TPS-calculated vs. measured dose around a prosthetic hip implant

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Introduction

An increasing number of patients requiring pelvic radiotherapy have hip prostheses but current radiotherapy Treatment Planning Systems (TPS) are not able to accurately calculate dose in their vicinity. This work compared planned and measured dose around a prosthetic hip suspended in a water bath to determine the magnitude of the error in calculated dose in conditions of transmission, back scatter and lateral scatter and to see if over-riding the HU of the prosthesis reduced any error.

Method

A phantom was constructed by suspending a prosthetic hip in a water-filled Perspex box which incorporated a tube to hold a Farmer chamber as shown in figure 1. Planning CT images were acquired on a Toshiba Aquilion scanner with the prosthesis at a range of distances from the chamber tube. These images were imported into the Eclipse TPS (AAA algorithm version 11031).

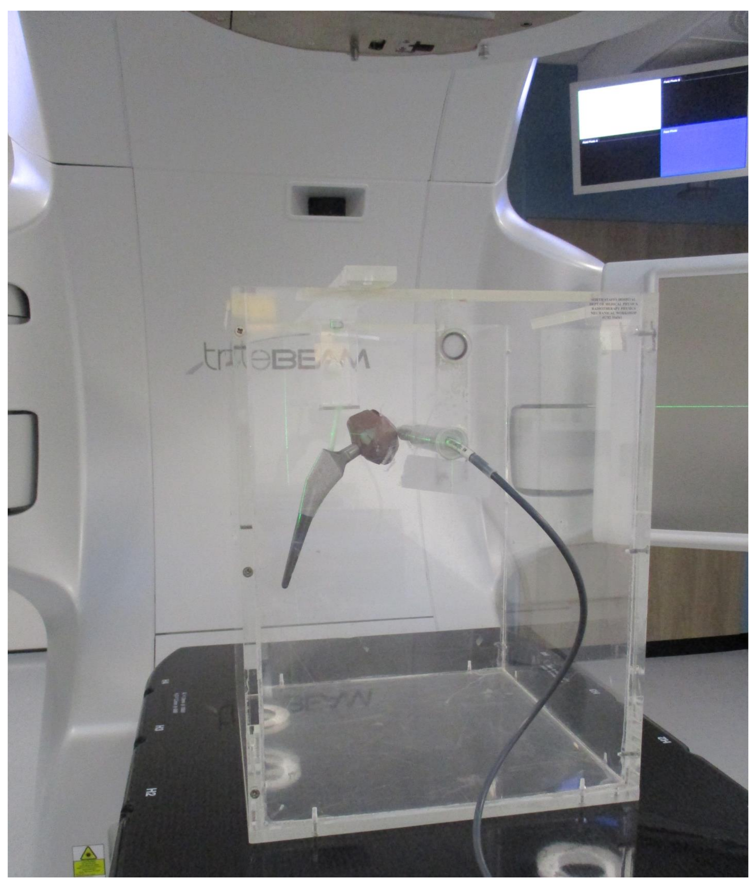

Figure 1. Hip prosthesis phantom

Planning

200MU were delivered by a 10cm x10cm 6MV beam in three conditions: to the right face of the phantom (gantry 270°, couch 0°) to measure transmitted dose as shown in figure 2, to the left (gantry 90°, couch 0°) to measure backscatter and to the superior (H) face of the phantom (gantry 270°, couch 270°) to measure lateral scatter. The planned dose in each condition was calculated at the chamber centre.

