Comparison of organ at risk doses in patients with larynx cancer for different jaw width in Helical Tomotherapy

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- Helical Tomotherapy is an advanced rotational treatment modality which uses Intensity Modulated fan beams in order to achieve highly conformal dose distribution.
- Helical Tomotherapy device has a 6 MV linear accelerator mounted on a slippery ring gantry . Beam is delivered to the patient with the gantry and couch in simultaneous motion like in helical Computed Tomography.
- Beams can be delivered from 51 directions (approximately every 7°).
- For each of these 51 projections, the beam is modulated with a 64-leaf binary multileaf collimator (MLC).

- IMRT delivery is achieved by moving 64 individual collimators towards in and out of a narrow beam. Each indivudual MLC leaf is either open or closed since the multileaf collimator (MLC) is binary.

- MlC's action is very quick thanks to pneumatic drive and a full opening-closure cycle takes only 20 ms.

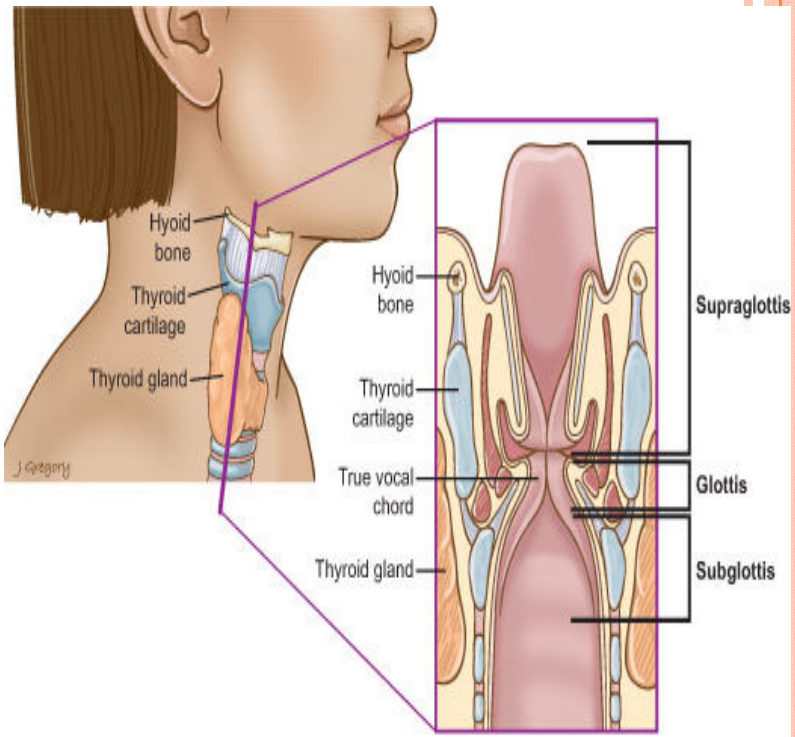
Optimal plan results depend on the capability of the optimizer and the use of appropriate planning parameters to achieve desired constraints.

There are some dose delivery parameters such as pitch, modulation factor and jaw width can be used in various combinations in order to get homogeneous dose distribution inside target and reduce the dose of organ at risk volumes.

Pitch is the ratio of the couch travel distance per a full gantry rotation to the beam width on the axis of rotation. This factor is equal or bigger than 1 for Computed Tomography. In HT, pitch is usually set to be around 0.3 although it may range in a big scale. Each voxel can be irradiated with more rotations by use of smaller pith values. Gantry rotations overlaps by use of smaller pitch values. Smaller pitch value means more gantry rotations and more overlaps.

Modulation factor is defined as the dividing greatest leaf opening time by average opening time of all non-zero leaf open time. A modulation factor (MF) of 1 means that the fields are not modulated. A higher MF may deliver higher dose gradients.

Larynx cancer is the most common one among the head and neck cancers and it can be found in the glottis, supraglottis or subglottis part of larynx. Larynx cancer responds well to treatment with appropriate diagnosis. Radiotherapy, is one of the treatment methods for larynx cancer and it aims to protect the critical organs as much as possible while giving the prescribed dose to the target tumor.



