

TOTAL MARROW IRRADIATION WITH RAPIDARC VOLUMETRIC ARC THERAPY

Bülent Aydogan, Ph.D.,^{1,2} Mete Yeginer, Ph.D.,³ Gulbin O. Kavak, Ph.D.,^{2,3}
John Fan, Ph.D.,⁴ James A. Radosevich, Ph.D.,³ and Kim Gwe-ya, Ph.D.⁵

1 Department of Radiation and Cellular Oncology, University of Chicago
Pritzker School of Medicine, Chicago, IL;

2 Department of Radiation Oncology, University of Illinois at Chicago Medical
Center, Chicago, IL;

3 Center for Molecular Biology of Oral Diseases, University of Illinois at
Chicago, Chicago, IL;

4 Department of Radiation Oncology, Edwards Hospital, Naperville, IL;

5 Department of Radiation Oncology, University of California, San Diego,
School of Medicine, La Jolla, CA



ELSEVIER

Int. J. Radiation Oncology Biol. Phys., Vol. ■, No. ■, pp. 1–8, 2011

Copyright © 2011 Elsevier Inc.

Printed in the USA. All rights reserved

0360-3016/\$ - see front matter

doi:10.1016/j.ijrobp.2010.11.035

PHYSICS CONTRIBUTION

TOTAL MARROW IRRADIATION WITH RAPIDARC VOLUMETRIC ARC THERAPY

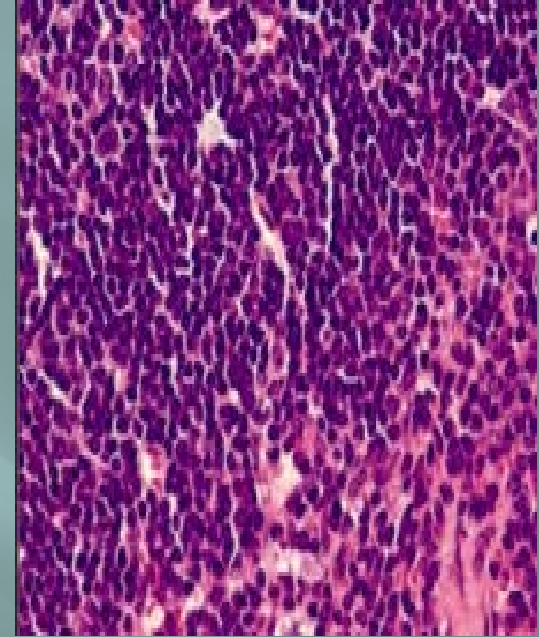
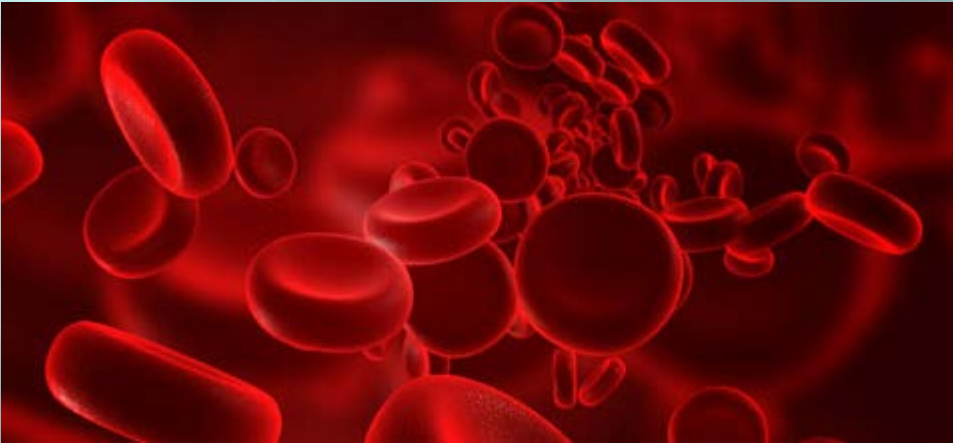
BULENT AYDOGAN, PH.D.,^{*†} METE YEGINER, PH.D.,[‡] GULBIN O. KAVAK,^{†‡} JOHN FAN, PH.D.,[§]
JAMES A. RADOSEVICH, PH.D.,[‡] AND KIM GWE-YA, PH.D.[¶]