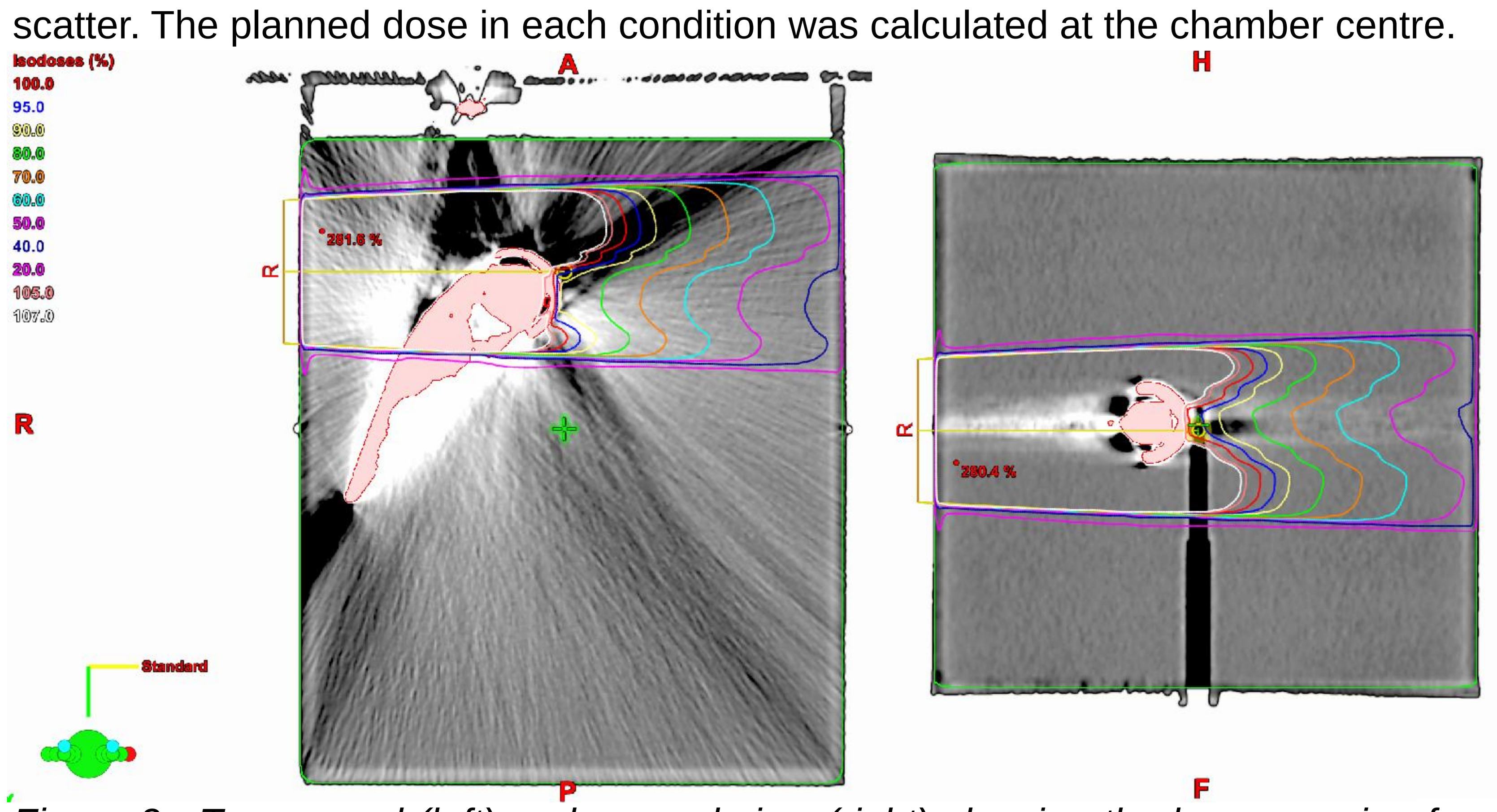

Figure 2. Transversal (left) and coronal view (right) showing the beam coming from the right and the chamber tube on the left.

Artefact removal

Streak artefacts were present in the CT images from the prosthesis. To eliminate these and any other stray artefact, the CT ranger tool was adjusted such that the dimensions of the outline of the prosthesis in Eclipse matched physical dimensions of the prosthesis. The HU within this structure were left as was and everything outside the prosthesis but inside the body structure (shown in green in figure 2), including the chamber tube, was set to an HU of 0.

Dose Measurement

The Farmer chamber reading was converted to dose using the calibration factor provided by NPL and correcting for temperature & pressure, ion recombination and machine output. A stem effect correction was made for measurements in the lateral scatter condition by comparing readings without the prosthesis with the couch at 0° and 270° and with the chamber centre at isocentre.

