Plasma Medicine: Innovative Methods of Diagnosis and Treatment of Chronic Wounds and Oncological Diseases

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Abstract. This paper examines the contemporary landscape and future potential of plasma medicine as a transformative branch of healthcare innovation. Centered on the use of cold atmospheric plasma, this emerging field has demonstrated remarkable effectiveness in treating chronic wounds, combating multidrug-resistant pathogens, managing dermatological and oncological conditions, and sterilizing medical instruments and surfaces. Emphasis is placed on understanding the mechanisms of action - especially the generation of reactive oxygen and nitrogen species that selectively target pathogenic microbes and cancer cells. International research findings further affirm the promising integration of plasma technologies into modern medical practice, highlighting both its benefits and challenges, along with its social and economic implications. Moreover, the rapid evolution of plasma medicine is opening new avenues for treatment strategies that may complement existing therapies to improve patient outcomes. Researcher explores innovative combinatory approaches and refining protocols to maximize clinical efficacy, ensuring that this technology can be standardized and broadly applied. These advancements position plasma medicine as a pivotal development in addressing complex global health challenges with safe, effective, and forward-thinking solutions. Ongoing research into plasma medicine is further enhanced by collaborative efforts among scientists, clinicians, and engineers. Their work is refining plasma device technology, standardizing treatment protocols, and deepening the understanding of cellular responses, which is crucial for optimizing therapeutic outcomes and ensuring the safe, widespread adoption of plasma-based interventions globally.

Keywords: plasma medicine, cold atmospheric plasma, multidrug-resistant pathogens, wound treatment, oncology, sterilization.

Introduction. Previously, the author highlighted the concepts of quantum medicine, bioquantum therapy and bioquantum medicine [1]. Meanwhile, Eastern medicine provided the key to a completely new type of treatment and pharmacotherapy, called digital medical technologies, quantum therapy, the latest medical technologies, combined pharmacotherapy with digital medical technologies [2, 3].

In the field of innovative developments, technologies and methods related to the field of quantum technologies, the field of so-called quantum medicine is occupied [4].

The origin of this concept goes back to the concept of quantum biology. A branch of biology whose goal is to consider living systems from the standpoint of quantum theory. In the concept of quantum biology, the terms of quantum mechanics are used to describe biological processes and dynamic molecular structures: absorption of electromagnetic radiation of a certain frequency; transformation of chemical energy into movement; magnetoreception in animals and Brownian motors in many cellular processes. Quantum physics and quantum chemistry gave rise to quantum biophysics and quantum biochemistry. And among them – quantum physiology, quantum biology, quantum medicine. The term "quantum medicine" was introduced in 1994 as a realization of the fundamental concepts presented by the quantum physics of the living [5, 6].

All aspects of the application of quantum theories and equipment, which are based on the principles of quantum physics, are applied directly to living, biological objects, consider the impact directly on biological objects. The medical work of doctors and other specialists in medicine and pharmacy begins in health care institutions with the use of bioresonance therapy devices. The individual frequency of electromagnetic waves affects different parts of the patient's system and organs. Control the patient's reactions to different wavelengths. In some cases, the patient's own sensations are also guided: does he feel warmth and tingling. After establishing the individual frequency of electromagnetic influence, the patient undergoes a course of procedures. The complex of quantum technologies and pharmaceuticals affects the disease at once in two directions – from the outside and from the inside. The patient's recovery time is shortened.

According to literature sources of 2014, Pogotova G.A. and Chekman I.S. emphasize the fact that thanks to achievements in the field of quantum physics, quantum mechanics, chemistry, electrodynamics, computer technologies, molecular biology, physiology, biochemistry, pharmacology, clinical pharmacy, theoretical foundations have been laid that contributed to the development of a new direction – quantum pharmacology, i.e. quantum pharmacy [7].

The author of the article continues the search for innovative methods of diagnosis and treatment. Among the possible ways of innovation is the expansion of the methods of bioquantum therapy and bioquantum medicine to the development of plasma medicine.

The purpose of the study was to analyze the current state and prospects for the development of plasma medicine, as an innovative direction that combines physical and biomedical sciences to solve urgent health problems. Special attention is paid to the possibilities of using cold atmospheric plasma in the treatment of multidrug-resistant infections, in particular, chronic wounds, dermatological and oncological diseases, as well as for the sterilization of medical instruments and surfaces.

The article also aims to highlight key achievements in this field, in particular the results of international studies that prove the effectiveness of plasma technologies, and to emphasize the importance of an interdisciplinary approach to solving global medical challenges. This article examines key aspects of plasma medicine, its potential benefits, and prospects for implementation in medical practice.

Materials and methods. The work uses the results of numerous international studies, particularly those conducted within the framework of scientific projects of the Max Planck Institute for Physics, covering the study of the properties of cold atmospheric plasma and its application in medicine [8].

A retrospective and documentary analysis were carried out based on publications in scientific journals, data from English-language sources, such as Wikipedia [9], and other evidentiary materials.

The research methodology is given in Fig. 1.

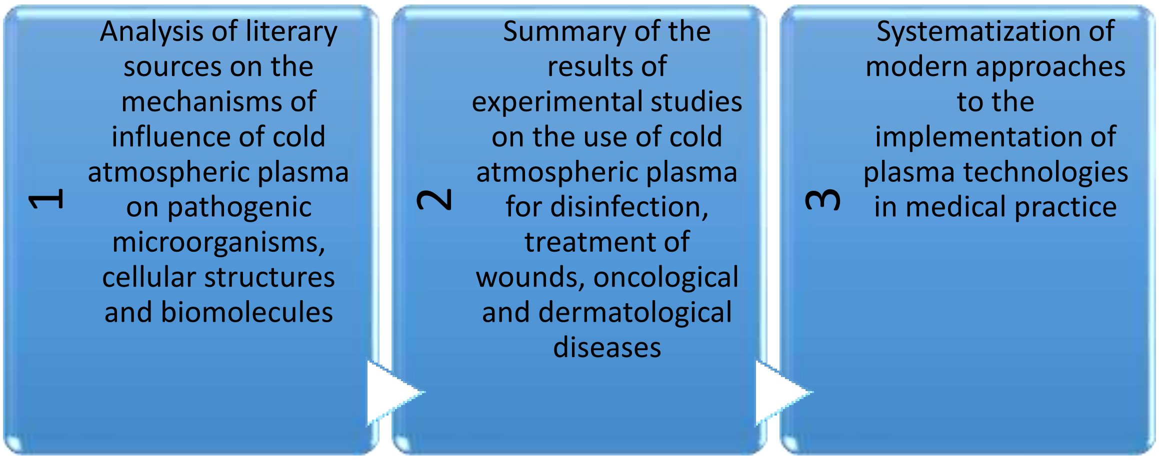

Fig. 1. Research methodology.

