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ORIGINAL ARTICLE

Dosimetric Comparison of Volumetric Arc Therapy Methods for Stereotactic Body Radiotherapy in Liver Metastasis

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OBJECTIVE

Volumetric arc therapy (VMAT) is advantageous for stereotactic body radiotherapy (SBRT) delivery; however, it is still unknown which rotational method is optimal for the treatment of liver metastases. This study aims to compare the dosimetric data of SBRT plans with VMAT techniques and helical tomotherapy (HT) in 18 liver metastasis patients.

METHODS

Three plans were generated: $VMAT_M$ was generated with Monaco Treatment Planning System (TPS), $VMAT_E$ with an Eclipse TPS, and HT plans were generated using a Hi-Art Tomotherapy system. The prescribed dose was 54 Gy delivered in three fractions. The planning target volume (PTV) doses and organs at risk (OAR) doses were compared between three plans.

RESULTS

All plans met the criteria for PTV coverage. Maximum PTV doses were significantly higher in $VMAT_M$ plan, and minimum PTV doses were significantly lower in $VMAT_E$ plan. The dose conformity and homogeneity indices of PTV were better in $VMAT_E$ plan. Only mean bowel maximum dose was significantly higher in HT plan compared to $VMAT_M$ plan only. The liver D_{mean} were significantly higher in PTV larger than 50 cm^3. Liver D_{mean} in PTV >50 cm^3 was significantly less in $VMAT_M$ plan compared to HT (p=0.04) and $VMAT_E$ plans (p=0.04).

CONCLUSION

All three plans met the criteria for PTV coverage with no significant difference in OARs doses. $VMAT_E$ plan yielded better homogeneity and conformity in PTV compared to $VMAT_M$ and HT, and healthy liver tissue was better spared especially in larger tumors (>50 cm^3) with $VMAT_E$ plans.

Keywords: Helical tomotherapy; liver metastasis; stereotactic body radiotherapy; volumetric arc therapy.

INTRODUCTION

The liver is the second most common site for the metastatic spread of cancer, mostly originating from colorectal, pancreas, and breast cancers.[1,2] Surgical resection is first treatment of choice for local treatment of liver metastasis (LM).[3,4] However, only few patients are amenable to surgical resection because of tumor size, location, and close proximity to major intrahepatic vascular structures.[5,6] Although the treatment option for LM has been considered palliative previously, different local treatment modalities, includ-

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ing surgery, transcatheter arterial chemoembolization (TACE), radiofrequency ablation, and radiotherapy (RT) have been applied in selected patients.[7,8] These local treatments could be applied alone or as an adjunct to systemic chemotherapeutic agents to improve outcomes.[7,9,10]

Over the past two decades, the role of RT in the management of LM has evolving with the increase in RT delivery techniques. Stereotactic body RT (SBRT), also known by stereotactic ablative body radiation, is a high precision RT technique that allows higher radiation doses to the target with a steep dose gradient. In other words, higher radiation doses could be delivered safely to the liver without causing functional compromise with new RT technics.[11] There are strong evidences that SBRT could be an effective treatment option for patients with LM that are unresectable or not amenable to RFA or TACE.[12,13] The local control rate is satisfactory with reports of being 90% or higher in selected patients, and with acceptable toxicity rates.[12,14]

Various technics have been used for hepatic SBRT, and the planning modalities for each RT technic may vary. Furthermore, the precise doses to the target volumes and dose constraints for both liver and organs at risk (OARs) have not yet been standardized. Although it has been previously demonstrated that volumetric arc therapy (VMAT) is advantageous for SBRT delivery in various cancer types,[15-17] it remains to be determined which rotational volumetric IMRT is advantageous for LM treatment.

We aim to compare VMAT to HT, both rotational techniques with different forms of implementation and requiring dedicated helical tomotherapy (HT) versus general purpose (VMAT) machines. The dosimetric data for target volumes and OARs were assessed; also target volume homogeneity and conformity were analyzed.

MATERIALS AND METHODS

Patients

We analyzed the dosimetric data of 18 consecutive patients with LM that are unresectable and not amenable for other local treatment modalities, and have been previously treated with liver SBRT at our department. Patient selection criteria included: ≤3 LM, maximum tumor diameter <6 cm, Karnofsky Performance Status ≥70, normal coagulation function, Child Pugh Status A-B, controlled primary disease, and life expectancy more than 3 months.

