Cancer Science 2020: Small Commissioning of a Flattening Filter Free (FFF) using an Anisotropic Analytical Algorithm (AAA), Bangladesh

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Aim: To compare the dosimetric parameters of the flattened and flattening filter free (FFF) beam and to validate the beam data using anisotropic analytical algorithm (AAA).

Materials and Methods: All the dosimetric data's (i.e. depth dose profiles, profile curves, output factors, penumbra etc.) required for the beam modeling of AAA were acquired using the Blue Phantom RFA for 6MV, 6FFF, 10MV & 10FFF. Progressive resolution Optimizer and Dose Volume Optimizer algorithm for VMAT and IMRT were are also configured in the beam model. Beam modeling of the AAA were compared with the measured datasets.

Standard medical electron linear accelerators (linacs) with flattened photon beams (also called flattening filter photon beam) are in clinical use from past 6 decades for treatment of cancer employing both conventional (e.g. parallel opposed field, box technique) and advanced (intensity-modulated radiotherapy, IMRT; intensity-modulated arc therapy, IMAT; volumetric modulated arc therapy, VMAT, etc.) techniques. The purpose of using flattening filter is to convert the forward peaked MeV bremsstrahlung photon intensity into uniform intensity pattern for obtaining clinically acceptable beam profile. However, recently introduced advanced techniques of radiotherapy are based on the further modulation in the intensity pattern of the flattened photon beam indicating that flattening of initially produced unflat beam is not necessary for such advanced treatment techniques. A number of studies were carried out on existing medical linac by removing the flattening filter (FF) to produce the unflat photon beam and demonstrated their feasibility in the implementation of advanced radiotherapy techniques. It was also demonstrated that the removal of the FF results in significant increase in dose rate by a factor of about 2-4, softening of the x-ray spectra leading to reduction in scattered radiation as well as reduction in neutron and photon leakage from the treatment head. Encouraged with such findings, manufacturers came forward with a modified version of linac designs incorporating the options of generating both flattened and unflattened photon beam for clinical use. This development has necessitated the modification in the evaluation criteria of the medical linacs before their clinical use. It is well known that the FF in a standard linac acts as an attenuator, beam hardener, and the scatterer. Due to removal of the FF, the dosimetric parameters such as field size definition, beam quality, surface dose, off axis ratio (OAR), beam flatness, symmetry, and penumbra as well as depth dose profiles of unflattened beam differs from flattened beam.

Fogliata *et al*. proposed new definitions for evaluating the beam characteristics of FFF photon beams generated by standard medical linacs for establishment of quality assurance (QA) programs in the clinical environment by modifying the definitions of dosimetry quality control parameters of FF beams. However, evaluating the dosimetry characteristics of FFF photon beam applying their definitions are complex in nature, which requires normalization/re-normalization of beam profiles and finding out the inflexion points by taking derivatives of the beam profiles. Evaluation of dosimetry characteristics of FFF beam as per their definitions requires the use of dedicated software and hence need further review and simplification so that the user can easily implement in the practice.

As of now, no standard acceptance test protocol containing easily implementable definitions of dosimetry parameters is available for unflat photon beam generated by standard medical linacs. The Atomic Energy Regulatory Board (AERB) of India constituted a Task Group (TG) comprising experts from regulatory agency, advisory body/research and technical institutions, and clinical radiotherapy centers in the country to evolve and recommend the acceptance criteria for the flattening filter-free (FFF) photon beams. The Task Group approached manufacturers/suppliers of standard medical linac for obtaining technical details about the technology of their FFF beam linac and their viewpoints in evaluating the characteristics of FFF photon beams. The information received from the manufacturers/suppliers as well as the data available in the literature were thoroughly reviewed and acceptance criteria for FFF photon beam from standard medical linac were evolved. One could think of using the available definitions of beam parameters prescribed for flat photon beams. However, some of the definitions of the beam parameters (e.g., flatness, symmetry, penumbra) prescribed for evaluating the characteristics of flat photon beams are not applicable to unflat photon beams because of significant differences in shape of their beam profiles. The rationale for prescribing the definitions of beam parameters was to make it applicable to the shape of beam profiles of unflat photon beams. This paper presents the evaluation criteria and recommendations of the AERB Task Group constituted for this purpose.

The technology of FFF beam linacs

Currently two vendors, namely M/s Varian Medical Systems, USA (TrueBeam System) and M/s Siemens Medical Solutions, Germany (PreScision package for upgrading their existing linac models of PRIMUS, ONCOR, and ARTISTE for generating unflat photon beams), are supplying electron medical linacs which are having capabilities of generating high-intensity unflat photon beams.

TrueBeam system is a new linac of Varian Medical Systems, which is designed to deliver flattened (FF), as well as flattening filter-free (FFF) photon beams. It represents a new platform of Varian linacs, where many key elements including the waveguide system, carousel assembly, beam generation, and monitoring control system differ from the preceding CLINAC series. TrueBeam system of M/s Varian Medical Systems is supplied to the user in two different versions, namely TrueBeam and TrueBeam STx. TrueBeam is a general purpose linac while TrueBeam STx is a special purpose linac, which is used for stereotactic irradiations. These linacs are capable of producing stable, high-intensity beam output (high dose rate) over a wide X-ray energy spectrum. It also contains a multiport X-ray filter management system (carousel) that accommodates field flattening filters and open ports. The dosimetry systems of these linacs (i.e., monitor chamber) are capable of accurately processing a wide range of ionization per pulse. The maximum dose rates of TrueBeam system are 1400 and 2400 MU/min for 6 MV (labeled as 6XFFF) and 10 MV (labeled as 10XFFF) X-rays, respectively.

M/s Siemens Medical Solutions introduced a new option called PreScision package for upgrading their existing linac models of PRIMUS, ONCOR, and ARTISTE for generating unflat photon beams. The PreScision feature supports stereotactic radiosurgery (SRS) as well as stereotactic radiotherapy (SRT) using the conventional linac and subsystems for the delivery of precision dose to tumors using high-intensity unflat photon beams. The PreScision option can be used for operating the linac up to the dose rate of 2000 MU/min for nominal unflat photon beam energy of 7 MV (labeled as 7UF). The quality index of unflattened 7UF photon beam is similar to quality index of 6 MV flattened photon beam.

Results: Due to the higher and lover energy component in 6FFF and 10FFF the surface doses are 10 to 12% higher compared to flattened 6MV and 10MV beams. FFF beam has a lower mean energy compared to the flattened beam and the beam quality index were 6MV 0.667, 6FFF 0.629, 10MV 0.74 and 10FFF 0.695 respectively. Gamma evaluation with +2% dose and 2mm distance criteria for the Open Beam, IMRT and VMAT plans were also performed and found a good agreement between the modeled and measured data.

Conclusion: We have successfully modeled the AAA algorithm for the flattened and FFF beams and achieved a good agreement with the calculated and measured value

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