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Dosimetric Analysis of Physical and Enhanced Dynamic Wedge and Its Implication in 3D-Conformal Radiotherapy Planning

Shahnawaz Ansari*, Subrat Satpathy, Anil Kumar, Santosh kumar, Nimish Kumar and BK Singh

Apollo Hospitals Bilaspur (C.G), Bilaspur, Chhattisgarh, India

***Corresponding author:** Ansari S, M.Sc (Physics), D.R.P, Apollo Hospitals Bilaspur (C.G), Bilaspur, Chhattisgarh, India, Tel: 8968708521; E-mail: ansarisnz05@gmail.com

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Abstract

Background: Across the history of radiotherapy, wedges are generally used to modify the shape of isodose lines to achieve desired clinical dose coverage to the target and to reduce the hot spot as well.

Aim: The main aim of this study was to analyse and compare the dosimetric properties of Varian's physical and enhanced dynamic wedges, and their dosimetric impact on radiotherapy plan (3D-Conformal).

Materials and Methods: All plans were generated and evaluated in Varian's eclipse planning system. For comparing the isodose line alteration, the plans were prepared in water phantom with field of size 10 cmx 10 cm. Wedges of angle 15°, 30°, 45° and 60° were used for generating isodose lines in the current study. All wedge factors were measured in water phantom using FC65 farmer type chamber.

Discussion: In the current study, the dosimetric characteristics of EDW and PW were analyzed and compared. For analyzing the impact of EDW and PW, 22 patients were taken into consideration, and 50 Gy dose was prescribed to PTV in 25 fractions.

Conclusion: The analysis of EDW and PW shows slightly different dosimetric features. EDW gives better target's coverage, less hyper dose and comparatively less MUs as compare to PW. Hence the use EDW in 3D-conformal radiotherapy plan is a prudent practice.

Keywords Isodose line; Physical wedge; Enhanced dynamic wedge

Background

Across the history of radiotherapy, wedges are generally used as tissue compensator and beam modifier to improve the dose coverage to the target. In enhanced dynamic wedge, the required dose distribution is being achieved by sweeping action one of the collimator jaws in two directions (IN and OUT) [1].Wedge filters are used to modify the shape of isodose curves, for that two beams are being deployed at different angles with small hinge angle at the target volume without creating a hotspot. The wedge angle refers to the angle through which the isodose curves are tilted, relative to their normal position perpendicular to the beam axis at reference depth. The international commission on radiation units and measurements (ICRU) recommendation for reference depth is 10 cm [2]. The presence of wedge filter in the beam path reduces the beam intensity and this must be taken into account during treatment planning. It is generally assumed that for wedged fields of different size, a single wedge factor measured for a reference field size is valid for calculation. Plta et al. examined field size dependence of a wedge factor using the Varian Clinac -4 wedge filters and Philip's SL75/5 auto wedge [3].

The Physical wedges (PW) have been the primarily means of producing the wedged fields. The required wedged dose profiles can also be achieved by computer control motion of one of the jaws. This kind of wedge is called dynamic wedge [4], which was first introduced by Varian medical system in early 1990s in linear accelerator [5]. The dynamic wedge provides a range of angle like 15°, 30°, 45°, and 60° for symmetrical field size up to 20 cm width. Capability of dynamic wedge is significantly improved by introducing the concept of Varian's enhanced dynamic wedge (EDW). Now the EDW provides wedge angle of 10°, 15°, 20°, 25°, 30°, 45°, and 60° for both symmetrical and asymmetrical field sizes up to 30 cm width. A number of studies have been conducted on PW and EDW [6-8]. Many studies related to comparison of Varian's PW and EDW still have not been reported [9-12].The dosimetric impact of enhanced dynamic wedge factors (EDWF) for symmetrical and asymmetrical photon fields have been discussed in many literatures. Physical wedge is going to out of phase in future. Hence it is essential to analyze and understand the features of enhanced dynamic wedge so that users can use it judiciously.

Aim

The main aim of this study was to analyze the dosimetric properties of Varian's physical and enhanced dynamic wedge, and their dosimetric effect in radiotherapy planning (3D-Conformal).

Material and methods

The analysis and comparison of wedge factors for PW and EDW, calculated MUs, beam profiles, maximum dose, 95% dose coverage to target, depth of 50% isodose curves, and the shape of toe and heel of 50% of isodose curve for reference field size 10 cmx 10 cm were examined for both 6 and 15 MV photons produced by Clinac - iX. In the current study both physical and enhanced dynamic wedge of angle 15°, 30°, 45°, and 60°, were used for measurements. And all measurements were carried out in water phantom (30 cm × 30 cm × 30 cm) and solid phantom with positional accuracy of dosimetry system +/- 0.5 mm.

