapy program. Hence, it was not

possible to compare the results of our study with those performed by other authors.

## Conclusions

1. There were significant differences in the results of laboratory tests between patients with cancer and those with malnutrition and neurological diseases. These were mainly lower levels of lymphocytes and glucose, and higher levels of platelets and CRP.

2. The greatest effect of nutritional treatment was observed in patients with malnutrition and neurological diseases. In the studied group of patients, selected parameters of biochemical tests (albumin, total protein, erythrocytes, hemoglobin, inorganic phosphorus, iron, glucose) reached the reference values after twelve months.

### Conflicts of Interest

The Authors declare no conflict of interest.

### Authors' Contributions

Conceptualization, M.KO. and E.G.; Methodology, M.KO., P.U. and M.KA.; Analysis, M.KO, M.KA. and D.SM.; Investigation, M.KO., M.KA., M.B.; Data Curation, M.B.; Writing – Original Draft Preparation, D.SM.; Writing – Review& Editing, E.G., P.U. and D.SM.; Visualization, M.KO. and M.B.; Supervision, E.G.; Funding Acquisition, E.G. and M.KA.

### Ethical Approval

The study was approved by the Bioethics Committee of Pomeranian Medical University (KB-0012/40/01/19).

### Informed Consent

Informed consent was obtained from the study participants.

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