NATIONAL TECHNICAL UNIVERSITY OF UKRAINE
«Igor SIKORSKI KYIV POLYTECNIC INSTITUTE»
FACULTY OF BIOMEDICAL ENGINEERING
DEPARTMENT OF BIOMEDICAL ENGINEERING

« Approved for defense»
Head of the Department of BMI
_____ Vladyslav SHLYKOV
(signature) (initials, surname)
“ ___ ” _____2023

Graduate work

to obtain a bachelor's degree

under the educational and professional program "Medical Engineering"

specialty 163 "Biomedical engineering"

on the topic: «Materials for reference labels in the radiation therapy»

Completed:
IV year student, group BM-93i
Fanous Fadi Youssri Fanous Ghali _____

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Assistant of the dep. BMI
Matvieieva Ilona Olehivna _____

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Kalinchyk V.V. _____

Reviewer:
Senior Lecturer at the BBZL, PhD,
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I certify that in this master's dissertation there are no borrowings from the works of other authors without appropriate references.

Student _____

Kyiv –2023

НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ УКРАЇНИ
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»
ФАКУЛЬТЕТ БІОМЕДИЧНОЇ ІНЖЕНЕРІЇ
КАФЕДРА БІОМЕДИЧНОЇ ІНЖЕНЕРІЇ

До захисту допущено:
Завідувач кафедри
_____ Владислав ШЛИКОВ
«___»_____20__ р.

Дипломна робота

на здобуття ступеня бакалавра

за освітньо-професійною програмою «Медична інженерія»

спеціальності 163 «Біомедична інженерія»

на тему: «Дослідження матеріалів для референтних міток для променевої терапії»

Виконав:
студент IV курсу, групи БМ-93і
Фанус Фаді Юссрі Фанус Гхалі _____

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асистент каф. БМІ
Матвєєва Ілона Олегівна _____

Консультант з охорони праці:
доц. каф. ОПЦБ, к.т.н.
Калінчик Віктор Васильович _____

Рецензент:
ст. викл. каф. ББЗЛ, , к.мед.н.
Лазарєв Ігор Альбертович _____

Засвідчую, що у цій дипломній роботі немає запозичень з праць інших авторів без відповідних посилань.
Студент _____

Київ – 2023

National Technical University of Ukraine
"Kyiv Polytechnic Institute named after Igor Sikorsky"
Faculty of Biomedical Engineering
Department of biomedical engineering

Level of higher education - first (bachelor's)

Specialty - 163 "Biomedical Engineering"

Educational and professional program "Medical engineering"

I APPROVE

Head of Department

_____ Vladyslav SHLYKOV

"___"_____20__ year.

TASK

for a diploma work for a student

Fanous Fadi Youssri Fanous Ghali

1. The topic of the work «Materials for reference labels in the radiation therapy», head of the work Ilona Olehivna Matvieieva, assistant of the dep. BMI, approved by order of the university dated May 26, 2023 No. 52/53 si
2. Deadline for student submission of work: 9 June 2023
3. Initial data for work: general characteristics of radiation therapy and topometric preparation, existing types of reference labels, their general characteristics, list of medical X-ray contrast materials.
4. The content of the work: conducting a literature review of radiopaque materials used in medicine and conducting a comparative evaluation of materials; study of the behavior of the material during CT for its direct further use in 2D, 2D+ and 3D computer planning; justification of the choice of material for radiopaque markers and research on the dependence of the size of the desired marker on the volume of

the tumor; marker design using Solid Works software; researching different options for attaching tags to the patient's body and choosing the most effective one.

5. A list of illustrative material (with an indication of posters, presentations, etc.): illustrations of the planning office during topometric preparation, dose planning, immobilization of the patient, Suremark markers, projected markers, CT images with various materials, adhesive base for attaching the marker to the patient's body, method of attaching the marker to the body.

6. Adviser of work sections

Department	Surname, initials and position adviser	Signature, date	
		task published	task accepted
Labor protection	Kalinchyk V.V. Assoc. prof. dep. «Safety of labor, industrial and of civil security»		

7. Issue date of the assignment_____

Calendar plan

№ by number	The name of the execution stages thesis	Deadline stages of work	Note
1	Get an assignment for DR	February 2023	
2	Review of literary sources	February 2023	
3	Analysis of the tasks	March 2023	
4	Selection of radiopaque materials	March 2023	
4	Marker modeling	April 2023	
5	Conducting experimental research	April 2023	
6	Analysis of research results	May 2023	
7	Selection of materials for markers	May 2023	
8	Selection of the type of attachment of the marker to the patient's body	May 2023	
9	Completion of the thesis	June 2023	
10	Preparation for defense DR	June 2023	
11	Receiving review and feedback	June 2023	
12	Defense of the thesis	June 2023	

Student Fanous Fadi Youssri Fanous Ghali

Supervisor Ilona MATVIEIEVA

Національний технічний університет України
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Кафедра біомедичної інженерії

Рівень вищої освіти перший (бакалаврський)
Спеціальність 163 «Біомедична інженерія»
Освітньо-професійна програма «Медична інженерія»

ЗАТВЕРДЖУЮ
Завідувач кафедри
_____ Владислав ШЛИКОВ
«___»_____2023 р.

ЗАВДАННЯ
на дипломну роботу студенту
Фанус Фаді Юссрі Фанус Гхалі

1. Тема роботи «Дослідження матеріалів для референтних міток для променевої терапії», керівник роботи Матвєєва Ілона Олегівна, асистент каф. БМІ, затверджені наказом по університету від **« 26 » травня 2023 р. № 52/23 si**.
2. Термін подання студентом роботи: 09 червня 2023 року
3. Вихідні дані до роботи: загальна характеристика променевої терапії та топометричної підготовки, існуючі види референтних міток, їх загальна характеристика, перелік медичних рентгенконтрастних матеріалів.
4. Зміст роботи: проведення літературного огляду рентгенконтрастних матеріалів, які використовуються в медицині та проведення порівняльної оцінки матеріалів; дослідження поведінки матеріалу під час проведення КТ для безпосередньо його подальшого використання в 2D, 2D+ і 3D комп'ютерного планування; обгрунтування вибору матеріалу для рентгенконтрастних маркерів та дослідження залежності розмірів потрібного

маркера від об'єму пухлини; проектування маркерів за допомогою програмного забезпечення Solid Works; дослідження різних варіантів кріплення міток до тіла пацієнта та вибір найефективнішого.

5. Перелік ілюстративного матеріалу (із зазначенням плакатів, презентацій тощо): ілюстрації кабінету планування при проведенні топометричної підготовки, планування дози, імобілізації пацієнта, маркери Suremark, спроектовані маркери, КТ-знімки з різними матеріалами, клейка основа кріплення маркера до тіла пацієнта, спосіб прикріплення мітки до тіла.

6. Консультанти розділів роботи

Розділ	Прізвище, ініціали та посада консультанта	Підпис, дата	
		завдання видав	завдання прийняв
Охорона праці	Калінчік В.В. Старший викладач кафедри «Охорона праці, промислової та цивільної безпеки»		

7. Дата видачі завдання _____

Календарний план

№ з/п	Назва етапів виконання дипломної роботи	Термін виконання етапів роботи	Примітка
1	Отримати завдання на ДР	Лютий 2023	
2	Огляд літературних джерел	Лютий 2023	
3	Аналіз поставлених задач	Березень 2023	
4	Вибір рентгенконтрастних матеріалів	Березень 2023	
4	Моделювання маркерів	Квітень 2023	
5	Проведення експериментальних досліджень	Квітень 2023	
6	Аналіз результатів дослідження	Травень 2023	
7	Вибір матеріалів для маркерів	Травень 2023	
8	Вибір типу кріплення маркера до тіла пацієнта	Травень 2023	
9	Оформлення дипломної роботи	Червень 2023	
10	Підготовка до захисту ДР	Червень 2023	
11	Отримання рецензії та відгуку	Червень 2023	
12	Захист дипломної роботи	Червень 2023	

Студент _____ Фанус Фаді Юссрі Фанус Гхалі

Керівник _____ Ілона МАТВЄЄВА

ANNOTATION

Theme of thesis: "Reference X-ray contrast labels for topometric preparation in radiotherapy".

Thesis contains 58 pages, 18 illustrations, 18 tables and 34 sources according to the list of references.

Actuality: for the treatment of malignant diseases radiotherapy is used, we receive accurate anatomical information of the biological properties of the tumor at the stage of topometric preparation of patients with reference X-ray contrast labels which are expensive and in limited quantities.

Purpose: the development of special X-ray contrast labels to improve the quality of anatomical and topographic sections using computer tomography (CT).

Tasks:

1. Conduct a literary review of all X-ray contrast materials used in medicine and conduct a comparative evaluation of materials;

2. Investigate the behavior of the material during the CT for its immediate use in 2D, 2D + and 3D computer programming;

3. To substantiate the choice of the material of X-ray contrast labels and to investigate the dependence of the size of the desired marker on the volume of the tumor;

4. Design a marker with SolidWorks;

5. Investigate different types of tag attachment to the patient's body and choose the most effective one.

Main results: a literary review of X-ray contrast materials used in medicine was carried out, a comparative evaluation of the materials was carried out, the behavior of the materials during the CT was investigated; the best material for X-ray contrast markers was selected and the best form of labels was selected, the dependence of the size of the marker on the volume of the tumor was studied; A

marker was constructed using SolidWorks, various ways of fixing labels to the patient's body and choosing the most effective one were studied.

Key words: radiotherapy, pre-radius stage, topometric preparation, reference labels, X-ray contrast markers.

АНОТАЦІЯ

Тема дипломної роботи: «Референтні рентгенконрастні мітки для топометричної підготовки в променевій терапії».

Обсяг пояснювальноої записки 58 сторінок, міститься 18 ілюстрацій, 18 таблиць. Загалом опрацьовано 34 джерела.

Актуальність: для лікування злоякісних захворювань використовуються променеву терапію, чітку анатомічну інформацію біологічних властивостей пухлини ми отримуємо на етапі топометричної підготовки хворих за допомогою референтних рентгенконтрастних міток, які є дороговартісними та в обмеженій кількості.

Мета: розробка спеціальних рентгенконтрастних поверхневих міток для покращення якості анатомно-топографічних зрізів за допомогою комп'ютерної томографії (КТ).

Завдання:

1. Провести літературний огляд всіх рентгенконтрастних матеріали, які використовуються в медицині та провести порівняльну оцінку матеріалів.
2. Дослідити поведінку матеріалу під час проведення КТ для безпосередньо його подальшого використання в 2D, 2D+ і 3D комп'ютерного планування.
3. Обгрунтувати вибір матеріалу рентгенконтрастних міток та дослідити залежність розмірів потрібного маркера від об'єму пухлини.
4. Сконструювати маркер за допомогою SolidWorks.
5. Дослідити різні варіанти кріплення мітки до тіла пацієнта та вибрати найефективніший.

Основні результати: проведено літературного огляду рентгенконтрастних матеріалів, які використовуються в медицині, проведення порівняльну оцінку матеріалів, досліджено поведінку матеріалів під час проведення КТ; вибрано найкращий матеріал для рентгенконтрастних

маркерів та обрано найкращу форму міток, досліджено залежність розмірів потрібного маркера від об’єму пухлини; сконструйовано маркер за допомогою SolidWorks, досліджено різних варіантів кріплення міток до тіла пацієнта та вибір найефективнішого.

Ключові слова: променева терапія, передпроменевий етап, топометрична підготовка, референтні мітки, рентгенконтрастні маркери.

CONTENT

					БМ93.20.2905.5223.ПЗ		
Вим		*№ докум.*		*Дата*			
Розробив		*Фаді Юссрі Фанус*			*Дослідження матеріалів для референтних міток для променевої терапії*	*Літ.*	*Лист* 11 / *Лстів* 58
Перевірив		*Матвєва І. О.*					
Реценз.		*Лазарєв І. А.*				*КПІ ім. Ігоря Сікорського ФБМІ БМ-93*	
Н. Контр.		*Андреєв П. І.*					
Затвердив		*Шликов В. В.*					

LIST OF CONVENTIONAL ABBREVIATIONS

2D	–	two-dimensional picture
2D+	–	two-dimensional picture plus
3D	–	three-dimensional picture
WHO	–	World Health Organization
Gr	–	Grey
CT	–	computer therapy
MRI	–	magnetic resonance imaging
PET	–	positron emission tomography
RT	–	radiation therapy

INTRODUCTION

According to WHO data, oncopathology has moved from 10th to 2nd place in the world in terms of morbidity and mortality over the last 100 years, second only to diseases of the cardiovascular system. Ukraine ranks 2nd in terms of cancer incidence [1]. According to experts, by 2020 the number of cancer patients in whom pathology was first detected will exceed 200,000 patients [2].

