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Technical Status and Development Trend of Medical Dynamic Multi-leaf Collimator

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Abstract

Medical multi-leaf collimator technology, as one of the core technologies in radiotherapy, effectively enhances the accuracy and safety of treatment by precisely controlling the shape of the radiation beam. This article first reviews the overall situation of cancer treatment and the important position of radiotherapy. Then, it deeply analyzes the basic principles, structural composition, working mechanism of DMLC (Dynamic Multi-Leaf Collimator) technology and its specific applications in clinical radiotherapy. On this basis, it further analyzes the development overview of DMLC technology at home and abroad, covering major manufacturers, technical parameters, market changes and the progress of localization. Finally, the article discusses the current challenges faced by DMLC technology and looks forward to its future development trends and research directions.

Keywords

Multi-leaf collimator, Radiotherapy, Leakage rate, Conformality.

1. INTRODUCTION

Cancer, as one of the major public health problems in the world, is posing a serious threat to human health as its incidence and mortality rates continue to rise. According to the statistics of the World Health Organization (WHO), there are more than 18 million new cancer cases and 9.6 million deaths globally every year. Among the many means of cancer treatment, radiation therapy has become an indispensable treatment modality with its unique advantages. Radiation therapy uses high-energy rays to destroy the DNA of tumor cells and prevent their proliferation, so as to achieve the therapeutic purpose. With the continuous advancement of medical technology, the accuracy and effectiveness of radiation therapy have been significantly improved, and it has become an important means of cancer treatment [1].

Cancer treatments mainly include surgery, chemotherapy, radiotherapy, targeted therapy and immunotherapy. Radiotherapy plays a big part in treating cancer because it’s non-invasive and usually comes with fewer side effects [2]. One of the key technologies used in modern radiotherapy is called Dynamic Multi-Leaf Curtain (DMLC) technology. It helps target tumor tissues more accurately by adjusting both the shape and strength of the radiation beam, while also protecting nearby healthy tissues as much as possible. At the heart of DMLC is the Multi-Leaf Curtain (MLC) system. This system uses several movable leaves that can change the shape of the radiation beam based on the size, shape, and location of the tumor. That way, the treatment fits the tumor more closely. Thanks to DMLC, radiotherapy has become more precise [3]. It causes less harm to normal tissues, lowers the chance of side effects, and ultimately improves patients’ quality of life. This paper looks at how DMLC technology has evolved, its

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current state, and where it might be headed in the future — all to support further research and real-world use in related areas.

2. MEDICAL MULTI-LEAF GRATING TECHNOLOGY OVERVIEW

DMLC is an advanced radiotherapy technique that dynamically adjusts the shape of the radiation beam to precisely match the three-dimensional morphology of the tumour by means of a computer-controlled multileaf grating system. The basic principle of DMLC is the use of multiple independently movable blades to form a variable grating, which can be rapidly opened or closed to control the distribution of the radiation beam. This technique allows radiation therapy to achieve a high degree of dose modulation during treatment, thereby minimising damage to surrounding normal tissue. This technique allows radiotherapy to achieve a high degree of dose modulation during treatment, thereby minimising damage to surrounding normal tissue.

The DMLC system consists of the following main components: blades, drive system, control system and positioning system. The blades are the core components of the DMLC and usually consist of tens to hundreds of blades that can be precisely adjusted to form the desired shape of the ray beam. The drive system is responsible for controlling the precise movement of the blades, usually using stepper motors or other high-precision drives. The control system calculates the trajectory and speed of the blades according to the treatment plan and ensures that the blades move according to the predefined programme. The positioning system ensures the precise positioning of the entire DMLC system so that it is accurately aligned with the position of the tumour [4].

Regarding the working mechanism, DMLC obtains the precise position and shape information of the tumour through the imaging system before treatment, and then calculates the movement trajectory of the blades using the treatment planning system (TPS). During treatment, the control system adjusts the position of the blades in real time based on these data to dynamically form a ray beam that matches the shape of the tumour. In this way, the radiation beam is able to precisely irradiate the tumour tissue while avoiding the surrounding normal tissue [5-6]. DMLC technology is extremely widely used in radiotherapy, especially in intensity-modulated radiation therapy (IMRT) and volume-modulated arc therapy (VMAT), where it plays a key role.