CT Calibration

The CT scanner at RSH is 16-bit allowing HUs of between -1000 and 64,533. The system was calibrated using an RMI phantom including inserts mimicking lung, brain, water and bone. An insert of steel of relative electron density 6.58, which corresponds to an HU of around 14,500, allowed the calibration curve to be extended. However, cupping artefact was evident on the CT images of the prosthesis indicating that the HUs assigned within the prosthesis would be erroneously low leading to incorrect dose modelling by Eclipse.

Results

Figure 3 shows the comparison between measured and calculated dose for the three conditions with the prosthesis at a range of distances from the chamber centre.

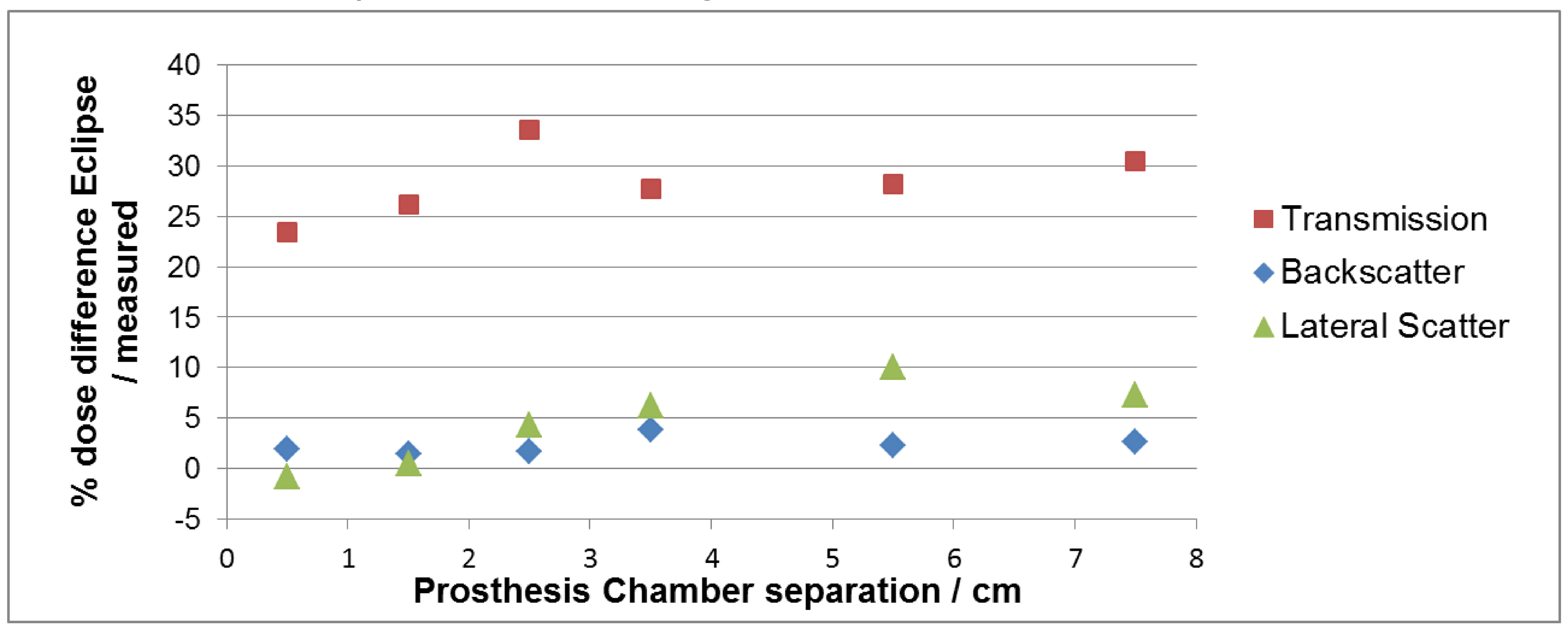

Figure 3. Percentage difference between planned and measured dose

Transmission: Figure 3 shows that Eclipse overestimates dose downstream of the prosthesis by 29 ± 6%.