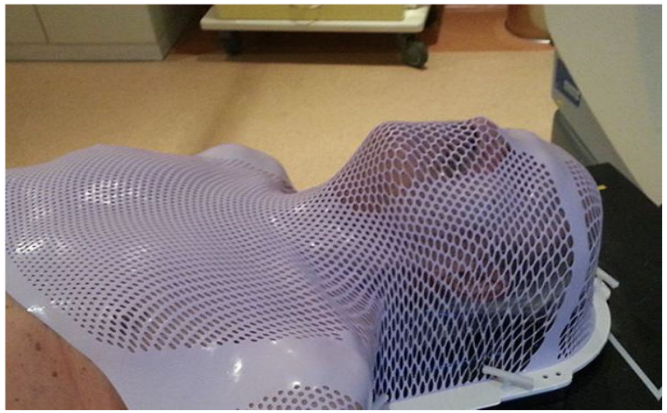
In this study we aimed to investigate the effect of jaw width parameter in Helical Tomotherapy on the doses of organ at risk (OAR) volumes including spinal cord, right/left carotid arteries, right/left submandibular glands and thyroid for larynx cancer patients.

This study was carried out in Inonu University, Turgut Ozal Hospital. Devices were used in the study stated as below.

Tomoterapi Hi-Art device

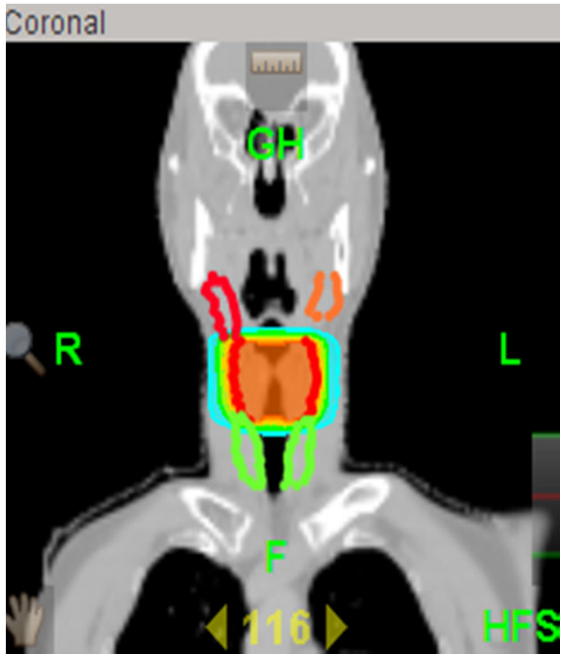
Volo Tomoterapi (Tomotherapy Inc., Madison, WI) TPS

