Local ozone therapy application methods in the surgical treatment of brain echinococcosis

Keneshbek Yrysov[1], Taalaybek Seyitbekov[2], Ismatilla Ydyrysov[3], Kanatbek Ismailov[4], Akylbek Isakov[5], Kyialbek Sakibaev[6], Abdyrakhman Eshiev[7]

[1]Department of Neurosurgery of Undergraduate and Postgraduate Study, I. K. Akhunbaev Kyrgyz State Medical Academy, Bishkek, Kyrgyzstan, E-mail: keneshbek.yrysov@gmail.com, https://orcid.org/0000-0001-5876-4976
[2]Department of Traumatology, Forensic Medicine with a course of radiation diagnostics, Osh State University, Osh, Kyrgyzstan, E-mail: tseiitbekov@oshsu.kg, https://orcid.org/0009-0007-1514-8795
[3]Department of Traumatology, Forensic Medicine with a course of radiation diagnostics, Osh State University, Osh, Kyrgyzstan, E-mail: iydyrysov@oshsu.kg, https://orcid.org/0009-0008-6178-8678
[4]Department of Traumatology, Forensic Medicine with a course of radiation diagnostics, Osh State University, Osh, Kyrgyzstan, E-mail: dr.kana@mail.ru, https://orcid.org/0009-0001-9622-8063
[5]Department of Urology, Dermatology, Ophthalmology and Otorhinolaryngology, Osh State University, Osh, Kyrgyzstan, isakov.a62@mail.ru, https://orcid.org/0009-0005-3598-7532
[6]Department of Normal and Topographic Anatomy with a course in Constitutional Human Typology Osh State University, Scientific Research Institute of Biomedical Problems of the Southern Branch of the National Academy of Sciences, Osh, Kyrgyzstan, E-mail: kyialbek@oshsu.kg (corresponding author), https://orcid.org/0000-0001-7303-1252
[7]Department of Surgical Dentistry with a course in Pediatric Dentistry, Osh State University, Scientific Research Institute of Biomedical Problems of the Southern Branch of the National Academy of Sciences, Osh, Kyrgyzstan, E-mail: eshiev-abdyrakhman@rambler.ru, https://orcid.org/0000-0003-2617-8360

KEYWORDS

recurrence, parasitic diseases, cystectomy, prevention of recurrence, cyst bed ablation

ABSTRACT

Echinococcosis of the brain is a severe parasitic disease that represents a significant medical problem in the Kyrgyz Republic, where there is an increase in the incidence, especially among children. The study aims to improve the results of neurosurgical treatment of patients with brain echinococcosis by using ozonated saline solution to treat residual cavities after the removal of parasitic cysts. The study included 34 patients who underwent surgery for brain echinococcosis at the Neurosurgery Clinic of the National Hospital under the Ministry of Health of the Kyrgyz Republic in the period from 2015 to 2022. During the operation, ozonated saline was used to fill and disinfect the remaining cavities. The results showed that the ozonated solution caused significant morphological changes in Echinococcal Protoscolexes, leading to the destruction of cellular components and loss of the parasites' ability to replicate. Within a year after operation, 88.2% of patients had no recurrence of the disease. In addition, most patients reported a significant improvement in their health, and the absence of headaches and seizures, which indicates the high quality of the treatment and its positive impact on the quality of life. The assessment of side effects and complications showed that ozone therapy is a safe treatment method with minimal side effects. The present study confirms the high efficacy of ozonated saline in the surgical treatment of brain echinococcosis, opening new perspectives for the use of this method in medical practice and offering an effective means for treating residual cavities, which significantly reduces the risk of recurrence and improves clinical outcomes.

1. Introduction

Brain echinococcosis is a severe parasitic disease that continues to be a significant medical problem in the world, especially in the Kyrgyz Republic. According to M.Zh. Aliev et al. [1], known for its hyperendemicity to liver echinococcosis, is facing an increasing incidence, especially among children. F. Rahim et al. [2] state that many patients are admitted for treatment with complicated forms of the disease, which indicates untimely diagnosis and the need to improve methods of treatment and prevention of recurrences. The problematic aspect of the study is the high complexity of treatment and prevention of recurrences of cerebral echinococcosis. One of the most promising techniques is the use of local ozone therapy aimed at the treatment of the residual cavity of parasitic cysts. Ozone, possessing powerful antimicrobial, antiviral and antifungal properties, can cause the death of microorganisms by damaging their plasma membranes.

