

COMBINED PHOTODYNAMIC THERAPY IN METASTATIC BREAST CANCER: POSSIBILITIES AND OUTCOMES (CLINICAL CASE)

Shanazarov N.A.¹, Kumisbekova R.K.², Albaev R.K.¹, Usenbay M.³, Tashpulatov T.B.¹,
Magzamova A.S.⁴, Disaenko K.S.⁵

¹Hospital of the President's Affairs Administration, Astana, Kazakhstan

²Multidisciplinary Medical Center, Akimat of Astana, Astana, Kazakhstan

³City Polyclinic No. 4, Akimat of Astana, Astana, Kazakhstan

⁴Multidisciplinary Regional Hospital, Health Department of Akmola Region, Astana, Kazakhstan

⁵Kostanay City Multidisciplinary Oncology Hospital, Kostanay, Kazakhstan

Abstract

The Center for Photodynamic Therapy of the Hospital of the Medical Center of the Administrative Department of the President of the Republic of Kazakhstan has clinical experience in treating cutaneous metastases of breast cancer. This paper presents the results of clinical observation of a patient with metastatic breast cancer who underwent combined photodynamic therapy, including systemic photomodification of blood and local irradiation of metastatic lesions. This clinical case is of particular interest since the patient did not receive standard antitumor treatments such as chemotherapy or hormone therapy. This was due to advanced age and decreased tolerance to aggressive treatment regimens associated with comorbidities, which limited the feasibility of conventional therapy. Despite the absence of systemic treatment, the use of combined photodynamic therapy resulted in a pronounced positive clinical response. A reduction in the size and infiltration of cutaneous metastatic lesions, as well as an improvement in the patient's general condition and quality of life, were observed. These findings demonstrate the potential of photodynamic therapy as an effective and safe alternative therapeutic approach for metastatic breast cancer, particularly in clinical situations where the use of standard treatment protocols is impossible or contraindicated.

Key words: photodynamic therapy, breast cancer, palliative care, quality of life.

Contacts: Kumisbekova R.K., e-mail: raushankumisbekova@gmail.com

For citation: Shanazarov N.A., Kumisbekova R.K., Albaev R.K., Usenbay M., Tashpulatov T.B., Magzamova A.S., Disaenko K.S. Combined photodynamic therapy for metastatic breast cancer: possibilities and results (clinical case), *Biomedical Photonics*, 2025, vol. 14, no. 4, pp. 49–55. doi: 10.24931/2413-9432-2025-14-4-49-55

КОМБИНИРОВАННАЯ ФОТОДИНАМИЧЕСКАЯ ТЕРАПИЯ ПРИ МЕТАСТАТИЧЕСКОМ РАКЕ МОЛОЧНОЙ ЖЕЛЕЗЫ: ВОЗМОЖНОСТИ И РЕЗУЛЬТАТЫ (КЛИНИЧЕСКОЕ НАБЛЮДЕНИЕ)

Н.А. Шаназаров¹, Р.К. Кумисбекова², Р.К. Албаев¹, М. Усенбай³, Т.Б. Ташпулатов¹,
А.С. Магзамова⁴, К.С. Дисаенко⁵

¹Больница Медицинского центра Управления делами Президента Республики Казахстан, Астана, Казахстан

²Многопрофильный медицинский центр акимата г. Астаны, Астана, Казахстан

³Городская поликлиника № 4 акимата г. Астана, Астана, Казахстан

⁴Многопрофильная областная больница при Управлении Здравоохранения Ақмолинской области, Астана, Казахстан

⁵Костанайская Городская Онкологическая Многопрофильная больница, Костанай, Казахстан

Резюме

Центр фотодинамической терапии Больницы Медицинского центра Управления делами Президента Республики Казахстан имеет клинический опыт лечения кожных метастазов рака молочной железы. В настоящей работе представлены результаты наблюдения за пациенткой с метастатическим раком молочной железы, которой была проведена комбинированная фотодинамическая терапия, включающая системную фотомодификацию крови и локальное воздействие на очаги поражения. Клинический случай представляет особый интерес, поскольку пациентка не получала стандартных методов противоопухолевого лечения, таких как химио- и гормонотерапия. Это обусловлено пожилым возрастом и сниженной переносимостью агрессивных лечебных схем на фоне сопутствующих заболеваний, что ограничивает возможности проведения традиционной терапии. Несмотря на отсутствие системного лечения, применение комбинированной фотодинамической терапии позволило достичь выраженного положительного клинического эффекта. Отмечено уменьшение размеров и инфильтрации кожных метастатических очагов, улучшение общего состояния и качества жизни пациентки. Полученные результаты демонстрируют потенциал фотодинамической терапии как эффективного и безопасного альтернативного метода воздействия при метастатическом раке молочной железы, особенно в клинических ситуациях, когда проведение стандартных схем лечения невозможно или противопоказано.

