Comparison of vidar dosimetry advantage pro and epson perfection V700 scanner in densitometry of radiochromic EBT2 film in measurement of high dose gradient

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Abstract. Nowadays the radiochromic film is widely used to obtain dose distribution in two dimensions with high spatial resolution, less energy dependence and near tissue equivalent. It can be a commissioning tool to verify high dose gradient of dose distribution for IMRT and VMAT techniques. However, the film scanner could affect the accuracy of dose distribution if lack of precaution. In this study, the comparison between Epson perfection V700 and Vidar Dosimetry Pro Advantage (RED) is evaluated in terms of the capability to verify the 2D dose distribution for conventional and VMAT techniques. The Gafchromic\(^\text{©} \) EBT2 films were read from two types of scanners (Epson perfection V700 and Vidar Dosimetry Pro Advantage) for volumetric modulated radiation therapy (VMAT) dosimetry. The software for analyzing the results of Epson perfection V700 and Vidar Dosimetry Pro Advantage are SNC Patient software and Omnipro’ IMRT software, respectively. Comparisons between measured and calculated dose distributions are reported as %passing rate and the gamma index for tolerance parameters of 3% and 3mm. The study found that the %passing rate obtained from Vidar scanner and Epson V700 scanner compared with Eclipse treatment planning system is more than 98% with the criteria of (3%/3mm).

1. Introduction

Treating patients with radiation is aimed towards the projection of the highest amount of radiation upon the tumor, with least amount of radiation affecting the surrounding tissues in order to cut back the side-effects resulting from radiation itself. Currently, there are numerous developments upon radiation technology and various techniques which mainly focus on the ability to project high amount of radiation on the tumor. Therefore, intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) are the two impacting techniques that are widely used due to the capabilities to control the projection of radiation upon objects similar to or, those near a to tumor (conformal). Furthermore, the accurate amount of radiation required for treatment plans could be obtained through the standards of measurement along with the suitable equipment for a conclusive result with accuracy. However, areas around the edges of the penumbra and intense radiation exposure techniques are the areas with a high amount of fluctuating radiations (High dose gradient). The examination of the latter technique requires radiation equipment with high spatial resolution and dose distribution (2D dose distribution) [2, 3].
Radiation detectors with ability to measure radiations flat or in a 2D form are often designed through the spread of radiations out to different points, often referred to as "Detector Array". The amount of detectors will determine the resolution of radiation measurement. Universal 2D radiation detectors (2D detector) include those like MapCheck and Matrixx, for instance. These equipment and their resolution upon radiation measurement depend upon the amount of detectors while the film is one of the radiation detectors that can measure radiations flat dimensionally and at the same instance, own higher resolution compared to other detectors. [4] Due to its usage limitations in which requires chemical processes to create visible images and must be processed only in dark rooms without light, the popularity of films gradually fades and led to the production of films that are usable in lighted rooms called "Radiochromic Films" [5, 6].

Among the Radiochromic films, the Gafchromic EBT2 film is the most common film in radiation treatment which is developed from its previous version (EBT film) to lessen the affects resulting from energy dependence, UV sensitivity, scratches from cuts, and further levels and balances the film's texture. In addition to the latter statements regarding the Gafchromic EBT2 film, its components are very similar to the tissues ($Z_{eff}$ value of EBT2 = 6.84, $Z_{eff}$ value of tissues = 7.42) [1] with a high spatial resolution appropriate for areas with high dose gradient of dose distribution for the IMRT and VMAT techniques. Nevertheless, a scanner is required and essential for accurate readings or to analyze results, as it will aid in the restriction of film resolution. Advice from major producers in reading EBT2 value will be needed during red light radiation activation and the scanner as Epson 10000XL, which is high in price. Along with radiotherapy in Thailand, either the "Roller Base Scanner" or the "Vidar Scanner" is used.

This research aims to compare the readings of EBT2 film values with the two scanners: Epson perfection V700 and Vidar Dosimetry Pro Advantage (RED), specifically high dose gradient and penumbra in volumetric modulated arc therapy (VMAT) according to Ramathibodi Hospital's Radiotherapy processes.