The research methodology included:

1. Analysis of literature sources on the mechanisms of influence of cold atmospheric plasma on pathogenic microorganisms, cellular structures, and biomolecules.
2. Generalization of the results of experimental studies on the use of cold atmospheric plasma for disinfection, treatment of wounds, oncological and dermatological diseases.

3. Systematization of modern approaches to the implementation of plasma technologies in medical, clinical, pharmaceutical practice.

Special attention is paid to assessing the effectiveness of plasma therapy in comparison with traditional methods of treatment, as well as analyzing its safety for medical use.

The research of the article is a fragment of research works of Private Scientific Institution "Scientific and Research University of Medical and Pharmaceutical Law" on the topic “Multidisciplinary research of post-traumatic stress disorders during war among patients (primarily combatants)” (state registration number 0124U002540, implementation period 2024-2028).

Results and discussion. Modern medicine faces several challenges, among which the spread of multidrug-resistant pathogens is a particular threat. This problem is exacerbated by the growing resistance of bacteria to antibiotics, which requires new approaches to the treatment of infectious diseases. One of the promising areas in addressing this issue is plasma medicine, an innovative field that combines plasma physics, biomedical sciences, and clinical medicine.

Cold atmospheric plasma has demonstrated effectiveness in deactivating a wide range of pathogens, including multidrug-resistant Staphylococcus aureus and Deinococcus radiodurans, known as one of the most resistant microorganisms in the world [8].

The application of cold atmospheric plasma covers not only the treatment of chronic wounds, dermatological and oncological diseases, but also the sterilization of medical equipment [9].

The development of plasma technologies opens new opportunities for the medicine of the future, allowing to effectively solve complex tasks in the field of healthcare.

Development of plasma medicine: the path to innovative methods of diagnosis and treatment of chronic wounds and oncological diseases [8, 9].

Plasma medicine is an innovative direction that combines plasma physics, biological sciences, and clinical medicine. Its main tool is cold atmospheric plasma, which has demonstrated extraordinary effectiveness in combating various medical challenges, including hospital-acquired infections, chronic wounds, oncological and dermatological diseases, post-traumatic stress disorders.

In this article, the author studies such an innovative topic as plasma medicine and its possibilities in the field of elimination of multidrug-resistant pathogens, as well as in the field of dermatology, oncology, and wound treatment.

As part of a multi-year international project carried out by one of the most influential scientific communities – the German Max Planck Research Society, which includes more than 80 institutes, laboratories and working groups, research has been conducted in the fields of astronomy, physics, chemistry, biology, and medicine [10].

It is noted that plasma medicine is a new interdisciplinary field that combines plasma physics, life science and clinical medicine. Its research focuses on treatment, oncology, and surgery, as well as disinfection. Most experiments are carried out in vitro or on animal models. Plasma medicine uses ionized gas (physical plasma). Physical plasma consists of positive ions, electrons, and chemically active particles [11].

Cold atmospheric plasma sources generate ions, active molecules and UV photons that are used to sterilize instruments, modify the properties of biomaterials, and even process human tissues for therapeutic purposes. This promising area is being actively studied worldwide [9, 12].

A microwave plasma device developed under the auspices of the Max Planck Institute for Physics treated multidrug-resistant Staphylococcus auris with plasma for 2 minutes and then incubated for 24 hours. Where plasma was applied, virtually no surviving bacteria were found, indicating a 99.9999% reduction in bacterial load. These results indicate that cold atmospheric plasma is certainly capable of inactivating key microbial contaminants in nosocomial infections [11-13].

Cold atmospheric plasma has been shown to be one of the most promising tools for the prevention of infectious diseases and nosocomial infections.

Cold atmospheric plasma is known to inactivate a wide range of microorganisms, such as bacteria, fungi, biofilms, viruses, and spores. Importantly, cold atmospheric plasma is also capable of inactivating antibiotic-resistant bacteria, such as multidrug-resistant Staphylococcus aureus. Even

Deinococcus radiodurans, the most resistant bacterium in the world (as listed in the Guinness Book of Records), can be inactivated by plasma within seconds [11].

Moreover, recent results show that microorganisms can also be inactivated through various fabrics (e.g. textiles), which opens even more areas of application. The use of cold atmospheric plasma in medicine and healthcare as a disinfectant will solve many problems - from irritated skin through hand disinfection and sterilization of surgical equipment to the prevention of nosocomial infections and the spread of resistant microorganisms [12, 13].

Many studies carried out in recent years have shown that all tested pathogens can be easily inactivated by cold atmospheric plasma in short time intervals, from a few seconds to a few minutes. This area of modern medicine has a deep history of scientific research and practical application [14].

The problem of the growth of multidrug-resistant infections is relevant today. The task set before many scientific teams around the world is to actively search for a solution to the problem of multidrug-resistant pathogens.

And it is in this area that cold atmospheric plasma has shown itself to be an extremely promising direction.

The largest collective study was conducted by the Max Planck Society [12].

Many years of research from more than 20 scientific universities, institutes and clinics in Europe, America and Japan have proven the high efficiency of plasma technologies in medical applications [13]. The areas of application of plasma technologies are shown in Fig. 2.

