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THE EFFECTIVENESS OF PHOTODYNAMIC THERAPY IN PEDIATRIC PRACTICE

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ЭФФЕКТИВНОСТЬ ФОТОДИНАМИЧЕСКОЙ ТЕРАПИИ В ПЕДИАТРИЧЕСКОЙ ПРАКТИКЕ

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Photodynamic therapy (PDT) is a relatively young but rapidly developing method of treatment. Currently, PDT is widely used in dentistry, dermatology, oncology and other fields of medicine. Cases of successful treatment of tumors of the head and neck, brain, lungs, pancreas, colon, breast, prostate, bladder, cervix and skin using PDT are described in literature. In addition, the effectiveness of PDT in the treatment of bacterial and fungal infections has been repeatedly proved. To date, there are a large number of studies on the use of PDT in various diseases in adults, but few data on this subject in children. The authors have been searching for publications in the electronic databases PubMed, Google Scholar and eLibrary by the following keywords: "PDT", "photodynamic therapy", "pediatrics", "children", "dermatology", "dentistry", "pulmonology", "ophthalmology", "oncology". The search was conducted from the moment of the foundation of the corresponding database to August 2023. PDT is an innovative method of treating neoplasms and bacterial infections. On the basis of the data obtained while conducting the study, it can be confirmed that applying PDT allows to reduce the number of surgical interventions and achieve the best treatment results. All the studies and clinical cases with the use of PDT in the treatment of various diseases in children, which are presented in this review, demonstrated that the treatment results were better than those with standard therapy. However, certain limitations must be taken into account, these include difficulties in selecting a photosensitizer and its route of administration. At present PDT is being actively studied in the pediatric population, but there are still many gaps that require additional large-scale studies.
Keywords. Photodynamic therapy, PDT, dermatology, pediatrics, children, oncology; ophthalmology, dentistry.

Осуществлен анализ литературных данных, посвященных использованию фотодинамической терапии (ФДТ) при различных заболеваниях в педиатрической популяции. ФДТ – относительно молодой, но быстро развивающийся метод лечения. В настоящее время ФДТ активно применяется в стоматологии, дерматологии, онкологии и других областях медицины. В литературе описаны случаи успешного лечения опухолей головы и шеи, головного мозга, легких, поджелудочной железы, толстой кишки, молочной железы, простаты, мочевого пузыря, шейки матки и кожи с использованием ФДТ. Кроме того, неоднократно доказывалась эффективность использования ФДТ в терапии бактериальных и грибковых инфекций. На сегодняшний день имеется большое количество исследований, посвященных применению ФДТ при различных заболеваниях у взрослых, однако данные по детям ограничены. Авторами был проведен поиск публикаций в электронных базах данных PubMed, Google Scholar и ELibrary. Поиск проводился по следующим ключевым словам: PDT, photodynamic therapy, pediatric, children, dermatology, dentistry, pulmonology, ophthalmology, oncology, «ФДТ», «фотодинамическая терапия», «педиатрия», «дети», «дерматология», «стоматология», «пульмонология», «офтальмология», «онкология». Поиск проводился во временном интервале с момента основания соответствующей базы данных по август 2023 г.
ФДТ является инновационным методом лечения новообразований и бактериальных инфекций. Основываясь на имеющихся данных, можно утверждать, что ФДТ позволяет сократить количество хирургических вмешательств и добиться наилучших результатов лечения. Все исследования и клинические случаи использования ФДТ в терапии различных заболеваний у детей, представленные в настоящем обзоре, продемонстрировали, что результаты лечения были лучше, чем при проведении стандартной терапии. Однако необходимо учитывать наличие определенных ограничений, включая трудности с подбором фотосенсибилизатора и его пути введения. На сегодняшний день ФДТ активно изучается в педиатрической популяции, однако остается много пробелов, которые требуют проведения дополнительных масштабных исследований.
Ключевые слова. Фотодинамическая терапия, ФДТ, дерматология, педиатрия, дети, онкология, офтальмология, стоматология.

Introduction

Photodynamic therapy (PDT) is a relatively young but rapidly developing method of treatment [1]. Currently, PDT is widely used in dentistry, dermatology, oncology and other fields of medicine [2; 3]. Cases of successful treatment of tumors of the head and neck, brain, lungs, pancreas, colon, breast, prostate, bladder, cervix and skin using PDT are described in literature [4–6]. In addition, the effectiveness of PDT in the treatment of bacterial and fungal infections has been repeatedly proved [7]. To date, there are a large number of studies on the use of PDT in various diseases in adults, but few data on this subject in children. Thus, the aim of this study is to analyze the literature data on the use of PDT for various diseases in the pediatric population.