The original HU of the prosthesis was between 3000 and 8500. If the HU of the prosthesis was over ridden to 8000 the planned dose had better agreement with the transmitted measured dose to within 4 ± 9%.

Back scatter: Eclipse calculated the same dose upstream of the prosthesis whether or not the prosthesis HUs had been set to 0, demonstrating that backscatter was not modelled.

Figure 4 shows that there was a small increase in dose within 1-2 cm of the prosthesis of around 1% consistent with a local increase in dose due to backscatter.

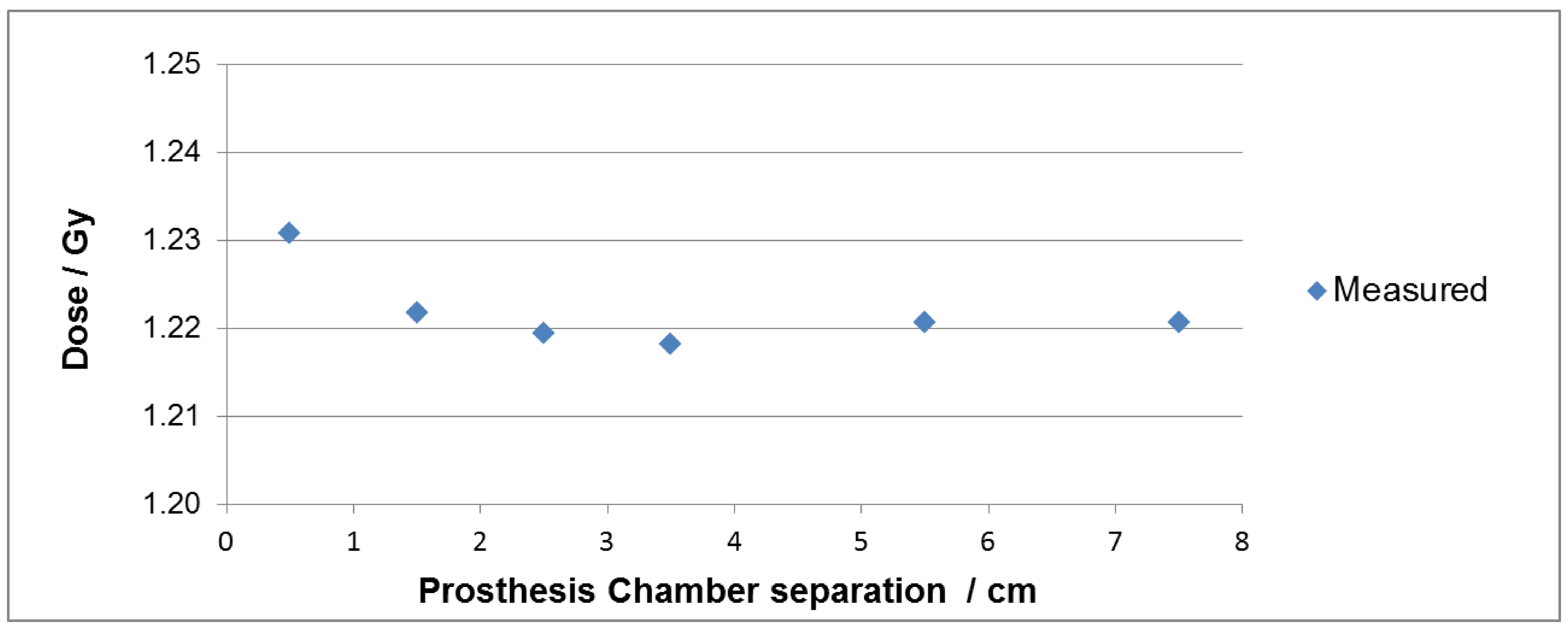

Figure 4. Measured and calculated dose in the back scatter condition

Lateral scatter: Lateral scatter appeared to be adequately modelled by Eclipse with measurements agreeing to within 2 ± 4%.

