Fricke-Xylenol orange-Gelatin gel dosimeter combined with RUBY modular QA phantom: Error detectability for stereotactic radiotherapy plan verification

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Résumé

Introduction: Gel dosimetry has been used for some time as QA tool in radiation therapy as it allows three-dimensional dose distributions measurements with high spatial resolution and an acceptable precision. The aim of this study was to evaluate the ability of Fricke-Xylenol Orange-Gelatin (FXG) gel operated with a dedicated modular phantom (Ruby®/PTW) to detect errors for Stereotactic Radiation Therapy (SRT) treatment plans in 3D, after a comparison with radiochromic films (2D).
Material and Methods: FXG gel samples hosted in 60 mL Teflon-FEP flasks were placed during irradiation in the Ruby® modular QA phantom (PTW), through a prototype insert newly designed for this purpose. The optical readouts of the gel were performed using a Vista16™ optical computed tomography scanner (ModusQA) operated at 633 nm wavelength. The irradiations were performed on a CyberKnife M6 system (Accuray). An MLC treatment plan was created using *Precision* TPS (Accuray), for a typical intra-cranial spherical dose distribution. In order to mimic various clinical errors, dose deviations for 1 % to 10 %, geometric anterior-posterior shifts from 0.5 mm to 4 mm, and MLC single bank shift from 0.5 mm to 2 mm were subsequently introduced. The gamma index pass rate and mean gamma indicators were used to compare planned and measured dose distributions using Verisoft software (PTW). A 5 % / 2 mm (local dose/distance) criterion was applied with a 35% cutoff threshold to eliminate artefacts from the gel flask edges. Film and gel measurements underwent planar 3D gamma analysis by comparing respectively film and gel dose distributions with the central calculated planar dose. 11 irradiations of the original plan were performed. The measured doses were first compared to the original plan without

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the introduction of errors; the average value and standard deviation of the mean gamma index were subsequently calculated. The measured doses were then compared to the original plan after the introduction of each error. We considered that the error was detectable when gamma index average value was higher than a threshold defined as the average value + 2.23 times the standard deviation of the mean gamma index value obtained for the plan without error.

Results: During the repeatability study, a dose difference of 2% at the target volume centroid was observed between the first gel matrix and the TPS. This deviation increased over time, exceeding 4% for the last gel flask. While waiting to implement countermeasures to confirm the results, the gel dose distribution was normalized using a pinpoint ionization chamber measurement as a reference. The smallest deviation detected and the corresponding Gamma passing rate are reported in Table 1 for gel dosimetry and film dosimetry for all error types. Error detectability analysis shows that the gel was able to detect dosimetric shifts of 4% versus 5% for films. The gel detected also spatial shifts of 1 mm in the anterior posterior axis and MLC bank shifts of 1.5 mm.

Conclusion: The results demonstrate that the FXG gel combined with a RUBY phantom is a robust method to detect both dosimetric and geometric plan delivery errors making it a promising QA tool for dosimetric audit in stereotactic radiotherapy. The 3D nature of the gel dosimeter enables a better spatial error detection than film dosimetry especially in the axis outside of the film plane. This gel study was performed in relative dose, however additional measurements aiming at obtaining absolute dose are being discussed.
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Mots-Clés: Gel dosimetry, audit, error detectability, stereotactic radiotherapy