Session 14: Poster highlights

14b. Medical Physics
Dosimetry and verification

Ben Mijnheer
Absorbed dose to water FeSO₄-based standard for ¹⁹²Ir HDR

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INTRODUCTION

Falling in line with the general trends of modern Radiation Metrology the quantity absorbed dose in water is the one mostly needed in clinical practice.

A few attempts have been reported to establish this quantity and potential good results of two techniques have been reported, firstly by Sarfehnia et al (2007) using a water based calorimeter and secondly by Austerlitz et al (2008) both with uncertainties still high, 5% and 8% respectively and the present work using ferrous sulphate-Fricke dosimeter.
Schematic diagram of the PMMA irradiation vessel
Dose Measurement Results

- Nominal (Gy) Measured (Gy)
  - 14: 13.98
  - 16: 15.94
  - 18: 17.62
  - 20: 20.14
  - 30: 30.17
  - 40: 39.37

- Uncertainty = 2.68

- R = 0.999599
CONCLUSIONS:

Chemical dosimetry using standard FeSO$_4$ solution in a PMMA containing vessel with uniform geometry relative to the source has shown to be a promising absorbed dose standard for HDR $^{192}$Ir source.

The overall uncertainties involving the vessel dimensions, wall thicknesses, dose calculation, wall attenuation, UV light band, source anisotropy, G value and the source transit time was estimated in 2.68 % $k=2$.

The major sources of uncertainties are the G values taken from the literature, and the temperature during irradiation and reading process.

A comparison is sought with the laboratory that is using the water based calorimeter.
Dosimetric characterization of an aSi-based EPID for patient-specific IMRT QA

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Havana, Cuba
y = 0.000x - 0.624  
$R^2 = 0.999$

y = 0.000x + 1.711  
$R^2 = 0.999$
Off axis sensitivity
Results

• field-size dependence of this device was studied and compared with phantom scatter factors at different depths in water, resulting in good agreement for the factor measured at 5 cm depth, $S_{cp}(z=5\text{cm})$

• EPID’s linearity yield a value better than 1.1 and 1.5% for 6 and 15MV foton beams respectively, for exposures in the range from 2-500 MU

• **EPID can be used for evaluation of beam dosimetric parameters, provided the dose is considered at a specific depth, which in our case was 5 cm in water**, where energy dependence of EPID response is compensated in acceptable range (max. 4%).
Dosimetric verification of radiotherapy treatment planning systems in Hungary

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We have used for the test measurements the *semi-anthropomorphic CIRS Thorax phantom* (CIRS Inc., Norfolk) lent by the IAEA. The properties of the CIRS Thorax phantom can be found in the IAEA TECDOC 1583

*The following treatment planning systems (TPS) were tested:*

**CMS XiO TPS** - Multi grid superposition
  - Fast Fourier Transform Convolution

**Varian CadPlan TPS** - Pencil beam convolution algorithm with Mod. Batho Power Law
  - Pencil beam convolution algorithm with non correction

**Oncentra MasterPlan TPS** - Collapsed Cone algorithm
  - Pencil Beam model

**ADAC Pinnacle** - Adaption convolution model

**Precise PLAN TPS** - Adaption convolution model

**Nucletron Helax TPS** - Pencil beam convolution algorithm

**Nucletron Plato TPS** - Pencil beam convolution algorithm

For the measurements we used in all centres our PTW Unidos (PTW, Freiburg) electrometer and the NE 2571 Farmer chamber.
Difference between measured and calculated point doses for each test case for model based algorithms (6 MV)
Conclusions

The different algorithms are fitted rather to the low energies than to the higher ones. In the case of Co-60 units and 6 MV photon energy we received the best results with CMS XiO TPS Multi grid superposition and ADAC Pinnacle adaption convolution model. The older TPSs like Helax and Plato had problems with the dose calculation in the region of inhomogeneities especially inside the lung.
In this work, output factors of small circular photon beams are evaluated in a homogeneous medium (water phantom) with two different detectors, radiochromic film (GafChromic, EBT International Specialty Products, USA) and a shielded solid diode detector PDF3G (IBA-Dosimetry, Germany). These results were compared with Monte Carlo radiation transport calculations.
The results showed in this work suggest that GafChromic EBT film is an adequate detector to determine output factors of small beams with an accuracy of 2.0%.

FIG 1. (a) Calibration curve of the EBT film using field size of $3 \times 3$ cm$^2$ covering a dose range between 1 to 420 cGy. (b) Output Factors as obtained with EBT, PFD$^{3G}$ diode and Monte Carlo simulations. The average standard deviation is indicated for each measuring device (2%).
TLD audits in non-reference conditions in radiotherapy centres in Poland

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Non-reference conditions

- **on-axis**: 8x8 cm$^2$, 10x10 cm$^2$ (open and wedged), 10x20 cm$^2$ - d=10 cm; 10x10 cm$^2$ - d=5/20 cm,

- **on-axis, fields formed by MLC**: six fields – reference, small, circular, inverted Y, irregular and irregular with wedge,

- **off-axis, symmetric fields**: 20x20 cm$^2$, d=10 cm, on - axis and ± 5 cm off- axis, profile X, Y- open and wedged,

- **off-axis, asymmetric fields**: d=10 cm, 10x10 cm$^2$, 10x15 cm$^2$. 
Example of the results

MLC-shaped field
2008

Motive: ref
- "small"
- "circular"
- "inverted" Y
- "irregular"
- "irregular"+wedge

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Conclusion

The nation-wide audit shows, that it is possible to keep the dose determination within the 5% limits by implementation of correct methodology and carefully carried-out measurements and calculations of doses.
Superficial dose distribution in breast for tangential photon beams, clinical examples

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Background

The work is focused on the superficial (0-2 cm) region of the breast. Measurements and calculations have been performed in a previous work in the case of cylindrical solid water phantom irradiated by 6 MV open tangential beams (Fig. 1).

