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Dosimetry

A phantom study of dose compensation behind hip prosthesis using portal dosimetry and dynamic MLC

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Abstract

***Background and purpose*: A dose compensation method is presented for patients with hip prosthesis based on Dynamic Multi Leaves Collimator (DMLC) planning. Calculations are done from an exit Portal Dose Image (PDI) from 6 MV Photon beam using an Electronic Portal Imaging Device (EPID) from Varian. Four different hip prostheses are used for this work.**

***Methods*: From an exit PDI the fluence needed to yield a uniform dose distribution behind the prosthesis is calculated. To back-project the dose distribution through the phantom, the lateral scatter is removed by deconvolution with a point spread function (PSF) determined for depths from 10 to 40 cm. The dose maximum, D_{max}, is determined from the primary plan which delivers the PDI. A further deconvolution to remove the dose glare effect in the EPID is performed as well. Additionally, this calculated fluence distribution is imported into the Treatment Planning System (TPS) for the final calculation of a DMLC plan. The fluence file contains information such as the relative central axis (CAX) position, grid size and fluence size needed for correct delivery of the DMLC plan.**

GafChromic EBT films positioned at 10 cm depth are used as verification of uniform dose distributions behind the prostheses. As the prosthesis is positioned at the phantom surface the dose verifications are done 10 cm from the prosthesis.

***Conclusion*: The film measurement with 6 MV photon beam shows uniform doses within 5% for most points, but with hot/cold spots of 10% near the femoral head prostheses.**

Keywords: Hip prosthesis; Dose compensation; Radiotherapy; Portal imaging

During a period from 1995 to 2002 the Danish National Board of Health ''Sundhedsstyrelsen'', registered an increasing number of patients undergoing surgery for hip implantation, from 1200 patients/million in 1995 to 1800 patients/million in 2002 [8].

For patients with hip prostheses intended for external radiotherapy, consideration should be given to the field arrangement as well as the calculations in the treatment planning system.

Artefacts in image reconstruction, incorrect Hounsfield Units, HU, and treatment planning systems that cannot handle high HU numbers are typical problems arising before treatment planning can be performed [7,16,19].

Current recommendations are to use radiation fields that avoid the prosthesis [16]. This is a common way to avoid problems with prostheses. But it is not necessarily an optimal solution, as dose to critical organs, such as rectum, bladder, etc., relative to the 3 or 4 field techniques [12] might rise to an unacceptable level.

AAPM TG 63 [16] describes the considerations that have to be taken into account for patients with hip prosthesis intended for radiotherapy in the pelvic region.

This report suggests a beam arrangement that avoids the prosthesis. If this is not possible and treatment through the prosthesis is used, attention to proper dose compensation and calculation is necessary.

For this work attention is focused on dose compensation/correction with calculations independent of the treatment planning system (TPS), computed tomography (CT) scanner and day to day variation in patient positioning.

It demonstrates a dose compensation method for patients with hip prosthesis intended for radiotherapy in the pelvic region with relatively large fields. These target areas are not suitable for sophisticated IMRT plans due to the size of the target.

Information from an open-field dose level (D_{max}) and the achieved portal dose image (PDI) from this field are used for calculation of the fluence matrix, compensating for attenuation behind the prosthesis.

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This fluence matrix is exported to the TPS for calculation of a dynamic multi leaves collimator (DMLC) plan to be added to the primary plan (a single open field). Fig. 1 shows the procedure for calculation of the compensating DMLC plan.

The overall calculation time for dose compensations and treatment of the primary and the DMLC plan is ≈10 min.

Materials and methods

The linear accelerator, linac, used in this study was a Varian 2100 CD with 6 and 18 MV photons. The linac is equipped with a 120 leaf Millennium MLC and an electronic portal imaging device (EPID), aS500 from Varian. Throughout the study only 6 MV photon beams are used for any calculations and measurements. The linac EPID is calibrated for dosimetry in the dose rate range 100—400 MU/min [24]. Images are automatically dark field and flood field corrected.

