TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Министерство науки и высшего образования Российской Федерации
федеральное государственное автономное
образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

School School of Nuclear Science & Engineering
Field of training (specialty) 14.04.02 «Nuclear Physics and Technology»
Division Division for Nuclear-Fuel Cycle

MASTER'S GRADUATION THESIS

Topic of research work
Radiotherapy course optimization for patients with colorectal cancer

UDC 539.16.04:616-018:15.849:616.351-006.6

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Group	Full name	Signature	Date
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ADMITTED TO DEFENSE:

Director of programme	Full name	Academic degree, academic rank	Signature	Date
Nuclear medicine	Cherepennikov Yu.M.	Ph.D		

Tomsk – 2020

Expected learning outcomes

Learning outcome (LO)code	Learning outcome (a graduate should be ready)	Requirements of the FSES HE, criteria and / or interested parties
Professional competencies		
LO1	To apply deep mathematical, scientific, socio-economic and professional knowledge for conducting theoretical and experimental research in the field of the use of nuclear science and technology.	FSES HE Requirements (BPC-1,2, PC-3, UC-1,3), Criterion 5 RAEE (p 1.1) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO2	To demonstrate ability to define, formulate, and solve interdisciplinary engineering tasks in the nuclear field using professional knowledge and modern research methods.	FSES HE Requirements (PC-9,10,13,14,15, BPC-1,3), Criterion 5 RAEE (p 1.2) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO3	To plan and conduct analytical, simulation and experimental studies in complex and uncertain conditions using modern technologies, and to evaluate critically research results.	FSES HE Requirements (PC-1,13,22, UC-2, BPC-1), Criterion 5 RAEE (p 1.3) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO4	To use basic and special approaches, skills and methods for identification, analysis, and solution of technical problems in the field of nuclear science and technology.	FSES HE Requirements (PC-2,4,6,8, UC-2, BPC-1), Criterion 5 RAEE (p 1.4) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO5	To operate modern physical equipment and instruments, to master technological processes in the course of preparation for the production of new materials, instruments, installations, and systems.	FSES HE Requirements (PC-5,7,11,12, UC-2, BPC-1), Criterion 5 RAEE (p 1.4) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"

LO6	To demonstrate ability to develop multioption schemes for achieving production goals with the effective use of available technical means and resources.	FSES HE Requirements (PC-16-21,23), Criterion 5 RAEE (p 1.5) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
Cultural competencies		
LO7	To demonstrate ability to use a creative approach to develop new ideas and methods for designing nuclear facilities, as well as to modernize and improve the applied technologies of nuclear production.	FSES HE Requirements (BPC-1,3, UC-3), Criterion 5 RAEE (p 2.4,2.5)
Basic professional competencies		
LO8	To demonstrate skills of independent learning and readiness for continuous self-development within the whole period of professional activity.	FSES HE Requirements (UC-3, PC-1, BPC-1), Criterion 5 RAEE (p 2.6) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO9	To use a foreign language at a level that enables a graduate to function successfully in the international environment, to develop documentation, and to introduce the results of their professional activity.	FSES HE Requirements (PC-11,16,17, BPC-3), Criterion 5 RAEE (p 2.2) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO10	To demonstrate independent thinking, to function efficiently in command-oriented tasks and to have a high level of productivity in the professional (sectoral), ethical and social environments, to lead professional teams, to set tasks, to assign responsibilities and bear liability for the results of work.	FSES HE Requirements (PC-18,23, UC-2), Criterion 5 RAEE (p 1.6,2.3) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"

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School School of Nuclear Science & Engineering
Field of training (specialty) 14.04.02 «Nuclear Physics and Technology»
Division Division for Nuclear-Fuel Cycle

APPROVED BY:
Director of the programme
_____ _____ Cherepennikov Yu.M.
(Signature) (Date) (Full name)

ASSIGNMENT
for the Graduation Thesis completion

In the form:

Master's thesis

For a student:

Group	**Full name**
0AM8M	Nguyen Tuan Anh

Topic of research work:

Radiotherapy course optimization for patients with colorectal cancer	
Approved by the order of the Director of School of Nuclear Science & Engineering (date, number):	

Deadline for completion of Master's Graduation Thesis:	

TERMS OF REFERENCE:

Initial data for research work: *(the name of the object of research or design; performance or load; mode of operation (continuous, periodic, cyclic, etc.); type of raw material or material of the product; requirements for the product, product or process; special requirements to the features of the operation of the object or product in terms of operational safety, environmental impact, energy costs; economic analysis, etc.)*	The result of the work will be a dosimetric analysis of the postoperative combined course of radiation therapy for colorectal cancer, using the XiO and HDRplus planning system with various topometric preparation methods

List of the issues to be investigated, designed and developed *(analytical review of literary sources with the purpose to study global scientific and technological achievements in the target field, formulation of the research purpose, design, construction, determination of the procedure for research, design, and construction, discussion of the research work results, formulation of additional sections to be developed; conclusions).*	Review of technical literature on this topic, conducting clinical dosimetry of radiation therapy devices, creating radiation plans for the stages of external beam radiation therapy and brachytherapy, calculation of radiation dose on critical organs, analysis of the data obtained
List of graphic material *(with an exact indication of mandatory drawings)*	

Advisors to the sections of the Master's Graduation Thesis
(with indication of sections)

Section	Advisor
Financial Management, Resource Efficiency and Resource Saving	Menshikova E.V.
Social responsibility	Verigin D.A.

Date of issuance of the assignment for Master's Graduation Thesis completion according to the schedule	

Assignment issued by a scientific supervisor / advisor (if any):

Position	Full name	Academic degree, academic status	Signature	Date
Associate Professor,	Cherepennikov Yu.M.	Ph.D		
Medical physicist Cancer Research Institute of Tomsk NRMC RAS	Turgunova N.D.			

Assignment accepted for execution by a student:

Group	Full name	Signature	Date
0AM8M	Nguyen Tuan Anh		

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School School of Nuclear Science & Engineering
Field of training (specialty) 14.04.02 «Nuclear Physics and Technology»
Level of education Master Degree Program
Division Division for Nuclear-Fuel Cycle
Period of completion 2018/2019 and 2019/2020 academic years

Form of presenting the work:

Master's Thesis

SCHEDULED ASSESSMENT CALENDAR
for the Master's Graduation Thesis completion

Deadline for completion of Master's Graduation Thesis:	

Assessment date	**Title of section (module) / type of work (research)**	**Maximum score for the section (module)**
27.01.2020	1. Preparation of technical specifications and selection of research areas	10
24.02.2020	2. Development of a common research methodology	10
23.03.2020	3. Selection and study of materials on the topic	10
13.04.2020	4. Obtaining the necessary experimental data and verification of the results	20
27.04.2020	5. Processing received data	20
18.05.2020	6. Registration of the work performed	15
29.05.2020	7. Preparation for defending a dissertation	15

COMPILED BY:
Scientific supervisor

Position	**Full name**	**Academic degree, academic rank**	**Signature**	**Date**
Associate Professor	Cherepennikov Yu.M.	Ph.D		

Adviser

Position	**Full name**	**Academic degree, academic rank**	**Signature**	**Date**
Medical physicist Cancer Research Institute of Tomsk NRMC RAS	Turgunova N.D.			

AGREED BY:
Director of the programme

Position	**Full name**	**Academic degree, academic rank**	**Signature**	**Date**
Associate Professor	Cherepennikov Yu.M.	Ph.D		

TASK FOR SECTION
«FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE SAVING»

For a student:

Group	Full name
0AM8M	Nguyen Tuan Anh

School	School of Nuclear Science & Engineering	**Division**	Division for Nuclear-Fuel Cycle
Degree	Master Degree Program	**Field of training/programme**	14.04.02 Nuclear physics and technology / Nuclear medicine

Input data to the section «Financial management, resource efficiency and resource saving»:	
1. *Resource cost of scientific and technical research (STR): material and technical, energetic, financial and human*	*The cost of special equipment 170,978 rubles.* *The basic salary of performers is 189848 rubles.* *Additional salary performers 18985 rubles.* *Contributions to extrabudgetary funds 62651 rubles.* *Overhead costs 62651 rubles.* *Other direct costs 3,538 rubles.*
2. *Expenditure rates and expenditure standards for resources*	*Industrial electricity tariff 5.8 per 1 kW* *The regional coefficient of the city of Tomsk -1.3*
3. *Current tax system, tax rates, charges rates, discounting rates and interest rates*	*The amount of contributions to extra-budgetary funds is 30%.*
The list of subjects to study, design and develop:	
1. *Assessment of commercial and innovative potential of STR*	*Competitive Technical Scorecard*
2. *Development of charter for scientific-research project*	*Hierarchical structure of work*
3. *Scheduling of STR management process: structure and timeline, budget, risk management*	*Assessment of the competitiveness of technical solutions* *SWOT Matrix* *R&D schedule and budget* *Gantt Chart*
A list of graphic material *(with list of mandatory blueprints):*	
1. *"Portrait" of the consumer of the results of STR* 2. *Market segmentation* 3. *Evaluation of the competitiveness of technical solutions* 4. *FAST chart* 5. *SWOT- analysis* 6. *Gantt chart and budget of scientific research* 7. *Assessment of resource, financial and economic efficiency of STR* 8. *Potential risks*	

Date of issuance of the task for the section according to the schedule	

The task was issued by adviser:

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Menshikova E.V.	Ph.D		

The task was accepted by the student:

Group	Full name	Signature	Date
0AM8M	Nguyen Tuan Anh		

Task for section
«Social responsibility»

For a student:

group	Full name
0AM8M	Nguyen Tuan Anh

School	School of Nuclear Science & Engineering	**Division**	Division for Nuclear-Fuel Cycle
Degree	Master Degree Program	**Field of training/programme**	14.04.02 Nuclear Physics and Technology/Nuclear Medicine

Title of graduation thesis:

Radiotherapy course optimization for patients with colorectal cancer	
Initial data for section «Social Responsibility»:	
1. Information about object of investigation (matter, material, device, algorithm, procedure, workplace) and area of its application	Object of investigation: the postoperative combined course of radiation therapy in patients with colorectal cancer. Application area: Cancer institutes, oncology clinics in Russia and around the world
List of items to be investigated and to be developed:	
1. Legal and organizational issues to provide safety: – Special (specific for operation of objects of investigation, designed workplace) legal rules of labor legislation; – Organizational activities for layout of workplace.	– Labour code of Russian Federation #197 from 30/12/2001 GOST 12.2.032-78 SSBT – Sanitary Rules 2.2.2/2.4.1340-03. Hygienic requirements for PC and work with it
2. Work Safety: 2.1. Analysis of identified harmful and dangerous factors 2.2. Justification of measures to reduce probability of harmful and dangerous factors	– Enchanced electromagnetic radiation level – Insufficient illumination of workplace – Excessive noise – Deviation of microclimate indicators – Electric shock – Ionizing radiation
3. Ecological safety:	– Indicate impact of linear accelerator on hydrosphere, atmosphere and lithosphere
4. Safety in emergency situations:	– Fire safety;

Date of issuance of the task for the section according to the schedule	

The task was issued by consultant:

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Verigin D.A.	Ph.D		

The task was accepted by the student:

Group	Full name	Signature	date
0AM8M	Nguyen Tuan Anh		

Abstract

Master’s graduation thesis consists of 88 p., 15 fig., 33 tab., 23 sources.

Key words: critical organs, radiation dose, external beam radiotherapy, brachytherapy, topometric preparation, postoperative combined course of radiation therapy.

Object of study: methods for reducing the dose on critical organs.

Aim of work: Optimization of the postoperative combined course of radiation therapy in patients with colorectal cancer to reduce the dose to critical organs, taking into account modern approaches to dosimetric planning

During the study, the following was carried out: a study of the technical literature, conducting clinical dosimetry of radiation therapy apparatuses, creating dosimetric plans for a postoperative combined course of radiation therapy for colorectal cancer, calculation and analysis of radiation dose on critical organs.