^{*}Department of Radiation and Cellular Oncology, University of Chicago Pritzker School of Medicine, Chicago, IL; [†]Department of Radiation Oncology, University of Illinois at Chicago Medical Center, Chicago, IL; [‡]Center for Molecular Biology of Oral Diseases, University of Illinois at Chicago, Chicago, IL; [§]Department of Radiation Oncology, Edwards Hospital, Naperville, IL; [¶]Department of Radiation Oncology, University of California, San Diego, School of Medicine, La Jolla, CA

Tüm Kemik İliği Işınlaması

Hematolojik maligniteli
(lymphoma veya myeloma)
hastalarda;

- ❖ Tümör hücrelerini yok etmek
- ❖ Kemik iliği transplantasyonu
öncesi hazırlık rejimi olarak



Linac ve Tomoterapi ile TMI (total marrow irradiation)

- ❖ Tedavi alanları geniş olduğundan her alan birden fazla (carriage grup) alan içeriyor
- ❖ Tedavi süresi oldukça uzun sürüyor
- ❖ Tomoterapi ve IM-TMI yaklaşık beam-on time 45-50 dk
- ❖ Setup süresi > 1 saat

Amaç

- ❖ Tüm Kemik İliği Işınlaması için RapidArc VMAT (Volumetric Arc Therapy) tekniğini uygulamak
- ❖ Planların doğrulamasını yapmak
- ❖ Elde edilen sonuçları sabit gantry açılı IM-TMI (Intensity modulated total marrow irradiation) ve Tomoterapi ile TMI sonuçlarıyla karşılaştırmak

Materyal ve Metod

- ❖ 6 hasta seçildi
- ❖ 512 x 512 piksel ve 3-5 mm aralığında Philips Brillance CT cihazı ile tarandı
- ❖ CTV : Baştan mid-femur a kadar tüm kemikler konturlandı
- ❖ PTV : CTV + 3mm margin

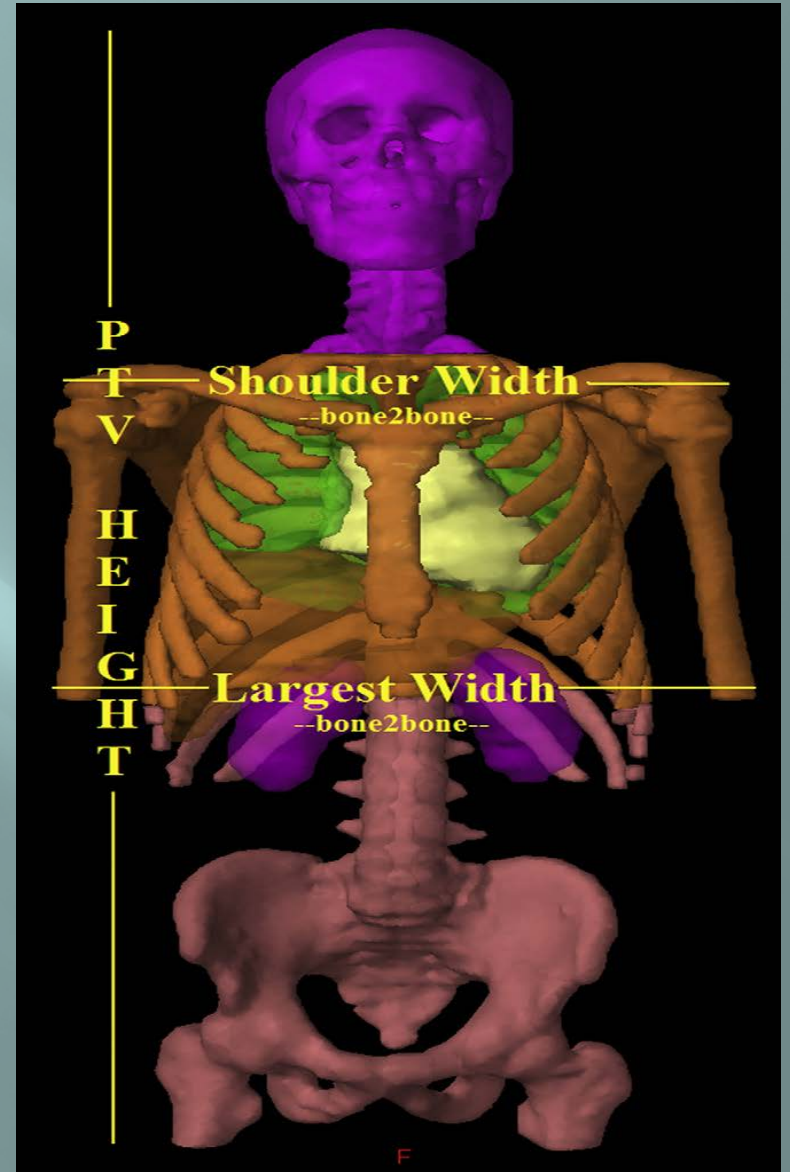
- ❖ PTV boyu 87-95 cm aralığında
- ❖ PTV genişliği 36-46 cm aralığında
- ❖ PTV Baş-Boyun, PTV göğüs ve PTV pelvis bölgeleri olarak 3 kısma ayrıldı
- ❖ Baş-boyun ile göğüs kısmı C5-C6 servikal vertebra seviyesinden bölündü
- ❖ Göğüs ile pelvis bölgesi ise T10-T12 torakal vertebra seviyesinden bölündü