Ключевые слова: фотодинамическая терапия, рак молочной железы, паллиативное лечение, качество жизни.

Контакты: Кумисбекова Р.К., e-mail: raushankumisbekova@gmail.com

Для цитирования: Шаназаров Н.А., Кумисбекова Р.К., Албаев Р.К., Усенбай М., Ташпулатов Т.Б., Магзамова А.С., Дисаенко К.С. Комбинированная фотодинамическая терапия при метастатическом раке молочной железы: возможности и результаты (клиническое наблюдение) // Biomedical Photonics. – 2025. – Т. 14, № 4. – С. 49–55. doi: 10.24931/2413-9432-2025-14-4-49-55

Introduction

Breast cancer (BC) remains one of the leading causes of morbidity and mortality among women, representing a serious medical and social problem worldwide [1,2]. Despite significant advances in early diagnosis and improved treatment methods, survival rates for common and metastatic forms of the disease remain unsatisfactory.

The modern concept of radical breast cancer treatment is based on the principles of multimodal therapy, including surgery, systemic drug treatment (neoadjuvant and adjuvant chemotherapy), as well as radiation therapy [3]. This comprehensive approach ensures local control of the tumor process and reduces the risk of recurrence. However, with the development of the metastatic form of the disease, systemic antitumor therapy is of primary importance, aimed at slowing the progression, controlling the metastatic process and maintaining a satisfactory quality of life in patients.

Currently, strategies for the systemic treatment of breast cancer include the use of chemotherapy, hormone therapy, targeted and immunotherapeutic drugs. The optimal choice of therapeutic tactics is determined by the molecular biological characteristics of the tumor, including the receptor status (ER, PR, HER2), the general somatic condition of the patient, the presence of concomitant diseases and previous treatment [3]. Individualization of systemic therapy makes it possible to increase its effectiveness, reduce the frequency of adverse events and thereby improve the quality of life of patients with a prolonged course of the metastatic process.

Despite the success of drug treatment, there remains a need to develop new methods aimed at

increasing local control and reducing systemic toxicity of therapy. One of these areas is photodynamic therapy (PDT), an innovative method based on the use of a photosensitizer (PS) that selectively accumulates in tumor cells. Under the influence of laser radiation of a certain wavelength, activated PS initiates photochemical reactions that cause damage to tumor cells and blood vessels, which ensures the selective destruction of pathological tissues, including in the postoperative area [5].

We present the results of clinical observation of a patient who received multi-course combined photodynamic therapy (PDT) for metastatic BC.

Materials and methods

The 84-year-old patient has been under medical supervision since 2021 for right breast cancer. After the diagnosis, the patient refused to undergo standard antitumor therapy. In November 2023, the patient complained of an unproductive cough and shortness of breath during exercise. In order to clarify the nature of the process and conduct symptomatic treatment, the patient was admitted to the Hospital of the Medical Center of the Office of the President of the Republic of Kazakhstan.

Computed tomography (CT) of the chest organs revealed multiple nodules in the projection of the right breast, axillary lymph nodes and skin. According to ultrasound examination of the liver, a formation in the right lobe was determined, regarded as a hemangioma or possible metastases. Additionally, a moderate amount of fluid in the pericardial cavity and signs of exudative pleurisy were noted.

For diagnostic purposes, pleurocentesis was performed, in which 220 ml of light yellow exudate was evacuated. Cytological examination of the material revealed mesotheliocytes with marked proliferation and tumor cells with signs of atypia. GeneXpert testing excluded the presence of *Mycobacterium tuberculosis*.

On the background of symptomatic therapy (diuretics, bronchodilators, mucolytics, anticoagulants), repeated accumulation of fluid in the pleural cavity was observed. Repeated pleurocentesis was performed with evacuation of 1100 ml of serous effusion.