As a result of the study, radiation dose on critical organs were evaluated, basic skills of creating plans for external beam radiation therapy and brachytherapy in XiO and HDRplus systems were mastered, experience was gained in contouring of critical organs.

Application area: in oncology clinics when creating plans for a postoperative combined course of radiation therapy for colorectal cancer.

The economic effectiveness of the significance of the work lies in the reduction of post-radiation reactions and, as a result, in the patients' better health. Master's thesis completed using the text editor Microsoft Office Word 2010

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Introduction

Every year, about 1 million new cases of colon cancer are diagnosed in the world and about 500 thousand patients die annually from this disease. Colon and rectal cancer is a malignant tumor of the colon, which ranks third in prevalence and accounts for 9.6% of all cancer cases in Russia [1].

Colorectal cancer is one of the most studied malignant tumors. As a rule, colorectal cancer is formed from benign intestinal polyps (adenomas). This process can take more than one year [2]. Signs and symptoms may include blood in the stool, weight loss, a change in bowel movements and always feeling tired. Most of the causes of bowel cancer are due to lifestyle and age factors, with only a few cases due to genetic disorders. Risk factors include diet, obesity, smoking, and less physical activity. Dietary factors that increase risk include red meat, processed meat for a long time, and alcohol. Another risk factor is inflammatory bowel disease, which includes Crohn's disease and ulcerative colitis. Some of the genetic conditions that can cause bowel cancer include: familial adenomatous polyposis (FAP) and hereditary nonpolyposis colorectal cancer (HNPCC). However, these cases are less than 5% of all cases. Bowel cancer usually begins with a benign tumor, usually in the form of a polyp, which gradually becomes cancerous [2].

The main approaches to the treatment of colorectal cancer are radiation therapy, chemotherapy and surgery. When conducting radiation therapy sessions, combined treatment is carried out, which includes brachytherapy and external beam radiation therapy. The main objective of radiation therapy is to irradiate the focus with minimal damage to normal tissues. The development of new approaches to optimizing the conduct of a postoperative combined course of radiation therapy in patients with colorectal cancer will reduce the dose load on critical organs and deliver the maximum dose to the tumor, which will improve the patient's quality of life.

Based on this problem, the aim of the work was set: Optimization of the postoperative combined course of radiation therapy in patients with colorectal cancer to reduce the dose load on critical organs, taking into account modern approaches to

dosimetric planning.

To achieve this aim, the following objectives were set:

1. A literature review of therapeutic approaches to the treatment of colorectal cancer;

2. Mastering the skills of using dosimetric planning systems XiO and HDRplus;

3. Creation of radiation plans for the external beam radiotherapy stage of the combined course of radiation therapy for colorectal cancer;

4. Creation of plans for irradiation of the brachytherapy stage of the combined radiation therapy course for colorectal cancer;

5. Calculation of radiation dose on critical organs for a combined course of radiation treatment for colorectal cancer;

6. Analysis of the results.

1 Therapeutic approaches to the treatment of colorectal cancer

1.1 The incidence of colorectal cancer

Colorectal cancer is a malignant tumor that develops from the cells of the rectum epithelium and is localized within 15 cm from the anus when measured with a rigid rectoscope [3]. In clinical practice and in describing the results of scientific research, rectal cancer is divided into lower ampullary (0-5 cm from the anocutanic line), medium ampullary (5-10 cm from the anocutanic line), upper ampullar (10-15 cm from the anocutanic line) [3].

Colorectal cancer accounts for approximately 12% of all cases of diagnosed colorectal cancer [4]. While the histological forms of these cancers are similar to the histological forms of colon cancer, their anatomical location below the peritoneum allows colon cancer to easily penetrate the surrounding pelvic soft tissue [4]. The close proximity to the anal sphincter and urogenital structures makes surgical excision more difficult and able to significantly affect the quality of life in the early stages of the disease [4].

The main danger of colorectal cancer is that in the later stages of development, it can cause intestinal obstruction (that is, completely block the intestinal lumen and obstruct the passage of food), and can also metastasize (i.e. form new foci of the disease) in the surrounding lymph nodes and other organs [3]. Fortunately, to date, most even advanced forms of colorectal cancer can be successfully cured, provided that the treatment is initially carried out by a qualified specialist in this field [3]. Most patients can fully recover and fully return to their usual lifestyle. The exception is situations when multiple metastases of colon cancer in other organs are initially detected [3]. But even in such cases, when it is impossible to completely cure, patients can significantly increase their life expectancy and alleviate the symptoms of the disease [3].

1.2 Clinical classification of rectal tumors

Colorectal cancer is a malignant tumor that develops from the cells of the rectum epithelium and is localized within 15 cm from the anus when measured with a

rigid rectoscope (C) [5]. In clinical practice and in describing the results of scientific research, the following classifications of colorectal cancer are used [5].

International Histological Classification (2010) [5]

Epithelial tumors

I. Benign tumors

a. Tubular adenoma.

b. Villous adenoma.

c. Tubulo-villous adenoma.

d. Adenomatous polyp.

II. Intraepithelial neoplasia (dysplasia) associated with chronic inflammatory bowel disease

a. High grade glandular intraepithelial neoplasia.

b. Low grade glandular intraepithelial neoplasia.

III. Crayfish*

a. Adenocarcinoma.

b. Mucous adenocarcinoma **.

c. Cricoid Cell Cancer ***.

d. Small cell carcinoma.

e. Squamous cell carcinoma.

f. Adeno-squamous cell carcinoma.

g. Medullary cancer.

h. Undifferentiated cancer.

* Tumors are divided into high (glandular structures are determined in more than 95% of cells), moderate (glandular structures are determined in 50-95% of cells), low-differentiated (glandular structures are defined in 5-50% of cells) and undifferentiated (glandular structures are determined in <5% of cells)

** Established if> 50% of the tumor volume is represented by extracellular mucus. Always regarded as low-grade.

*** Established if> 50% of the intracellular volume is represented by mucus. Always regarded as low-grade.

Colorectal cancer standardization according to TNM7 (2009) and Dukes [5]

For colorectal cancer, a single classification is used.

Symbol T (tumor) contains the following gradations:

TX - insufficient data to evaluate the primary tumor.

Tis - pre-invasive carcinoma (intra-epithelial invasion or invasion of the own plate of the mucous membrane).

T1 - the tumor spreads into the submucosal layer of the intestinal wall

T2 - the tumor spreads to the muscle layer, without germination of the intestinal wall.

T3 - a tumor sprouts all layers of the intestinal wall with spread into the pararectal tissue, without damage to neighboring organs.

For tumors located in the upper ampullar and rectosigmoid sections of the rectum (covered by the peritoneum), the T3 symbol characterizes the spread of the tumor to subserosis (the serous membrane does not germinate).

T4 - the tumor grows into the surrounding organs and tissues or the serous membrane when localized in the upper ampullar and rectosigmoid sections of the rectum (covered with peritoneum).

T4a - germination of the visceral peritoneum

T4b - germination in other organs and structures

The symbol N (nodules) indicates the presence or absence of metastases in the regional lymph nodes

NX - insufficient data to assess regional lymph nodes.

N0 - there are no lesions of regional lymph nodes.

N1 - metastases in 1-3 (inclusive) regional lymph nodes.

N1a - metastases in 1 regional lymph node.

N1b - 2-3 lymph nodes.

N1c - Disseminates in the mesentery without damage to the regional lymph nodes

N2 - metastases in more than 3 regional lymph nodes.

N2a - 4-6 lymph nodes are affected.

N2b - 7 or more lymph nodes are affected.

Symbol M (metastases) characterizes the presence or absence of distant metastases

M0 - there are no distant metastases.

M1 - the presence of distant metastases.

M1a - the presence of distant metastases in one organ.

M1b - the presence of distant metastases in more than one organ or peritoneum.

Dukes's A - Tumor growth is limited to the bowel wall

Dukes's B - A tumor spread to surrounding tissues; no lymph node metastases

Dukes's C - Tumors with any degree of local distribution in the presence of metastases in regional lymph nodes

The TNM system provides an AJCC/UICC stage classification that parallels the Dukes' classification system. The relationship between the Dukes' and TNM systems is shown in Table 1.1.

Table 1.1 – Grouping stages

Stage	**T**	**N**	**M**	**Dukes**
0	is	0	0	A
I	1, 2	0	0	A
II	3, 4	0	0	B
IIA	3	0	0	B
IIB	4a	0	0	B
IIC	4b	0	0	B
III	Any	1, 2	0	C
IIIA	1, 2	1	0	C

	1	2a	0	
IIIB	3, 4a 2, 3	1 2a	0 0	C
IIIC	4b 4a 3, 4a	1, 2a, 2b 2a 2b	0 0 0	C
IV	Any	Any	1	C
IVa	Any	Any	1a	C
IVb	Any	Any	1b	C

The T-stage indicates the depth of local infiltration of the tumor into the bowel wall, the N-stage information on lymph nodes involved by the tumor and the M-stage information on distant metastases. In table 1.2 show definitions of regional lymph nodes depending on the location of the tumor

Table 1.2 - Definition of regional lymph nodes depending on the location of the tumor

Tumor location	Regional lymph nodes
Rectum	Rectalis superior, mesorectum lymph nodes, lateral sacral, presacral obstructive, mesenterica inferior

Kikuchi Staging of Early Colorectal Cancer [5]

When planning a local excision of T1 rectal cancer, a detailed staging of the disease is proposed according to the following criteria based on MRI and TRUS data:

T1sm1 - depth of invasion of the submucosal layer to 1/3.

T1sm2 - moderate depth of invasion of the submucosal layer - up to 2/3

T1sm3 - complete tumor invasion of the entire submucosal layer

When the T1sm3 stage is established, the risk of regional lymph node damage reaches 20-27% and, in the absence of clinical contraindications, patients should be offered surgery in the amount of total or partial mesorectumectomy. The final staging

according to Kikuchi is carried out according to the results of histological examination after removal of the tumor.

1.3 Colorectal Cancer Therapy

Studies have shown that these various treatment approaches provide similar benefits regardless of the patient's age. However, older adults may have unique treatment challenges. Learn more about the specific effects of surgery, chemotherapy, and radiation therapy on older adults. In order to tailor the treatment to each patient, all treatment decisions should consider such factors as:

- The patient's other medical conditions
- The patient's overall health
- Potential side effects of the treatment plan
- Other medications that the patient already takes
- The patient's nutritional status and social support
- Below are explanations about each main type of colorectal cancer treatment.

1.3.1 Surgery

Before surgery, in all patients with colorectal cancer, it is necessary to obtain informed consent for surgical intervention and the formation (even if this is not assumed in the plan of operation) of a colostomy (C) [6]. Routine mechanical preparation of the intestine does not affect the number of complications according to randomized trials, but can be performed at the discretion of the operating surgeon (B) [5].

If the cancer is found at a very early stage, it can be removed during colonoscopy. For people with localized cancer, the most appropriate treatment is to complete excision surgery with the appropriate margin. This can either be done by open abdominal surgery or sometimes internal star surgery. The colon may be resumed or there may be a colon (an external device).

If only a few metastases in the liver or lungs can also be removed. Sometimes chemotherapy is used before surgery to shrink the cancer before trying to remove it.

The two most common places of recurrence of colorectal cancer are liver and lung.

When more than 80% of colorectal cancer arises from adenoma polyps, this cancer screening is effective not only for early detection but also for prevention. Screening for colon cancer cases tends to occur two to three years before a diagnosis of symptomatic cases. Any polyps found can be removed, usually by endoscopy, and thus prevent cancer from turning into. Screening is able to reduce colorectal cancer deaths by 60%.

The three main screening tests are blood occult stool test, flexible sigmoidoscopy, and colonoscopy. Of the three, only sigmoidoscopy may not screen on the right side of the colon, where 42% of all malignant tumors are found. colonoscopy via a CT scan appears as good as standard endoscopy to detect large but expensive cancers and tumors, combined with radiation exposure, and cannot eliminate any abnormal growth detected as Standard endoscopy.

