

Comparison of Dose to Organs at Risk in Radiotherapy for Stomach MALT Lymphoma

: 3-Dimensional vs. Intensity-Modulation vs. MR Guidance

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Purpose

- To retrospectively analyze dosimetric parameters of volumetric-modulated arc therapy (VMAT) and 3Dconformal radiotherapy (3D-CRT) delivered to extranodal marginal zone B-cell lymphomas of mucosaassociated lymphoid tissue in the stomach (gastric MALT lymphoma)
- To find out advantages of VMAT and conditions for definite benefits of VMAT and to feasibility of MRguided approach.

Methods and Materials

- ✤ Inclusion criteria
 - ✓ Diagnosed as stage I/II gastric MALT lymphoma in 2005 2018
 - ✓ Available accessibility of radiotherapy information
- Number of patients: 50 (VMAT (n = 14), 3D-CRT (n = 36))

Categorization of geometric relationship of the PTV and kidney(s) according to (a) no overlap between PTV

Dose-volume parameters of OAR by radiotherapy technique and the status of PTV overlap with kidney(s)

	PTV overlap with kidney(s)	3D-CRT	VMAT	p ^{a)}
V ₁₅ (%) of the right kidney	Νο	4.42 ± 9.58 (n=17)	3.67 ± 5.52 (n=10)	0.728
	Yes	6.62 ± 8.84 (n=19)	4.11 ± 7.71 (n=4)	0.407
V ₁₅ (%) of the left kidney	No	6.68 ± 13.0 (n=17)	6.64 ± 11.7 (n=10)	0.306
	Yes	22.6 ± 15.1 (n=19)	6.95 ± 3.86 (n=4)	0.007
D _{mean} of the liver (Gy)	No	9.2 ± 2.0 (n=17)	7.9 ± 1.9 (n=10)	0.097
	Yes	11.6 ± 4.7 (n=19)	8.3 ± 1.1 (n=4)	0.089
D _{mean} of the duodenum (Gy)	No	13.1 ± 7.5 (n=17)	15.4 ± 5.9 (n=10)	0.246
	Yes	13.2 ± 8.4 (n=19)	17.2 ± 10.7 (n=4)	0.395

and kidney(s) (type I) and (b) overlap between PTV and kidney(s) (type II)



PTV, planning target volume; RK, right kidney; LK, left kidney.

Patient Characteristics

		All (%)	3D-CRT(%)	VMAT(%)	
		(n=50)	(n=36)	(n=14)	р
Gender	Male	21 (42.0)	18 (50.0)	3 (21.4)	D.066 ^{a)}
	Female	29 (58.0)	18 (50.0)	11 (78.6)	
Age (yr)	Median (range)	53 (25-80)	53 (25-80)	49 (47-69)).857 ^{b)}
	≥ 60	20 (40.0)	15 (41.7)	5 (35.7) (D.700 ^{a)}
	< 60	30 (60.0)	21 (58.3)	9 (64.3)	

Values are presented as mean \pm standard deviation.

3D-CRT, three-dimensional conformal radiotherapy; VMAT, volumetric modulated arc therapy; V15, percentage of irradiated volume receiving 15 Gy or higher. a)Mann Whitney U-test.

✤ V₁₅ of the kidney by the minimal distance between PTV and non-overlapped kidney(s)

V ₁₅ (%)	Minimal distance	3D-CRT	VMAT	p ^{a)}
Right kidney	≤ 2.0cm	6.98 ± 9.23 (n=22)	6.65 ± 6.57 (n=8)	0.739
	> 2.0cm	3.39 ± 8.85 (n=14)	0.00 ± 0.00 (n=6)	0.157
Left kidney	≤ 2.0cm	16.9 ± 16.2 (n=32)	7.43 ± 10.6 (n=12)	0.037
	> 2.0cm	0.75 ± 1.40 (n=4)	2.57 ± 0.00 (n=2)	0.340

Values are presented as mean ± standard deviation.

3D-CRT, three-dimensional conformal radiotherapy; VMAT, volumetric modulated arc therapy; V15, percentage of irradiated volume receiving 15 Gy or higher. a)Mann Whitney U-test.