Upon examination, the patient's general condition was assessed as moderate, due to respiratory failure. The right mammary gland is almost completely replaced by a tumor infiltrate, and there are 13 × 10 cm ulcers on the skin of the chest on the right. A dense, rounded tumor of 6 × 7.5 × 8 cm in size with signs of skin infiltration was detected in the left mammary gland.

Based on a set of anamnestic, clinical and instrumental data, in 2021, the diagnosis was established: right breast cancer cT4NxM0 (2021). In 2023, the progression of the disease with the collapse of the right breast tumor was revealed. Metastases to the left mammary gland, lymph nodes of the axillary, supraclavicular and cervical regions on both sides, multiple metastases to the lungs, exudative pleurisy on the left were identified.

The patient had the following concomitant diseases: arterial hypertension of the III degree (very high risk of cardiovascular complications), chronic heart failure of the II–III functional class according to NYHA.

Based on the results of an interdisciplinary consultation with oncologists, a biopsy and an immunohistochemical study were recommended to select the optimal drug therapy regimen. The patient refused the proposed treatment.

As part of palliative care, combined PDT was performed at the Photodynamic Therapy Center of the Hospital of the Medical Center of the Office of the President of the Republic of Kazakhstan.

Photodynamic therapy was started in November 2023. The courses were conducted with an interval of 3 weeks.

To carry out PDT, a PS based on e6 chloride was used (photolon, JSC Belmedpreparaty, Republic of Belarus). PS was administered intravenously at a dose of 100 mg diluted in 200 ml of saline solution for 30 minutes. Blood photomodification was performed for 30 minutes (output power of the light fiber is 100 MW). 2.5 hours after intravenous blood photomodification, the affected chest area was irradiated with a "Latus-Fara" device (irradiation from two fields with an output power of 0.20 W for 20 minutes per field, total exposure

time of 40 minutes, light dose 200–400 J/cm²). The tolerability of the procedure was satisfactory.

Results

The patient underwent 28 PDT sessions. According to CT scans of the chest organs performed between January and December 2024 (once every 3 months), stabilization of the tumor process was noted. In a control study in May 2025, an increase in the total size of foci was recorded by more than 20% according to the RECIST 1.1 criteria, which is regarded as disease progression (Table).

Clinically, positive dynamics were noted, including a decrease in the severity of bronchitis syndrome, an improvement in general well-being and a preservation of appetite. At the same time, there was a moderate pain syndrome associated with the presence of a wound surface in the chest wall, as well as shortness of breath due to left-sided exudative pleurisy (Fig. 1,2).

During the first year of follow-up (January–December 2024), CT data showed stabilization of the process without the appearance of new metastatic foci. Further progression in 2025 was accompanied by an increase in pleural effusion and the detection of new metastatic changes in the lungs (Fig. 3,4).

PDT demonstrated local efficacy in a patient with metastatic breast cancer, ensuring stabilization of the process for 12 months while maintaining a satisfactory quality of life (Fig. 5,6). Unlike chemo and radiation therapy, PDT did not cause systemic toxicity, as it is a method of selective action on tumor tissues. The introduction of PS into the bloodstream ensures its predominant accumulation in tumor cells, and subsequent laser irradiation activates the process of generation of reactive oxygen species, inducing apoptosis and necrosis of tumor cells and blood vessels [6].

The presented clinical case demonstrates the possibilities of PDT as an effective and clinically significant method of local control in a patient with metastatic breast cancer. Despite the disseminated nature of the disease, PDT made it possible to achieve stabilization of the process during the year, reduce local manifestations and pronounced clinical improvement with a good tolerance profile.

Discussion

In recent years, PDT has been considered as a promising direction in the complex treatment of malignant neoplasms, including breast cancer. The presented clinical case demonstrates the possibility of achieving stabilization of the disease in a patient with a metastatic process when using PDT in a palliative regime. Within a year after the start of treatment, it was possible to maintain the general condition, reduce the

Таблица

Оценка динамики опухолевого процесса по RECIST 1.1 по данным КТ органов грудной клетки