Table 1. Planning target volume width, height, and volume

Variable	P1	P2	P3	P4	P5	P6	Average	SD
PTV (cm ³)	6,704	7,334	6,467	7,171	6,233	6,532	6,740	428
PTV height (cm)	95.0	91.0	87.3	88.2	87.0	87.0	89.3	3.2
PTV width (cm)	44.8	42.3	40.9	44.2	46.2	36.1	42.4	3.6

Abbreviations: P = patient; SD = standard deviation.

- ▣ Kritik organlar:
akciğerler, beyin,
gözler, oral kavite,
kalp, böbrekler,
karaciğer ve bağırsak
- ▣ Konturlama süresi
yaklaşık 4 saat

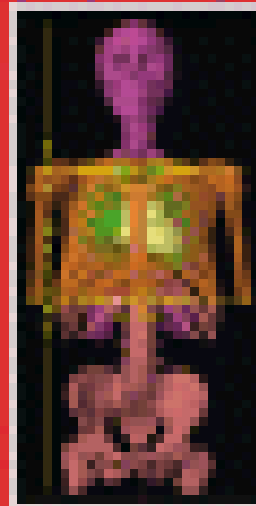


Volume 10 Number 1 April 2001

Radiation Oncology

ISSN 1073-4498

ISSN 1073-4498



Special Section of
Abstracts and Reviews of the 1999
Annual Meeting of the American Society for
Therapeutic Radiology and Oncology (ASTRO)

Volume 10 Number 1
April 2001

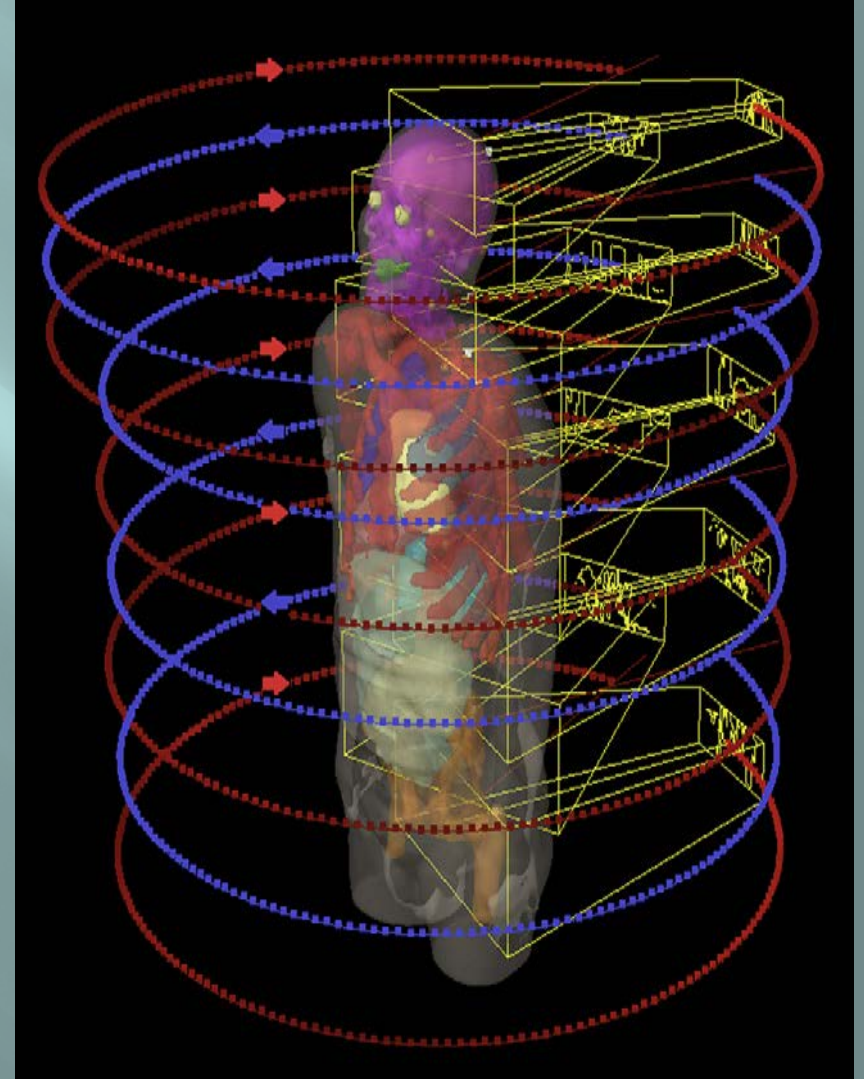
Special Section of
Abstracts and Reviews of the
1999 Annual Meeting of the
American Society for
Therapeutic Radiology and Oncology (ASTRO)