Enhanced dynamic wedge is designed in such a way that there is no need to use external beam modifier to create dose profiles, instead wedge isodose profiles are being created by the sweeping action of one of the jaws from open to closed position while the beam is ON.

Generally EDW factor is measured as the ratio between the ion chamber integrated reading on the central axis of a wedged field and the integrated reading at the same depth for open field of same size, and same monitor units [13]. The dose rate and jaw speed are also varied during the treatment, which is the function of energy, field size and wedge angle. Two wedge orientations Y1- IN and Y2 - OUT are possible.

Enhanced dynamic wedge uses a single segmented treatment table for all field size, with 30 cm field width, and the moving jaw travels a maximum distance of 29.5 cm with 9.5 cm across the central axis. It also allows the use of asymmetric fields. This creates dose gradient across the field.

The wedges used in Varian Clinac - iX have nominal angles 15°, 30°, 45°, and 60° with four orientation (LEFT, RIGHT, IN ,OUT). These filters are made of lead and steel alloy. The physical wedge factor is measured as the ratio of dose in water at reference point of measurement on the central axis with and without wedge for same number of Monitor Units (MUs). This is calculated with the following equation:

WF (FS, d) = Dw (FS, d) / DO (FS, d)

Where DW (FS, d) is the dose at a specified point 'd' along the central axis in a specified field size 'FS' with the wedge in place and Do (FS, d) is the dose at the same point in an open field of equal dimensions for the same number of MU.

The relevant plans were generated in eclipse TPS, and all measurements carried out on Clinac - iX, a dual energy accelerator (Varian Oncology System). The wedge factors for EDW and PW for both 6 and 15 MV photons were measured in water phantom (35 cm × 35 cm × 35 cm)by using FC65 farmer type chamber and UNIDOS E elecrometer (PTW, Germany) at reference depth 10 cm.

All profiles were generated at depth 10 cm for both type of wedges by using OCTAVIUS detector 729 T10040 and Multi Check software (PTW - Freiburg, Germany), internal software version 6.1.7601.

Isodose curves for 6 and 15 MV photons with 10 cm × 10 cm field size were generated for 15°, 30°, 45°, and 60° wedges (both EDW and PW) by using eclipse treatment planning system (Varian oncology system), version 11.0.

Four fields were deployed to generate the plans at angles 0°, 180°, 90°and 270°. Energy of 6 or 15MV or both were used in patient's treatment planning as per clinical requirement. For comparative analysis of dosimetric features, our medical physics team has recorded PTV mean dose, modal dose, median dose, maximum dose, 95% of prescribed dose coverage to target (V95) and number of MUs.

Results

We have observed very slight difference in maximum and minimum value of PTV-mean, modal and median dose which is tabulated in **Table 1**.

Table 1 Maximum and minimum Mean, modal, and median dose of plans with EDW and PW.

Wedge Type	PTV					
	Mean dose (Gy)		Modal Dose (Gy)		Median dose (Gy)	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
EDW	51.1	49.7	51.4	49.9	51.1	49.9
PW	50.8	49.4	51.3	49.4	50.9	49.7

All the plans, incorporated with EDW, gives comparatively less number of MUs. This is displayed in **Figures 1 and 2** by bar diagram. Mean values of MUs in EDW is found significantly less as compare to that of PW.

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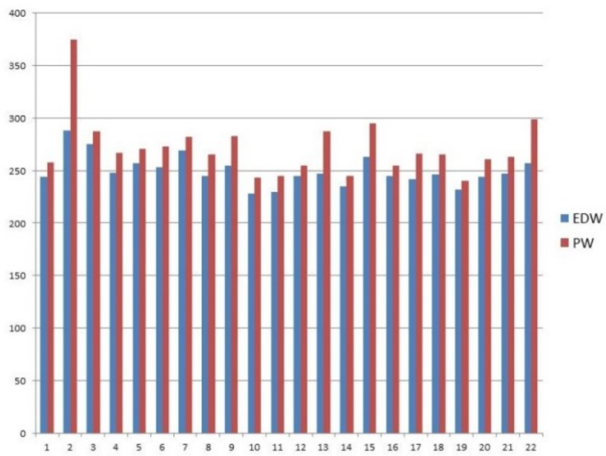

Figure 1 Comparison of MUs obtained in each plan.