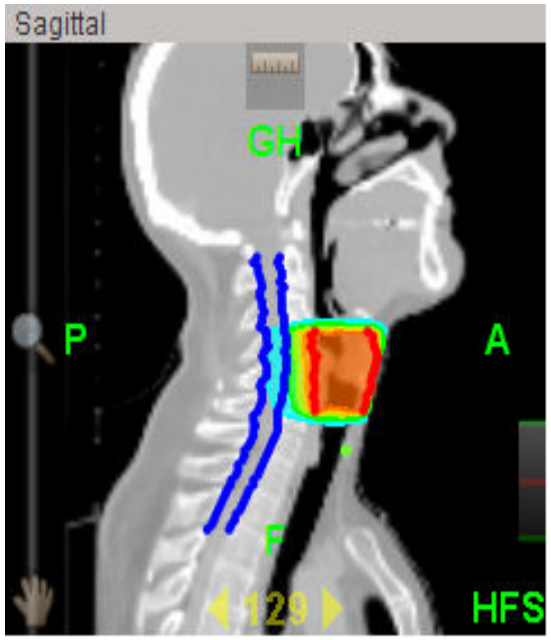
Head and neck thermoplastic mask

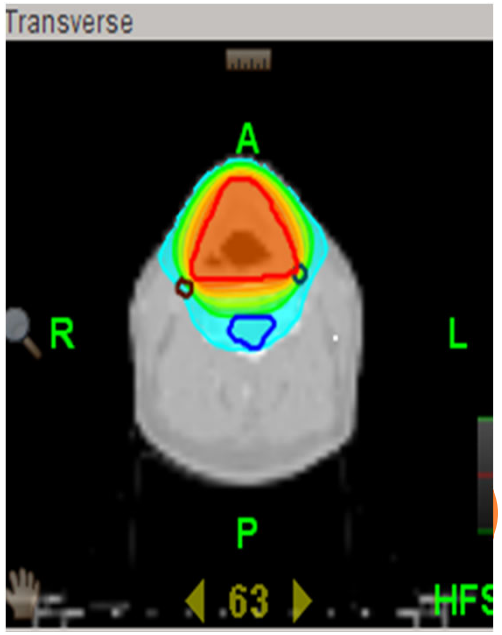


Fifteen unoperated, early-stage (T1N0M0) laryngeal cancer patients were included to the study. All organ at risk volumes and Planning target volume (PTV) were delineated by radiation oncologist according to RTOG reports and their clinical experiences.

Three different IMRT plans with the jaw width of 1, 2.5 and 5 cm were generated for each patient using inverse treatment method inTomotherpy Hi-Art Volo (Tomotherapy Inc., Madison, WI) treatment planning g system (TPS). Pitch and modulation factor were set to be 0.287 and 2 for all treatment plans, respectively. Prescribed dose to planning target volume (PTV) was 63 Gy in 28 fractions. Dose volume histograms were used to compare doses to OAR.







Dose Constrains

Dose constrains defined for organ at risk volumes based on the RTOG reports and some studies performed for larynx radiotherapy.

Carotid arteries	V35	< %25
	V50	< %4
	V63	< %1
Spinal Cord	Maksimum	< 45 Gy
Thyroid	mean	< 15 Gy
	V30	< %20
	V50	< %15
R/L Submandibular glands	mean	< 10 Gy

Inverse Planning

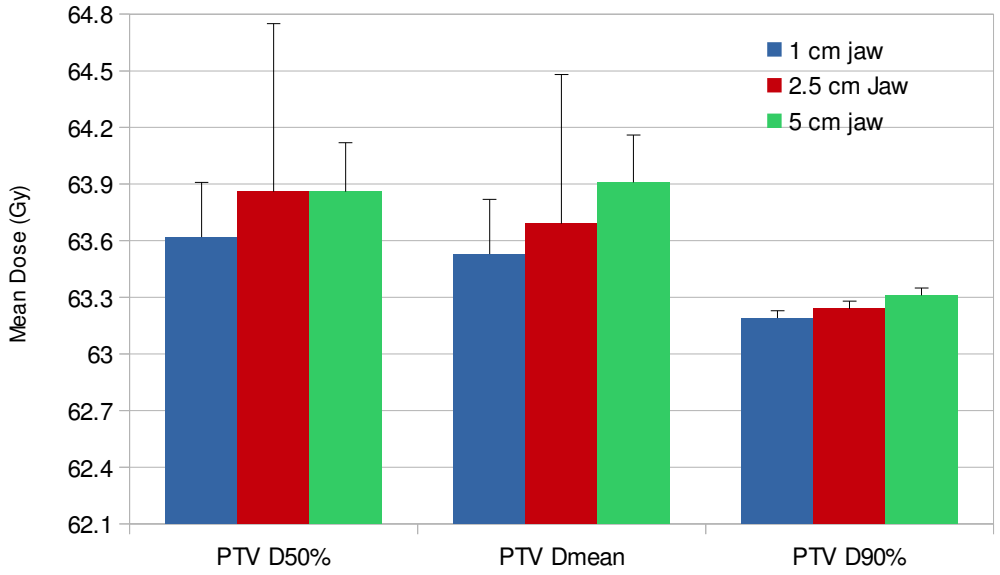
Target Constraints

Name	Display	Color		Blocked	Use	Importance	Max Dose [Gy]	Max Dose Pen.	DVH Vol	DVH Dose [Gy]	Min Dose [Gy]	Min Dose Pen.
PTV	☑		1	Unblocked	☑	200	63.00	7500	95.00	63.00	63.00	7000