Simulation, Delineation, and Image Registration

Patients underwent 1.25 mm multi-slice contrast enhanced planning computed tomography (CT) from tracheal bifurcation to the lower border of the kidneys for simulation (Optima 580, (GE Healthcare, Waukesha, WI, USA). Patients were positioned supine with arms above the head and immobilized using a Body-FIX® bluebag with vacuum wrap (Elekta, Stockholm, Sweden). An abdominal compress was also used to minimize the target volume motion.

Magnetic resonance imaging and 18-Fluorodeoxyglucose positron emission tomography CT were fused with planning CTs to help clinicians localize the target volume precisely, where appropriate. Gross tumor volume (GTV) included the visible tumor in imaging; however, no clinical tumor volume was defined. Planning tumor volume (PTV) was expanded with a 7 mm in all directions except for 12 mm craniocaudal margin.[12,18,19] No fiducial markers were implanted before treatment planning.

Treatment Planning

Three different plans were generated with same CT images including the same GTV, PTV, and OARS. The prescribed dose was 54 Gy delivered in three fractions, and the dose was prescribed to 90% isodose line. Treatment was delivered every other day. First VMAT plan ($VMAT_M$) was calculated with the Monaco Treatment Planning System (TPS) version 5.10 (Elekta Ltd, Crawley, UK) using the Monte Carlo photon algorithm and a sliding window multileaf collimator (MLC) delivery technique. All treatment plans were performed for delivery with an Axesse® linear accelerator (Elekta AB, Stockholm, Sweden). VMAT plans consisted of double or triple 358° arcs.

Second VMAT plan ($VMAT_E$) was generated with an Eclipse version 13.7 (Varian Medical Systems, Palo Alto, CA, USA) with using Acuros algorithm with 6MV energy (MLC; Varian RapidArc, Varian Medical Systems, Palo Alto, California, USA). Similar to $VMAT_M$ plan, $VMAT_E$ plans also consisted of double or triple arcs that included 179° as the starting angle, and 359° as the end angle. All VMAT plans were generated in the same manner, including same arc numbers and angles to provide adequate target coverage and dose constraints.

The HT plans were generated using a Hi-Art Tomotherapy system (TomoTherapy Inc., Madison, WI, USA), a helical fan-beam IMRT using 6-MV photon with inverse planning software. The HT plans were made for the TomoEdge™ Dynamic Jaws system of the TomoHDA™ series. A collimator aperture of 2.5 cm, pitch of

Table 1 Dose volume histogram parameters for planning target volume according to radiotherapy techniques

Parameters	$VMAT_M$ (Mean±SD)	HT (Mean±SD)	$VMAT_E$ (Mean±SD)	p ($VMAT_M$ vs. HT)	p ($VMAT_M$ vs. $VMAT_E$)	p (HT vs. $VMAT_E$)
D_{mean} (Gy)	55.8±0.6	54.7±0.2	53.6±0.8	<0.001	<0.001	<0.001
$D_{2\%}$ (Gy)	56.9±1.0	55.3±0.3	55.2±1.2	<0.001	<0.001	0.5
$D_{98\%}$ (Gy)	54.2±0.7	54.0±0.2	52.5±0.5	0.2	<0.001	<0.001
$D_{90\%}$ (Gy)	54.8±0.6	54.3±0.2	52.3±2.3	<0.001	<0.001	<0.001
CI	0.65±0.08	0.66±0.09	0.66±0.08	0.02	0.003	0.001
HI	1.05±0.02	1.03±0.01	1.01±0.01	<0.001	<0.001	<0.001

VMAT: Volumetric arc therapy; $VMAT_M$: VMAT with Monaco treatment planning system; $VMAT_E$: VMAT with Eclipse treatment planning system; HT: Helical tomotherapy; SD: standard deviation; CI: conformity index; HI: homogeneity index; Gy: Gray

0.287, and modulation factor of 2.5 were used, which has been previously defined.[20,21] Dose calculations were performed using the fine-dose calculation grid (1 mm in the craniocaudal direction over a 256×256 matrix in the axial plane from the original CT scan).

