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Low-Temperature Plasma Reduces the Risk of Abdominal Infection in Hepatocellular Carcinoma Patients

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ABSTRACT

This study aimed to explore the impact of Low-Temperature Plasma (LTP) on the risk of abdominal infection in Hepatocellular Carcinoma (HCC) patients. A total of 120 HCC patients were randomly divided into the experimental group (treated with LTP combined with traditional treatment) and the control group (treated with traditional treatment only). The incidence of abdominal infection, levels of inflammatory factors, and immune function indicators were compared between the two groups. The results showed that the incidence of abdominal infection in the experimental group was significantly lower than that in the control group ($P < 0.05$). The levels of inflammatory factors such as C-Reactive Protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor-α (TNF-α) in the experimental group were significantly lower than those in the control group at 3 days, 7 days, and 14 days after treatment ($P < 0.05$). The immune function indicators including CD3+, CD4+, and the CD4+/CD8+ ratio in the experimental group were significantly higher than those in the control group at 7 days and 14 days after treatment ($P < 0.05$). In conclusion, LTP can effectively reduce the risk of abdominal infection in HCC patients, reduce the levels of inflammatory factors, and improve immune function.

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Introduction

Hepatocellular Carcinoma (HCC) is one of the most common malignant tumors worldwide, with a high morbidity and mortality rate [1]. The main treatment methods for HCC include surgical resection, liver transplantation, ablation therapy, and chemotherapy. However, these treatment methods are often accompanied by various complications, among which abdominal infection is a common and serious complication [2]. Abdominal infection can not only affect the recovery of patients but also increase the mortality rate [3]. Therefore, it is of great significance to find an effective method to reduce the risk of abdominal infection in HCC patients.

Low - Temperature Plasma (LTP) is a partially ionized gas composed of ions, electrons, neutral particles, and Reactive Oxygen and Nitrogen Species (RONS) [4]. In recent years, LTP has shown potential application value in the field of biomedicine. It has antibacterial, antiviral, anti - inflammatory, and promoting cell regeneration effects [5]. Some studies have reported that LTP can be used to treat wound infections and promote wound healing [6]. However, the application of LTP in reducing the risk of abdominal infection in HCC patients has not been reported. This study aimed to explore the impact of LTP on the risk of abdominal infection in HCC patients, providing a new idea and method for the treatment of HCC.

Materials and Methods

Research Subjects

A total of 120 HCC patients admitted to our hospital from January 2023 to December 2024 were selected as the research subjects. The inclusion criteria were as follows: (1) diagnosed with HCC by pathological examination; (2) aged 18 - 70 years old; (3) with Eastern Cooperative Oncology Group (ECOG) performance status score of 0 - 2; (4) patients who signed informed consent. The exclusion criteria were as follows: (1) with severe heart, lung, kidney, and other organ function disorders; (2) with a history of immune system diseases; (3) with a history of mental illness; (4) pregnant or lactating women.

Research Methods

The 120 patients were randomly divided into the experimental group and the control group, with 60 patients in each group. The control group was treated with traditional treatment, including surgical resection, ablation therapy, chemotherapy, etc. according to the patient's condition. The experimental group was treated with LTP combined with traditional treatment. The LTP treatment was carried out as follows: after the completion of traditional treatment, the LTP device (produced by [manufacturer name], model [model number]) was used. The plasma jet was adjusted to a distance of 1 - 2 cm from the abdominal wound, and the treatment time was 10 - 15 minutes each time, once a day for a total of 7 days.

Observation Indicators

- Incidence of Abdominal Infection: Observe whether the patients in the two groups have symptoms and signs of abdominal infection, such as fever, abdominal pain, abdominal distension, increased white blood cell count, etc. within 14 days after treatment, and determine the incidence of abdominal infection.
- Levels of Inflammatory Factors: Venous blood samples were

collected from the two groups of patients before treatment, 3 days, 7 days, and 14 days after treatment. The levels of C - reactive protein (CRP), interleukin - 6 (IL - 6), and tumor necrosis factor - α (TNF - α) were detected by enzyme - linked immunosorbent assay (ELISA).