There were many studies on this topic. R. Kuehn et al. [3] concluded that the application of the developed measures of residual cavity prevention in hepatic echinococcosis reduced the incidence of complications. In the control group of 63 patients, residual cavities occurred in 9.5% and other complications occurred in 7.9%. In the main group of 32 patients, the use of a haemostatic collagen sponge and infrared irradiation reduced the incidence of residual cavities to 6.3% and completely excluded other complications. N.B. Kasyev et al. [4] in an epidemiological study concluded that complicated forms of the disease in 64.7% of operated patients prolonged the period of hospitalisation by 5.3±2.4 days. Recurrences were noted in 6.5% of postoperative cases and postoperative mortality was 2.2%. The decrease in new cases of echinococcosis in 2019-2021 is due to underdiagnosis, migration and worsening socioeconomic status [5, 6]. B.T. Toktogaziev et al. [7] studied the use of laparoscopy in the treatment of echinococcal cysts. The results of the research showed that this method is effective and safe. Laparoscopic surgeries reduce the invasiveness of the procedure, shorten hospitalisation and reduce the risk of postoperative complications. Despite the significant contribution of these studies, several unresolved issues remain. The main problem is the insufficient effectiveness of the existing methods of residual cavity treatment after the removal of echinococcal cysts. Previous studies have not paid sufficient attention to the use of ozonated physiological solutions for the treatment of residual cavities of parasitic cysts.

To address the stated problem, the study seeks to improve neurosurgical outcomes in patients with cerebral echinococcosis by using ozonated saline solution to treat residual cavities. Ozone is a potent disinfectant, and its use can significantly reduce the risk of recurrence and improve overall clinical outcomes. In this context, the new direction of disinfection and treatment of parasitic cysts and fibrous capsules in echinococcosis through topical ozone therapy seems particularly relevant.

The study aims to improve the results of neurosurgical treatment of patients with cerebral echinococcosis. Clinical results of using ozonated saline solution to treat residual cavities after removal of parasitic cysts in patients with cerebral echinococcosis will be analysed in this study. It is expected that the use of this technique will significantly reduce the risk of disease recurrence and increase the effectiveness of treatment.

2. Materials and Methods

The study involved 34 patients who underwent surgery for cerebral echinococcosis at the Neurosurgery Clinic of the National Hospital under the Ministry of Health of the Kyrgyz Republic in the period from 2015 to 2022. Patients were selected based on the following criteria: age from 11 to 70 years, confirmed diagnosis of brain echinococcosis using computed tomography (CT) and magnetic resonance imaging (MRI), presence of a residual cavity after removal of the parasitic cyst, patient consent to participate in the study and the use of ozone therapy. Of the total number of patients, 20 were female (58.8%) and 14 were male (41.2%). The average age of the patients was 35 years.

CT was used for the initial visualisation of the cysts, which provided a detailed image of the cysts' structure, location and size. CT examination is an essential step in diagnosis, as it is used to detect cysts even in the early stages of the disease and to assess the extent of their impact on the

surrounding brain tissue. MRI was used to study the cysts in detail and assess the condition of the surrounding tissues, as well as to determine more precisely the nature of the cysts and to identify complications. MRI provides high-quality images of the soft tissue of the brain, which is particularly important for differential diagnosis and surgical planning. Diagnosis of cerebral echinococcosis was performed using the following methods: CT was used for primary visualisation of cysts and assessment of their structure, and MRI was used for detailed study of cysts and assessment of the state of surrounding tissues. Diagnostics revealed that 21 patients (61.8%) had single-chamber cysts, 8 patients (23.5%) had multiple cysts, 2 patients (5.9%) had cysts with calcification, and 3 patients (8.8%) had cysts with decomposition and suppuration.

All operations were performed under general anaesthesia using craniotomy and brain revision. During the operation, the fibrous capsule was opened and the fluid and chitinous shell of the echinococcal cyst were removed. Ozonated physiological solution (OPS) of sodium chloride was used to treat the residual cavity. OPS was prepared as follows: the solution was ozonated using an OML-100 Ozonator by bubbling the physiological solution with an ozone-oxygen mixture with a concentration of 10-15 mg/L for 20 minutes at a room temperature of 18-20°C. The ozonated solution was prepared directly during the operation and used to fill the residual cavity.

The residual cavity was treated as follows: the cavity was filled with OPS with a concentration of 10-15 mg/l, the cavity was tamponed with gauze napkins impregnated with OPS, and the exposure was maintained for 10-15 minutes after exposure to the gauze napkins and the ozonated solution was removed. After the puncture of the echinococcal cyst and fluid removal, the material was taken for cytological and histological examination. For cytological examination, smears were made from the sediment of echinococcal fluid on a slide and stained with azure-eosin. For histological examination, preparations from the inner wall of the fibrous capsule and chitinous shell were prepared in the same way and examined under a light microscope.

The effectiveness of ozone therapy was evaluated according to the following criteria: morphological changes of Echinococcal Protoscolexes under the influence of OPS, frequency of disease recurrence within one year after surgery, clinical results and patient recovery. Descriptive statistics methods were used to analyse the obtained data, including calculation of the mean, standard deviation and percentage distribution. Comparative analysis was performed using the chi-square criterion and t-test for independent samples. The results were considered statistically significant at $p<0.05$.

