LETTER TO THE EDITOR

A gravity-oriented-device for IMRT can never rival other IMRT delivery methods

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The Editor,

Sir,

Before the modern development of conformal radiation therapy (CFRT) and intensity modulated radiation therapy (IMRT) it was proposed that concave isodose distributions could be obtained by rotating an x-ray beam through angle $2\pi$ whilst continuously shaping the geometric aperture to the beam’s-eye-view of the planning target volume (PTV) and simultaneously shielding organs at risk (OAR) through the use of some gravity-oriented device (christened by others: GOD) or by shielding blocks, rotated by cog and chain mechanisms (Webb 2003). Some of the earliest work emanated from Proimos (1960, 1961, 1963, 1969), Proimos et al (1966), Rawlinson and Cunningham (1972), Ilfeld et al (1971), and more recently Casebow (1990). A review was written by Webb (1993). Recently further ideas on GODs have been published (Proimos and Danciu 1997a, 1997b, Danciu and Proimos 1999).

These methods were not widely developed because of these disadvantages:

- GODs were difficult to fabricate;
- an individual one was needed for each patient;
- being essentially binary modulators of the primary fluence (ignoring leakage), they did not generate the beam profiles with modulation computed by inverse planning mimicking the inverse of the CT process (e.g. Bortfeld et al 1990);
- they only shaped the transaxial dose distribution; all transaxial planes were shaped the same;
- they made no use of preferential beam angles.

Recently a somewhat tantalizing abstract appeared suggesting that the absorber be a box of mercury in which a suitably demagnified model of the PTV was suspended (Oh et al 2003). This claimed that, after a complete rotation, the 80% isodose line wrapped around the PTV. No further details were given nor explanation of why this should work. Many, including the author, would worry about the practicality of suspending a box of mercury above the patient.

This suggestion is just one option from a wider subset of possibilities one may consider in which differential attenuation of the materials within and without the PTV model might control the resulting isodose contours. This letter gives a general computation technique and an example, but concludes not endorsing the approach.

Instead of the use of the mercury box, it is proposed that the gravity-oriented absorber comprise a model of the patient outline geometrically scaled by the appropriate demagnification to account for its position between source and isocentre (figure 1). Inside this outline is placed a model of the PTV also suitably demagnified. The absorber then comprises materials of two x-ray linear attenuation coefficients, one for the PTV model and one for the ‘bath’ in which it resides (i.e. all the non-PTV-model volume). As the gantry rotates so the absorber hangs under gravity and the intensity profile developed at any orientation thus depends on...
the pathlengths through the model at that orientation. As well as the variable path length of attenuation through the absorber it is assumed that the beam is always geometrically collimated to the beam’s-eye-view of the PTV. The problem then reduces to finding the optimum pair of attenuation coefficients and optimum unmodulated input fluence.

The problem was solved by a simple form of inverse planning. The two attenuation coefficients and the input fluence, to be modulated by the GOD, were iteratively adjusted and, for each triplet adopted, the dose distribution was computed using a simple exponential dose model appropriate to 6 MV x-rays ($\mu = 0.049 \text{ cm}^{-1}$ in water/tissue). The rms difference between this computed dose and the dose prescription, weighted by importance factors for PTV, OARs and the rest of the body, was used as a cost function. At each iteration, values of the two attenuation coefficients and the input fluence which generated a dose distribution which reduced the cost function were adopted, replacing whatever values had been obtained up to that iteration. After 5000 iterations the outcome was a dose distribution, the input fluence and the two x-ray linear attenuation coefficients.