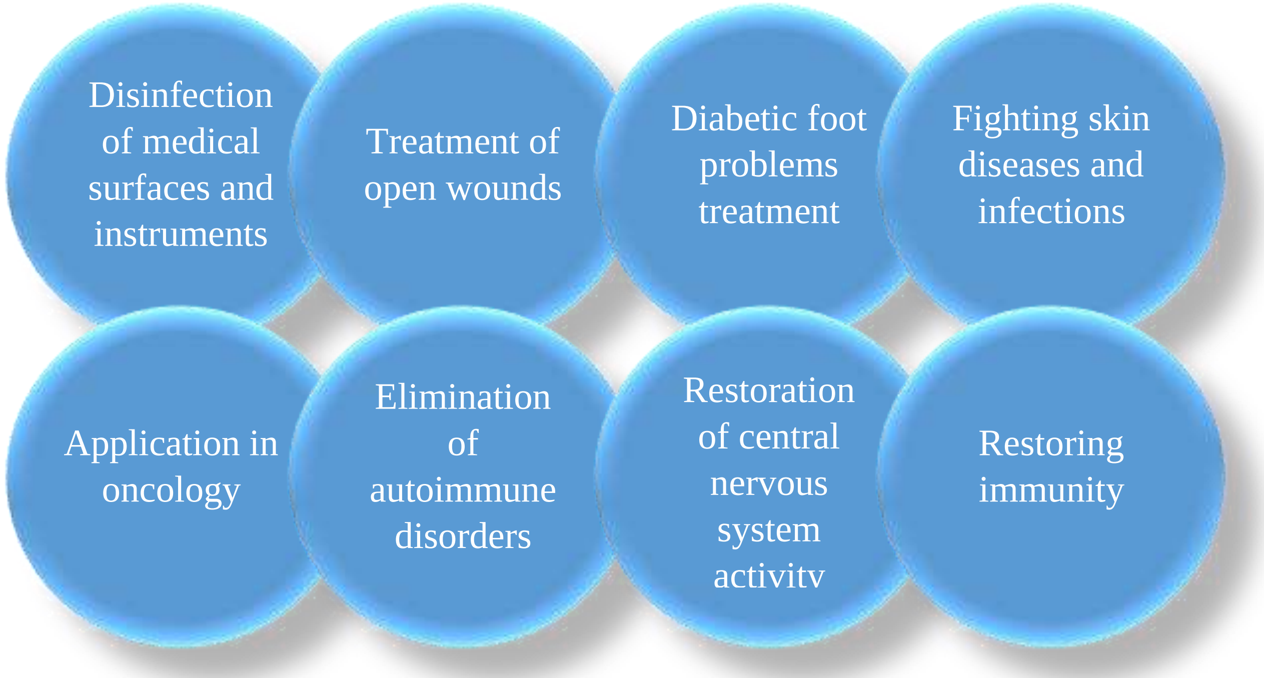

Fig. 2. Areas of application of plasma technologies.

In all these areas, the use of cold atmospheric plasma has shown extraordinary efficiency. Fig. 3 shows one of the types of cold atmospheric plasma, which has the appearance of a thin lightning, visible only in the dark under magnification.

Fig. 3. Cold atmospheric plasma [12].

Cold atmospheric plasma is therefore an ionized gas containing positive ions, negative ions, or electrons, depending on the type of plasma.

Cold atmospheric plasma sources used for plasma medicine are typically low-temperature plasmas, and they generate ions, chemically active atoms and molecules, and UV photons [14].

These active species generated by cold atmospheric plasma are useful for several biomedical applications, such as the sterilization of implants and surgical instruments, and the modification of biomaterial surface properties.

Plasma can also be used in sensitive areas, such as its use to affect the surface of the human body or internal organs for medical purposes. This possibility is being intensively studied by research groups around the world, as part of interdisciplinary research in plasma medicine. Fig. 4 shows a prototype plasma source.

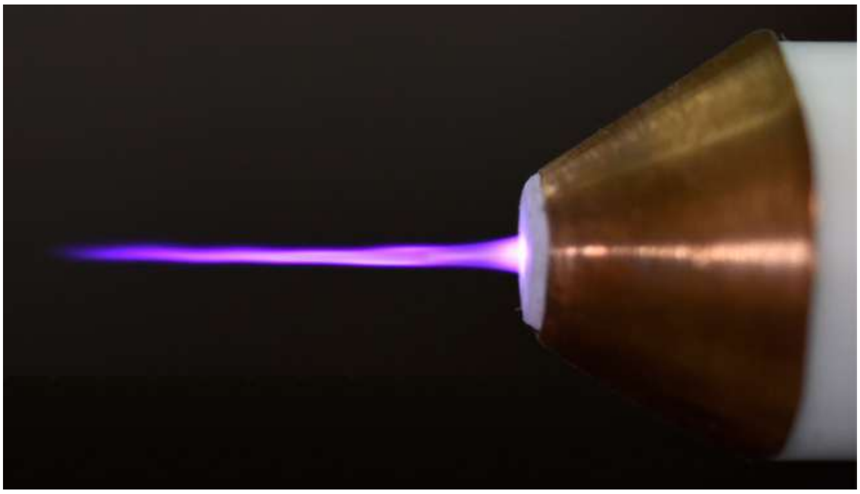

Fig. 4. Plasma source prototype [9].

Plasma sources used in plasma medicine are usually “low temperature” plasma sources (not more than 50^{o}C), operating at atmospheric pressure, or in the form of a very thin, harmless lightning jet.

In this case, the plasma does not leave the jet, and only neutral atoms, ions, molecules, and photons reach the point of application. Low temperature plasma jets have been used in various biomedical applications, ranging from the inactivation of bacteria to the destruction of cancer cells.

Applications

Plasma medicine can be divided into five main areas (Fig. 5).