Materials and methods

The authors have been searching for publications in the electronic databases PubMed, Google Scholar and eLibrary by the following keywords: "PDT", "photodynamic therapy", "pediatric", "children", "dermatology", "dentistry", "pulmonology", "ophthalmology", "oncology", «ФДТ», «фотодинамическая терапия», «педиатрия», «дети», «дерматология», «стоматология», «пульмонология», «офтальмология», «онкология». The search was conducted in the time interval from the moment the corresponding database was founded until August 2023. The authors independently analyzed article titles and abstracts, after which the full text of relevant studies was extracted.

Mechanism of action of PDT and application scope

The PDT mechanism is based on the oxidation of biomolecules under the influence of light of the appropriate wavelength due to the preliminary introduction of a so-called photosensitizer into the irradiated area. A photosensitizer is a pharmacological drug capable of selectively accumulating in pathologically altered tissues. When the area treated with photosensitizer is locally illuminated with laser radiation of a certain wavelength, the so-called photocytotoxic effect occurs. This process can proceed according to two mechanisms [8; 9].

Type I – light energy is transferred from excited molecules to biomolecules via electron / hydrogen transfer upon direct contact, where it accumulates and causes specific damage to biomolecules.

Type II – light energy is transferred to molecular oxygen, which then produces singlet oxygen, which is extremely reactive and can damage both cellular proteins and DNA [8].

In addition to the direct cytotoxic effect leading to cell apoptosis, there are other destructive mechanisms such as occlusion of blood vessels and the release of lymph and cytokines [9]. The degree of damage and the mechanism of action depend on the type of photosensitizer used, as well as the type of cells being affected, the concentration of the photosensitizer itself, and the wavelength of the light used. To date, the effectiveness of PDT has been proven and introduced into clinical practice in the treatment of superficial lesions [5; 11]. However, in the case of deeper lesions, certain difficulties arise associated with the placement of the photosensitizer and the limited penetrating ability of the light wave. Thanks to the rapid development of technology, fiber optic endoscopes make it possible to penetrate hard-to-reach places and directly deliver light with the required wavelength [12; 13]. Photosensitizers themselves are also constantly modified by the addition of various organ-specific carriers. This allows the photosensitizer to be delivered to the target organ after intravenous administration. At the same time, it has a protective effect on other organs in the case of potential pathological effects of PDT on healthy tissues [14; 15]. Attempts have also been made to introduce photosensitizers that bind to receptors on the surface of cancer cells, such as estrogen, progesterone, or EGFR [16; 17].

The use of PDT allows patients to avoid complex surgical procedures. In addition, PDT has recently begun to be used in dentistry, particularly in endodontics, to achieve an antimicrobial effect [18].

Use of PDT for skin diseases in children

The occurrence of skin cancer in childhood is rare. However, some genetic syndromes, such as Gorlin syndrome or xeroderma pigmentosum, may predispose to the development of skin tumors from childhood.

Basal cell nevus syndrome (BCNS), also known as Gorlin syndrome, is caused by mutations in the PTCH1 gene and is inherited in an autosomal dominant pattern. BCNS is characterized by multiple basal cell carcinomas (BCC) in combination with dental, bone, ophthalmological, and neurological defects. C. Girard et al. used PDT to treat Gorlin syndrome in children. The authors showed that the effectiveness of PDT using 5-aminolevulinic acid (5-ALA) for superficial lesions ranged from 78 to 100 %. The researchers did not report any signs of toxicity [19]. A.R. Oseroff et al. performed several sessions of 10 % ALA PDT in children using a laser for smaller diameter areas (2 to 7 cm) and a lamp for larger diameter areas (up to 16 cm in diameter). Each patient required four to seven sessions. Patients reported no new BCCs at PDT sites during 6 years of examination [20]. The results of therapy of 33 patients with BCNS in the age range of 9–79 years were described by J. Loncaster et al. [21]. The authors used ALA-PDT and MAL (methylaminolevulinic acid)-PDT, obtaining different results depending on the thickness of the lesions. The authors performed ultrasound to assess lesion thickness and used topical PDT to treat only superficial lesions (<2 mm thick). To reach deeper lesions, a systemic photosensitizer was administered. At 12 months, local control rates were 73.0 % for lesions < 1 mm, 40.8 % for lesions 1 to 2 mm, and 59.3 % for lesions > 2 mm [21]. Patients with Gorlin syndrome are highly susceptible to DNA damage from treatments such as ionizing radiation. However, A.R. Oseroff et al. found no evidence that ALA-PDT induces or promotes the development of BCC in pediatric patients [20]. It is important to note that the effective radiation dose may be reduced due to the different pigmentation of BCC. Preliminary removal of pigmented BCC may help to cope with this problem. In a group of adult patients, A.G. Salvio et al. performed the removal of 30 pigmented BCCs before

