Contribution ID: **8** Type: **Oral**

EPR dosimetry in the radiotherapy dose range using a benchtop spectrometer: Dose uncertainties for alanine and lithium formate dosimeters.

Thursday, 21 November 2019 15:00 (15 minutes)

Introduction
In electron paramagnetic resonance (EPR) dosimetry, water equivalent dosimeter materials such as alanine (Al) or, more recently, lithium formate monohydrate (LFM) featuring low fading rates (a few percent per year) and a linear dose response are typically used. The dependency of the dosimeter response on beam energy, dose rate and beam angle is usually negligible for therapeutic beams offering high potential for applications in radiotherapy. Moreover, EPR dosimetry provides a non-destructive readout allowing repetitive measurements. Despite its favorable characteristics, EPR dosimetry is not widespread in the clinics due to the reported sensitivity limitations at the therapeutic dose level and the associated efforts. In the present work, we compared commercial Al pellets with self-manufactured LFM pellet dosimeters regarding the dose uncertainty in the dose range from 1 to 70 Gy by using a 'practical' EPR dosimetry system.

Materials and Methods
The Al pellets were purchased from Aerial, whereas the LFM pellets were pressed in-house. All pellets had a diameter of 4 mm and a height of 2 mm (Al) or 4 mm (LFM). The pellets were irradiated to doses of 1, 5, 20, 50 or 70 Gy by a clinical 6 MV photon beam. In total, 25 pellets per material (5 per dose value) were examined. For each pellet, five independent EPR measurements were performed on a benchtop EPR spectrometer (MiniScope MS 5000) within five weeks following irradiation. The measurement time of a single readout was restricted to 10 min per pellet. Dose values were reconstructed from EPR signal amplitudes using an in-house developed spectral fitting procedure.

Results
In terms of dose uncertainty, the self-made LFM pellets are superior to the commercially available Al pellets, mainly due to the higher EPR signal intensity resulting from the increased pellet mass and the narrower EPR spectrum. The relative dose uncertainties (1σ) for a single readout at doses ≥ 5 Gy are below 2.8 % (Al) and 1.0 % (LFM) but increase to 12.3 % (Al) and 2.6 % (LFM) at 1 Gy. The uncertainties at 1 Gy decrease to 2.6 % (Al) and 0.8 % (LFM) when five independent readouts are averaged.

Conclusions
In the case of the LFM pellets, the EPR dosimetry system shows a high level of precision down to 1 Gy being suitable for routine QA applications in radiotherapy (e.g. in-vivo or small field dosimetry). The uncertainties can be further decreased by averaging several independent measurements. This rather time-consuming procedure is especially advisable when using the commercial Al pellets.

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Session Classification: Session III: Dosimetry I - Chair: Dr. Sheeba Thengumpallil