3. Results

3.1. General characteristics of patients

This study included 34 patients who underwent surgery for cerebral echinococcosis. The average age of the patients was 35 years, with 20 patients being female (58.8%) and 14 patients being male (41.2%). All patients underwent a preliminary examination with CT and MRI, which allowed a detailed study of the structure of the cysts and the condition of the surrounding tissues. Of the total number of patients, 21 (61.8%) had unicameral cysts, 8 (23.5%) had multiple cysts, 2 (5.9%) had cysts with calcification, and 3 (8.8%) had cysts with decomposition and suppuration (Table 1).

Table 1. Distribution of patients by gender and age

Age in years	Male	Female	Total
11-45	11 (45.8%)	13 (54.2%)	24 (70.6%)
46-60	2 (40%)	3 (60%)	5 (14.7%)
Older than 60 years	1 (20%)	4 (80%)	5 (14.7%)
Total	14 (41.2%)	20 (58.8%)	34 (100%)

Source: compiled by the authors.

Diagnosis of cerebral echinococcosis was performed using several highly informative imaging methods that provide an accurate assessment of the patient's condition. CT was used for the primary visualisation of the cysts, which provided a detailed image of the cyst structure, location and size. CT examination is an important stage in diagnosis, as it detects the presence of cysts even at the early stages of the disease and assesses the degree of their influence on the surrounding brain tissue. MRI has been used to study the cysts in detail and assess the condition of the surrounding tissues, as well as to determine more precisely the nature of the cysts and to identify complications. MRI allows obtaining high-quality images of soft brain tissues, which is especially important for differential diagnosis and surgical planning.

The diagnosis revealed that 21 patients (61.8%) had unicameral cysts, which are single, isolated masses. These cysts usually have clear boundaries and can be surgically removed easily. Multiple cysts, also known as daughter cysts, were identified in 8 patients (23.5%). These masses are characterised by the presence of multiple cysts, which complicates their surgical removal and increases the risk of recurrence. Two patients (5.9%) were diagnosed with calcified cysts, indicating a prolonged course of the disease and suggesting the possibility of the presence of old, calcified cysts, which may present certain difficulties in removal (Table 2).

Table 2. Distribution of patients by CT/MRI data

Ultrasound data of cysts	Absolute number	%
Single chamber	21	61.8
Multiple chamber	8	23.5
With calcification	2	5.9
With decomposition and abscessing	3	8.8
Total	34	100

Source: compiled by the authors.

Cysts with decomposition and suppuration were detected in 3 patients (8.8%), indicating the presence of complicated forms of echinococcosis requiring a more aggressive and comprehensive approach to treatment.

3.2. Surgery and ozone therapy

All operations were performed under general anaesthesia using craniotomy and brain revision. During the operation, the fibrous capsule was opened and the fluid and chitinous shell of the echinococcal cyst were removed. To treat the residual cavity, sodium chloride OPS was used, which was prepared as follows: the solution was ozonated using an OML-100 Ozonator by bubbling physiological solution with an ozone-oxygen mixture with a concentration of 10-15 mg/L for 20 minutes at a room temperature of 18-20 °C. The ozonated solution was prepared directly during the operation and used to fill the residual cavity.

The residual cavity was treated as follows: the cavity was filled with OPS with a concentration of 10-15 mg/l, the cavity was tamponed with gauze napkins impregnated with OPS, and the exposure was maintained for 10-15 minutes after exposure to the gauze napkins and the ozonated solution was removed. After the puncture of the echinococcal cyst and fluid removal, the material was taken for cytological and histological examination. For cytological examination, smears were made from the sediment of echinococcal fluid on a slide and stained with azure-eosin. For histological examination, preparations from the inner wall of the fibrous capsule and chitinous sheath were prepared similarly and examined under a light microscope. Treatment outcomes were evaluated based on several criteria, including morphological changes of Echinococcal Protoscolexes under the influence of OPS, disease recurrence rate at one year postoperatively, and overall clinical results and patient recovery.

3.3. Morphological changes in Echinococcus Protoscolexes

Morphological changes of Echinococcus Protoscolexes under the influence of OPS were studied using cytological and histological studies. Tissue and fluid samples were taken before and after OPS treatment and examined under a light microscope. Before OPS treatment, Protoscolexes had a normal structure with well-defined chitinous shells and cell membranes (Figure 1).

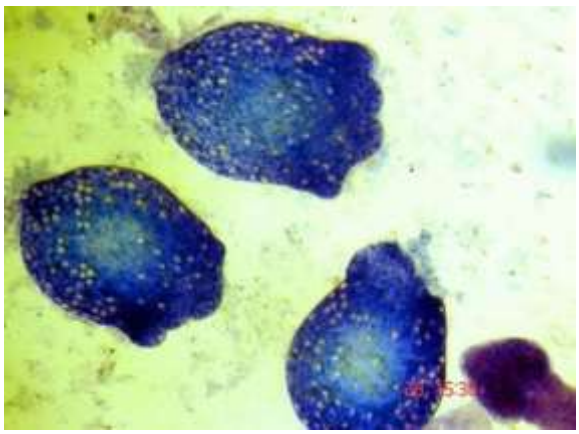

Figure 1. Microscopic picture of Echinococcus Protoscolexes before treatment with OPS. Azure eosin colouring. Magnification 10x7

Source: compiled by the authors.