Dose Constraints

The OARs, including kidneys, liver, bowel, and spinal cord, were contoured by the same physician. The dose volume histograms generated from three different TPSs were analyzed, and comparison was made between plans. We adopted the constraint that at least 700 cm^3 of healthy liver (entire liver volume minus cumulative GTV) should receive <15 Gy in three fractions. Other dose constraints of OARs included: total kidney volumes V35 <15 Gy (volume receiving 15Gy should be less than 35%), maximum dose ($D1cm^3$) of spinal cord <18 Gy, D1cc for duodenum <21 Gy, $D1cm^3$ for small bowel <21 Gy, $D1cm^3$ for esophagus< 21 Gy, $D1cm^3$ for stomach <21 Gy, $D1cm^3$ for heart <30 Gy, and D30 cm^3 for the ribs <30 Gy.

Plan Evaluation

For all patients, cumulative dose-volume histograms and dosimetric parameters were calculated and compared for the PTV and OARs. Target volume coverage was compared in terms of the minimal (D_{min}), maximal (D_{max}), and mean doses (D_{mean}). D_{xx} was defined as the minimum dose in the most irradiated XX cm^3 tissue volume. D_2 and D_{98}, the minimal doses to 2% and 98% of the target volume, respectively, were used as surrogates for the maximum and minimum doses. Target homogeneity and conformity indices (HI and CI, respectively) were compared. The HI was calculated as $HI=([D_2-D_{98}]/D_{50})$, where a greater HI value indicated poorer uniformity of dose distribution.[22] The CI was calculated as $V_{T,ref}/V_T \times V_{T,ref}/V_{ref}$, where $V_{T,ref}$ was the volume of the target covered by the reference isodose line, V_T was PTV, and V_{ref} was the volume of tissue covered by the reference isodose line. The reference isodose was selected as 95% of the prescribed dose. The value of CI varied between 0 and 1, with a value closer to 1 indicating better conformity of the dose to PTV.[23]

Statistical Analysis

Statistical analysis was performed using SPSS software v. 21.0 (SPSS Inc., Chicago, IL). The Wilcoxon's matched-pairs test was used to determine statistical differences between volumes and doses in $VMAT_M$, $VMAT_E$, and HT plans. The dose-volume parameters of PTV and OARs for each planning system were measured and compared to each other. The mean liver doses (D_{mean}) and doses of 700 cc healthy liver (D_{700cc}) according to PTV subgroups (<50 cm^3 vs. >50 cm^3) was compared according plans. The Mann-Whitney U-test was used to compare volumes or dose values in independent patient groups. All p-values reported were two-sided, and $p<0.05$ was considered significant.

RESULTS

Target Volume Doses

The mean GTV and PTV volumes were 11.1 cm^3 (range, 0.7-55.2 cm^3) and 52.8 cm^3 (range, 13.4-164.0 cm^3), respectively. The dosimetric parameters for target volumes are summarized in Table 1. All plans met the criteria for PTV coverage (Fig. 1). The average maximum doses for PTV were significantly higher in $VMAT_M$ plans (56.9±1.0 Gy) compared to HT (55.3±0.3 Gy; $p<0.001$) and $VMAT_E$ plans (55.2±1.2 Gy; $p<0.001$); however, there was no significant difference between $VMAT_E$ and HT plans ($p=0.51$). Minimum doses were significantly lower in $VMAT_E$ plan

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Table 2 The dosimetric parameters of organs at risk for three different radiotherapy plans

Parameters	$VMAT_M$ (Mean±SD)	HT (Mean±SD)	$VMAT_E$ (Mean±SD)	p ($VMAT_M$ vs. HT)	p ($VMAT_M$ vs. $VMAT_E$)	p (HT vs. $VMAT_E$)
Kidney						
Mean (Gy)	1.58±1.16	2.13±1.57	1.73±1.11	0.2	0.2	0.6
$V_{20\%}$	1.03±1.24	1.87±1.46	1.60±1.19	0.2	0.6	0.3
$V_{30\%}$	0.66±1.15	1.11±1.24	0.80±1.16	0.3	0.6	0.2
Bowel						
Max dose (Gy)	1.21±1.06	2.00±1.65	1.53±1.36	0.03	0.4	0.2
Spinal cord						
Max dose (Gy)	8.77±5.01	10.20±4.42	9.40±4.65	0.1	0.5	0.4
$D_{1\%}$ (Gy)	8.13±4.69	9.65±4.28	8.61±4.26	0.08	0.6	0.3

VMAT: Volumetric arc therapy; HT: Helical tomotherapy; $VMAT_M$: VMAT with Monaco treatment planning system; $VMAT_E$: VMAT with Eclipse treatment planning system; SD: standard deviation; Gy: Gray

Table 3 The dosimetric parameters for liver volumes for three different radiotherapy plans

