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3D measurement of absolute radiation dose in grid therapy

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1. Introduction

Spatially fractionated radiotherapy through a grid is a concept which has a long history [1,2] and was routinely used in orthovoltage radiation therapy in the middle of last century to minimize damage to the skin and subcutaneous tissue [3–5]. With the advent of megavoltage radiotherapy and its skin sparing effects the use of grids in radiotherapy declined in the 1970s. However there has recently been a revival of the technique for use in palliative treatments with a single fraction of 10 to 20 Gy [6–10].

In this work the absolute 3D dose distribution in a grid irradiation is measured for photons using a combination of film and gel dosimetry.

2. Methods and materials

The grid is an 8 cm-thick lead block containing cylindrical holes. The central axis of each hole was drilled to match the divergence of the radiation beam from its central axis. However, the inner wall of each hole was not divergent, i.e. the holes were cylindrical in shape rather than conical. The holes were arranged in a hexagonal array such that at the isocentre they projected 1.3 cm diameter circles separated by 1.8 cm when the grid is mounted on a linear accelerator (linac) head. The grid was designed to be mounted on the accessory tray of a linear accelerator as shown in figure 1 and is capable of projecting field sizes of up to 15 × 15 cm² at the isocentre.

For measurement of the dose a MAGIC gel [11] and Kodak X-Omat V film was used. The gel phantoms were cubic blocks with sides of 16.0 × 14.5 × 13.0 cm³ with two filling holes on one of the 16.0 × 14.5 cm² sides. The phantom was irradiated through the grid using a 10 × 10 cm² field of 10 MV X-rays from an Elekta SL25 linear accelerator. 2200 monitor units were set with the 16.0 × 14.5 cm² surface of the phantom positioned at the isocentre. One day after irradiation the gel dosimeter was imaged in the head coil of a 1.5 T Siemens Vision Magnetom MRI scanner using a standard Siemens multiple-spin-echo sequence (se_16_360B130.wkc) with 16 echoes, echo spacing (TE) of 22.5 ms and
repetition time (TR) of 2000 ms. Parameters included slice thickness of 5 mm, field of view $256 \times 256$ mm$^2$ and image size of $256 \times 256$ pixels resulting in voxels of $1 \times 1 \times 5$ mm$^3$.

Figure 1. The grid (left) and the grid mounted on an Elekta SL25 linear accelerator (right).

3. Results

The irradiated gel phantom is shown in figure 2a, and figure 2b shows the 25 % and 75 % isodose contours taken from the MRI images. Contours resulting from film measurements of the depth-dose along the central axis and cross-beam profile at $d_{\text{max}}$ are shown in figures 2c and 2d respectively. Results indicate that the main source of dose in the ‘shaded’ areas of the grid is the divergence of the primary beam and its multiple penumbrae.

Figure 3a shows percentage depth-dose data along the central axis, which corresponds to an open hole in the grid. Figure 3b shows the proportional increase of open field central-axis percentage-depth data when compared to that of a grid field. The results indicate that the minimum dose under the shielded portions of the grid is between 20 and 30% of the peak grid dose at a given depth. As the spacing between the divergent holes increases with depth, the greater contribution of scattered radiation compensates for the penumbral overlapping near the surface (at $d_{\text{max}}$).
Figure 2. Photograph of the irradiated gel phantom (a), 25 % and 75 % isodose surfaces from the gel dosimeter (b), isodose plot through the central axis from film (c) and cross beam profile at dmax from film (d).

Figure 3. Central axis depth-dose data for open field and grid field (a). Results of open field percentage depth-data divided by grid field percentage-depth data (b).
4. Conclusion

Grid therapy is considered to offer significant therapeutic advantages over conventional radiotherapy, particularly for palliative treatments [9,11]. This work has shown that when planning for a treatment through a grid, careful consideration must be taken of the very different dosimetry characteristics of the irradiated volumes compared to open field treatments.

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