**Effect of β-glucan Supplementation on Levels of IgM, IgA, IgG and Its Subclasses IgG1, IgG2, IgG3, and IgG4 in Cancer Patients**

Richter Josef, Kral Vlastimil, Vetvicka Vaclav, Rajnohova Dobiasova Lucie, Fernandez-Botran Rafael

**ABSTRACT**

**AIM:** The role of β-glucan supplementation on cancer development is well established. In this report we focused on the effects of glucan on levels of individual classes and subclasses of immunoglobulins.

**MATERIALS AND METHODS:** We evaluated the levels of IgM, IgG, IgA, IgG1, IgG2, IgG3 and IgG4 in 39 patients diagnosed with breast or colorectal cancer.

**RESULTS:** We found a significant decrease of IgG1 levels in the placebo group, which was particularly pronounced in females.

**CONCLUSIONS:** Short-term glucan supplementation significantly stabilized levels of IgG1 resulting in maintaining anti-infectious immunity. The decrease in IgG1 levels found in the placebo group was clearly caused by a complex therapy of cancer disease.

**Key words:** Glucan; Immunoglobulins; Cancer; Treatment

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by IL-4 induction[9]. Detailed ways of induction of different B cell responses involving pleitropic variants of IL-4 are currently being studied[10]. It was suggested that in patients with elevated levels of specific anti-cancer antibodies have a better prognosis of survival[9]. In 40% of patients with mammary cancer, it was shown that the presence of anti-MUC-1 antibodies correlates with better prognosis[19].

Patients recovering from cancer treatment and suffering from stress related fatigue were used in our study for search of possible innovation of immune functions by affecting not only cellular immunity, but also specific and nonspecific humoral immunity. Based on excellent results in supplementing the diet with β-glucan[11,12,13] we decided to evaluate the effects of short term supplementation with β-glucan. β-Glucan is part of the group of biologically active materials and consists of highly conserved structural components of cell wall of yeast, mushroom and seaweed. With over 15,000 published papers, it is not surprising that more and more attention is focused on β-glucan in medicine. Effects of β-glucan supplementation on cancer growth, allergy, autoimmune diseases, gastrointestinal tract problems, infections and other pathophysiological problems were repeatedly demonstrated[12-14] (for review see Vetvicka[15], Vannucci[16]). Our own experience with the positive effects of the addition of glucan to the diet of patients finishing their cancer treatment on cellular immunity led us to this study evaluating effects of glucan supplementation on humoral immunity and on possible elimination of stress and additional side effects of cancer treatment.

Changes of cognitive functions connected with chemotherapy are significant, particularly due to the high frequency in patients treated for breast cancer[16]. The range of factors playing role in disrupting cognitive functions is clearly defined in Tannock et al[20]. Briefly, these factors involve effects of treatment, depression, fatigue, fear, changes in coagulability of microvascular small blood vessels, induction of endogenous hormones and cytokines and also genetic disposition. One cannot forget depressed function of reflex pump (P-glycoprotein), deficit of DNA repair mechanisms and deregulation of immune functions[21]. Some authors even suggested possible correlation between clinical manifestation of insomnia and immune mechanisms[22,18]. Studies focusing on the problems mentioned above are currently the focus of numerous laboratories[22-24]. Numerous studies, with respect of our current study, evaluated the neurolecular effects of exogenous polysaccharides. These studies showed that many plant-based polysaccharides have positive effects on cognitive functions in both healthy population and in cancer patients[20]. In our study, we observed that supplementation with glucan caused some effects on cognitive functions and feelings.

Abnormalities within the immune system appearing during fatigue can play some role in the development and progress of insomnia. Repeated proofs of cognitive deficits in cancer patients (during and after clinical treatment) led to extensive research of possible changes in functions of the central nervous system. In most patients, we can observe a connection between disruption of cognitive functions (memory and attention) and disease. Some hypothesize that inflammation or immune dysfunctions, microvascular damage or genetic predisposition can be involved in these changes[17-19]. Complex cancer treatment, endocrinal changes, mood swings (depression and fear) and pro-inflammatory cytokines can negatively influence neuropsychical function and performance of brain. Subjective problems connected with deterioration of cognitive function are often described as “chemobrain”[20]. These problems are most commonly accompanied with mood swings, but might be influenced by additional factors. With well-established central role of cytokines in neuro-immuno-endocrine axis one can speculate that these bioactive molecules can affect cognition via several various mechanisms[21-25]. The brain is not only independently immunoactive, but performs numerous complex immune interactions with the rest of the body. Peripheral cytokines penetrate blood-brain barrier not only via active mechanisms, but also indirectly via vagal stimulation. In addition, it is known that some cytokines results in negative effects on cognitive functions[19]. Additional factors might be hormonal changes, particularly estrogen and testosterone, and attention fatigue[11].

