Master's Thesis Engineering Technology

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Implementation of gEUD-based planning system for prostate cancer

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Introduction

The **Limburgs Oncologisch Centrum (LOC)** performs radiotherapy treatments of Jessa hospital Hasselt and ZOL hospital Genk. Currently, dose/volume-constraints are used for the treatment planning of volumetric modulated arc therapy (VMAT) prostate treatments. An alternative approach could be the use of Equivalent Uniform Dose (EUD) in the optimization. EUD is a parameter that can be used for **comparing non-uniform doses**. Generalized EUD **(gEUD) is an organ-specific parameter** that takes into account the biological effect on the organ as a result of the dose that is deposited in that organ. gEUD is defined by a more general formula than EUD and is therefore the more general equivalent of EUD. This gEUD-based treatment planning should, based on the literature, be a more biologically-driven way of planning.

The aim of this research is to investigate if it would be **feasible to use gEUD-constraints instead** of the dose/volume-constraints. An improvement can be more sparing of the Organs At Risk (OARs) or a simpler, more efficient way to get the same result. To come to a conclusion, different aspects need to be studied: the feasibility using gEUD for prostate treatments, the creation of plans of equal quality using gEUD and the possibility of increasing plan quality, with or without compromises to target or organs at risk. The results of the optimization are within the Varian Eclipse® treatment planning system (TPS) always given in a dose-volume histogram as visualized by figure 1.

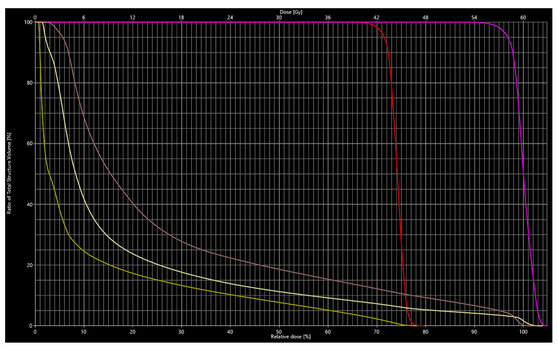

Figure 1: DVH plan using dose/volume-constraints

Method

First, an **a posteriori study** is executed to define a baseline for the practical study. Data is used of **106 patients** who are **already treated** for prostate cancer. **Statistical calculations** are performed for the numerical data of the patient's treatment plan, every time with a different value for the **volume parameter a**. The same calculations are executed for rectum, intestines, bladder and target (PTV BST). Microsoft Excel is used for all these calculations.

Structure: RECTUM											
Approval Status: Approved											
Plan: PROSTAAT											
Course: C1											
Volume [cm³]: 66.9											
Dose Cover.[%]: 100.0											
Sampling Cover.[%]: 100.0											
Min Dose [%]: 6.4											
Max Dose [%]: 102.5											
Mean Dose [%]: 45.1											
Modal Dose [%]: 11.2											
Median Dose [%]: 39.3											
STD [%]: 28.4				Total dose (Gy)	60						
Equiv. Sphere Diam. [cm]: 5.0				Mean dose (%)	45,10%						
Conformity Index: N/A				Mean dose (Gy)	27,06						
Gradient Measure [cm]: N/A											
Dose Level [Gy]:				V (cm³):	66,9			EUD rectum with D			
RTOG CI:				a	0,5			in Gy	24,19		
Paddick CI:				n	2			in %	40,31		
GI:											
ICRU83 HI:				(alfa/beta) ratio	3			EUD rectum with EQD2			
D99.0% [%]:				Aantal fx	20			in Gy	22,29		
:				dDose (%)	0,1			in %	45,60		
Relative dose [%]	Dose [Gy]	dVolume / dDose [cm³ / %]		EQD2 [Gy]	EQD2 [%]	v*d^a in Gy		v*EQD2^a in Gy	v*d^a in [%]	v*EQD2^a in [%]	
0,05	0,03	0		0,018009	0,030025	0		0	0	0	
0,15	0,09	0		0,054081	0,090225	0		0	0	0	
0,25	0,15	0		0,090225	0,150625	0		0	0	0	
0,35	0,21	0		0,126441	0,211225	0		0	0	0	
0,45	0,27	0		0,162729	0,272025	0		0	0	0	
0,55	0,33	0		0,199089	0,333025	0		0	0	0	

Figure 2: Excel work file for statistical calculations for rectum

Second, a **practical study** is performed for **ten** of the previous **treated patients** by using the Varian Eclipse® TPS, that is used by the LOC. This practical study is divided in two separate parts. First, **reconstructing plans** by using gEUD-constraints, and next **improving** the **plans** by using gEUD-constraints. In the first part, the original plan, created with dose/volume-constraints, is recreated with gEUD-constraints to investigate whether it can deliver plans of the same quality. In the second part, the aim is to improve the original plan by using these gEUD-constraints instead of the dose/volume-constraints. Because the gEUD-constraints are used in practical cases, this study comes to conclusions about the advantages and disadvantages of the practical use of this way of treatment planning.

Lastly, the result of the practical study are compared to the information from the literature to investigate **how biological** this "biological" way of treatment planning is **in reality**.

Results

To get a good view of the results of the **a posteriori study**, the calculated gEUD-values are all patterned in histograms per organ. A histogram is made for every value of a for which the calculated gEUD-values are patterned. Figure 3 shows the **extrema of the a-value** for each organ.