MAL-PDT and obtained a complete response to therapy in 100 % of cases with no relapses after 24 months of examination [22]. The suitability of this method should also be investigated in the pediatric population.

There is a report of a 12-year-old boy with Bowen's disease who underwent therapy using MAL-PDT. After two PDT sessions, which were carried out with breaks for 3 weeks, the lesion was completely removed. Nine months after the procedure, no relapses were observed [23].

M. Xu et al. conducted a study involving 12 children with pointed condyloma. The children underwent PDT therapy using the photosensitizer 5-ALA. Red light with a wavelength of 635 nm was used as a light source for 20 min. Positive changes were observed after using PDT. In addition, no relapse of the disease was observed. The authors showed that PDT is highly effective for perianal and intraanal lesions with minimal side effects [24].

Flat warts (FW) are a superficial viral skin disease that is extremely common in childhood. F. Borgia et al. evaluated the efficacy of conventional PDT (C-PDT) compared to daylight PDT (DL-PDT) using 10 % ALA. The authors included 30 patients under 18 years of age with FW on the face in the study. The patients were divided equally into two groups: Group 1 – received C-PDT; Group 2 – DL-PDT. The therapeutic intervention was performed three times with a monthly interval. The treatment results were assessed at 4, 8, 12, and 24 weeks. The authors identified the following criteria for the effectiveness of the therapy: excellent (reduction in the total number of FWs by 75–100 %); very good (reduction by 74–50 %); good (reduction by 49–25 %); weak (reduction by less than 25 % or no response). The study found that DL-PDT in combination with 5-ALA is a safer and more effective method. Patients reported better tolerability and absence of pain [25]. In another study, the same authors described a clinical case of an 8-year-old girl who received PDT for FW on the eyelids, nose, and cheeks. t5-ALA was applied topically as a photosensitizer, and sunlight was the light source. The method was used twice, with an interval of one month between treatments. Six weeks after the last treatment session, the scars had completely disappeared without recurrence [26].

The effectiveness of PDT was also demonstrated in the description of a clinical case of a 6-year-old girl who had a history of multiple warts on her foot for a year. Physical examination revealed a subungual papilloma and multiple hyperkeratotic plaques on the dorsum of the left foot. Cryotherapy performed 3 months earlier was ineffective; therefore, PDT was used. After 6 weeks, the lesions were removed without any side effects. PDT may be an alternative treatment for warts, especially in patients who are not responsive to routine treatment. Regression of FW is promoted by two main mechanisms: 1) generation of cytotoxic radicals that destroy keratinocytes via apoptosis; 2) stimulation of specific immune responses releasing various cytokines (IL-1β, IL-2 and tumor necrosis factor alpha). In this study, FWs were removed after only two sessions [27; 28].

A. Ding et al. performed PDT using 5-ALA as a photosensitizer in six patients diagnosed with squamous cell carcinoma localized on the face. The results of the study showed complete removal of foci within a month of therapy [29]. Thus, it can be assumed that ALA-PDT is highly effective, especially in cases where other therapy does not show results [29]. M. Chen et al. demonstrated the effectiveness of PDT using the example of a 9-year-old girl with papillary lesions in the vulva. Just one hour after PDT, tumor cells began to fragment with pronounced damage to organelles, and after 4 hours, the authors noted cell necrosis. The papillary lesion completely disappeared after one week of PDT. Electron microscopy showed that PDT mainly damaged acanthocytes and koilocytes in virus-infected tissue [30].