Parameters	$VMAT_M$ (Mean±SD)	HT (Mean±SD)	$VMAT_E$ (Mean±SD)	p ($VMAT_M$ vs. HT)	p ($VMAT_M$ vs. $VMAT_E$)	p (HT vs. $VMAT_E$)
Mean dose (Gy)	9.0±2.8	9.3±3.1	9.0±3.2	0.21	0.12	0.91
Maximum dose (Gy)	57.4±1.7	55.7±0.4	54.5±0.3	<0.001	<0.001	<0.001
V_{10}	28.5±9.8	31.9±11.5	37.0±15.6	0.005	<0.001	0.03
V_{20}	14.7±8.4	15.7±10.3	19.8±11.8	0.29	<0.001	<0.001
V_{30}	7.3±4.2	7.5±4.6	11.5±8.1	0.41	0.001	0.001
V_{40}	4.7±3.0	4.8±3.2	5.8±1.3	0.76	0.002	0.004

VMAT: volumetric arc therapy; $VMAT_M$: VMAT with Monaco treatment planning system; $VMAT_E$: VMAT with Eclipse treatment planning system; HT: helical tomotherapy; SD: standard deviation; Gy: Gray

compared to $VMAT_M$ plan (p<0.001) and HT plan (p<0.001), however no significant difference in minimum doses between $VMAT_E$ and HT plans. Mean PTV doses were significantly higher in $VMAT_M$ compared to other plans.

The HI was significantly higher in $VMAT_M$ plan (1.05±0.02) compared to HT plan (1.03±0.01; p<0.001) and $VMAT_E$ (1.01±0.01; p<0.001) plans, similarly the HI was significantly higher in HT plan compared to $VMAT_E$ plan (p<0.001). $VMAT_E$ plans achieved superior CI compared to $VMAT_M$ plan (p=0.003) and HT (p=0.001) plans. The mean monitor units (MU) in $VMAT_E$ plan were significantly higher than those measured in $VMAT_M$ plan (5145±391 vs. 3874±1421; p=0.02).

OAR Doses

A comparison of the dosimetric parameters of OARs for each of the plan types is listed in Table 2. The D_{mean}, V20 and V30 of both kidneys did not differ significantly for $VMAT_M$, HT, and $VMAT_E$ plans. Maximum bowel dose was significantly higher in HT plan compared to $VMAT_M$ plan only (2.00±1.65 Gy vs. 1.21±1.06 Gy; p=0.03), but there was no significant difference in bowel doses between $VMAT_M$ and $VMAT_E$ plans, and HT and $VMAT_E$ plans. Spinal cord mean maximum doses did not differ significantly between techniques.

Liver Dosimetry

The dosimetric parameters for liver volumes are summarized in Table 3. Although liver D_{mean} doses did not differ significantly between VMAT plans and HT plan (Fig. 2a), maximum doses were significantly higher in $VMAT_M$ plan (57.4±1.7 Gy) compared to HT plan (55.7±0.4 Gy; p<0.001) and $VMAT_E$ plan (54.5±0.3 Gy; p<0.001). The mean liver D_{700cc} for $VMAT_1$, HT, and VMAT plans was 5.6±4.0 Gy, 6.5±4.6 Gy and 6.5±4.9 Gy, respectively, and no significant difference was observed between plans (Fig. 1b). The liver doses from V10-V40 were significantly higher in $VMAT_E$ plan compared to $VMAT_M$ and HT plans (Fig. 3). The liver