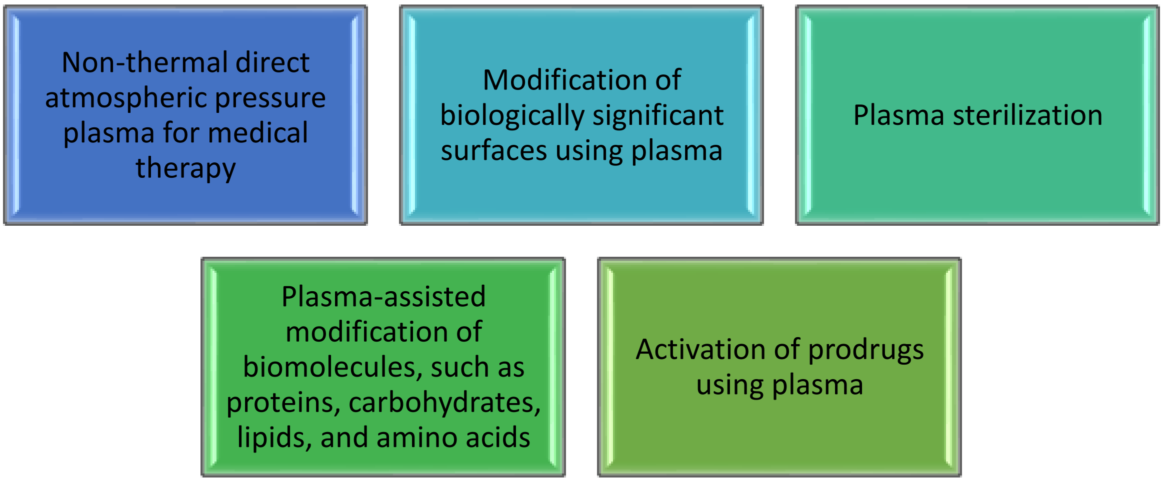

Fig. 5. Directions of application of plasma medicine.

High reactivity of plasma is a result of various components of plasma:

- electromagnetic radiation;
- UV;
- visible light;
- infrared radiation;
- high-frequency electromagnetic fields (ions, electrons, radicals).

According to the generally accepted approaches of science of the 20th century, the phenomena of plasma application in medicine were primarily attributed to the influence due to gases with high oxidative activity formed in plasma, as well as due to the so-called particles (ions, electrons, etc.).

However, experiments in the programs of recent decades have shown that plasma can also affect closed cavities. For example, on the internal cavities of medical instruments, effectively eliminate chronic foot fungus directly through thick socks, eliminate biofilms through bandages and even plaster. This made me think that the effect of plasma can be explained by electromagnetic radiation. The only question is to choose the optimal frequencies of the electromagnetic field and the power of the plasma.

Based on the analysis of literature data, it was found that thanks to the high-power electromagnetic field, from plasma sources of about 30 kV and current strength up to 150 mA, the effect is provided to the entire depth of the patient's body, without any negative effects. At the same time, damaged, as well as malignant (oncological) cells of the patient's body have a negative charge, and the plasma flow has a positive charge, so these cells attract the proton flow to themselves, due to which the activity of the mitochondrial proton pump is restored. Behind the scenes of this process, cancer cells, as well as cells damaged in any way, are restored.

This effect is effective in oncology, the treatment of deep infected wounds, and the treatment of central nervous system disorders [15-17].

Plasma technologies are also widely used to affect the skin surface, which explains the widespread use in plasma dermatology [18].

The first successes were achieved by German scientists who used plasma therapy to treat chronic ulcers [19].

These studies led to the development of plasma devices that are now used in clinical practice in the European Union.

In the United States, a joint group of academic scientists from the Nyheim Plasma Institute at Drexel University pioneered the use of plasma for the treatment of precancerous (actinic) keratosis and warts.

The same group was able to show promising results in the treatment of hair loss (androgenetic alopecia) using a modified protocol called indirect plasma therapy.

The successful plasma treatment of actinic keratosis was repeated by another group of scientists in Germany using a different type of plasma device. Such data demonstrate the value of this technology even compared to conventional pharmacotherapy methods with topical application of drugs (diclofenac).

Clinical trials are underway in dermatology for the treatment of acne, rosacea, hair loss and other conditions. The understanding gained from studying plasma treatment of skin diseases may also help in the development of new plasma medicine strategies for the treatment of internal organs.

Cold atmospheric plasma is used to treat chronic wounds. Preliminary results show that cold atmospheric plasma therapy can be quite effective. This point is important, given the large number of wounds received by combatants in conditions of military conflicts.

Our research group has developed a plasma device "ProtonPlasmaTherapy" which has the appropriate certification as a medical physiotherapy class 2A. It shows very high efficiency in the treatment and disinfection of wounds.

The author of the article notes that when used for health-improving and therapeutic purposes, many positive results were obtained when applied to such problems as wounds that are difficult to heal, varicose veins, rehabilitation after chemotherapy, autoimmune diseases, the consequences of CNS lesions after Lyme disease and other CNS disorders, such as multiple sclerosis, Alzheimer's disease, Parkinson's disease, dementia, etc.

In the author's opinion, there are 2 most visible mechanisms of plasma action: biochemical and biophysical.

The plasma process generates reactive oxygen and nitrogen species, which include free radicals. This increases oxidative stress on cells, which causes selective destruction of cancer cells that are already exposed to oxidative stress. Also, prokaryotic cells may be more sensitive to oxidative stress than eukaryotic cells, which allows them to destroy bacteria.

It is known that electric fields can affect cell membranes with the method of electroporation, electrotransfer. The electric fields on cells treated with a plasma jet can be high enough to cause electroporation, which can directly affect the behavior of the cell or may simply allow more reactive species to penetrate the cell.

It is known that both the physical and chemical properties of plasma cause the uptake of nanomaterials by cells. For example, cancer cells can absorb 20 ng of gold nanoparticles under the influence of cold plasma doses [20].

On the other hand, the combination of plasma medicine methods with pharmacotherapy to achieve the effect of potentiation is promising.

Potentiation is known as a biophysical phenomenon. It can be observed not only in the case of the combined interaction of individual medicines, but also in the case of the interaction of cold atmospheric plasma and methods of physiotherapeutic influence (Fig. 6).