Table

Assessment of tumor dynamics according to RECIST 1.1 based on chest CT data

Дата обследования (КТ органов грудной клетки) Date of examination (Chest CT)	Таргетные очаги Targeted lesions	Нетаргетные очаги Non-targeted lesions	Общая оценка по RECIST Overall RECIST score	Комментарии Comments
18.01.24	Образования в молочных железах, аксиллярные лимфоузлы, множественные очаги в легких Formations in the mammary glands, axillary lymph nodes, multiple foci in the lungs	Плевральные выпоты, лимфогенный канцероматоз Pleural effusions, lymphogenous carcinomatosis	Базовое исследование Basic Study	Установлены исходные очаги для последующей оценки динамики Initial lesions were identified for subsequent progression assessment
30.07.24	Уменьшение опухоли в молочных железах и лимфоузлах Reduction of tumors in the mammary glands and lymph nodes	Прогрессия в легких (увеличение узлов, матовость, канцероматоз), плеврального выпота Progression in the lungs (enlarged nodes, haziness, carcinomatosis), pleural effusion	Относительная стабилизация Relative Stabilization	Частичный ответ по таргетным очагам, но прогрессия по нетаргетным Partial response in targeted lesions, but progression in non-targeted lesions
04.12.24	Без существенной динамики в молочных железах и лимфоузлах No significant changes in the mammary glands and lymph nodes	Стабилизация в легких, без нарастания выпота Stabilization in the lungs, without increasing effusion	Стабилизация Stabilization	Стабилизация Stabilization
27.05.25	Увеличение очагов в правом лёгком молочных железах, появление нового очага в S6 Enlargement of lesions in the right lung and mammary glands, appearance of a new lesion in S6	Нарастание плеврального выпота слева до ~600 мл, стабильность остальных Increase of pleural effusion on the left to ~600 ml, stability of the rest	Прогрессирование Progression	Прогрессия подтверждённых очагов >20%, нарастание плеврального выпота Progression of confirmed lesions >20%, increase in pleural effusion

Примечание: С января по декабрь 2024 года у пациентки наблюдалась стабилизация процесса по данным КТ, без признаков роста или новых метастатических очагов

Note: From January to December 2024, the patient demonstrated disease stabilization according to CT data, with no signs of tumor growth or new metastatic lesions.

severity of symptoms and local control of the tumor process, which is confirmed by CT data and clinical improvement.

Unlike traditional methods of treatment – chemotherapy and radiation therapy – PDT is characterized by minimal systemic toxicity and a gentle effect on healthy tissues, which is especially important for elderly and comorbid patients.

The results of domestic and foreign studies confirm the high effectiveness of PDT in local and recurrent forms of breast cancer. The frequency of complete response in chest wall lesions reaches 60-73%, the

overall response is up to 90%, while side effects are limited to mild photosensitivity, pain syndrome, and skin hyperemia [7,8]. These data are consistent with the presented clinical observation, which recorded a long-term stabilization of the tumor process without significant complications.

Of particular interest is the additional mechanism of action of PDT – activation of the antitumor immune response. Under the influence of a photochemical reaction, tumor antigens are released and antigen-presenting cells are activated, which contributes to the development of a secondary immune response