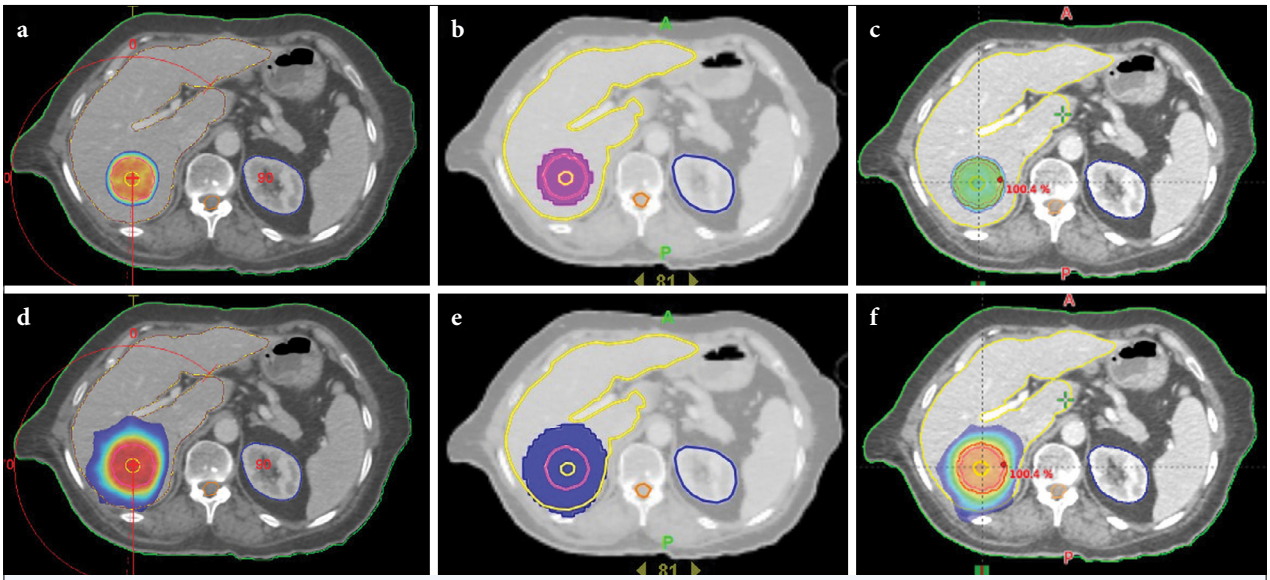

Fig. 1. Representative axial computed tomography slices showing 90% of prescribed dose distributions for (a) $VMAT_M$, (b) HT, and (c) $VMAT_E$ plans, and 50% of prescribed dose distributions for (d) $VMAT_M$, (e) HT, and (f) $VMAT_E$ plans.
VMAT: Volumetric arc therapy; $VMAT_M$: VMAT with Monaco treatment planning system; $VMAT_E$: VMAT with Eclipse treatment planning system; HT: Helical tomotherapy.

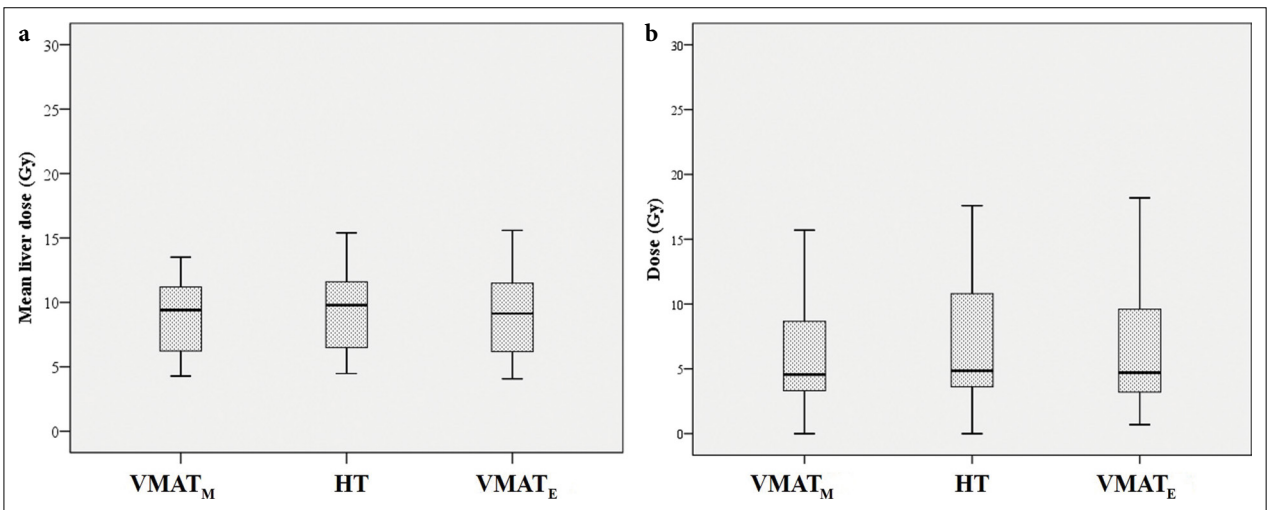

Fig. 2. Box plot graph demonstrating (a) mean liver doses and (b) mean doses of 700 cm^3 of healthy liver for VMAT and HT plans.
VMAT: Volumetric arc therapy; HT: Helical tomotherapy; $VMAT_M$: VMAT with Monaco treatment planning system; $VMAT_E$: VMAT with Eclipse treatment planning system; Gy: Gray.

dose volume parameters of $VMAT_M$ and HT plans were similar except for V10 values, which significantly lower in $VMAT_M$ plan.