Actuality of theme. Today, all the more modern methods of radiation therapy are used for the treatment of malignant diseases. Their appearance is related to the desire to improve the accuracy of delivering the dose to the target and to reduce the radiation load on the surrounding healthy tissues as much as possible. Radiation therapy takes place in several stages.

The task of radiation therapy planning is to choose the optimal combination based on anatomical and topometric data, radiobiological parameters and acceptable levels of load on critical organs.

Pre-radiation topometric preparation is a more important stage of treatment. It is at this stage that anatomical and topographical sections of the tumor are made with the help of previously placed reference marks on the body, determination of its volume, level of occurrence, determination of syntopy of the tumor and adjacent critical organs [3].

Therefore, the correct selection of reference X-ray contrast markers at the stage of topometric preparation of radiation treatment of patients through the use of modern planning technologies (3D), which provides anatomical information obtained using such an imaging method as computed tomography (CT), as well as taking into account biological properties tumors, is relevant and the goal of our research.

Purpose: development of special radiopaque surface labels to improve the quality of anatomical and topographic sections using computer tomography (CT).

To achieve the goal, the following tasks were formed:

1. Conduct a literature review of all radiopaque materials used in medicine and conduct a comparative evaluation of the materials.

2. To study the behavior of the material during CT for its immediate further use in 2D, 2D+ and 3D computer planning.

3. To justify the choice of radiopaque material and to investigate the dependence of the size of the desired marker on the volume of the tumor.

4. Construct a marker using SolidWorks.

5. Explore different options for attaching the tag to the patient's body and choose the most effective one.

Scientific novelty of the obtained results. The paper proposes a new solution to one of the main tasks of PT - obtaining clear anatomical and topometric images due to the development of high-quality reference X-ray contrast markers, which are used to guide the study of tumors and adjacent critical organs at the stage of pre-radiation topometric preparation using CT.

SECTION 1

TERMS

1.1 General provisions of radiation therapy

Radiotherapy (or radiotherapy) is a method of treating tumors (and some non-neoplastic) with ionizing radiation, which is created thanks to the operation of special devices with a radioactive emitter [4].

Radiation therapy can be prescribed as the main and only method of treatment or as an additional to surgery or chemotherapy. In such cases, we are talking about combined treatment. Irradiation can be carried out in the preoperative and/or postoperative period. Radiation therapy improves the results of surgical treatment [5]. After irradiation of a tumor that was initially inoperable, it is possible to resect the organ or remove it completely within the limits of healthy organs. When prescribing postoperative radiation therapy, emphasis is placed on irradiation of the surgical site (operative field), as well as areas of regional metastasis [4].

The effect of radiation therapy is primarily aimed at destroying tumor cells. As it turned out, tumor cells are more sensitive to ionizing radiation than cells of healthy tissues [6]. Ionizing radiation converts water molecules into peroxide radicals, which have a harmful effect on the cell. The more active a cell is, the more severe damage it receives.

Now radiation therapy is a large medical and technological chain, the exclusion of one of the links of which will undoubtedly lead to a deterioration in the quality of treatment. According to the conclusions of WHO experts, the success of PT depends approximately 50% on the radiosensitivity of the tumor, 25% on hardware equipment, and the other 25% on the treatment plan itself and adherence to it during all sessions [6, 7].

1.2 Diagnostic methods

The main method currently used for pre-radiation preparation of patients for radiotherapy is X-ray computed tomography. Due to its ability to directly reflect electron density, as well as availability and geometric accuracy, X-ray computed tomography is currently the ideal method for topometric preparation and radiation therapy planning [7].

Other methods of image reconstruction - magnetic resonance imaging, emission tomography and ultrasound - play a very important, albeit auxiliary, role in clinical practice. These methods significantly expand the possibilities for diagnosis and localization of malignant diseases, as well as tracking metabolic changes during therapy. In particular, positron emission tomography is particularly useful for evaluating the process of metastasis, and magnetic resonance imaging is a unique method of differential diagnosis of soft tissues. Ultrasound examination is particularly useful for a number of specific localizations, in particular, for the study of tumors of the prostate and rectum. Some of the imaging methods known today are accompanied by less harmful effects on the human body than methods that use ionizing radiation,

1.3 Modern types of radiation therapy

Currently, in practice, various types of radiation therapy are used, based on the use of various types of ionizing radiation. Gamma radiation from radioactive isotopes, bremsstrahlung radiation from linear accelerators, electron beams from linear accelerators or β-emitting radioactive isotopes, as well as neutron and heavy nuclear particle beams are used as therapeutic radiation. According to the localization conditions of the pathological focus, radiation therapy is divided into the following types:

1. Surface therapy - the cell is located on the surface of the body or at a shallow depth below the surface;

2. Intracavitary therapy - the cell is located in such a way that access to it is possible through natural cavities of the body or an opening created surgically (brachytherapy);

3. Deep therapy - the focus is located in the body at a great depth.

As part of intracavity radiation therapy, methods of intratissue and contact irradiation are used. Intratissue irradiation is implemented using the introduction of a radioactive source of needles, seeds, etc. in the cell. At the same time, not only the area of pathology is irradiated β- and γ- radiations from a radioactive isotope, but also secondary X-rays that occur as a result of electron inhibition in body tissues.

Contact radiation is based on the location of the source close to the surface of the body above the focus or in its immediate vicinity, for example in natural cavities of the body. For this purpose, different applicators are used, specialized for different cases of localization of the disease. Intratissue and contact radiation methods are not applicable for studying many tumor foci located at a great depth. In such cases, the remote method of irradiation is the most effective.

Remote radiation therapy is a method of radiation therapy in which irradiation is carried out by a source located some distance from the patient's body. A beam of rays enters the body through a certain area of the surface, which is called the radiation field. Remote therapy is divided into static (when the radiation source and the patient remain stationary during irradiation) and dynamic (the radiation source moves around the patient during irradiation) [9].

1.4 Stages of radiation therapy

Modern radiology is an ultra-complicated, expensive nuclear-physical complex for medical use, consisting of accelerator complexes with multi-petal collimators,

with the help of which irradiation is carried out with modulation of the intensity of the radiation beam and visual control of the accuracy of each PT session in real time with clear topometry, dosimetric planning and clinical dosimetry, which guarantee the quality and conformity of irradiation, radiation scalpels ("gamma-knife", "x-knife" and "cyberknife"), equipment for emission and positron emission tomography (PET centers) [9, 10, 11].

The process of radiation therapy includes several stages:

1. At the first stage, the diagnosis of the tumor, determination of its localization and stage of the disease, spread of the tumor to adjacent healthy tissues is carried out. At this stage, various methods of clinical examination of patients are used, and various examination methods may be used - X-ray and magnetic tomography, ultrasound, positron emission tomography, etc. [12, 13];

2. At the second stage, anatomic and topometric preparation of the patient takes place: scanning the patient on a CT scan with a flat table top; designation of external tags on the skin or fixing devices; creation of contours of targets and critical anatomical structures, and then, with the help of the radiation therapy planning system, the configuration of radiation beams and their modifiers is set, the distribution doses are calculated and the radiation plan is optimized;

3. The last stage is therapeutic irradiation, which is accompanied by procedures for dosimetric control, verification and documentation of the radiation therapy process. For radiation verification, modern radiotherapy facilities are equipped with devices for obtaining digital portal images. Phantoms, means for patient dosimetry are used for dosimetry and quality control [14].

Conclusions to section 1

Thus, various complex diagnostic and therapeutic equipment is needed to ensure high quality of the radiation therapy process. The most important stage is the

pre-radiation stage. It is at this stage that anatomical and topographical sections of the tumor are made with the help of previously placed reference marks on the body, determination of its volume, level of occurrence, determination of syntopy of the tumor and adjacent critical organs.

SECTION 2

PRE-RADIATION THERAPY

2.1 Topometric preparation of the patient

Clinical topometry (Topo- + buckwheat. metreō to measure, determine) - a section of diagnostics devoted to methods of measurement and large-scale graphic display of individual topographical-anatomical relationships, including taking into account pathological changes in organs and tissues [14, 15].

One of the important stages of the patient's pre-radiation preparation is the marking process. During the process, first of all, the patient is placed in the treatment position and immobilized using the same means as on the therapeutic apparatus.

Based on the data of diagnostic studies, the doctor determines the isocenter on the patient's skin. The isocenter is the point of intersection of the axes of rotation of the linear accelerator, the collimator assembly and the couch. The moving lasers of the positioning system are switched to the position of the selected isocenter, and marks for the treatment position of the patient's body are applied to the patient's skin (or to the immobilization mask). X-ray contrast markers are used to ensure the visibility of these points on the images obtained after scanning. In addition, areas such as scars, lymph nodes, or borders of the field of previous treatment can be marked [16].

The topometrist applies marks on the patient's skin according to the projections of the lasers: two lateral, longitudinal and transverse (axial), as well as a mark for the reference point (sticks an X-ray contrast mark on the skin or on the mask)

Next, the scanning process is carried out. It is decisive, since the data generated at this stage will provide all the information about the patient, on the basis of which the treatment technique will be selected. This procedure is carried out on X-ray computer tomographs with a flat X-ray transparent table and a laser positioning system [17]. Computed tomography data provide an anatomical representation of the

patient and are used by the dose calculation algorithm for individual calculation for each patient, because they contain information about tissue density expressed in Hounsfield numbers.

The positioning of the patient during the CT scan must exactly correspond to the following placement in the treatment position on the linear accelerator.

After the scan is completed, the radiologist transmits the data to the planning station (Fig. 2.1) [18].

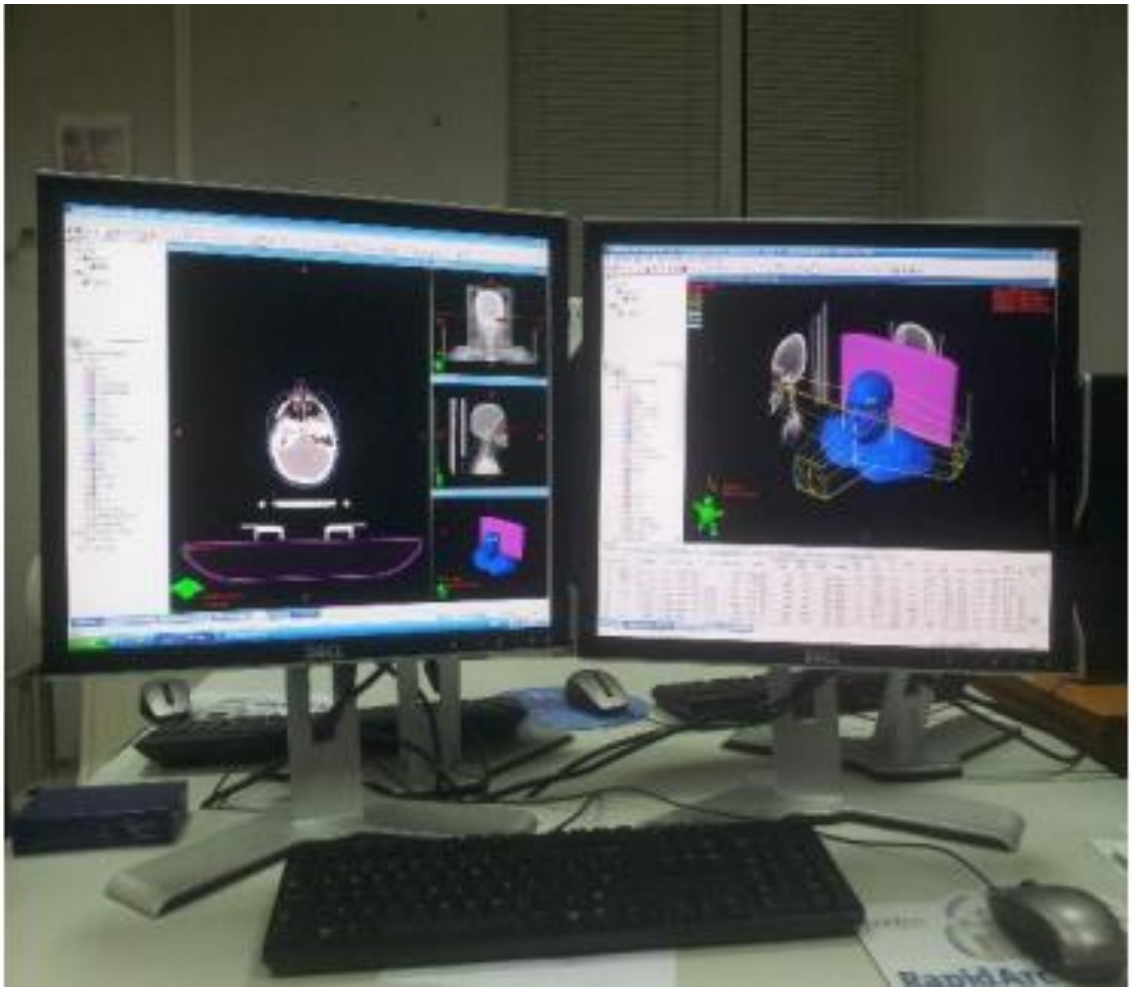

Figure 2.1 - Computer planning

Contouring of the volumes of irradiation and critical organs is carried out by a radiation therapist with the involvement, if necessary, of a radiologist. When planning radiation treatment, contouring of irradiation volumes is carried out [15].