1.3.2 Chemotherapy

In both colon and rectal cancers, chemotherapy may be used in addition to surgery in certain cases. The decision to add chemotherapy in the management of colon and rectal cancer depends on the stage of the disease. In stage I colon cancer, no chemotherapy is indicated, and surgery is the definitive treatment. The role of chemotherapy in Stage II colon cancer is controversial, and is often not provided unless risk factors such as tumor T4 or incomplete sampling lymph nodes are identified. It is well known that patients who perform abnormalities of inappropriate gene repair do not benefit from chemotherapy. For stage III and stage IV colon cancer, chemotherapy is an integral part of treatment.

The minimum amount of chemotherapy for stage IIB-III includes fluoropyrimidines, which can be used in various ways: by jet (Mayo clinic mode, Roswell Park), infusion (De Gramount, AIO modes) or orally (capecitabine) (Table 1.3). 5-fluorouracil jet modes are more toxic, but no less effective in adjuvant therapy than infusion.

Table 1.3 – Modes of fluoropyrimidines used in the treatment of colorectal cancer.

Mode	Scheme
Clinics of Meiko	A drug of 20 mg / m2 iv in the stream followed by a bolus of 5-FU 425 mg / m2, 1-5 days. Beginning of the next course on the 29th day
Roswell Park	LV 500 mg / m2 iv 2-hour infusion followed by a 5-FU bolus 500 mg / m2. Weekly for 6 weeks followed by a 2-week break.
AIO	LV 500 mg / m2 iv for 2 hours followed by 24-hour infusion of 5-FU 2600 mg / m2 Weekly, long lasting.
Modified LV5FU2 (modified De Gramont mode)	An IV drug of 400 mg / m2 iv for 2 hours followed by a 5-FU bolus of 400 mg / m2 and a subsequent 46-hour infusion of 5-FU 2400 mg / m2 (1200 mg / m2 per day). Beginning of the next course on the 15th day.
Capecitabine	2500 mg / m2 per day for 1-14 days. Beginning of the next course on the 22nd day.

1.3.3 Radiotherapy

Intraoperative radiotherapy (IORT) refers to the treatment in the operating room which is specially equipped to provide radiation during surgery [6]. IORT is usually performed when surgery for locally widespread cancer or stage 2 to stage 4 cancer has recur in the pelvis. Several studies have demonstrated good control of recurrence tumors when surgery is combined with both IORT and traditional radiotherapy. External beam radiation (EBRT) therapy can be more accurately moved to cancer areas by using CT scanners and special computers. This ability is called holographic radiation or 3D-CRT. The use of 3D-CRT appears to reduce the likelihood of damage to nearby normal organ structures, such as the bladder or

rectum because 3D-CRT may better target cancer areas. Intensively modulated radiotherapy should be used only in clinical trials or in non-standard clinical situations, for example, repeated irradiation in case of relapse or in case of unique anatomical features of the patient [6]. The amount of radiation includes the primary tumor and regional lymph nodes (presacral and internal iliac) (Table 1.4) [6].

In the treatment of colorectal cancer, radiation therapy as a supportive method before and after surgery, in some cases, is indicated alone. According to the doctor's cancer treatment regimen, depending on each case, the appointment of radiation therapy for colorectal cancer patients has different purposes:

- Support for pre-surgical treatment helps to reduce malignant tumors, creating favorable conditions for more successful surgeries. Radiotherapy may also be used in combination with chemotherapy prior to colorectal cancer surgery to kill more cancer cells.
- Supporting postoperative treatment to prevent recurrence of cancer: With colorectal cancer, it is still possible for cancer cells to attach to an internal organ or to the abdominal wall. In this case, the surgeon is not sure that all the cancer cells are removed, so radiation therapy is often ordered after surgery to assist in killing the remaining cells, helping patients reduce the risk. relapse of disease.
- Radiotherapy alone: Radiotherapy is also used alone for patients who do not meet the health conditions for surgery, or to treat patients with recurrent colon cancer. For patients with advanced cancer, radiation also plays a role in reducing pain, alleviating the symptoms of colon cancer and prolonging life for patients.

Radiation cancer is rarely used in the treatment of metastatic colon cancer.

Table 1.4 – Principles for planning radiation therapy for colorectal cancer (Table Russco – Brief guidelines for radiation therapy of colon cancer: preradiation preparation, contouring, planning principles)

Target volume	Definition and Description
GTV (gross tumor volume)	– Primary tumor: the entire tumor volume, as determined by examination – Regional lymph nodes: include all lymph nodes with a size of ≥1.5 cm
CTVHR (high-risk clinical target volume)	– Includes GTV with a minimum indentation of 1.5–2 cm down, the entire rectum, – the peritoneum, presacral and retrosacral space, but excludes intact bones, muscles or air – 1-2 cm should be added to the border around the areas of tumor invasion in neighboring organs – The capture of the entire sacral space and mesorectum should be considered. – Any mesorectal lymph nodes visible on CT and MRI should be included.
Clinical volume of standard risk (CTV-SR)	– Covers the entire mesorectum, the right and left internal iliac lymph nodes for - T3 tumors, the right and left external lymph nodes - for T4 tumors – For T4 tumors with spread to adjacent organs, 1-2 cm should be added towards invasion – Upper border: entire rectum, mesorectum (usually up to L5 / S1) and at least 2 cm above the macroscopic spread of the tumor – Lower bound: CTV should extend to the bottom of the pelvis or at least 2 cm below the macroscopic spread of the tumor

	– To cover the lymph nodes, a border of 0.7 cm should be made around the iliac vessels (with the exception of muscles and bones) – To cover the external iliac vessels (for T4 lesions), it is necessary to expand the border by 1 cm in the anterior-lateral direction – Any adjacent small lymph nodes should be included in the volume. – 1–1.5 cm per bladder should be added in front to account for changes in the filling of the bladder and rectum – 1.8 cm of the width of the volume between the external and internal iliac vessels is required to cover the obstructive lymph nodes
PTV (planning target volume)	– Each CTV + 0.5–1 cm, depending on the level of training of the doctor, the accuracy of reproduction of the styling, the frequency of image processing, as well as the use of IGRT

Doses of radiotherapy

A genus of 1.8 Gy to an TD of 50.4 Gy or a genus of 2 Gy to an TD of 50–52 Gy [6]. Inoperable tumors may require an TD of more than 54 Gy, if it is technically possible. The restriction of TD to the small intestine is 45 Gy. Fluoropyrimidine-based chemotherapy should be given simultaneously with RT. A short course of RT (5 Gy × 5 fractions) can be performed in patients with T3 tumors according to an MRI study. Surgical intervention is performed within 3 days after completion of the large-fraction RT course (surgical treatment is acceptable 4-6 weeks after its completion). Surgical treatment in the range from 3 days to 4 weeks after completion

of RT may be associated with an increased risk of postoperative reactions and is not recommended [6].

If there is a suspicion of involvement of the lateral edge of the resection according to the data of a preoperative examination or low-lying tumors, CLT is indicated against fluoropyrimidines. Surgical intervention is performed after 8 weeks. after completion of a prolonged course of chemoradiotherapy. In case of locally widespread inoperable tumors (with T4N0-2), a prolonged course of simultaneous CLT is mandatory at the first stage. Adjuvant distant radiotherapy: with ${}_{p}T_{3b-4}N_{0-2}$, ${}_{p}T_{1-4}N_{1-2}$ or involvement of the lateral edge of the resection, postoperative CRT in TD 50–52 Gy is indicated during therapy with fluoropyrimidines followed by adjuvant chemotherapy. Only in some highly located pT3N0 tumors after radical intervention and without negative prognostic factors is it possible to refuse adjuvant RT and CT. With technical availability, it is possible to supplement the course of RT using local hyperthermia on the 3rd, 4th and 5th days with a temperature of 41–43 ° C for 60 minutes [6].

Brachytherapy

Brachytherapy was carried out on the MultiSourse HDR gamma therapeutic apparatus in the regime: dose per fraction 3.0 Gy, multiplicity - 2 times to the implant to TD 15.0 Gy. Dosimetric planning was carried out using the HDR system based on SKT data. The ionizing radiation source in the perrest applicator was sequentially moved along the catheter in increments of 5 or 10 mm. The maximum number of active positions in the applicator was 15, which made it possible to widely vary the size of the irradiated target during further dosimetric planning with optimization of the dose distribution under fractional exposure [7].

1.4 Features of the treatment of colorectal cancer with stage $T_3N_1M_0$

In case of localized and locally advanced rectal cancer of the $T_3N_1M_0$ stage with lower ampullary tumor localization, it is recommended that preoperative radiation / chemoradiotherapy and subsequent radical surgical treatment be included in the volume of total or partial mesorectumectomy [4].

The level of credibility of the recommendations is A (the level of credibility of evidence is Ia)

Comments: When a tumor is localized in the mid-ampullar region and there is no involvement of the circular edges of the resection (based on MRI data), two options for preoperative therapy are possible:

1) a course of external conformal radiation therapy. dose per fraction for the primary tumor and the region of regional metastasis of 5 Gy, 5 fractions up to TD 25 Gy for 5 consecutive days, followed by surgical treatment for 3 days; permissible increase in the time interval before surgery up to 4-6 weeks [4];

2) a course of external conformal radiation therapy in combination with chemotherapy with fluoropyrimidines. Radiation therapy dose per fraction 2 Gy, TD 44 Gy on the zone of regional metastasis. TD 50-54 Gy per primary tumor. Treatment daily, 5 times a week, with photons of 6-18 MeV (see section 4.3). Surgical intervention is planned 6-8 weeks after completion of chemoradiotherapy [4].

3) in specialized clinics for patients with tumor localization in the mid-upper ampullar part of the rectum with lesions of ≤ 3 lymph nodes according to MRI data of less than 10 mm and uninvolved mesorectal fascia, surgical treatment without preoperative radiation / chemoradiotherapy is acceptable [4].

If potential circular edges of the resection are suspected according to preoperative examination (MRI) or low-lying tumors, a course of external conformal radiation therapy is indicated in combination with chemotherapy with fluoropyrimidines. Radiation therapy dose per fraction 2 Gy, TD 44 Gy on the zone of regional metastasis. TD 54 Gy per primary tumor. Treatment daily, 5 times a week, with photons of 6-18 MeV. Surgical intervention is planned 6-8 weeks after the end of the course of chemoradiotherapy. In elderly patients with severe concomitant diseases, it is permissible to conduct external conformal radiation therapy of dose per fraction 5 Gy, TD 25 Gy for 5 consecutive days with a prolonged interval (6-10 weeks) before evaluating the effect and resolving the issue of surgical intervention [4].

It is possible to use a simultaneous integrated boost using intensely modulated radiation therapy. For example: T3N0-1

- PTV (standard risk): 1.8 Gy / fraction - 45Gy [4]
- PTV (high risk): 2.0 Gy / fraction - 50Gy [4]

2 Assessment of critical organ dose rates in the treatment of colorectal cancer

2.1 Equipment for topometric preparation

2.1.1 Computed tomography scanner SOMATOM Emotion

The Siemens SOMATOM Emotion tomography (Figure 2.1) is the minimum radiation exposure in the industry with high-quality imaging [9]. The basic equipment of SOMATOM Emotion is equipped with an effective air cooling system of the gantry. In addition, it includes powerful means of three-dimensional post-processing of images, angiography and multiplanar reconstruction. There is an expanded set of additional software and hardware-software packages [9].

Figure 2.1 – Computed tomography scanner SOMATOM Emotion

The device provides expert-grade scanner performance, presenting the minimum requirements for time, area and connected scanner power of 70 kVA [9].

SOMATOM Emotion scanners provide the user with unique convenience and performance clinical tools for interactive visualization of anatomical scan volumes, software for conducting examinations with contrast enhancement, iterative image reconstruction technology to minimize the level of radiation exposure to the patient. They allow screening of the lungs and large intestine, virtual endoscopy, perfusion and intervention under CT control, a quantitative assessment of vascular disorders,

including visualization of large vessels of the heart [9]. On the SOMATOM Emotion 16 scanner, basic cardiological studies are possible, including a quantitative assessment of the calcium of the coronary arteries and visualization of large coronary vessels [9].