AMERICAN SOCIETY FOR
THERAPEUTIC RADIATION
ONCOLOGY

- ▣ Varian Eclipse Tedavi Planlama Sistemi, version 8.6
- ▣ PRO (Progressive resolution optimization) algorithm
- ▣ Her bir plan yaklaşık 2 saat sürmüştür
- ▣ Her bir PTV volümü için 3 farklı plan ve 3 farklı isocenter kullanılmıştır
- ▣ 330° lik ark kullanılmıştır

- ▣ İlk ark: 165° - 195°
saat yönünün tersi
- ▣ İkinci ark: 195° - 165°
saat yönünde
- ▣ Üçüncü ark: 165° - 195°
saat yönünün tersi
- ▣ Toplam 2970°



- ▣ Sıcak-soğuk noktaları ayarlamak için ikinci ark ilk ark ile 2cm üst üste getirilmiştir.
- ▣ Kolimatör açısı: 90
- ▣ Baş-Boyun: 10cm x 40 cm alan boyutları
- ▣ Göğüs: 12 cm x 40 cm alan boyutları
- ▣ Pelvis: 16 cm x 40 cm alan boyutları

Plan verification

- ▣ MapCheck 2 ve MapPHAN fantom (Sun Nuclear)
- ▣ Eclipse tedavi planlama sistemi version 8.6
- ▣ 5 cm water equivalent buildup
- ▣ Fantom Type-S Head Extension (civco) üzerine yerleştirildi
- ▣ MapCheck application software version 5.0
- ▣ Çakışma bölgesi için pinpoint iyon odası yerleştirildi (0.0125 cm^3)
- ▣ 3mm DTA %3 DA kriterinde γ analizi yapıldı

BULGULAR



Fig. 2. RapidArc volumetric arc therapy total marrow irradiation isodose distributions in colorwash: (a) head and neck axial, (b) chest axial, (c) sagittal, and (d) coronal view. Dose range shown from 6 (blue) to 12 Gy (red).

Table 2. Planning target volume dose

Variable	P1	P2	P3	P4	P5	P6	Average	SD
D ₉₉	11.7	11.7	11.7	11.7	11.7	11.6	11.7	0.0
D ₁	14.2	14.1	14.2	14.4	14.3	14.4	14.3	0.1
Mean dose	12.8	12.7	12.8	12.9	12.9	12.9	12.8	0.1
3D maximum	15.8	15.7	15.7	15.8	15.9	15.7	15.8	0.1

Abbreviations: D_n = radiation dose delivered to *n* percentage of the planning target volume; 3D maximum = three-dimensional global dose maximum; other abbreviations as in Table 1.

Table 3. Median doses for organs at risk

OAR	Median dose (Gy)						Average	SD
	P1	P2	P3	P4	P5	P6		
Lungs	7.6	7.5	6.8	7.2	7.0	7.2	7.2	0.3
Heart	5.1	5.9	6.1	4.9	6.3	4.5	5.5	0.7
Kidneys	5.7	5.9	4.8	5.3	6.1	4.8	5.4	0.6
Liver	5.9	5.8	5.7	5.8	5.9	6.1	5.9	0.1
Bowels	6.3	5.6	5.6	5.8	6.3	5.8	5.9	0.3
Brain	7.7	6.9	6.9	7.8	7.2	7.8	7.4	0.4
Eyes	5.7	5.6	5.5	6.3	5.3	7.5	6.0	0.8
Lenses	4.0	3.9	3.9	4.8	3.5	4.7	4.1	0.5
Oral cavity	6.9	5.7	5.6	7.5	5.8	5.1	6.1	0.9

Abbreviations: OAR = organ at risk; other abbreviations as in Table 1.