Nevus flammeus (port-wine stain) is a congenital permanent developmental defect that occurs in 0.1–2 % of newborns. It appears as a unilateral or bilateral spot of irregular shape, clearly defined, bright pink or purple color [31]. There have been several attempts to use PDT in the treatment of nevus flammeus in children. T. Chun-Hua et al. conducted a retrospective study by evaluating 439 case histories of children with nevus flammeus, whose therapy was carried out using PDT [32]. Hematoporphyrin monomethyl ether was used as a photosensitizer, and a green laser with a wavelength of 532 nm was used as a light source, which was applied for approximately 20–25 min. The results of the study showed that 95 % of patients demonstrated an effective response to the therapy. Transient side effects in the form of edema, purpura and pigmentation were leveled without additional treatment and only 2 % of patients had scars. Y. Huang et al. conducted a similar study, which included 212 patients with a mean age of 13.01 ± 12.67 years [33]. The authors found that patients who received more than three PDT sessions demonstrated a better response compared to those who received less than three sessions ($p = 0.003$). In general, PDT with hemoporphyrin is an effective treatment for nevus flammeus in children [31–36], but there are reports of the impossibility of complete removal of lesions located deeper or having a larger diameter due to limited penetration of light into the skin [37].

Use of PDT in pediatric dentistry

The scope of PDT application in dentistry is extremely broad and includes the treatment of acute and chronic gingivitis, alveolitis, and peri-implantitis. In addition, PDT has begun to be actively used in endodontics for the purpose of antibacterial treatment of prepared carious cavities and root canals of teeth [38].

A. Alsaif et al. showed a reduction in the total number of bacteria by approximately 95 % when PDT affected oral biofilm. The authors concluded that PDT contributes to increased clinical efficacy by reducing the overall treatment time for oral diseases [39]. M. Bargrizan et al. showed that antibacterial PDT removes planktonic bacteria, plaque, and oral biofilm [40]. E.P. Rosa et al. evaluated the effectiveness of antibacterial PDT in patients with braces. The authors included 34 patients of both sexes with gingivitis who had been wearing braces for more than 12 months. Methylene blue was used as a photosensitizer, and a red laser diode with a wavelength of 660 nm was used as a light source. PDT resulted in significant removal of biofilm, which in turn reduced the extent of tissue damage [41]. Other authors have also confirmed that antibacterial PDT, this time using chlorine, has a pronounced bactericidal effect on biofilms, making it an effective treatment for acute and recurrent oral diseases [42]. L.P. Kiselnikova and G.I. Kuznetsova presented the results of treatment of 81 adolescent children with chronic gingivitis, who were divided into two groups: 1st – treatment using photoactivated antisepsis; 2nd – standard therapy. Patients in group 1 showed a more pronounced decrease in the PMA and CPI indices compared to patients in group 2 [43]. C.B. Okamoto et al. assessed the effectiveness of PDT in eliminating microorganisms from inside the root canals of the tooth. Methylene blue was used as a photosensitizer, and the light source was a laser with a wavelength of 660 nm. The result of the experiment was the complete (with 100 % efficiency) removal of bacteria in the root canals [44]. Similar results regarding the antibacterial treatment of root canals were obtained by K.G. Karakov et al. [45].

S.L. Pinheiro et al. evaluated the effectiveness of PDT therapy in children with pulp necrosis in primary teeth by quantitatively determining live bacteria. PDT was performed using a diode after the introduction of toluidine blue as a photosensitizer. As a result, a reduction in the number of microorganisms with an efficiency of 98.37 % was observed. The study concluded that PDT is a therapy that helps reduce the population of microorganisms in primary teeth with pulp necrosis [46].

N.K.S. Mslik and O.H. Alkadhi evaluated the effectiveness of PDT therapy against oral candidiasis in children with gingivitis. The average age of patients was 16 years. The results of the study showed a statistically significant decrease in the number of candida in the oral cavity [47].

V.C. Ribeiro da Silva et al. studied the effectiveness of PDT in the treatment of stomatitis in children [48]. The study included 29 patients aged 10 months to 18 years, who were divided into two groups. Patients in the first group received PDT using 0.01 % methylene blue as a photosensitizer and a red laser (660 nm) as a light source; patients in the second group received low-level laser therapy. In both groups, patients reported a significant reduction in pain.

One of the main tasks in pediatric dentistry is the preservation of baby teeth with pulpitis caused by caries or traumatic impact. De Sant'Anna presented a clinical case of post-traumatic pulpitis that developed in a 5-year-old boy with type I diabetes [49]. The author successfully applied PDT for root canal disinfection using methylene blue (50 μ / ml) as a photosensitizer. The advantages of PDT included a reduction in procedure time, which is extremely important when working with children. A.C. Da Mota et al. also evaluated the effectiveness of PDT in the treatment of pulpitis in primary teeth [50]. The study included children aged 3–6 years with pulpitis.