Siemens SOMATOM Emotion - Excellence in Image Detailing:

– The smallest focal spot;
– Use of UFC detectors;
– Excellent collimation width up to 0.5 mm;
– Reduce radiation exposure up to 72% with CARE Dose4D technology.

2.2 Radiotherapy equipment

2.2.1 Gamma-therapeutic apparatus Therathon Equinox 80

Theratron Equinox gamma (Figure 2.2) therapeutic apparatus manufactured by the Canadian company MDS Nordion is intended for the treatment of oncological diseases using a beam of photon (gamma) radiation from a cobalt-60 radionuclide source using external radiation therapy [10]. The highest quality and efficiency of the Theratron Equinox apparatus is based on the vast experience of MDS Nordion, which was at the forefront of the external gamma-ray therapy method [10]. As you know, the world's first distant treatment was carried out in 1951 in Canada, on a cobalt gamma apparatus created by Eldorado Mining and Refining, which later became part of MDS Nordion. When developing the Theratron Equinox, technical solutions were also used that were worked out during the release of previous-generation Theratron devices (Phoenix, Series 700, Elite). In its technical and clinical parameters, Theratron Equinox is almost identical to linear accelerators with an energy of 4-6 MeV, and is much superior to other gamma devices [8]. Using the Theratron Equinox, even with a minimal configuration, it is possible to perform any conventional methods of radiation therapy (and this is at least 60-70% of patients who are shown radiation therapy); however, with its unique technical characteristics, more complex, high-tech methods are available to him.

The design of the device is made according to the original scheme: a protective head (with a source supply mechanism, a rotary collimator, etc.) is mounted on a G-shaped rotating frame (gantry). The apparatus also includes a treatment table and a control system. The device uses a cobalt-60 radionuclide with a nominal activity of 250 to 555 TBq (7 to 15 thousand curies) as a radiation source

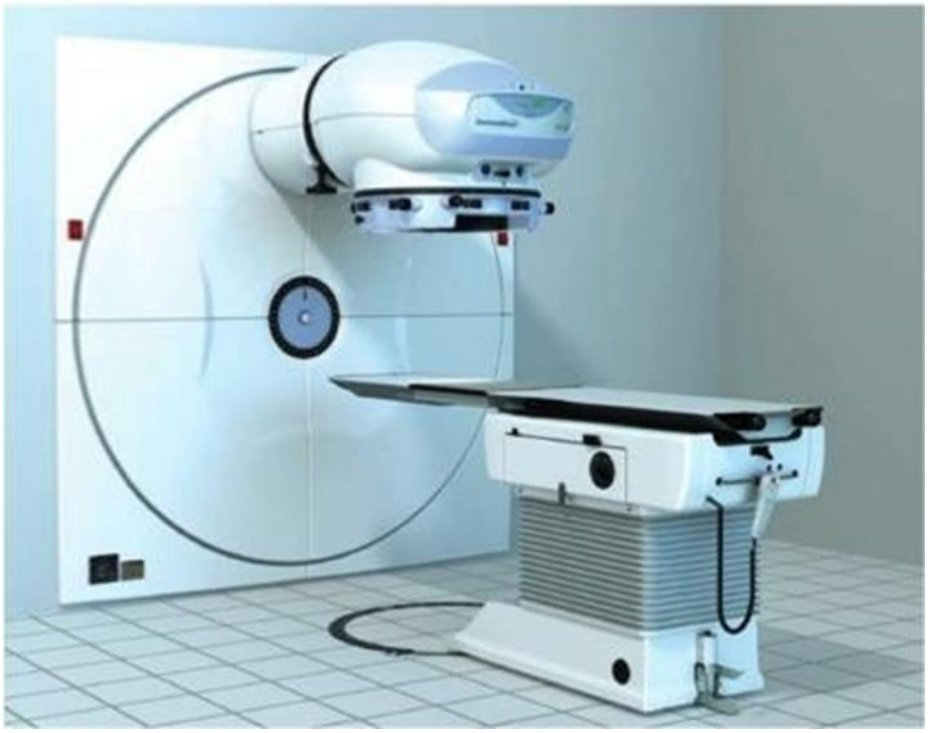

Figure 2.2 – Theratron Equinox 80

Theratron Equinox has the following features:

– The most important characteristics of the beam (dose rate, penumbra, etc.) are not inferior to a linear accelerator with photon energy of 4-6 MeV, with significant cost savings;

– Compact sources of Co-60 can work up to 10 years without recharging;

– Avanza universal table is suitable for the most complex treatment methods: radiation therapy with intensity modulation (LTMI), stereotactic radiation therapy (SLT), etc.

– High dose rate and narrow penumbra made it possible for the first time to use a multi-leaf collimator for conformal irradiation and tomotherapy;

– Compatibility with verification systems using standard protocols;

– It can be placed in standard canyons built for the Russian installations "ROKUS", "AGAT-R", etc.

– In the present work, this apparatus, equipped with a Co-60 source, is used as a radiation source for conducting the external beam radiotherapy stage of a combined course of postoperative radiation therapy of colorectal cancer [10].

2.2.2 Linear accelerator SL75-5-MT

The medical linear electron accelerator SL75-5-MT (Figure 2.3) is an isocentric megavolt therapeutic unit designed for radiation therapy with bremsstrahlung in static and rotational modes [11].

The linear accelerator generates bremsstrahlung with an energy of 6 MeV and provides a maximum absorbed dose rate at a distance of 1 meter from the target in the range of 350-500 Rad / min [11].

In 1997-2002 NIIEFA organized mass production of SL75-5-MT accelerators. During this period, 58 cars were manufactured. Accelerators are delivered and put into operation in oncological clinics of Russia.

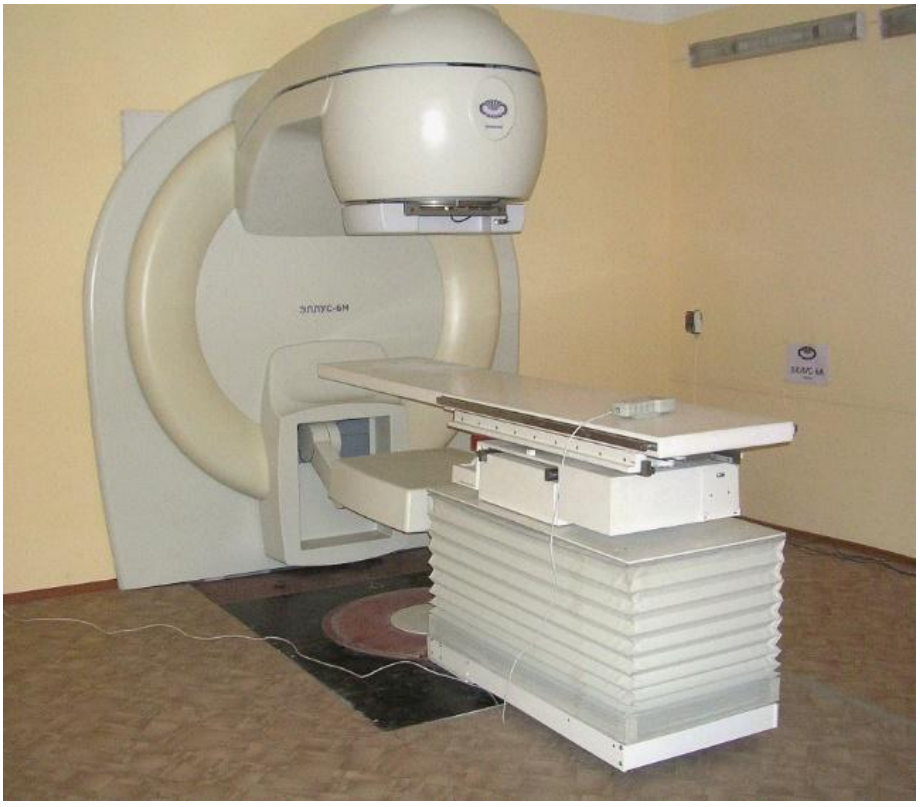

Figure 2.3 – Linear accelerator SL75-5-MT

To ensure the operation of the accelerator systems and the safe conduct of treatment, the accelerator kit also includes [11]:

– Treatment Room Parameter Monitor
– Heat exchanger
– Voltage regulator
– Isocenter Laser Pointer Kit
– Television surveillance and speakerphone system
– Shadow block tray
– Tool kit
– Spare parts

The SL75-5-MT accelerators were supplied with the Wellhofer water phantom, Keithley clinical dosimeter and treatment planning system [11].

On the basis of the SL75-5-MT accelerator, the Ellus-6M linear electron accelerator was developed and manufactured

2.2.3 Elekta Synergy linear accelerator

Elekta Synergy is a linear therapeutic accelerator designed for external radiation therapy of various malignant neoplasms [12].

The Elekta Synergy® linear accelerator (Figure 2.4) was developed in close collaboration with the world's leading clinical institutions in the field of radiotherapy, which is why the system addressed such important issues for oncologists and radiologists as imaging during a radiotherapy session for better cancer treatment. It was this system that was the first in the world that allowed the use of 3D volumetric images in daily practice during radiation therapy, with high resolution to visualize not only hard, but also soft tissue formations [12]. This solved two main problems of modern radiation therapy: the movement of internal organs during the session and errors in the placement of the patient [12].

Figure 2.4 – Elekta Synergy Linear Accelerator

The volumetric image allows doctors to see the tumor, intact healthy organs and tissues surrounding the tumor, as well as their movement between and during irradiation. These opportunities are expanding and improving to this day. The modern linear accelerator Elekta Synergy provides ample opportunities for 3D and 4D volume imaging of soft tissues, 2D imaging of the fluoroscopic mode for targets with a high frequency of movement. Elekta Synergy provides highly accurate tumor irradiation with minimal harm to surrounding healthy tissue.

The quality of the radiation therapy intensity is monitored by the high resolution Advanced Visual Control (IGRT) system in 2D / 3D / 4D mode.

High accuracy and excellent clinical results are achieved thanks to integrated modules with a common isocenter, namely a digital linear accelerator, a megavolt portal image device, a high resolution volumetric X-ray tomography system, as well as a fully integrated multi-petal collimator.

As a result, both the patient and the doctors are guaranteed high accuracy of dose adjustment, clinical reliability and the ability to increase the dose delivered to the tumor, reducing the burden on surrounding healthy tissues [13].

In the present work, this apparatus is used as a radiation source for conducting the remote stage of a combined course of postoperative radiation therapy of colorectal cancer [13].

2.2.4 MultiSourse HDR brachytherapy machine

MultiSource HDR (Figure 2.5) - a gamma system operating on the principle of sequential automatic source injection, is intended for use in the entire spectrum of contact radiation therapy. Along with the widespread source of Ir 192, the MultiSource HDR installation can use the Co-60 source [14].

Figure 2.5 – Brachytherapy machine Multisource HDR

The MultiSource HDR is a 20-channel sequential automatic source injection system. The system is equipped with a wide range of applicators and catheters, includes innovative software with a convenient interface, as well as a unique security system for implementing various brachytherapy techniques: brachytherapy, intraluminal, interstitial, superficial, intraoperative [14]. The device is safe, accurate and at the same time cost-effective and comfortable to use. Co-60 miniature source and advantages of its use:

The main advantage of using the Co-60 source is its longer half-life (5.27 years) and, accordingly, a longer service life without recharging, which allows significant cost savings.

The high radiation and mechanical resistance of the capsule guarantees operation for at least 5 years without recharging (or 100 thousand duty cycles).

Thus, solving clinical problems at the same level as the devices with the source Ir-192, the installation of MultiSource HDR with the source Co 60 will allow the medical institution to achieve cost savings of up to $ 300,000 in a 5-year perspective [14].

The Co-60 miniature source, as well as the Ir-192, can be used with universal applicators. Given the almost identical clinical parameters of the two sources, Co-60 is highly cost-effective. In addition, because of the simpler spectrum and radiation energy, the dose distributions of Co-60 are more “smooth”, they are less affected by the heterogeneity of the medium (including metal parts of the applicators) [14].