PDI, are obtained from the EPID in IMRT mode at a dose rate of 300 MU/min and exported as ASCII files for further calculations.

GafChromic EBT films are used to verify dose and alignment of the DMLC plan.

Reference films used for calibration were exposed in the dose range from 0 to 3 Gy in steps of 0.5 Gy. Films were read out on a flatbed HP 5590 scanner three days after exposure, using the ''RisøScan'' software for dose conversion [9,10]. The scanner uses the built-in warm-up procedure and three dummy scans were performed, to ensure light equivalence, before each film scan. The settings for brightness/gamma were fixed to ensure consistent scan conditions with the calibrated films. Images were stored as.bmp files which is the standard for the ''RisøScan'' software.

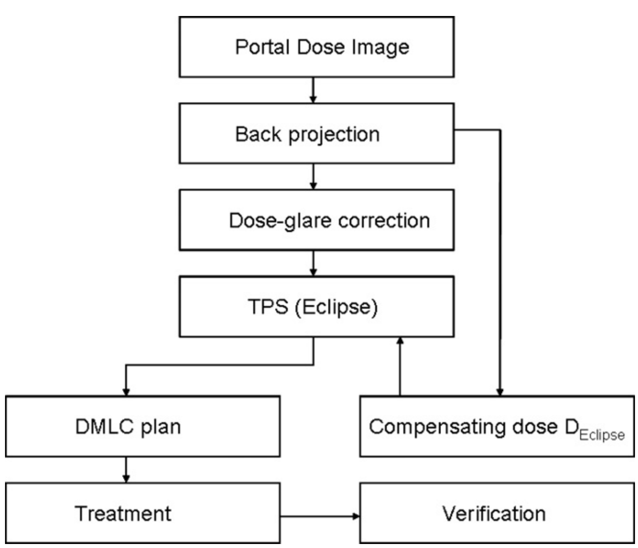

Fig. 1. The compensating DMLC plan is based on a PDI obtained with a hip prosthesis on a solid water phantom. Corrections for scatter in the phantom and dose glare in the EPID are performed to determine the fluence behind the prosthesis. The fluence and dose needed to yield a uniform dose distribution behind the prosthesis is calculated and imported into the TPS (Eclipse) to calculate a DMLC plan. Verifications of the total dose distributions are done with GafChromic EBT films.

Prostheses used are Co—Cr—Mo and Ti alloys mounted with a stainless steel or ceramic head, Fig. 2. The prostheses are produced by Biomet Cementing Technologies AB, Sweden. These are commonly used prostheses and are representative for an object found inside a patient intended for radiotherapy.

The absorption material consists of slices of solid water phantoms (epoxy) with a total thickness of 40 cm, Fig. 3A and B. The phantom is located behind the prosthesis. No materials are placed above the prosthesis and in this study no corrections for ''tissue'' above the prosthesis have been made. The source to surface distance (SSD) to the plane behind the prosthesis is 90 cm and the source EPID distance is 160 cm.

Calculations are done with in-house software, developed with Matlab V.7, running on a PC with Pentium 4 processor @ 2.4 GHz. Calculation time for fluence determination is ≈2 min. The fluence file output is in ASCII format with file header containing information of the fluence size, alignment, resolution and the fluence matrix data.

The treatment planning system is Varian Eclipse, V.7.

Back-projection

The portal dose image is the result of interaction of the incoming fluence with the prosthesis and solid water phantom as well as the EPID. Several works have been done in the attempt to back-project the portal dose measurement [3—5,11,13—15,17,21,22] to calculate either incident fluence or midplane dose.

To simplify the process of calculations, the measured PDI is assumed to be a result of the incident fluence attenuation through the absorbing materials and disturbed by lateral scattering in the phantom, as well as perturbations inside the EPID.

Fig. 2. Four different types of hip prostheses listed from 1 to 4. These prostheses are commonly used for patients undergoing hip surgery. Hip prosthesis no. 2 is Co—Cr—Mo alloy, the other three are Ti alloys. The head/junction is made of either stainless steel or ceramic materials. The ceramic head is used for hip prostheses no. 1 and no. 4.