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Dosimetric Planning of Interstitial Brachytherapy for Head and Neck Tumor

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Abstract

Dosimetric calculations of radiation pin sources ^{252}Cf were carried out; in order to evaluate the effect of treatment the final data was analyzed. As a result of the study calculated values of the duration of exposure and absorbed dose were analyzed; the correspondence between the presence of radiation reactions, and causes their manifestations and sources layout were observed; selected sources layouts with a definite diagnosis was compared, under which they were applied.

Keywords: brachytherapy, tumors of the head and neck, radiation planning

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1. INTRODUCTION

Malignant tumors of the oral cavity represent one of the most complicated medical and social problems in modern oncology and belong to the group of socially significant diseases, being one of the causes of disability and death of the population. In a comparative evaluation of different methods of radiotherapy of malignant neoplasms, the method of contact radiation therapy becomes especially important. In the treatment of patients with oropharyngeal tumors, the technique of interstitial neutron therapy by californium-252 sources deserves special attention [1-2].

Treatment of squamous cell carcinoma of the oral cavity and oropharyngeal area is a laborious and it is not a completely solved problem of modern oncology. Anatomical and functional features of these areas, the propensity of malignant neoplasms of this localization to rapid infiltrative growth, early metastasis to the lymph nodes of the neck cause a severe course of the disease and create significant difficulties in treatment [2-3]. According to statistics for years 2015-2016:

- 6th place in the world among malignant neoplasms [4]

- Annually in the whole world 275 thousand new cases of squamous cell carcinoma of the oral mucosa are registered [4]
- Tumors of the oral cavity in 62% of cases are diagnosed in later stages (III-IV) [5]

2. MATERIALS AND METHODS

Preparations of ^{252}Cf are sources of fast neutrons with an average energy of 2.35 MeV and gamma radiation with an average energy of about 1 MeV. The half-life of the ^{252}Cf radionuclide is 2.63 years. The ^{252}Cf radioactive pin sources consist of two parts: a hollow capsule-intrastate and a radioactive source. Capsules of medical sources are made of corrosion-resistant stainless steel or platinum and its alloys. The use of capsules made of platinum provides a sufficiently reliable filtration of ^{252}Cf radiation from β- and γ-radiation co-occurring to neutron radiation. Intrastat is needle-shaped. One end is pointed for easy insertion into the tissue, the other has a hole in the end for insertion into the radioactive source. The hole is somewhat flared and looks like a tiny funnel. At the level of the narrow part of the funnel, a wire loop is soldered to the needle, which is used to fix the intrastate to the skin or mucous membrane and simultaneously prevents the capsule from sinking into the tissue. The external diameter of the needle-intrastate is 1.8 mm, the diameter of the canal is 1.4 mm. The ^{252}Cf kit contains sources with active lengths of 10, 20 and 30 mm [6-7].

The biological effect of ^{252}Cf radiation is largely determined by the dense ionizing component (neutrons with an average energy of 2.3 MeV), which at a physical dose is more than 60%. Since the RBE of neutrons of this energy is in the range of 2-5 for various reactions, then at irradiation with sources of ^{252}Cf not less than 80% of the observed effect is due to the action of the dense ionizing component [8].

Planning interstitial radiation therapy is carried out during pre-radial preparation and involves the solution of several problems. The first is to determine the size of the tumor and choose the target volume. Due to the fact that the clinical forms of the tumor are extremely diverse, it is necessary to use all possible diagnostic methods to obtain the necessary information on the topography of the tumor, its size, its relationship with the adjacent tissues and organs. Currently used methods for assessing the boundaries of the tumor process are very relative, so it is reasonable to include in the target volume, the tissue adjacent to the tumor at a distance of at least 0.5 cm from its detectable boundaries. The next task of planning interstitial radiation therapy is to choose a scheme for placing needle-intrastates with radioactive sources, which ensures the formation of the optimal dose field, taking into account the specific irradiated volume [9].

Sources are located in the Paris system: radioactive preparations are distributed in one plane, or in two parallel planes. The sources of neighboring planes are opposite one another or displaced by half the distance between them.

Sources should have the same linear density, be in tissues parallel to each other and at equal distances (8-15 mm), which, depending on the active length of the sources, can not be less than 0.5 and greater than 2 cm. In the distribution of sources according to the Paris system, a homogeneous dose field is created, which makes possible to apply these principles when using neutron and gamma ^{252}Cf radiation. The irradiated volumes in their section have the form of a square, a rectangle or an ellipse [9-11].