2.3 Dosimetric planning system

2.3.1 XiO dosimetric planning system

XiO is a 3D radiation therapy planning system (Fig. 2.6) to calculate the dose in this system, an algorithm is used based on measuring the dose in the phantom at various depths and at different field sizes. Such planning allows calculating the dose at any point of the patient’s body, for any arrangement of the rays, taking into account the heterogeneity of the irradiated structures [15].

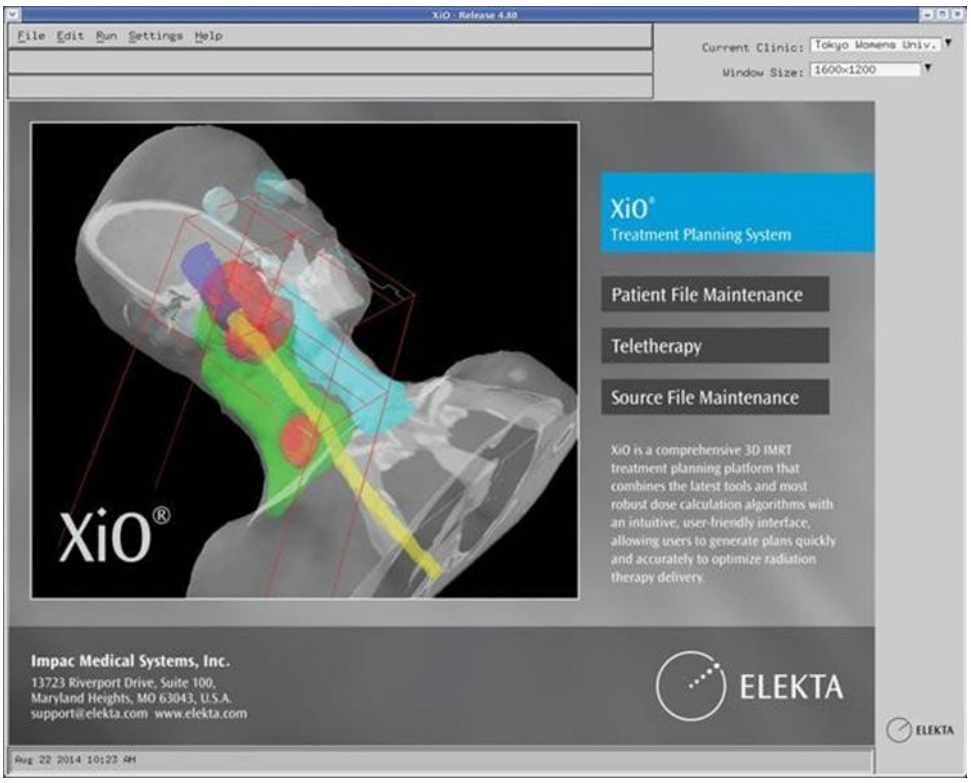

Figure 2.6 – XiO Planning System Interface

The treatment plan is the main component of the planned course of radiation therapy for the patient. It is a collection of data files on the basis of which the radiation dose is calculated.

– The radiation therapy plan determines the application of radiation sources and includes the following parameters:

– patient information;

– information about radiation sources (radiation beams used during external radiation therapy, or groups of sources used during brachytherapy);

– information about the procedure for patient exposure.

The XiO system stores the personal and anatomical data of each patient for whom a radiation therapy plan is created. All stored data is assigned a unique patient identifier specified by the user.

The radiation therapy plan can be two-dimensional or three-dimensional (2D or 3D), depending on the nature of the study. The planning mode determines how the plan looks on the screen, the settings of the plan parameters and the procedure for calculating the radiation dose.

The calculation area is the area within the anatomical structure for which the radiation dose is calculated. Dose calculation is based on points established only within the region and at its border. Outside the calculation area, the dose value is zero.

Patches of tissue of non-uniform density are associated with the calculation area and may or may not be taken into account when calculating the dose.

If the dose is calculated without taking into account the heterogeneity of the tissue, the entire volumetric structure inside the patient's body is perceived as water with a uniform density. The relative electron density of anatomical structures and tumors is not taken into account.

To account for the features of the anatomical structures, tissue density and geometric parameters of the patient, a correction for heterogeneity should be used. If the dose is calculated taking into account the heterogeneity of the tissue, you can use one of two methods for calculating the tissue density of anatomical structures.

Information about the source of radiation. Before using XiO for the first time, a medical physicist collects a large amount of information from the equipment installed in your facility and enters it into the XiO system. This information mainly consists of the measurement results obtained from the linear accelerator, and acceptance tests of a number of XiO system programs. The process of integrating the XiO system into the infrastructure of a medical institution is called commissioning (or commissioning) and is an important responsibility of a medical physicist. The planning of radiation therapy using the XiO system can only begin after its commissioning [15].

Each radiation source for external radiation therapy is assigned an installation identifier. This identifier is set by the user and allows you to restore the source data used in the radiation therapy plan [15].

Source parameters - these are all parameters of the radiation beam that determine the order of patient exposure specified in the treatment plan. In the plans of external radiation therapy, these parameters determine the procedure for bringing individual radiation beams to the patient.

Information about the wedge and compensator. The wedge data includes the type of wedge and the parameters needed to calculate the correction factors and the degree of attenuation of the radiation provided by the wedges. The XiO system supports the following types of wedges [15].

Electric wedge - a wedge that is installed at an angle to summarize a single fraction as part of an irradiation session and then is removed to summarize the remaining fractions.

Compensating filter (or compensator) - this data includes the type of compensating filter and the parameters necessary to add the compensating filter data to the radiation therapy plan. A compensating filter attenuates the radiation beam before it reaches the patient's body. The purpose of using such filters is to even out the dose distribution in depth, taking into account the heterogeneity of the patient's body (surface irregularities or the presence of internal seals) [15].

2.3.2 HDRplus dosimetric planning system

The HDRplus software product is a radiation therapy planning system designed to plan high-dose and pulsed brachytherapy in combination with an appropriate device for administering a radioactive drug. Using this software package allows research on the basis of one or two combined image sequences, isocentric orthogonal or semi-orthogonal x-ray films, non-isocentric x-ray films using a Reco-Box reconstruction cube or no images at all [16].

When starting a new study, you must first enter the general patient and study data.

Image-based planning requires downloading them into the study using one of several available methods (scanner, video capture system, network support for transferring DICOM files, or downloading files from a storage medium, i.e. CD, DVD, flash card, etc.d.).

The next step is the construction of the contours of the planned target volume and risk organs, as well as the automatic generation of points with a dose description for image sequences or placing groups of dose control points with the mouse on plans based on orthogonal images. Further reconstruction of the applicators, for studies

based on image sequences. After editing the required dose limits for different groups of points, an automatic calculation of the exposure time can be carried out [16].

The results of the planning process can be viewed in two-dimensional and three-dimensional form. You can check each slice of the image, as well as view the standard types: sagittal, coronal and transverse.

With a three-dimensional display, you can see all the contoured organs, applicators, dose control points in any orientation at various angles.

You can also enable display of isodose surfaces for dose settings. Due to the property of choosing the color code for the surface of the isodoses, the current dose levels can be marked with colors on the surfaces of the structures.

To evaluate the planning results, HDRplus calculates and displays various dose-volume histograms (cumulative and differential), as well as histograms of various parameters, such as Dxx, Dccm, Vxx, COIN, etc.

After planning, a thorough review of the report is required. The study should be archived for future reference. You can use the patient manager to open saved studies.

Using the highest quality equipment for ultrasound, CT, X-ray and MR examination provides the best research results. Before using images to create a new study, it is necessary to check the operability and accuracy of the equipment for obtaining images. In addition, the clinical accuracy and completeness of the images used should be verified [16].

2.4 Determination of exposure and risk organs volume

Estimated target volumes in the postoperative period are presented in table 2.1. (CTV - clinical target volume) extends to the bottom of the pelvis or at least 1 cm below the anastomosis or stump of the rectum. With sphincter-saving abdominal-perineal extirpation, a surgical bed should be included in the irradiation zone, extending down to the perineal scar. The scar should be indicated by a radiopaque marker [8].

Table 2.1 – Principles for planning radiation therapy for colorectal cancer

Target volume	Definition and Description
GTV (gross tumor volume)	– Primary tumor: the entire tumor volume, as determined by examination – Regional lymph nodes: include all lymph nodes with a size of ≥1.5 cm
CTVHR (high-risk clinical target volume)	– Includes GTV with a minimum indentation of 1.5–2 cm down, the entire rectum, – the peritoneum, presacral and retrosacral space, but excludes intact bones, muscles or air – 1-2 cm should be added to the border around the areas of tumor invasion in neighboring organs – The capture of the entire sacral space and mesorectum should be considered. – Any mesorectal lymph nodes visible on CT and MRI should be included.
Clinical volume of standard risk (CTV-SR)	– Covers the entire mesorectum, the right and left internal iliac lymph nodes for - T3 tumors, the right and left external lymph nodes - for T4 tumors – For T4 tumors with spread to adjacent organs, 1-2 cm should be added towards invasion – Upper border: entire rectum, mesorectum (usually up to L5 / S1) and at least 2 cm above the macroscopic spread of the tumor – Lower bound: CTV should extend to the bottom of the pelvis or at least 2 cm below the macroscopic spread of the tumor – To cover the lymph nodes, a border of 0.7 cm should be made around the iliac vessels (with the

	exception of muscles and bones) – To cover the external iliac vessels (for T4 lesions), it is necessary to expand the border by 1 cm in the anterior-lateral direction – Any adjacent small lymph nodes should be included in the volume. – 1–1.5 cm per bladder should be added in front to account for changes in the filling of the bladder and rectum – 1.8 cm of the width of the volume between the external and internal iliac vessels is required to cover the obstructive lymph nodes
PTV (planning target volume)	– Each CTV + 0.5–1 cm, depending on the level of training of the doctor, the accuracy of reproduction of the styling, the frequency of image processing, as well as the use of IGRT

4 Financial management, resource efficiency and resource saving

The purpose of this section discusses the issues of competitiveness, resource efficiency and resource saving, as well as financial costs regarding the object of study of Master's thesis. Competitiveness analysis is carried out for this purpose. SWOT analysis helps to identify strengths, weaknesses, opportunities and threats associated with the project, and give an idea of working with them in each particular case. For the development of the project requires funds that go to the salaries of project participants and the necessary equipment, a complete list is given in the relevant section. The calculation of the resource efficiency indicator helps to make a final assessment of the technical decision on individual criteria and in general.

The result of the study is the optimization of radiation dose for the postoperative combined course of radiation therapy for colorectal cancer.

4.1 Competitiveness analysis of technical solutions

In order to find sources of financing for the project, it is necessary, first, to determine the commercial value of the work. Analysis of competitive technical solutions in terms of resource efficiency and resource saving allows to evaluate the comparative effectiveness of scientific development. This analysis is advisable to carry out using an evaluation card.

First of all, it is necessary to analyze possible technical solutions and choose the best one based on the considered technical and economic criteria.

Evaluation map analysis presented in Table 1. The position of your research and competitors is evaluated for each indicator by you on a five-point scale, where 1 is the weakest position and 5 is the strongest. The weights of indicators determined by you in the amount should be 1. Analysis of competitive technical solutions is determined by the formula:

$$C = \sum W_i \cdot P_i,,$$

C - the competitiveness of research or a competitor;

Wi– criterion weight;

Pi – point of i-th criteria.

When analyzing the scorecard, it was revealed that this project is not inferior to its competitors, but even surpasses them. Losing in memory costs, the development is very curled from a large amount of memory, unlike its competitors.

