Conference Paper

Fiber Optic Devices for Endobiliary Photodynamic Therapy

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Abstract

The aim of the study is to optimize the irradiation procedure during endobiliary photodynamic therapy for patients with cholangiocarcinoma. The studies were performed using fiber-optic light delivery tools in various configurations and using different irradiation power levels. Control of photosensitizer accumulation at the site of therapy was also applied. It is shown that the use of fiber-optic light delivery tools with cylindrical diffusers provides more effective and less painful photodynamic therapy. It is shown that after the injection of the photosensitizer, there is an optimal time for the therapy, when the maximum difference in the accumulation of the photosensitizer in the tumor is observed in comparison with the intact tissue.

Keywords: endobiliary photodynamic therapy, fluorescent diagnostics, fiber-optic light delivery tools, cholangiocarcinoma

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1. Introduction

Cholangiocarcinoma develops when malignant (cancerous) tumors appear in one of the ducts that transport bile from the liver to the duodenum. Cancer can occur in any part of the bile duct. Based on the location of the tumor, the cancer of the bile ducts can be intrahepatic when it is located inside the liver, or extrahepatic, when it occurs in the bile ducts that are located outside the liver. Despite the fact that bile duct cancer is a rare form of cancer and occurs mainly in people over 50, it is an aggressive form of cancer that progresses quickly and is difficult to treat.

One of the methods of treatment of cholangiocarcinoma is photodynamic therapy (PDT) [1–3]. The patient is injected with a photosensitizer, which accumulates in the tumor tissue. The photosensitizer itself is non-toxic, but when it is exposed to light of a certain wavelength, the photosensitizer, due to a photochemical reaction, allows the adjacent tissues to be destroyed. PDT is a promising new approach to inoperable bile duct cancer, in particular for palliative treatment.

For successful therapy, it is necessary to determine the level of the photosensitizer accumulation in the place where the therapy is planned. PDT will be effective only when the level of accumulation of the photosensitizer is sufficient [4].

Fiber-optic systems are usually used to deliver light to a patient and to collect a response signal [5, 6].

Currently, there are difficulties in treating bile ducts with percutaneous endobiliary PDT using ordinary fiber-optic light delivery tools that emit light ahead (in the axial direction).

2. Materials and Methods

Hilar cholangiocarcinoma has a small thickness, but is usually extended to a considerable length along the bile duct. In order to provide the radiation dose required for photodynamic therapy using ordinary fiber-optic light delivery tools, we can:

1. increase the radiation power; however, due to the increase in irradiation power, the patient experiences severe pain, which prevents the further implementation of therapy and
2. increase the time of therapy, but this is often impossible due to the limitation of the duration of the procedure (~1 hour).

Both of these approaches are not optimal.

Based on this, we propose using fiber-optic tools with radial diffusers for this type of therapy. And to optimize therapy for both the optical power of the laser source used and the time of the procedure, it is necessary to use fiber-optic tools with different diffuser lengths, depending on the length of neoplasm along the bile duct.

A set of fiber optic tools with cylindrical diffusers with different lengths was made. The set was made using 500 μm polymer optical fibers with SMA-905 connectors, which are commonly used for photodynamic therapy. The length of the cylindrical diffusers was 6, 5, 4, and 3 cm. This length range is optimal for different cholangiocarcinoma variants. Measurements showed that light distribution over the entire length of diffuser was uniform. The output power densities of fiber optic tools were 30, 50, 70 and 100 mW/cm^2, respectively. Fiber optic tool sample is shown in Figure 1, in the center.

