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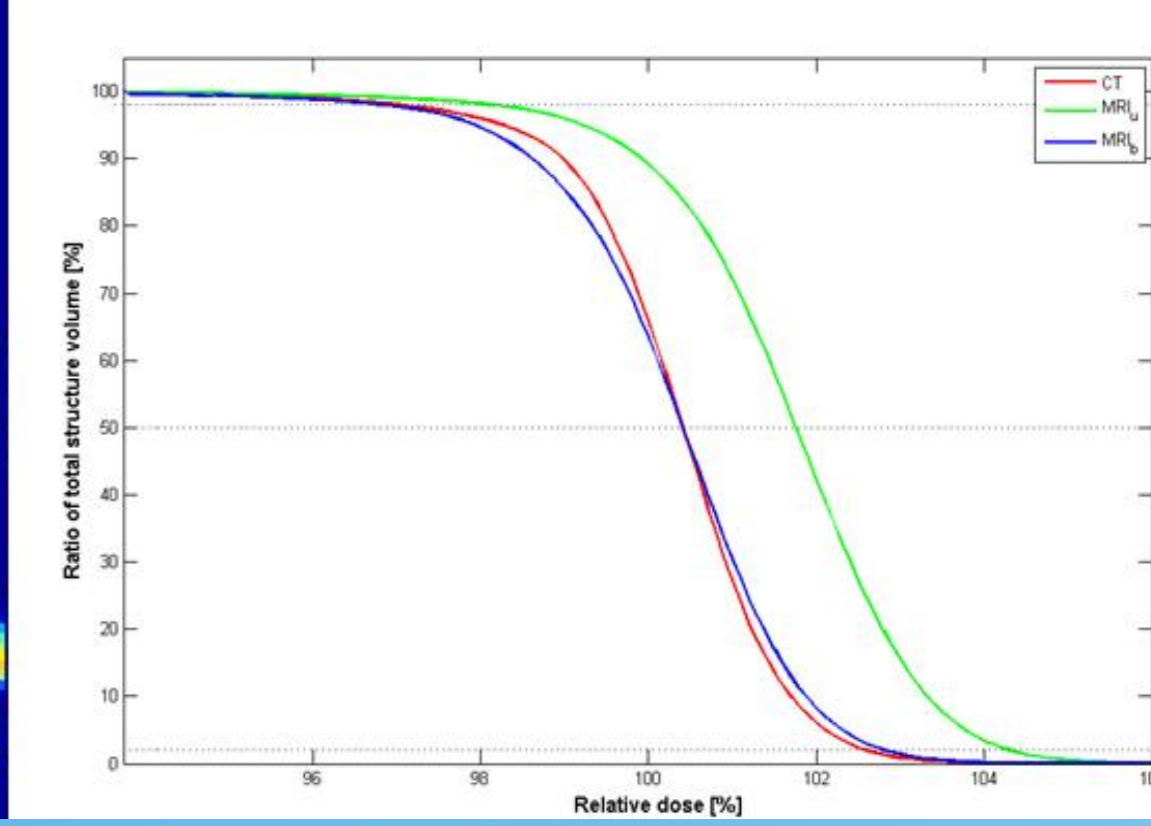
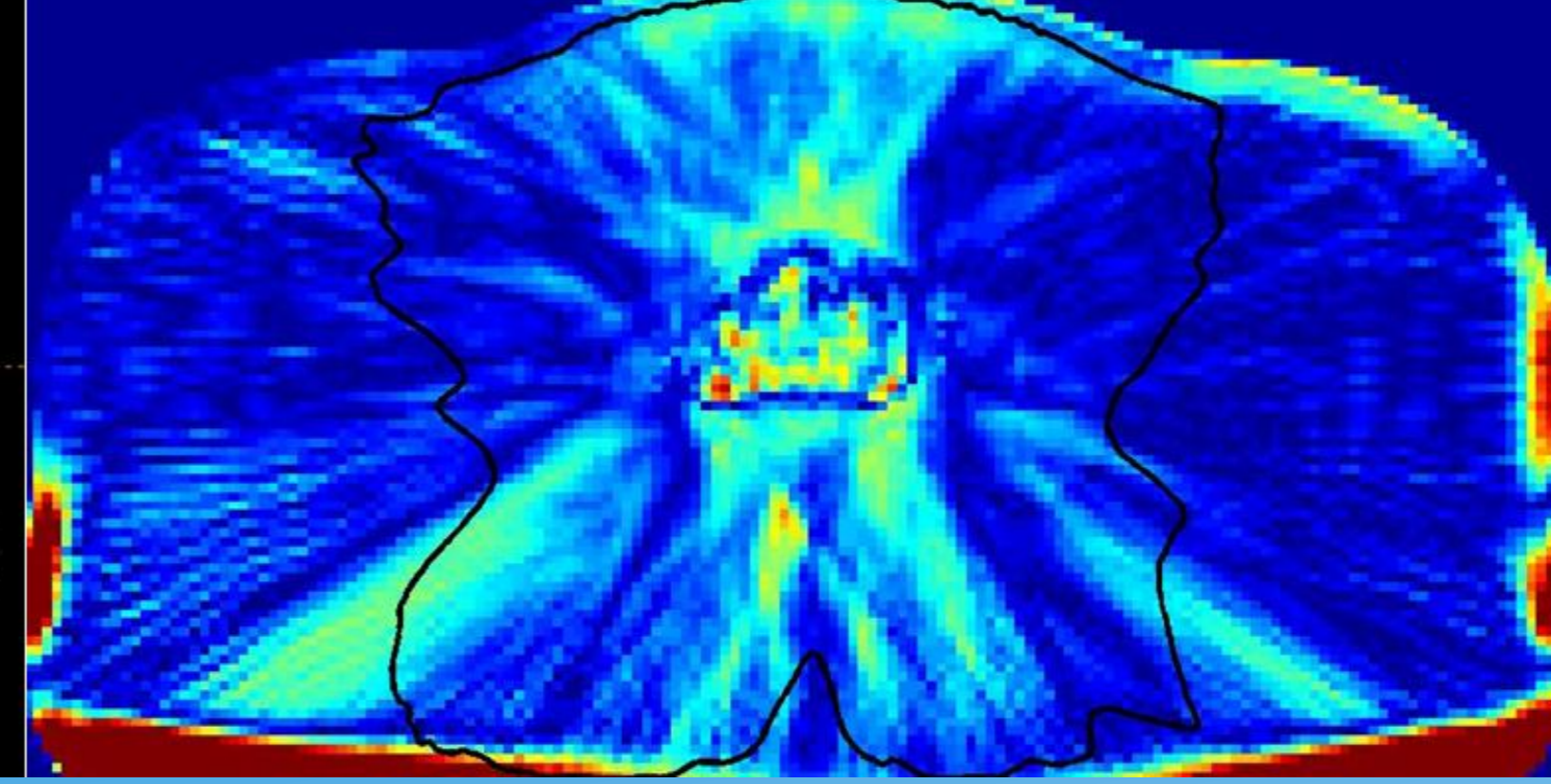