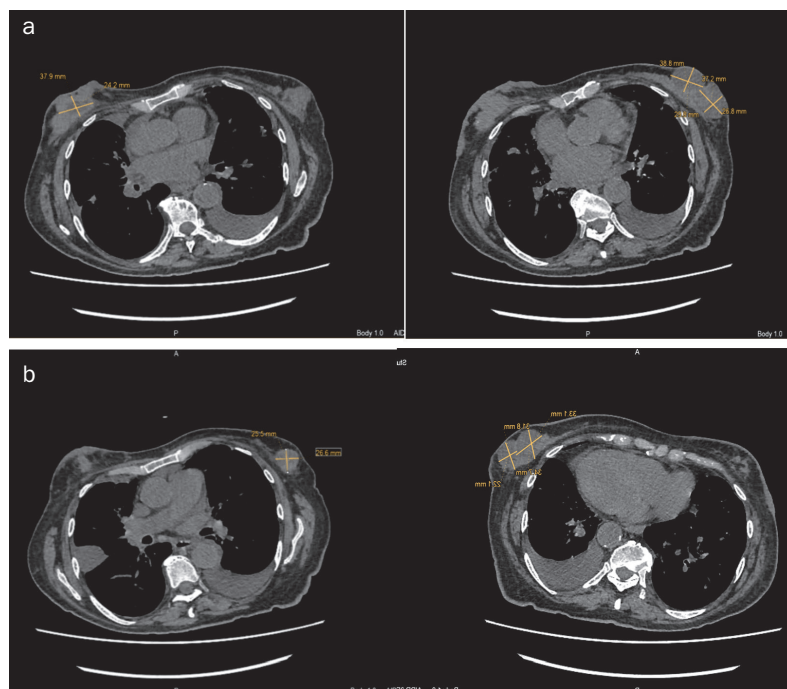


Рис. 1. Результаты КТ органов грудной клетки без контраста от 18.01.24:
а – опухолевое образование в правой молочной железе 3,7х2,4х4,4 см, в структуре левой молочной железы множественные кистозные образования (n~7), размеры наиболее крупного до 3,8х2,9х3,0 см;
б – в плевральной полости слева и вдоль междолевой щели справа визуализируется выпот, с компрессионным субателектазом, толщиной до 3,0 см.

Fig. 1. Results of a chest CT scan without contrast, 18.01.24:
а – a tumor in the right breast measuring 3.7 x 2.4 x 4.4 cm; multiple cystic lesions (n~7) in the left breast, the largest measuring up to 3.8 x 2.9 x 3.0 cm;
б – effusion with compression subatelectasis up to 3.0 cm thick is visible in the pleural cavity on the left and along the interlobar fissure on the right.

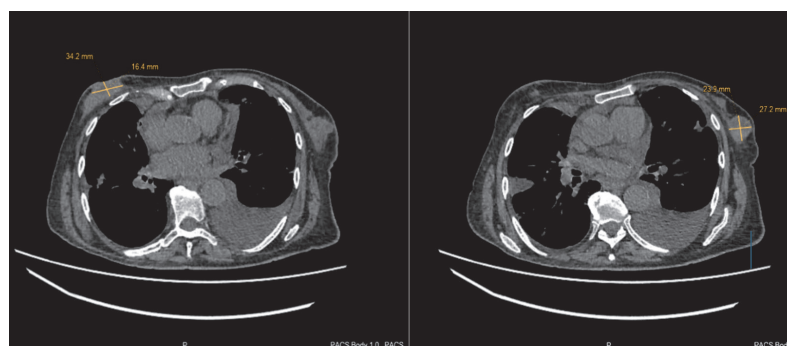


Рис. 2. Результаты КТ органов грудной клетки без контраста от 30.07.24 (уменьшение размеров образований в структуре молочных желез, наиболее крупные уменьшены справа до 3,4х1,6х2,6см (3,7х2,4х4,4 см), слева до 2,7х2,3х3,0см (3,8х2,9х3,0см); уменьшение аксиллярных лимфоузлов; прогрессирование в легких: увеличение количества и размеров узлов, увеличение плеврального выпота слева).

Fig. 2. Results of CT scan of chest organs without contrast from 30.07.24 (decrease in size of formations in the structure of mammary glands, the largest ones have decreased on the right to 3.4x1.6x2.6 cm (3.7x2.4x4.4 cm), on the left to 2.7x2.3x3.0 cm (3.8x2.9x3.0 cm); decrease in axillary lymph nodes; progression in the lungs: increase in the number and size of nodes, increase in pleural effusion on the left).

