UDC: 53.083

DOI: 10.52532/2663-4864-2023-2-68-4-8

DEVELOPING AND IMPLEMENTING THE QUALITY CONTROL PROGRAM ON A LINEAR ACCELERATOR

T.Yu. ANTROPOVA[1], K.D. DATBAEV[1,2], E.I. ISHKININ[1], B.G. LATYPOVA1, O.K. SEITOV[1,2], Zh.T. KHUDAIBERGENOV[1,2]

[1]«Almaty Oncological Center» MSE on REM, Almaty, the Republic of Kazakhstan;
[2]«Kazakh Institute of Oncology and Radiology» JSC, Almaty, the Republic of Kazakhstan

ABSTRACT

Relevance: *The article deals with modern problems in the field of ensuring the quality of services provided on linear accelerators from the point of view of the regulatory framework, as well as from the point of view of the frequency of control procedures. The scientific novelty lies in elaborating a linear accelerator quality control program with detailed procedure descriptions and testing frequency recommendations.*

The study aimed to *develop and test a set of simple methods for controlling the linear accelerator's mechanical and dosimetric parameters, which would meet the minimum requirements for high-tech radiation therapy following IAEA and AAPM international recommendations.*

Methods: *In developing the quality control program for the TrueBeamSTx linear accelerator (Varian, USA) installed at the Almaty Oncological Center (AOC, Kazakhstan), we relied on the recommendations of the International Atomic Energy Agency (IAEA) and the American Association of Physicists in Medicine (AAPM), taking into account that intensity-modulated radiotherapy (IMRT, VMAT), stereotactic radiosurgery and stereotactic radiotherapy (SRS, SRT), using image-guided radiation therapy (IGRT) will be performed on the accelerator, which imposes more stringent requirements for control of both mechanical and dosimetry characteristics.*

Results: *Over three years of operation, the TrueBeamSTx accelerator shows good stability of mechanical and dosimetric characteristics, verified using systematic tests according to the quality control program developed by the authors of this article. The IAEA/WHO mail dose monitoring program using radiophotoluminescent detectors, implemented in 2019-2022, showed high dosimetric measurements and calculations accuracy of 0.1-1.7%, at a tolerance of 5%.*

Conclusion: *A quality control program for a high-energy linear accelerator has been developed; the results obtained for all characteristics correspond to the permissible values. The effective and safe use of radiotherapy requires the development of a quality control program for all radiotherapy equipment specifically for each institution and independent verification of the implementation of this program.*

Keywords: *radiation therapy, linear accelerator, quality control, dosimetric equipment.*

Introduction: One of the most important components of the radiotherapy quality assurance program is the control of the physical and technical parameters of the equipment used. According to the generally accepted recommendations of the International Commission on Radiation Units and Measurements (ICRU) [1], in radiation therapy, the dose delivered to the patient should be within ± 5% of the prescribed dose. Each stage of radiation therapy must be performed with an error of less than 5%.

The dosimetric and mechanical characteristics of the radiation device must ensure the accurate implementation of the calculated dosimetric plan for radiation treatment for each patient. A quality control program is required for each radiotherapy device to ensure periodic monitoring of the mechanical and dosimetric characteristics of the device that affect the accuracy of dose delivery to the focus. There are many valid international recommendations for periodic monitoring of radiation therapy devices' mechanical and dosimetric characteristics, including linear accelerators [2, 3]. However, they are just recommendations that must be adapted to the specific device and institution that conducts radiation therapy, the radiation treatment methods used, and the available dosimetric and other auxiliary equipment. The quality control program is based on the data obtained during the beam apparatus acceptance and preparation for clinical operation (commissioning). This data is specific for each type of apparatus and dosimetric planning system. Developing a quality control program is among the most important responsibilities of medical physicists in a radiation therapy department.

Gaps in the existing regulatory framework of providing oncological care to patients in the Republic of Kazakhstan were identified, and ways to correct them were described in terms of ensuring the quality provision of high-tech radiation therapy services at linear accelerators. Effective and safe delivery of radiotherapy requires the development of a quality control program for all types of radiotherapy equipment specific to each institution and independent verification of the implementation of this program.