3. RESULTS

With the method of interstitial therapy using californium-252 sources in the A. Tsyb Medical Radiological Research Center (Obninsk), 97 patients were treated. Between 2006 and 2013, 175 plans were set. According to the frequency of the schemes, clinical cases were distributed as follows: the ellipse scheme was applied 70 times, 1 square was used 10 times, 2 squares - 15 times, 3 squares - 2 times.

We selected 20 cases out of the total number. In 9 cases out of 20 sources were arranged according to the ellipse scheme, in 5 cases - according to the scheme of 1 square, in 1 case - according to the scheme of 3 squares, in 5 cases - according to the scheme of 2 squares.

4. DISCUSSION

4.1. Analysis of the irradiation duration

Its value may depend on the set of some parameters, such as: the dose of neutrons set by the doctor, the size of the tumor, the layout of the sources, the number of sources, i.e. the mass of each source, the reference dose rate, the activity of the sources.

As a result of the analysis, it was concluded that the parameter greatly determining the duration of irradiation is the prescribed dose of neutrons. This dependence has a directly proportional character, i.e. the larger the dose assigned by the doctor, the

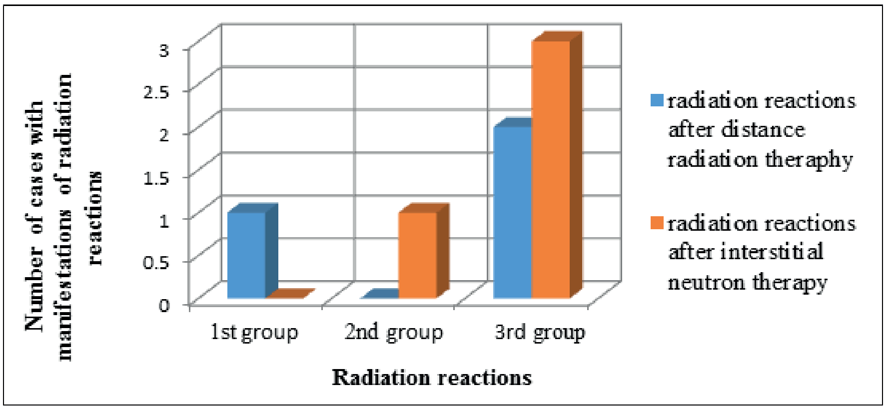

Figure 1: The number of radiation reactions in a certain group of patients.

greater the duration of irradiation. As for the other parameters included in the formula for determining this value, they affect the value of the irradiation duration indirectly. The choice of the scheme depends mainly on the size of the tumor. Based on this, the size of the scheme is determined and, thereby, the number of sources. The reference absorbed dose also depends on the scheme and the distance between the sources.

As a result of the *dose rate analysis at the tumor boundary*, it was revealed that the dependence of this value on the duration of irradiation is inversely proportional, i.e, the longer the irradiation time, the smaller the value of the absorbed dose of neutrons. The type of the dependence of the dose rate on the tumor boundary on the mass of the sources, as well as the dose of neutrons at the reference point, is directly proportional, which follows from the formula determining this value.

4.2. Setting correspondence between the presence of radiation reactions, and the causes of their manifestation and the layout of the sources

Radiation reactions were manifested in 7 cases out of 20 examined (35% of cases), either after preoperative treatment, or after interstitial neutron therapy. And in these 7 cases included patients belonging to three separate groups, united by the principle of combining several treatment methods: 1 group (interstitial therapy in an independent manner), 2 group (distance electronic therapy + interstitial therapy), 3 group (distance gamma therapy + interstitial therapy). Mainly, they occurred in the form of mucositis of I-III degree, edema and hyperemia in the brachytherapy area. This is clearly can be seen in Figure 1.

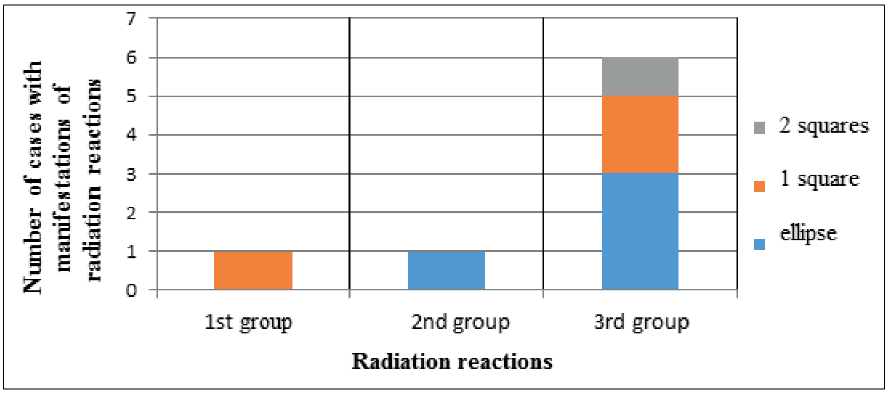

Figure 2: The presence of radiation reactions, manifested after remote radiation therapy or interstitial neutron therapy, depending on the chosen arrangement of sources.