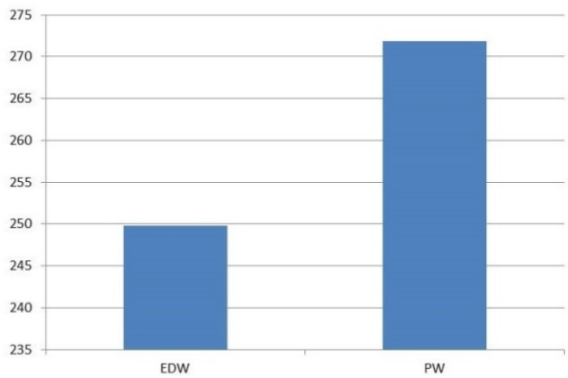

Figure 2 Comparison of mean of MUs of all plans.

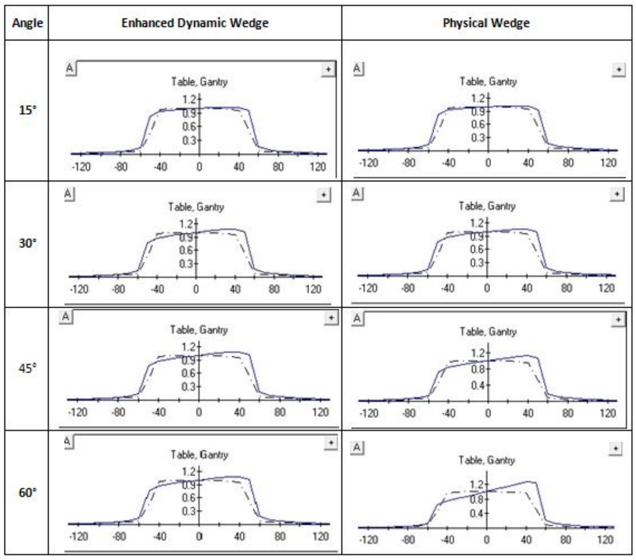

Figure 3 Profiles at 10 cm depth for Varian's physical and enhanced dynamic wedge for 6 MV photon.

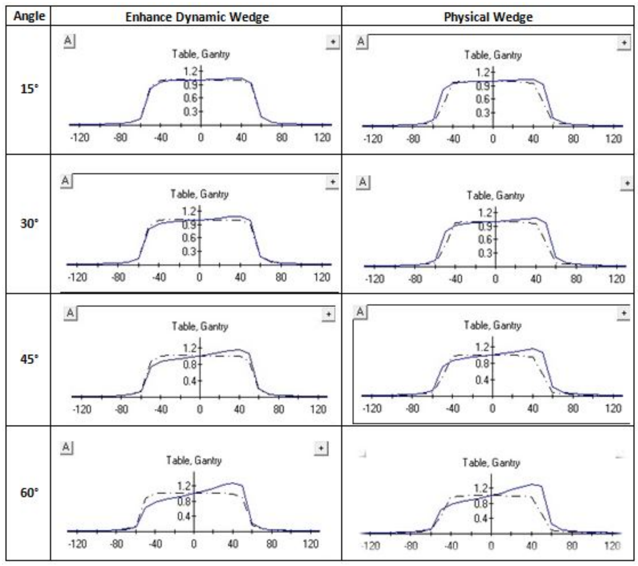

Figure 4 Profiles at 10 cm depth for Varian's physical and enhanced dynamic wedge for 15 MV photon.

The wedge profiles of Varian's PW and EDW for 6 and 15 MV photon for different wedge angle are displayed in **Figures 3 and 4**. The dotted line in the figures shows the standard profile without wedge by which we can easily observe the differences.

Standard deviation is also found less in all plans done with EDW. This is shown in **Figures 5 and 6**. PTV-mean dose is almost same in both types of plan.

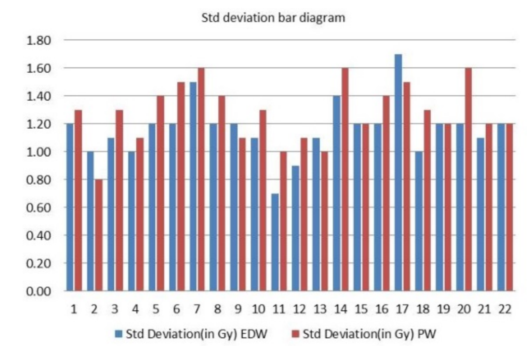

Figure 5 Standard deviation of each plan with EDW and PW.