Regions at Risk Constraints

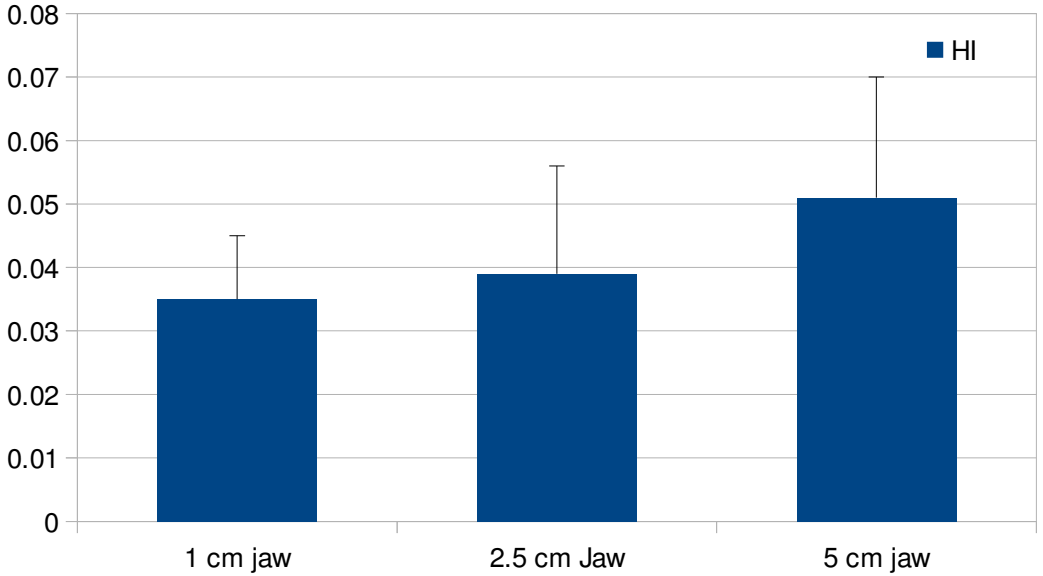
Name	Display	Color		Blocked	Use	Importance	Max Dose [Gy]	Max Dose Pen.	DVH Vol	DVH Dose [Gy]	DVH Pt. Pen.
Left carotid	☑		1	Unblocked	☑	11	63.00	1000	25.00	35.00	2000
Right carotid	☑		2	Unblocked	☑	9	63.00	1000	20.00	30.00	1000
Spinal cord	☑		3	Unblocked	☑	9	40.00	1500	1.00	1.00	1
Thyroid	☑		4	Unblocked	☑	5	63.00	550	1.00	1.00	1
Left submandibular	☑		5	Unblocked	☑	1	1.00	1	1.00	1.00	1
Right submandibul	☑		6	Unblocked	☑	1	1.00	1	1.00	1.00	1

Planning Target Volume



	PTV $D_{\%50}$ (Gy)			PTV Dmean (Gy)			PTV D%90 (Gy)		
	Jaw 1cm	Jaw 2,5cm	Jaw 5cm	Jaw 1cm	Jaw 2,5cm	Jaw 5cm	Jaw 1cm	Jaw 2,5cm	Jaw 5cm
Mean	63,62	63,86	63,86	63,53	63,69	63,91	63,19	63,24	63,31
Std. deviat	0,29	0,89	0,26	0,29	0,79	0,25	0,04	0,04	0,04
Median	63,58	63,70	63,89	63,63	63,68	63,94	63,19	63,25	63,32
Max	64,65	66,15	64,19	63,73	66,10	64,29	63,28	62,98	63,42
Min	63,39	62,60	63,21	62,53	62,65	63,27	63,11	61,77	63,20
p value		0,010			0,001			0,000	