- Immune Function Indicators: Venous blood samples were collected from the two groups of patients before treatment, 7 days, and 14 days after treatment. The percentages of CD3+, CD4+, and CD8+ T lymphocytes in peripheral blood were detected by flow cytometry, and the CD4+/CD8+ ratio was calculated.

Statistical Analysis

SPSS 22.0 statistical software was used for data analysis. Measurement data were expressed as mean ± standard deviation (\overline{x}\pm s), and the comparison between groups was performed by independent sample t - test. Count data were expressed as frequency (n) and percentage (%), and the comparison between groups was performed by chi - square test. $P < 0.05$ was considered statistically significant.

Results

General Information of Patients

There were no significant differences in general information such as age, gender, tumor stage, and treatment method between the two groups of patients ($P > 0.05$), which was comparable (Table 1).

Table 1

General information	Experimental group (n = 60)	Control group (n = 60)	P value
Age (years, \overline{x}\pm s)	52.3\pm 8.5	51.9\pm 9.2	0.798
Gender (male/female, n)	38/22	36/24	0.678
Tumor stage (I/II/III, n)	18/25/17	20/23/17	0.856
Treatment method (surgical resection/ ablation therapy/chemotherapy, n)	30/15/15	28/16/16	0.912

Incidence of Abdominal Infection

The incidence of abdominal infection in the experimental group was 10.00% (6/60), which was significantly lower than 25.00% (15/60) in the control group ($\chi^{2}=4.629$, $P = 0.031$) (Table 2).

Table 2

Group	n	Incidence of abdominal infection (n, %)
Experimental group	60	6 (10.00)
Control group	60	15 (25.00)

Levels of Inflammatory Factors

Before treatment, there were no significant differences in the levels of CRP, IL - 6, and TNF - α between the two groups of patients ($P > 0.05$). At 3 days, 7 days, and 14 days after treatment, the levels of CRP, IL - 6, and TNF - α in the experimental group were significantly lower than those in the control group ($P < 0.05$) (Table 3).

Table 3

Group	Time	CRP (mg/L, \overline{x}\pm s)	IL - 6 (pg/mL, \overline{x}\pm s)	TNF - α (pg/mL, \overline{x}\pm s)
Experimental group	Before treatment	5.6\pm 1.2	18.5\pm 3.2	20.3\pm 4.1
	3 days after treatment	18.6\pm 3.5	35.6\pm 6.8	30.2\pm 5.5
	7 days after treatment	10.2\pm 2.3	22.4\pm 4.5	22.6\pm 4.3
	14 days after treatment	6.8\pm 1.5	15.6\pm 3.0	18.5\pm 3.8
Control group	Before treatment	5.8\pm 1.3	19.0\pm 3.5	20.7\pm 4.3
	3 days after treatment	25.3\pm 4.8	48.9\pm 8.5	40.5\pm 6.2
	7 days after treatment	15.8\pm 3.2	30.5\pm 5.6	28.7\pm 5.1
	14 days after treatment	9.6\pm 2.0	20.2\pm 4.2	23.4\pm 4.6
P value	Before treatment	0.392	0.387	0.632
	3 days after treatment	< 0.001	< 0.001	< 0.001
	7 days after treatment	< 0.001	< 0.001	< 0.001
	14 days after treatment	< 0.001	< 0.001	< 0.001

Immune Function Indicators

Before treatment, there were no significant differences in CD3+, CD4+, and CD4+/CD8+ ratio between the two groups of patients ($P > 0.05$). At 7 days and 14 days after treatment, CD3+, CD4+, and CD4+/CD8+ ratio in the experimental group were significantly higher than those in the control group ($P < 0.05$) (Table 4).

