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EASTERN TIME [GMT-4]

Real-time MOSkin™ in-vivo rectal dosimetry for TRUS based HDR prostate brachytherapy

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INTRODUCTION

Significant advancements in the field of brachytherapy over the last several decades have led to the rapid implementation of trans-rectal ultrasound (TRUS) based high dose rate (HDR) prostate brachytherapy (pBT). The advantages of TRUS based HDR pBT over the traditional CT based technique include improved prostate gland visualisation and the ability to performed the entire procedure in the operating room without moving the patient.

However, numerous studies have still reported significant uncertainty in identification of the catheters [1] or movement of the catheters in the time between imaging and treatment [2]. These uncertainties have been shown to have a significant effect on the plan quality [3], therefore there is a need for rigorous in-vivo treatment verification.

One such method of in-vivo verification is in-vivo dosimetry (IVD). IVD in brachytherapy has been shown to be extremely difficult due to the high dose gradient fields associated with the brachytherapy sources [4]. This issue however has been overcome previously in TRUS based HDR pBT through coupling of the detector to the TRUS probe [5].

AIMS

To compare the dose measured in-vivo by MOSkin™ dosimeters (Centre for Medical Radiation Physics, University of Wollongong, Wollongong, Australia) coupled to a TRUS probe to the dose predicted by the brachytherapy treatment planning system (BTPS) during HDR pBT.

The secondary aim of the study was to examine the feasibility of performing real-time catheter-by-catheter analysis of the in-vivo rectal dosimetry during TRUS based HDR pBT.

METHOD

- Thirteen patients (20 treatment fractions) were included for analysis in this study.
- Treatment plans were planned on the Oncentra Prostate BTPS (v4.2, Elekta Brachytherapy, Veenendaal, The Netherlands) and delivered using an Elekta Brachytherapy Flexitron remote brachytherapy afterloader.
- Prior to commencement of the case, 4 MOSkin™ dosimeters were placed onto the TRUS probe (Type 8848, BK Medical Systems, Herlev, Denmark) secured with Kapton tape. The dosimeters were placed with 1.5 cm spacing, at an angle of 90° from the transducers on the surface of the probe (so as not to perturb the image).
- Immediately prior to treatment the TRUS probe was rotated by 90° so that the MOSkin™ dosimeters were oriented towards the anterior rectal wall.
- Measured MOSkin™ doses were retrospectively compared to those from the BTPS for both the total treatment fraction and on a catheter-by-catheter basis.

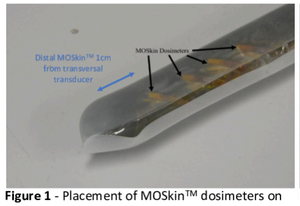

Figure 1 - Placement of MOSkin™ dosimeters on the surface of the TRUS probe.

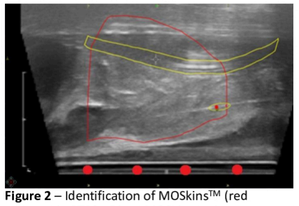

Figure 2 – Identification of MOSkins™ (red spheres) in BTPS. (Distal MOSkin™ aligned to base)

RESULTS

- The MOSkin™ measured and BTPS predicted doses were compared via relative differences, i.e. $\Delta_{DDPvsBTPS} = (D_{DPP}-D_{BTPS}) / D_{DPP}$. This comparison was performed for both the complete treatment fraction and catheter-by-catheter analysis.
- The average per fraction $\Delta_{DDPvsBTPS}$ was -1.6% ± 11.1% (k=1), with a maximum of +25.7% and a minimum of -29.2%. Forty-three measurements (68%) had a $\Delta_{DDPvsBTPS}$ less than ±11.5% (the total combined uncertainty estimate) relative to the BTPS predicted dose. No fractions included in this study had greater than 50% of the MOSkin™ measurements with $\Delta_{DDPvsBTPS}$ outside of the ±11.7% combined measurement uncertainty.
- The average $\Delta_{DDPvsBTPS}$ per catheter was 2.5% ± 16.9% (k=1). Six-hundred-and-eighty-five of the per catheter MOSkin™ measurement points (64%) had a $\Delta_{DDPvsBTPS}$ less than ±11.5% (the total combined uncertainty estimate) relative to the BTPS predicted dose.

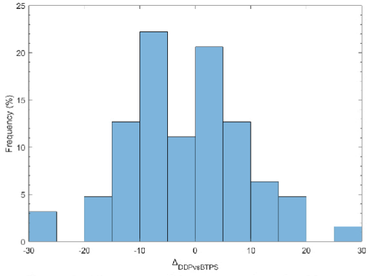

Figure 3 - Histogram of $\Delta_{DDPvsBTPS}$ values for 63 MOSkin™ measurement points across 20 treatment fractions.