2. Materials and methods

Gafchromic EBT2 film (ISP Corporation, Wayne, NJ) owns an non-symmetrical structure with an active layer for UV and visible light protection, where its atomic composition is made up of H (40.85%), C (42.37%), O(16.59%), N(0.01%), Li(0.1%), K(0.01%), Br(0.01%), and Cl(0.04%) [7]. EBT2 film that has not been radiated will give off a yellowish hue; once radiated, areas of radiation will be affected as the initial color yellow changes into blue or navy blue in which the intensity of colors relate to the amount of radiation received. Within this research conducted, the Conventional technique and the advance technique are used along with Varian’s Clinac iX linear accelerator: LINAC of 6 MV and treatment planning equipment Eclipse V.8.9.21.

Throughout this research, the EBT2 film was used from the same batch (lot A04251303) in which was cut down into pieces. Each piece has the size of $3 \times 3$ cm$^2$, where the uniformity was measured by placing the film pieces onto a 10 cm-thick model (solid water phantom: RW3, PTW, Freiburg, Germany) and a 5 cm-thick solid water phantom was placed on top of the films. Then the amount of radiation was measured with photon energy of 6 MV, field size of $10 \times 10$ cm$^2$, SSD 95 cm, depth of 5cm, and 200 cGy of radiation. After 24 hours of radiation, the films were placed at the center of the Epson scanner V700 which used for reading the pixel values through a program called "Image J (ROI 1 $\times 1$ cm$^2$). Each film will be measured 3 times.

Calibration curve was created as the well-cut EBT2 films which were radiated with a photon energy of 6 MV, field size of $10 \times 10$ cm$^2$, SSD 95 cm, depth of 5 cm, and the amount of radiation as follows: 0, 10, 20, 30, 40, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800 cGy. The setup was similar to that of the uniformity measurement of the films, where each amount of radiation was given onto 3 pieces of film. After 24 hours of radiation, an Epson scanner V700 and Vidar Dosimetry Pro Advantage (RED) was used to read the films in order to create a calibration curve through SNC patient software and Omnipro I’mRT as for the Epson scanner V700 and for Vidar Dosimetry Pro Advantage (RED), accordingly.
In terms of the conventional technique, this technique consists of both open fields and wedge fields with sizes of 60° and a penumbra of 5 × 5 and 10 × 10 cm², treatment planning equipment Eclipse TPS, photon energy of 6 MV, SSD 95 cm, depth of 5 cm, and the amount of radiation at 200 cGy. Then, within each treatment plan, export dose plan was performed to compare the EBT2 film that measures with monitoring units resulting from the calculation and that has been setup similar to that of the field's uniformity measurement.

Treatment planning for volumetric modulated arc therapy (VMAT) runs its treatment procedures according to the provisions of TG-119, specifically the mock head and neck, and mock prostate with its CT structure from test suited by Task Group 119 which photon energy of 6 MV of 2 arcs and a half (2Arc - half) by Eclipse treatment planning with AAA algorithm version 8.9.17. For mock prostate, the structures of prostate CTV is roughly ellipsoidal, with the posterior concavity, with right-left, anterior-posterior, and superior-inferior dimensions of 4.0, 2.6, and 6.5 cm, respectively. The prostate PTV is expanded 0.6 cm around the CTV. The rectum is a cylinder with a diameter of 1.5 cm that abuts the indented posterior aspect of the prostate. The PTV includes about one per three of the rectal volume on the widest PTV slice. The bladder is roughly ellipsoidal with right-left, anterior-posterior, and superior-inferior dimensions of 5.0, 4.0, and 5.0 cm, respectively, and is centered on the superior aspect of the prostate. As part of mock head and neck, The PTV includes all anterior volume from the base of the skull to the upper neck, including the posterior neck nodes. The PTV is retracted from the skin by 0.6 cm. There is a gap of about 1.5 cm between the cord and the PTV. Dose goals used for planning and accepted treatment plan when dose distribution at 95 percent isodose is cover the PTV;[8] Then, a verification plan will be created in a phantom of 30 × 30 × 10 cm³ and a 5 cm deep export dose plan within each treatment plan in order to compare with EBT2 film that will measure with monitor units obtained from the verification plan. The EBT2 film uses the Isocentric Mounting Fixture (IMF) in which stretches across the head of the gantry, then inserts and tightly locks Mapcheck2 into IMF. After the latter process, place EBT2 film with a size of 8 × 10 cm² on the center of the CAX, then a 5 cm-thick solid water phantom on the EBT2 film, and expose radiation according to the treatment plan. Film reading will occur after 24 hours radiation of red light (636 nm) through the Epson scanner V700 (SNC patient software) and Vidar Dosimetry Pro Advantage (RED) (Omnipro I’mRT) with a resolution of 75 and 72 dpi respectively. The comparison between the calculation of dose distribution and values resulting from measurement with EBT2 film will be done with the usage of a % pass rate and Gamma index with a tolerance of 3% and 3 mm.

