DETERMINATION OF THE RELATIVE DOSE DISTRIBUTION AROUND AN INTRABEAM® ELECTRONIC BRACHYTHERAPY SOURCE USING FRICKE GEL DOSIMETRY

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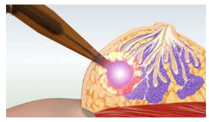
Introduction and context

Intraoperating Radiation Therapy is a cancer treatment technique using low energy photon beams, that is seeing a regain of interest those last years, as it enables an irradiation of the tumor bed with doses comparable to external radiotherapy while preserving the surrounding organs at risk. Zeiss' INTRABEAM®system (IB), providing X-Rays of energies below 50 keV, is the **most represented one in France**, mainly for breast cancer treatment purposes.

However, IB is lacking **a dosimetric reference and a dose distribution independent from the manufacturer**, and traceable to a national standard. Thus, LNHB undertook a project for the establishment of a dosimetric reference in terms of absorbed dose to water for INTRABEAM® system mounted with a spherical applicator dedicated to breast lesions [1].



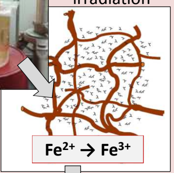
→ In this context, the **dose distribution around the system, determined** using Fricke gel dosimetry with Magnetic Resonance Imaging (MRI) readings and MC **calculations,** was **compared** to Zeiss data [1].

Measurement of the relative dose distribution around IB source

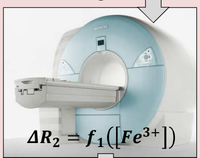
GEL DOSIMETRY PRINCIPLE

IB source in gel

Chemical reactions under irradiation



MRI readings



1

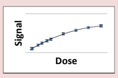
ΔR_2 distribution

$\{k_{B_1,i}\}$ 2

Inhomogeneity correction

$\{\overline{\Delta R}_{2,\text{gel,i}_{\text{corr}}}\}$

Calibration



3

$D_{\text{gel}} = f_2(\Delta R_{2,\text{gel}})$

Absorbed dose to the gel distribution

$\{D_{\text{gel,i}}\}$

4

Absorbed dose to water distribution

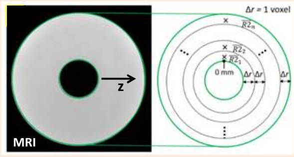
$\{D_{\text{water,i}}\}$

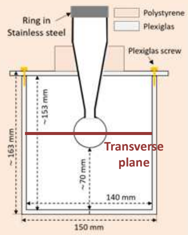
1 Irradiation and MRI measurements

- Irradiation of a cylindrical phantom filled with gel at Saint Louis Hospital
- Readings in a 1.5 T Philips Achieva MRI (IR4M, Orsay) for R_2 measurement

→ Data analysis along the transverse plane : Developement of a program to calculate the mean $\overline{R_2}(z)$ into circular Regions of Interest (ROI)

→ $\overline{R_2}(z)$ values are systematically corrected from the value measured in a non-irradiated gel, $\overline{R_{2,0}}$ ⇨ $\{\overline{\Delta R}_{2,\text{gel,i}}\}$





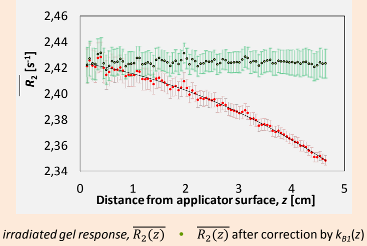
With $\overline{R_2}(z)$: Mean transverse relaxation rate measured in the gel at a depth z into the gel

$\overline{\Delta R_2}(z)$: Mean variation of the relaxation rate in s^{-1}, measured by MRI : $\overline{\Delta R_2} = \overline{R_2} - \overline{R_{2,0}}$

2 Homogeneity correction

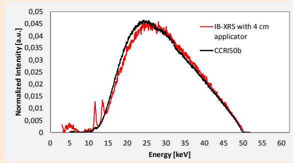
- Inhomogeneities of B_1 magnetic field into the coil, generated while reading the gel, may end up to producing artifacts, and must be corrected for.
- Correction factors $\{k_{B_1,i}\}$ were determined, reading homogeneous, non-irradiated gels.