The fact that the interaction of cytokines with neurons and glial cells leads to a decrease in cognitive functions is well established (for review see Wilson et al[26]). The dysregulation of both peripheral and central nervous system cytokine network strongly affects the immune system. It is clear that to ensure optimal treatment of these late consequences, evaluation of patients at the end of oncologic treatment needs to gain more interest from multidisciplinary teams.

**MATERIALS AND METHODS**

**Glucan**

Yeast-derived insoluble Glucan #300 (> 85% dry w/w basis) was purchased from Transfer Point (Columbia, SC, USA). This glucan contains 96% carbohydrates and 2.1% proteins. Neutral sugar analysis confirmed 91.3% glucose and 8% mannose.

**Protocol**

The same protocol described in Richter et al[15] was used throughout this study. Briefly, a randomized, double-blind, placebo-controlled trial compared β-glucan #300 and a placebo in people after complex surgical, radiation and/or chemotherapy treatment of cancer. Out of a total of 39 patients, 10 were males and 29 females with a diagnosis of breast or colorectal cancer. All patients underwent basic immunologic screening with evaluation of full spectrum of inflammatory reaction, cancer markers and cellular immunity. In all patients, medical evaluation revealed chronic fatigue syndrome with significant problems in cognitive functions. In addition to evaluations at the Department of Clinical Immunology, all patients were also evaluated by an oncologist.

Out of a total of 39 patients, 23 individuals obtained glucan #300 at a daily dose of 200 mg, 16 patients obtained a placebo which was not distinguishable from the glucan in shape, color or size. All participants were introduced to IMULITE analyzer, treatment program and agreed to proposed treatment in writing. The placebo group consisted of 6 males and 10 females with an average age of 58.4 ± 2.9 years. The glucan supplemented group consisted of 4 males and 19 females with an average age of 58.6 ± 3.8 years. After three months of application, all patients underwent a final evaluation of blood parameters and cognitive functions. This study was performed in full agreement with the Helsinki declaration (revised version 2000.09.01) and was in full compliance with the rules for clinical testing in the Czech Republic.

We measured the levels of IgA, IgG and IgM and subclasses IgG1, IgG2, IgG3 and IgG4 using nephelometer Siemens BM II (Siemens Health Care, Diagnostics, Germany) as suggested by the manufacturer. Relevant antibodies and controls were provided by Siemens. Evaluation employed IMULITE 20 analyzer.

**Statistical analysis**

Statistical significance was evaluated by a pair t-test using GraphPad Prism 5.04 software (GraphPad Software, USA). An average and standard deviation was evaluated after determination of composition of standard values (D’Agostino, Pearson). In case of non-standard composition, we converted the values into logarithms.
Figure 1 IgG, IgA and IgM levels in the groups of cancer patients supplemented BG and PL.

Figure 2 IgG1 Women

RESULTS

Table 1 and Figure 1 summarize immunoglobulin levels. These data show that three months glucan supplementation did not change the immunoglobulin levels, the changes between original and endpoint levels are not statistically significant. In all classes of immunoglobulins, the levels correspond to control levels at the same geographical region with respect to both sex and age.

A different situation was found when we focused on IgG subclasses. Average levels of IgG1 showed a significant decrease in the placebo group from 7.13 to 6.01 mg/ml ($p < 0.0394$), but no such effects were found in the glucan-supplemented group (6.67 and 6.12 mg/mL with $p < 0.4505$). All other IgG subclasses showed no changes. The only interesting change was found in the case of

Table 1 Paired t-test was used for statistical evaluation (see Methods section). Data are shown as mg/ml. Patient clinical status is given in Methods section.

|       | IgG    | IgA     | IgM     | IgG1   | IgG2   | IgG3   | IgG4   |
|-------|--------|---------|---------|--------|--------|--------|--------|
|       | day 1  | day 90  | day 1   | day 90 | day 1  | day 90 | day 1  | day 90 |
| Placebo |        |         |         |        |        |        |        |        |
| n     | 16     | 16      | 16      | 16     | 16     | 16     | 16     | 16     |
| mean  | 10.88  | 10.85   | 1.94    | 1.95   | 1.91   | 1.95   | 7.13   | 6.01   |
| SD    | 0.87   | 0.74    | 0.22    | 0.22   | 0.22   | 0.22   | 0.88   | 0.88   |
| Paired-t-test | 0.871 | 0.966    | 0.359   | 0.039  | 0.994  | 0.984  | 0.104  | 0.104  |
| Glukan |        |         |         |        |        |        |        |        |
| n     | 23     | 23      | 23      | 23     | 23     | 23     | 23     | 23     |
| mean  | 11.39  | 11.74   | 2.22    | 2.22   | 1.98   | 1.98   | 6.67   | 6.12   |
| SD    | 2.8    | 2.91    | 0.18    | 0.18   | 0.17   | 0.16   | 1.35   | 1.51   |
| Paired-t-test | 0.311 | 0.788    | 0.926   | 0.451  | 0.982  | 0.558  | 0.495  | 0.495  |
IgG4, where neither glucan nor placebo showed any effects, but a significant change between both groups was found. The high average level of IgG4 in the placebo group is caused by one patient with IgG4 levels of 3.82 mg/mL (and 3.68 mg/mL at the end of experiment) corresponds with an IgG4-related disease diagnosis.