The study aimed to develop and test a set of simple methods for controlling the linear accelerator's mechanical and dosimetric parameters, which would meet

the minimum requirements for high-tech radiation therapy following IAEA and AAPM international recommendations.

Materials and methods: When developing a quality control program for the TrueBeamSTx linear accelerator (Varian, CA, USA) installed in the Almaty Cancer Center (Kazakhstan), we relied on the recommendations of the International Atomic Energy Agency (IAEA) [2] and the American Society of Medical Physicists (American Association of Medical Physicists). Physicists in Medicine, AAPM) [3-5], taking into account that the accelerator will perform radiation therapy with intensity modulation (IMRT, VMAT), stereotactic radiosurgery, and stereotactic radiotherapy (SRS, SRT) using image guidance (IGRT), which imposes more stringent requirements for the control of both mechanical and dosimetric characteristics. Dosimetry equipment from IBA- Dosimetry (Schwarzenbrück, Germany), as well as phantoms and accessories supplied with the accelerator and quality control plans embedded in the accelerator software, allow performing many, but not all, of the necessary tests, so some additional equipment such as Iso-Align device (CIVCO, USA) and RTQA2 radiochromic film (Gafchromic, NJ, USA).

The protocols of all dosimetric and mechanical tests are kept according to the quality control program developed by the authors of this article and approved by the head of the AOC. Statistics are kept of all measurements taken with an analysis of deviations from the baseline data.

Results: In creating a quality control program, the methods for performing some tests had to be developed independently since sufficiently detailed information was not always available in the literature. We set the frequency of tests in such a way as to provide the necessary control procedures in a short time due to the large therapeutic load of the device, as well as taking into account the available dosimetric equipment. So, it is necessary to check several characteristics of the accelerator daily before the start of medical work, such as the accuracy of the light field dimensions, the accuracy of lasers and the optical rangefinder, the constancy of the radiation output of each beam (the TrueBeamSTx accelerator has six photon beams: 4, 6, 10, 15 MV and beams 6 and 10 MV with high dose rate without equalizing filter). The Machine Performance Check (MPC) program included in the TrueBeam accelerator software, using a special IsoCal phantom, allows you to check the main geometric and radiation characteristics in 30 minutes.

Over three years of operation, the TrueBeamSTx accelerator shows good mechanical and dosimetric stability, verified using systematic tests according to the quality control program developed in the Radiation Therapy Department of the AOC. Participation in the IAEA/WHO mail dose monitoring program using radiophotoluminescent detectors in 2019-2022. showed high dosimetric measurements and calculations accuracy of 0.1 -1.7%, at a tolerance of 5% [6] (Table 1).

Table 1 – Results of daily monitoring of geometric and radiation characteristics according to the Machine Performance Check (MPC) program for the period 2019-2022

Characteristic	Tolerance for MRS	Average actual value
Gantry position	0.3°	0.23
Collimator position	0.5°	0.13
The position of the petals of a multi-leaf collimator	0.5 mm	0.25
Treatment table position longitudinal transverse vertical turn	 0.7mm 0.7mm 1.9 mm 0.4°	 0.17mm 0.12 mm 0.07 mm 0.06°
Radiation output constancy	2%	0.65%
Beam uniformity	2%	0.35%
Isocenter position of MV imaging Position of the isocenter of KV imaging	0.5 mm 0.5 mm	0.19 mm 0.23 mm

After several months of daily MRS performance, we were convinced of the stability of all controlled characteristics and reduced the frequency of this test to three times a week. However, since it is unacceptable to rely on only one method of control, weekly, we check the mechanical and dosimetric characteristics using the StarTrack detector array, control the constancy of the radiation output, energy, symmetry, and uniformity of the beams, as well as the accuracy of lasers, rangefinder, light field dimensions.

We perform monthly verification of the radiation yield of photon beams by taking measurements using an ionization chamber in a water phantom according to the IAEA dosimetric protocol TRS-398 [7]. The beam is calibrated if the dose rate deviation at the maximum depth exceeds 1% of the required value (1 cGy per 1 monitor unit).