The liver D_{mean} according to tumor volume is presented in Figure 4a. The D_{mean} of liver was significantly higher in PTV larger than 50 cm^3 compared to PTV <50 cm^3 in $VMAT_M$ plan (11.54±1.49 Gy vs. 7.42±2.27 Gy; p<0.001), $VMAT_E$ plan (12.18±1.90 Gy vs. 7.51±2.25 Gy; p<0.001), and HT plan 12.03±2.01 vs. 7.11±2.19 Gy; p<0.001) (Fig. 5a). Liver D_{mean} in PTV >50 cm^3 was significantly less in $VMAT_M$ plan compared to HT (p=0.04) and $VMAT_E$ plans (p=0.04).

There were no significant difference in mean liver D_{700cc} between PTV <50 cm^3 and PTV >50 cm^3 in $VMAT_M$ (4.52±2.63 Gy vs. 7.41±5.24 Gy; p=0.21) and HT plans (5.59±3.49 Gy vs. 7.93±5.95 Gy; p=0.37) (Fig.

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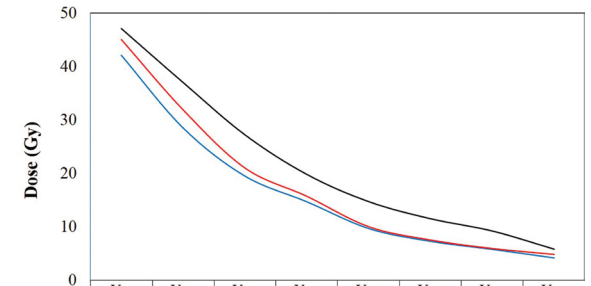

	V_5	V_{10}	V_{15}	V_{20}	V_{25}	V_{30}	V_{35}	V_{40}
$VMAT_M$	42.10	28.5	19.5	14.7	9.7	7.3	5.8	4.2
HT	45.1	31.9	21	15.7	10	7.5	5.9	4.8
$VMAT_E$	47.1	37	27.2	19.8	14.7	11.5	9.2	5.8

Fig. 3. The mean dosimetric indices for the healthy liver volume receiving 10-40 Gy with the three techniques.
VMAT: Volumetric arc therapy; $VMAT_M$: VMAT with Monaco treatment planning system; $VMAT_E$: VMAT with Eclipse treatment planning system; HT: Helical tomotherapy; Gy: Gray.

5b). However, mean liver D_{700cc} was significantly higher in larger PTV compared to small PTV in $VMAT_E$ plan only (9.64±5.89 Gy vs. 4.51±2.93 Gy; p=0.03). The liver D_{700cc} was significantly higher in PTV >50 cm^3 with $VMAT_E$ plan compared to HT plan (p=0.001) and $VMAT_M$ plan (p=0.03).

DISCUSSION

To the best of our knowledge, our study was the first dosimetric study comparing two modern VMAT techniques and HT for patients with LM. Although all three SBRT plans met the criteria for PTV coverage, $VMAT_E$ plan yielded better HI and CI compared to other plans. There was no significant difference in terms of kidney, bowel, and spinal cord doses. Mean liver doses were not significantly different in the plans; however, liver doses from V10 to V40 were significantly higher in $VMAT_M$ plan compared to $VMAT_E$ and HT plans. We also found that $VMAT_M$ plan better spared liver in larger tumors compared to small tumors, and the liver doses increased with the increasing tumor size in $VMAT_E$ plan.