3. HISTORY OF MEDICAL MULTI-LEAF GRATINGS

Radiotherapy, as an important means of cancer treatment, has undergone an evolution in technology from primary to modern. Early radiotherapy techniques were relatively primitive, relying mainly on simple radiation sources to irradiate tumours. With the advancement of technology, multi-leaf grating (MLC) was developed in order to increase the precision of treatment and reduce the damage to the surrounding normal tissues [7]. Multi-leaf gratings opened a new chapter in radiotherapy technology by precisely controlling the shape of the radiation beam, making radiotherapy more precise.

As shown in Figure 1 [8], In the early days of multileaf gratings, blade adjustment often relied on manual operation, which was not only inefficient but also limited in accuracy. As shown in Figure 2, With the development of electronic technology and computer technology, electric multi-leaf grating gradually replaced manual operation. The motorised multi-leaf grating controls the movement of the blades by means of a motor, which greatly improves the speed and accuracy of adjustment, making radiotherapy more efficient and precise. This change has significantly improved the quality of radiotherapy and patient outcomes [9].

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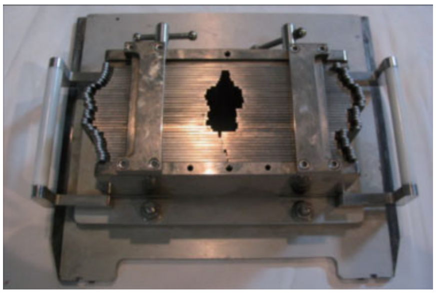

Figure 1. Manual multi-leaf grating

Figure 2. Dynamic multi-leaf collimator

The birth of Dynamic Multi-Leaf Grating (DMLC) technology marks another major leap in radiotherapy technology. DMLC technology can adjust the ray beam according to the real-time position and shape changes of the tumour through the real-time dynamic adjustment of the computer-controlled blades to achieve precise irradiation of the tumour. The application of DMLC technology not only improves the accuracy of the treatment, but also shortens the treatment time, and reduces the discomfort of the patients [10]. With the continuous progress of technology, the performance of the DMLC system has been continuously improved, and the movement speed and positioning accuracy of the blades have been significantly improved, which makes the DMLC show greater advantages in dealing with complex cases. The development of modern DMLC technology has revolutionised radiotherapy, providing cancer patients with more precise and safer treatments.

4. CURRENT STATUS OF DMLC TECHNOLOGY DEVELOPMENT AT HOME AND ABROAD

4.1. Overview of foreign DMLC technology development

In the international market, the development of Dynamic Multi-Leaf Grating (DMLC) technology has centred on a few leading medical device manufacturers. These companies are driving the advancement of DMLC technology through continuous technological innovations and product upgrades. Key manufacturers include Varian Medical Systems, Elekta and Siemens Healthcare. The DMLC products manufactured by these companies are not only technologically advanced, but also hold a large share of the market.Varian's Eclipse series and Elekta's Synergy series are two widely known DMLC products, which are favoured by clinicians for their high-precision dosage control and excellent conformal capabilities.Siemens' ONCOR Impression series also offers advanced DMLC solutions, and these products are widely used around the world [11-12].

Foreign DMLC technologies excel in technical performance, particularly in terms of blade accuracy control, dynamic response speed, and conformability. For example, according to a study, novel DMLC systems (e.g., DMLC-120) have achieved sub-millimetre accuracy in terms of blade position precision and repeatability, which significantly improves the accuracy of radiation therapy. In addition, these systems have made significant progress in reducing the

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leakage rate when the blade is closed [13]. In terms of market dynamics, the DMLC market continues to grow with the increasing demand for cancer treatment and advancements in radiotherapy technology. Rising demand for high-precision radiotherapy equipment in healthcare facilities is driving the rapid development of DMLC technology. At the same time, the cost-benefit ratio of DMLC systems is also improving with technological advancements, making these advanced treatment devices affordable for more healthcare organisations [14].

4.2. Overview of domestic DMLC technology development

The country has made remarkable progress in the research and development of DMLC technology, and some local enterprises have successfully developed DMLC products with independent intellectual property rights. These products are gradually approaching the international advanced level in terms of design and function, and are characterised by easy operation, strong adaptability and high cost-effectiveness. Domestic DMLC products have been optimised in terms of blade design, drive system and control system to meet the needs of different medical institutions. At the same time, domestic products have a greater advantage in price, which helps to reduce the procurement cost of medical institutions and promote the popularisation and application of DMLC technology [15-16].