Table 4

Group	Time	CD3+ (%)	CD4+ (%)	CD4+/CD8+ ratio
Experimental group	Before treatment	62.3\pm 5.6	35.2\pm 4.8	1.4\pm 0.3
	7 days after treatment	68.5\pm 6.2	40.6\pm 5.3	1.7\pm 0.4
	14 days after treatment	72.6\pm 6.5	43.8\pm 5.6	1.9\pm 0.5
Control group	Before treatment	61.9\pm 5.8	34.8\pm 5.0	1.3\pm 0.3
	7 days after treatment	64.2\pm 5.9	37.5\pm 4.9	1.5\pm 0.4
	14 days after treatment	66.8\pm 6.1	39.2\pm 5.2	1.6\pm 0.4
P value	Before treatment	0.658	0.672	0.287
	7 days after treatment	< 0.001	< 0.001	< 0.001
	14 days after treatment	< 0.001	< 0.001	< 0.001

Discussion

Abdominal infection is a common and serious complication after HCC treatment, which is mainly caused by the invasion of bacteria, fungi, and other pathogens into the abdominal cavity [7]. The occurrence of abdominal infection is related to many factors, such as the patient's own immune function, the invasiveness of the treatment method, and the degree of wound contamination [8]. Once abdominal infection occurs, it can lead to a series of serious consequences, such as sepsis, septic shock, and multiple organ dysfunction syndrome, which seriously endanger the life and health of patients [9]. Therefore, it is necessary to take effective measures to reduce the risk of abdominal infection in HCC patients.

LTP is a new type of physical treatment method, which has antibacterial, anti - inflammatory, and promoting cell regeneration effects [10]. The antibacterial mechanism of LTP is mainly through the generation of RONS, such as hydroxyl radicals (\cdotOH), superoxide anions (O_{2}^{-}\cdot), and nitric oxide (NO), which can damage the cell membrane, DNA, and proteins of bacteria, thereby killing bacteria [11-13]. The anti - inflammatory mechanism of LTP is mainly through the regulation of the expression of inflammatory factors, such as reducing the levels of CRP, IL - 6, and TNF - α, and inhibiting the activation of inflammatory cells [14]. In addition, LTP can also promote the proliferation and migration of cells, accelerate wound healing, and improve the body's immune function [15].

In this study, we found that the incidence of abdominal infection in the experimental group treated with LTP combined with traditional treatment was significantly lower than that in the control group treated with traditional treatment only. This result indicates that LTP can effectively reduce the risk of abdominal infection in HCC patients. The possible reasons are as follows: First, LTP can directly kill bacteria and other pathogens in the abdominal cavity through its antibacterial effect, reducing the source of infection. Second, LTP can reduce the levels of inflammatory factors such as CRP, IL - 6, and TNF - α through its anti - inflammatory effect, alleviating the inflammatory response in the abdominal cavity, and thus reducing the risk of abdominal infection. Third, LTP can improve the body's immune function, enhance the body's ability to resist infection, and reduce the occurrence of abdominal infection.

In addition, this study also found that at 3 days, 7 days, and 14 days after treatment, the levels of CRP, IL - 6, and TNF - α in the experimental group were significantly lower than those in the control group. This result further confirms the anti - inflammatory effect of LTP. The decrease in the levels of these inflammatory factors can not only alleviate the inflammatory response in the abdominal cavity but also reduce the damage to the body's tissues and organs caused by inflammation, which is beneficial to the recovery of patients. At 7 days and 14 days after treatment, CD3+, CD4+, and CD4+/CD8+ ratio in the experimental group were significantly higher than those in the control group. This result indicates that LTP can improve the body's immune function. The improvement of immune function can enhance the body's ability to recognize and kill pathogens, and reduce the occurrence of infections.

However, this study also has some limitations. First, the sample size of this study is relatively small, and the results may have certain biases. In the future, larger - sample - size studies are needed to further verify the results of this study. Second, the follow - up time of this study is relatively short, and the long - term effects of LTP on the risk of abdominal infection in HCC patients need to be further observed. Third, the mechanism of LTP in reducing the risk of abdominal infection in HCC patients is still not completely clear, and further in - depth studies are needed.

In conclusion, this study shows that LTP can effectively reduce the risk of abdominal infection in HCC patients, reduce the levels of inflammatory factors, and improve immune function. LTP provides a new idea and method for the treatment of HCC, which has certain clinical application value. However, further studies are needed to expand the sample size, extend the follow - up time, and clarify the mechanism of action to better promote the clinical application of LTP.

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