Significant changes were observed after treatment with OPS for 5 minutes: the Protoscolexes swelled, their chitinous membranes and cell membranes were destroyed, and the internal contents of the cells leaked out (Figure 2).

Figure 2. Microscopic picture of Echinococcus Protoscolexes after treatment with OPS with an exposure of 5 minutes. Azure eosin colouring. Magnification 10x7

Source: compiled by the authors.

When the treatment time was increased to 10-15 min, the changes became more pronounced, leading to the destruction of cellular components and loss of the ability of Protoscolexes to replicate. The changes included swelling of the syncytial layer of the tegument, appearance of small depressions and perforations, loss of hooks, delamination and destruction of the germinative sheath of Protoscolexes, reduction in the number of calcareous cells, and deformation of the crown of hooks. Cells of the germinative sheath of Protoscolexes were vacuolised and lost connection with each other.

Condensation of membrane structures, granular and fibrillar elements, and destruction of cytoplasmic organoids were observed in their cytoplasm. After a longer treatment (10-15 min), the germinal elements of lacrocystis completely lost their cellular structure and turned into a heterogeneous gel containing separate accumulations of fine-grained dense material and fibrous structures resembling osmiophilic corpuscles formed because of condensation of material of calcareous corpuscles and fragments of delaminated cuticular shell of lacrocystis (Figure 3).

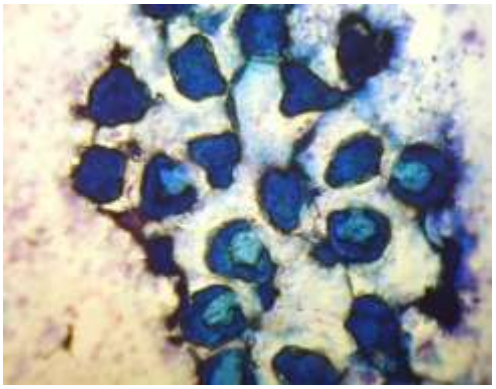

Figure 3. Microscopic picture of Echinococcus Protoscolexes after OPS processing with an exposure time of 10-15 minutes. Azure eosin colouring. Magnification 10x7

Source: compiled by the authors.

The recurrence rate was assessed within one year after surgery. Of the 34 patients included in the study, 30 (88.2%) had no recurrences within one year after surgery. In 4 patients (11.8%), recurrence was detected, which required additional treatment. It is important to note that all patients who had recurrences had multiple cysts or cysts with decomposition and suppuration, indicating a higher complexity of treatment for these forms of the disease.

3.4. Clinical outcomes and patient recovery

Clinical outcomes and patient recovery were assessed based on subjective and objective measures. Patients underwent regular check-ups and follow-up examinations, including CT and MRI scans, to assess brain health and identify recurrences. Subjective measures included assessment of patients' well-being, presence or absence of headaches, seizures, neurological symptoms and general activity level. Objective indicators included the results of neuroimaging studies, data on the presence or absence of inflammatory processes and general blood biochemical parameters. Of 34 patients, 28 (82.4%) reported significant improvement in well-being and absence of headaches and seizures 3 months after surgery. In 6 patients (17.6%), minor neurological symptoms such as mild headaches and episodic seizures persisted and required additional treatment and monitoring. At 6 months after surgery, 32 patients (94.1%) had improved, while 2 patients (5.9%) still had minor neurological symptoms.

Neuroimaging studies performed 3 and 6 months after surgery demonstrated no recurrence of cysts in 30 patients (88.2%). In 4 patients (11.8%), in whom recurrences were detected, additional therapeutic measures, including repeated operations and drug therapy, were required. Blood biochemical parameters and the presence of inflammatory processes were also important criteria for assessing the effectiveness of patient treatment. In most patients 1 month after the operation normalisation of blood biochemical indices was observed, which indicated the absence of inflammatory processes and successful surgical intervention. Elevated levels of inflammatory

markers were detected in 4 patients (11.8%), which required additional use of anti-inflammatory and antibacterial drugs.

3.5. Comparative analysis of patient groups

To evaluate the effectiveness of ozone therapy, a comparative analysis of patient groups was carried out depending on the type of cysts and the presence of complications among patients. Patients were divided into the following groups: unicompartmental cysts, multiple cysts, cysts with calcification and cysts with decomposition and suppuration. The results demonstrated that patients with unicompartmental cysts and cysts with calcification had a significantly lower rate of recurrence and complications compared to patients with multiple cysts alongside cysts with decomposition and suppuration.

In patients with single-chamber cysts (21 patients), no recurrences were recorded within a year after surgery, indicating the high efficacy of ozone therapy in this group. In patients with multiple cysts (8 patients) recurrences were detected in 2 patients (25%), indicating the need for more careful observation and application of additional methods of treatment. No recurrences were registered in patients with cysts with calcification (2 patients), which confirms the effectiveness of ozone therapy in this group. In patients with cysts with decomposition and suppuration (3 patients) recurrences were detected in 2 patients (66.7%), which indicates the complexity of treatment of these forms of the disease and the need to develop additional methods of therapy.