With the improvement of domestic medical equipment manufacturing level, the localisation process of DMLC technology is accelerating. Through technological innovation and market expansion, domestic enterprises have gradually broken the monopoly of foreign manufacturers in the high-end medical equipment market. In terms of market demand, with the rising incidence of cancer and the popularity of radiotherapy technology, the demand for DMLC systems continues to grow. In addition, the support of national policies and the advancement of healthcare reform have also provided a favourable market environment for the development of domestic DMLC technology [17].

In terms of technical performance, the gap between domestic and foreign DMLC products in terms of blade precision control, dynamic response speed, and conformity is gradually narrowing. Domestic DMLC products have reached or approached the international advanced level in some key technical indicators. With the continuous maturity of the technology and further development of the market, it is expected that domestic DMLC products will be more widely used and recognised in the future [18].

5. KEY TECHNOLOGIES AND CHALLENGES

5.1. Blade design

Blade design is a crucial aspect of Dynamic Multi-Leaf Grating (DMLC) technology, which is directly related to the accuracy and effectiveness of the treatment. The main function of the blades is to create an irradiated area that matches the shape of the tumour through modulation of the radiation beam, while maximising the protection of the surrounding normal tissue. By design, the blade needs to have good rigidity and stability to ensure reliability during high-speed movement and precise positioning. The choice of material, shape, size and number of blades are all key factors to be considered in the design [19]. The material needs to be strong while minimising the absorption and scattering of radiation. The shape and size of the blade affects the precision of the regulation of the radiation beam and the uniformity of the irradiation field. Therefore, the blade design needs to find the optimal balance between therapeutic effect, system performance and economy.

5.2. Drive system

The DMLC drive system is the core component of the dynamic multi-leaf collimator (DMLC) technology, responsible for the precise movement of the leaves and the dynamic shaping of the

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beam. Its two key performance indicators, dynamic response speed and positioning accuracy, have a decisive impact on the accuracy of radiotherapy [20]. An ideal drive system must possess the characteristics of high speed, high precision, and high reliability. The system design must strictly consider the weight of the leaves, the range of motion, and the required acceleration. The motors that drive the movement of the optical grating leaves are generally divided into three types: micro stepping motors, DC servo motors, and brushless DC motors. Among them, the brushless DC motor, by replacing mechanical brushes with electronic components, can precisely and quickly control the movement of the leaves and is widely used [21]. To ensure the accuracy of movement, a feedback mechanism (such as encoders) is integrated into the system to achieve real-time monitoring of the leaf position and closed-loop dynamic adjustment.

5.3. Leakage rate

Leakage rate refers to the potential exposure of surrounding normal tissues to radiation beams that are not completely blocked when the DMLC blade is closed. This indicator is directly related to the safety and effectiveness of radiation therapy, as an excessive leakage rate may result in the surrounding normal tissues receiving an unnecessary radiation dose, increasing the risk of side effects. Therefore, the leakage rate is one of the important parameters to measure the performance of a DMLC system. During the design and optimisation of DMLCs, reducing the leakage rate is a key objective to improve the system performance. This is usually achieved by improving the blade design, material selection and manufacturing process [22]. The sealing of the blades, the matching accuracy between the blades, and the accuracy of the control system all affect the leakage rate. In addition, the use of advanced computer algorithms for precise control of blade movement can also effectively reduce leakage injection.

5.4. Conformality

Conformity is a key indicator of the quality of a radiation treatment plan, describing how well the shape of the radiation beam matches the contours of the tumour target area. High conformality means that the radiation beam is able to closely follow the shape of the tumour, thus maximising the destruction of tumour cells while reducing exposure to surrounding normal tissue. This is crucial for improving treatment efficacy and reducing side effects. In DMLC technology, the shape of the radiation beam can be modulated to achieve conformal irradiation of the tumour by precisely controlling the movement of the blades. Improvement in conformality relies on optimisation of the blade design, precise control of the drive system and advanced algorithms in the treatment planning system. The blade design needs to ensure that the desired beam shape is created at different angles and positions, while the drive system needs to ensure precise adjustment of the blade position [23-24].