Dose distributions and beam profiles are monitored quarterly on a beam scanning system with a large water phantom Blue Phantom 2. Quarterly, the coincidence of the radiation and mechanical isocenters of the accelerator is checked using radiochromic film RTQA2, Ashland (Starshot test). The analysis is carried out using the IsoCheck program. The discrepancy is always less than 1 mm, which meets the stereotaxis tolerance.

The annual control also includes checking the stability of the dependence of the radiation output on the field size (output factors), coefficients of all dynamic wedges, linearity, and constancy of output of monitor units. Over three years of operation of the TrueBeamSTx accelerator, our measurements have shown the high stability of these characteristics (Table 2).

Table 2 – Stability of dosimetric characteristics of photon beams of the TrueBeamSTx accelerator for 2019-2022

Characteristic	Dose at the reference point	Beam energy (quality index)	Radiation output coefficients	Dynamic wedge coefficients
Discrepancy with base data	0.1-0.9%	0.1-0.6%	0.1 -0.8%	0-0.5%
Tolerance	1 %	1%	2%	2%

Intensity-modulated radiation therapy requires high patient positioning accuracy, which is achieved using the IGRT technique. The TrueBeamSTx accelerator has kilovolt X-ray (imaging, fluoroscopy, and cone beam computed tomography) and megavoltage (portal imaging) imaging systems. Portal dosimetry using the EPID megavoltage imaging system is also used to verify intensity-modulated dosimetric treatment plans. Therefore, the accuracy of imaging systems requires systematic monitoring. Varian accelerators have calibration programs for all modes of visualization systems (PVA Calibration). These calibrations are performed monthly after the calibration of the radiation output (absolute dosimetry). However, because stereotaxic therapy requires higher accuracy, we began to calibrate and verify the isocenter weekly (i.e., checking if the imaging system isocenter matches the accelerator isocenter accurately enough). The weekly discrepancy does not exceed 0.2 cm; after calibration and verification, it does not exceed 0.02 cm. Since stereotaxic radiosurgery requires alignment of the imaging isocenters and the device within 1 mm, we perform additional calibration and verification before each SRS session.

The accuracy of the treatment table movement through the images is checked weekly using a cubic plastic phantom with a contrasting ball in the center (Cubic Phantom). Positioning correction based on CBCT images is performed with an accuracy of less than 1 mm.

Based on the recommendations of AARM [4], we developed tests to control megavoltage and kilovoltage imaging systems using phantoms CatPhan 604, Las Vegas phantom, and Leeds TOR 18FG, performed twice a year. Controlled characteristics include scaling, spatial resolution, contrast, image uniformity and noise, and consistency of Hounsfield units for CBCT images.

The quality control program also includes tests for the multileaf collimator (MLC). These are weekly checks of petal positioning accuracy and position reproducibility in static mode (test plans are available in the accelerator software), as well as tests to check the MLC in dynamic mode, which are carried out according to the plans and analysis methods developed by Varian for all types of MLC. Once a year, the conformity of the light and radiation fields created by the MLC is checked using radiochromic film RTQA2, and the dosimetric gap and the transmittance of the MLC are measured.

Measurements of dosimetric characteristics are carried out after performing checks on mechanical parameters. Most mechanical tests (checking the position of the isocenter, the accuracy of the gantry, collimator, and treatment table movements, the position of the collimator shutters, optical rangefinder readings, etc.) are conveniently and quickly performed using the Iso-Align device, CIRS (multipurpose device for precise alignment).

Since quarterly and yearly measurements take a long time, we take them in the evenings and on weekends so as not to stop the patient's treatment process.