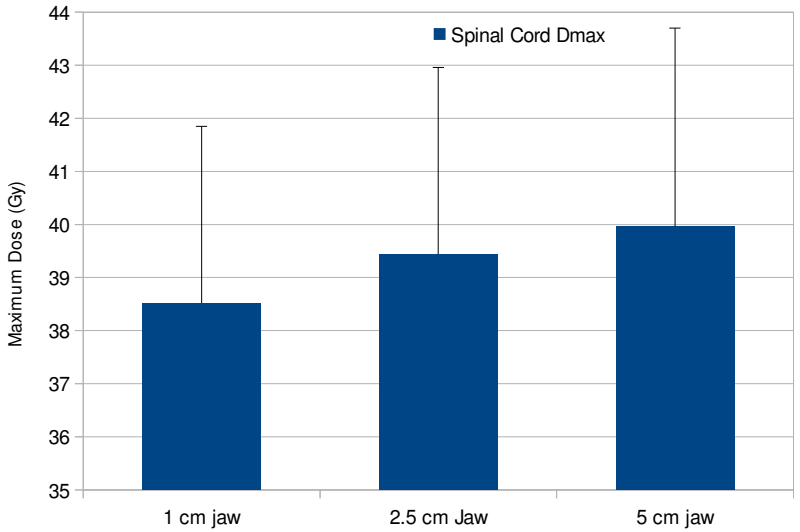
Homogeneity Index (HI)values



$$HI = \frac{D_{\%2} - D_{\%98}}{D_{\%50}}$$

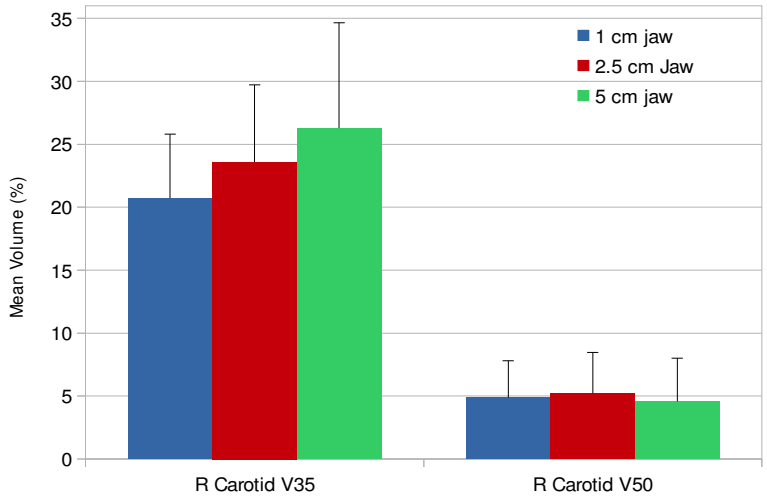
	HI		
	Jaw 1cm	**Jaw 2,5cm**	**Jaw 5cm**
Mean	0,035	0,039	0,051
Std. deviat.	0,010	0,017	0,019
Median	0,034	0,033	0,045
Max.	0,052	0,087	0,104
Min.	0,013	0,013	0,026
p value		0,045	

Spinal Cord

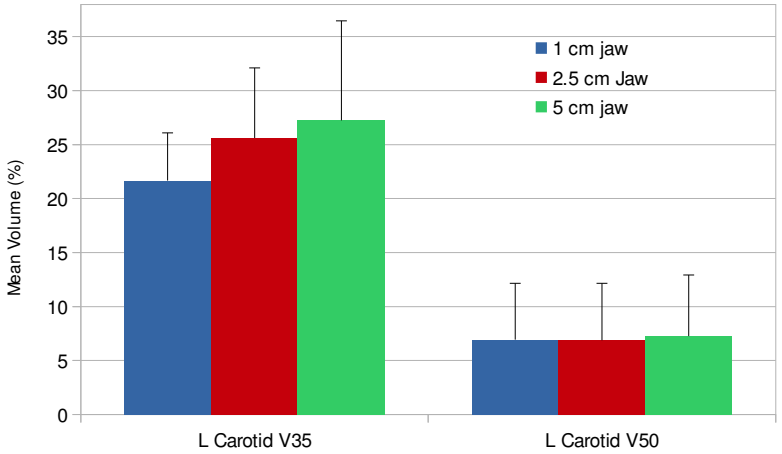


	Spinal cord Dmax(Gy)		
	Jaw 1cm	**Jaw 2,5cm**	**Jaw 5cm**
Mean	38,52	39,44	39,96
Std. deviat	3,33	3,52	3,74
Median	38,64	39,56	41,2
Max	43,53	43,88	44,54
Min	32,78	33,98	33,07
p value		0,408	