3.6. Assessment of side effects and complications

Side effects and complications associated with the use of ozone therapy were also assessed during the study. No significant side effects were observed in most patients, indicating the safety of this treatment method. Only 3 patients (8.8%) had mild side effects, such as temporary skin redness and slight burning in injections, which did not require additional treatment and resolved on independently within a few days.

Complications associated with surgical intervention and the use of ozone therapy were minimal. Postoperative infections developed in 2 patients (5.9%) and were successfully treated with antibiotic therapy. In 1 patient (2.9%), minor bleeding in surgical intervention was recorded, which was quickly stopped. Thus, the employment of ozone therapy in combination with surgical treatment of cerebral echinococcosis has demonstrated its safety and low complication rate.

3.7. The impact of ozone therapy on the quality of life of patients

Evaluation of the effect of ozone therapy on the patient's quality of life was one of the important aspects of the study. Before treatment, most patients reported poor quality of life due to frequent headaches, seizures, neurological symptoms and general deterioration of well-being. After surgery and ozone therapy, a significant improvement in the quality of life was recorded in 28 patients (82.4%).

Patients noted a decrease in the frequency and intensity of headaches, a reduction in seizures, and an improvement in general well-being and ability to perform everyday tasks. In 6 patients (17.6%) the improvements were less significant, but they also noted some positive changes in their condition. Thus, ozone therapy has shown its effectiveness not only in treating the disease but also in improving the quality of life of patients.

3.8. Long-term results and follow-up

To assess the long-term results of treatment and the possibility of disease recurrence, patients were monitored for one year after surgery. Regular follow-up examinations, including CT and MRI scans, as well as blood tests, allowed for the timely detection of complications and recurrences.

One year after the operation, 30 patients (88.2%) had no recurrences of the disease, which indicates the high efficiency of ozone therapy. Relapses were recorded in 4 patients (11.8%), which

required additional treatment measures. It is worth noting that all patients with relapses had multiple cysts or cysts with decomposition and suppuration, which indicates the need to develop additional treatments for these forms of the disease.

4. Discussion

The results of this study confirm the high efficacy of ozone therapy in the surgical treatment of cerebral echinococcosis. OPS demonstrated pronounced antimicrobial, antiviral and antifungal properties, which significantly reduced the risk of recurrence and improved overall clinical outcomes. One of the key points is that ozone therapy has shown high effectiveness in treating the residual cavity after the removal of parasitic cysts. Morphological changes of Echinococcus Protoscolexes under the influence of OPS observed in the study indicate that ozone has a devastating effect on parasites, leading to the destruction of cellular components. This is confirmed by a significant reduction in the frequency of disease recurrence in patients treated with ozone therapy.

Y. Yang et al. [8] demonstrated that the combination of UV irradiation and ozone therapy significantly enhances the phagocytic and bactericidal activity of macrophages against *Staphylococcus aureus*. Combined exposure to UV and ozone also promotes bone regeneration, highlighting the potential of ozone therapy in the treatment of infections and tissue regeneration. Moreover, J. Zeng et al. [9] demonstrated that topical ozone therapy significantly reduces SCORAD scores and inflammatory cell infiltration in affected skin areas in atopic dermatitis. Ozone treatment restores the microbiological diversity of the skin by reducing the proportion of *Staphylococcus aureus*, which contributes to the improvement of patients with atopic dermatitis. Furthermore, R. Shahanenko et al. [10] showed that ozonated saline solution completely prevents the growth of *Staphylococcus aureus*, *Enterococcus faecalis* and *Escherichia coli* in purulent wounds after a single application. Ozone therapy has demonstrated pronounced antimicrobial properties and can be used as an adjunctive or alternative therapy for bacterial infections. In addition, R. Bahramabadi et al. [11] found that ozone produced by corona discharge effectively inhibits the growth of *Klebsiella pneumoniae*, *Escherichia coli* and *Staphylococcus aureus*. This confirms the potential of ozone therapy as an effective antimicrobial agent against pathogenic bacteria. Lastly, A. Roth et al. [12] observed that a portable ozone therapy system shows effective bactericidal properties against *Pseudomonas aeruginosa* and *Staphylococcus epidermidis*. These data prove that ozone therapy can be a promising alternative for the treatment of infected wounds by stimulating localised tissue repair without adversely affecting human cells. Compared to conventional treatments, ozone therapy offers additional benefits in terms of reducing the risk of infectious complications and disease recurrence. Traditional methods, including surgical removal of cysts without additional treatment of the residual cavity, often lead to relapses due to the inability to completely remove all parasitic elements. The use of ozonated saline solution solves this problem by ensuring complete disinfection of the residual cavity and preventing further development of parasites.