2.2 Irradiation volumes

The rules for allocation of exposure volumes are described in the report of the International Commission on Radiation Units and Measurements No. 50 (ICRU Report 50), the scheme of exposure volumes is presented in fig. 2.2 [19].

For this, 5 irradiation volumes are allocated (Fig. 2.2).

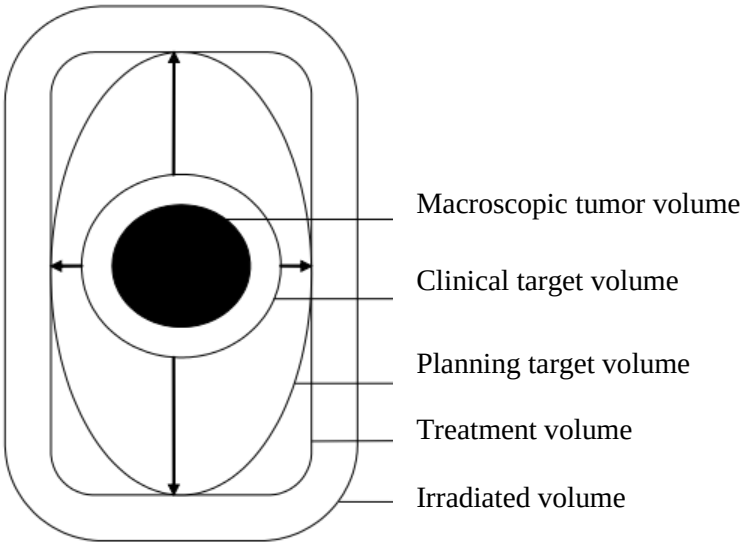

Figure 2.2 - Scheme of irradiation volumes

The main clinical volume (macroscopic volume of the tumor) - includes the visible tumor and the zone of peritumorous edema according to the data of instrumental studies. The clinical volume of the target includes the tumor itself and the area of its subclinical spread. The concept of clinical volume is clinical and anatomical. Planning target volume – includes the clinical volume and surrounding tissue, adjusted for variations in size, shape, and position relative to the treatment beam. The planning volume is a geometric concept that allows you to be sure that the clinical volume will receive the proper radiation dose. Next, taking into account the histological variant of the tumor and its radiosensitivity, the treatment volume and the irradiated volume are determined.

2.3 X-ray computed tomography

Computed tomography (CT) is a method of examining the internal organs of a person using X-ray radiation. The method is a reconstruction of tomographic planes (sections) of the object based on a large number of measurements of the absorption of X-ray radiation by tissues of different densities, or projections produced during the scanning process.

For the first time, the idea of the computed tomography method was proposed by Radon in 1917. In 1972, at the annual conference of the British Institute of Radiology, Hounsfield reported on the creation of an X-ray computed tomography device adapted to the conditions of the clinic. This device became the CT scanner of the head, which passed clinical tests already in 1973. Since 1976, testing of systems for the study of the whole body began [20].

X-ray computed tomography, or CT scanner–is a device designed to create images of thin cross-sections of the human body, and is used for a wide range of diagnostic procedures. The result of a CT scan is usually a set of cross-sectional images, or tomograms, based on mathematical processing of which a three-dimensional representation of the patient's internal anatomy can be reproduced.

2.4 Method of patient immobilization

In order to increase the reproducibility of laying, various immobilizing devices are used (Fig. 2.3).

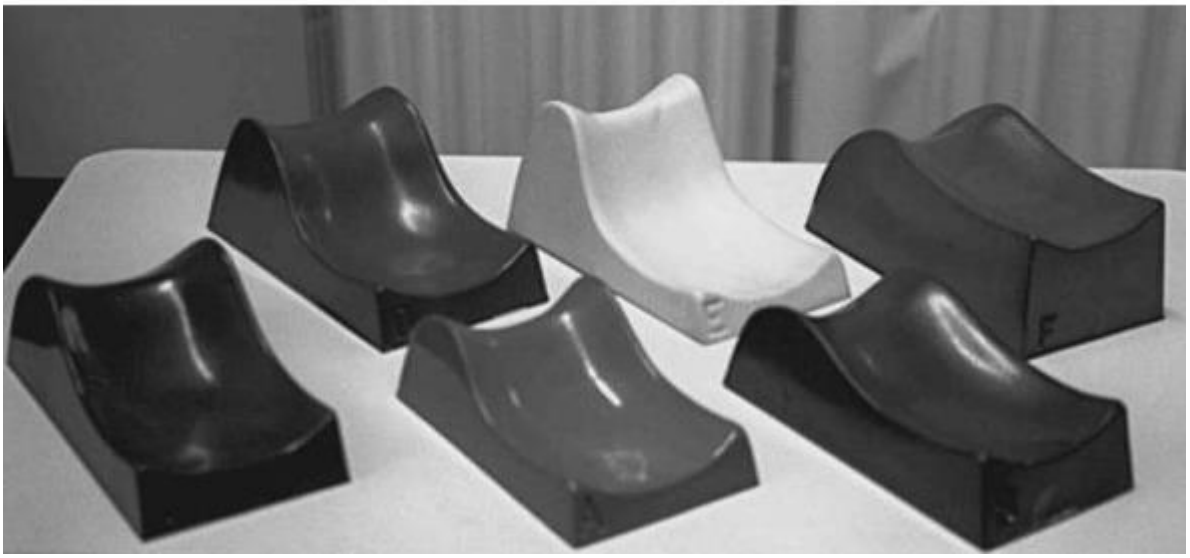

Figure 2.3 - Headrests

The primary purpose of using immobilizing devices is to limit the patient's movement and reduce the likelihood of significant errors when placing the patient in the treatment position (Fig. 2.4). In addition, these devices make it possible to reduce the time of the patient's daily styling and stabilize the relationship between external marks and internal anatomical structures.

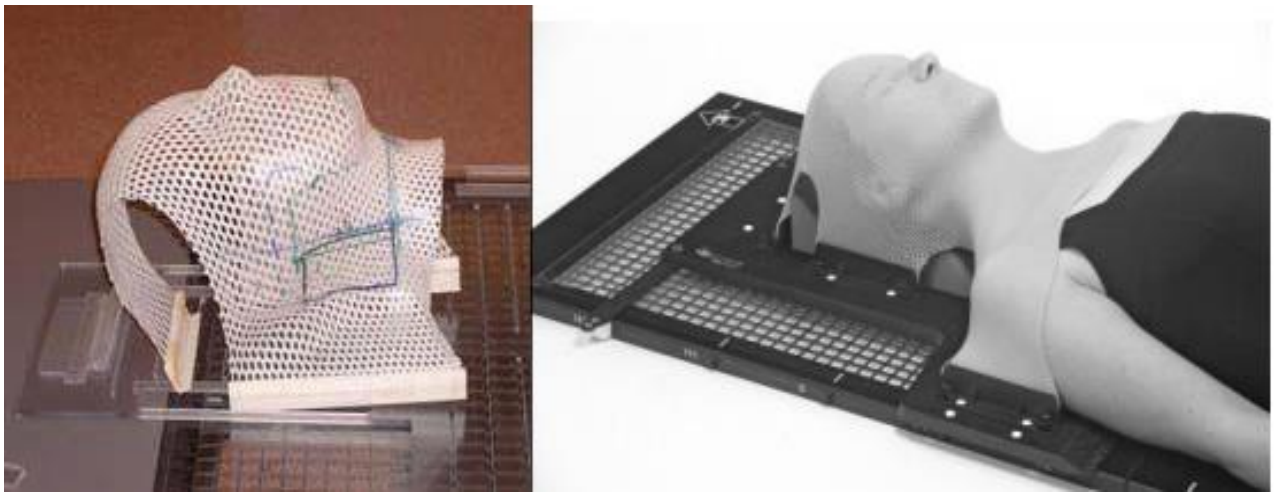

Figure 2.4 - Masks

If the individual device for immobilization is kept until the end of the treatment and after its completion, then it can be used in diagnostic examinations, which is important for the interpretation of clinical results [21].

2.5 Irradiation methods

In addition to traditional treatment methods used in typical clinical situations, special radiation therapy techniques have been developed for less common diseases that require an individualized approach. Examples of such special procedures are stereotaxic radiosurgery, used for arteriovenous formations that are not malignant but can be fatal, as well as for the treatment of brain tumors with distinct borders [22].

In some cases, they resort to full body irradiation, which is used as a preparatory stage before bone marrow transplantation. A full beam of electrons irradiated on the skin is used to treat mycoses. Intraoperative radiation therapy is used for those tumors that are deeply located and are not subject to traditional external beam radiation. Each of these techniques requires serious dosimetric training that precedes clinical implementation.

There is also equipment for specialized radiation treatment, namely units for therapy using proton and neutron beams. However, the cost of such equipment is very high, and the benefits of these treatment methods are only available in specific and infrequent clinical cases. These techniques are not currently as available in the clinic as techniques using photons and electrons.

2.6 In vivo dosimetry

Radiation oncologists often need information about the actual dose delivered to critical structures, which are sometimes very close to the boundaries of the radiation

field, so even a small change in beam orientation or patient position can lead to large changes in the measured dose. The most reliable dosimetry results can be obtained in areas with not very sharp changes in dose, as well as on the surface of the skin or in body cavities such as the mouth, trachea, stomach, vagina, uterus or rectum.

In vivo dosimetry is a method of controlling the process of dose planning and delivery as a whole, which consists in placing dosimeters on or inside the patient. An alternative form of assessment of planning accuracy in vivo consists in the use of portal verification images, which are subject to direct comparison with the reconstructed digital radiograph created with the help of a computer planning system [23].

In vivo dosimetry, it is possible to distinguish the measurement of the dose at the entrance, the measurement of the dose at the exit, and the measurement of the dose inside the cavities:

1. Measuring the dose at the entrance serves to check the performance of the processing treatment device, as well as the accuracy of patient placement;

2. Measuring the dose at the exit serves to check the dose calculation algorithm and determine the influence of variations in the shape, size and density of the patient's body on the dose calculation process;

3. Sometimes it is also possible to determine the dose in easily accessible internal body cavities, such as the oral cavity, esophagus, vagina, bladder and rectum.

In vivo dose measurements serve not only to verify dose delivery to the target, but are also used to estimate the dose to organs at risk (e.g., lens of the eye, lung) or in situations where the dose is difficult to predict (e.g., non-standard distance from the source to the skin or bolus use).

Conclusions to section 2

As a result of the literature review, radiation therapy was considered as one of the most important methods of oncology treatment today. The stages of treatment were analyzed and it was proved that the stage of topometric preparation of the patient is the most important [24], because at this stage anatomical and topographic sections of the tumor, determination of its volume, level of occurrence, determination of syntopy of the tumor and adjacent critical organs are performed. In order to increase the reproducibility of laying, various immobilizing devices are used. For accurate and clear determination of tumor volumes, special X-ray contrast markers are required. Therefore, the task is to develop and design these labels.

SECTION 3

DEVELOPMENT OF MARKERS

3.1 Dependence of the size and shape of the labels on the volume of the patient's tumor

Before scanning, the X-ray technician attaches a dot X-ray contrast label to the reference label and controls that the thickness of the section during scanning corresponds to the required one [19].

Reference marks are placed in the zone of intersection of the axes of the location of the tumor and additionally on the immobile parts of the body:

- tumors of the head and neck - in the projection of the main process;
- tumors of the chest - the middle of the handle of the sternum;
- tumors of the abdominal cavity - the middle of the xiphoid process;
- tumors of the pelvis - the greater trochanter or the middle of the symphysis.