Table 4.1. Evaluation card for comparison of competitive technical solutions

Evaluation criteria example	Criterion weight	Points		Competitiveness Taking into account weight coefficients	
		P_f	P_{i1}	C_f	C_{i1}
1	2	3	4	5	6
Technical criteria for evaluating resource efficiency					
1. Operating time for the visualization	0,2	5	3	1	0,4
2. Noise immunity	0,1	5	5	0,5	0,4
3. Radiation dose to critical organs	0,15	4	3	0,5	0,5
4. Planning simplicity	0,1	5	2		
5. Safety	0,1	4	4	0,5	0,5
6. Lack of expensive equipment to implement the method	0,15	3	5	0,75	0,65
Economic criteria for performance evaluation					
1. Product competitiveness	0,05	5	5	0,25	0,2
2. Research funding	0,1	3	5	0,5	0,6
3. Price	0,05	4	4	0,25	0,3
Total	**1**			**5**	**3,6**

As the analysis showed, the use of external radiation therapy techniques is more competitive, since it has a higher accuracy of dose delivery and a reduced dose load on critical organs and tissues.

4.2 SWOT analysis

Complex analysis solution with the greatest competitiveness is carried out with the method of the SWOT analysis: Strengths, Weaknesses, Opportunities and Threats. The analysis has several stages. The first stage consists of describing the strengths and weaknesses of the project, identifying opportunities and threats to the project that have emerged or may appear in its external environment. The second stage consists of identifying the compatibility of the strengths and weaknesses of the project with the external environmental conditions. This compatibility or incompatibility should help to identify what strategic changes are needed.

Table 4.2− SWOT analysis

	Strengths: S1. Reducing the dose to critical organs; S2. Reduced load the dose to the patient; S3. Simplicity and accessibility of the equipment used.	**Weaknesses:** W1. Requires expensive equipment for a more accurate result. W2. More labor intensive patient preparation process.
Opportunities: O1. Using results to evaluate patient dose O2. The emergence of additional demand for the finished product.	*1. The implementation of the processing of results without the use of unnecessarily expensive training will provide an opportunity for tremendous cost savings, and as a result, increases the number of organizations interested in the study.* *2. Reducing the dose load on the patient makes it possible to conduct additional and adjust the course of treatment*	*1. It is necessary to have expensive equipment for a more accurate result of the dose assessment result.* *2. The complexity of the patient preparation process provides increased data collection that can be used to evaluate treatment dynamics.*
Threats: T1. The complexity of funding from both the university and the state. T2. The difficulty of repairing equipment in equipment in the event of a breakdown.	*1. Reducing the dose load on the patient makes it possible to conduct additional research and adjust the course of treatment, which gives an advantage over competitors and additional income* *2. The implementation of the processing of results without the use of complex programs will not give us a delay in obtaining complete results for the study.*	*1. It is possible to avoid the purchase and repair of expensive equipment by the method of import substitution.* *2. The development of new scanning protocols will reduce the time of data collection, and the selection of the optimal scanning mode will increase the operating life and reduce the risk of breakdowns*

4.3 Project Initiation

The initiation process group consists of processes that are performed to define a new project or a new phase of an existing one. In the initiation processes, the initial purpose and content are determined and the initial financial resources are fixed. The internal and external stakeholders of the project who will interact and influence the overall result of the research project are determined.

Table 4.3 – Stakeholders of the project

Project stakeholders	**Stakeholder expectations**
Oncology Clinics and Dispensaries and Patients	Reduction of radiation dose on critical organs. Reducing the risks of late radiation reactions of the body. Reduced recovery time after treatment due to reduced radiation exposure
Medical Physicists	Lower labor costs for drawing up a treatment plan for the patient due to the lack of the need to go through all possible treatment methods

Table 4.4 – Purpose and results of the project

Purpose of project:	Optimization of the postoperative combined course of radiation therapy in patients with colorectal cancer
Expected results of the project:	1. Reduced radiation load on critical organs due to optimization of plans. 2. Improved dose distribution using various planning techniques
Criteria for acceptance of the project result:	1. Irradiate the maximum possible volume tumors with minimal exposure critical organs. 2. The plan meets the requirements of QUANTEC.
Requirements for the project result:	**Requirement:**
	The project must be completed by June 1, 2019.
	The results obtained must satisfy acceptance criteria for the project result (row above)
	The results of scientific research should be presented at one of the All-Russian / regional conferences and have a publication in one of the scientific journals.

4.3.1 The organizational structure of the project

It is necessary to solve the some questions: who will be part of the working group of this project, determine the role of each participant in this project, and prescribe the functions of the participants and their number of labor hours in the project.

Table 3.4 – Project working group

№	Participant	Role in the project	Functions	Labor time, hours.
1	Cherepennikov Yury Mikhailovich. Associate Professor, Nuclear Fuel Cycle Department	Project Manager	Responsible for the implementation of the project within the specified resource limits, coordinates the activities of project participants.	30
2	Turgunova Natalya Dzhuraboevna. Medical physicist of the Department of Radiotherapy, Research Institute of Oncology, Tomsk State Research Center	Project consultant	Responsible for helping Master in the creation of treatment plans and helps in processing the data.	80
3	Nguyen Tuan An undergraduate NI TPU	Project Executor	A review of literature sources. Creation of patient exposure plans for all studied exposure techniques. Comparison of plans. Assessment of radiation dose on critical organs. Writing a master's thesis.	870
Total:				980

4.3.2 Project limitations

Project limitations are all factors that can be as a restriction on the degree of freedom of the project team members.

Table 4.5 – Project limitations

Factors	**Limitations / Assumptions**
3.1. Project's budget	508651 rubles
3.1.1. Source of financing	State financing TPU
3.2. Project timeline:	01/02/2020 - 31/05/2020
3.2.1. Date of approval of plan of project	**11/02/2020**
3.2.2. Completion date	**31/05/2020**

4.4 Project Schedule

As part of planning a science project, you need to build a project timeline and a Gantt Chart.

Table 4.6 – Project Control Events

Job title	Duration, working days	Start date	Date of completion	Participants
Development of technical specifications	2	07.02.2020	09.02.2020	Supervisor
Drawing up technical specifications	3	11.02.2020	13.02.2020	Supervisor
Determining the direction of research	3	13.02.200	15.02.2020	Supervisor Student
Analysis and study of technical literature	18	15.02.2020	10.03.2020	Student
Equipment study	26	02.03.2020	02.04.2020	Student
Dosimetry of equipment for radiation therapy	9	02.04.2020	11.04.2020	Student Consultant
Topometric preparation	3	11.04.2020	13.04.2020	Student Consultant
Preparation of dosimetric plans for a combined course of radiation therapy	4	13.04.2020	17.04.2020	Student Consultant
Analysis and processing of data	3	17.04.2020	19.04.2020	Student
Calculation of radiation dose for a complete combined course of radiation therapy	23	19.04.2020	19.05.2020	Student
Analysis of calculations	2	19.05.2020	21.05.2020	Student
Registration of the work performed	37	10.04.2020	26.05.2020	Student
Preparation for the defense of the thesis	17	26.05.2020	14.06.2020	Student

Table 4.7 – Gantt chart

№	Activities	Participants	T_c, days	Duration of the project												
				February		March			April			May			June	
				1	2	1	2	3	1	2	3	1	2	3		
1	Development of technical specifications	Project leader	2													
2	Drawing up technical specifications	Project leader	2													
3	Determining the direction of research	Project leader Student	2													
4	Analysis and study of technical literature	Student	24													
5	Equipment study	Student	31													
6	Dosimetry of equipment for radiation therapy	Student Consultant	9													
7	Topometric preparation	Student Consultant	2													
8	Preparation of dosimetric plans for a combined course of radiation therapy	Student Consultant	4													
9	Analysis and processing of data	Student	2													
10	Calculation of radiation dose for a complete combined course of radiation therapy	Student	30													
11	Analysis of calculations	Student	5													
12	Registration of the work performed	Student	46													
13	Preparation for the defense of the thesis	Student	20													

A Gantt chart, or harmonogram, is a type of bar chart that illustrates a project schedule. This chart lists the tasks to be performed on the vertical axis, and time intervals on the horizontal axis. The width of the horizontal bars in the graph shows the duration of each activity.

4.5 Scientific and technical research budget

The amount of costs associated with the implementation of this work is the basis for the formation of the project budget. This budget will be presented as the lower limit of project costs when forming a contract with the customer.

To form the final cost value, all calculated costs for individual items related to the manager and the student are summed.

In the process of budgeting, the following grouping of costs by items is used:

- Material costs of scientific and technical research;
- costs of special equipment for scientific work (Depreciation of equipment used for design);
- basic salary;
- additional salary;
- labor tax;
- overhead.

Table 4.8 – The budget for scientific and technical research is shown in table:

Name	Material costs	Costs of special equipment	Basic salary	Additional salary	labor tax	Overhead	Total cost
Cost, rubles	3538	170978,46	189848	189985	62651	62651	**508651**

4.5.1 Calculation of material costs

The calculation of material costs is carried out according to the formula:

$$C_m = (1 + k_T) \cdot \sum_{i=1}^{m} P_i \cdot N_{consi},$$

where m – the number of types of material resources consumed in the performance of scientific research;

N_{consi} – the amount of material resources of the i-th species planned to be used when performing scientific research (units, kg, m, m^2, etc.);

P_i – the acquisition price of a unit of the i-th type of material resources consumed (rub./units, rub./kg, rub./m, rub./m^2, etc.);

k_T – coefficient taking into account transportation costs.

Prices for material resources can be set according to data posted on relevant websites on the Internet by manufacturers (or supplier organizations).

Energy costs are calculated by the formula:

$$C = P_{el} \cdot P \cdot F_{eq},$$

where P_{el} − power rates (5.8 rubles per 1 kWh);

P − power of equipment, kW;

F_{eq} − equipment usage time, hours.

Table 4.9 – Material costs

Name	Work time, h	Electric energy consumption, kW	Price per unit, rub.	Material costs, rub.
Computer	580	0,5	5,8	1682
CT-scan	30	30	5,8	348
Equinox 80	1	100	5,8	580
MultiSourse HDR	2	80	5,8	928
Total				3538

The equipment used in the dissertation was already available in the radiology department. This article includes all costs associated with the purchase of special equipment. The cost of equipment used in the dissertation is taken into account in the form of depreciation. In this dissertation, the special equipment necessary for conducting experimental work includes the MultiSourse HDR contact

radiation therapy apparatus (brachytherapy), which was created by the leading global corporation for the development and production of high-tech medical equipment and information systems for radiation therapy in Sweden and the approximate the cost is 80,000,000 rubles for a designated life of 30 years; for external beam radiation therapy, the Equinox 80 apparatus was used; estimated cost 130,000,000 rubles - 25 years old, Siemens CT scanner 70,000,000 rubles - 25 years old. The planning system "XiO" and "HDRplus" worth 10,000,000 and 15,000,000 rubles, respectively.

The cost of equipment used in the implementation of a specific scientific project and available in this scientific and technical organization is taken into account in the form of depreciation:

$$A = \frac{A_{EM}}{T}, A_{DA} = \frac{A}{365}, A_{DAD} = A_{DA} \cdot N$$

where A_{DR} – depreciation rate, %

A_{EM} – equipment amount

A_{DA} – depreciation amount, ruble in a day

A_{DAD} – depreciation amount during the scientific work, rubles

N – Number of days of operation

T – Service life

Table 4.10 – Depreciation deductions

№	Name of equipment	Days of operation	Cost	Depreciation deductions
1	MultiSourse HDR	2	80 million.rub	14611,87 rub
2	Equinox 80	1	120 million.rub	14246,46 rub
3	CT scanner	2	70 million.rub	15342,46 rub
4	Xio Planning system	15	10 million.rub	82191,78 rub
5	HDRplus Planning system	30	15 million.rub	123287,67 rub
Total				170978,46 rub

4.5.2 Basic salary

This point includes the basic salary of participants directly involved in the implementation of work on this research. The value of salary costs is determined based on the labor intensity of the work performed and the current salary system

The basic salary (S_b) is calculated according to the following formula:

$$S_{\text{b}} = S_a \cdot T_{\text{w}}, \tag{3.3}$$

where Sb – basic salary per participant;

T_{w} – the duration of the work performed by the scientific and technical worker, working days;

Sa - the average daily salary of an participant, rub.