Carotid arteries

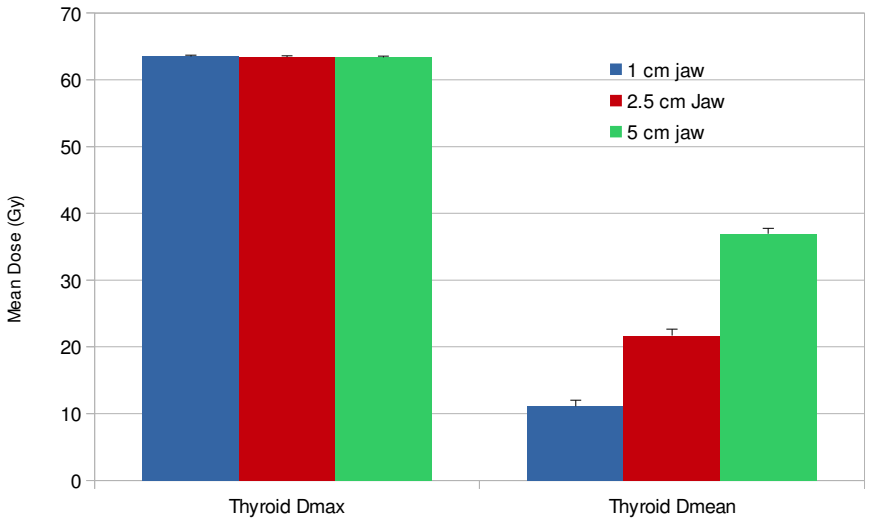


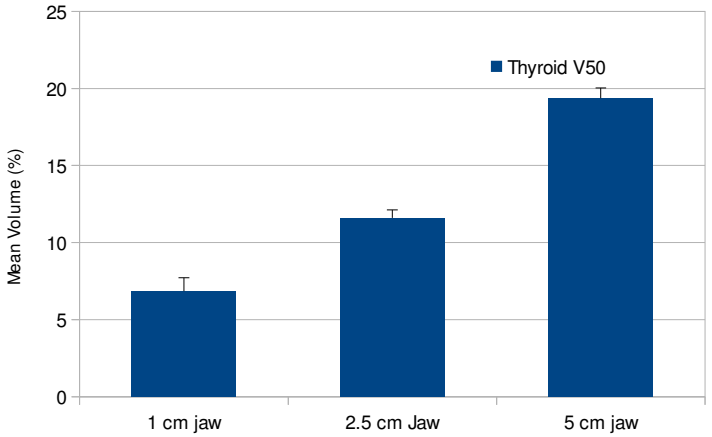
	V35 (% Volume)			V50 (% Volume)		
	Jaw 1cm	Jaw 2,5cm	Jaw 5cm	Jaw 1cm	Jaw 2,5cm	Jaw 5cm
Mean	20,72	23,60	26,29	4,87	5,21	4,56
Std. deviat	5,08	6,11	8,37	2,93	3,27	3,44
Median	19,95	20,87	25,46	5,43	5,29	3,91
Max	30,71	33,49	39,53	9,22	11,63	10,70
Min	15,00	16,19	17,25	0,59	0,95	0,00
p value		0,088			0,851	



	V35 (% Volume)			V50 (% Volume)		
	Jaw 1cm	Jaw 2,5cm	Jaw 5cm	Jaw 1cm	Jaw 2,5cm	Jaw 5cm
Mean	21,69	25,63	27,24	6,94	6,87	7,27
Std. deviat	4,40	6,48	9,23	5,21	5,28	5,66
Median	21,92	24,97	27,00	5,60	5,37	5,84
Max	29,16	38,76	45,00	18,35	16,62	19,20
Min	15,65	17,74	16,25	0,56	0,56	0,56
p value		0,190			0,910	