Significant differences in IgG1 levels were found when we divided groups according to sex (Figure 2). In the female placebo group the level of IgG1 significantly decreased from 7.41 ± 1.33 to 6.47 ± 1.37 mg/mL (p < 0.0213), in the male placebo group we found a small decrease from 7.17 ± 1.04 to 6.22 ± 1.61 mg/mL (p < 0.1615). In the female glucan group the IgG1 levels did not change (7.03 ± 1.92 to 7.14 ± 2.23 mg/mL, p < 0.6634), in the male glucan group the differences in the IgG1 levels seem to be strong, but due to the limited number of patients they are not statistically significant (7.11 ± 2.32 to 4.89 ± 0.95 mg/mL, p < 0.1046).

To evaluate multidimensional markers of fatigue, we used bases gain from several studies[20,24,25]. Our results clearly showed improvements in both groups - 43.8% improvement in the placebo group and 87.0% improvement in the glucan supplemented group. Improvement in the placebo group can be explained by well-known placebo effects. In a follow-up study, we will use a group of patients with no intervention at all.

**DISCUSSION**

Together with more successful oncological treatments, the number of patients after systemic oncological treatment in the general population steadily and significantly increases. Another reason for this trend is the wider spectrum of indication of adjuvant treatment. On the other hand, programs which would specifically concentrate on problems of patients in remission are still lacking. Late effects of oncological treatment can significantly lower quality of life and possibility of survival even after long remission. Higher mortality can be caused by late relapse of original cancer, secondary malignity connected with the oncological treatment, individual predisposition to malignant diseases or direct or indirect effects of cancer treatment (either chemotherapy or irradiation). One cannot forget the effects of after-treatment including higher fatigue, loss of sleep and cognitive problems. Fatigue is one of the most common and at the same time most limiting impacts of cancer treatments. Fatigue as a multidimensional syndrome can be influenced by several physiological and biological factors. Sleep problems represent a problem often connected with fatigue. Effects of radiotherapy on induction of cancer-related fatigue (CRF) were described in patients undergoing treatment of oncological diseases, particularly of colon and uterus cancer[22]. These authors suggested a possible connection with induction of systemic inflammation and discuss the possible impact of anemia. In addition, levels of plasmatic citrulline were suggested as an indicator of intestinal damage. We can clearly establish CRF diagnosis in over 80 percent of patients, in one third of patients these problems can last several years[22-24].

Effects of glucan supplementation in cancer patients, both during and after treatment, are already well established. Glucan affects virtually all facets of both cellular and humoral immunity[1,2,3,4,10,12,23]. Together, with other authors Ostrasrahimi et al[33], we conclude that glucan is beneficial in complementary and adjuvant therapy of cancer, increases quality of life, and reduces both psychical and pathophysiological impacts of anticanter treatment[26,33]. Glucan supplementation can influence the levels of IgG, interferon gamma and other hematological parameters[34]. In clinical trials, short term glucan supplementation strongly influenced levels of secretory immunoglobulins[33]. In our study, 200 mg/day did not change total levels of individual groups of immunoglobulins, but caused significant changes in levels of IgG1. In the placebo group, a strong decrease of IgG1 levels occurred, whereas glucan supplementation inhibited these changes. When we divided the individual groups into males and females, we found that these changes were significant only in the females group.

Our findings are accompanied by findings of significant improvements in cognitive functions and in the reduction of risk of respiratory tract infections. Among our patients we founda patient after complex treatment of colorectal carcinoma with extreme levels of IgG4. These levels, together with other parameters, fulfilled all conditions for diagnosis of IgG4-related disease[36,39]. This patient was part of the placebo group and no changes of IgG4 levels were found. This particular patient is still evaluated in our Department and the possibility of using glucan supplementation aimed on regulation of his cytokine network, phagocytosis and antibody-dependent cellular cytotoxicity is discussed[36].

**CONCLUSIONS**

Our results indicate that short-term supplementation with orally-given glucan significantly stabilized levels of IgG1 resulting in maintaining anti-infectious immunity. All other Ig classes and subclasses were not affected. The decrease in IgG1 levels found in the placebo group was clearly caused by a complex therapy of cancer disease. Our study continues by evaluating the activation of dendritic cells via Dectin-1 with a possibility of affecting B-cell immune response[37].

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