The authors divided the patients into two groups: 1st – experimental (PDT); 2nd – control (standard therapy). Methylene blue at a concentration of 0.005 % was used as a photosensitizer. The light source was a laser (660 nm) with an energy of 4 J and an average power of 100 MW, the effect was carried out for 40 s. Based on the results of the study, the authors concluded that antibacterial PDT is highly effective against microorganisms, does not cause resistance, and is a comfortable method for patients, since it does not cause pain.

R. Fekrazad et al. evaluated the effectiveness of antibacterial PDT in children with severe caries [51]. The study group consisted of 22 children with severe caries aged 3–6 years. The oral cavity was treated with toluidine blue for 1 min and irradiated with a LED for 150 s. Saliva samples from each treated child were collected in three stages: before the examination, 1 hour after the procedure, and 7 days after the procedure. At each stage, the authors determined the amount of Streptococcus mutans. After the experiment, the authors concluded that the amount of Streptococcus mutans in saliva decreased significantly after 1 hour, but 7 days after the treatment, their number returned to the original values. Similar conclusions were presented by L.V.G.L. Alves et al., who confirmed the effectiveness of PDT against cariogenic microorganisms after selective removal of caries without damaging composite dental materials [52]. A. Potapchuk et al. conducted a study involving 35 children with caries aged 12–15 years who underwent PDT. The antibacterial effect was assessed using polymerase chain reaction. The authors found a statistically significant reduction in microorganisms such as Enterococcus faecalis, Veilonella and Candida albicans. After the experiment, it was established that PDT in the treatment of dentin caries is a highly effective and pathogenetically proven method, providing a significant reduction in facultative and obligate types of carious microorganisms [53]. L.T. Carvalho et al. described the effectiveness of antibacterial PDT in a 9-year-old patient with deep caries of the first molar of the right lower jaw. Six months after treatment, no traces of caries were found, which confirmed the effectiveness of the technique used [54]. PDT is characterized by a high level of comfort for pediatric patients, as it has a low level of noise and vibration, as well as painlessness.

Use of PDT in recurrent respiratory papillomatosis

Recurrent respiratory papillomatosis (RRP) is one of the most challenging problems among benign tumors of the upper and lower respiratory tract. Dissemination of the tumor process and damage to the lung tissue not only create the possibility of malignancy, but also complicate the choice of treatment tactics and in many ways limit surgical options, necessitating a multidisciplinary approach [55]. RRP is characterized by a relapsing course, as well as extremely rapid growth of neoplasms, which can be life-threatening. In most cases, treatment of RRP requires complex surgical interventions. PDT can be used as an adjuvant treatment for RRP. For example, A. Lieder et al. found that PDT, both as an independent therapy and in combination with surgical treatment, brings therapeutic benefits in children and adults with RRP [56]. Another example of the use of PDT in RRP is a clinical study conducted by M.J. Shikowitz et al. [57], which included 23 patients (children and adults) diagnosed with RRP. Hydroxyphenyl chlorine was used as a photosensitizer. The authors demonstrated that PDT contributed to an improvement in the immune response and prognosis of the disease.

Use of PDT in children's ophthalmology

Choroidal neovascularization (CNV) is a pathological mechanism common to many eye diseases. It involves the proliferation of small vessels originating from the choroidal capillaries that penetrate through Bruch's membrane into the space beneath the retinal pigment epithelium, as well as into the cells of the retinal pigment epithelium and photoreceptors. Newly formed vessels are highly fragile and have a tortuous structure. If these vessels are damaged, blood accumulates in the subretinal space, causing hemorrhagic retinal detachment, which ultimately leads to the formation of a discoid fibrous vascular scar [58]. S. Ozdek et al. used PDT to treat CNV in four children, and clinical efficacy was assessed using fluorescein angiography and optical coherence tomography [59]. All patients responded well to PDT. The efficiency of visual acuity improvement was 80 %. Improvement or stabilization of visual acuity was maintained for an average of 25 months of observation. The aim of the study by A. Lipski et al. was to determine the therapeutic potential of PDT using verteporfin in patients with CNV [60]. The results of the study demonstrated high efficacy and tolerability of PDT in a group of patients with visual impairment. D. Sьsskind et al. assessed the effectiveness of PDT in the treatment of exudative limited choroidal hemangioma [61]. According to the results of the study, the authors noted an improvement in visual acuity in all patients. In turn, the average thickness of the retina was reduced. It has been proven that PDT is an effective and safe procedure in the treatment of exudative choroidal hemangioma. Similar results were presented by C. YŸldŸrŸm et al. in a description of a clinical case of a 10-year-old girl with CNV who lost vision in her right eye. The authors used PDT with verteporfin. Improvement of visual acuity up to 80 % and resorption of subretinal fluid were observed after four months of therapy [62]. After one year of observation, no relapses of the disease were observed. In turn, in the study of F. Giansanti et al., which included five patients aged 7–15 years who were treated with PDT, infiltration decreased and atrophic changes occurred in the retinal pigment epithelium. Visual acuity was stable [63].