When conducting pre-radiation preparation in planning conditions, it is necessary to develop the volumes of the target, as well as critical organs on 20-40 CT scans. The scanning step is determined depending on the specific clinical situation:

- with lung cancer - 0.7-1.0 cm;
- brain tumors - 0.3-0.5 cm;
- pancreatic cancer - 0.5 cm;
- prostate cancer - 0.3 cm.

The radiopaque reference mark should fall into one of the 20-40 CT scans so as not to overlap the next slice. That is, the size of the labels should correspond to the step of CT scanning of the tumor and should not go beyond its limits [25].

To facilitate the production of labels, it is advisable to use two forms: ball-shaped (Fig. 3.1) and cross-shaped (Fig. 3.2). The shape of the labels is designed using SolidWorks software.

Figure 3.1 - Design of a spherical shape of an X-ray contrast label

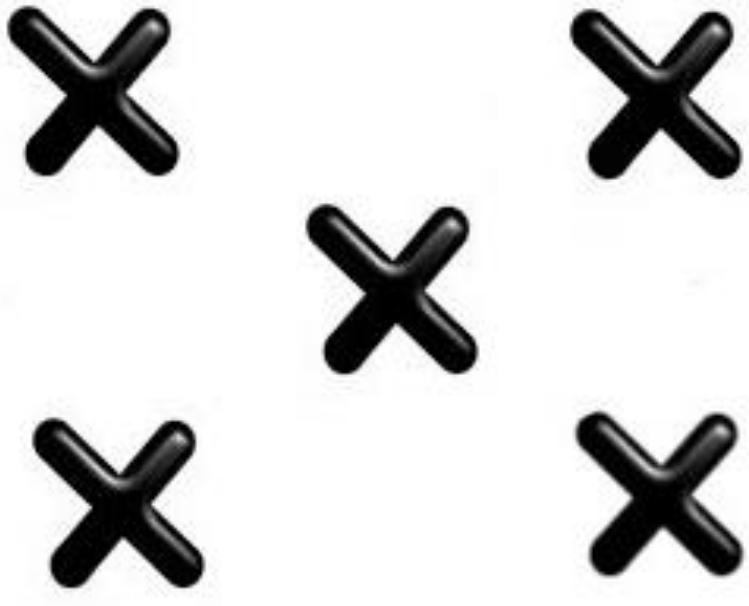

Figure 3.2 - Design of a cross-shaped radiopaque label

The radiologist attaches the X-ray contrast label at the intersection of the axes formed by the lasers of the corresponding equipment on the patient's body (Fig. 3.3) [15], therefore, for easier and accurate attachment, it is advisable to use the cross-shaped shape of the X-ray contrast labels so that the sides of the labels clearly coincide with the directions of the laser axes.

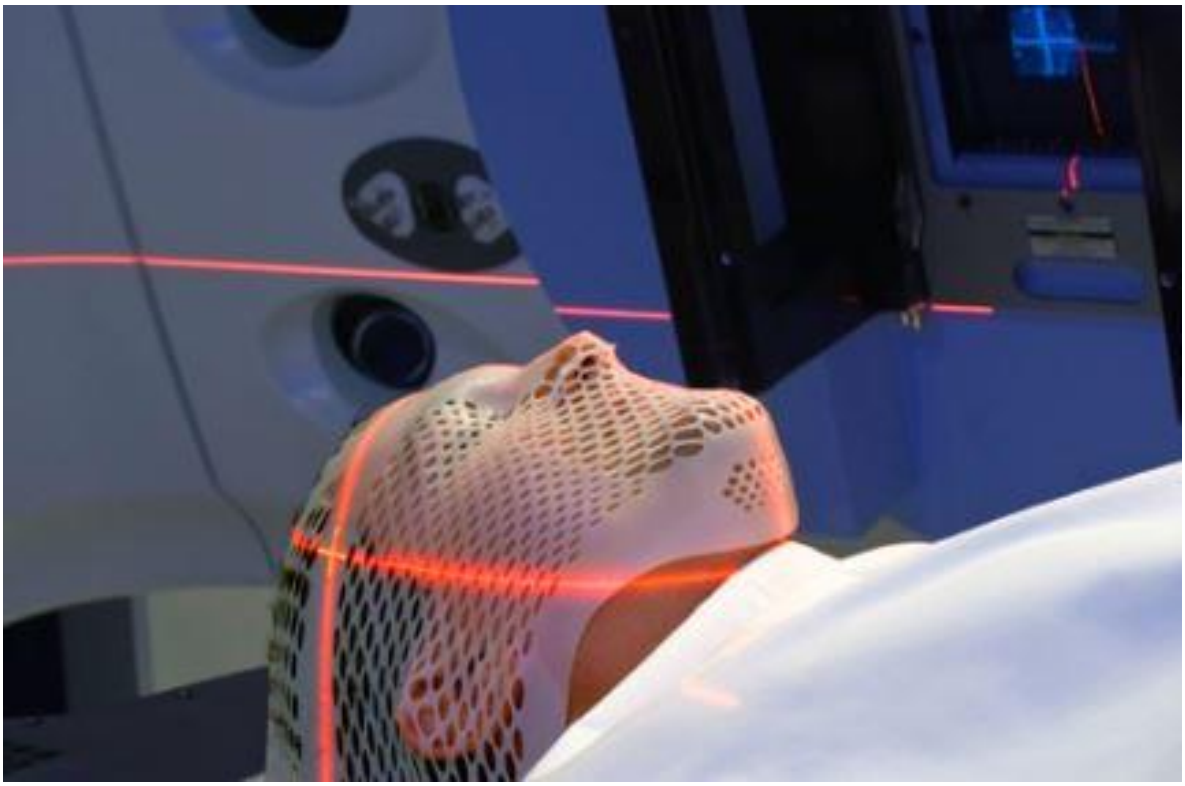

Figure 3.3 - Formed lasers on the patient's body [15]

Given that all tumors to be treated with radiation therapy correspond to tumor volumes for the clinical situations listed above, 3 label sizes are required:

- 0.8 × 0.8 cm;
- 0.4 × 0.4 cm;
- 0.2 × 0.2 cm.

In one clinical practice: the patient is 6 years old (Fig. 3.4). Diagnosis: extrarenal rhabdoid tumor of parapharyngeal localization on the left. CT scan - a picture at the stage of topometric preparation with labels of the American manufacturer Suremark (Fig. 3.5), which are marked in yellow (Fig. 3.4) [24].

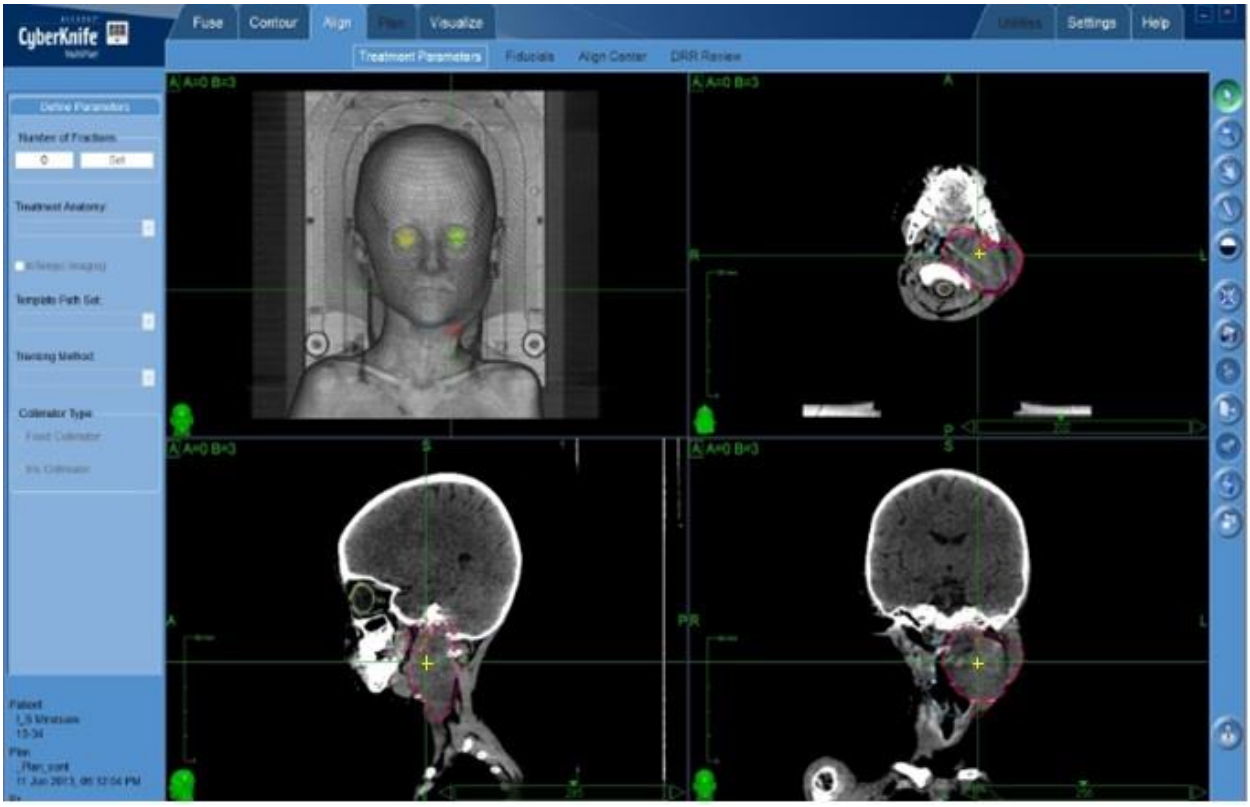

Figure 3.4 - CT - images at the stage of topometric preparation of the patient

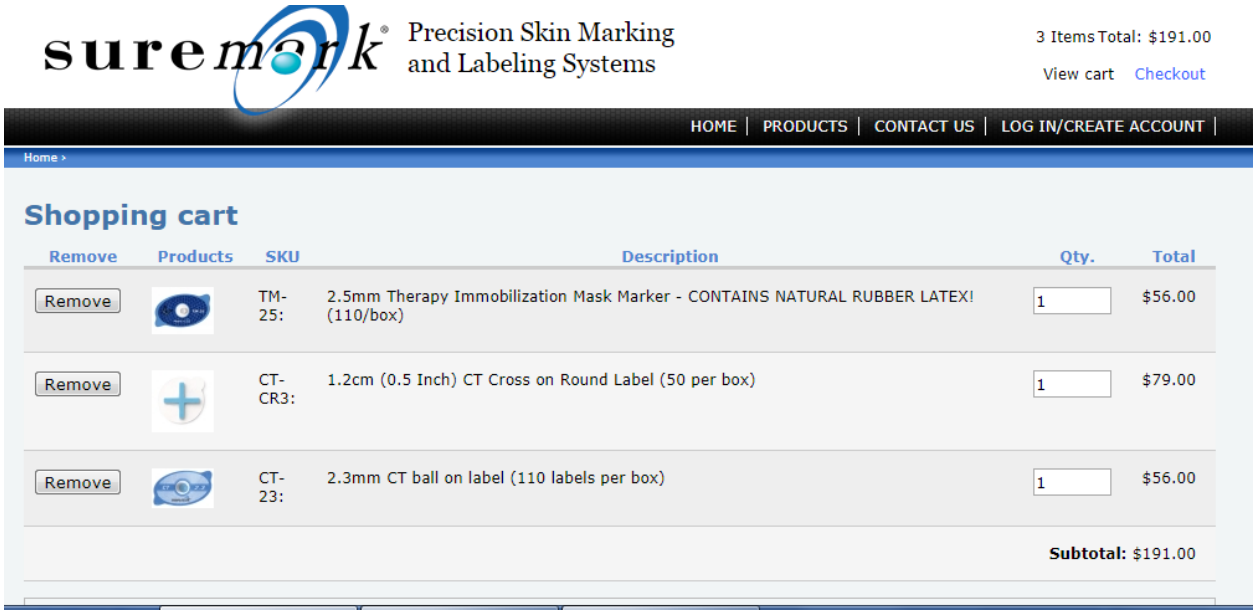

Figure 3.5 - Cost of 3 different radiopaque labels from the official website https://www.suremark.com

These tags behave well during CT - diagnosis - do not give any artifacts and are well biocompatible, but they are too expensive for Ukraine (Fig. 3.5).

3.2 Comparative characteristics of surface marks of different materials

Stainless steel. Stainless steel 316L is widely used in the manufacture of medical equipment and is an irreplaceable material that meets all standards of hygiene, strength and quality. Steel 316L, which contains expensive molybdenum and has high chemical resistance, is used by doctors for implantation in the human body [26].

