HDR Brachytherapy dosimetry: Clinical use of micro-silica bead TLD & Gafchromic EBT3 film

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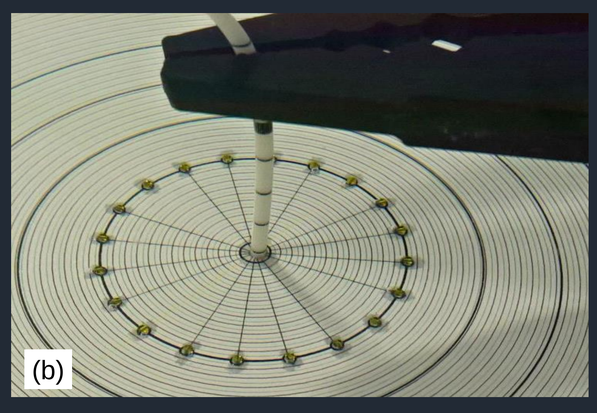
Objectives

- To develop a novel high resolution experimental method for validating Monte Carlo-derived TG-43 brachytherapy source data, and model-based treatment planning systems. Experimental verification is recommended in the "Report of the High Energy Brachytherapy Source Dosimetry (HEBD) Working Group, 2012"[1], however, the steep dose gradients with a wide dynamic dose range and rapid change in dose rate has been a limitation for the ability of common detectors to obtain accurate measurements.
- In this study, we tested a micro silica bead TLDs recently developed at University of Surrey for suitability to perform accurate dose measurements around ^{60}Co and ^{192}Ir clinical HDR brachytherapy sources. The micro silica beads proven dosimetric characteristics (independency from dose rate and angle of radiation incidence)[2] accompanied by small 'donut shape' physical dimensions (1.2 mm diameter and 0.9 mm thickness (Fig. 1 (a)) along with chemically inert nature, ease of use and reusability were considered as a very promising detectors for this application[3].

Materials & Methods

Novel dosimeter positioning templates were designed and produced using AutoCAD software. The micro silica bead TLDs were threaded using cotton yarns and stitched onto the template to accurately position the dosimeters within ± 0.1 mm (k=1), in a cubic water tank of 400 mm size in each dimension (Fig 1(b) and 1(c)).

The measurement setup for radial dose distribution and dose linearity is shown on (Fig 1(b)) and (Fig 1(c)). The used dose rates were form 10 to 4000 cGy/min and dose ranged from 0.5 to 40 Gy. The results of dose distribution measurements around the sources were compared to TG-43 tabulated data and simultaneously irradiated EBT3 Gafchromic film. A TOLEDO TL system was employed for read out of the TLDs. Triple-channel dosimetry using FilmQAPro with uncertainty reduction technique was used for film dosimetry.