S.-Y. Chan et al. [13] showed that the developed algorithm for selecting tactics of surgical treatment of hepatic echinococcosis, including an integrated approach to the choice of access, treatment method and residual cavity removal, as well as prophylactic chemotherapy, improved the quality of treatment. The recurrence rate decreased from 11.9% to 2.6%, demonstrating the high efficacy of the proposed method. In addition to this, M. Al-Saeedi et al. [14] conducted a systematic review and meta-analysis evaluating intraoperative and postoperative complications of endocystectomy for hepatic echinococcosis. The recurrence rate was 4.8% (95% CI: 3.1-6.8; $p<0.001$), confirming the high efficacy and low recurrence rate of this surgical treatment method. Subsequently, V. Shaprinskiy et al. [15] analysed the incidence of complications and recurrences after surgical treatment of hepatic echinococcosis. They found that no recurrences of the disease were observed after radical operations, whereas after palliative operations recurrences occurred in 2.63% of patients. The data show that ozone therapy is a safe treatment method with minimal side effects. Most patients had no significant side effects and only 3 patients (8.8%) had mild side effects such as

temporary skin redness and mild burning in the injection area, which did not require additional treatment and resolved independently within a few days. Complications associated with surgery and ozone therapy were minimal and were successfully managed with standard therapy.

L. Re et al. [16] have shown that ozone therapy is safe and effective when practised correctly. An analysis of various publications showed that most cases of adverse reactions were related to infections or injuries due to misuse rather than to ozone itself. Millions of patients treated with ozone therapy over the past 40 years demonstrate its safety and efficacy. In addition to this, A. U. Machado and R.V. Contri [17] conducted a systematic review of clinical trials to evaluate the efficacy and safety of ozone therapy for the treatment of dermatological diseases. They found that in most cases, ozone therapy showed a low probability of toxicity with proper dosage and methods of application. Mild side effects were observed in three clinical trials, while serious side effects were observed in only one study. Furthermore, S. Kaymaz et al. [18] evaluated the efficacy and safety of topical ozone therapy in patients with systemic sclerosis and resistant ulcers. They determined that ozone therapy significantly improved clinical parameters and functional activity without serious side effects. The success rate was significantly higher in the group receiving ozone therapy compared to the control group (92% vs 42%, p=0.01). Evaluation of the effect of ozone therapy on the quality of life of patients showed significant improvements. Most patients noted a reduction in the frequency and intensity of headaches, a decrease in seizures and an improvement in general well-being. This indicates that ozone therapy is not only effective in treating the disease itself but also helps to improve the quality of life of patients. B. Clavo et al. [19] demonstrated that the use of ozone therapy in patients with chemotherapy-induced chronic pain significantly improved quality of life. Ozone medical treatment reduced pain scores on a visual analogue scale (VAS) from 7 to 4 at the end of therapy and maintained the improvements up to 6 months after treatment. Furthermore, K. Szklener et al. [20] showed that ozone therapy improves the quality of life in patients with chemotherapy-induced peripheral neuropathy. Oxidative stress and inflammation were reduced by ozone therapy, which was confirmed by a significant reduction in pain levels and improvement in the patient's general well-being.

Long-term results of the study confirm the high efficacy of ozone therapy in preventing recurrences of the disease. One year after surgery, 88.2% of patients had no recurrences of the disease, which indicates a long-term positive effect of ozone therapy. Considering the complexity of the treatment of cerebral echinococcosis, especially in the case of multiple cysts and cysts with decomposition and suppuration, the results indicate the need for further research in this area to optimise treatment methods and improve clinical outcomes. M. Akhmadzoda et al. [21] demonstrated that the use of ultralow-temperature liquid nitrogen in the surgical treatment of combined liver and lung echinococcosis significantly reduced the incidence of postoperative complications and recurrences. In the main group of patients, the complication rate was 9.7%, with the only case requiring reoperation (1.38%), in contrast to the control group, where complications occurred in 24% of patients. In addition to this, M. Qin et al. [22] investigated the management of patients with echinococcosis treated with albendazole in three provinces of China. The study showed a low rate of re-examination and re-examination in patients, indicating the need to improve the management and follow-up of patients. Only 21.92% and 23.19% of patients were followed up and re-examined the theoretically required number of times. T. Karakök et al. [23] presented a case of a patient with disseminated echinococcosis who survived for five years after diagnosis. The patient with multiple echinococcal lesions in various organs, including the brain, lungs, and liver, received comprehensive treatment that achieved long-term survival and control of the disease.

The results of the study confirm the high efficacy of ozone therapy in the surgical treatment of cerebral echinococcosis. The ozonated saline solution showed strong antimicrobial properties, significantly reducing the risk of recurrence and improving clinical outcomes. Studies also demonstrated that ozone therapy promotes parasite destruction and is effective in treating residual cavities after cyst removal. The technique proved to be safe and improved the quality of life of

patients, reducing the incidence of complications and ensuring long-term recurrence-free survival in most patients.