6. GROWING TREND

6.1. Improved blade response and positioning accuracy

Improving both blade responsiveness and positioning accuracy are critical to achieving more efficient and precise radiotherapy. Increased blade responsiveness means that the blade can reach its intended position faster, resulting in shorter treatment times and improved treatment efficiency, while also better adapting to changes in tumour dynamics, such as respiratory movements [25]. The increased positioning accuracy then ensures that the blades can be precisely adjusted to the position required by the treatment plan to create a beam of radiation that is highly consistent with the shape of the tumour. This not only increases the homogeneity of the dose distribution in the tumour area, but also reduces the risk of side effects by reducing unnecessary irradiation of the surrounding normal tissue.

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6.2. Reduced leakage rate

Reducing the leakage rate is a key direction to enhance the performance of DMLC systems, as it is directly related to the safety and effectiveness of radiotherapy.

Single-layer gratings often require a tongue-and-groove design in order to minimise radiation leakage [26]. As shown in Fig. 3, this design blocks the rays by inter-embedding the blades, but this structure may limit the further improvement of treatment accuracy. Furthermore, it was discovered in clinical practice that there was a dovetail groove effect, which was not conducive to improving the treatment accuracy. Moreover, the processing of this type of blade was very difficult, causing problems in the assembly of the blades and gradually leading to its abandonment.

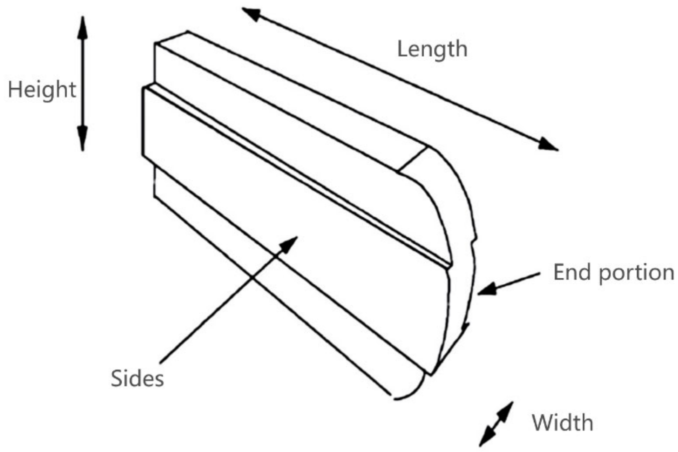

Figure 3. The blade structure of the multi-leaf grating

In recent years, double multi-leaf grating technology has been gradually applied in the field of radiotherapy. Taking the double-layer parallel multi-leaf grating equipped with the Varian Halcyon accelerator as an example [27-28], it has already achieved a target-area conformal effect comparable to that of a single-layer grating in clinical treatment. Compared with the traditional single-layer structure, this technology has four outstanding advantages: it significantly reduces processing difficulty by reducing the number of tongue and groove structures; the target area dose coverage is comparable to that of a single-layer grating; the staggered design of the double-blade layers effectively prevents leakage from the slit field, and the leakage rate is significantly better than that of a single-layer structure; and the elimination of friction resistance of tongue and groove increases the speed of movement of the blades, which directly reduces the length of a single treatment session.

Topolnjak further proposes a three-layer staggered MLC design [29-30]: three layers of conventional MLC blade units are arranged at an intersection angle of 60° to form a symmetric projection in the isocentric plane, eliminating the need for rack rotation and thus simplifying the mechanical system, as shown in Figure 4. This structure brings double breakthroughs: zero leakage is achieved by virtue of the dynamic shielding mechanism between layers, which can completely solve the problem of inter-blade leakage without relying on the concave-convex groove structure; and ultra-limit accuracy is achieved by the fact that, despite the width of a single-layer blade being 10mm, its conformal accuracy can rival that of a single-layer system with a 4mm narrow blade through the three-dimensional superposition effect, which breaks the limitations of the physical dimensions and makes a revolutionary enhancement.