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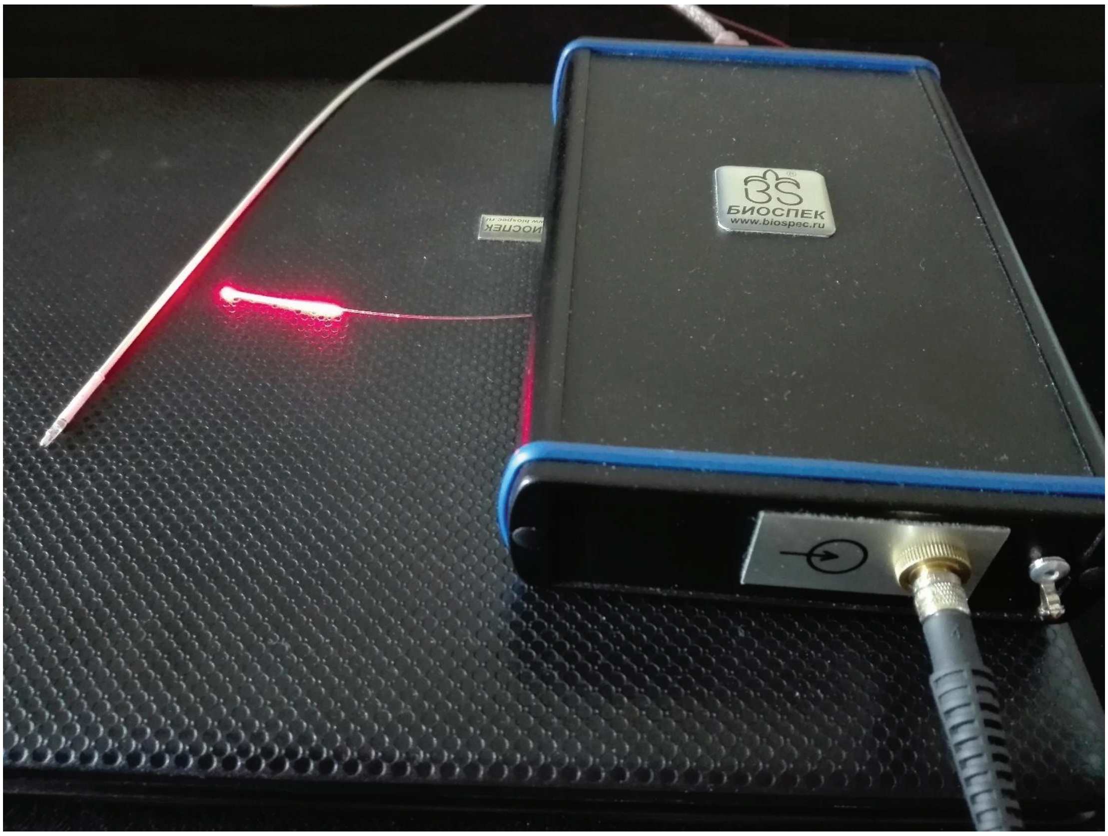

Figure 1: Modified diagnostic fiber-optic probe (left), PDT fiber optic tool sample (center) and spectral analyzer, a part of the LESA-01-BIOSPEC (right).

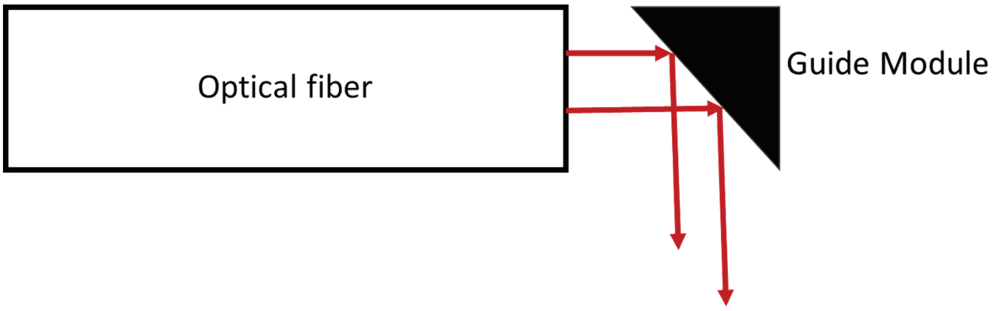

Figure 2: Modified diagnostic fiber-optic probe. The scheme of work.

Chlorin e6 derivative photosensitizers were used in the study. To control the accumulation of the photosensitizer, the laser electronic spectrum analyzer LESA-01-BIOSPEC (Moscow, Russia) was used. This device is widely used for PDT control purpose [7, 8], but in this study the diagnostic fiber-optic probe was equipped with an additional reflector to better estimate the accumulation of the photosensitizer in the walls of the bile ducts. The scheme of work is shown in Figure 2. Modified diagnostic fiber-optic probe is shown in Figure 1, on the left. Spectral analyzer, a part of the LESA-01-BIOSPEC, is shown in Figure 1, on the right.