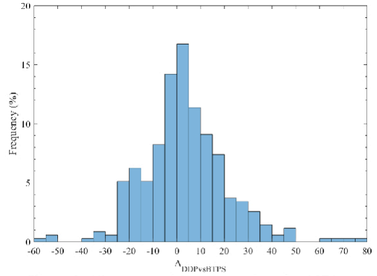

Figure 4 - Histogram of $\Delta_{DDPvsBTPS}$ values for 1071 MOSkin™ measurement points across 342 measured catheters

Table 1 - Summary of $\Delta_{DDPvsBTPS}$ and absolute dose differences between MOSkin™ measured and BTPS predicted dose on a per catheter basis.

	$\Delta_{DDPvsBTPS}$ (%)	Dose difference (cGy)
Average	2.5	0.1
Standard Deviation	16.9	5.7
Minimum	-57.9	-35.8
Maximum	71.4	24.7

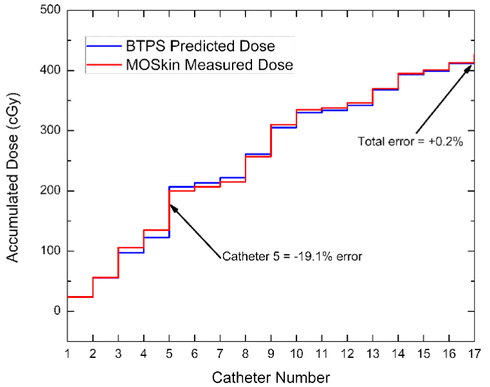

Figure 5 - BTPS predicted (blue) vs MOSkin™ measured (red) dose accumulated across catheters for one of the fractions included in this study.

DISCUSSION

- This result compares favourably with the previous results presented by Carrara et al. [5] where DPP measurements over 18 TRUS based HDR pBT fractions yielded an agreement with treatment planning predicted doses to within -2.1% ± 8.3% (k=1).
- Modern HDR pBT treatment regimens often deliver the full brachytherapy prescription dose in a single fraction, and it is therefore necessary for devices performing IVD to report dose to organs at risk prior to the end of the treatment fraction. The results presented in this study show that this may indeed be feasible using MOSkin™ dosimeters as part of a DPP. Even after excluding MOSkin™ measurements from analysis due to the small (<10 cGy), contribution to the total rectal dose, a minimum of 2 MOSkin™ dosimeters were available for analysis across all catheters measured in this study.
- Inclusion of multiple dosimeters in the per catheter analysis results in improved redundancy to potential dosimeter errors and an increased ability to detect potential treatment delivery errors. For example, it may be appropriate to investigate a potential treatment delivery error if more than 50% of MOSkin™ dosimeters are showing a $\Delta_{DDPvsBTPS}$ of greater than 11.7% on a per catheter basis. No catheters analysed in this study were found to have >50% of measurement points with a $\Delta_{DDPvsBTPS}$ >11.7%. Based on these results, a minimum of 4 dosimeters should be used when performing real-time in-vivo rectal dosimetry for HDR pBT.
- Analysis of the per catheter results in the context of treatment verification is difficult. This is exemplified in Figure 5, where catheter 5 in the treatment plan has a $\Delta_{DDPvsBTPS}$ of -19.1%, but the total treatment fraction $\Delta_{DDPvsBTPS}$ is only 0.2%. Whilst the total dose to the rectum for the treatment fraction was found to be within tolerance, if the error for this catheter was related to an incorrect catheter reconstruction in the BTPS, it may have resulted in an overdose to the urethra or significant loss in target coverage.

REFERENCES

[1] **Rylander S et al**. Dosimetric impact of contouring and needle reconstruction uncertainties in US-, CT-, and MRI-based high dose rate prostate brachytherapy treatment planning. *Radiotherapy and Oncology 2017; 123: 125-32.*

[2] **Milickovic N et al**. 4D analysis of influence of patient movement and anatomy alteration on the quality of 3D U/S-based prostate HDR brachytherapy treatment delivery. *Medical Physics 2011; 38: 4982-93.*

[3] **Poder J et al**. Derivation of in-vivo source tracking error thresholds for TRUS-based HDR prostate brachytherapy through simulation of source positioning errors. *Brachytherapy 2019; 18: 711-19.*

[4] **Tanderup K et al**. In-vivo dosimetry in brachytherapy. *Medical Physics 2013; 40; 070902-1 - 16.*

[5] **Carrara M et al**. Study of the correlation between rectal wall in-vivo dosimetry performed with MOSkins and implant modification during TRUS-guided HDR prostate brachytherapy. *Radiation Measurements 2017; 106; 385-90.*

CONCLUSIONS

- This study presents a method for in-vivo rectal dosimetry during TRUS-based HDR pBT using MOSkin™ dosimeters.
- The results of the study were found to agree well with previously published data, despite differences in clinical workflows.
- Analysis of MOSkin™ measured doses as compared to BTPS predicted doses on a per catheter basis was found to be feasible.
- Inclusion of multiple dosimeters improved redundancy to potential dosimeter errors and increased probability of detecting potential treatment errors.
- Measurement uncertainty could be decreased significantly through fabrication of TRUS probes with well defined recesses for placement of MOSkin™ dosimeters.
- The methodology presented in this study could be followed when implementing real-time in-vivo rectal dosimetry for HDR pBT delivered in a single fraction.

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