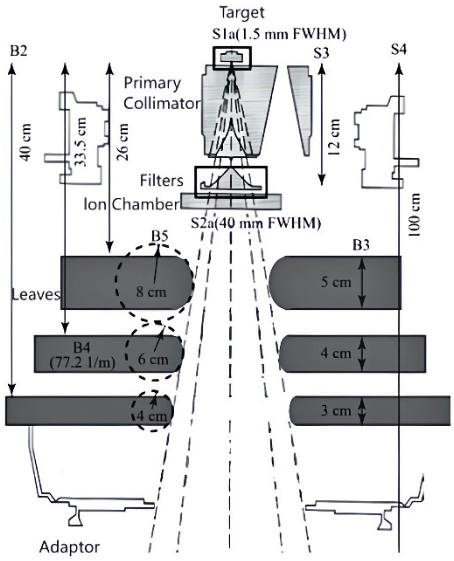

Figure 4. Schematic diagram of 3-layer grating

6.3. Improvement of conformability

Improving conformality is an important direction in the development of DMLC technology, as it determines how well the radiation beam matches the tumour target area in radiation therapy. Miniature Dynamic Multi-Leaf Gratings provide excellent conformal accuracy due to their fine blade design, and are particularly suited to situations where the accuracy of the radiotherapy field edge is critical. Industry leaders such as Elekta, Varian, Siemens and Acrel have conducted in-depth research and launched products for mMLC. Although miniature gratings exhibit high conformal accuracy over small fields of view, their field of view coverage is limited. In contrast, large gratings are usually designed with narrow blades in the centre field region to improve conformal accuracy, but their conformal performance is relatively poor when dealing with large fields [31]. The characteristic parameters of the different miniature gratings are shown in Table 1.

Table 1. Characteristic parameters of different miniature gratings

Brands and Models	Marksmanship (mm×mm)	Blade width (mm)
Elekta Apex mMLC	120×140	2.45
MRC Systems Moduleaf	120×100	2.5
BrainLAB ABM3	100×100	3.0
Wellhofer Dosmetrie miniMLC	90×90	4.5
Varian HD 120MLC	220×400	2.5-5
InCise 2 MLC	115×100	3.85

6.4. Enhanced dynamic response performance

Enhancing the dynamic response performance of DMLC is the key to improving the efficiency and effectiveness of radiotherapy. Dynamic response performance refers to the system's ability to quickly adapt to changes in tumour position when executing treatment plans, and is particularly important when dealing with tumour movement due to breathing, organ peristalsis, etc. This improved performance means that the DMLC system is able to adjust the shape and intensity of the radiation beam in real time, ensuring that a high degree of dose conformity and

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precision is maintained even when the tumour position changes. In order to achieve this, DMLC systems need to integrate more advanced real-time imaging and monitoring technologies to continuously track the position of the tumour during treatment [32]. Also, optimised algorithms and software are key to improving the dynamic response performance, as they are able to predict the trend of tumour movement and adjust accordingly in advance.

6.5. Reduced failure rates and increased reliability

Improving the reliability and reducing the failure rate of DMLC systems is critical to ensuring the quality of radiotherapy treatments and patient safety. A highly reliable DMLC system can operate consistently and stably, reducing the risk of treatment interruptions and ensuring that patients receive accurate and continuous radiotherapy. The reliability of a system depends on several factors, including the durability of the hardware, the stability of the software, and the redundancy of the overall design [33]. To reduce the failure rate, manufacturers need to use high-quality materials and advanced manufacturing processes to ensure that all components of the DMLC system have long-term stable performance. In addition, the system should be designed with fault detection and self-healing capabilities in mind so that problems can be quickly identified and action taken when they occur.

7. CONCLUSION

DMLC technology plays a crucial role in modern radiotherapy, providing precise dose distribution and highly conformal irradiation that significantly enhances treatment efficacy and reduces damage to surrounding normal tissues. This not only improves the tumour control rate, but also improves the quality of life of patients, which has significant clinical value. Despite the gap between domestic and international DMLC technology, the rapid development of domestic technology and the advancement of the localisation process are of great significance in reducing medical costs, improving the manufacturing level of domestic medical equipment, and guaranteeing medical safety. Future research on DMLC technology should focus on improving blade design, drive system performance, dynamic response capability, reducing leakage rate and improving conformability. At the same time, interdisciplinary cooperation should be strengthened to develop smarter and more efficient DMLC systems by combining cutting-edge technologies such as artificial intelligence and big data.

