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CORRELATION BETWEEN DETECTOR ARRAY MEASUREMENTS AND A COMPUTER ALGORITHM FOR ENHANCED DYNAMIC WEDGE PROFILES

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Abstract—Verification of dosimetric data computed by a treatment planning system is necessary in the commissioning process for any clinical software, just as it is necessary for any annual quality assurance testing. Direct verification of the dosimetric data is achievable when calculating the enhanced dynamic wedge (EDW) off-axis ratio at each point of interest. As mathematical models for hand-calculating such factors are still evolving, measurement of these external beam arrangements has proven significantly more accurate. This research presents a correlation for measured and planned data, specific for 6- and 18-MV photon beams on a Varian 21EX linear accelerator, using the EDW mode. Field generation was created using the Varian Eclipse treatment planning system. On treatment field delivery, the Sun Nuclear MapCHECK diode array was used to plot each beam profile in 2 dimensions. Wedge angles of 10°, 15°, 20°, 25°, 30°, 45° and 60° were studied here, under isocentric geometry, at a fixed water equivalent depth of 15 cm. Field size dependence was considered with each wedge and energy combination, where symmetric apertures of 5 × 5 cm^2, 10 × 10 cm^2, 15 × 15 cm^2 and 20 × 20 cm^2 were used. Accurate dosimetric results were found to be achievable when using this treatment planning system to within 2.8% maximum deviation, and to within 1% deviation averaged over all. The diode array also proved to be simple and ideally suited for EDW measurements.

Key Words: **Diode, Eclipse, EDW, MapCHECK.**

INTRODUCTION

Treatment planning systems are used routinely in therapeutic physics departments to qualitatively and quantitatively approximate dose delivery to a patient or phantom given a strict set of beam requirements.[1–4] These systems have the capability of generating plans for both electron and photon beams. For electrons, the application of a field shaping cone and possibly a lead cutout may be used. For photon beams, the number of applicable accessories and modes are significantly greater. Treatment planning systems have the ability to take into account the increasingly complex abilities of modern linear accelerators for both radiation types. For photons, this may include a need to estimate effects of blocking, field size changes, wedge angle dependence, and modulation of the output intensity throughout treatment. For some photon accessories and modes, a variety of different options exist.

To directly verify the computational achievements of a treatment planning system, measurements need to be made with the particle accelerator setup to the same identical specifications as were planned. For years, scientists struggled with the intricacy of such measurements. Depending on the detectors available for use and the necessity of beam data collection, an experiment might take minutes or even hours. The decision as to which detector type to use is still the first question to answer.

A device for measuring photon beam radiation has come available, having a large number of detectors affixed in a polycarbonate material. Driven by computer software, the instrument permits each diode to simultaneously measure radiation output from photon beams throughout its large 2Đ area. Using the device enables the researcher to gather data quickly for plan result verification. Data collection is not limited to a single coordinate for the detector with this instrument. A beam profile can be plotted within the software along any radial or transverse direction. Much of the data analysis may be conducted without the need of additional spreadsheets.

Here, we have sought to determine the accuracy of our treatment planning system to represent the physical nature of using the enhanced dynamic wedge (EDW) mode option on our therapeutic linear accelerator. As mathematical models for determining EDW data are still evolving, the most suitable source for validation is direct measurement only.[5–8] The measurement tool of choice was the large detector array mentioned. The ability of the planning system to precisely determine the intensity of radiation output off of the central axis is studied. Devi-

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ations and characteristics of the planned profiles and measured profiles for EDW are discussed.

METHODS AND MATERIALS

The particle accelerator, 21EX Clinac (Varian Medical Systems, Inc.), has been commissioned for use at this facility and is used in these experiments. This linear accelerator was engineered to generate photon beams of nominal energy 6 and 18 MV. The linac may be programmed to deliver wedge-shaped dose distributions by combining blocking jaw movement along the y-axis with computer controlled dose delivery. This is known as the EDW mode for photon beams.

Planning is facilitated by using the Varian Eclipse treatment planning system. The system was commissioned to use Varian 21EX Clinac output data for computation of dose using the Photon Pencil Beam Convolution 7310 algorithm in External Beam Planning Software 6.5. Beams were transferred to the linear accelerator though Varian Vision Record & Verify Software 6.5 and the RT Chart Application.