The average daily salary is calculated by the formula:

$$S_d = \frac{S_m \cdot M}{F_{\text{v}}}, \tag{3.4}$$

где S_m – monthly salary of an participant, rub .;

M – the number of months of work without leave during the year:

at holiday in 48 days, M = 11.2 months, 6 day per week;

F_{v} – valid annual fund of working time of scientific and technical personnel (251 days).

Table 4.11 – The valid annual fund of working time

Working time indicators	
Calendar number of days	365
The number of non-working days - weekend - holidays	 52 14
Loss of working time - vacation - sick absence	48
The valid annual fund of working time	251

Monthly salary is calculated by formula:

$$S_{month} = S_{base} \cdot (k_{premium} + k_{bonus}) \cdot k_{reg},$$

where S_{base} – base salary, rubles;

$k_{premium}$ – premium rate;

k_{bonus} – bonus rate;

k_{reg} – regional rate.

Table 4.12 – Calculation of the base salaries

Performers	S_{base}, rubles	$k_{premium}$	k_{bonus}	k_{reg}	S_{month}, rub.	W_d, rub.	T_p, work days	W_{base}, rub.
Project Leader	35 120			1,3	45630	1901	8	15208
Consultant	30000				39000	1950	15	29250
Student	17310				22503	938	155	145390
Total								**189848**

4.5.3 Additional salary

This point includes the amount of payments stipulated by the legislation on labor, for example, payment of regular and additional holidays; payment of time associated with state and public duties; payment for work experience, etc.

Additional salaries are calculated on the basis of 10-15% of the base salary of workers:

$$W_{add} = k_{extra} \cdot W_{base}, \quad \text{(x)}$$

where W_{add} – additional salary, rubles;

k_{extra} – additional salary coefficient (10%);

W_{base} – base salary, rubles.

Table 4.13 – Additional salary

	Project leader	**Consultant**	**Student**
Additional salary coefficient	0,1		
Salary, rubles	15208	29250	145390
Additional salary, rubles	1521	2925	14539
Total, rubles	**18985**		

4.5.4 Labor tax

Tax to extra-budgetary funds are compulsory according to the norms established by the legislation of the Russian Federation to the state social insurance (SIF), pension fund (PF) and medical insurance (FCMIF) from the costs of workers.

Payment to extra-budgetary funds is determined of the formula:

$$P_{social} = k_b \cdot (W_{base} + W_{add}) \quad \text{x)}$$

where k_b – coefficient of deductions for labor tax.

In accordance with the Federal law of July 24, 2009 No. 212-FL, the amount of insurance contributions is set at 30%. Institutions conducting educational and scientific activities have rate - 27.1%.

Table 4.14 – Labor tax

	Project leader	**Consultant**	**Student**
Coefficient of deductions	0,3		
Salary, rubles	16729	32175	159929
Labor tax, rubles	5019	9653	47979
Total	**62651**		

4.5.5 Overhead costs

Overhead costs include other management and maintenance costs that can be allocated directly to the project. In addition, this includes expenses for the

maintenance, operation and repair of equipment, production tools and equipment, buildings, structures, etc.

Overhead costs account from 30% to 90% of the amount of base and additional salary of employees.

Overhead is calculated according to the formula:

$$C_{ov} = k_{ov} \cdot (W_{base} + W_{add})$$

where k_{ov} – overhead rate.

Table 4.15 – Overhead

	Project leader	**Consultant**	**Student**
Overhead rate	0,3		
Salary, rubles	16729	32175	159929
Overhead, rubles	5019	9653	47979
Total	**62651**		

4.5.6 Formation of budget costs

The calculated cost of research is the basis for budgeting project costs. Determining the budget for the scientific research is given in the table .

Table 5.16 – Items expenses grouping

Name	**Cost, rubles**
1. Material costs	3538
2. Basic salary	189848
3. Additional salary	18985
4. Labor tax	62651
5. Overhead	62651
6. Costs of special equipment	170978,46
Total planned cost	**508651**

5 Social responsibility

5.1 Introduction

Colorectal cancer is one of the commonest cancers worldwide. Radiotherapy has been established as an indispensable component of treatment. Although conventional radiotherapy provides good local control, radiotherapy treatment side-effects, local recurrence and distant metastasis remain to be the concerns. With the recent technological advancements, various special radiotherapy treatment options have been offered. Purpose of work: Optimization of postoperative a combined course of radiation therapy in patients with colorectal cancer for reduce dose on critical organs, taking into account modern approaches to topometry and dosimetric planning. The research can be used for reference and application for cancer institutes in Russia and around the world.

5.2 Legal and organizational items in providing safety

Nowadays one of the main way to radical improvement of all prophylactic work referred to reduce Total Incidents Rate and occupational morbidity is the widespread implementation of an integrated Occupational Safety and Health management system. That means combining isolated activities into a single system of targeted actions at all levels and stages of the production process.

Occupational safety is a system of legislative, socio-economic, organizational, technological, hygienic and therapeutic and prophylactic measures and tools that ensure the safety, preservation of health and human performance in the work process [1].

According to the Labor Code of the Russian Federation, every employee has the right:

- to have a workplace that meets Occupational safety requirements;

- to have a compulsory social insurance against accidents at manufacturing and occupational diseases;

- to receive reliable information from the employer, relevant government bodies and public organizations on conditions and Occupational safety at the

workplace, about the existing risk of damage to health, as well as measures to protect against harmful and (or) hazardous factors;

- to refuse carrying out work in case of danger to his life and health due to violation of Occupational safety requirements;

- be provided with personal and collective protective equipment in compliance with Occupational safety requirements at the expense of the employer;

- for training in safe work methods and techniques at the expense of the employer;

- for personal participation or participation through their representatives in consideration of issues related to ensuring safe working conditions in his workplace, and in the investigation of the accident with him at work or occupational disease;

- for extraordinary medical examination in accordance with medical recommendations with preservation of his place of work (position) and secondary earnings during the passage of the specified medical examination;

- for warranties and compensation established in accordance with this Code, collective agreement, agreement, local regulatory an act, an employment contract, if he is engaged in work with harmful and (or) hazardous working conditions.

The labor code of the Russian Federation states that normal working hours may not exceed 40 hours per week, The employer must keep track of the time worked by each employee.

Rules for labor protection and safety measures are introduced in order to prevent accidents, ensure safe working conditions for workers and are mandatory for workers, managers, engineers and technicians.

5.3 Basic ergonomic requirements for the correct location and arrangement of researcher's workplace

The workplace when working with a PC should be at least 6 square meters. The legroom should correspond to the following parameters: the legroom height is at least 600 mm, the seat distance to the lower edge of the working surface is at least 150 mm, and the seat height is 420 mm. It is worth noting that the height of the table should depend on the growth of the operator.

The following requirements are also provided for the organization of the workplace of the PC user: The design of the working chair should ensure the maintenance of a rational working posture while working on the PC and allow the posture to be changed in order to reduce the static tension of the neck and shoulder muscles and back to prevent the development of fatigue.

The type of working chair should be selected taking into account the growth of the user, the nature and duration of work with the PC. The working chair should be lifting and swivel, adjustable in height and angle of inclination of the seat and back, as well as the distance of the back from the front edge of the seat, while the adjustment of each parameter should be independent, easy to carry out and have a secure fit.

5.4 Occupational safety

A dangerous factor or industrial hazard is a factor whose impact under certain conditions leads to trauma or other sudden, severe deterioration of health of the worker [1].

A harmful factor or industrial health hazard is a factor, the effect of which on a worker under certain conditions leads to a disease or a decrease in working capacity.

5.4.1 Analysis of harmful and dangerous factors that can create object of investigation

The object of investigation is “The postoperative a combined course of radiation therapy in patients with colorectal cancer”. Therefore object of investigation itself cannot cause harmful and dangerous factors.

5.4.2. Analysis of harmful and dangerous factors that can arise at workplace during investigation

The working conditions in the workplace are characterized by the presence of hazardous and harmful factors, which are classified by groups of elements: physical, chemical, biological, psychophysiological. The main elements of the production process that form dangerous and harmful factors are presented in Table 1.

Table 5.1 – Possible hazardous and harmful factors

Factors (GOST 12.0.003-2015)	Work stages			Legal documents
	Development	Manufacture	Exploitation	
1. Deviation of microclimate indicators	+	+	+	Sanitary rules 2.2.2 / 2.4.1340–03. Sanitary and epidemiological rules and regulations "Hygienic requirements for personal electronic computers and work organization." Sanitary rules 2.2.1 / 2.1.1.1278–03. Hygienic requirements for natural, artificial and combined lighting of residential and public buildings. Sanitary rules 2.2.4 / 2.1.8.562–96. Noise at workplaces, in premises of residential, public buildings and in the construction area. Sanitary rules 2.2.4.548–96. Hygienic requirements for the microclimate of industrial premises. Sanitary rules GOST 12.1.038-82 SSBT. Electrical safety. Maximum
2. Excessive noise		+	+	
3.Increased level of electromagnetic radiation	+	+	+	
4.Insufficient illumination of the working area		+	+	
5. Abnormally high voltage value in the circuit, the	+	+	+	

closure which may occur through the human body				permissible levels of touch voltages and currents.
6. Increased levels of ionizing radiation	+	+	+	Sanitary Rules 2.6.1. 2523 -0 9. Radiation Safety Standards (NRB-99/2009).

The following factors effect on person working on a computer:

- physical:
  - temperature and humidity;
  - noise;
  - static electricity;
  - electromagnetic field of low purity;
  - illumination;
  - presence of radiation;
- psychophysiological:
  - psychophysiological dangerous and harmful factors are divided into:
- physical overload (static, dynamic)
- mental stress (mental overstrain, monotony of work, emotional overload).

Deviation of microclimate indicators

The air of the working area (microclimate) is determined by the following parameters: temperature, relative humidity, air speed. The optimum and permissible values of the microclimate characteristics are established in accordance with [2] and are given in Table 4.2.

Table 5.2 – Optimal and permissible parameters of the microclimate

Period of the year	Temperature, ^{C}	Relative humidity,%	Speed of air movement, m/s
Cold and changing of seasons	23-25	40-60	0.1

Warm	23-25	40	0.1

Excessive noise

Noise and vibration worsen working conditions, have a harmful effect on the human body, namely, the organs of hearing and the whole body through the central nervous system. It result in weakened attention, deteriorated memory, decreased response, and increased number of errors in work. Noise can be generated by operating equipment, air conditioning units, daylight illuminating devices, as well as spread from the outside. When working on a PC, the noise level in the workplace should not exceed 50 dB.

Increased level of electromagnetic radiation

The screen and system blocks produce electromagnetic radiation. Its main part comes from the system unit and the video cable. According to [2], the intensity of the electromagnetic field at a distance of 50 cm around the screen along the electrical component should be no more than:

– in the frequency range 5 Hz - 2 kHz - 25 V / m;
– in the frequency range 2 kHz - 400 kHz - 2.5 V / m.

The magnetic flux density should be no more than:

– in the frequency range 5 Hz - 2 kHz - 250 nT;
– in the frequency range 2 kHz - 400 kHz - 25 nT.

Abnormally high voltage value in the circuit

Depending on the conditions in the room, the risk of electric shock to a person increases or decreases. Do not operate the electronic device in conditions of high humidity (relative air humidity exceeds 75% for a long time), high temperature (more than 35 ° C), the presence of conductive dust, conductive floors and the possibility of simultaneous contact with metal components connected to the ground and the metal casing of electrical equipment. The operator works with electrical devices: a computer (display, system unit, etc.) and peripheral devices. There is a risk of electric shock in the following cases:

– with direct contact with current-carrying parts during computer repair;

– when touched by non-live parts that are under voltage (in case of violation of insulation of current-carrying parts of the computer);

– when touched with the floor, walls that are under voltage;

– short-circuited in high-voltage units: power supply and display unit.

Table 5.3 – Upper limits for values of contact current and voltage

	Voltage, V	Current, mA
Alternate, 50 Hz	2	0.3
Alternate, 400 Hz	3	0.4
Direct	8	1.0

Insufficient illumination of the working area

Light sources can be both natural and artificial. The natural source of the light in the room is the sun, artificial light are lamps. With long work in low illumination conditions and in violation of other parameters of the illumination, visual perception decreases, myopia, eye disease develops, and headaches appear.