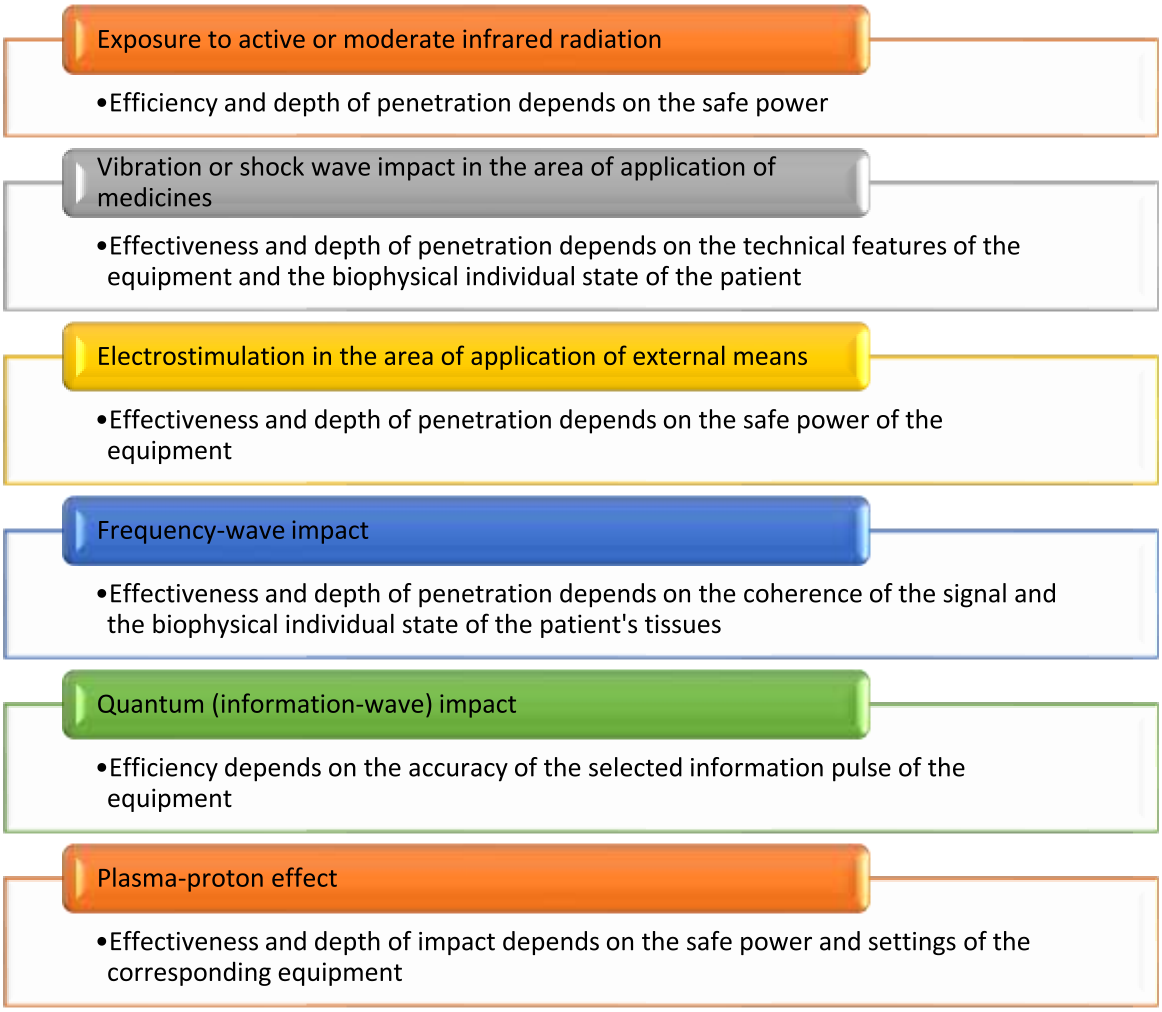

Fig. 6. Examples of potentiation when combining plasma medicine methods with pharmacotherapy.

Potentiation is a type of interaction of medicines, which is a separate case of synergism. In the case of potentiation, the effect of the simultaneous use of several medicines is significantly greater than the sum of the effects of each medicine used separately in the same dose. In the case of summation, the effect is approximately equal to the sum of the effects of individual medicines. Such frequency-wave exposure using the Bicom Optima equipment (Germany) and the “ProtonPlasmaTherapy” proton-plasma complex (Ukraine) can provide several times higher biophysical coherence in combination with the use of other pharmacological medicines that cause potentiation [21, 22].

The combination of pharmacotherapy, plasma and frequency-wave exposure makes it possible to reduce the dose of medicines, during chemotherapy, by several times, for patients with intolerance to high doses of any medicine.

Plasma medicine has turned out to be an extremely broad area for study and application. And it is plasma medicine that can now be used extremely effectively for the treatment of severe infected and non-infected wounds, and can also give a cumulative effect in the field of cancer treatment, post-traumatic stress disorders and other serious diseases, thanks to the combination of the capabilities of plasma therapy and the capabilities of modern pharmacology.

The main theses of the application of cold atmospheric plasma are shown in Fig. 7.