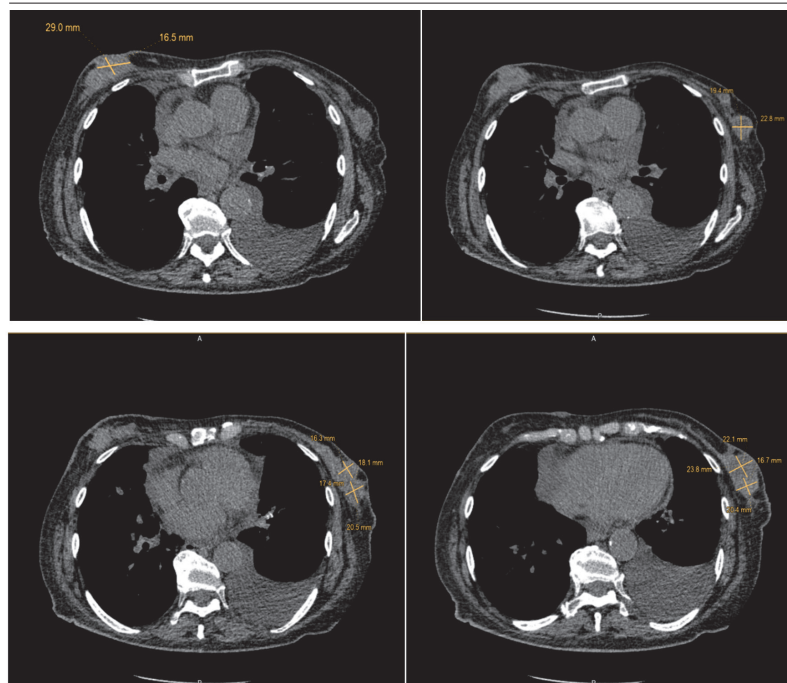


Рис. 3. Результаты КТ органов грудной клетки без контраста 04.12.24 (таргетные очаги (молочные железы, лимфоузлы) – без существенной динамики, некоторые очаги в легких – уменьшение/исчезновение матовости, выпот – без изменений).

Fig. 3. Results of CT scan of the chest organs without contrast 12/04/24 (target lesions (mammary glands, lymph nodes) – no significant dynamics, some lesions in the lungs – decrease/disappearance of haze, effusion – unchanged).

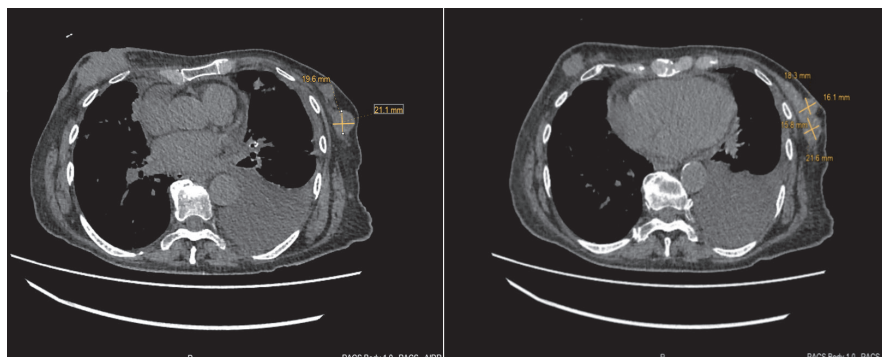


Рис. 4. Результаты КТ органов грудной клетки без контраста от 27.05.25 (несмотря на небольшие изменения по отдельным очагам, общее увеличение подтвержденных метастатических очагов превышает 20% — признак прогрессирования).

Fig. 4. Results of CT scan of the chest organs without contrast from 27.05.25 (despite minor changes in individual lesions, the overall increase in confirmed metastatic lesions exceeds 20% – a sign of progression).



Рис. 5. Опухоль до начала ФДТ: правая молочная железа практически полностью отсутствует за счёт опухолевой инфильтрации, на коже грудной клетки справа изъязвления на площади 13x10 см, в левой молочной железе опухолевое образование округлой формы размером 6x7x5 см плотной консистенции с инфильтрацией кожи.

Fig. 5. Tumor before PDT: the right mammary gland is almost completely absent due to tumor infiltration, on the skin of the chest on the right there are lesions on an area of 13x10 cm, in the left mammary gland there is a round tumor formation measuring 6x7x5 cm of dense consistency with skin infiltration.



Рис. 6. Состояние после ФДТ: в верхнебоковом квадранте грудной клетки (правая сторона) визуализируется участок деформированной кожи с выраженными признаками инфильтрации, кожа втянута, с рубцовыми изменениями, пигментными пятнами и следами после сеансов ФДТ.

Fig. 6. Condition after PDT: in the upper lateral quadrant of the chest (right side) an area of deformed skin with pronounced signs of infiltration is visualized, the skin is retracted, with cicatricial changes, pigment spots and traces after PDT sessions.

and reduces the likelihood of local relapses [9-11]. This feature opens up prospects for the combined use of PDT with immunotherapy and targeted agents, which is actively being investigated in modern oncology.

The socio-clinical aspect of the use of PDT should also be noted. For some patients, especially the elderly, the rejection of standard protocols is associated not only with medical contraindications, but also with subjective factors such as fear of side effects, decreased motivation, or previous negative treatment experiences. In such cases, PDT can be considered as a method of choice that provides a balance between the effectiveness and tolerability of therapy. This approach is consistent with the principles of personalized and value-based cancer care, where the therapeutic strategy is adapted to the individual characteristics of the patient.