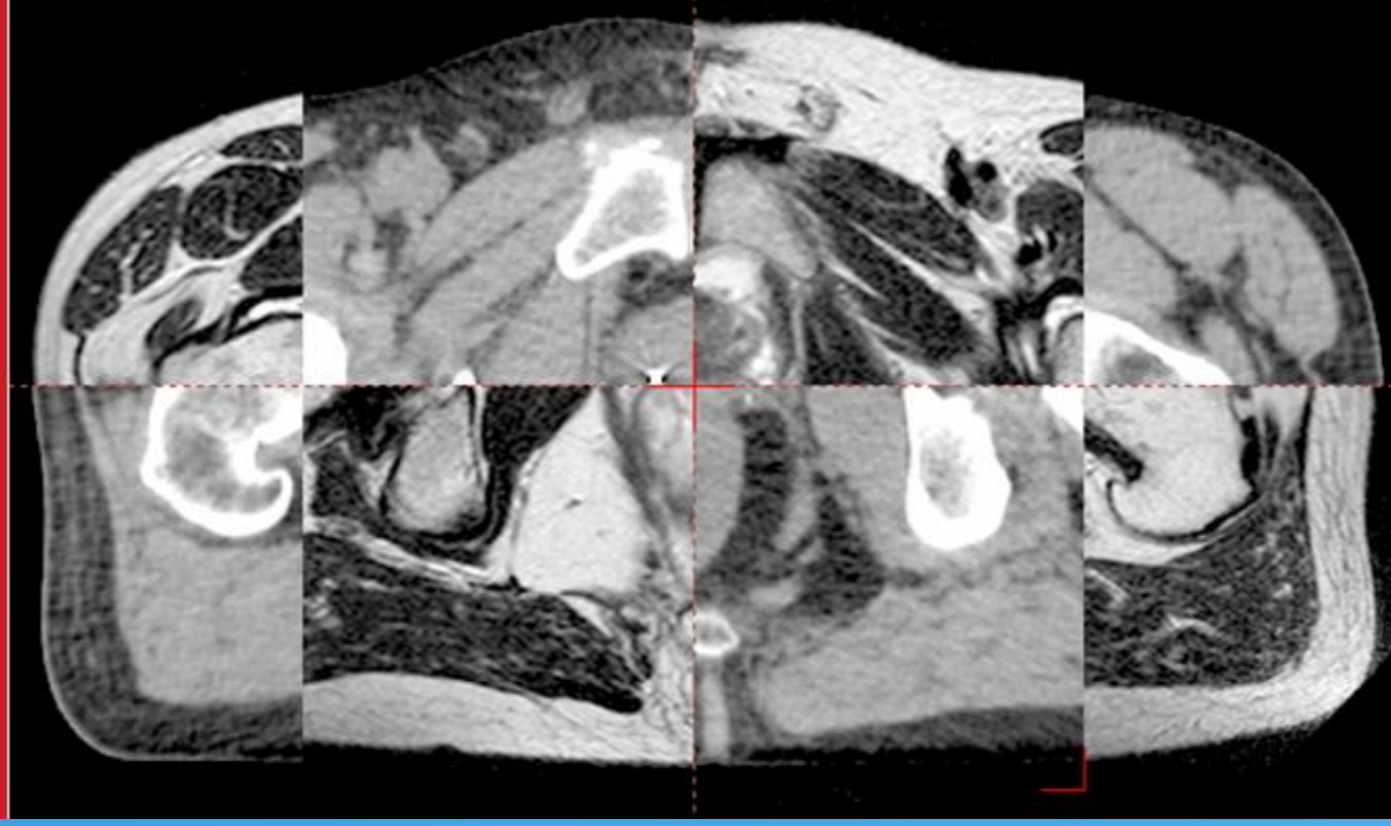
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Statistical analysis of MRI-only based dose planning

