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Evaluation of dosimetric impact of Flattening Filter-Free(FFF) Photon Beams in 3D conformal radiotherapy

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Abstract: Flattening Filter Free (FFF) photon beams have been frequently used in radiotherapy clinical practice. This study aimed to analyze the dosimetric quality of the FFF beams, as compared to the standard flattened beams (FB) for plans of treatment of three patients involving three cancer sites using the 6 and 10 MV photon energies and the 3D conformal radiotherapy technique (3D-CRT). The doses to the planning target volumes (PTVs) and organs at risk (OARs) were compared. The dose-volume histogram curves analysis show that no significant differences between FFF and FB plans were found in the coverage and mean dose for the PTV, the OAR revealed slight differences. So the FFF photon beam achieved comparable dosimetric quality as the standard flat beam.

***Keywords*:** Flattening Filter Free (FFF), 3D conformal radiotherapy (3D-CRT), Treatment planning, Dosimetric evaluation

Düzleştirici Filtresiz Foton Kirişlerin (FFF) 3D Konformal Radyoterapide Dozimetrik Etkilerinin Değerlendirilmesi

Özet: Düzleştirici Filtre Serbest (FFF) foton ışınları, radyoterapi klinik pratiğinde sıklıkla kullanılmaktadır. Bu çalışmada, 6 ve 10 MV foton enerjileri ve 3D konformal radyoterapi tekniği (3D-CRT) kullanılarak üç kanser bölgesi içeren üç hastanın tedavi planları için standart düzleştirilmiş kirişlere (FB) kıyasla FFF ışınlarının dozimetrik kalitesini analiz etmeyi amaçladık. Planlanan hedef hacim dozları (PTV'ler) ve risk altındaki organlar (OAR'ler) karşılaştırıldı. Doz-hacim histogram eğrileri analizi, FFF ve FB planları arasında PTV için ortalama doz ve ortalama doz arasında anlamlı bir fark bulunmadığını, OAR'ın hafif farklılıklar olduğunu göstermektedir. Böylece FFF foton ışını, standart düz kiriş olarak karşılaştırılabilir dozimetrik kaliteye ulaşmıştır.

***Anahtar Kelimeler*:** Düzleştirici Filtresiz (FFF), 3D konformal radyoterapi (3D-CRT), Tedavi planlaması, Dozimetrik değerlendirme

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1. INTRODUCTION

The principle of radiotherapy is to deliver a uniform dose to the cancerous tumor, a dose large enough to ensure sterilization, and try to avoid the healthy surrounding organs or minimize their dose deposited to limit secondary complications [1].

Conventionally, for a linear accelerator, as the intensity of the photons is greater at the center of the beam due to the anisotropic angular distribution, a conically shaped flattening filter is introduced at the center of the beam to obtain a uniform transverse intensity but due to the progression of new treatment techniques that do not require uniform fluency profiles, The flattening filter-free (FFF) radiation beams have recently become available on modern linear accelerators and it has been frequently used in radiotherapy clinical practice [2, 3]. Many research focused on analyzing characteristics of FFF beams and their possible clinical use has been reported. [2-11]. At first, the interest for these beams was mainly related to the increase of the dose rate. However, FFF beams have been shown to have many other characteristics that differentiate them from flattened beams. For the use of this type of beams, Several aspects related to treatment planning, optimization and dosimetry need to be studied in more details in order to facilitate the clinical implementation of FFF beams [10].

The use of an FFF beam for treatment delivery should be discussed separately for each technique. But the 3D Conformal radiation therapy (3D-CRT) has not been studied in detail with respect to planning with un-flattened beams. This study aimed to analyze and evaluate the dosimetric quality of the FFF photon beams for the 3D-CRT, as compared to the standard flattened photon beams (FB).

2. METHODS

A total of six treatment plans with 3D-CRT were generated for 3 patients acquired at the University Hospital center "Ben badis" of Constantine and randomly selected, involving three cancer sites: head & neck (nasopharyngeal carcinoma), thorax (lung) and pelvis (prostate) using both FB and FFF beams and preserving the same plans details.

In this study, all plans were generated in "Eclipse" treatment planning system (TPS) of "Varian Medical Systems". The analytical anisotropic algorithm AAA (version 10.0.28) was applied for dose calculation by processing technique of field in field (FiF) comprises using a photon beams of 6 and 10 MV energies with or without flattening filter from a "True Beam" linear accelerator with different number and angles of fields according to the cancer site such as described below:

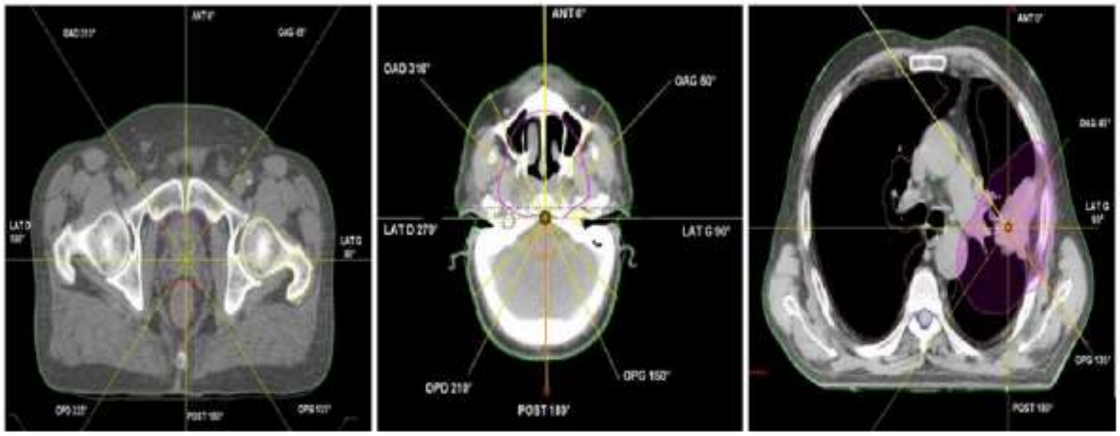

Figure 1. Planning techniques used for prostate, head & neck and lung at anti cancer center, University hospital -Ben Badis-Constantine (Algeria).