Austenitic steel 316L has the following chemical composition: Fe; <0.03% C; 1 - 18.5% Sg; 10 - 14% Ni; 2 - 3% Mo; <2% Mn; <1% Si; <0.045% P; <0.03% S.

However, the clinical use of stainless steel is limited by the ferromagnetic nature of the alloy and its low density. These properties make stainless steel poorly visible in X-rays and CT/MRI scans. Also, many patients may have an allergic reaction to nickel. In particular, the presence of nickel, chromium and molybdenum ions cause a local immune reaction and inflammation.

Given that stainless steel is poorly visible on X-ray images, it is impossible to use this material.

Platinoiridium alloys. Alloys of the Pt-Ir system (90% Pt and 10% Ir) are often used in such a medical area as stenting. Such alloys were successfully tested on animals [27]. Platinoiridium alloys show excellent X-ray contrast, which makes it possible to obtain 3D images at CT. In general, these alloys have high corrosion resistance, but low mechanical properties. The alloy has fairly good biocompatibility, but sometimes (up to 3% of patients) minor inflammatory reactions are present. The results of clinical tests show that the use of this material is effective, but given the possible inflammatory reactions, its use is impossible (Fig. 3.6).

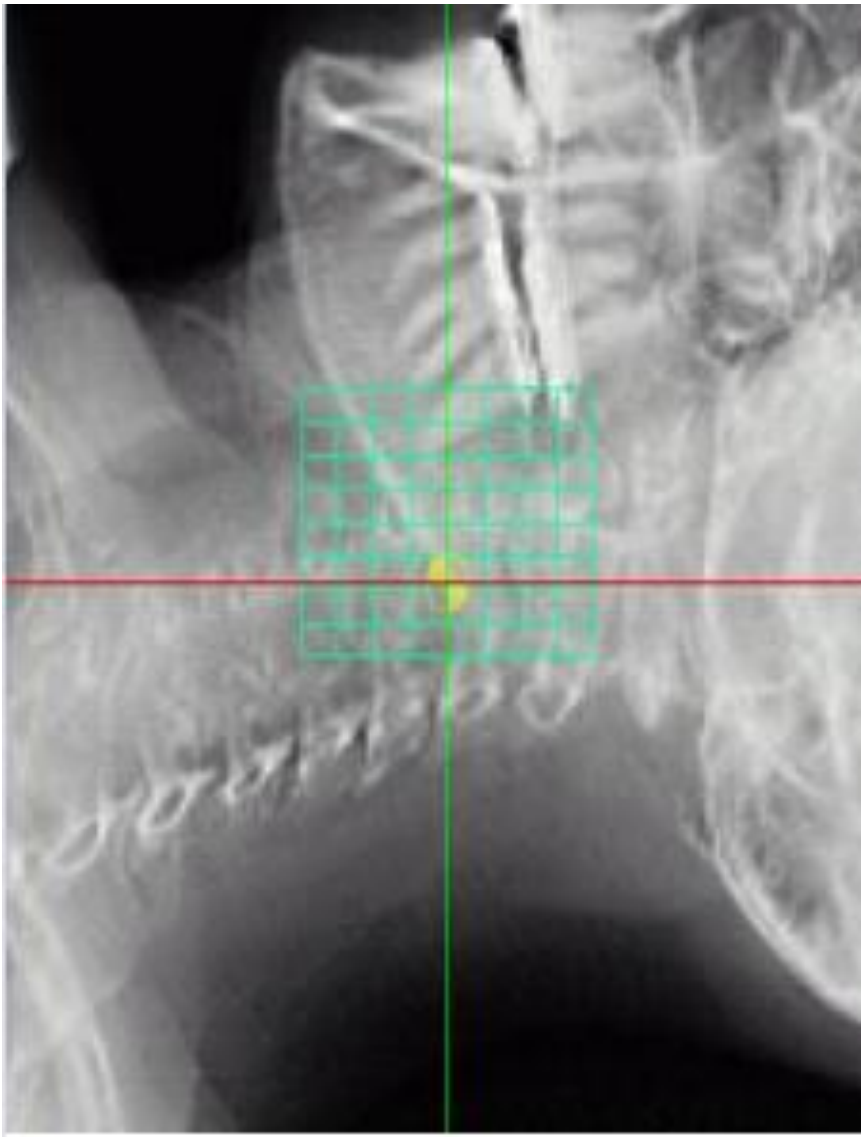

Figure 3.6 - CT image using platinum iridium alloys

Tantalum. Tantalum has good biocompatibility and high corrosion resistance [28]. In medicine, tantalum is often used to coat stainless steel to increase biocompatibility. It is clearly visible on X-rays and CT/MRI, but imaging artifacts are possible. The commercial potential of tantalum products is much smaller than that of stainless steel products.

By superimposing two CT images, we can see artifacts, so it is impossible to use tantalum for labels (Fig. 3.7).

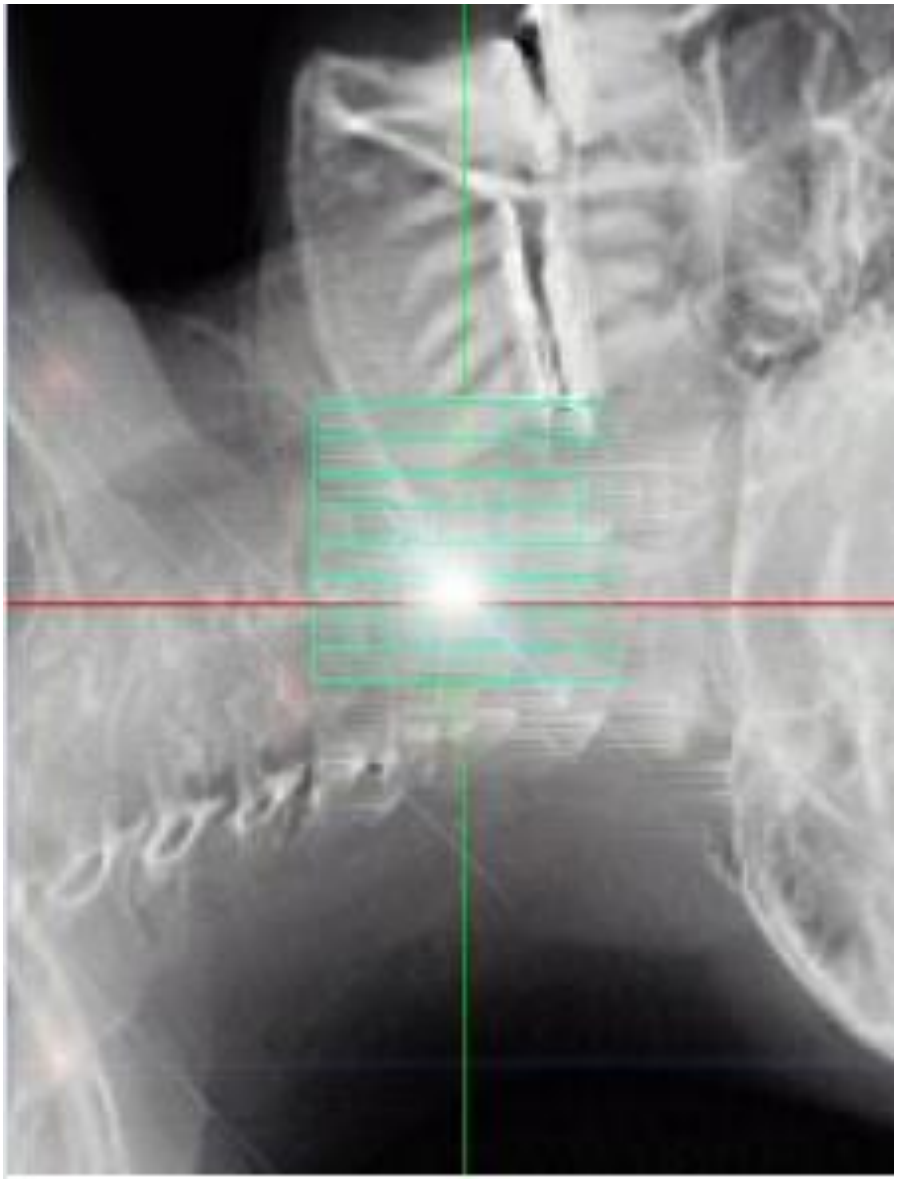

Figure 3.7 – CT scan using tantalum

Titanium and its alloys. Titanium and its alloys have biocompatibility, high corrosion resistance, and are intensively used in orthopedics and dentistry. It is not advisable to consider titanium as a separate element, so it is better to use it as a coating for stainless steel. Such alloys as VT6C, VT8, VT14, VT16, and VT23 are characterized by a high degree of biocompatibility [29].

Taking into account the behavior of titanium during X-ray radiation and CT, in the topometric preparation we will get a high-quality image without artifacts (Fig. 3.8).

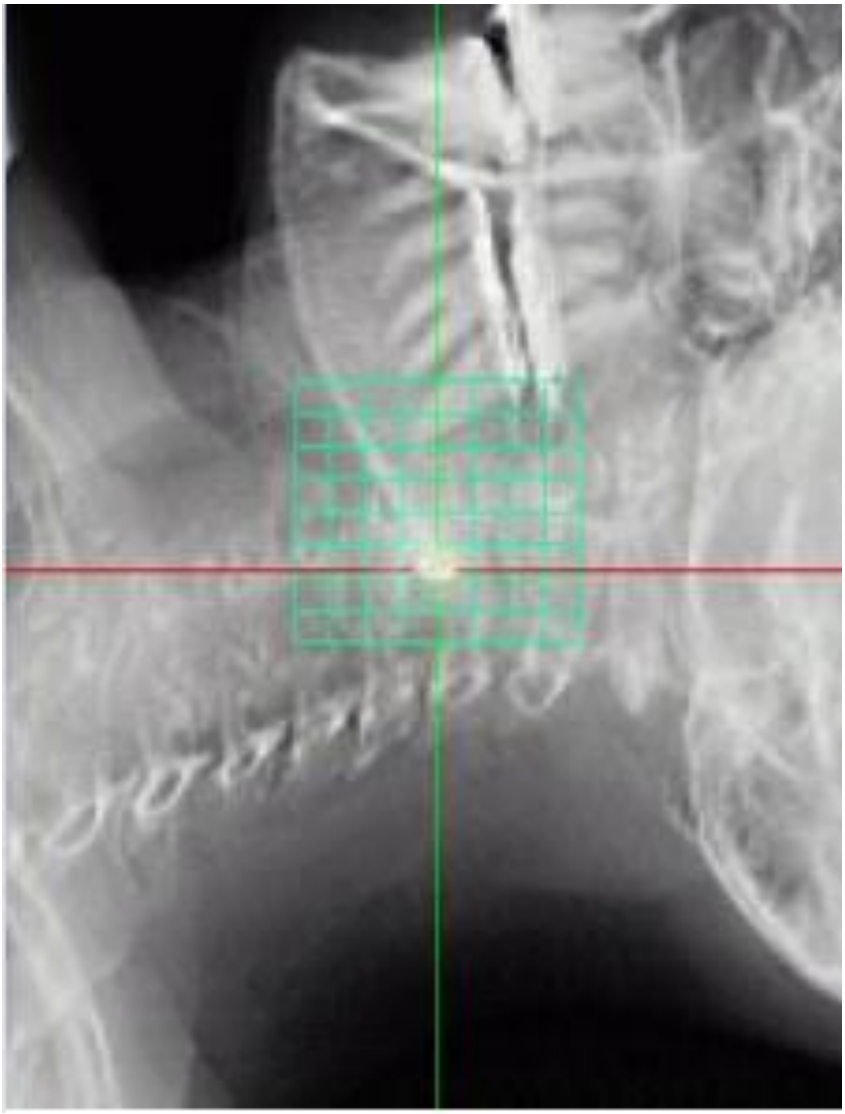

Figure 3.8 - CT scan using titanium

Nitinol. Nitinol is an alloy of 49.5-57.5% Ni and titanium. It has the effect of "shape memory" and hyperelasticity [30]. These properties make it possible to change the shape of the product when heated, which would be good for a marker, but the disadvantage of nitinol is that it is poorly visible under X-ray radiation.

Considering this, we cannot use it for topometric training, since finding the reference point of the equipment is impossible.

Cobalt-based alloys. Cobalt-based alloys usually have excellent characteristics: biocompatibility, X-ray contrast, strength, absence of ferromagnetism [31]. Among the cobalt alloys, the L605 alloy (Co-20Cr-15W-10Ni) has the best properties. It is

stronger than stainless steel, so it is possible to produce a thinner material (by 20%) while maintaining the same X-ray contrast.