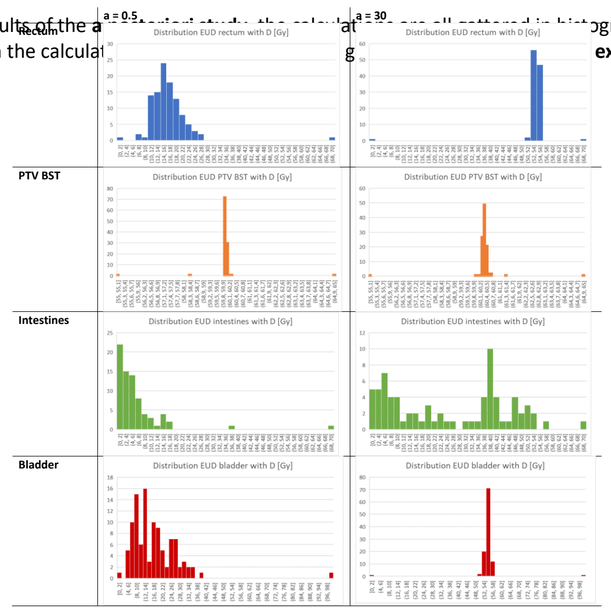

Figure 3: results EUD with dose for a = 0.5 and a = 30

For all ten patients it was **possible to reconstruct** the original plan by using gEUD-constraints in the **practical study**. In the second part, **improvement** of the plan was achieved **for six out of ten patients**. In figure 4 the reconstructed and improved plan are compared with each other and are marked with squares and triangles respectively. With the resulting EUD-values the NTCP-values are calculated and ev[illegible]evel. The results are probability that the two data series belong to the sh[illegible]

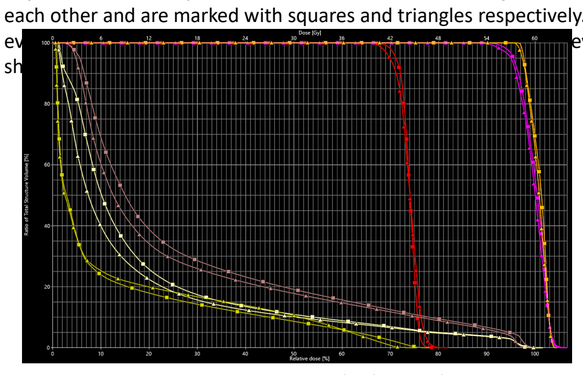

Figure 4: Comparison reconstructed and improved DVHs

Table 1: results of paired, two-tailed t-test for EUD- and NTCP-value of rectum and bladder

	Paired, two-tailed t-test for EUD-values	Paired, two-tailed t-test for NTCP-values
Rectum	0.287699972	0.049210766
Bladder	0.001847983	0.824038131

To be able to come to a conclusion about how "biological" this way of treatment planning is in reality the results from the literature are compared with the results from the practical study. This comparison showed that the results are not alike.

Conclusion

Out of the **a posteriori study** can be concluded that the volume-effects for rectum and bladder are alike and opposite to the effect for the intestines. **For rectum and bladder** the distribution increases and therefore the peak gets finer with an increasing a-value and this peak also shifts to the right. This means that there is a **starting EUD-value** that can be used for the treatment planning of these organs for every patient. Since there is no clear peak for the **intestines**, can be concluded that there is **no clear baseline** for the planning of the intestines that can be used for every single patient. The result for the **PTV** are **not significant**.

The conclusion from the **practical study** is that it is possible to create the **same quality of treatment plans** with EUD-constraints as with the dose/volume-constraints. This was possible for all ten patients this was tried for. Using EUD-constraints **can** even result in plans that **have more sparing of the OARs**. That was the case for six out of ten patients in this study. From the practical experience using the EUD-constraints for planning can be concluded that the **use of these constraints** is **straightforward and very easy to use** for the worker since one constraint replaces multiple dose-volume constraints. The a-values indicates which region of the DVH will be affected in what way by placing that constraint. a=0.5, as visualized by figure 5, affects the low-dose region. a-values 1 and 10 affect the whole DVH and the high-dose region respectively. Another conclusion is that the effect of a slightly changing a-value is small. This indicates that the **a-value** will **not** be the **most important parameter to get** exactly **wright** for the treatment planning. There are less constraints required to for creating the same plan with EUD-constraints than with dose/volume-constraints. This will result in a **less time consuming** treatment planning protocol.

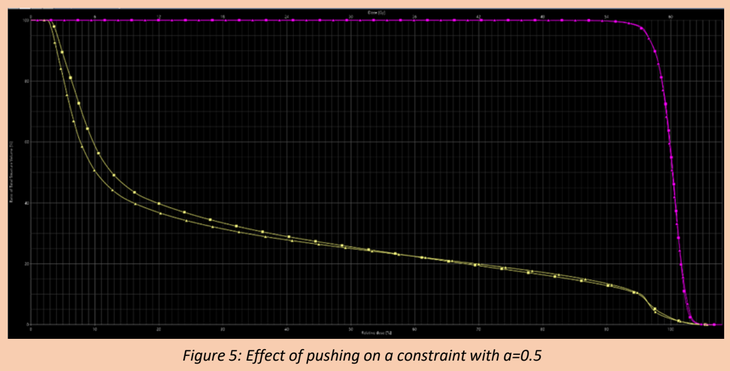

Figure 5: Effect of pushing on a constraint with a=0.5

Out of the comparison of the results from the literature and the practical study can be concluded that the gEUD-based treatment planning is **not directly linked to the biological nature** of the tissues since there is a large difference between the two.

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