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Introduction

In RT, multimodality imaging is increasingly combined for a better tumour delineation. The CT has a high geometrical accuracy and a direct connection to electron density while the MRI provides additional soft-tissue contrast to CT. Registration of MRI and CT can however, introduce systematic errors. MRI-only based RT eliminates these errors and reduce the time and costs of a CT scan. This study investigates the dosimetric differences of a treatment plan when the dose calculation is based on MRI as compared to CT.

Material and methods

The investigated diagnostic groups are displayed in Table 1.

Diagnostic group				
	Head & Neck (Oro - and hypopharynx)	Sarcoma (Extremities)	Prostate	Pelvic (Not prostate)
# of patients	18	6	21	9
Delivery technique	Static IMRT	APPA	VMAT	VMAT

Table 1 Data from each patient contains a CT scan (Phillips Big Bore CT), a T2 weighted MRI scan (1T Panorama Phillips), a structure set and a clinically approved treatment plan. The treatment planning system is Eclipse v.10.0 (Varian Medical Systems).

The dose is calculated based on the MRI data as seen in Figure 1. The body is outlined separately on both the MRI and the CT. The CT based clinical treatment plan and structure set are registered to the corresponding MRI and the dose distribution is re-calculated with fixed MUs.

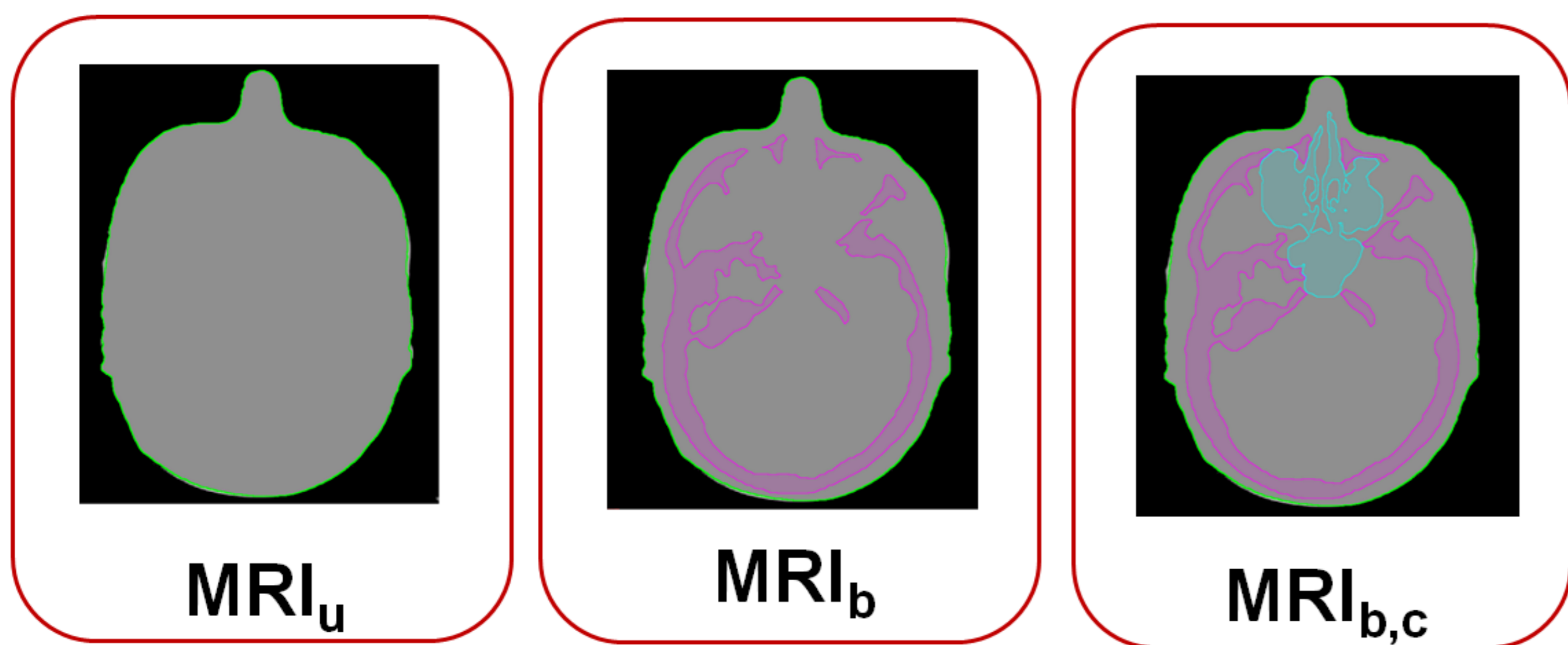


Figure 1 MRI_u: A homogeneous density assigned MRI where the entire body is assigned an HU equal to water. MRI_b: A heterogeneous density assigned MRI where the CT segmented bone is transferred to the MRI and assigned an age dependent HU based on ICRU report 46. For H&N patients, air cavities are also investigated (MRI_{b,c}).