![Fig. 1. Dose differences in a phantom for two opposed tangential beams. 100% correspond to the MC dose at isocenter. (a) AAA – MC, (b) PBC – MC](image)

The objective of this study is to investigate the superficial dose by using patient CT data.

Monte Carlo calculations are performed for six patient geometries for tangential 6 MV opposed beams of size and angle of incidence close to the planned ones. Open beams are considered without wedge and MLC.

Results

![Fig. 2. Dose differences between Eclipse and Monte Carlo results at isocenter plane: (a) CT slice at isocenter, (b) AAA – MC, (c) PBC – MC](image)

A case in Fig. 2 is shown where the dose comparison between Eclipse and Monte Carlo results follows the predictions based on the cylindrical phantom:

AAA data agree well with MC results at the beam entrances and are more than 4% lower the first 4 mm transverse to the beam.
PBC significantly underestimates the superficial dose transverse to the beam and gives more than 5% lower dose the first 6 mm in the whole superficial region.
Results-cont

A different case, where the dose comparison is not in agreement with the conclusions for cylindrical phantom is illustrated in the figure.

AAA dose values around posterior beam entrance are higher than the corresponding Monte Carlo ones (see the marked region). An opposite tendency is observed in the anterior superficial region of the breast where the AAA results are lower than the Monte Carlo data.

PBC underestimation of the dose transverse to the beam is still clearly seen. However, the band with lower dose along the breast/air interface is getting narrower around beam entrances. Regions with higher PBC dose values than Monte Carlo ones are seen in the lateral part of the breast.

Conclusions

• The behavior of AAA and PBC calculation algorithms derived in a case of solid water phantom can not be directly translated to real patient geometries.

• Quantitative agreement between MC and AAA calculations varies strongly with the breast shape. AAA has superior accuracy to PBC.

• PBC systematically underestimates the dose in the superficial region, in particular transverse to the beams.

• The breast part transverse to the beams receives full dose beyond 2-4 mm without added bolus material.
Use of An Amorphous Silicon Electron Portal Imaging Device for Fast and Accurate MLC Leaf position verification

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Results

In our experience, it is possible to detect leaf gap deviations by visual inspection with an accuracy of 1 mm. In order to quantify leaf gap deviations of 0.5 mm, the film should be scanned, digitized and analyzed using a film dosimetry program which is time consuming.

Kodak XV film with 2 mm. buildup
The results with the EPID are in good agreement with film, while giving easier visual inspection than film without being scanned.
Without digitizing the film, we can only visually inspect the film. We have demonstrated in this study that an EPID is as sensitive a QA tool as film for our routine DMLC QA procedure. It can therefore be concluded that film can be replaced by an EPID for such a procedure.
Verification of Leksell Gamma Plan (LGP) predictions of Gamma Knife (GK) dose distributions using PAGAT polymer gel dosimeters in an inhomogeneous phantom

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A 3D image was constructed from 17 sequential axial planes with 1 mm thickness and 2 mm spacing and 16 interpolated planes which were interleaved between the 17 planes.
2D dose distribution of irradiations with 18 mm (a, b) and 8 mm collimators (c, d) of a GK unit obtained using PAGAT polymer gel dosimeters.
The presence of inhomogeneities may cause dose differences that are not in accordance with the accuracy required for treatments with GK radiosurgery, and may cause considerable errors in the dose calculation when assuming that the target volume consists of homogeneous material.
Dosimetric characteristics OF 2-D ion chamber array matrix for IMRT dose verification

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9th February 2008
Results of the study

1. Absolute dose estimation based on $D_{ij} = (M - B)_{ij} \times N_{DW} (^{60}Co) \times K_{uni\ ij} \times K_{TP} \times K_{user}$

where $(M_{ij} - B_{ij})$ – corrected reading for background, $K_{TP} -$ pressure and temperature correction, $N_{DW} (^{60}Co)$ – cobalt calibration factor, $K_{uni\ ij}$ - uniformity correction factor and $K_{user}$ determined for photons. Results were comparable with ion chamber measurement within 2%.

2. I’matriXX device was checked for dose linearity from 2 – 500 MU for both 6 & 18 MV photons and found to be linear.

3. System was checked for dose rate effect in the range of 100 – 600 MU/min and it was found to be independent of dose rate for both energies.

9th February 2008
4. The device was used for estimating output factor and output factors were comparable with that of ionization chamber measurements.

5. TPS generated fluence patterns like field-in-field, pyramidal test and chair test were measured with I’matriXX device and the same was compared with film dosimetry system and found to be in good agreement with TPS calculated fluence ($\gamma \leq 1$ is greater than 95% for 3% delta dose and 3 mm DTA).

6. IMRT patient plan fluence (1 prostate & 1 head and neck) measured by I’matriXX device & Film dosimetry system and found to be in good agreement with TPS calculated fluence ($\gamma \leq 1$ is greater than 97% for 3% delta dose and 3 mm DTA for each field).
CONCLUSION

- The measurements and evaluation proves that l’matriXX can be used to quantify the absolute dose.

- Useful for wide range of dose verification.

- Real-time measurement helps to fasten the measurement procedure in verification of IMRT fields.

- The detectors are linear to dose and independent of dose rate. These results are comparable to results obtained by Herzen et al (2007).

9th February 2008
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Many thanks for your attention!