Taking this into account, we can use a label of a smaller size than is necessary with other material (Fig. 3.9). Image without artifacts.

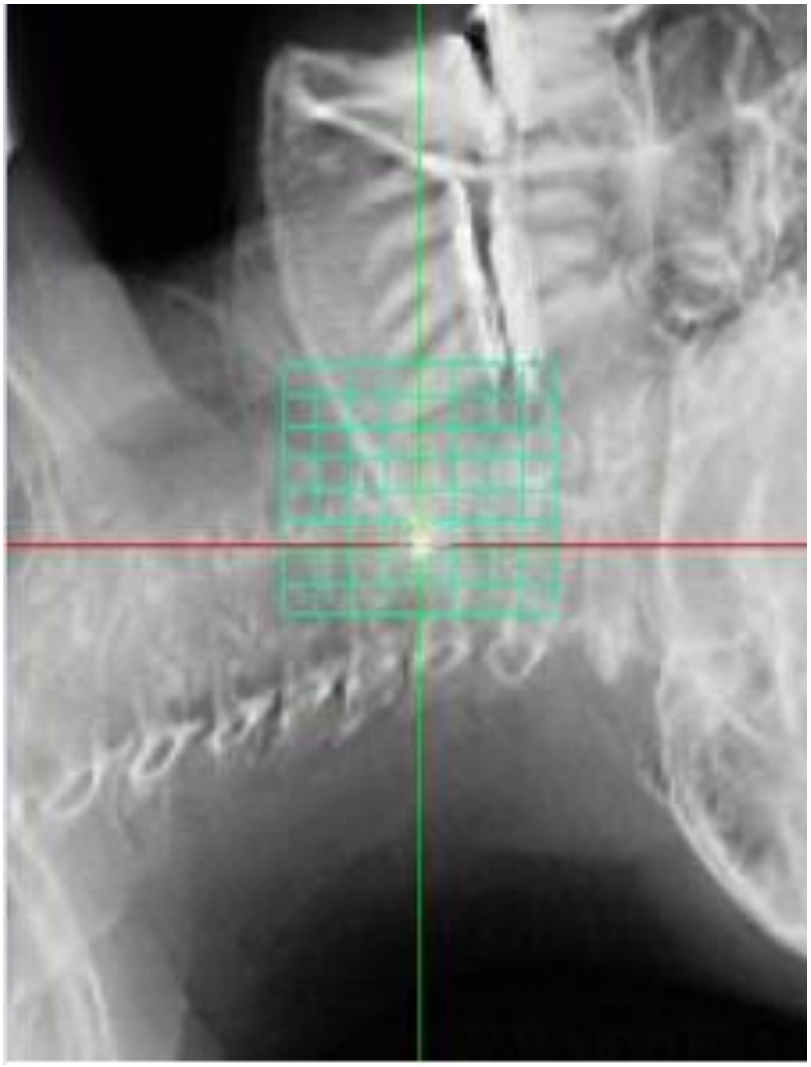

Figure 3.9 - CT - picture using alloy L605 (Co-20Cr-15W-10Ni)

The following tables (Table 3.1, Table 3.2) present their comparative characteristics based on theoretical and obtained data.

Table 3.1 – Comparative characteristics of materials

Material	X-ray contrast	Biocompatibility	Possible artifacts
Stainless steel	+	+	+
Platinoiridium alloys	+	-	-
Tantalum	+	+	+

Continuation of table 3.1

Titanium	+	+	-
Cobalt chrome alloy	+	+	-
Nitinol	-	+	+

Table 3.2 – Chemical composition and density of materials

Material	Storage	Density
Stainless steel	C+Si+Mu+P+S+Cr+Ni+M	7.89 g/см^3
Platinoiridium alloys	Pt+Ir	21.5 g/см^3
Tantalum	Ta	16.65 g/см^3
Titanium	You	4.54 g/см^3
Cobalt chrome alloy	Co+Cr+Mo	8.8 g/см^3
Nitinol	Ni+Ti	6.45 g/см^3

Based on the practically obtained data, we can say that the density affects the X-ray contrast of the material and possible artifacts.

3.3 Method of attaching the marker to the patient's body

For easier and clear attachment of the marker to the patient's body, it is advisable to use a transparent double biocompatible hypoallergenic polymer layer on an adhesive base, between which the label is located directly.

Materials used for adhesive plasters can be used as a basis. Among all types of plasters, it is worth highlighting:

1. Polymer patches (Fig. 3.10) – base: microperforated polyethylene film; adhesive surface: polyacrylate glue [32]. The color is transparent. Hypoallergenic plaster with a porous transparent film is air- and vapor-permeable, water-resistant; securely held, removed painlessly and without residue; easily tears in both directions; indifferent to X-ray radiation, resistant to temperature effects, so it can be successfully used for CT - diagnostics.

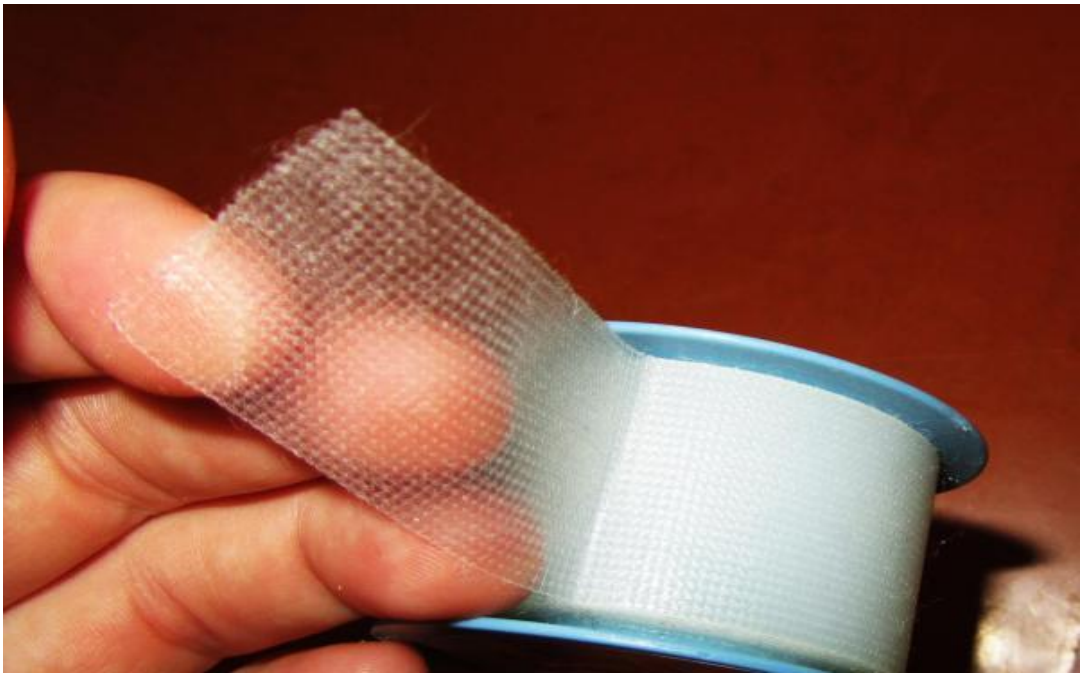

Figure 3.10 – Plaster on a polymer hypoallergenic base

2. Plaster on a fabric base (Fig. 3.11) - base: cotton; adhesive surface: polyacrylate glue, zinc oxide glue based on natural rubber [33]. The color is flesh-colored and white, which makes it impossible to clearly apply lasers and a reference mark, so the use of materials based on such adhesive plasters is impossible.

Figure 3.11 – Fabric-based patch

3. Plaster on a silk basis (Fig. 3.12) - basis: viscose silk; adhesive surface: polyacrylate glue [34]. Taking into account the fact that patients may experience minor body burns and an increased allergic reaction during radiation therapy, the use of silk-based plasters is not possible.

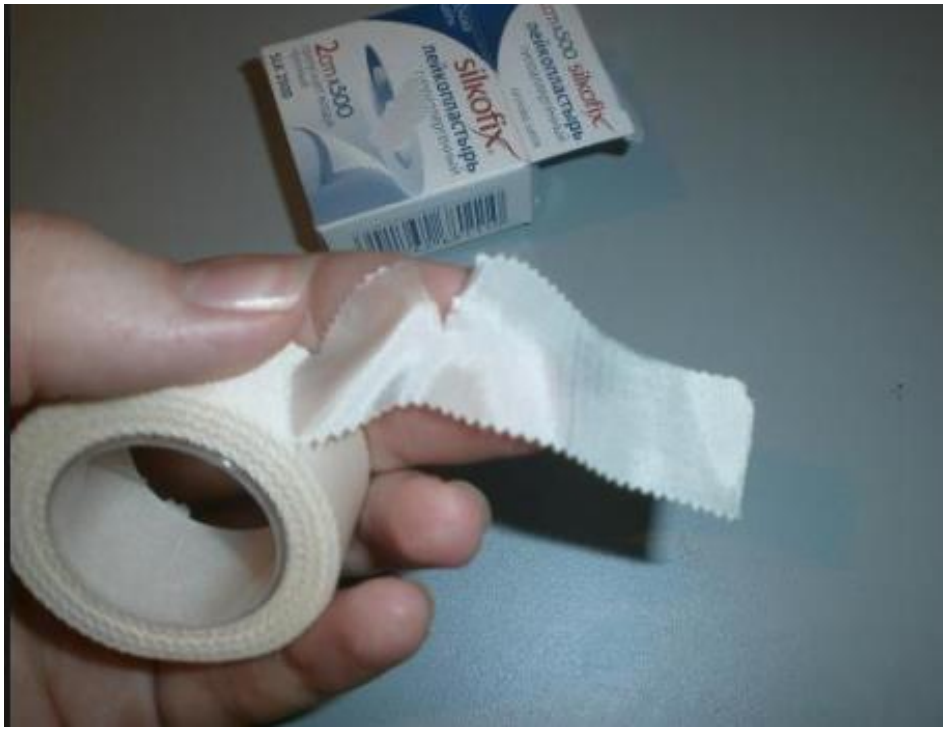

Figure 3.12 – Plaster on a silk base

Given the fact that the polymer plaster is transparent in color and hypoallergenic, it can be successfully used for CT - diagnostics.

3.4 Design of the finished product

Polymer-based markers with an adhesive base, which can already be used for topometric preparation, were designed using the Solid Works 2018 software (Fig. 3.13). This tag has a hypoallergenic adhesive layer and a porous transparent film that is air and vapor permeable, waterproof, securely held on the patient's body and painlessly and without residue removal with a good adhesive surface, easy to tear in

both directions, which ensures easy use, indifferent to X-rays , resistant to temperature effects

Figure 3.13 – Design of the finished product using Solid Works

The finished result can be implemented in clinical practice.

Conclusions to section III

In the course of experimental research, X-ray contrast materials were considered and the chosen cross-shaped label shape was justified. The best material for the label can be considered titanium and cobalt chrome alloy. I chose the method of attaching the tag to the patient's body and designed the final result using Solid Works 2018 software.

SECTION 4
LABOR PROTECTION

The thesis task has the following topic: "X-ray contrast reference marks for topometric sawing in radiation therapy", the purpose of which is the production of an X-ray contrast reference mark with the help of which the location and detailed scanning of the tumor is determined using an X-ray computer tomography. CT scans of various materials used in medicine were performed and the behavior of each of them was investigated. Toshiba Aqullion 64 hardware.

In this section of the diploma thesis, the room in which the testing of labels from different materials is carried out will be considered. Also, all dangerous and harmful phenomena that may occur in the future during work in the CT office will be considered, conclusions will be made about the compliance of working conditions with the established norms, and suggestions for their improvement will be put forward.

4.1. General characteristics of working conditions in the CT office.

Let us give the characteristics of the working conditions in the CT office (Table 4.1).