5. Conclusions

The use of ozonated saline solution in the surgical treatment of cerebral echinococcosis has shown high efficiency. Ozone therapy contributed to a significant reduction in the frequency of recurrence of the disease, as evidenced by the absence of recurrence in 88.2% of patients within one year after surgery. Ozonated saline caused significant morphological changes in Echinococcus protoscoleus, leading to the destruction of cellular components and loss of the parasites' ability to replicate, which confirms the high antiparasitic activity of ozone therapy.

Ozone therapy offers additional advantages over conventional treatment methods, including reduced risk of infectious complications and recurrences. The use of ozonated saline solution to treat residual cavities provides complete disinfection and prevents further development of parasites. This method is safe, with minimal side effects. Mild side effects, such as temporary skin redness and slight burning in the injection area, did not require additional treatment and resolved independently within a few days. Complications associated with surgery were minimal and were successfully managed with standard therapy. Assessment of the quality of life of the patients showed significant improvements. The majority of patients noted a decrease in the frequency and intensity of headaches, a reduction in seizures and an improvement in general well-being. Ozone therapy contributes not only to the effective treatment of the disease but also to the improvement of the quality of life of patients. Long-term study results confirm the effectiveness of ozone therapy in preventing recurrences of the disease. The high recurrence-free rate in patients with single-chamber cysts and cysts with calcification indicates the possibility of wide application of ozone therapy in the treatment of these forms of echinococcosis.

Despite the positive results, further studies are needed to confirm the findings and optimise treatments. Future studies should include randomised controlled trials with larger numbers of participants to better assess the efficacy of ozone therapy. Ozone therapy offers new perspectives in the treatment of cerebral echinococcosis and other parasitic diseases. Ozonated saline solution can be used as an effective treatment for residual cavities after surgical removal of cysts, which can significantly reduce the risk of recurrence and improve clinical outcomes.

References

1. Aliev, M.Zh., Kalybekov, T.A., Niiazbekov, K.I. 2021. The prevalence of echinococcosis and the causes of its growth (literature review). *Science, New Technologies and Innovations in Kyrgyzstan*, 2, 32-37. http://science-journal.kg/media/Papers/nntiik/2021/2/%D0%9D%D0%9D%D0%A2-2_2021_32-37.pdf
2. Rahim, F., Toguzbaeva, K., Dzhusupov, K.O. 2024. The impact of human cystic echinococcosis in the Central Asian region, 1990-2019. *Turkish Journal of Parasitology*, 48(2), 89-95. https://doi.org/10.4274/tpd.galenos.2024.64326
3. Kuehn, R., Uchiumi, L.J., Tamarozzi, F. 2024. Treatment of uncomplicated hepatic cystic echinococcosis (hydatid disease). *Cochrane Database of Systematic Reviews*, 7, CD015573. https://doi.org/10.1002/14651858.CD015573
4. Kasyev, N.B., Bashirov, R.M., Ajtnazarov, M.S., Niyazov, B.S., Emilbekov, U.E. 2023. Epidemiological aspects of echinococcosis in the Kyrgyz Republic. *Euroasian Health Journal*, 3(1), 73-80. https://doi.org/10.54890/1694-6405_2023_1_73
5. Nuruev, M., Sakibaev, K., Dzholdosheva, G., Maksimova, K., Kanymgul, A.K. 2023. Features of circumference sizes in women of different constitutional groups. *Clinical Physiology and Functional Imaging*, 43(1), 40-46. https://doi.org/10.1111/cpf.12791
6. Zhanybek kyzy, K., Sakibaev, K., Sattarov, A., Dzholdosheva, G., & Zholdosheva, E. 2023. Absolute content of bone component in the body of Kyrgyz children with different somatotypes

in the early childhood. *Child`S Health*, 18(7), 506–512. https://doi.org/10.22141/2224-0551.18.7.2023.1643

