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Original research article

The accuracy of treatment planning system dose modelling in the presence of brass mesh bolus

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ABSTRACT

Aim: This work assesses the dosimetric accuracy of three commercial treatment planning system (TPS) photon dose calculation algorithms in the presence of brass mesh used as a bolus.

Background: Bolus material is used in radiotherapy to provide dose build-up where superficial tissues require irradiation. They are generally water equivalent but high density materials can also be used.

Materials and methods: Dose calculations were performed on Monaco and Masterplan TPS (Elekta AB, Sweden) using phantoms defined by the three DICOM CT image sets of water equivalent blocks (no bolus, 1 layer and 2 layers of brass mesh) exported from the CT scanner. The effect of the mesh on monitor units, build-up dose, phantom exit dose and beam penumbra were compared to measured data.

Results: Dose calculations for 6 and 15 MV photon beams on plain water equivalent phantoms were seen to agree well with measurement validating the basic planning system algorithms and models. Dose in the build-up region, phantom exit dose and beam penumbra were poorly modelled in the presence of the brass mesh. The beam attenuation created by the bolus material was overestimated by all three calculation algorithms, at both photon energies, e.g. 1.6% for one layer and up to 3.1% for two layers at 6 MV. The poor modelling of the physical situation in the build-up region is in part a consequence of the high HU artefact caused by the mesh in the CT image.

Conclusions: CT imaging is not recommended with the brass mesh bolus in situ due to the poor accuracy of the subsequent TPS modelling.

1. Background

The clinical use of tangential photon field irradiation for the adjuvant treatment of breast cancer is a mainstay of radiotherapy. Where superficial tumour irradiation and skin involvement is indicated, bolus material is commonly used to increase dose to a therapeutic level at or near the skin surface. This usually takes the form of a tissue equivalent layer placed onto the patient for the duration of a treatment

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fraction. Materials with a high atomic number have also been cited in the literature as being used as an alternative to water equivalent materials.[1,2] High atomic number materials have been reported as being advantageous in terms of better skin conformity/contact which, in turn, should lead to a more even dose over the patients contour. Indeed, it has been reported[3] that inhomogeneous skin dose and 'hot-spots' are a direct consequence of air gaps and poor surface adhesion of water equivalent bolus materials.

The radiotherapy patient pathway requires consistent patient set-up and positioning throughout: from localisation imaging in the form of a planning CT scan to the final fraction of external beam treatment delivery. With this in mind, localisation imaging with the patient in their treatment position, including any accessories, such as bolus material is imperative. The position and weight of the bolus may lead to changes in the patient contour shape which should be considered when dose planning. Unnecessary uncertainties in patient set-up and dosimetry may be introduced if patients are localised without any bolus material in situ and should therefore be considered part of the patient positioning. Mesh bolus (Whiting and Davis, Attleboro Falls, MA) is made of brass which has a mass density 8.5 g cm^{-3} and therefore, when scanned, generates a Hounsfield Unit (HU) value in excess of the normal range found in human tissues. Even a thin mesh may lead to image artefacts which could impact clinical acceptability of patient images.

Type A and B treatment planning system dose calculation algorithms such as Pencil Beam,[4] Collapsed Cone[5] and Monte Carlo[6] vary in their sophistication and accuracy of dose modelling within heterogeneous media.[7] Their limitations when faced with high atomic number (Z) to tissue interfaces such as hip prosthesis, and tissue expanders,[8–10] have been discussed in the published literature. The accuracy of dose calculations may be expected to fall below internationally accepted standards when compared against directly measured data under these circumstances.[11,12] High Z interfaces are considered to fall within the most complex group of published dose calculation accuracy standards (4% where there are high doses and small dose gradients or 3 mm/15% in the build-up and penumbra regions[11]). An AAPM report[12] highlights the need for advanced Type B algorithms to be used when calculating dose in heterogeneous media and suggests that Pencil Beam (Type A) algorithms show unacceptable accuracy. The Medical Physicist should understand the calculation limitations and carefully evaluate dose calculations beyond high density materials.[12] The aim of this article is to demonstrate the treatment planning system modelling of megavoltage photon beams at/or near the interface between water equivalent phantoms and brass mesh bolus using three commercially available dose calculation algorithms. The dosimetric validation was assessed against previously published measured data.[13]

2. Materials and methods

2.1. *Localisation imaging*

All CT scans were acquired using a Toshiba Aquilion (Toshiba, Zoetmeer, The Netherlands) wide bore scanner operating at 120 kV and 50 mA. A standard breast imaging protocol was employed generating contiguous 3 mm slices over a 500 mm wide scan reconstruction field of view. A thickness of 15 cm of 25 cm × 25 cm WT1 solid water blocks (Scanplas, St Bartholomew's, London) was scanned uncovered and then with 1 and 2 layers of brass mesh bolus draped over the top.

The three image sets formed the basis for determining the HU in the image across the phantom/air interface. The HUs within the image were determined by plotting a profile across the phantom/air interface on the CT slice through the centre of the WT1 blocks using ImageJ (v. 1.46r) software (http://imagej.nih.gov/ij). The images were exported to both Oncentra Masterplan (OMP) V4.3 and Monaco V5.1 treatment planning systems (Elekta AB, Sweden) to assess dosimetric calculation accuracy. The effect of scanning with the brass mesh in situ in terms of image noise, contrast and spatial resolution were not addressed in this paper although may have a bearing on the clinical acceptability of the patient CT scans for treatment planning.

2.2. *Treatment planning system modelling*

Dose calculations were performed using Monaco and OMP Treatment Planning Systems on the three DICOM image datasets of the WT1 blocks exported from the CT scanner. The dose calculation voxel sizes were set to 0.2 cm × 0.2 cm × 0.3 cm (anterior–posterior, lateral, longitudinal). The Monte Carlo algorithm was employed in the Monaco system with the statistical uncertainty per plan set to 0.5% and calculating dose to medium. Monaco dose profiles were determined within the exported DICOM dose file using ImageJ software (http://imagej.nih.gov/ij). Both the Pencil Beam and Collapsed Cone algorithms were used for dose calculation in OMP. Dose calculations using the integrated line dose tool were carried out at a resolution of 0.1 cm in OMP. A previously validated local Elekta Synergy linac with Agility MLC (Elekta AB, Sweden) 6 MV and 15 MV clinical beam data models within each planning system were used for this work. Both treatment planning systems require Hounsfield Unit to electron density conversion data to be able to use the CT images for dose calculation. In the case of OMP, this is predefined by the vendor and the user is unable to change the data. The data is based on the work of Knoos.[14] The conversion table in Monaco is user defined. In our case, the data for this was obtained by scanning a Gammex RMI phantom with inserts of known electron density. The densest insert had an electron density of ~1.7 relative to water and a corresponding Hounsfield Unit value of ~1200. Data for HU up to 2000 was used in Monaco by linear extrapolation.

2.3. *Attenuation*

The planning system estimate of the attenuation coefficient of the brass bolus was determined for each of the three algorithms under consideration. The number of Monitor Units calculated to deliver 1 Gy at an SSD of 90 cm, 10 cm deep, on the plain phantom was determined by measurement using a 10 cm × 10 cm open field for both 6 MV and 15 MV. A farmer type chamber with an absorbed dose calibration traceable to the UK primary standard was used for measurements. The