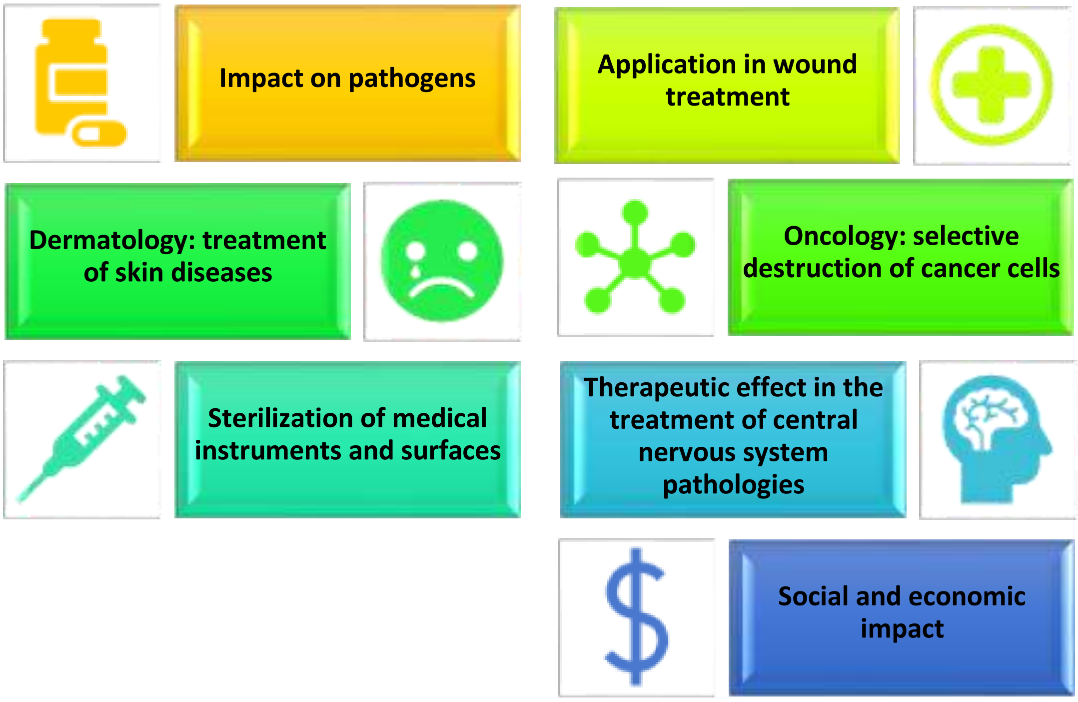

Fig. 7. Main theses of the application of cold atmospheric plasma.

So, let us note the main results of the study.

The effect of cold plasma on pathogens

Studies conducted within the framework of the Max Planck Institute for Physics confirmed that cold atmospheric plasma can inactivate a wide range of microorganisms, including bacteria, viruses, fungi, biofilms, and spores. In the case of the use of cold atmospheric plasma, a decrease in the bacterial load by 99.9999% was observed for multi-resistant Staphylococcus aureus within a few minutes [8].

One of the important advantages of cold atmospheric plasma is the ability to penetrate fabrics, textiles, and even medical plaster materials, which opens prospects for its use in conditions where conventional disinfection methods are insufficient. For example, cold atmospheric plasma effectively eliminates fungal infections even through protective shoes or socks.

Application of cold atmospheric plasma in wound treatment

Chronic wounds, in particular trophic ulcers, diabetic foot wounds and deep infectious lesions, remain a complex medical problem. Traditional treatment methods are often ineffective due to the presence of biofilms, which protect pathogenic microorganisms from the effects of antibiotics.

Studies have shown that cold atmospheric plasma not only destroys biofilms, but also stimulates tissue regeneration processes. For example, under the influence of plasma therapy, faster wound healing, reduced inflammation, and restoration of tissue structure were observed. This opens new possibilities for wound treatment, especially in conditions of high risk of infections.

Oncology: selective destruction of cancer cells

Another important area of application of cold atmospheric plasma is oncology. It has been found that plasma generates reactive oxygen and nitrogen species (ROS/RNS), which cause oxidative stress in cells. This mechanism allows for the selective destruction of cancer cells, which are more sensitive to oxidative stress than healthy cells.

Studies have shown that cold atmospheric plasma can be effective in treating various types of cancer, including skin, subcutaneous and internal tumors. Experimental results confirm the possibility of combining plasma therapy with chemotherapeutic agents to enhance the therapeutic effect.

Dermatology: treatment of skin diseases

Plasma medicine is actively used in dermatology to treat acne, rosacea, warts, and other skin diseases. Specialized plasma devices are already used in clinical practice in the European Union to treat chronic ulcers.

In addition, the use of cold atmospheric plasma for the treatment of hair loss (androgenetic alopecia) is promising. According to studies, plasma therapy stimulates the activity of hair follicles, contributing to the restoration of hair growth.

Sterilization of medical instruments and surfaces

One of the most practical areas of application of cold atmospheric plasma is disinfection and sterilization. Plasma treatment provides deep cleaning of surfaces from pathogens, including those that are multi-resistant to conventional antiseptics.

The advantage of cold atmospheric plasma in this context is its ability to sterilize even hard-to-reach places, such as the internal cavities of medical instruments, due to the influence of electromagnetic radiation and reactive oxygen and nitrogen species.

The role of electromagnetic radiation

Modern studies have shown that the effects of cold atmospheric plasma are largely due to the electromagnetic radiation that is created during the operation of plasma sources. This allows you to influence even deep tissues of the body without violating their integrity.

In studies conducted by the Max Planck Institute for Physics, it was found that a high-power electromagnetic field (up to 30,000 Volts) provides a therapeutic effect in the treatment of deep infections, cancer and pathologies of the central nervous system.

Advantages and challenges of plasma medicine (Fig. 8, Fig. 9).