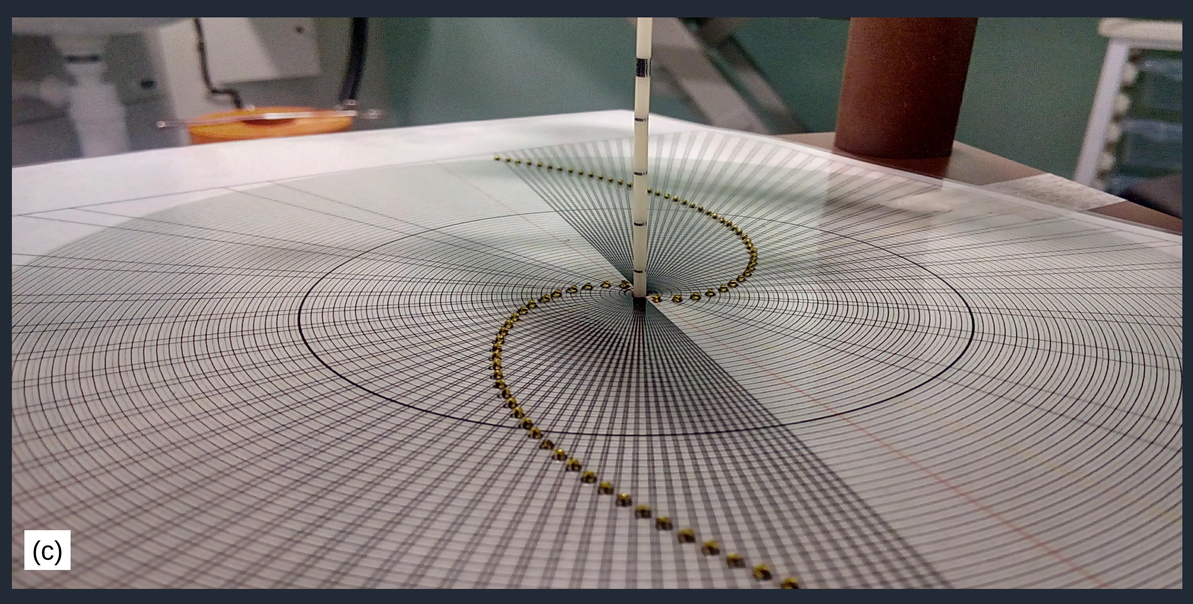
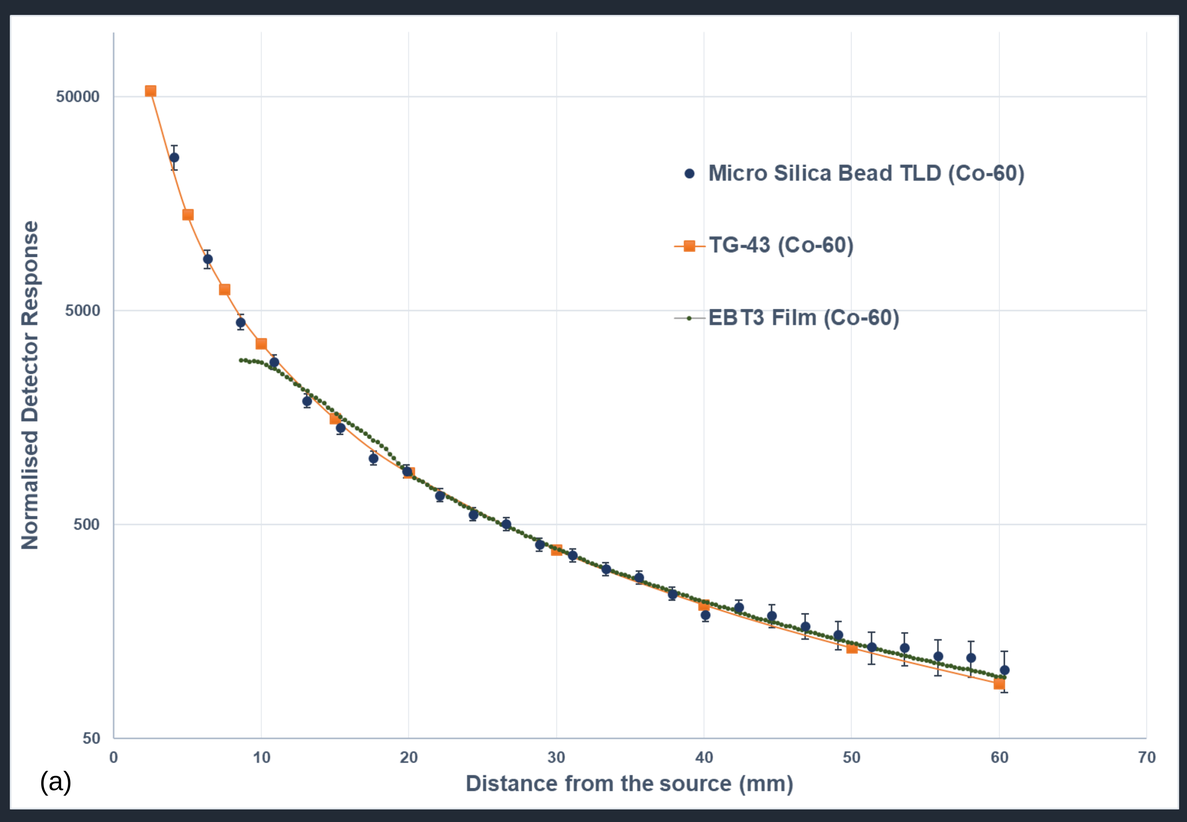


Figure 1: (a) the micro silica bead TLDs; (b) TLDs stitched onto the template and positioned in the water tank for dose linearity assessment with fixed diameter (20 mm) circle of detectors around the sources; (c) radial dose measurement with the two spiral arrangements of detectors to avoid attenuation from neighbouring detectors, and with 180º positioning of each pair of TLDs to mitigate source position uncertainties in the horizontal plane.