Sturge-Weber syndrome is an encephalotrigeminal angiomatosis that is related to hereditary neurocutaneous syndromes (phakomatoses). Eye lesions occur in 30–70 % of cases and are represented by a disruption in the formation of the capillary wall of the conjunctiva, episclera and iris, glaucoma, an increase in the size of the cornea, and choroidal hemangioma [64]. R. Nugent et al. described a clinical case of a 6-year-old girl with Sturge-Weber syndrome who was treated using PDT. As a result of the therapy, the exudate completely resolved within 3 months after treatment [65]. M. Mauget-Faяsse et al. assessed the efficacy and safety of PDT in combination with verteporfin in children and young people with subfoveal choroidal neovascularization [66]. As a result of PDT, visual acuity improved, vascular anastomosis was formed, and no serious side effects were observed. M.E. Farah et al. evaluated the role of PDT using verteporfin in the treatment of subfoveal choroidal neovascularization in Vogt-Koyanagi-Harada syndrome. A case of a 9-year-old patient was analyzed in which complete regression of the lesion within one week after the start of treatment was observed [67].

Use of PDT in case of malignant neogloms in children

Brain tumors occurring in the pediatric population have significant differences from those in adults, which is expressed mainly in their localization and histopathology. The selection of therapeutic tactics must be carefully considered, since not all forms of treatment used in adult patients can be used in children. To date, there is data on the use of PDT in childhood oncological diseases both in vitro and in vivo. M. Schwake et al. evaluated the antitumor activity of PDT in vitro on four different cell lines of brain tumors that arise in childhood. The authors used a diode with a wavelength of 635 nm, the exposure time was 250 s. 5-ALA and protoporphyrin were used as photosensitizers. The results of the study showed the destruction of all malignant cells in the studied lines [68]. M.H. Schmidt et al. conducted a study involving 20 patients with recurrent malignant brain tumors who were treated using PDT [69]. Porphyrin was used as a photosensitizer, while a light-emitting diode was used as a light source. All treated patients showed stabilization of tumor growth, which was assessed using MRI. P.J Lou et al. analyzed interstitial PDT (injection of the drug directly into the tissues). Clinical trials have supported the hypothesis that interstitial PDT provides pain relief in terminal advanced head and neck cancer. It is a treatment option that should be added to those available for complex head and neck cancer syndromes [70].

PDT is an extremely promising method for adjuvant treatment of oncological diseases. One of the main advantages of PDT is the low number of side effects, which is especially important in the treatment of children. PDT is increasingly being used in children worldwide with satisfactory results. Expanding research into the use of PDT in childhood cancers provides an opportunity to develop an effective adjuvant therapy method and forms the basis for reducing the need for surgical interventions. In addition, PDT opens up prospects for increasing the survival rate of cancer patients.

Difficulties in using PDT in children

Despite the undeniable advantages described above, PDT may have certain limitations when used in children. One of the limitations is the choice of the least toxic photosensitizer, as well as the correct titration of its dose for each specific case. Because of the need to administer a photosensitizer prior to exposure to the light source, the patient may have varying reactions to a relatively long waiting period, which can range from a few minutes to several days. For deep lesions, the photosensitizer is administered intravenously, which can be difficult, especially in children.

Conclusions

PDT is an innovative method for treating neoplasms and bacterial infections. Based on the available data, it can be stated that PDT allows to reduce the number of surgical interventions and achieve the best treatment results. All studies and clinical cases of using PDT in the treatment of various diseases in children presented in this review demonstrated that the treatment results were better than with standard therapy. However, it is necessary to take into account the presence of certain limitations, including difficulties in selecting a photosensitizer and its route of administration. To date, PDT is actively studied in the pediatric population, but there are many gaps that require additional large-scale studies.

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Daribaeva N.A. – data acquisition, article editing.

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