7. Toktogaziev, B.T., Omorov, K.R., Hamidjonov, Y.H., Miklukhin, D.S. 2022. Laparoscopic method of treatment of combined liver and greater oil echinococcosis. Clinical case. *Health Care of Kyrgyzstan Scientific and Practical Journal*, 1, 72-76. https://www.zdrav.kg/images/72-76.pdf
8. Yang, Y., Zhang, H., Komasa, S., Morimoto, Y., Sekino, T., Kawazoe, T., Okazaki, J. 2021. UV/ozone irradiation manipulates immune response for antibacterial activity and bone regeneration on titanium. *Materials Science & Engineering: C*, 129, 112377. https://doi.org/10.1016/j.msec.2021.112377
9. Zeng, J., Dou, J., Gao, L., Xiang, Y., Huang, J., Ding, S., Chen, J., Zeng, Q., Luo, Z., Tan, W., Lu, J. 2020. Topical ozone therapy restores microbiome diversity in atopic dermatitis. *International Immunopharmacology*, 80, 106191. https://doi.org/10.1016/j.intimp.2020.106191
10. Shahanenko, R., Ilnitskiy, M., Shahanenko, V., Rublenko, S. 2020. Ozonetherapy as a new antimicrobic strategy, 2, 195-200. https://doi.org/10.33245/2310-4902-2020-160-2-195-200
11. Bahramabadi, R., Yazdian, P., Hakimi, H. 2020. Antibacterial effects of ozone generated in corona air plasma. *Progress in Biological Sciences*. https://doi.org/10.22059/PBS.2020.275930.1330
12. Roth, A., Elkashif, A., Selvamani, V., Stucky, R.A., Seleem, M.N., Ziaie, B., Rahimi, R. 2020. Wearable and flexible ozone generating system for treatment of infected dermal wounds. *Frontiers in Bioengineering and Biotechnology*, 8, 458. https://doi.org/10.3389/fbioe.2020.00458
13. Chan, S.-Y., Chang, Y., Polpichai, N., Lee, Y.-T., Ma, K.S.-K. 2024. Treatment with antihistamines and the risk of liver cancer in patients with viral hepatitis: A multi-center cohort study. *Viruses*, 16(6), 940. https://doi.org/10.3390/v16060940
14. Al-Saeedi, M., Ramouz, A., Khajeh, E., El Rafidi, A., Ghamarnejad, O., Shafiei, S., Ali-Hasan-Al-Saegh, S., Probst, P., Stojković, M., Weber, T.F., Hoffmann, K., Mehrabi, A. 2021. Endocystectomy as a conservative surgical treatment for hepatic cystic echinococcosis: A systematic review with single-arm meta-analysis. *PLoS Neglected Tropical Diseases*, 15(5), e0009365. https://doi.org/10.1371/journal.pntd.0009365
15. Shaprinskiy, V., Verba, A., Formanchuk, T., Formanchuk, A., Chernychenko, O. 2022. Surgical treatment of echinococcosis of the liver and its complications. *Medical News*, 75(1(2)), 244-250. https://doi.org/10.36740/wlek202201217
16. Re, L., Noci, J.B., Serra, M.E.G., Mollica, P., Bonetti, M., Travagli, V. 2020. Safety, pitfalls, and misunderstandings about the use of ozone therapy as a regenerative medicine tool. A narrative article. *Journal of Biological Regulators and Homeostatic Agents*, 34(4(S1)), 1-13. https://www.biolifesas.org/EN/Y2020/V34/I4(S1)/
17. Machado, A.U., Contri, R.V. 2022. Effectiveness and safety of ozone therapy for dermatological disorders: A literature review of clinical trials. *Indian Journal of Dermatology*, 67(4), 479. https://doi.org/10.4103/ijd.ijd_152_22
18. Kaymaz, S., Karasu, U., Alkan, H., Ulutaş, F., Yaşar, C.A., Ök, Z.D., Çobankara, V., Yiğit, M., Yıldız, N., Ardıç, F. 2022. Efficacy of local oxygen-ozone therapy for the treatment of digital ulcers refractory to medical therapy in systemic sclerosis: A randomized controlled study. *Modern Rheumatology*, 32(6), 1102-1107. https://doi.org/10.1093/mr/roab117
19. Clavo, B., Rodríguez-Abreu, D., Galván, S., Federico, M., Martínez-Sánchez, G., Ramallo-Fariña, Y., Antonelli, C., Benítez, G., Rey-Baltar, D., Jorge, I.J., Rodríguez-Esparragón, F., Serrano-Aguilar, P. 2022. Long-term improvement by ozone treatment in chronic pain secondary to chemotherapy-induced peripheral neuropathy: A preliminary report. *Frontiers in Physiology*, 13, 935269. https://doi.org/10.3389/fphys.2022.935269

20. Szklener, K., Rudzińska, A., Juchaniuk, P., Kabała, Z., Mańdziuk, S. 2023. Ozone in chemotherapy-induced peripheral neuropathy – Current state of art, possibilities, and perspectives. *International Journal of Molecular Sciences*, 24(6), 5279. https://doi.org/10.3390/ijms24065279
21. Akhmadzoda, M., Khomidov, A.T., Rashidov, F.S., Boboev, H.O., Safarov, B.D. 2023. Surgical treatment of combined echinococcosis of the liver and lungs. *Health care of Tajikistan*, 2, 29-37. https://doi.org/10.52888/0514-2515-2023-357-2-29-37
22. Qin, M., Wang, L., Wang, Y., Wang, X., Lei, J., Cheng, X., Feng, Y., Hou, Y., Wang, Q., Xue, C., Gavotte, L., Frutos, R. 2023. Investigation on the management for patients with echinococcosis treated with albendazole – Three PLADs, China, 2019. *China CDC Weekly*, 5(20), 437-441. https://doi.org/10.46234/ccdcw2023.083
23. Karakök, T., Ata, N., Kılıç, E.K., Kınıklı, S. 2023. A disseminated echinococcosis patient with five years survival from turkey: A case report. *Iranian Journal of Parasitology*, 18(2), 262-267. https://doi.org/10.18502/ijpa.v18i2.13194