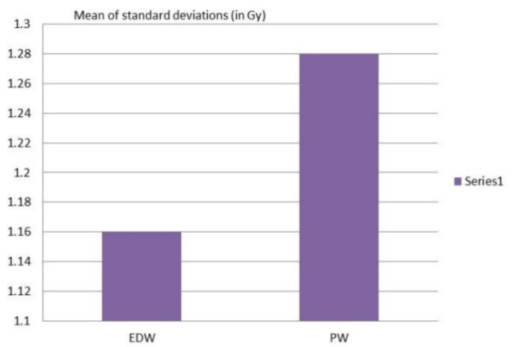

Figure 6 Mean of Std deviation for EDW and PW.

In analyzing the characteristics of PW and EDW, we noticed significant differences which further affect the number of MUs calculated in TPS.

A steep gradient has been observed in 60° physical wedge profile as compare to that of 60° enhanced dynamic wedge for both energy 6 and 15 MV.

Maximum mean dose to bladder and rectum are found equivalent in both type of plan which is tabulated in **Table 2**. All the plans with physical wedge have shown comparatively more standard deviation; while wedge factor has been found less in PW as compare to EDW.

Table 2 Maximum mean dose of OARs in each type of plan.

Wedge type	Maximum mean dose (Gy)	
	Rectum	Bladder
EDW	50.9	51.5
PW	50.7	50.8

Discussion

This study is designed for analyzing the characteristics of EDW and PW, and its therapeutic impact in 3D-conformal plan. It encompasses the dosimetric analysis of EDW and PW, and its dosimetric effect in radiotherapy treatment plan. For comparing the impact of EDW and PW, 22 patients were taken for this study, and 50 Gy dose was prescribed to PTV in 25 fraction per fraction daily, and five days a week.

Clinical advantages of Varian enhanced dynamic wedges (EDW) and Siemens virtual wedge (VW) have already discussed in many articles [14-21]. The profiles for 6 and 15 MV photon at depth 10 cm were generated in slab phantom (relative density 1.04 gm/cc). The Isodose lines like 100%, 90 %, 80%, and 50% for X-ray 6 and 15 MV were analyzed , and generated in virtual water phantom(30 cmx 30 cmx 30 cm) using eclipse TPS. All wedge factors were measured at 10 cm depth in water phantom keeping 'IN' orientation of wedges.

Analysis of profiles

Profiles for PW and EDW are found significantly different, particularly in lower energy (6MV). The profile gradient is almost same for 15° and 30° in both 6 and 15 MV photon, but noticeable difference observed in 45° and 60° wedges. PW of 60° has steep gradient as compare to EDW. The smooth gradient of EDW enhances the target coverage while steep gradient may cause under dosing the target.

Analysis of wedge factors

The physical and the enhanced dynamic wedge factors for the selected angles 15°, 30°, 45°, and 60° have been analyzed and compared. The wedge factors for 6 and 15 MV photons are shown in **Table 3**. In analysis, the wedge factor for EDW has been found numerically higher as compare to that of PW in each angle starting from 15° to 60°.

Table 3 Wedge factors for 6 and 15MV at 10 cm depth.

	6MV		15MV	
	Wedge Factors at depth = 10 cm		Wedge Factors at depth = 10 cm	
Angle	EDW	PW	EDW	PW
15°	0.9241	0.7705	0.9409	0.815
30°	0.8523	0.6171	0.8829	0.6812
45°	0.7704	0.4901	0.8136	0.521
60°	0.6603	0.403	0.7154	0.4306

Analysis of isodose curves

We analyzed and measured all isodose lines 100%, 90%, 80% and 50% which are generated in virtual water phantom using eclipse TPS at SSD = 100 cm. These curves are measured for both the photons 6 and 15 MV. It is observed that Isodose curves for 15° and 30° wedges are almost same. But 80% and 50% isodose curves for both energy are significantly differed.

This is displayed in **Figures 7 and 8**. The shape of isodose curves plays an important role in target's coverage. Hence, the selection of wedge depends upon the clinically required isodose line which may cover whole target.