DOZ VOLÜM HİSTOGRAMI

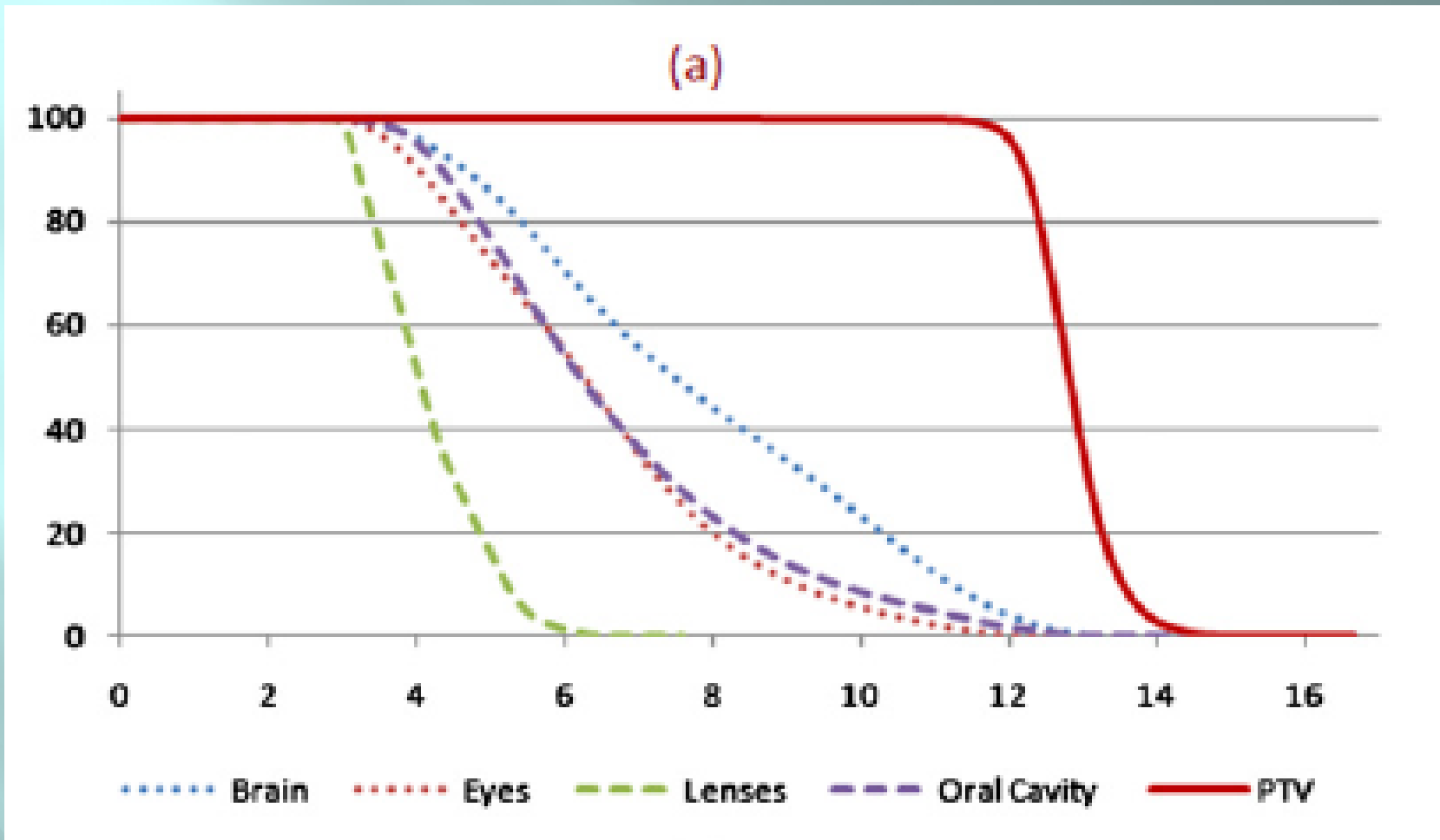


Fig. 3. Average organ at risk and planning target volume (PTV) dose–volume histograms for 6 patients. (a) Head and neck, (b) chest, and (c) pelvis.