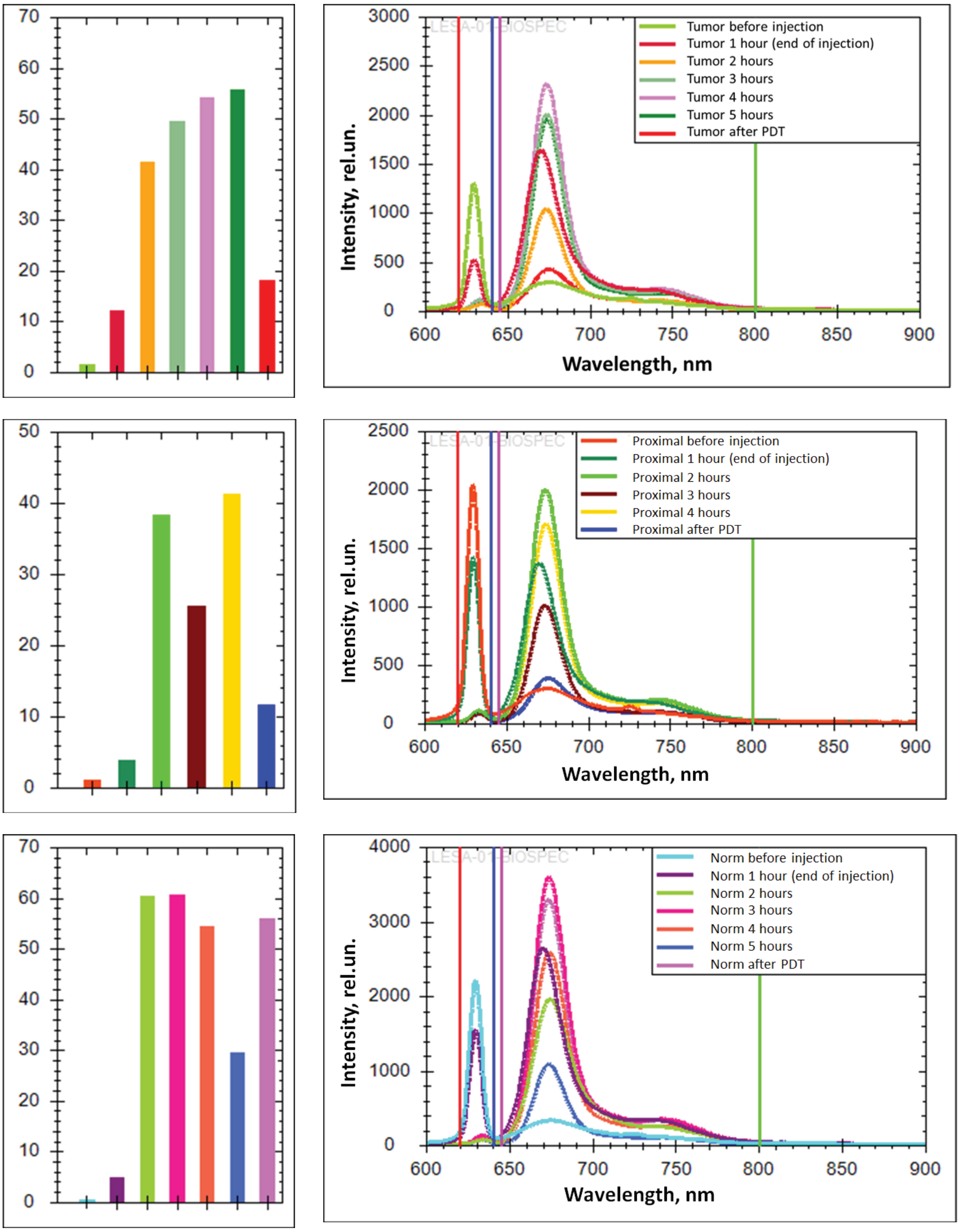

Figure 3: Fluorescent Index graphs and spectral data.

3. Results

Spectral data were collected during fluorescent diagnostics. Spectral data represent the dependence of fluorescence intensity and intensity of backscattering laser light as a function of wavelength. To obtain the comparative data, which is called the fluorescence index, it is necessary to divide the area of region under the fluorescence curve into the area of region under the backscattering laser light curve. The Fluorescence Index is usually measured for tumor, proximal and normal parts of the organ. These data show the level of contrast and activation of the photosensitizer in these areas.

Measurements of the accumulation of the photosensitizer at 1, 2, 3, 4 and 5 hours after injection were made. Spectral data and the Fluorescence Index are shown in Figure 3. The fluorescence index shows that after 5 hours after injection, the maximum contrast in accumulation between the tumor and the intact tissue is observed.

4. Conclusions

It is shown that the use of fiber-optic light delivery tools with cylindrical diffusers provides more effective and less painful photodynamic therapy. It is shown that after the injection of the photosensitizer, there is an optimal time for the therapy, when the maximum difference in the accumulation of the photosensitizer in the tumor is observed in comparison with the intact tissue.

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