Discussion: Systematic testing of the performance of the radiotherapy machine is essential to ensure the accuracy and effectiveness of radiotherapy. This is a complex consisting of daily, weekly, monthly, quarterly, and annual checks, and they should be carried out by physicists and engineers of the radiation therapy department, as established by the "Standard for the Provision of Oncological Care to the Population of the Republic of Kazakhstan," paragraph 2, p. 79 [8], which is in line with international practice. This is a necessary and obligatory aspect of the use of medical particle accelerators, for which a license is issued by the Committee for Nuclear and Energy Supervision and Control of the Republic of Kazakhstan (RK) ("Handling devices and installations generating ionizing radiation"). Unfortunately, at present, permission to conduct operations to control the quality of the operation of sources of ionizing radiation, as well as instruments, equipment, and installations containing such sources or generating ionizing radiation, is issued by a license for the provision of services in the field of the use of atomic energy. This is done by analogy with the control of operational parameters of X-ray diagnostic devices, the annual conduct of which is regulated by the "Sanitary and epidemiological requirements for radiation-hazardous objects" [9], without taking into account the difference in quality control for X-ray diagnostic devices and medical accelerators. If it is sufficient for X-ray diagnostics to monitor the performance once a year, this may not be

enough for radiotherapy devices. Due to this approach, the quality control program implemented by the physicists and engineers of the clinic is not taken into account when issuing licenses. It is necessary to make adjustments to the regulations of the Ministry of Health of the Republic of Kazakhstan and the Committee for Nuclear and Energy Supervision and Control of the Ministry of Energy of the Republic of Kazakhstan and include the Quality Control Program in the set of documents for issuing a license to handle devices and installations that generate ionizing radiation. Unfortunately, not all radiation therapy departments of medical institutions of the Republic of Kazakhstan have and implement quality control programs that include all the necessary aspects and meet the current requirements. We believe independent control could be carried out by an expert group of qualified specialists, physicists, and engineers, approved by the Ministry of Health of the Republic of Kazakhstan. The experts included in this group would systematically conduct such checks and assist hospital professionals in establishing quality control programs and developing test methods to improve radiotherapy delivery accuracy. To ensure the quality and safety of radiotherapy, it is very important to independently control the performance of dosimetric measurements and other procedures included in the quality control program of the radiotherapy device [10].

Conclusion: We have developed a quality control program for a high-energy linear accelerator, the results of which correspond to the permissible values in all characteristics. For the effective and safe use of radiotherapy, it is necessary to develop a quality control program for all types of radiotherapy equipment specific to each institution and independently verify the implementation of this program.

References:

1. Determination of absorbed dose in a patient irradiated by beams of X or gamma rays in radiotherapy procedures. ICRU report 24. US: International Commission on Radiation Units and Measurements. – 1987. https://inis.iaea.org/search/searchsinglerecord.aspx?recordsFor=SingleRecord&RN=25005992

2. International Atomic Energy Agency (IAEA). Setting Up a Radiotherapy Program: Clinical, Medical Physics, Radiation Protection and Safety Aspects. – Vienna, 2008. https://www-pub.iaea.org/mtcd/publications/pdf/pub1296_web.pdf

3. Klein EE, Hanley J., Bayouth J., Yin FF, Simon W., Dresser S., Serago C., Aguirre F., Ma L., Arjomandy B., Liu C., Sandin C., Holmes T American Association of Physicists in Medicine. Task Group 142 report: quality assurance of medical accelerators // Med. Phys. - 2009. - Vol. 36. - P. 4197-4212. https://doi.org/10.1118/1.3190392

4. Bissonnette JP, Balter PA, Dong L., Langen KM, Lovelock DM, Miften M., Moseley DJ, Pouliot J., Sonke JJ, Yoo S. Quality assurance for image-guided radiation therapy utilizing CT-based technologies: a report of the AAPM TG-179 // Med. Phys. - 2012. - Vol. 39. - P. 1946-1963. https://doi.org/10.1118/1.3690466 .