To replicate the problem investigated by Oh et al (2003), the two-dimensional single-slice problem was solved with the beams being one-dimensional, created by the passage of x-rays through a two-dimensional demagnified model of the slice with the patient outline and the PTV. The case illustrated is for a prostate-shaped PTV with concavities in its outline. Rotation therapy was simulated by computing the profiles at 60 gantry orientations spaced at $6^\circ$ intervals. The importance factors of the prostate, organs at risk (the rectum and bladder were outlined) and rest of body (ROB) were weighted 70:20:0.5 with the dose prescriptions of 100:50:50. Had lower doses been specified to OAR and ROB the PTV dose would have been compromised. Demagnification was by a factor of 2 implying the GOD is halfway between source and isocentre.
Figure 2 shows the outcome. The optimum $\mu$ for the PTV model was zero indicating the PTV model should be an empty shell as also suggested by Oh et al (2003). The optimum $\mu$ for the ‘bath’ was $\mu = 0.159 \text{ cm}^{-1}$ for an input fluence of 11.45 units. (The arbitrary fluence units are such that when attenuated by the GOD and the depths into the patient and the values summed from all beam directions, they aim to create the prescription dose of 100 arbitrary dose units. The method to convert to dose in grays and fluence in MUs was discussed in appendix 2 of Oldham and Webb (1997).) The $\mu$ value of the ‘bath’ is close to the x-ray linear attenuation coefficient of titanium ($\mu = 0.188 \text{ cm}^{-1}$) and could be realized in granular form if titanium granules were ‘diluted’ with granules of lower density to create the required $\mu$ on average. It must also be realized that this is a highly degenerate problem. There are a large number of combinations of triplets that could construct almost the same dose distribution. However, the disadvantages of using mercury are avoided.

From this representative example we see:

- the isodose lines are nowhere near as good as those that can be obtained using modern IMRT techniques;
- the technique does not exploit gantry angle selection to spare normal tissues;
- the technique does not exploit 3D shaping of beam fluences whereas it is known that such 3D beam optimization for modern IMRT techniques can lead to a high degree of sparing dose to organs at risk;
it would be just as complicated to make the dilute bath material as the GODs proposed many years ago. One option could be to ‘force’ a specific single (but not mercury) bath material and optimize only the input fluence. Even so the technique remains two dimensional (dose to all transaxial sections the same). A three-dimensional version of the technique would be theoretically possible but the 3D GOD would be impossibly difficult to construct and use;

- the number of monitor units required would be prohibitively high leading to concerns about leakage, inefficient treatment time and high scatter dose;

- compared with other IMRT delivery methods, the absorber would lead to increased scatter dose and also loss of skin sparing;

- attempting GOD IMRT for tumour sites in regions of tissue inhomogeneity would be less successful because accounting for these cannot be included in the GOD model;

- if leakage and scatter dose were computed and added the situation would be even worse than shown in figure 2.

In conclusion, it is recommended that considering GODs again for IMRT delivery is not state-of-the art and whilst the ‘mercury disadvantage’ can be overcome, the reawakening of interest is mainly academic and should be abandoned.

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References


Casebow M 1990 A modified synchronous shielding technique in rotation therapy Br. J. Radiol. 63 482–7

Danciu C and Proimos B S 1999 Gravity oriented absorbers in conformal radiotherapy for cervix cancer Radiother. Oncol. 51 (Suppl 1) S38

Ilfeld D N, Wright K A and Salzman F A 1971 Synchronous shielding and field shaping for megavolt irradiation of advanced cervical carcinoma Am. J. Roentgenol. 112 792–6


Proimos B S 1960 Synchronous field shaping in rotational megavolt therapy Radiology 74 753–7

Proimos B S 1961 Synchronous protection and field shaping in cyclotherapy Radiology 77 591–9

Proimos B S 1963 New accessories for precise teletherapy with 60Co units Radiology 81 307–16

Proimos B S 1969 Shaping the dose distribution through a tumour model Radiology 92 130–5
Proimos B S, Tsialas S P and Coutroubas S C 1966 Gravity oriented filters in arc cobalt therapy Radiology 87 933–7
Rawlinson J A and Cunningham J R 1972 An examination of synchronous shielding in 60Co rotational therapy Radiology 102 667–71