According to the standard, the illumination on the table surface in the area of the working document should be 300-500 lux. Lighting should not create glare on the surface of the monitor. Illumination of the monitor surface should not be more than 300 lux.

The brightness of the lamps of common light in the area with radiation angles from 50 to 90° should be no more than 200 cd/m, the protective angle of the lamps should be at least 40°. The safety factor for lamps of common light should be assumed to be 1.4. The ripple coefficient should not exceed 5%.

Increased levels of ionizing radiation

Ionizing radiation is radiation that could ionize molecules and atoms. This effect is widely used in energetics and industry. However, there is health hazard. In living tissue, this radiation could damage cells that result in two types of effects. Deterministic effects (harmful tissue reactions) due to exposure with high doses and stochastic effects due to DNA destruction and mutations (for example, induction of cancer).

To provide radiation safety with using sources of ionizing radiation one must use next principles:

a) keep individual radiation doses from all radiation sources not higher than permissible exposure;

b) forbid all activity with using radiation sources if profit is low than risk of possible hazard;

c) keep individual radiation doses from all radiation sources as low as possible.

There are two groups of people related to work with radiation: personnel, who works with ionizing radiation, and population.

Table 5.4 – Dose limit

Quantity	Dose limits	
	personnel	population
Effective dose	20 mSv per year in average during 5 years, but not higher than 50 mSv per year	1 mSv per year in average during 5 years, but not higher than 5 mSv per year
Equivalent dose per year in eye's lens	150 mSv	15 mSv
skin	500 mSv	50 mSv
Hands and feet	500 mSv	50 mSv

Effective dose for personnel must not exceed 1000 mSv for 50 years of working activity, and for population must not exceed 70 mSv for 70 years of life.

In addition, for women from personnel of age below 45 years there is limit of 1 mSv per month of equivalent dose on lower abdomen. During gestation and breast feeding women must not work with radiation sources.

For students older than 16, who uses radiation sources in study process or who is in rooms with increased level of ionizing radiation, dose limits are quarter part of dose limits of personnel.

5.4.3 Justification of measures to reduce the levels of exposure to hazardous and harmful factors on the researcher

Deviation of microclimate indicators

The measures for improving the air environment in the production room include: the correct organization of ventilation and air conditioning, heating of room. Ventilation can be realized naturally and mechanically. In the room, the following volumes of outside air must be delivered:

– at least 30 m^3 per hour per person for the volume of the room up to 20 m^3 per person;

– natural ventilation is allowed for the volume of the room more than 40 m^3 per person and if there is no emission of harmful substances.

The heating system must provide sufficient, constant and uniform heating of the air. Water heating should be used in rooms with increased requirements for clean air.

The parameters of the microclimate in the laboratory regulated by the central heating system, have the following values: humidity 40%, air speed 0.1 m / s, summer temperature 20-25 ° C, in winter 13-15 ° C. Natural ventilation is provided in the laboratory. Air enters and leaves through the cracks, windows, doors. The main disadvantage of such ventilation is that the fresh air enters the room without preliminary cleaning and heating.

Excessive noise

In research audiences, there are various kinds of noises that are generated by both internal and external noise sources. The internal sources of noise are working equipment, personal computer, printer, ventilation system, as well as computer equipment of other engineers in the audience. If the maximum permissible conditions are exceeded, it is sufficient to use sound-absorbing materials in the room (sound-absorbing wall and ceiling cladding, window curtains). To reduce the noise

penetrating outside the premises, install seals around the perimeter of the doors and windows.

Increased level of electromagnetic radiation

There are the following ways to protect against EMF:

- increase the distance from the source (the screen should be at least 50 cm from the user);
- the use of pre-screen filters, special screens and other personal protective equipment.

When working with a computer, the ionizing radiation source is a display. Under the influence of ionizing radiation in the body, there may be a violation of normal blood coagulability, an increase in the fragility of blood vessels, a decrease in immunity, etc. The dose of irradiation at a distance of 20 cm to the display is 50 μrem / hr. According to the norms [2], the design of the computer should provide the power of the exposure dose of x-rays at any point at a distance of 0.05 m from the screen no more than 100 μR / h.

Fatigue of the organs of vision can be associated with both insufficient illumination and excessive illumination, as well as with the wrong direction of light.

Increased levels of ionizing radiation

In case of radiation accident, responsible personnel must take all measures to restore control of radiation sources and reduce to minimum radiation doses, number of irradiated persons, radioactive pollution of the environment, economic and social losses caused with radioactive pollution.

Radiation control is a main part of radiation safety and radiation protection. It is aimed at not exceeding the established basic dose limits and permissible levels of radiation, obtaining the necessary information to optimize protection and making decisions about interference in the case of radiation accidents, contamination of the environment and buildings with radionuclides.

The radiation control is control of:

- Radiation characteristics of radiation sources, pollution in air, liquid and solid wastes.

- Radiation factors developed with technological processes in working places and environment.
- Radiation factors of contaminated environment.
- Irradiation dose levels of personnel and population.
- The main controlled parameters are:
- Annual effective and equivalent doses
- intake and body content of radionuclides
- volume or specific activity of radionuclides in air, water, food products, building materials and etc.
- radioactive contamination of skin, clothes, footwear, working places and etc.
- dose and power of external irradiation.
- particles and photons flux density.

Radiation protection office establish control levels of all controlled parameters in according to not exceed dose limits and keep dose levels as low as possible. In case of exceeding control levels radiation protection officers start investigation of exceed causes and take actions to eliminate this exceeding.

uring planning and implementation of radiation safety precautions, taking any actions about radiation safety and analysis of effectiveness of mentioned action and precautions one must value radiation safety with next factors:

- characteristics of radioactive contamination of the environment;
- probability of radiation accidents and scale of accidents;
- degree of readiness to effective elimination of radiation accidents and its aftermathches;
- number of persons irradiated with doses higher than controlled limits of doses;
- analysis of actions for providing radiation safety, meeting requirements, rules, standards of radiation safety;
- analysis of irradiation doses obtained by groups of population from all ionizing radiation sources.

Abnormally high voltage value in the circuit

Measures to ensure the electrical safety of electrical installations:

- disconnection of voltage from live parts, on which or near to which work will be carried out, and taking measures to ensure the impossibility of applying voltage to the workplace;
- posting of posters indicating the place of work;
- electrical grounding of the housings of all installations through a neutral wire;
- coating of metal surfaces of tools with reliable insulation;
- inaccessibility of current-carrying parts of equipment (the conclusion in the case of electroporating elements, the conclusion in the body of current-carrying parts) [3].

Insufficient illumination of the working area

Desktops should be placed in such a way that the monitors are oriented sideways to the light openings, so that natural light falls mainly on the left.

Also, as a means of protection to minimize the impact of the factor, local lighting should be installed due to insufficient lighting, window openings should be equipped with adjustable devices such as blinds, curtains, external visors, etc.

5.5 Ecological safety

5.5.1 Analysis of the impact of the research object on the environment

Sources of ionizing radiation used in medicine could be divided into two groups: radioactive substances and radiation generators. The difference is that radiation generators like accelerators and x-ray tubes emit ionizing radiation only when they are turned on.

In ordinary work with necessary safety precautions, there are insignificant impact of using sources of ionizing radiation on environment. The immediate effect of ionizing radiation is ionization of air in room, but after a specified time the ionization disappears.

The danger of using radioactive materials could occur only in accidents with stealing and loosing these materials due to high toxicity.

5.5.2 Analysis of the environmental impact of the research process

Process of investigation itself in the thesis do not have essential effect on environment. One of hazardous waste is fluorescent lamps. Mercury in fluorescent lamps is a hazardous substance and its improper disposal greatly poisons the environment.

Outdated devices goes to an enterprise that has the right to process wastes. It is possible to isolate precious metals with a purity in the range of 99.95–99.99% from computer components. A closed production cycle consists of the following stages: primary sorting of equipment; the allocation of precious, ferrous and non-ferrous metals and other materials; melting; refining and processing of metals. Thus, there is an effective disposal of computer devices.

5.5.3 Justification of environmental protection measures

Pollution reduction is possible due to the improvement of devices that produces electricity, the use of more economical and efficient technologies, the use of new methods for generating electricity and the introduction of modern methods and methods for cleaning and neutralizing industrial waste. In addition, this problem should be solved by efficient and economical use of electricity by consumers themselves. This is the use of more economical devices, as well as efficient regimes of these devices. This also includes compliance with production discipline in the framework of the proper use of electricity.

Simple conclusion is that it is necessary to strive to reduce energy consumption, to develop and implement systems with low energy consumption. In modern computers, modes with reduced power consumption during long-term idle are widely used.

5.6 Safety in emergency

5.6.1 Analysis of probable emergencies that may occur at the workplace during research

The fire is the most probable emergency in our life. Possible causes of fire:

– malfunction of current-carrying parts of installations;
– work with open electrical equipment;

– short circuits in the power supply;

– non-compliance with fire safety regulations;

– presence of combustible components: documents, doors, tables, cable insulation, etc.

Activities on fire prevention are divided into: organizational, technical, operational and regime.

5.6.2 Substantiation of measures for the prevention of emergencies and the development of procedures in case of emergencies

Organizational measures provide for correct operation of equipment, proper maintenance of buildings and territories, fire instruction for workers and employees, training of production personnel for fire safety rules, issuing instructions, posters, and the existence of an evacuation plan.

The technical measures include compliance with fire regulations, norms for the design of buildings, the installation of electrical wires and equipment, heating, ventilation, lighting, the correct placement of equipment.

The regime measures include the establishment of rules for the organization of work, and compliance with fire-fighting measures. To prevent fire from short circuits, overloads, etc., the following fire safety rules must be observed:

– elimination of the formation of a flammable environment (sealing equipment, control of the air, working and emergency ventilation);

– use in the construction and decoration of buildings of non-combustible or difficultly combustible materials;

– the correct operation of the equipment (proper inclusion of equipment in the electrical supply network, monitoring of heating equipment);

– correct maintenance of buildings and territories (exclusion of the source of ignition - prevention of spontaneous combustion of substances, restriction of fire works);

– training of production personnel in fire safety rules;

– the publication of instructions, posters, the existence of an evacuation plan;

– compliance with fire regulations, norms in the design of buildings, in the organization of electrical wires and equipment, heating, ventilation, lighting;

– the correct placement of equipment;

– well-time preventive inspection, repair and testing of equipment.

– In the case of an emergency, it is necessary to:

– inform the management (duty officer);

– call the Emergency Service or the Ministry of Emergency Situations - tel. 112;

– take measures to eliminate the accident in accordance with the instructions.

Conclusion

During the master's thesis:

- A literature review of the research topic was conducted.
- Clinical dosimetry protocols were studied and measurements were made for radiation therapy devices: Equinox 80, Elekta Synergy, MultiSourse HDR.
- The basic skills of using dosimetric planning XiO system for the external beam radiotherapy stage of RT and HDRplus for the brachytherapy stage of RT have been mastered.
- Plans have been made for irradiating the external beam radiotherapy stage of a combined course of radiation therapy for colorectal cancer, implemented in the form of conventional and conformal RT.
- Plans have been made for irradiating the brachytherapy stage of the combined course of radiation therapy for colorectal cancer.
- Radiation dose on critical organs have been calculated for a combined course of radiation therapy for colorectal cancer, taking into account modern approaches to topometry.
- The analysis of the results obtained.

According to the results of the study, the following recommendations were made:

- Conformal radiation therapy at the external beam radiotherapy stage of the combined course allows you to reduce radiation dose on critical organs, which will reduce the risk of acute postradiation reactions.
- The use of computed tomography to visualize the amount of radiation during sessions of brachytherapy radiation therapy will increase the accuracy of dose delivery.
- The use of computed tomography to visualize the volume of radiation during brachytherapy sessions will allow a quantitative assessment of the level of dose loading on critical organs.

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