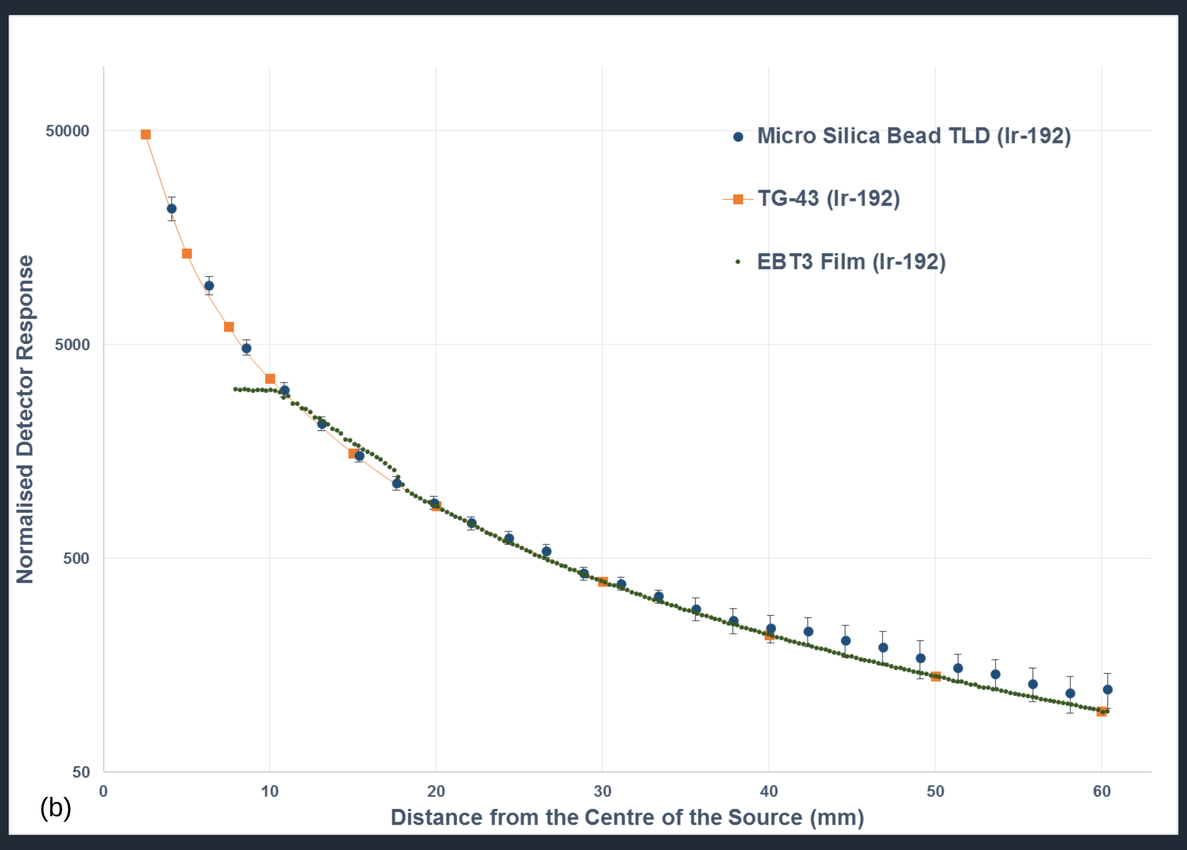


Figure 2: Measured radial dose for (a) Co-60 and (b) Ir-192 sources, using micro silica bead TLDs, and EBT3 film compared to TG-43 data. Data normalised at 20 mm distance from the sources due to the relevance of the point to the Manchester treatment planning system. The error bars show the combined experimental uncertainty of 3.4 % to 31.4% (k=2), which is mainly caused by source positioning errors at Z-axis (a maximum of 2 mm incorrectly positioning of the source on the z-axis was considered) followed by the TLD reading process (3 % at 2 Gy). The lateral positioning error was mitigated by the experimental design.

Results & Discussion

The novel experimental method suitably addressed the dosimetry challenges.

- A linear dose response was observed in the investigated range, 0.5–40 Gy, with a correlation coefficient of $R^2 > 0.999$.
- The ability of detector to assess the high gradient dose distribution with variable dose rate within the range of 10–4000 cGy/min around the sources was compared to the TG-43 data and to that of EBT3 film and found to be within experimental uncertainty (Fig 2 (a) and (b)).

Conclusion

A novel, high spatial resolution experimental method was developed for validating brachytherapy dosimetry using micro silica bead TLDs on high precision templates. The measured radial dose distributions around both of the Co-60 and Ir-192 sources were comparable within the experimental uncertainty to the relevant TG-43 data and performed equally well to that of EBT3 Gafchromic film measurement in terms of the dynamic dose range evaluated without the disadvantage of dose saturation. The experimental method presented is suitable to address the challenge of HDR brachytherapy dosimetry.

References

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