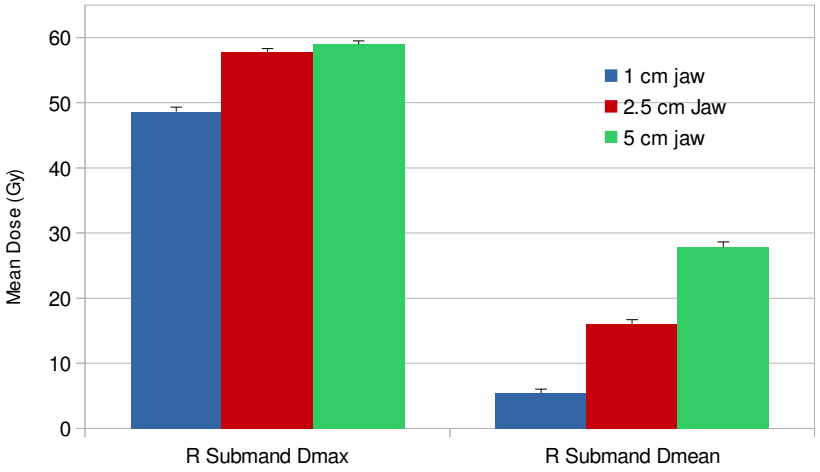
Thyroid

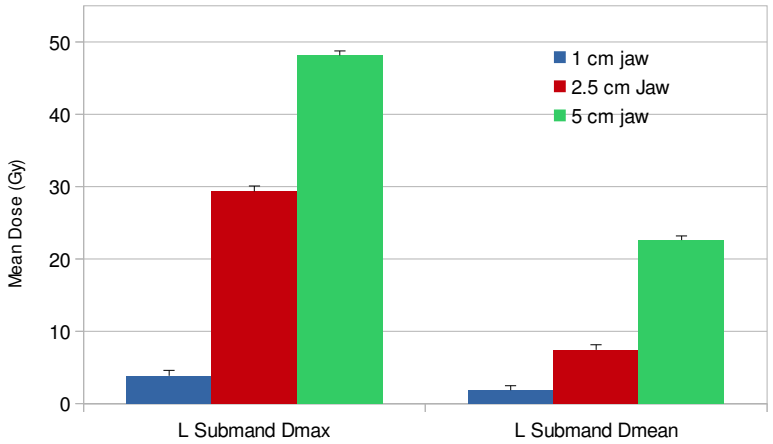




	Thyroid Dmax (Gy)			Thyroid Dmean (Gy)			Thyroid V50 (%)		
	Jaw 1cm	Jaw 2,5cm	Jaw 5cm	Jaw 1cm	Jaw 2,5cm	Jaw 5cm	Jaw 1cm	Jaw 2,5cm	Jaw 5cm
Mean	63,52	63,38	63,35	11.13	21,69	36,95	6,84	11,6	19,38
Std. deviat	0,17	0,23	0,19	0,89	0,98	0,80	0,87	0,52	0,66
Median	63,49	63,32	63,28	10,84	21,65	36,94	6,47	11,46	19,27
Max	64,65	66,15	64,19	63,73	66,	64,29	63,28	62,98	63,42
Min	63,21	63,11	63,14	5,33	20,02	35,69	5,33	10,84	18,33
p value		0,063			0,000			0,000	

Submandibular Glands





	R Submand Dmax (Gy)			S Man Dmean (Gy)		
	Jaw 1cm	Jaw 2,5cm	Jaw 5cm	Jaw 1cm	Jaw 2,5cm	Jaw 5cm
Mean	48,65	57,71	58,95	5,40	16,02	27,79
Std. deviat	0,69	0,61	0,56	0,62	0,67	0,82
Median	48,81	57,73	58,93	5,32	16,07	27,56
Max	49,75	58,99	59,66	7,02	17,26	29,84
Min	46,98	56,44	57,94	4,79	15,23	26,64
p value		<0,0001			<0,0001	

	LSubmand Dmax (Gy)			LSubmand Dmean (Gy)		
	Jaw 1cm	Jaw 2,5cm	Jaw 5cm	Jaw 1cm	Jaw 2,5cm	Jaw 5cm
Mean	3,87	29,34	48,13	1,85	7,45	22,63
Std. deviat	0,75	0,75	0,62	0,65	0,72	0,56
Median	3,55	29,22	48,15	2,02	7,26	22,55
Max	5,24	30,43	49,24	3,32	8,66	23,56
Min	2,98	28,28	46,98	1.05	6,42	21,88
p value		<0,0001			<0,0001	

Jaw width has not a significant effect to reduce the doses of OAR at close proximity to the PTV such as spinal cord and carotid arteries.

Doses of OAR located away from the PTV including tyroid and submandubular glands significantly decrease as jaw width decreases in larynx cancer treatment with tomotherapy..