The differences in the dose distributions are quantified using DVH points. The reported DVH points for the target volumes are chosen in accordance with ICRU report 83. The DVH points for the organs at risk are based on our local clinical guidelines as well as QUANTEC.

In addition, a gamma volume histogram (GVH) was calculated to quantify the fraction of the volume contained within the 20%-isodose that fulfills the γ -criteria. An one-way two-tailed ANOVA and paired t-tests are used to investigate the dose differences. The assumptions of the ANOVA are fulfilled since the data are normally distributed with constant variances. The evaluation is performed with a significance level of $p < 0.05$.

Results

The results of the differences in the DVH points are displayed in Table 2 and Table 3. The mean differences are in the order of 2 %. The results of the GVH are displayed in Table 4.

Diagnostic group	Volume (# of patients)	Parameter	MRI _u [%]	MRI _b [%]	MRI _{b,c} [%]	Significant
H&N (Oro - and hypopharynx)	PTV(18)	D _{median}	1.0 ± 1.9	-0.6 ± 1.2	0.02 ± 3.0	A, B, C, E
		D _{98%}	1.6 ± 2.3	0.006 ± 1.8	-1.0 ± 2.8	A, B, D, E, F
		D _{2%}	1.2 ± 2.0	-0.4 ± 0.9	0.4 ± 4.3	NS
	CTV(18)	D _{median}	1.0 ± 1.9	-0.4 ± 1.4	-0.05 ± 3.1	NS
		D _{98%}	1.4 ± 2.9	-0.2 ± 2.4	-0.6 ± 3.2	A, B, E
		D _{2%}	1.4 ± 2.0	-0.3 ± 1.1	0.3 ± 4.5	NS
Medulla(18)	D _{max}	0.8 ± 3.6	-1.4 ± 3.8	-1.4 ± 3.6	NS	
Brainstem(12)	D _{max}	-0.05 ± 20.0	-3.3 ± 19.2	-3.2 ± 19.4	NS	
Parotid sin.(17)	D _{median}	-2.0 ± 7.6	-3.1 ± 8.0	-2.1 ± 9.3	NS	
Parotid dxt.(18)	D _{median}	0.8 ± 10.6	-0.3 ± 10.5	0.8 ± 12.4	NS	

Table 2 The mean value ± two standard deviations of the percentage differences with respect to CT. **A:** MRI_u vs. CT, **B:** MRI_u vs. MRI_b, **C:** MRI_u vs. CT, **D:** MRI_{b,c} vs. CT, **E:** MRI_u vs. MRI_{b,c}, **F:** MRI_b vs. MRI_{b,c}. NS=Not significant.