DOZ VOLÜM HİSTOGRAMI

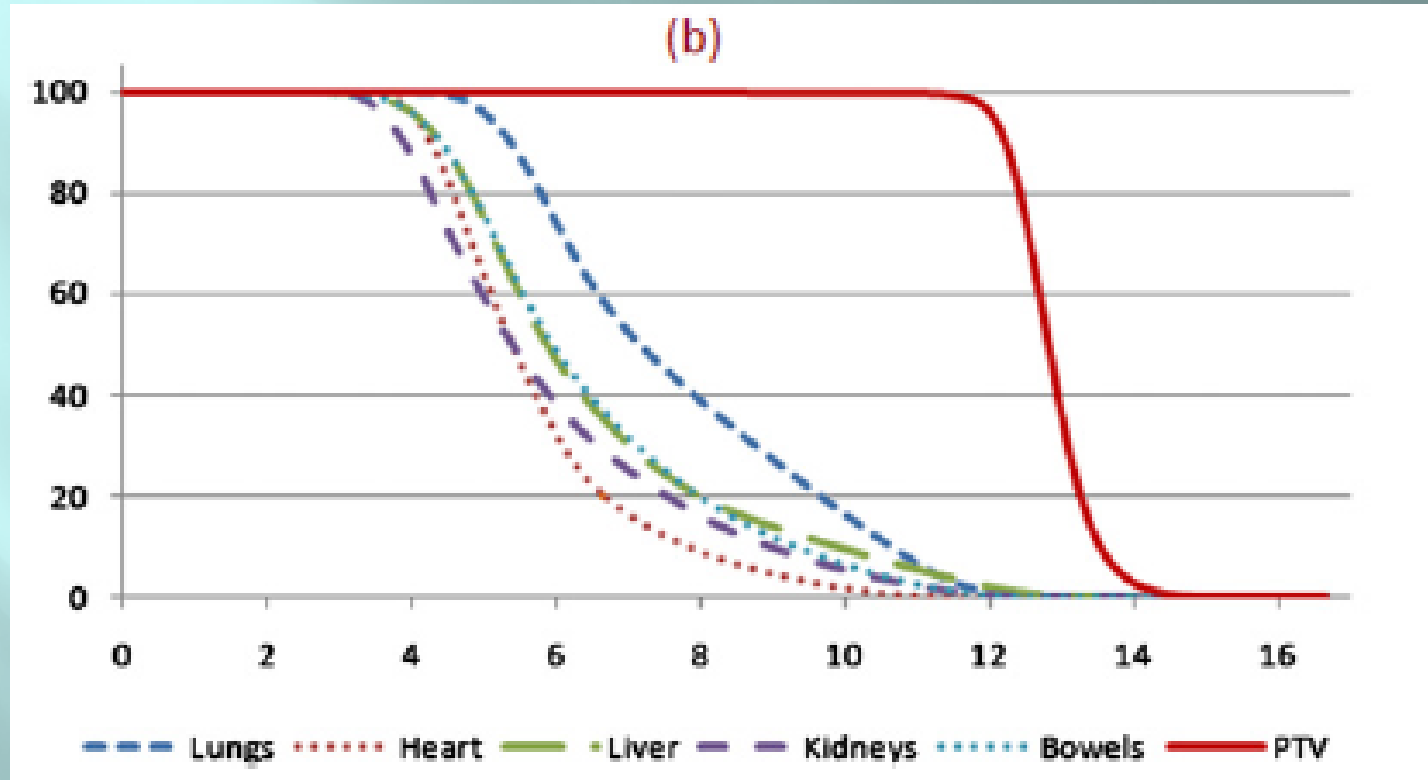


Fig. 3. Average organ at risk and planning target volume (PTV) dose-volume histograms for 6 patients. (a) Head and neck, (b) chest, and (c) pelvis.

Table 4. Average D_1 , D_{99} , and maximum OAR doses

OAR	Maximum (Gy)	D_1 (Gy)	D_{99} (Gy)
Lungs	13.3	11.9	4.7
Heart	12.0	10.7	4.6
Kidneys	12.9	11.4	3.3
Liver	13.5	12.6	3.3
Bowels	13.3	11.4	3.6
Brain	13.7	12.5	3.5
Eyes	12.6	11.9	3.2
Lenses	6.3	6.0	3.1
Oral cavity	12.6	11.8	4.0

Abbreviations: D_n = radiation dose delivered to n percentage of planning target volume; OAR = organ at risk.