Table 4.1 – Characteristics of the premises

No	Name	Main characteristics	number	Position in the picture
Rooms				
1	Dimensions (office + control room)	6170×7300×3000 + 3000×6000×3000;S=63,041 m2; V=189.54 m3	-	-
2	Number of employees	X-ray technician, topometrist, radiation therapist, radiologist	4	-

Continuation Table 4.1

Decoration				
3	Ceiling thickness and coverage	200 mm, 0.5 mm thick lead	-	-
4.	Wall thickness and coating	500 mm (external), 250 mm (internal), 0.5 mm thick lead	-	-
5.	Floor thickness and coverage	200 mm, linoleum	-	-
Equipment and equipment				
6.	Naturally lit,	The window is tiltable Dimensions: 1200×1000 mm Material: plastic	2	-
7.	Door, OMiS Classic PG 1090	Dimensions 1090×2000 mm Material: iron with lead coating	1	-
8.	Drainage and water supply	Sink, CERSANIT PRESIDENT rectangular with back Dimensions: 550×420×150 mm Material: porcelain	1	17
9	Lamplight Eurolamp	Characteristics of 40W E40 6500K	4	-
10.	Toshiba Aquillion 64	Gentry: Dimensions 2280×768×1780 mm; Voltage 380-480 V, 50/60 Hz; The class of the product according to the method of protection is I, Product class by degree of protection:	1	1
		The patient's table The dimensions are 1700 x 750 x 520 mm Material: radiopaque iron, fabric upholstery and paralon. The maximum weight of the patient is 135 kg.	1	2
11.	Power connection cabinet	Dimensions 750×300×815 mm The material is wood	1	3
12	Laptop HP ProBook 4540S	Dimensions 380x265x200 Technical characteristics Screen 15.6" IPS (1920x1080)V=220V, I=1.8 A. 27.5 W	1	8
13	Cart for the monitor	Dimensions 540×580×1140 mm	1	4
14.	Injector system	Dimensions 650×600×800 mm	1	5
15.	Distribution cabinet	Dimensions 550×220×800 mm	1	6
16.	Control panel with container	Dimensions 600×858×700 mm	1	7
17	Image processing system with a container	Dimensions 660×860×700 mm	1	9

ContinuationTable 4.1

18.	Demonstration negatoscope	Dimensions 440×730×120 mm	1	10
20.	Doctor's desk	Dimensions 1132×630×750 mm	1	11
21.	Operator's desk (X-ray technician)	The dimensions are 1400×800×730 mm	1	12
22.	Chair	Dimensions 430×440×770	2	13
23.	X-ray protective viewing window	Dimensions 1000×800 mm	1	14
24.	Bactericidal wall-mounted irradiator	Dimensions 1070×140×80 mm	1	15
25.	Couch for the patient	Dimensions 1970×670×520 mm	1	16
26	Fire extinguisher VP-10	The dimensions are 300×300×500 mm	1	18

In fig. 4.1. the plan of the room of the CT office and the operator's room is shown.

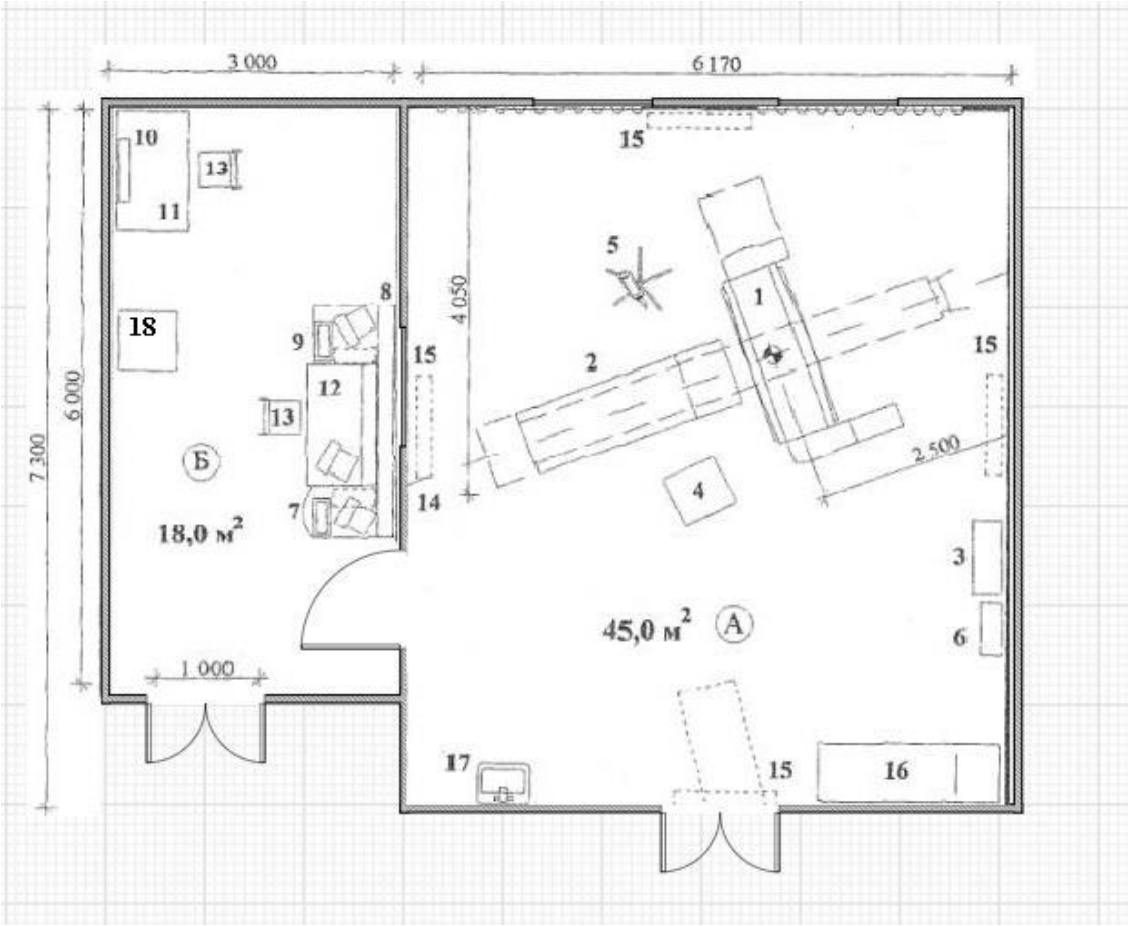

Figure 4.1–Plan of the room for CT - diagnostics

«A» - is an office, «B» - is an operator's room

The office for CT scanning should consist of two rooms: an office and an operator's room.

4.2 Compliance with the requirements of volume and area per employee and location of technological equipment

Let's calculate the volume and area of the premises for one employee:

$$S_1 = \frac{S_{ma} - S_{ea}}{n} = \frac{63{,}041 - 4{,}2}{4} = 14.71\ m^2 (4.1)$$

where S_{ma}– mixing area, S_{ea} – equipment area, n – number of employees.

$$V_1 = \frac{V_{vr} - V_{ve}}{4} = \frac{189{,}54 - 3.823}{4} = 46{,}43\ m^3 (4.2)$$

where V_{vr}–volume of the room, V_{ve}– volume of equipment, n- the number of employees.

Table 4.2–Comparison of the obtained data with normative values

Parameters	Normative value	Actual values
Usable area per 1 employee, (m2)	4.5	14.71
Useful volume per 1 worker, (m3)	15	46,43
Minimum width of passage	1.5	1.5
Distance from the machines to the walls in the working area (m):		
Toshiba Aquillion 64	1.00	2.5

After comparing the actual and normative parameters of the laboratory, it can be concluded that the premises meet all the requirements.Normalization measures are not required.

4.3 Assessment of dangerous and harmful production factors

Analysis of potential hazards created at indoor workplaces during the operation of technological equipment and development of measures to improve (normalize) working conditions.

During work, laboratory workers will encounter various harmful factors that will negatively affect their health, as a result of which labor productivity will decrease, which is extremely important for production.

Table 4.3 - Dangerous and harmful production factors

Physical	X-ray radiation	Electronic safety	Fire safety	Noise
Chemical	Lead dust in the air, on the surface of the equipment, the floor, walls, windows			
Biological	Airborne and contact transmission of infection.			

There is also an impact on health and a threat to the life of the patient and staff.

4.3.1 Danger associated with X-ray radiation

The room is equipped with gantry equipment, which emits X-ray radiation, which can pose a danger to a person if the duration of the session is not observed or the number of procedures is increased. The characteristics are given in table 4.4.

Table 4.4 - Consequences of X-ray radiation

No	The name of the equipment	A source of danger	Causes of danger	Consequences of danger

1	CT Toshiba Aqullion 64	X-ray radiation	Non-observance of the duration of the procedure or increase in the number of sessions, malfunction of the device	Impact on the immune system, nervous endocrine system, burns

Table 4.5-Real and normative values of X-ray radiation

No	The danger factor	Real value	Normative values
1	X-ray radiation	0.7 gentry/day	0.5 gentry/day

Table 4.6 – Hazard prevention measures

No	A group of nomenclature activities with OP	Event type	Selection criteria
1.	Technical measures	Lead hopper (cabinet) 0.5 mm thick	X-ray protection
2.	Organizational measures	Instruction on dose distribution	Training on safety during equipment operation
		Checking the health of the X-ray tube	Control of indicators and well-being of patients
3.	Regime	Illumination "Entry prohibited" from the time of the procedure, closing the entrance door, automatic shutdown of the device during unforeseen situations	Protection against exposure of outsiders
4.	Operational	Verification of measuring devices	Credibility of information
		Timely replacement of equipment parts that are out of order or damaged	Control of the performance of devices
5.	PPE	Unforeseen.	

4.3.2 Electronic safety

Since in the room where pre-radiation therapy is carried out, there are devices that consume electricity, according to the regulations, it belongs to the category with an increased risk of electrocution. Therefore, considerable attention is paid to the electrical safety of the assembly shop.

Table 4.7–The main sources of electronic safety, which are created in the technological process in the CT cabinet

No	The name of the equipment	A source of danger	Causes of danger	Consequences of danger
1	Toshiba Aquillion 64	the gentry	The presence of metal non-radiocontrast parts on the patient's body, the presence of pacemakers	electrocution, impaired cardiac activity and breathing, receiving other electrical injuries
		network cable	insulation damage (human and technological factor)	
2.	Laptop HP ProBook 4540S	network cable	insulation damage (human and technological factor)	electrocution, heart failure and breathing

Table 4.8 -Real and regulatory factors of sources of electronic safety, which are created in devices

No	The danger factor	Real value	Normative values
1	Direct current in CT nodes	510 mA	300 mA of direct current is a malfunction of the heart muscle
2	Alternating current in network power cables.	11 - 14 A	60 mA of alternating current with a contact time of 1s - malfunction of the heart muscle

Table 4.9 – Measures against electric shock

No	A group of nomenclature activities with OP	Event type	Selection criteria
1.	Technical measures	Grounding and use of fuses (PN-2). floor insulation with linoleum	Electrical insulation
2.	Organizational measures	Instruction on electrical safety	Training on safety during equipment operation
3.	Regime	See Table 4.7	
4.	Operational	Verification of measuring devices	Credibility of information

Continuation of table 4.9

		Timely replacement of equipment parts that are out of order or damaged	Control of the performance of devices
		Checking electrical devices using a megohmmeter at least once a year	Control of indicators of current surges
5.	PPE	Exclusion of the presence of non-X-ray contrast metal structures on the patient's body	Protection against electric shock

This room is classified as without increased danger, during the day it does not exceed 35°C; relative humidity less than 75. Non-conductive floor. Absence of conductive dust.

4.3.3 Fire hazard

Table 4.10 –The main sources of fire danger, which are created in the technological process of diagnostics

No	The name of the equipment	A source of danger	Causes of danger	Consequences of danger
1	Toshiba Aquillion 64	X-ray tube	A damaged X-ray tube can emit any dose of X-ray radiation, regardless of the specified parameters (technological factor)	The occurrence of a fire that can cause harm to a person, as well as damage or destroy equipment.
		Network cable	Insulation damage (human and technological factor)	
2	Laptop HP ProBook 4540S	Network cable	Insulation damage (human and technological factor)	The occurrence of a fire, which can harm a person, as well as destroy valuable equipment.

Table 4.11 – Characteristics of the premises

Classes and subclasses of possible fires	class A (A1)	Burning of solids accompanied by smoldering
	class E	Burning electrical installations under voltage
Combustibility groups of materials and substances present in this room	Non-combustible (non-combustible) and combustible (combustible). There are no substances capable of self-ignition in this room.	
Fire hazard category of the premises	category D,P-IIa class zone	A space within a building that contains solid combustibles and materials.

Table 4.12 - Safety measures

No	A group of nomenclature activities with OP	Event type	Selection criteria
1.	Technical measures	Availability of smoke detectors	Timely exit from the premises during a fire
		Using a VP-10 fire extinguisher, there is a fire hydrant and hose in the common corridor	Fire extinguishing method
2.	Organizational measures	Planned briefing on safety and evacuation techniques	Training on fire safety during equipment operation and evacuation
		Planned inspection of all equipment, timely detection and elimination of malfunctions	Equipment control
3.	Regime	See Table 4.7	
4.	Operational	Verification of measuring devices	Credibility of information
		Automatic means of extinguishing fires and alarms that provide notification of the start of a fire	Fire indication
5.	PPE	Respirators and masks, isolating self-rescuers	Individual protection

4.3.4 Noise

Table 4.13– Sources of noise

No	The name of the equipment	A source of danger	Causes of danger	Consequences of danger
1	Toshiba Aquillion 61	Gentry	X-ray radiation	Depression of the central nervous system.

