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abstract

Energy Modulation and Flattening Filter Application in Photon Beam Linear Accelerators for Brain Tumor Treatment: The Simulated and Patient Data Analysis

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Energy Modulation and Flattening Filter Application in Photon Beam Linear Accelerators for Brain Tumor Treatment: The Simulated and Patient Data Analysis

Author: Shehwar Khan[1,2], Faiza Anjum[3], Asghar Ali[3], Hamidullah[2], Samah Abdullah Abdel Azeem[4,5], Jeong Ryeol Choi[6]

Affiliation: [1]Combined Military Hospital, Lahore, Pakistan
[2]Riphah International University, Lahore, Pakistan
[3]University of Lahore, Lahore, Pakistan
[4]College of Science and humanities in AL Kharj prince sattam bin abdulaziz University, Al Kharj, Saudi Arabia
[5]Faculty of Women for Arts Science and education ,Ain Sham University,Cario,Egypt
[6]Kyonggi university, Suwon, Republic of Korea

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Introduction: Radiotherapy for brain tumors demands exceptionally high dose conformity and efficiency while rigorously sparing critical healthy tissues. This study aims to comprehensively investigate and compare the dosimetric characteristics and clinical implications of traditional Flattening Filter (FF) photon beams versus Energy Modulation (EM) or Flattening Filter Free (FFF) photon beams in linear accelerators (Linacs) for the treatment of intracranial lesions.

Methodology: The analysis utilized a dual-method approach combining Monte Carlo simulations for accurate beam modeling and a retrospective review of patient data derived from clinically optimized treatment plans. Key dosimetric indices—including Planning Target Volume (PTV) coverage, Organ at Risk (OAR) sparing (e.g., brainstem, optic structures), Dose Conformity Index (CI), and Homogeneity Index (HI)—were evaluated. Furthermore, treatment efficiency, quantified by Monitor Units (MU) and treatment time, was assessed between the two delivery modalities.

Results: The results demonstrated that EM/FFF photon beams offer superior dosimetric performance, specifically yielding better dose conformity to complex PTV shapes and a marked reduction in low-dose and peripheral dose compared to FF beams. Analysis of patient data confirmed that the EM/FFF technique achieved clinically acceptable or improved PTV

coverage while significantly lowering the mean and maximum doses delivered to critical OARs. Crucially, the FFF technique reduced the required MU count by an average of 40-60%, translating to a substantial decrease in overall treatment delivery time.

Conclusion: Energy modulation and FFF technology provide tangible dosimetric advantages and clinical efficiencies for brain tumor radiotherapy. Their implementation allows for increased precision in dose delivery, enhanced tissue sparing, and reduced patient immobilization time, supporting their adoption as the preferred technique for advanced intracranial treatment protocols.

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