The SBRT is gaining importance as a non-invasive and effective treatment method for patients with LM. Although surgery still remains the treatment of choice in LM, most patients cannot undergo surgery because of comorbidity, poor performance status, or tumor related factors such as size, location, and relationship with vascular structures.[5,6] SBRT offers non-invasive, effective, and safe local treatment in patients with LM. The feasibility of SBRT for LM was demonstrated by numerous studies with 1-and 2-year local control rates ranging from 70% to 100% and 60% to 90%, respectively.[9] Toxicity profile of SBRT compared to other invasive/minimally invasive local therapies is quite better. The reported Grade III or higher toxicity rates were 1-10%, and the incidence of radiation induced liver disease (RILD) ranged between 1% and 5%.[12,14,19]

The feasibility and efficiency of VMAT in SBRT for liver tumors were shown in various dosimetric and clinical studies.[16,19,24] Recently, Qui et al.[24] demonstrated an acceptable target volume coverage with VMAT technique in nine patients with liver tumors. The authors pointed that out that the main advantages of VMAT plans were substantial decrease in beam on time and lower MU. Thomas et al.[25] demonstrated

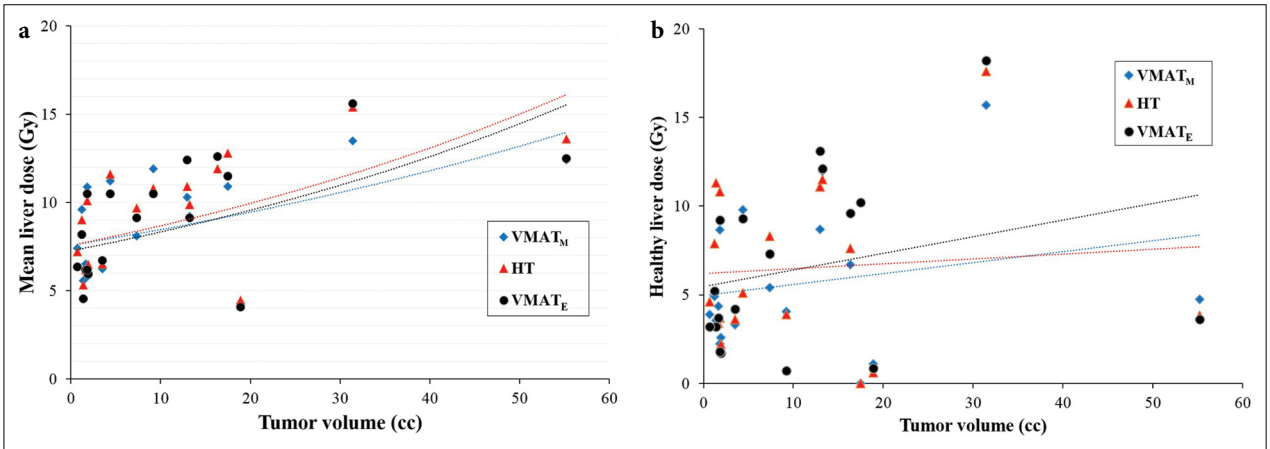

Fig. 4. (a) Mean liver doses and (b) mean doses of 700 cm^3 of healthy liver according to tumor volume in three techniques.
VMAT: Volumetric arc therapy; $VMAT_M$: VMAT with Monaco treatment planning system; $VMAT_E$: VMAT with Eclipse treatment planning system; HT: Helical tomotherapy; Gy: Gray.