5. Hanley J., Dresser S., Simon W., Flinn R., Klein E., Letourneau D., Liu C., Yin FF, Arjomandy B., Ma L., Aguirre F., Jones J., Bayouth J., Holmes T. AAPM Task Group 198 Report: An implementation guide for TG 142 quality assurance of medical accelerators // Med. Phys . - 2021. - Vol . 48(10). – P. e830-e885. https://doi.org/10.1002/mp.14992

6. Izhevska I. Principles for the provision of the IAEA/WHO service for postal TLD verification of beam calibration for radiotherapy centers. – International Atomic Energy Agency (IAEA), IAEA Laboratories in Seibersdorf , Austria, 2012. [Izhevska I. _ principles pre-delivery uslugi MAGATE '/ VOZ po pochtovoj TLD - proverke calibration puchkov dlya radioterapevticheskix centers . – International agentstvo po atomnoj e'nergii (MAGATE ') , Laboratorii MAGATE'v _ _ Zajbersdorfe , Avstriya , 2012]. http :// www - naweb . iaea . org / nahu / DMRP / documents / Principles _ of _ Operation _ (Russian. pdf

7. International Atomic Energy Agency (IAEA). Absorbed Dose Determination in External Beam Radiotherapy // Technical Reports Series. – 2000. – No. 398. https://www-pub.iaea.org/mtcd/publications/pdf/trs398_scr.pdf

8. On approval of the standard for organizing the provision of oncological care to the population of the Republic of Kazakhstan. Order of the Minister of Health of the Republic of Kazakhstan dated November 12, 2021, No. ҚР DSM-112 [Ob utverzhdenyi standarta organization okazanya onkologicheskoi pomoschi naselenyiu Republic of Kazakhstan. Prikaz Ministra zdrowoohronenyia Respubliki Kazakhstan dated November 12, 2021 year , No. KR DSM-112 (in Russ.)]. https://adilet.zan.kz/rus/docs/V2100025167

9. On approval of the Sanitary Rules "Sanitary and Epidemiological Requirements for Radiation Hazardous Facilities". Order of the Minister of Health of the Republic of Kazakhstan dated August 25, 2022, No. ҚР DSM-90 [Ob affirmzhdenii Sanitaryx pravil "Sanitarno-e'pidemiologicheskie" trebovaniya k radiacionno-opasnym ob"ektam". Prikaz Ministra health protection Republican Kazakhstan dated August 25 , 2022 , no . Қ R DSM-90 (in Russ.)]. https://adilet.zan.kz/rus/docs/V22000

10. Accuracy Requirements and Uncertainty Factors in Radiation Therapy / / . – 2022. – No. 31 _ _ _ _ _ neopredelennosti v luchevoj therapy / / . – 2022. – No. 31] https://www-pub.iaea.org/MTCD/publications/PDF/P1679_HH31_web.pdf

АҢДАТПА

СЫЗЫҚТЫҚ ҮДЕТКІШТІҢ САПАСЫН БАҚЫЛАУ БАҒДАРЛАМАСЫН ҚҰРУ ЖӘНЕ ОРЫНДАУ

Т.Ю. Антропова[1], К.Д. Датбаев[1,2], Е.И. Ишкинин[1], Б.Ғ. Латыпова[1], О.Қ. Сеитов[1,2], Ж.Т. Худайбергенов[1,2]

[1]«Алматы онкология орталығы» ШЖҚ КМК, Алматы, Қазақстан Республикасы;
[2]«Қазақ онкология және радиология ғылыми-зерттеу институты» АҚ, Алматы, Қазақстан Республикасы

Өзектілігі: *Мақалада көрсетілетін қызметтердің сапасын қамтамасыз ету саласындағы заманауи проблемалар нормативтік-құқықтық база тұрғысынан қарастырылған, сондай-ақ сызықтық үдеткіштерде-тексеру процедураларының жиілігі бойынша бақылау. Ғылыми жаңалық процедуралардың өзін егжей-тегжейлі сипаттайтын және сынақтардың жиілігі бойынша ұсыныстары бар желілік үдеткіштің сапасын бақылау бағдарламасын әзірлеуде жатыр.*

Зерттеудің мақсаты *– құрылғының механикалық және дозиметриялық параметрлерін бақылаудың қарапайым әдістерінің кешенін әзірлеу және сынау, бірақ олар халықаралық ұсынымдарға сәйкес жоғары технологиялық сәулелік терапияға қойылатын минималды талаптарға жауап береді. Атом энергиясы жөніндегі халықаралық агенттік (МАГАТЭ) және Американдық медициналық физиктер қоғамы (AAPM).*