Table 4.14 -Actual and normative values

No	The danger factor	Real value	Normative values
1	X-ray tube	70 dBA	50 dBA

Table 4.15 - Safety measures

No	A group of nomenclature activities with OP	Event type	Selection criteria
1.	Technical measures	Not provided	
2.	Organizational measures	Not provided	
3.	Regime	Not provided	
4.	Operational	Not provided	
5.	PPE	Means of protection against noise (headphones).	Blockage of sound wave paths to the patient's hearing aid

4.3.5 Biological hazard

Table 4.16–The main sources of biological danger that are created in the process of using CT

No	The name of the equipment	A source of danger	Causes of danger	Consequences of danger
1	Toshiba Aquillion 64	The surface of the patient's table	Microorganisms are the causative agents of diseases that are transmitted through skin-to-skin contact.	Skin disease.

Table 4.15-Real and normative values of biohazard sources.

No	The danger factor	Real value	Normative values
1	Microorganisms on the surface of the table	Presence.	Absence.

Table 4.16 - Safety measures

No	A group of nomenclature activities with OP	Event type	Selection criteria
1.	Technical measures	Not provided.	
2.	Organizational measures	Briefing on biosafety issues	Training on safety during equipment operation
3.	Regime	Not provided	
4.	Operational	Wiping the patient's table with antiseptic solutions	Reduction of the number of microorganisms.
5.	PPE	Disposable gloves.	Reducing the risk of infection.

Conclusion to SECTION IV

In this section, the working conditions in the room for CT were analyzed, according to the calculations, they satisfy the normative value.

Also considered are the main types of danger, such as fire, electrical, biological, X-ray radiation, and noise. A number of measures have been developed to reduce the risk of occurrence of each of the hazards.

CONCLUSIONS

In the course of this work there were:

1. A review of the literature and basic concepts of radiation therapy was conducted.

2. The stages of treatment are considereddetailing the first stage - the stage of topometric preparation of the patient, which is considered one of the most important steps in the treatment, where anatomical and topographic sections of the tumor are made.

3. X-ray contrast materials were selected and their comparative characteristics were carried out in relation to CT images, which were formed as a result of overlaying the image of the material and the CT image of the patient, taken from the official website of the Accuray company (USA).

4. The best artifact-free reference tag material is titanium and cobalt-chromium alloy.

5. I chose the best shape of the label - cross-shaped with the following dimensions:

0.8 × 0.8 cm, 0.4 × 0.4 cm, 0.2 × 0.2 cm, depending on the volume of tumors.

6. Using SolidWorks 2018 software, a cross-shaped label was designed from titanium and cobalt chrome alloy.

7. A comparative characterization of the materials for attaching the label was carried out and the method of attachment to the patient's body was chosen.

8. A patch on a microperforated polyethylene film with an adhesive surface containing polyacrylate glue, which is indifferent to X-ray radiation and resistant to temperature effects, was used to attach the label.

9. Using Solid Works 2018 software, a reference radiopaque label with a mounting surface was designed.

REFERENCES

1. Fedorenko Z.P. Cancer in Ukraine, 2014–2015. Morbidity, mortality, performance indicators of the oncology service / Z. P. Fedorenko, Yu. Y. Mykhailovych. // Bulletin of the National Chancery Registry of Ukraine. – 2016. – No. 18. - P. 124.

2. Fedorenko Z.P. Cancer in Ukraine, 2014–2015. Morbidity, mortality, performance indicators of the oncology service / Z. P. Fedorenko, Yu. Y. Mykhailovych. // Bulletin of the National Chancery Registry of Ukraine. – 2016. – No. 18. - P. 147.

3. A. V. Boyko Modern radiation therapy: achievements and prospects / A. V. Boyko, G. B. Goldobenko, K. N. Kostromin // Vopr. oncology - 2015. - Vol. 41, No. 2. - P. 83–90.

4. Dependence of the results of radiation therapy of patients with malignant neoplasms on the method of topometric preparation / V. S. Ivankova, T. V. Skomorokhova, O. Yu. Stolyarova, V. A. Pylnov // VII Congress of the Ukrainian Society of Radiation Oncologists (UTRO) with the participation of international specialists, June 28–30, 2017, Chernivtsi. - Ukr. radio journal – 2017. – Appendix 3. – P. 48–49.

5. Modern methods of radiation therapy / I. I. Minaylo, O. I. Vorobeychikova, N. A. Artemova, V. V. Synayko. // 3. – 2015. – P. 320–322.

6. A practical guide to ICRU 50 volume and dose specifications for 3D conformal therapy / Purdy JA, Starkschall CF, // A Practical Guide to 3D Planning and Conformal Radiation Therapy. - 2014. - C. 25-34.

7. Ensuring the quality of remote radiation therapy in cancer patients / V. S. Ivankova, T. V. Skomorokhova, G. M. Shevchenko [and others] // Radiation diagnostics, radiation therapy – 2016. – No. 2–3. – pp. 85–87.

8. Intraoperative radiation therapy: reality and perspective / Novikov V. A., Vasiliev R. V., Choinzonov E. L. [and others] // Malignant tumors. – 2017. – Vol. 3, No. 1. – P. 35–40.

9. Main stages of development of radiation therapy methods and contemporary preparation of oncological patients for conformal irradiation / Panshin G.A. // Bulletin of the Russian National Research Council. – 2014. P. 212–223.

10. Results of cancer radiation therapy / O.A. Kravets, L.A. Maryina, M.I. Nechushkin. // Herald of the Russian National Center for N.N. Blokhin RAMS. 2014. - No. 21(1). – pp. 12–16.

11. Moskvyna N.A. Optimizing radiation regimes in radiation therapy: diss. Ph.D. physics and mathematics Nauk / N. A. Moskvyna – Irkutsk, 2004. – 149 p

12. Kozhanov L.G. Principles of early diagnosis of malignant neoplasms / L.G. Kozhanov, N.Kh. Shatskaya, L.A. Luchikhin. // Herald of otorhinolaryngology. – 2018. – No. 5. - pp. 7–10.

13. The influence of the quality of topometric training on the effectiveness of treatment of patients with malignant neoplasms / V. S. Ivankova, T. V. Skomorokhova, O. Yu. Stolyarova, G. V. Galyas // Ukr. radio journal – 2017. – Vol. 25, issue 2. – P. 117–122.

14. The role of topometric training in the treatment of patients with locally advanced forms of malignant neoplasms / V. S. Ivankova, T. V. Skomorokhova, T. V. Khrulenko, H. M. Shevchenko, G. L. Gorelina, I. Yu. Lyalka , I. P. Otroshchenko, L. T. Khrulenko, N. P. Dotsenko // Olbia Forum - 2012: Strategies of Ukraine in the geopolitical space: theses of international science and practice conference, Sevastopol, June 6–10, 2012. – Mykolaiv, 2012. – Vol. 3. – P. 28–29.

15. Skomorokhova T. V. Optimization of planning and radiation treatment of patients with tumors of the upper respiratory tract: dissertation. Ph.D. honey. Sciences / Skomorokhova T. V. – Kyiv, 2020. – 207 p.

16. Implementation of modern technologies in the practice of radiation therapy for patients with malignant tumors of the upper respiratory tract / V. S. Ivankova, T. V. Skomorokhova, O. Yu. Stolyarova, N. P. Dotsenko, A. A. Makarenko, G. V. Galyas // Ukr. radio journal – 2016. – Vol. 24, issue 2. – P. 53–58.

17. Comparative assessment of the effectiveness of radiation treatment of malignant tumors of the upper respiratory tract / V. S. Ivankova, T. V. Skomorokhova, O. Yu. Stolyarova, M. I. Krotevich, M. I. Palii, N. P. Dotsenko, V T. Perepechkina, L. T. Khrulenko // Radiology in Ukraine: II Nation. congress with international participation, March 26–28, 2018, Kyiv. – Radiation diagnostics, radiation therapy. – 2018. – No. 1–2. - p. 120.

18. Implementation of modern technologies in the practice of radiation therapy in oncological patients / V. S. Ivankova, O. Yu. Stolyarova, M. S. Krotevich, M. I. Palii // Olviy forum – 2019: scientific materials. - practice conf. - Scientific works. "Man-made safety" series. – 2019. – Issue 198, vol. 210. - pp. 109–113.

19. Implementation of a new technology of radiation treatment of patients with malignant brain tumors using a linear accelerator / O. B. Knyazeva, T. V. Udatova, L. T. Khrulenko, N. B. Dotsenko, G. Yu. Chornai, T. I Loshak, L.R. Romanova, E.V. Korobko // Ibid. - P. 193-194.

20. Mrochek A.G. Qualifying tests for radiation diagnostics: situational problems / A.G. Mrochek, A.N. Mykhaylov, A.G. Chernenko. - Minsk, 2020. – P. 442.

21. The prediction of late rectal complications in patients treated with high dose – rate brachytherapy for carcinoma of the cervix / B. Clark, L. Souhami, T. Roman [et al.] // Int. J. Radiat. Oncol. Biol. Phys. – 2018. - Vol. 38, No. 5. - P. 989-993.

22. Possibilities of the differentiated approach of the combined application of remote radiation therapy and high-dose brachytherapy in patients with locally advanced cervical cancer / N. V. Tyueva, V. G. Dubinina, O. V. Lukyanchuk [and others] // Ukr. radio journal - 2019. - Vol. 21, issue 2. – PP. 241–244.

23. Vasylchenko I. L. The use of local induction heating in the treatment of malignant neoplasms / I. L. Vasylchenko, M. V. Vynogradov, D. A. Pastushenko // Vopr. oncology - 2019. - Vol. 59, No. 2. - P. 84.

24. Feller L. Oral Squamous Cell Carcinoma: Epidemiology, Clinical Presentation and Treatment / L. Feller, J. Lemmer // J. Cancer Therapy. - 2012. - Vol. 3. – P. 263–268.

25. Complex treatment of patients with resectable cancer of the oral cavity stages III-IV. Modern state of the problem / O. V. Kravets [et al.] // Klin. oncology – 2016. – No. 4 (12). - pp. 62–66.

26. Stainless steel. Designation according to international standards [Electronic resource] // Goodner. – 2019. – Resource access mode: http://www.goodner.ru/services/info/marks/316l-ti/. – Access date: 04/26/2023

27. Platinum alloys with iridium [Electronic resource] // Chemist's Handbook 28. – 2021. – Resource access mode: https://chem21.info/info/444935/. – Access date: 04/26/2023

28. Refractory metal tantalum [Electronic resource] // Metotechnika - Mode of access to the resource: https://www.metotech.ru/tantal-opisanie.htm. – Access date: 04/21/2023

29. A. Ilyin A. A. APPLICATION OF TITANIUM AND TITANIUM ALLOYS IN MEDICINE [Electronic resource] / A. A. Ilyin, M. Yu. Kollerov // Electron-radiation Metallurgical Plant - Resource access mode: http://www.titanium - fiko.com.ua/pages/webmed/medik1.htm. – Date of access: 23/04/2023

30. Unusual properties of nitinol and its application in medicine [Electronic resource] // Medical Internet Conferences - Resource access mode: https://medconfer.com/node/5453. – Access date: 04/22/2012

31. ALLOYS OF PRECIOUS METALS [Electronic resource] // Основы МЕТЕРИАЛОВЕДЕНИЯ – Resource access mode: https://dentaltechnic.info/index.php/obshie-voprosy/ – Access date: 04/21/2023

32. L/PLASTYIR ON A POLYMER BASE HYPOALLERGENNY [Electronic resource] // Торговый дом "Veramed" - Mode of access to the resource: http://вера-мед.рф/l-plastyir-na-polimernoy-osnove-gipoallergennyiy-1- sm-h-500sm-kartup-ka. – Access date: 05/22/2023

33. HYPOALLERGENY TISSUE-BASED L/PLASTYIR [Electronic resource] // "Veramed" - Resource access mode: http:///l-plastyir-na-tkanevoy-osnove-gipoallergennyiy-1- sm-h-500sm-kartup-ka. – Access date: 05/22/2023

34. PLASTER ON SILK BASE [Electronic resource] // Veramed - Mode of access to the resource: http:///lplastyr-na-shelkovoj-osnove-gipoallergennyj-125-sm-h -500-sm – Access date: 05/22/2019