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Multienergetic verification of dynamic wedge angles in medical accelerators using multichannel linear array

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ABSTRACT

Background: The aim of the modern radiotherapy is to get a homogenous dose distribution in PTV, which is obtained by using for example physical or dynamic wedges. The using of a physical wedge has provided such isodose distributions but their use resulted in detrimental dosimetric consequences, for example beam hardening effects and practical consequences of filter handling or possible misalignment. Linear accelerators are now equipped with collimator jaws systems and controlled by modern computers and it is possible to generate wedge shaped isodose distributions dynamically. Because of a more comfortable use of a dynamic wedge, there are alternatives to the standard physical wedge. During the treatment, different segments of the treatment field can be exposed to the primary beam at different intervals of time. This process of shrinking the field while modulating the collimator jaw velocity and dose rate creates the desired wedge-shaped isodose gradient across the treatment field. Dynamic wedges can replace physical wedges but they need more precise dosimetry and quality control procedures.

Aim: The aim of this study was to perform a multienergetic verification of dynamic wedge angles using the multichannel detector PTW LA48 linear array.

Material and methods: The measurements of angle value of dynamic wedges were performed for Clinac 2300 C/D accelerators (Varian). The accelerator was equipped with the EDW option for 6 MV and 15 MV photon beams. In this case, 7 wedge angle values were used: 10°, 15°, 20°, 25°, 30°, 45° and 60°. The dynamic wedges are realized by continuous movement of one collimator jaw. The field size is gradually reduced until the collimator is almost completely closed or the field increases, while the beam is on. The measurements were divided in two steps: in the first step, the dynamic wedges were verified with the recommended values and in the second step there the planned and measured angles of dynamic wedges were compared. Measurements were made by means of LA48 linear array of ionization chambers (PTW). The results of the measurements were compared with the reference profile produced by the treatment planning system ECLIPSE 8.5 (Varian).

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Results: The results showed differences between measured and calculated angle of dynamic wedges. The differences were observed for both energies in the case of a small angle value. For energies 6 MV and 15 MV, almost all percentage difference between the measured and calculated profile was lower than 5%. The biggest difference was observed in the first step of measurements when the angle of Dynamic Wedge was verified. The comparison between the planned and measured angle value of Dynamic Wedge showed the difference between 0.1% and 4.5%.

The difference for 6 MV for the angle value of 10° in orientation IN was 1.1% and for energy 15 MV in the same case the difference was 3.8%. Thinner wedges exhibit less difference.

Conclusion: It is necessary to provide comprehensive quality control procedure for enhanced dynamic wedges. Verification measurements should be an obligatory procedure in the recommendation for the testing of medical accelerators. These results are the preliminary results to provide measurements in other Polish Cancer Centres.

1. Background

Radiotherapy is one of the methods for treatment of cancer and is used in about 50% of tumours diagnosed in the population. For treatment of cancer external beam photon radiotherapy is used. This kind of treatment uses several different radiation beams from various directions which intersect at the tumour or target within the patient.[1] The purpose of modern radiotherapy is to receive an optimal dose distribution in target volume while sparing healthy tissue. It is possible to very precisely irradiate the volume of tumour sparing healthy tissue near the tumour owing to a rapid development of medical equipment resulting in new technologies in radiotherapy.[1]

In the process of radiotherapy, it is very important to use modern equipment for irradiation. Linear accelerators are important equipment in the process of cancer treatment. Nowadays, medical accelerators are used to achieve medical goals. The accelerators are equipped with different kinds of equipment which are used to modulate dose distribution in patient body. The individual patient anatomy demand the use of wedge shaped isodose distributions to compensate for missing tissue, irregular surface and irregular tumour volumes.[1] Among solutions used are: boluses, individual shields, multileaf collimators, physical wedges and dynamic wedges, IMRT (Intensity Modulated Radiotherapy), VMAT. However, in many clinical situations, physical wedges can be used, even though they have many limitations, such as specified limit values of physical wedges, available wedging dimensions smaller than that for open fields, long irradiation times, change of power spectrum after the beam crosses the wedge, and possible collisions of the wedge holder with the therapeutic table in isocentric techniques.[2,4] The medical accelerator Clinac is equipped with four sigmoidal, physical wedges of stainless steel as standard accessories (15°, 30°, 45°, 60°). The 15°, 30° physical wedges are optimized to accommodate the maximum field size of 20 cm × 40 cm and the 60° can accommodate a maximum field size of 15 cm × 40 cm.

The use of physical wedge have provided such isodose distributions but resulted in detrimental dosimetric consequences, for example, beam hardening effects, and practical consequences of filter handling or possible misalignment.[1,3] Linear accelerators are now controlled by modern computers and it is possible to generate wedge-shaped isodose distributions dynamically. Being more convenient to use, dynamic wedges are alternative to the standard physical wedges. Dynamic wedges are the system of collimator jaws controlled by a computer. Collimator jaws motions are used to adjust the most optimal dose distributions.[4] Because of the jaw motion, different parts of the field are exposed to the primary beam for different lengths of time. This creates a wedged dose gradient across the field. During the treatment, different segments of the field can be exposed to the primary beam for different intervals of time. This process of shrinking the field while modulating the collimator jaw velocity and dose rate creates the desired wedge-shaped isodose gradient across the treatment field.[1] For the first time modulation of radiation beam using dynamic wedge shape was proposed by Kijewski in 1978.[5] One of the first commercial products using dynamic wedges was introduced in the early 90s by Varian and it provided four wedge angles of 15°, 30°, 45° and 60°. The company has equipped a linear accelerator Clinac series C. Dynamic wedges were significantly improved by the introduction of Enhanced Dynamic Wedges (EDWs). An EDW has seven wedge angles (10°, 15°, 20°, 25°, 30°, 45° and 60°) for both symmetric and asymmetric field sizes.[6,7] The collimator is equipped with four independent jaws. The upper jaws are assigned as Y1 and Y2; they can move from a full open position to 10 cm across the central axis, thus allowing field sizes of up to 30 cm along the wedge direction. Indicating the moving jaw two wedge orientations are available: (Y1)-IN and (Y2)-OUT.[8] To programme the Dynamic Wedges (DWs) 256 Segmented Treatment Tables (STTs) were used providing continuous outputs as a function of jaw positions for all beam energies of symmetrical fields within the range of 4–20 cm.[7] The STTs are implemented on Varian Clinac console to control the dose rate and jaw movement to produce a set of DWs. STTs include also information on the moving collimator position versus cumulative weighting of monitor units. The EDWs which are the second generation of DWs use a single STT.[7] The distributions of doses obtained during irradiation using a dynamic wedge is similar to the that we can receive during irradiation with the use of a physical wedge filter. The parameter which characterizes both the physical and dynamic wedges is angle. In the