Әдістері: *Алматыдағы онкологиялық орталықта (Қазақстан) орнатылған TrueBeamSTx сызықтық үдеткішінің (Varian, АҚШ) сапасын бақылау бағдарламасын жасау кезінде біз МАГАТЭ және AAPM ұсыныстарына сүйендік. Үдеткіш интенсивтік модуляцияланған сәулелік терапияны (IMRT, VMAT), стереотактикалық радиохирургияны және кескінді басқаратын стереотаксикалық сәулелік терапияны (SRS, SRT) орындайды.*

Механикалық және дозиметриялық сипаттамаларды бақылауға қатаң талаптар қойылады.

Нәтижелер: *Үш жылдық жұмыс кезеңінде TrueBeamSTx үдеткіші механикалық және дозиметриялық сипаттамалардың жақсы тұрақтылығын көрсетеді, ол мақала авторлары әзірлеген жүйелі сынақтар арқылы тексерілді. Сапасын бақылау бағдарламасы 2019-2022 жж. радиофотолюминесцентті детекторларды пайдалана отырып, МАГАТЭ/ӘДҰ пошта дозасын бақылау бағдарламасына қатысу. дозиметриялық өлшеулер мен есептеулердің жоғары дәлдігін көрсетті: 0,1-1,7% рұқсат етілген 5%.*

Қорытынды: *Жоғары энергиялық сызықтық үдеткішке сапасын бақылау бағдарламасы әзірленді; барлық сипаттамалар бойынша алынған нәтижелер рұқсат етілген мәндерге сәйкес келеді. Сәулелік терапияны тиімді және қауіпсіз қолдану үшін сәулелік терапия жабдықтарының барлық түрлерінің сапасын бақылау бағдарламасын әзірлеу қажет. әрбір мекемеге тән, сондай-ақ осы бағдарламаның орындалуын тәуелсіз тексеру*

Түйін сөздер: *сәулелік терапия, сызықтық үдеткіш, сапаны бақылау, дозиметриялық жабдықтар.*

АННОТАЦИЯ

СОЗДАНИЕ И ВЫПОЛНЕНИЕ ПРОГРАММЫ КОНТРОЛЯ КАЧЕСТВА ЛИНЕЙНОГО УСКОРИТЕЛЯ

Т.Ю. Антропова[1], К.Д. Датбаев[1,2], Е.И. Ишкинин[1], Б.Г. Латыпова[1], О.К. Сеитов[1,2], Ж.Т. Худайбергенов[1,2]

[1]КГП на ПХВ «Алматинский Онкологический Центр», Алматы, Республика Казахстан;
[2]АО «Казахский научно-исследовательский институт онкологии и радиологии», Алматы, Республика Казахстан

Актуальность: *В статье рассматриваются современные проблемы в области обеспечения качества проводимых услуг на линейных ускорителях с точки зрения нормативно-правовой базы, а также с точки зрения частоты проведения процедур контроля. Научная новизна заключается в разработке программы контроля качества линейного ускорителя с подробным описанием самих процедур и с рекомендациями по частоте проведения тестов.*

Цель исследования *– разработка и апробация набора достаточно простых методик контроля механических и дозиметрических параметров аппарата, которые, тем не менее, соответствовали бы минимальным требованиям для проведения высокотехнологичной лучевой терапии согласно международным рекомендациям Международного агентства по атомной энергии (МАГАТЭ) и Американского общества медицинских физиков (AAPM).*

Методы: *При разработке программы контроля качества для линейного ускорителя TrueBeamSTx (Varian, США), установленного в Алматинском онкологическом центре (Казахстан), мы опирались на рекомендации МАГАТЭ и AAPM с учетом того, что на ускорителе будет выполняться лучевая терапия с модуляцией интенсивности (IMRT, VMAT), стереотаксическая радиохирургия и стереотаксическая лучевая терапия (SRS, SRT) с использованием контроля по изображениям (IGRT), что предъявляет более жесткие требования к контролю как механических, так и дозиметрических характеристик.*