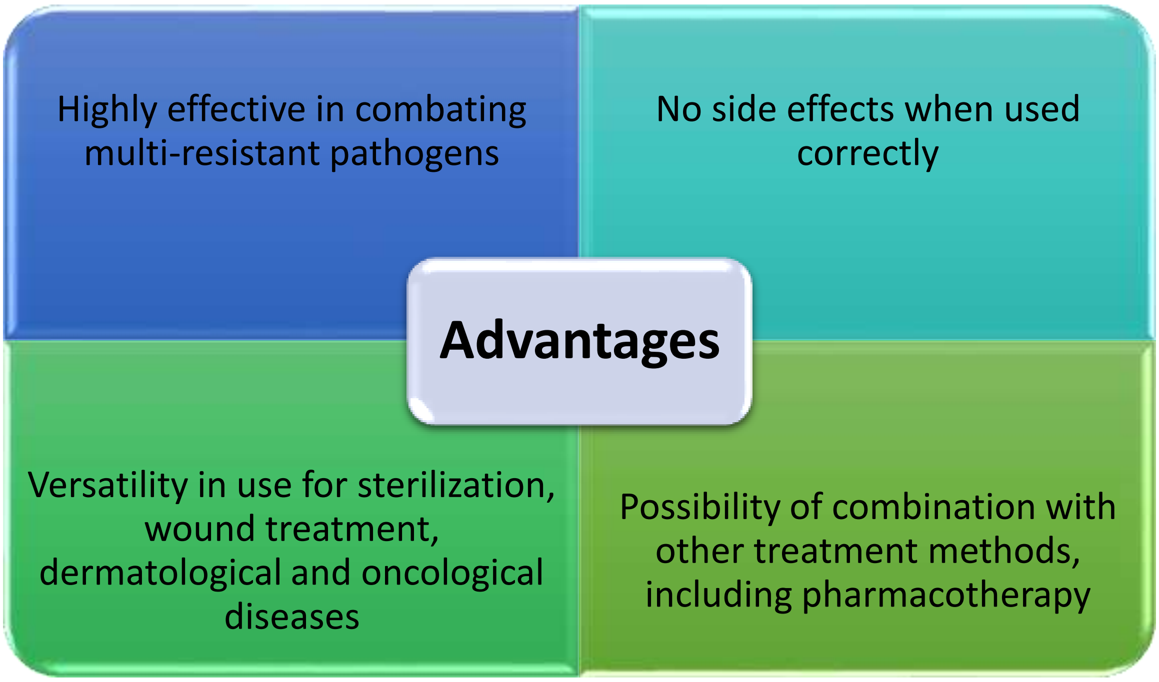

Fig. 8. Advantages of plasma medicine.

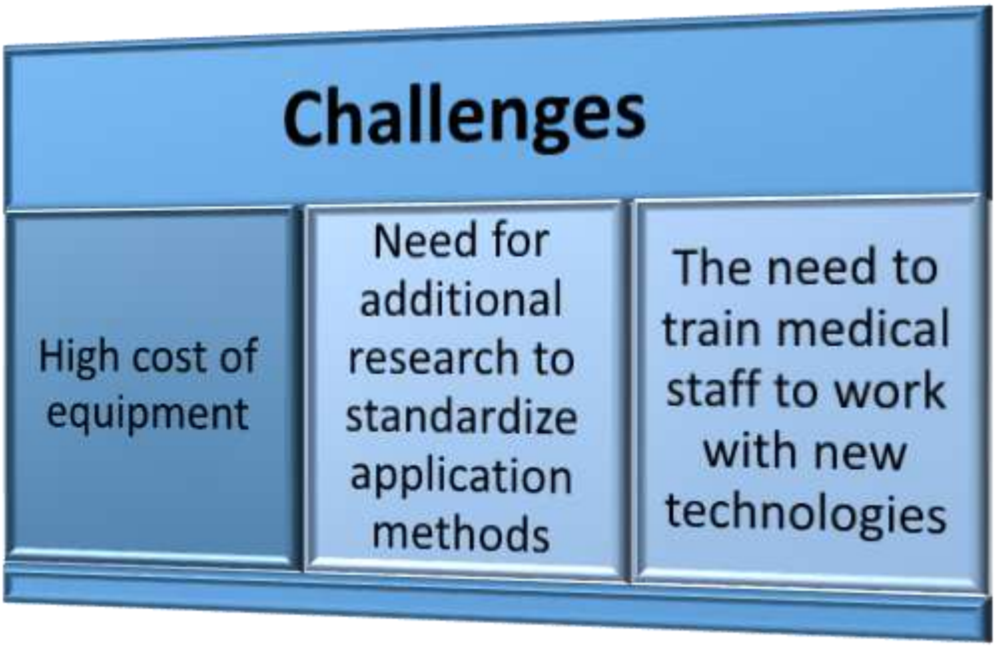

Fig. 9. Challenges of plasma medicine.

Social and economic impact

The introduction of plasma technologies into medicine can have a significant socio-economic effect. Reducing the prevalence of nosocomial infections, accelerating the healing process of wounds, and treating complex diseases will contribute to improving the quality of medical services and reducing the cost of long-term treatment.

During military conflicts, such as the current events in Ukraine, the possibility of effective treatment of wounds using plasma therapy becomes especially relevant, as it helps to preserve the life and health of victims.

Prospects for further research

Further development of plasma medicine involves the creation of compact equipment, expanding the range of its application and detailed study of the mechanisms of plasma influence on various cells and tissues.

Integration of plasma technologies with modern digital methods of diagnosis and therapy can bring medicine to a new level, providing a personalized approach to treatment.

Conclusions. Plasma medicine is a promising area of modern science that combines physics, biomedicine, and clinical practice. Thanks to the use of cold atmospheric plasma, significant progress is being made in solving current medical challenges, including the fight against multidrug-resistant pathogens, the treatment of chronic wounds, dermatological and oncological diseases.

Treatment of chronic wounds: cold atmospheric plasma promotes faster healing and reduces inflammatory processes, which makes it especially useful in conditions of limited access to traditional medical care.

Oncological prospects: plasma therapy selectively destroys cancer cells, reducing side effects compared to chemotherapy, and can potentially be used as an addition to traditional treatment methods.

Innovations in dermatology: cold atmospheric plasma is actively used to treat skin diseases and hair loss, showing high efficiency even in difficult cases.

Effectiveness of cold atmospheric plasma in disinfection and sterilization: cold plasma demonstrates a high ability to destroy a wide range of microorganisms, including antibiotic-resistant bacteria and biofilms. Its use can significantly reduce the risk of nosocomial infections.

Advantages in sterilization: the use of cold atmospheric plasma for cleaning medical instruments ensures the safety and accessibility of this process even in difficult-to-reach conditions.

Despite significant achievements, plasma medicine requires further research to improve technologies, standardize methods and ensure wide access to this technology. Integration of cold atmospheric plasma with pharmacotherapy into medical and pharmaceutical, clinical practice can radically change approaches to treatment and prevention, contributing to increasing the efficiency of medical care. Plasma medicine opens new horizons for modern science and medicine, offering effective and safe solutions for the treatment of diseases that may have previously been considered incurable.