REFERENCES

[1] ZHOU Jingrun, ZHU Shaolin, ZHU Lei, ZHANG Han, and HE Lemin, “Design and clinical application evaluation of multi-leaf collimators”, Chinese Journal of Medical Instrumentation, 2023, Vol. 32 (2), p202-208

[2] LIU Fubo, LI Guangjun1, SHEN Jiuling, LI Liqin, and BAI Sen, “A review of progress of real-time tumor tracking radiotherapy technology based on dynamic multi-leaf collimator”, Biomedical Engineering, 2017, Vol. 34 (1), p145-149

[3] Zhang Mengmeng, “Research of multi - leaf collimator”, Modern Instruments & Medical Treatment, 2023, Vol. 29 (3), p66-72

[4] Ravindra Shende, and Ganesh Patel, “Validation of Dosimetric Leaf Gap (DLG) prior to its implementation in Treatment Planning System(TPS): TrueBeamTM millennium 120 leaf MLC”, Practical Oncology And Radiotherapy, 2017, Vol. 22, p485-494

[5] LYU Jun, CHEN Liuli, WEN Ruijun, LONG Pengcheng, SHANG Leiming, and HU Liqin, “Structural Design and Penumbra Analysis of Dynamic Multi-leaf Collimator Leaf End”, Chinese Medical Instrumentation, 2023, Vol. 47 (4), p377-382

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202508_11(8).0005

[6] YU Quan-da, and ZHENG Xue, “Failure analysis and maintenance of medical linear accelerator MLC”, China Medical Equipment, 2021, Vol. 18 (7), p186-188

[7] LUO Yu, “Elekta Synergy Medical Linear Accelerator Multi-Leaf Grating Troubleshooting and Repair”, Medical Equipment, 2019, Vol. 32 (13), p127-128

[8] GUO Zhao, “Technical Status and Development Trend of Dynamic Multileaf Grating Collimator”, China Medical Devices, 2021, Vol. 36 (1), p154-158

[9] CHEN Chaomin, “Research on Three-Dimensional Static Intensity-Modulated Radiation Therapy Technology”, Southern Medical University, 2007

[10] TAN Jian-feng, and LU Xu-we, “Dosimetric difference comparison between dynamic multi -leave collimators intensity -modulated radiotherapy and step shoot intensity-modulated radiotherapy in cervical cancer treatment”, BME ＆ Clin Med, 2019, Vol. 23 (6), p 661-665

[11] Qihui Lyu, Ryan Neph, Victoria Y Yu, Dan Ruan, and Ke Sheng, “Single-Arc VMAT optimization for Dual-Layer MLC”, Phy Med Biol, 2019, Vol. 64 (9), 095028

[12] Tze Yee Lim, Irena Dragojević, David Hoffman, Everardo Flores-Martinez, and Gwe-Ya Kim, “Characterization of the Halcyon multileaf collimator system”, Radiation Oncology Physics, 2019, Vol. 20 (7), p202-203

[13] Ryohei Miyasaka, SangYong Cho, Takuya Hiraoka, Kohei Chiba, Toru Kawachi, Tetsurou Katayose, Yuhi Suda, and Ryusuke Hara, “Investigation of Halcyon multi-leaf collimator model in Eclipse treatment planning system: A focus on the VMAT dose calculation with the Acuros XB algorithm”, Applied Clinical Medical Physics, 2022, Vol. 23 (3), e13519

[14] Rohani S. A., Mahdavi S. R., Mostaar A., Ueltzhöffer S., Mohammadi R., and Geraily Gh., “Physical and Dosimetric Aspect of Euromechanics Add-on Multileaf Collimator on Varian Clinac 2100 C/D”, J Biomed Phys Eng, 2019, Vol. 9 (1), p29-36

[15] XIE Chuanbina, SHEN Hongfenga, DAI Xiangkuna, GAO Wenchaob, WANG Junliangb, LIU Yanlia, YU weia, and QU Baolin, “Stability Analysis for Domestic Medical Linear Accelerator VenusX”, China Medical Devices, 2021, Vol. 36 (4), p61-64,75

[16] Cao Maomao, and Chen Wanqing, “Interpretation on the global cancer statistics of GLOBOCAN 2020”, Chinese Journal of the Frontiers of Medical Science (Electronic Version), 2021, Vol. 13 (3), p63-69

[17] MA Tianbin, JIANG Zhendong, YU Haidong, ZHANG Hanxiong, HU Dan, and CHEN Yibiao, “Multileaf collimators of two different leaf widths in radiotherapy of nasopharyngeal carcinoma: a dosimetric comparison”, Chinese Journal of Medical Physics, 2021, Vol. 38 (3), p302-307

[18] Zhang Chunlei, Zhang Hui, Ye Peiqing, and Zhang Luhong, “Inductance Analysis of Two-Phase Slotless Tubular Permanent Magnet Synchronous Linear Motor”, Transactions of China Electrotechnical Society, 2021, Vol. 38 (3), p1159-1168