Результаты: *За трехлетний период эксплуатации ускоритель TrueBeamSTx показывает хорошую стабильность механических и дозиметрических характеристик, что проверяется с помощью систематических тестов по разработанной авторами статьи программе контроля качества. Участие в программе почтового контроля доз МАГАТЭ/ВОЗ с помощью радиофотолюминесцентных детекторов в 2019-2022 гг. показало высокую точность дозиметрических измерений и расчетов: 0,1-1,7% при допуске 5%.*

Заключение: *Была разработана программа контроля качества для высокоэнергетического линейного ускорителя; полученные результаты по всем характеристикам соответствуют допустимым значениям. Для эффективного и безопасного использования лучевой терапии необходима разработка программы контроля качества, для всех видов оборудования лучевой терапии конкретно для каждого учреждения, а также независимая проверка выполнения этой программы.*

Ключевые слова: *лучевая терапия, линейный ускоритель, контроль качества, дозиметрическое оборудование.*

Transparency of the study: *Authors take full responsibility for the content of this manuscript.*
Conflict of Interest: *Authors declare no conflict of interest.*
Financing: *The study was conducted at "Almaty oncological center" MSE on REM.*
Authors' input: *contribution to the study concept – Antropova T.Yu., Datbaev K.D.; study design – Ishkinin E.I., Latypova B.G., Seitov O.K.; execution of the stated scientific study – T.; interpretation of the stated scientific study – Latypova B.G., Ishkinin E.I.; preparation of the manuscript – Antropova T.Yu., Datbaev K.D.*

Authors' data:
Antropova T.Yu. – physicist, Physics Teacher, Medical Physicist of the Department of Radiation Therapy, "Almaty oncological Center" MSE on REM, Almaty, the Republic of Kazakhstan, tel. +77055652245, e-mail: tantropova@mail.ru, ORCID ID: 0009-0007-5324-194X;
Datbaev K.D. (corresponding author) – Master of Technical Sciences, Linear Accelerator Maintenance Engineer, Department of Dosimetry and Physical and Technical Support of Radiation Therapy, "Kazakh Institute of Oncology and Radiology" JSC; Medical Physicist, Department of Radiation Therapy, "Almaty Oncological Center" MSE on REM, Almaty, the Republic of Kazakhstan, tel. +77718507486, e-mail: kairdatbayev@gmail.com, ORCID ID: 0000-0002-0453-2878;
Ishkinin E.I. – Ph.D., Head of the Department of Radiation Therapy, "Almaty Oncological Center" MSE on REM, Almaty, the Republic of Kazakhstan, tel. +77772332963, e-mail: ishkininy@gmail.com, ORCID ID: 0000-0001-5784-1255;
Latypova B.G. – Master of Engineering and Technology, Medical Physicist of the Department of Radiation Therapy, "Almaty Oncological Center" MSE on REM, Almaty, the Republic of Kazakhstan, tel. +77718507487, e-mail: latypova_bota@mail.ru, ORCID ID: 0009-0003-6209-0048;
Seitov O.K. – Linear Accelerator Maintenance Engineer, Department of Dosimetry and Physical and Technical Support of Radiation Therapy, "Kazakh Institute of Oncology and Radiology" JSC; Engineer, Radiation Therapy Department, "Almaty Oncological Center" MSE on REM, Almaty, the Republic of Kazakhstan, tel. +77074857830, e-mail: olzhas_seitov@mail.ru, ORCID ID: 0009-0004-9477-3262;
Khudaibergenov Zh.T. – Linear Accelerator Maintenance Engineer, Department of Dosimetry and Physical and Technical Support of Radiation Ther-apy, "Kazakh Institute of Oncology and Radiology" JSC; Engineer, Radiation Therapy Department, "Almaty Oncological Center" MSE on REM, Almaty, the Republic of Kazakhstan, tel. +77077179845, e-mail: zhodi1990@gmail.com, ORCID ID: 0009-0003-1180-8566.

Correspondence address: Datbaev K.D., "Almaty Oncological Center" MSE on REM, Papanin St. 220a, Almaty 050000, the Republic of Kazakhstan.