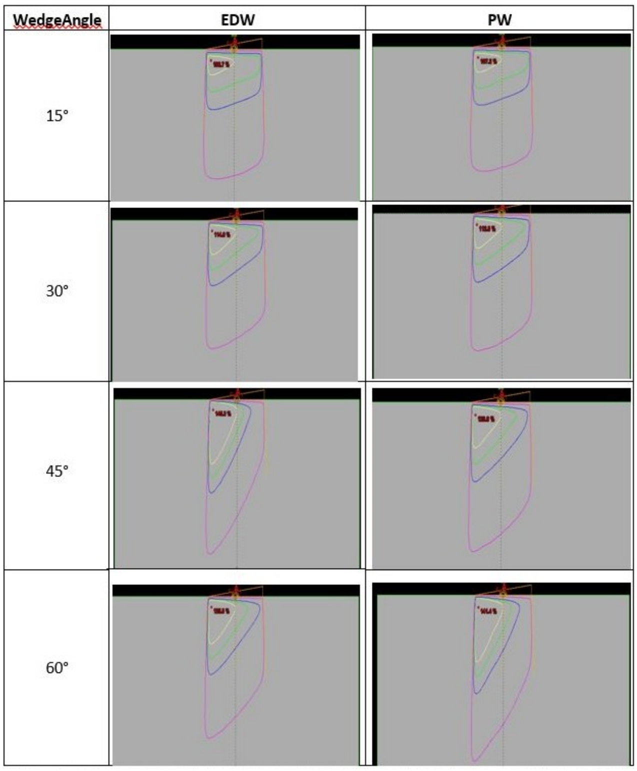

Figure 7 Isodose curves [100%, 90%, 80% and 50%] of different wedge angles for 6MV photon.

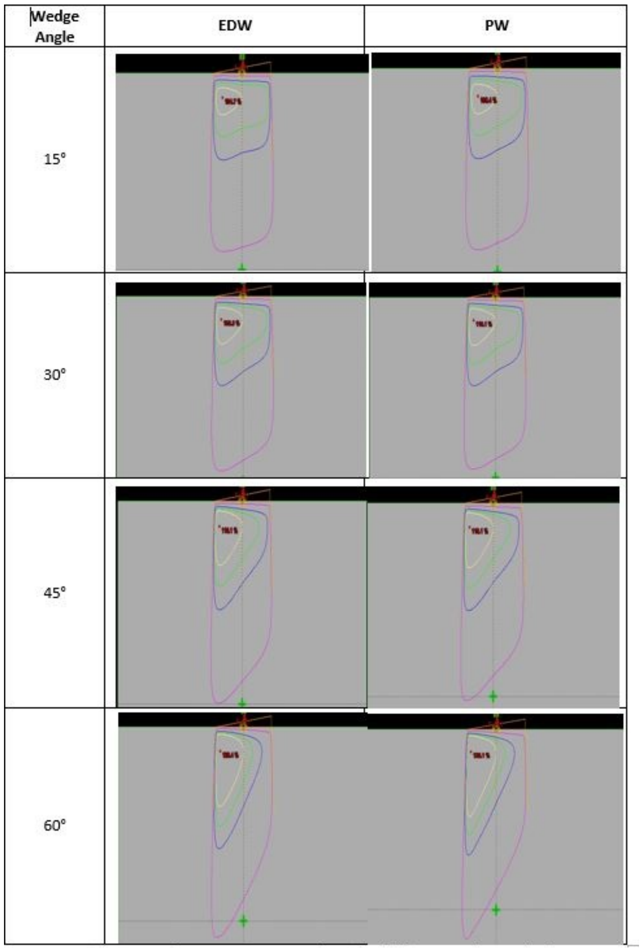

Figure 8 Isodose curves [100%, 90%, 80% and 50%] of different wedge angles for 15 MV photon.

Clinical evaluation and dosimetric comparison

For clinical evaluation, 22 patients of cervical cancer were taken randomly of heterogeneous age group, and four beams have been deployed at 0°, 180°, 90° and 270°. Both 6 and 15 MV photon were used for 3D-radiotherapy planning. Number of MUs is found less in plan incorporated with EDW as compared to that of PW. Global maximum dose is reported as 55.1 Gy in a plan having EDW.

Conclusion

A significant difference has been observed during the analysis of dosimetric features of EDW and PW. The major advantage of EDW is that it yields less number of MUs as compare to PW, which further reduces the treatment time. If 15 MV is used in the plan, EDW reduces the neutron menace because of comparatively less treatment time. The use of EDW in 3D-conformal radiotherapy plan provides ease to operators in treating the patients, so that they can focus more on patients set up. Conclusively, the current study advises the users to use EDW in place of PW whenever it is required in 3D-conformal plan.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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