Thus, the clinical example presented in this study confirms the potential of PDT as an effective and safe method of local exposure in metastatic breast cancer.

The use of PDT made it possible to achieve clinical and radiological control while maintaining a high quality of life for the patient, which underlines the importance of the method in palliative practice and the need for further study.

Conclusion

This clinical observation demonstrates that PDT can be considered as an effective and minimally invasive alternative or supplement to standard treatments for metastatic breast cancer. The use of PDT made it possible to achieve lasting stabilization of the disease, clinical improvement and good tolerability of therapy without the development of systemic side effects.

PDT has a number of advantages – selectivity of exposure, the possibility of repeated use, minimal toxicity and the potential for immunostimulating action. These characteristics make the method especially valuable in the treatment of patients with disabilities for standard treatment regimens.

REFERENCES

1. International Agency for Research on Cancer. Absolute numbers, incidence, females, in 2022 [Electronic resource]. Available from: https://gco.iarc.who.int/today/en/dataviz/pie?mode=cancer&group_populations=1&sexes=2.
2. Shanazarov N., Zhapparov Y., Kumisbekova R., Turzhanova D., Zulkhash N. Association of gene polymorphisms with breast cancer risk in the Kazakh population. *Asian Pac. J. Cancer Prev*, 2023, vol. 24, pp. 4195-4207. doi: 10.31557/APJCP.2023.24.12.4195.
3. Tyulyandin S.A., Artamonova E.V., Zhigulev A.N., et al. Breast cancer. Practical recommendations of RUSSCO, part 1.2. *Malig. Tumors*, 2024, vol. 14 (3s2), pp. 32-81. doi: 10.18027/2224-5057-2024-14-3s2-1.2-01.
4. Zhukova L.G., Andreeva Y.Y., Zavalishina L.E., Zakiriyakhodjaev A.D., Koroleva I.A., Nazarenko A.V., et al. Breast cancer: Clinical guidelines. *Mod. Oncol*, 2021, vol. 23 (1), pp. 5-40. doi: 10.26442/18151434.2021.1.200823.
5. Gelfond M.L., Rogachev M.V. Photodynamic therapy: fundamental and practical aspects. A textbook for students of higher and additional professional education. *St. Petersburg: N.N. Petrov National Medical Research Center of Oncology. Ministry of Health of the Russian Federation*, 2018, pp. 148.
6. Correia J.H., Rodrigues J.A., Pimenta S., Dong T., Yang Z. Photodynamic therapy review: principles, photosensitizers, applications, and future directions. *Pharmaceutics*, 2021, vol. 13 (9), pp. article 1332. doi: 10.3390/pharmaceutics13091332.
7. Banerjee S.M., El-Sheikh S., Malhotra A., Mosse C.A., Parker S., Williams N.R., et al. Photodynamic therapy in primary breast cancer. *J. Clin. Med*, 2020, vol. 9 (2), pp. 483. doi: 10.3390/jcm9020483.
8. Goranskaya E.V., Ragulin Yu.A., Kapinus V.N., et al. Immediate results of photodynamic therapy for intradermal metastases of breast cancer. *Oncosurgery*, 2011, vol. 3 (2), pp. 21-22.
9. Moret F., Reddi E. Strategies for optimizing the delivery to tumors of macrocyclic photosensitizers used in photodynamic therapy (PDT). *J. Porphyr. Phthalocyanines*, 2017, vol. 21, pp. 239-256.
10. Anokhin A.A., et al. Tumor-specific immune response after photodynamic therapy. *Med. J*, 2016, vol. 18 (5), pp. 405-416. doi: 10.15789/1563-0625-2016-5-405-416.
11. Filonenko E.V., Serova L.G. Photodynamic therapy in clinical practice. *Biomedical Photonics*, 2016, vol. 5 (2), pp. 26-37.
12. Rakhimzhanova R.I., Shanazarov N.A., Turzhanova D.E. Photodynamic therapy of intradermal metastases of breast cancer (literature review). *Biomedical Photonics*, 2019, vol. 8 (3), pp. 36-42. doi: 10.24931/2413-9432-2019-8-3-36-42.
13. Shanazarov N., Zinchenko S., Zhapparov E., et al. The clinical case of successful application of photodynamic therapy in the treatment of skin metastases of breast cancer. *BioNanoSci.*, 2021, vol. 11, pp. 957-961. doi: 10.1007/s12668-021-00907-5.
14. Li T., Yan L. Functional polymer nanocarriers for photodynamic therapy. *Pharmaceutics (Basel)*, 2018, vol. 11 (4), pp. 133