Figure 5 shows dose measured in the lateral scatter condition. The measurement closest to the prosthesis was around 5% higher than those within 2-3cm, which would be consistent with the backscatter measurement but there are limited measurements within the main beam to assess baseline dose.

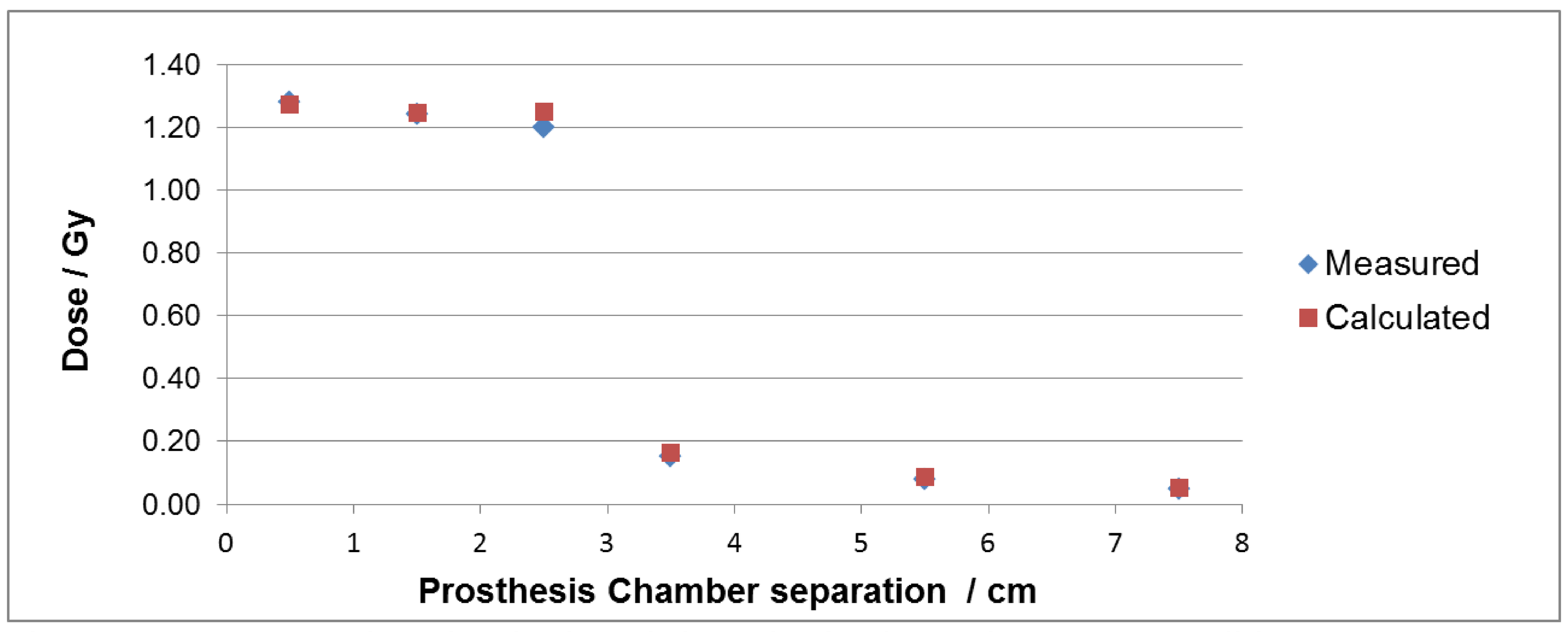

Figure 5. Measured and calculated dose in the lateral scatter condition

Conclusions

This work confirmed that Eclipse does not accurately model dose through high density prostheses and it is recommended, as per previous work[2,3,4], that treatment beams do not enter through prostheses. A simple density over-ride, which may be prosthesis dependent, will remove a large proportion of the gross error allowing a more realistic estimate of dose. Increased dose due to scatter from the prosthesis may pose a risk of necrosis[2]. Increased dose was measured within 1-2cm of the prosthesis but this method did not have adequate spatial resolution to determine dose very close to the prosthesis, where doses could be high.

References:

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