Diagnostic group	Volume (# of patients)	Parameter	MRI _u [%]	MRI _b [%]	Significant
Prostate	PTV (21)	D _{median}	1.3 ± 1.4	-0.0002 ± 1.1	A, B
		D _{98%}	1.4 ± 1.9	-0.03 ± 1.7	A, B
		D _{2%}	1.4 ± 1.3	-0.02 ± 1.0	A, B
	CTV (21)	D _{median}	1.3 ± 1.4	-0.005 ± 1.1	A, B
		D _{98%}	1.4 ± 1.5	0.1 ± 1.3	A, B
		D _{2%}	1.3 ± 1.4	0.1 ± 1.8	A, B
	Rectum*(12)	D _{10%}	2.0 ± 1.7	0.6 ± 1.6	NS
		D _{30%}	1.9 ± 2.5	0.8 ± 2.5	NS
		D _{60%}	1.0 ± 3.0	0.2 ± 3.0	NS
	Rectum**(9)	D _{10%}	2.2 ± 3.0	0.9 ± 3.0	NS
		D _{30%}	0.8 ± 1.5	-0.008 ± 1.3	NS
		D _{60%}	-0.006 ± 1.6	0.7 ± 1.6	NS
Sarcoma (Extremities)	PTV(6)	D _{median}	-1.0 ± 1.8	-1.6 ± 3.0	NS
		D _{98%}	-2.2 ± 19.1	-2.3 ± 19.2	NS
		D _{2%}	-1.4 ± 3.2	-1.5 ± 3.6	NS
	CTV(6)	D _{median}	-1.2 ± 2.3	-1.5 ± 2.8	NS
		D _{98%}	-0.9 ± 17.7	-1.1 ± 17.3	NS
		D _{2%}	-1.6 ± 3.7	-1.6 ± 3.7	NS
Pelvic (Not prostate)	PTV(9)	D _{median}	0.3 ± 1.1	-0.2 ± 1.2	NS
		D _{98%}	-0.8 ± 2.1	-1.2 ± 2.3	NS
		D _{2%}	0.7 ± 1.4	0.7 ± 1.6	NS
	CTV(9)	D _{median}	0.4 ± 1.1	0.9 ± 6.6	NS
		D _{98%}	-0.1 ± 1.7	-0.6 ± 1.5	NS
		D _{2%}	0.7 ± 1.5	0.2 ± 1.8	NS
	Femur dxt.(8)	D _{mean}	0.1 ± 3.1	-0.2 ± 2.3	NS
		D _{max}	0.3 ± 2.5	-0.4 ± 1.4	NS
	Femur sin.(8)	D _{mean}	0.3 ± 1.1	-0.5 ± 1.3	NS
D _{max}		0.1 ± 1.5	-0.2 ± 3.3	NS	

Table 3 The mean value ± two standard deviations of the percentage differences with respect to CT. *Prescribed dose of 70 Gy. **Prescribed dose of 78 Gy. **A:** MRI_u vs. CT, **B:** MRI_u vs. MRI_b. NS=Not significant.

Diagnostic group	Volume (# of patients)	γ -criteria	MRI _u [%]	MRI _b [%]	Significant
Prostate (18)	20%-isodose	$\gamma_{3mm/3\%}$	89.7 [79.0-99.6]	90.2 [81.3-99.7]	S
		$\gamma_{2mm/3\%}$	86.7 [71.7-99.3]	87.6 [76.0-99.4]	S
		$\gamma_{2mm/2\%}$	79.4 [58.6-97.7]	81.5 [65.9-98.6]	S

Table 4 The mean value [range] of the percentage of points that fulfill the γ -criteria. S=Significant.

Conclusion

The investigated DVH points show that MRI-only based RT gives results similar to CT based RT. The main differences are in the order of 2 %. In general it is necessary to correct for bone density although water density correction is enough in most cases. However, the analysis only describes similarities in DVH points and not in the shape of the DVH. Even though the mean differences are non-significant there might be unacceptable differences for the individual patient. The obtained results are consistent with those previously reported. The GVH evaluation support the DVH evaluation for the prostate patients. MRI-only based RT seems to be a feasible alternative to CT based RT.