For the prostate case, the cumulative dose given for treatment is 74 Gy with energy of 10 MV and 8 fields at angles 0, 45, 90, 135, 180, 225, 270, 315°, for the lung is 66Gy with energy of 6 MV and 5 fields at 0, 45, 90, 135, 180° and the nasopharyngeal carcinoma case is delivered 70 Gy by 7 fields at 50, 90, 150, 180, 210, 270, 310° with energy of 6 MV.

Based on the information analyze from the dose volume histograms (DVHs), the doses to the planning target volumes (PTVs) and organs at risk (OARs) of FFF beams were compared with the FB plans for each case.

3. RESULTS and DISCUSSION

The doses to the planning target volumes (PTVs) and organs at risk (OARs) are calculated and presented in the dose volume histograms (DVH) curves. The results obtained are shown below.

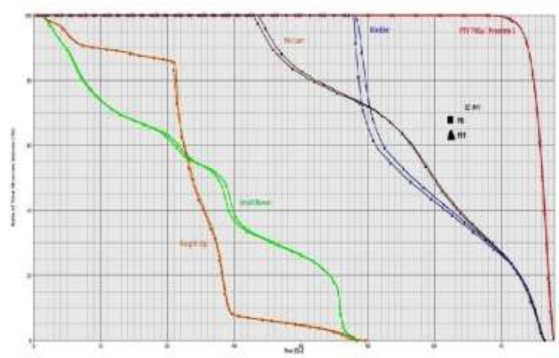

Figure 2. DVH comparison between FFF and FB plans of prostate 3D-CRT using 10MV energy.

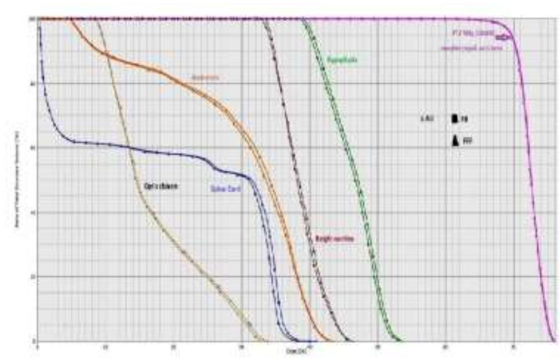

Figure 3. DVH comparison between FFF and FB plans of head & neck 3D-CRT using 6MV energy.

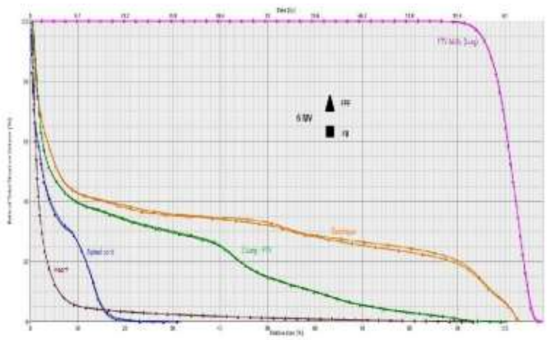

Figure 4. DVH comparison between FFF and FB plans of head & neck 3D-CRT using 6MV energy.

These curves shown in figures (2, 3 and 4) represent the variation of percentage irradiated volume as a function of the dose delivered to PTV and OARs for the three cases nasopharyngeal carcinoma, prostate and lung respectively with 3D-CRT field in field technique. In general, the DVH curves analysis show that the FFF beam provides similar target coverage and homogeneity dose as the flattened beam for the three cases with improved a little dose sparing to organs-at-risk (OARs).

In this study, the surface dose when using FFF beams could not be evaluated but many authors reported that it is increased [10-11]. Based on these results, there were no substantial differences and no clear dosimetric advantage exists in using flattened beams instead of unflattened beams. It should be noted that the time required to produce the plans was the same for the unflattened and flattened photon beams but due to the high dose rate the beam-on time is reduced which is potentially beneficial for treatment.

From the results obtained, we note a good agreement with the results reported in the literature for other planning system [4] and other different techniques such as the IMRT [5], Rapid-Arc [3-6-7] and stereotactic body radiotherapy (SBRT) [8-9].

4. CONCLUSION

This study aimed to assess whether FFF beams might be of clinical value, specifically in 3D-CRT. A dosimetric comparison was made between plans with and without a flattening filter to estimate the quality of the FFF beam plans. In general, plans are very similar for both types of beams with slight differences in the dose to organs at risk, but nothing statistically significant. Results reveal that it is possible to create 3D conformal plans with the 6 and 10 MV FFF beam that are clinically acceptable. More studies are recommended to specify and quantify the clinical advantages of FFF beams, especially for treatment planning, quality assurance and long term clinical evaluation.

Conflicts of interest: The authors stated that did not have conflict of interests.

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