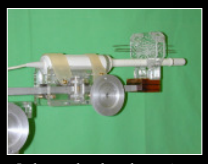
Dosimetric evaluation of interstitial high-dose-rate implants for localised prostate cancer

Fröhlich G.[1,2], Major T.[2], Ágoston P.[2], Lövey J.[2], Somogyi A.[2], Fodor J.[2]

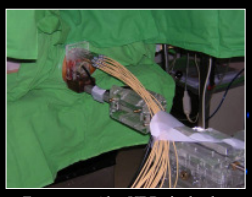
1. Semmelweis University, Doctorial School, Budapest, Hungary
2. National Institute of Oncology, Department of Radiotherapy, Budapest, Hungary

Introduction

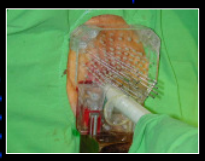
We use transrectal ultrasound-guided interstitial prostate brachytherapy as a boost treatment in combination with teletherapy to patients with localised intermediate- or high-risk prostate cancer. Dose distributions of the implants performed with a high-dose-rate Ir-192 source were dosimetrically evaluated.



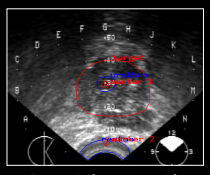
In-house developed stepping unit with the template



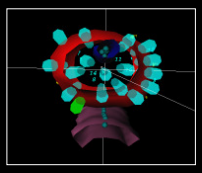
Treatment with a HDR afterloader



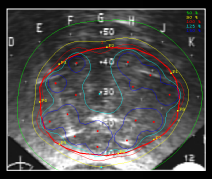
The template with insertion needles



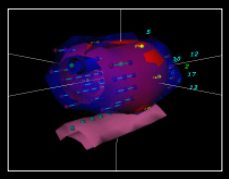
Anatomical contours with urethra- and rectum dose points



3D anatomical reconstruction with the needles



Dose distribution in the reference slice



3D dose distribution around the target volume

Materials and methods

Treatment plans of 134 implants for 126 patient were evaluated using dose-volume histograms. Geometrical optimization was applied and 10 Gy dose was prescribed to surface of the prostate. The tolerance dose to the urethra and the rectum was 125% and 80%. Graphical optimization was used when the dose coverage needed improvements. The volume of the prostate was measured, and its fraction receiving 90%, 100%, 150% and 200% of the prescribed dose was calculated (V90, V100, V150, V200). The dose delivered to 90% of the prostate volume (D90), the minimum dose in the prostate (D_{min}), maximal dose to the rectum (D_r) and the urethra (D_u) reference points, dose to volume of 2 cm^3 of the rectum (D_2) and 0.1 cm^3 and 1% of the urethra ($D_{0.1}$, D1) were determined. Correlation analysis was performed between point and volume doses. The dose non-uniformity ratio (DNR) and the dose homogeneity index (DHI) were calculated to quantify the dose homogeneity. The coverage index (CI) was determined, and the dose conformality to the target volume was assessed with the use of the conformal index (COIN). In most patients in-vivo dose measurement was performed in the rectum with semiconductor detectors.

* Dose Nonuniformity Ratio :

$$DNR = \frac{V_{1.5ref}}{V_{ref}}$$

* Dose Homogeneity Index :

$$DHI = \frac{V100 - V150}{V100}$$

* Coverage Index :

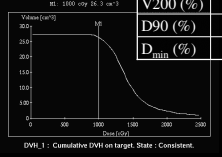
$$CI = \frac{V100}{100}$$

* Conformal Index :

$$COIN = \frac{PTV_{ref}}{V_{PTV}} \cdot \frac{PTV_{ref}}{V_{ref}} = CI \cdot \frac{PTV_{ref}}{V_{ref}}$$

Volume- and dose parameters for target

	mean	SD	min.	max.
V_p (cm^3)	24.9	10.3	6	65.4
V90 (%)	98	4	77	110
V100 (%)	94	6	65	98
V150 (%)	42	10	17	71
V200 (%)	14	5	5	33
D90 (%)	106	8	71	118
D_{min} (%)	81	10	44	96



Results

The volume parameters, quality indices and dose parameters in critical structures are presented in the tables. On average, 94% of the target volume received at least the prescribed dose, CI=0.94 (0.68-0.98), the mean COIN was 0.64 (0.42-0.82), while the mean DHI was 0.56 (0.27-0.87).

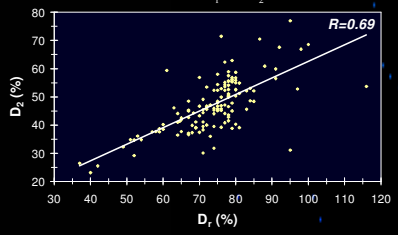
The mean maximal measured dose in the rectum was 2.7 Gy (0.3-6 Gy).

The correlation coefficients were: $R(D_r,D_2)=0.69$, $R(D_u,D_{0.1})=0.55$, $R(D_u,D1)=0.23$.

Quality indices

	mean	SD	min.	max.
Number of needles	16 (median)	3.06	7	23
DNR	0.39	0.08	0.2	0.58
DHI	0.56	0.11	0.27	0.87
CI	0.94	0.05	0.68	0.98
COIN	0.64	0.07	0.42	0.82

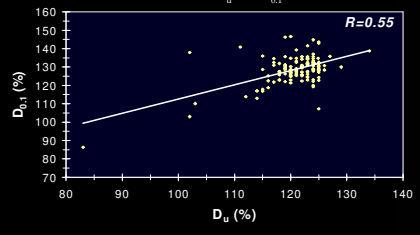
Correlation between D_r and D_2 for the rectum



Relative dose values in the rectum and urethra

	mean	SD	min.	max.
$D^r_{in\ vivo}$(%)	26	1	2	73
D_r(%)	74	11	37	116
D_u%)	121	5	83	134
D_2(%)	48	10	23	77
$D_{0.1}$(%)	129	8	86	160
D1(%)	144	18	93	253

Correlation between D_u and $D_{0.1}$ for the urethra



Conclusions

The treatment plans based on the real positions of catheters provided acceptable dose distributions. In the majority of our cases the dose to the urethra and the rectum was kept below our tolerance level. The dose to the rectum can be estimated correctly by the reference point dose but for the urethra dose determination the D1 volumetric parameter is recommended to use. To find correlations between dose-volume parameters and side effects requires further analysis.

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