ЛИТЕРАТУРА

1. Absolute numbers, Incidence, Females, in 2022 [Электронный ресурс] // International Agency for Research on Cancer – URL: https://gco.iarc.who.int/today/en/dataviz/pie?mode=cancer&group_populations=1&sexes=2
2. Shanazarov N., Zhapparov Y., Kumisbekova R., Turzhanova D., Zulkhash N. Association of Gene Polymorphisms with Breast Cancer Risk in the Kazakh Population // *Asian Pac. J. Cancer Prev.* – 2023. – Vol. 24. – P. 4195-4207. doi: 10.31557/APJCP.2023.24.12.4195.
3. Тюляндин С.А., Артамонова Е.В., Жигулев А.Н. и соавт. Рак молочной железы. Практические рекомендации RUSSCO, часть 1.2 // *Злокачественные опухоли.* – 2024. – Т. 14, № 3s2. – С. 32-81. doi: 10.18027/2224-5057-2024-14-3s2-1.2-01.
4. Жукова Л.Г., Андреева Ю.Ю., Завалишина Л.Э., и др. Рак молочной железы: клинические рекомендации // *Современная онкология.* – 2021. – Т. 23, № 1. – С. 5-40. doi: 10.26442/18151434.2021.1.200823.
5. Гельфонд М.Л., Рогачёв М.В. Фотодинамическая терапия: фундаментальные и практические аспекты: учебное пособие для обучающихся в системе высшего и дополнительного проф. образования. – Санкт-Петербург: НМИЦ онкологии им. Н.Н. Петрова Минздрава РФ. – 2018. – С. 148.
6. Correia J.H., Rodrigues J.A., Pimenta S., Dong T., Yang Z. Photodynamic Therapy Review: Principles, Photosensitizers, Applications, and Future Directions // *Pharmaceutics.* – 2021. – Vol. 13(9). – Article 1332. doi: 10.3390/pharmaceutics13091332.
7. Banerjee S.M., El-Sheikh S., Malhotra A., Mosse C.A., Parker S., Williams N.R., MacRobert A.J., Hamoudi R., Bown S.G., Keshtgar M.R. Photodynamic Therapy in Primary Breast Cancer // *J. Clin. Med.* – 2020. – Vol. 9(2). – P. 483. doi: 10.3390/jcm9020483.
8. Горанская Е.В., Рагулин Ю. А., Капинус В. Н. и др. Непосредственные результаты фотодинамической терапии внутрикожных метастазов рака молочной железы // *Онкохирургия.* – 2011. – Т. 3, № 2. – С. 21-22.
9. Moret F., Reddi E. Strategies for optimizing the delivery to tumors of macrocyclic photosensitizers used in photodynamic therapy (PDT) // *J. Porphyr. Phthalocyanines.* – 2017. – Vol. 21. – P. 239-256.
10. Анохин А.А. и др. Опухолеспецифический иммунный ответ после фотодинамической терапии // *Медицинский журнал.* – 2016. – Т. 18, № 5. – С. 405-416. doi: 10.15789/1563-0625-2016-5-405-416.
11. Филоненко Е. В., Серова Л. Г. Фотодинамическая терапия в клинической практике // *Biomedical Photonics.* – 2016. – Т. 5, № 2. – С. 26-37.
12. Рахимжанова Р.И., Шаназаров Н.А., Туржанова Д.Е. Фотодинамическая терапия внутрикожных метастазов рака молочной железы (обзор литературы) // *Biomedical Photonics.* – 2019. – Т. 8, № 3. – С. 36-42. doi: 10.24931/2413-9432-2019-8-3-36-42.
13. Shanazarov N., Zinchenko S., Zhapparov E., et al. The Clinical Case of Successful Application of Photodynamic Therapy in the Skin Metastases Treatment of Breast Cancer // *BioNanoSci.* – 2021. – Vol. 11. – P. 957-961. doi: 10.1007/s12668-021-00907-5.
14. Li T., Yan L. Functional Polymer Nanocarriers for Photodynamic Therapy // *Pharmaceutics (Basel).* – 2018. – Vol. 11(4). – P. 133.