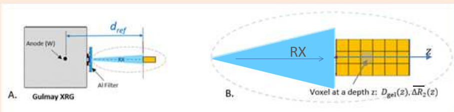
$$\{\overline{\Delta R}_{2,\text{gel,i}}\} \xrightarrow{\{k_{B_1,i}\}} \{\overline{\Delta R}_{2,\text{gel,i}_{\text{corr}}}\}$$

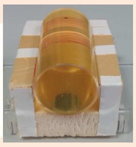


3 Gel calibration method $D_{\text{gel}} = f(\Delta R_{2,\text{gel}})$

Dose calibration was performed in a **CCRI50b reference beam**, produced by our conventional X-Ray generator, as its energy spectrum is close to the IB system one when mounted with the considered applicator. Thus, no energy dependence correction was needed.

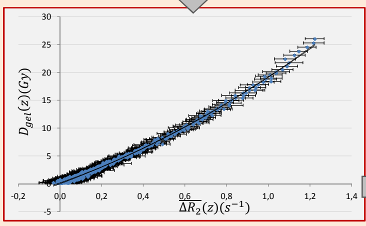




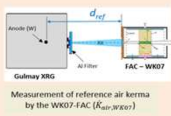


- $D_{\text{gel}}(z)$: in Gy, absorbed dose to the gel at a depth z :

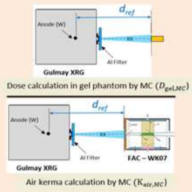
$$D_{\text{gel}}(z) = \left(\frac{D_{\text{gel}}(z)}{K_{\text{air}}}\right)_{\text{MC}} \cdot \dot{K}_{\text{air,WK07}} \cdot t$$



- $\left(D_{\text{gel}}(z)\right)_{MC}$ and $(K_{\text{air}})_{\text{MC}}$: in Gy, respectively absorbed dose to the calibration gel phantom at depth z into the gel and air Kerma at reference distance, both calculated using the PENELOPE MC code [2]
- $\dot{K}_{\text{air,WK07}}$: in Gy.s^{-1}, air kerma rate at reference distance, determined using the LNE-LNHB the free-air chamber WK07 [3]
- t: in s, irradiation time



x t x

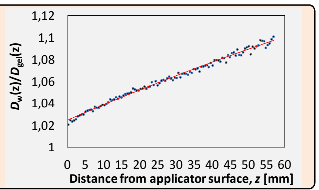


$$\{\overline{\Delta R}_{2,\text{gel,i}_{\text{corr}}}\} \longrightarrow \{D_{\text{gel,i}}\}$$

4 Conversion $\{D_{\text{gel,i}}\} \longrightarrow \{D_{\text{water,i}}\}$

Obtained from MC modeling of the experiment with gel poured into the the phantom on one hand, and with water on another hand.

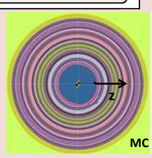
- $D_w(z)$: absorbed dose to water at depth z into the phantom, in Gy

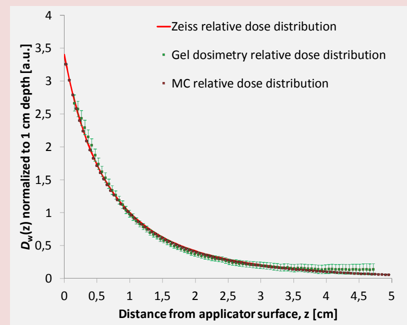


RELATIVE DOSE DISTRIBUTION

Comparison of the relative absorbed dose to water distribution measured with the gel with those obtained using MC calculation, and provided by Zeiss.

→ MC modeling of the configuration of the system described in part 1 for relative absorbed dose to water distribution calculation.





Conclusion

- A **protocol of relative dose distribution measurement** around IB source with a spherical applicator using Fricke gel dosimetry with MRI readings was developed, and the correction factors to be applied, determined. This method shows a **good agreement** with the associated **relative dose distribution calculated by MC**.
- The results obtained show a **good agreement with the manufacturer's data**. These values need to be calibrated with an absolute absorbed dose to water value at the reference depth, i.e. at 1 cm.
- This absolute value was determined, and is presented on poster for ECMP 2018 [4].

References

[1] A. Abudraa', Thesis, 2017
[2] F. Salvat, NEA, OECD, 2006
[3] W. Ksouri, Thesis, 2008.
[4] I. Aubineau-Lanièce, Poster P172, ECMP 2018

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