Using a computer-generated 30 × 30 × 30-cm^3 water phantom, assigned unit density, 7 treatment fields were assigned to a point of calculation existing at the centroid of the phantom. The reference point lies exactly along the central axis of each beam. At 15-cm depth to the point, the source-to-surface distance (SSD) is 85 cm. The source-to-axis of rotation distance is 100 cm for the linear accelerator. Backscatter media has 15-cm thickness beyond the point of calculation.

The prescription tied into this point is 700-cGy total dose. As all beams are equally weighted, the beam-on time reflects the required amount of irradiation time necessary for the isocenter point to receive 100 cGy from each beam.

Every beam was programmed for nominal energy 6 MV and a dose rate of 400 MU/min. The mechanical setup includes a field size of 20 × 20-cm^2, a gantry angle of 180°, a collimator angle of 90°, and a couch angle of 180°. Beams were each designated to operate in EDW mode with a unique EDW angle. Wedge angles available on the 21EX clinic are 10°, 15°, 20°, 25°, 30°, 45° and 60°.[9] The orientation of the wedge was chosen such that the heel is in the left lateral direction. For the wedge-IN option, the EDW dose distribution is generated when an upper jaw (Y_1) moves across the open field during treatment, while upper jaw (Y_2) and both lower jaws (X_1 and X_2) are fixed.[10–13]

Tools are available within the Eclipse software to review and format planned data. Isodose plots are seen in all 3-dimensional views of the phantom object. Only the axial view was magnified and analyzed for this study. One may create a plot of percentage dose vs. distance off-axis by using the line dose profile tool, permitting the examination of off-axis ratios with respect to the central axis.[14] Assessment was executed for the plane including the reference point, along the EDW direction heel to toe. The measurement tool was helpful to identify the exact location of points of interest we wished to document. For a square 20-cm field, the heel and toe off-axis profile data from the plan were observed at lateral (X) coordinates ± 5 cm, ± 4 cm, ± 3 cm, ± 2 cm, ± 1 cm, as well as at the central axis in the line dose profile. The plan was then moved to treatment software.

Using the same technique, plans were created for field sizes of 15 × 15 cm^2, 10 × 10 cm^2 and 5 × 5 cm^2. The observed off-axis profile data were observed at lateral coordinates ± 4 cm, ± 3 cm, ± 2 cm, ± 1 cm, and central axis for the 15-cm field, at ± 3 cm, ± 2 cm, ± 1 cm, and central axis for the 10-cm field and at ± 1 cm and central axis for the 5-cm field. The points of interest were chosen to avoid penumbral changes in the profile's general form. This was based on clinical relevance to typical dosimetry planning needs. Once a plan was created for each field size, it was moved to treatment software. The entire process was repeated for the 18-MV nominal energy photon beams.

The 2Đ array, called MapCHECK (Sun Nuclear Model 1175, Melbourne, FL), was chosen to provide measurements to validate the treatment planning system results. The MapCHECK device contains 445 N-type diodes in a variably spaced 22 × 22-cm^2 area. The center 10 × 10-cm^2 grid detector spacing is 1 cm. Each row of detectors is offset by 0.7 cm. The active detector area is small at 0.8 × 0.8 mm^2, sufficient to provide adequate resolution for wedge profile gradients.

The device was calibrated following output verification using a reference thimble chamber and electrometer. Outputs from 6- and 18-MV beams were each found to be 1.000 Gy/MU at 400 MU/min based on the AAPM TG-51 protocol.[15] The geometrical setup incorporated a field size of 10 × 10-cm^2 at the SAD and a water calibration depth of 1.5 cm for 6 MV and 3.5 cm for 18 MV.

An illustration and thorough description of the MapCHECK device has already been published by Jursinic and Nelms.[16] Verification of an alternative treatment planning system was discussed in his research as it applied to only intensity modulated radiation therapy delivery.[16] Similar to this research, a linear array of diodes was used to commission the EDW in a different treatment planning system, identified in research by Zhu *et al.*[17]

The MapCHECK device was positioned on the treatment table with electronics away from the face of the gantry. As the inherent depth of the material upstream from the detectors is only 2 g/cm^2, additional buildup material is required to match the planned depth of 15 cm. This was achieved with 13 cm of available Plastic Water (Computerized Imaging Reference Systems, Inc., Norfolk, VA) placed directly on the surface of the device. The accurate room lasers, light field, and bubble level were used to align the 2Đ array grid axis