Scatter plot of the kidney V15 by its minimal distance from the PTV in the right (a) and the left kidney (b)



H. Pylori	Positive	21 (42.0)	17 (47.2)	4 (28.6)	0.230 ^{a)}
	Negative	29 (58.0)	19 (52.8)	10 (71.4)	
Stage	IE	41 (82.0)	30 (83.3)	11 (78.6)	0.514 ^{a)}
	IIE	9 (18.0)	6 (16.7)	3 (21.4)	
PTV volume (cc)	Median (range)	575.1 (334.0-1362.0)	685.4 (334.0-1362.0)	492.9 (402.3-611.7)	0.010 ^{b)}
	≥ 600 cc	21 (42.0)	20 (55.6)	1 (7.1)	0.002 ^{a)}
	< 600 cc	29 (58.0)	16 (44.4)	13 (92.9)	
Mean PTV margir	n (cm)	1.06 ± 0.62	1.28 ± 0.60	0.50 ± 0.00	< 0.001 ^{b)}
PTV overlap with	kidney(s)				
	No (type I)	27 (54.0)	17 (47.2)	10 (71.4)	0.123 ^{a)}
	Yes (type II)	23 (46.0)	19 (52.8)	4 (28.6)	

4-----5.0 0.0 0.0 6.00 8.00 0.00 0.50 1.00 Minimal distance (cm *Pearson's correlation coefficient

Dose-volume parameters of kidneys - VMAT plan versus iPRV-corrected VMAT plan

	Parameter	VMAT	iPRV-corrected VMAT	p ^{a)}
Right Kidney	Volume (mL)	128.3 ± 16.7	162.2 ± 13.1	0.001
	D _{mean} (Gy)	4.7 ± 2.3	4.6 ± 2.3	0.893
	V ₁₅ (%)	3.8 ± 5.9	3.8 ± 5.7	0.634
Left Kidney	Volume (mL)	135.4 ± 19.2	177.2 ± 30.7	< 0.001
	D _{mean} (Gy)	4.8 ± 3.2	4.7 ± 3.2	0.888
	V ₁₅ (%)	6.7 ± 9.9	5.8 ± 7.3	0.682

3D-CRT, three-dimensional conformal radiotherapy; VMAT, volumetric modulated arc therapy; HP, Helicobacter pylori; PTV, planning target volume. a)Fisher's exact test; b)Student's t-test.

Results

Dose-volume parameters of PTV and organs at risk (OARs) by 3D-CRT or VMAT plan

		3D-CRT	VMAT	a)	
Parameters		(n=36)	(n=14)	p",	
PTV	D _{max} (Gy)	32.7 ± 0.5	33.4 ± 0.3	< 0.005	
	D _{mean} (Gy)	30.6 ± 4.3	31.5 ± 0.1	0.444	
	V ₉₈ (%)	97.0 ± 3.8	99.7 ± 0.5	0.010	
	Conformity Index (CI)	0.970 ± 0.038	0.997 ± 0.005	0.010	
	Homogeneity Index (HI)	0.056 ± 0.011	0.042 ± 0.009	< 0.001	
Right Kidney	D _{mean} (Gy)	3.1 ± 2.7	4.7 ± 2.3	0.096	
	V ₁₅ (%)	5.6 ± 9.1	3.8 ± 5.9	0.473	
Left Kidney	D _{mean} (Gy)	5.7 ± 4.3	4.8 ± 3.2	0.372	
	V ₁₅ (%)	15.1 ± 16.1	6.7 ± 9.9	0.065	
Liver	D _{mean} (Gy)	10.5 ± 3.8	8.0 ± 1.7	0.026	
	V ₁₅ (%)	28.3 ± 16.4	16.3 ± 3.4	0.008	
Duodenum	D _{mean} (Gy)	13.1 ± 7.8	15.9 ± 6.9	0.259	
	V ₁₅ (%)	39.9 ± 28.3	48.6 ± 24.6	0.201	

Values are presented as mean ± standard deviation.

VMAT, volumetric modulated arc therapy; iPRV, integrated planning organ at risk volume; Dmean, mean dose; V15, percentage of irradiated volume receiving 15 Gy or higher.

a)Student's t-test.

Differences in treatment time and Monitor Unit by radiotherapy technique

	3D-CRT VMAT		a)
	(n=36)	(n=14)	p",
Treatment time (min) ^{b)}	5.6 ± 1.1	1.6 ± 0.6	< 0.001
Monitor unit	235.6 ± 20.5	366.6 ± 23.6	< 0.001

Values are presented as mean ± standard deviation.

3D-CRT, 3D-conformal radiotherapy; VMAT, volumetric modulated arc therapy

a) Student's t-test

b) From beam-on to beam-off, not including time consumed for set-up or immobilization.

Values are presented as mean \pm standard deviation.

3D-CRT, three-dimensional conformal radiotherapy; VMAT, volumetric modulated arc therapy; PTV, Planning Target volume; Dmax, maximum dose; Dmean, mean dose adjusted to the total dose of 30.6Gy; V98, percentage of the PTV receiving 98% of the prescription dose; V15, percentage of irradiated volume receiving 15 Gy or higher. a)Student's t-test.

Discrepancies of target volume in MR guidance radiotherapy



Conclusions

- VMAT significantly increased Monitor Units, reduced treatment time and radiation dose to the liver and kidneys.
- The benefit of VMAT was definite in reducing the left kidney V15, especially in geometrically challenging conditions of overlap or close separation between the planning target volume (PTV) and kidney(s).
- Algorithm for MR-guidance needs to be further improved.