[19] Peiris GS, Whelan B, Hardcastle N, and Sheehy SL, “The effect of multi-leaf collimator leaf width on VMAT treatment plan quality”, Journal of Applied Clinical Medical Physics, 2025, Vol. 26, e70018

[20] Yang Jiming, Ma Min, Wu Yong, and Ren Jiangping, “Tolerance and dosimetric study of multi-leaf collimator leaf position accuracy for dynamic intensity-modulated radiotherapy”, Chinese Journal of Radiation Oncology, 2021, Vol. 30 (11), p1167-1172

[21] Qiu M, Zhong J, Xiao Z, and Deng Y, “From plan to delivery: Machine learning based positional accuracy prediction of multi-leaf collimator and estimation of delivery effect in volumetric modulated arc therapy”, Journal of applied clinical medical physics, 2024, Vol. 25 (9), e14437

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202508_11(8).0005

[22] Raj A, Khanna D, Vt H, Padmanabhan S, Mohandass P, “Evaluation of dosimetric effect of millennium and high definition multi leaf collimator using 6 MV photon beams”, Asian Pacific Journal of Cancer Prevention, 2021, Vol. 22 (12), p3883-3888

[23] Andrew Morrow, Nickolas Trisnadi, Heeteak Chung, “Multi-level multi-leaf collimators: Optimization of layer thicknesses and a feasibility study”, Medical Physics, 2022, Vol. 49 (2), p792-800

[24] Nels C. Knutson, PhD, William R. Kennedy, MD, Francisco J. Reynoso, PhD, Jiayuan Peng, MS, Lauren E. Henke, MD, Eric Laugeman, MS, Michael Watts, MS, Jessica Hillard, MS, Ana Heermann, AS, Geoffrey D. Hugo, PhD, Sasa Mutic, PhD and Bin Cai, and PhD, “Intracranial Stereotactic Radiation Therapy With a Jawless Ring Gantry Linear Accelerator Equipped With New Dual Layer Multileaf Collimator”, Advances in Radiation Oncology, 2020, Vol. 5 (3), p482-489

[25] LI Xiaohong1, MEI Jie2, LONG Hao3, and YANG Jing, “Study on the Performance of Two-Dimensional Semiconductor Matrix and Its Application in Dose Verification of Multi-Target Radiotherapy Plan”, China Medical Devices, 2022, Vol. 37 (4), p23-26,34

[26] SM Chae, GW Lee, and SH Son, “The effect of multileaf collimator leaf width on the radiosurgery planning for spine lesion treatment in terms of the modulated techniques and target complexity”, Radiation Oncology, 2014, Vol. 9 (1), p72

[27] YAO Jonathan Yi, “A Multiple layer multileaf collimator”, US, EP0751532B1[P], 1999

[28] MOSHE Ein-Gal, “Multiple layer multileaf collimator”, EP, US6266393B1[P], 2001

[29] ZHU Zhiqiang, CHENG Peng, CHEN Liuli, et al, “Technical Status and Development Trend of Medical Electron Linear Accelerators[J]”, Chinese Journal of Medical Instrumentation, 2024, Vol. 48 (2), p184-191

[30] Topolnjak R, Van der Heide UA, Raaymakers BW, et al, “A six-bank multi-leaf system for high precision shaping of large fields[J]”, Phys Med Biol, 2004, Vol. 49 (12), p2645-2656

[31] Chen Liuli, Lv Jun, Zhu Zhiqiang, Shang Leiming, Long Pengcheng, and Hu Liqin, “A Summary of Technical Development of Medical Dynamic Multi-leaf Collimator”, Medical Equipment, 2023 ,Vol. 36, (1), p156-160

[32] Zadnorouzi M, Abtahi SMM, “Artificial intelligence (AI) applications in improvement of IMRT and VMAT radiotherapy treatment planning processes: A systematic review”, Radiography, 2024 ,Vol. 9, (49), p1530-1535

[33] Fodil NE, Abdelhakem MM, Yahia GA, and Ammar H, “Evaluation of Dynamic Multi-Leaf Collimator (MLC) versus Fixed MLC for Intensity Modulated Radiotherapy (IMRT) Using the Agility 160-Leaf Collimator” 2024, Vol. 25, (7), p2467-2474