Declaration of conflict interest. The author declares that he is the sole author of this work and has approved it for publication. The author certifies that the research was conducted in the absence of any commercial or financial relationships that could be interpreted as a conflict or potential conflict of interest.

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Ethical approval. Ethical clearance was obtained from the administration of the European Academy of Digital Medical Technologies – "Re-Generation" Medical Center (Kyiv, Ukraine). Permission statement for conducting the experiments was received from the administration of the Academy of Digital Medical Technologies – "Re-Generation" medical Center (Kyiv, Ukraine). Before any data collection, the main purpose of the study was clearly explained to each department (concerned personnel).

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Data availability statement. The datasets analyzed during the current study are available from the corresponding author on reasonable request.

References.

1. Titarenko Y., Shapovalov V. The Latest Quantum and Medical, Quantum and Pharmaceutical Technologies in Countering the Criminal and Legal, Forensic and Pharmaceutical Risks of Circulation of Falsified Drugs. *SSP Modern Law and Practice*. 2024. Vol.4. No.2. P.1-25. URL: https://doi.org/10.53933/sspmlp.v4i2.149
2. Quantum medicine – treatment using electromagnetic waves. *Popular Science Blog "Intellect"*. 2024. URL: https://www.npblog.com.ua/meditsina/235-kvantova-meditsina-likuvannja-za-dopomogoju-elektromagnitnih-hvil.html
3. Bisiani J., Anugu A., Pentyala S. It's time to go quantum in medicine. *Journal of Clinical Medicine*. 2023. Vol.12. No.13. P.e4506. URL: https://doi.org/10.3390/jcm12134506
4. Song S., She Z. (2022) . Quantum theory-based physical model of the human body in TCM. *Digital Chinese Medicine*. 2022. Vol.5. No.4. P.354-359. URL: https://doi.org/10.1016/j.dcmed.2022.12.002
5. Maurer N., Nissel H., Egerbacher M. et al. Anatomical evidence of acupuncture meridians in the human extracellular matrix: Results from a macroscopic and microscopic interdisciplinary multicentre study on human corpses. *Evidence-Based Complementary and Alternative Medicine*. 2019. Article ID 6976892, P.1-8. URL: https://doi.org/10.1155/2019/69768924
6. Li J., Wang Q., Liang H., et al. Biophysical characteristics of meridians and acupoints: a systematic review. *Evidence-Based Complementary and Alternative Medicine*. 2012. Article ID 793841, P.1-6. URL: https://doi.org/10.1155/2012/793841
7. Pogotova G.A., Chekman I.S. Quantum-pharmacological studies of the properties of antioxidants as medicinal products. *Ukrainian Medical Journal*. 2014. No.3. P.97-100. URL: https://umj.com.ua/uk/publikatsia-75175-kvantovo-farmakologichni-doslidzhennya-vlastivostej-antioksidantiv-yak-likarskix-zasobiv

8. Press release from the Max Planck Institute for Plasma Physics. URL: https://projects.mpe.mpg.de/theory/plasma-med/media/PSRev14.pdf
9. Plasma medicine. *Wikipedia.* URL: https://en.wikipedia.org/wiki/Plasma_medicine
10. Kong M.G., Kroesen G., Morfill G. et al. Plasma medicine: an introductory review. *New Journal of Physics.* 2009. Vol. 11. DOI: 10.1088/1367-2630/11/11/115012
11. Boxhammer V., Morfill G. E., Jokipii J.R. et al. Bacteticidal action of cold atmospheric plasma in solution. *New Journal of Physics.* 2012. Vol. 14. DOI 10.1088/1367-2630/14/11/113042
12. Planck Max. Basic research in space – Application on Earth. *Public service review.* Vol. 14. URL: https://projects.mpe.mpg.de/theory/plasma-med/media/PSRev14.pdf
13. Fridman A., Friedman G. *Plasma Medicine*. 2008.Wiley.
14. Woedtke V.T., Reuter S., Masur K. et al. Plasmas for medicine. *Physics Reports*. 2013. Vol. 530. No. 4. P. 291–320.
15. Yan D., Sherman J.H., Keidar M. Cold atmospheric plasma, a novel promising anti-cancer treatment modality. *Oncotarget.* 2017. Vol. 8. No. 9. P. 15977–15995.
16. Laroussi M. Plasma medicine: A brief introduction. *Plasma.* 2014. Vol. 1. No. 1. P. 47–60.
17. Hirst A.M., Frame F.M., Arya M. et al. Low-temperature plasmas as emerging cancer therapeutics: The state of play and thoughts for the future. *Tumor Biology*. 2016. Vol. 37. No. 6. P. 7029–7038.
18. Heinlin J., Morfill G., Landthaler M. et al. Plasma medicine: Possible applications in dermatology. *Journal of the German Society of Dermatology*. 2010. Vol. 8. No. 12. P. 968–976.
19. Isbary G., Heinlin J., Shimizu T. et al. Successful and safe use of 2 min cold atmospheric argon plasma in chronic wounds: Results of a randomized controlled trial. *British Journal of Dermatology*. 2012. Vol. 167. No. 2. P. 404–410.
20. Privat-Maldonado A., Schmidt A., Lin A. et al. ROS from cold physical plasmas: Key mechanisms in cancer therapy. *Clinical Plasma Medicine*. 2019. Vol. 13. P. 1–6.
21. Titarenko I. Bioresonance therapy as an innovative method of bioquantum medicine. *SSP Modern Pharmacy and Medicine*. 2024. Vol.4. No.4. P.1-20. URL: https://doi.org/10.53933/sspmpm.v4i4.166
22. Titarenko I. Application of Innovative Digital Medical Technologies of Bioquantum Medicine and Therapy in Elimination of Allergy Symptoms. *SSP Modern Pharmacy and Medicine*. 2024. Vol.4. No.3. P.1-10. URL: https://doi.org/10.53933/sspmpm.v4i3.156