Table 5. Comparison of RapidArc VMAT-TMI and fixed gantry linear accelerator IM-TMI technique

OAR	Average median dose (Gy)		Difference* (%)
	RapidArc VMAT-TMI	LINAC-based IM-TMI	
Lungs	7.2 ± 0.3	7.2 ± 0.4	0.0
Heart	5.5 ± 0.7	7.3 ± 0.7	−24.7
Kidneys	5.4 ± 0.6	5.4 ± 0.5	0.0
Liver	5.9 ± 0.1	6.5 ± 0.3	−9.2
Bowels	5.9 ± 0.3	6.5 ± 0.2	−9.2
Brain	7.4 ± 0.4	7.0 ± 0.5	5.7
Eyes	6.0 ± 0.8	5.0 ± 0.5	20.0
Lenses	4.5 ± 0.5	3.4 ± 0.4	32.4
Oral cavity	6.1 ± 0.9	4.9 ± 0.7	24.5

Abbreviations: VMAT = volumetric arc therapy; TMI = total marrow irradiation; IM = intensity-modulated; OAR = organ at risk; LINAC = linear accelerator.

Data presented as mean ± standard deviation.

Percentage of volume receiving dose of ≥ 12 Gy = 95% (12).

* Negative values indicate percentage of improvement with RapidArc VMAT technique.

Table 6. Comparison of RapidArc VMAT-TMI and tomotherapy IM-TMI

OAR	Average median dose (Gy)		Difference* (%)
	RapidArc VMAT-TMI [†]	Tomotherapy	
Lungs	5.6 ± 0.3	5.9	−5.1
Heart	4.9 ± 0.6	6.0	−18.3
Kidneys	3.5 ± 0.7	7.2	−51.4
Liver	4.7 ± 0.2	7.5	−37.3
Bowels	4.6 ± 0.3	4.8	−4.2
Brain	5.8 ± 0.4	6.4	−9.4
Eyes	3.6 ± 0.2	6.0	−40.0
Lenses	2.4 ± 0.2	1.7	41.2
Oral cavity	1.7 ± 0.1	2.3	−26.1

Abbreviations as in Table 5.

Percentage of planning target volume receiving dose of ≥ 12 Gy = 85% (9).

* Negative values indicate percentage of improvement with RapidArc VMAT technique.

[†] Data presented as mean ± standard deviation.

Plan verifikasyon sonuçları

Table 7. Summary of treatment verification

Plan	Point dose difference (%)	Points with $\gamma < 1$ (%)
H&N	-1.24 ± 0.7	98.7 ± 0.8
Chest	-2.50 ± 0.8	98.0 ± 0.7
Pelvis	-2.64 ± 0.8	98.4 ± 0.5

Abbreviation: H&N = head and neck.

Data presented as mean $\pm$ standard deviation.

Point dose difference measured with ion chamber and MapCheck dosimetry with γ -analysis criteria (3-mm distance to agreement and 3%).

QA File Parameter

Patient Name : PT_3
 Patient ID : 100000024
 Plan Date : 25/8/2010
 SSD : 90
 Depth : 5
 Energy : 0
 Angle :

Relative Comparison

% Diff : 3.0
 Distance (mm) : 3.0
 Threshold : 10.0
 Rotation Angle : 0.0 Degs
 Meas Uncertainty : Yes

Summary (Gamma Analysis)

Total Points : 663
 Passed : 659
 Failed : 4
 % Passed : 99.4

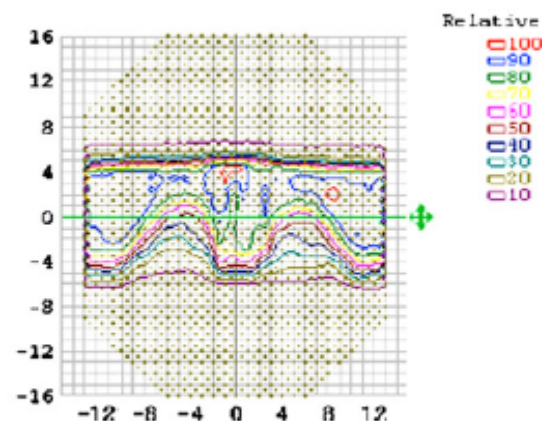
Dose Values in cGy

	Calc	Normal	Picked
Set1	109.75	137.29	109.75
Set2	112.29	136.47	112.29
Set1-Set2	-2.54	0.82	-2.54
% Diff	-1.86	0.60	-1.86
DTA(mm)	0.00	0.00	0.00
Coords (y,x) cm	0,0	-0.5,12.5	0,0