3. Results

The results have found that scanning with Epson scanner is affected strongly by light source uniformity more than that of Vidar Dosimetry Pro Advantage (RED), especially areas around the edges of the scanned parts which are different from the values measured at the center of the scanning area over 5%. With uniformity measured at the center of the scan area, the results have shown that at each area of the film has a percentage difference within 2%.

Figure 1 and 2 show the calibration curves of Epson Perfection V700 and Vidar Dosimetry Pro Advantage (RED), respectively. Due to different software analysis, Dose (cGy) and Scanner response go on the X and Y axis respectively for the calibration curve of Epson Perfection V700 however Optical Density (OD) and Dose (cGy) are the function in X and Y axis, respectively for the calibration curve of Vidar Dosimetry Pro Advantage (RED).

Once the percentage of the passing rate (% passing rate) obtained from the Eclipse treatment planning is compared to film reading with Epson perfection V700 and Vidar Dosimetry Pro Advantage (RED) through criteria of 3% and 3 mm, it is found that both scanners give off over 98% of the % passing rate in open fields and wedge fields in all areas of penumbra as illustrated in table 1.
Table 1. % passing rate in open fields and wedge fields in all areas of penumbra.

| Field Size (cm²) | Vidar Dosimetry Pro Advantage (RED) | Epson Perfection V700 |
|-----------------|-------------------------------------|-----------------------|
| Open field      |                                     |                       |
| 5 × 5           | 99.6                                | 99.8                  |
| 10 × 10         | 99.3                                | 99.1                  |
| Wedge Field     |                                     |                       |
| 5 × 5           | 98.5                                | 98.5                  |
| 10 × 10         | 98.2                                | 98.1                  |

On the other hand, treatment plans within the mock head and neck, which were done with the VMAT technique, has a % passing rate of 96.5% in which it is slightly more than that of those scanned with Epson perfection V700 (94%). However, a treatment plan in mock prostate gives a % passing rate of more than 96%, scanned by both scanners: Epson perfection V700 and Vidar Dosimetry Pro Advantage (RED). The results are shown in table 2.

Table 2. % passing rate in mock head and neck and mock prostate.

|                     | Vidar Dosimetry Pro Advantage (RED) | Epson Perfection V700 |
|---------------------|-------------------------------------|-----------------------|
| Mock head and neck  | 96.5                                | 94.0                  |
| Mock Prostate       | 97.6                                | 96.7                  |

4. Conclusion
This research has no means to correct uniformity (uniformity correction) for Epson scanners (which are flatbed scanners) as there is an aim to compare the abilities of the scanners in the appliance to realistic procedures. Within this conducted research, it is crucial to use the software in order to compare and contrast between Epson perfection V700 and Vidar Dosimetry Pro Advantage (RED). As a result, there is a difference in the specification of spatial resolution of 75 dpi for Epson perfection V700 and 72 dpi for Vidar Dosimetry Pro Advantage (RED). With % passing rates of both open fields and wedge fields obtained from the comparison between treatment plan equipment and scanning with Epson perfection V700 in a penumbra of 5 × 5 cm² are considered, the outcome is more than that of the Vidar Dosimetry Pro Advantage (RED) which is also measured in the same penumbra. However, when the penumbra area increases within the VMAT, the results have showed that the % passing rate of Vidar Dosimetry Pro Advantage (RED) is slightly more than that of Epson perfection V700. The calibration curve of Epson perfection V700 and Vidar Dosimetry Pro Advantage (RED) are used in different software As a result, the calibration curve is different in plotting. However when analysis by gamma index it gives nearly the same result, so the calibration curve from different software does not affect the evaluation when using the gamma index. For Vidar Dosimetry Pro Advantage (RED), it was difficult for controlling the position of film to be the same position. In contrast Epson perfection V700 will not found this issue. But from preliminary tests about the intensity of the light source, we found that the flatbed scanner (Epson perfection V700) have significant difference of the intensity of light compared to that at the
center of the scan area. With results in hand, it is most probable to learn that there is a difference in procedure between light source uniformity and the software used in comparing, which then leads to the main aim of this conducted research in order to encourage future research and studies.

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