It was found that radiation reactions occurred both after preoperative remote radiation therapy (42.86%) and after interstitial neutron therapy (57.14%). However, radiation reactions after brachytherapy were recorded more often than after the preoperative course of therapy.

During the analysis of clinical data, it was found that the majority of radiation reactions occurred when using the ellipse source arrangement (57.14%), which can be found in Figure 2.

On the basis of the data obtained, it can be assumed that the causes of the manifestation of radiation reactions are associated with several factors:

The presence of radiation reactions depends on the individual sensitivity of the person. Radiation reactions of mucous membranes progresses during irradiation of hollow organs (larynx, oral cavity, esophagus, intestine, bladder, etc.). The radiosensitivity of the mucous membranes depends on the histological structure, which is different even within the same cavity organ [12]. Hence it can be concluded that the choice of the sources arrangement is made based on the anatomical location of the tumor and its morphological structure.

The manifestation of radiation reactions is associated with the type of the interstitial therapy procedure. This method of treatment has some damaging character due to the fact that intrastates are injected directly into the tissue.

The cause of development of radiation reactions can also be overirradiation, which can be associated with a human factor (for example, the irradiation error when laying the patient or injecting endostats into the tissue).

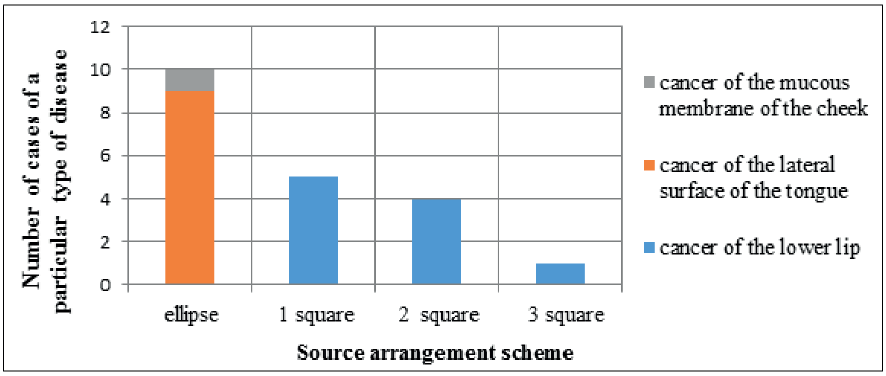

Figure 3: The relation between location schemes of the pin sources of californium-252 for interstitial neutron therapy with the diagnosis at which they were used.

4.3. Matching of the choice of source arrangement schemes with the diagnosis under which they were applied

Summarizing, we can say that for our study we selected patients in the number of 20 people with 3 types of cancer of the oral cavity. Particularly: lower lip cancer (different location of the tumor on the lower lip) - 10 cases (50%), cancer of the lateral surface of the tongue (different tumor location on the lateral surface of the tongue) - 9 cases (45%), mucosal cancer of cheek - 1 case (5%). The ratio of the location of the tumor and the sources arrangement for interstitial neutron therapy is graphically depicted in Figure 3.

Estimating the situation with the choice of source location schemes for a specific diagnosis, it can be concluded that different cases of the lower lip tumor location were treated with a square scheme (100%). The determination of the squares number depends only on the size of the tumor. Tumors located in different ways on the lateral surface of the tongue were treated with an ellipse scheme (100%).

5. CONCLUSION

1. The duration of irradiation depends on a number of parameters, but the determining factor is the dose of neutrons prescribed by the doctor. This relationship is directly proportional. The dependence of the absorbed neutron dose rate on the tumor boundary on the duration of irradiation is inversely proportional.

2. Radiation reactions were recorded in 35% of the cases considered. After remote radiation therapy, radiation reactions were detected in 42.86% of cases, after interstitial neutron brachytherapy - in 57.14% of cases. Regarding the layouts of

the sources, the radiation reactions were distributed as follows: ”ellipse” - 57.14%, ”1 square” - 28.57%, ”2 squares” - 14.29%.

3. Cancer of the lateral surface of the tongue and mucous membrane of the cheek was treated with the ”ellipse” scheme - 100%, the cancer of the lower lip - with the ”square” scheme (100%). Thus, the choice of the scheme is based on the anatomical location of the tumor for convenience.

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