Notes

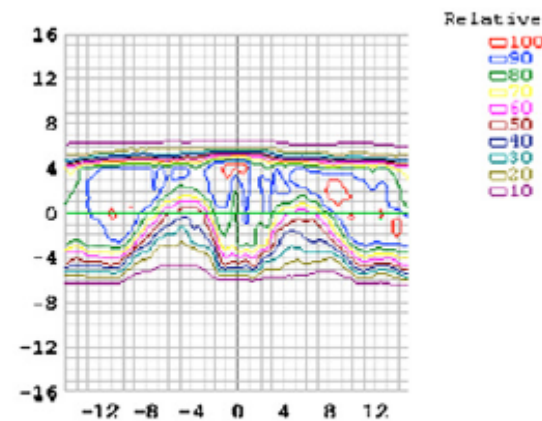
Reviewed By :

Set1



P:\Radiation Oncology\IMRT QA\Plan...\CH_3b1.txt

Set2



P:\Radiation Oncology\IMRT QA\Pla...\CH_3b1.dcm

Set1-Set2

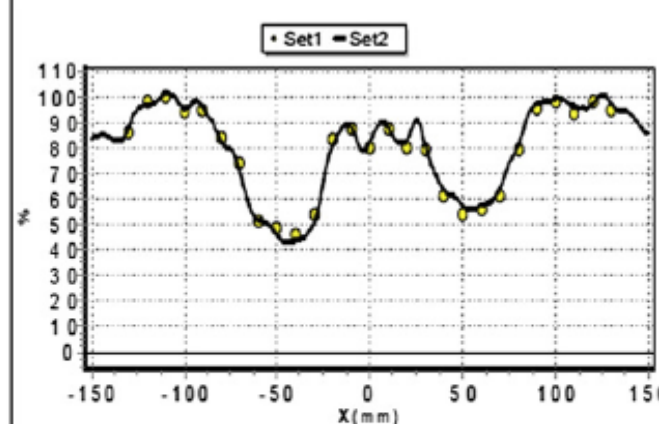
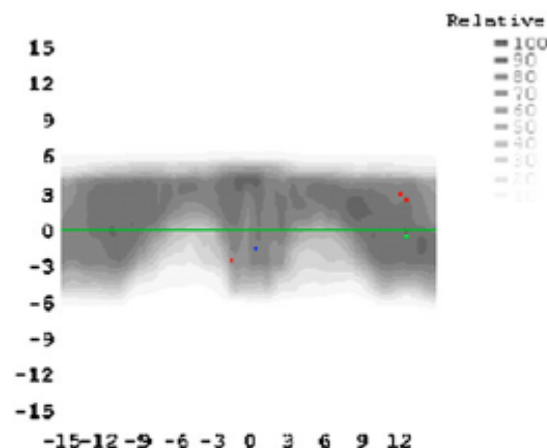


Fig. 4. Screenshot of MapCheck plan analysis demonstrating agreement between measured and planned dose distribution. QA = quality assurance; DTA = distance to agreement.

- ▣ Toplam ortalama tedavi süresi : 18.3 ± 2.3 / hasta
(beam on time)
- ▣ Her ark yaklaşık 2 dk
(Dose rate 600 monitor units/min)
- ▣ Toplam monitor unit %50 azalmıştır

ÖZET

- ▣ Tedavi süresi 45-50 dk dan yaklaşık 18 dk azalmıştır
- ▣ OAR dozları sabit gantry IMTMI ile karşılaştırıldığında: karaciğer ve bağırsaklarda %9.2, kalp dozunda %24.7 azaldığı gözlenmiştir
- ▣ OAR dozları tomoterapi ile karşılaştırıldığında : akciğerler için %5.1, gözler için %40, böbrekler için %51.4 azalma gözlenmiştir

Sonuç

Rapid Arc VMAT tekniğiyle TMI ;

- ✓ Tedavi süresini azaltmaktadır
- ✓ Daha iyi kritik organ dozları sağlamaktadır
- ✓ Klinik olarak uygulanabiliridir

TEŞEKKÜRLER