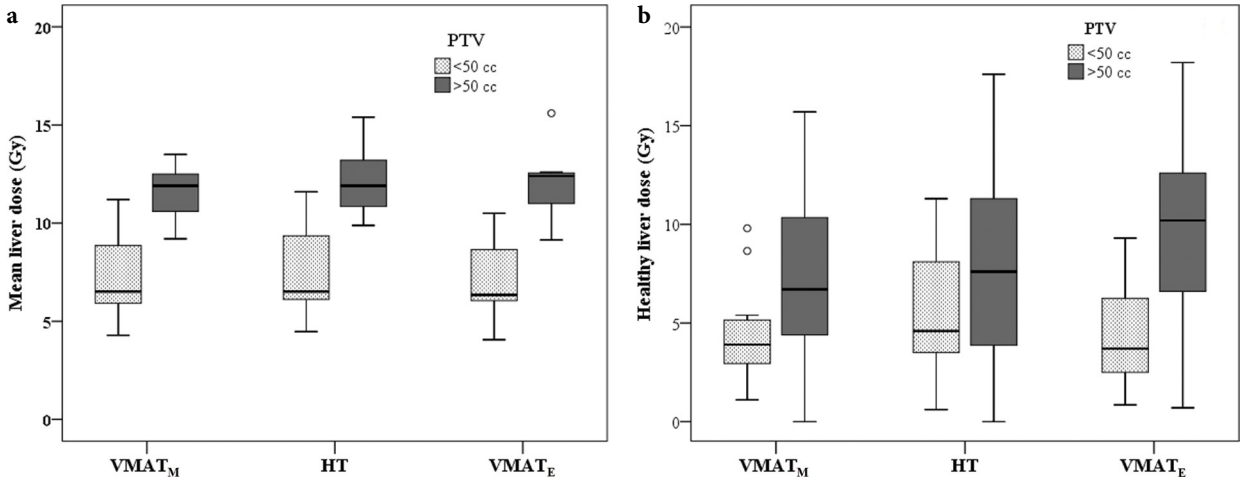

Fig. 5. Box-plot graphs demonstrating the (a) mean liver doses and (b) mean doses of 700 cm³ of healthy liver according to planning tumor volume <50 cc and >50 cc.
PTV: Planning target volume; VMAT: Volumetric arc therapy; VMAT$_M$: VMAT with Monaco treatment planning system; VMAT$_E$: VMAT with Eclipse treatment planning system; HT: Helical tomotherapy; Gy: Gray.

that inversely optimized IMRT plans were dosimetrically superior to conventional IMRT plans with shorter delivery times. Paik et al.[16] analyzed the dosimetric comparison of VMAT and robotic radiosurgery in 29 liver tumors. They reported better conformity in robotic radiosurgery plans while VMAT plans had also good dosimetric distribution, better sparing healthy liver, and shorter beam on time. Our study supported the feasibility of VMAT plans in liver SBRT with acceptable OARs doses and good homogeneity even in large tumors.

HT based SBRT was investigated by Baisden et al.[26] in a phase I study. They hypothesized that the maximum tolerable dose delivered to a lesion by HT based SBRT could be predicted based on the PTV and liver volume. The authors found that HT was capable of performing SBRT for liver lesions with adequate target dose while sparing normal tissues. Furthermore, Engels et al.[15] conducted a phase II study of HT in the multidisciplinary treatment of oligometastatic colorectal cancer. They treated a total of 53 metastasis of lung, liver, and lymph nodes. They reported the actuarial 1-year local control, progression-free survival, and overall survival were 54%, 14%, and 78%, respectively, with only 4% Grade III toxicity. Lee et al.[27] analyzed SBRT with HT for patients with hepatic oligometastasis. 54 hepatic lesions were treated, and 1-and 2-year local control rates were 59.9 and 49.0%, respectively, without any Grade 3 or higher toxicity. Our dosimetric study also supported that HT was a feasible technique for liver SBRT compared to with modern VMAT techniques.

Historically, the most common toxicity with liver SBRT had been reported as RILD. In most of the recent studies, the rates of RILD were reported <1%. [28] The generally-accepted dose constraint for the healthy liver was 700 cm³ <15 Gy, for minimizing the risk of RILD.[17,29] Although, in the current study, the dose constraints for both OARs and healthy liver were acquired, our dosimetric analysis indicated that liver doses increased with the increased tumor size in VMAT$_E$ plan. However, VMAT$_M$ was advantageous in achieving lower liver mean doses and better sparing healthy liver in larger tumors.

Our study had certain limitations. First, due to its retrospective nature, we only compared the dosimetric parameters of two different VMAT techniques and HT in the management of LM in a limited cohort of patients. Second, considering the fact that a comparison of dosimetric parameters does not indicate a comparison of clinical effectiveness, our results should be interpreted carefully in the absence of clinical studies. Finally, long follow-up periods are essential for better analyzing the tolerance and/or toxicity profile of OARs. Nevertheless, this study is important as it is the first dosimetric study comparing two modern VMAT techniques and HT technique in the treatment planning for LM.

CONCLUSION

Through the dosimetric comparison of SBRT plans with two modern VMAT techniques and HT tech-

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nique for LM, we found that all three SBRT plans met the criteria for PTV coverage with no significant difference in terms of OARs doses including mean liver doses. $VMAT_E$ plan yielded better HI and CI compared to $VMAT_M$ and HT, but liver doses from V10 to V40 were higher in $VMAT_E$ plans compared to other plans. Although liver doses were higher in patients with larger tumors in all plans, $VMAT_M$ plan better spared liver in larger tumors compared to small tumors, and the liver doses increased with the increasing tumor size in $VMAT_E$ plan. Because this study is a dosimetric study, the clinical results of this study are required to interpret these findings in clinical practice.

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Conflict of Interest: All authors declared no conflict of interest.

Ethics Committee Approval: The study was approved by the Baskent University Faculty of Medicine Ethics Committee (no: KA18/148, date: 30/04/2018).

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