



XIV Ulusal Medikal
Fizik Kongresi

21-24 Kasım 2013 Kervansaray Lara Convention Center/ANTALYA

CYBERKNİFE TEDAVİ METODLARI VE KLİNİK UYGULAMALARI

Med. Fiz. Uzm. Nadir KÜÇÜK
Özel Anadolu Sağlık Merkezi
23 Kasım 2013

İÇERİK

- ❑ Cyberknife Genel Bakış
- ❑ Cyberknife Tedavi Metodları
- ❑ İntrakraniyal Cyberknife Uygulamaları
- ❑ Ekstrakraniyal Cyberknife Uygulamaları

NEDEN SRS/SBRT ?

- SBRT Anket-1600 RO

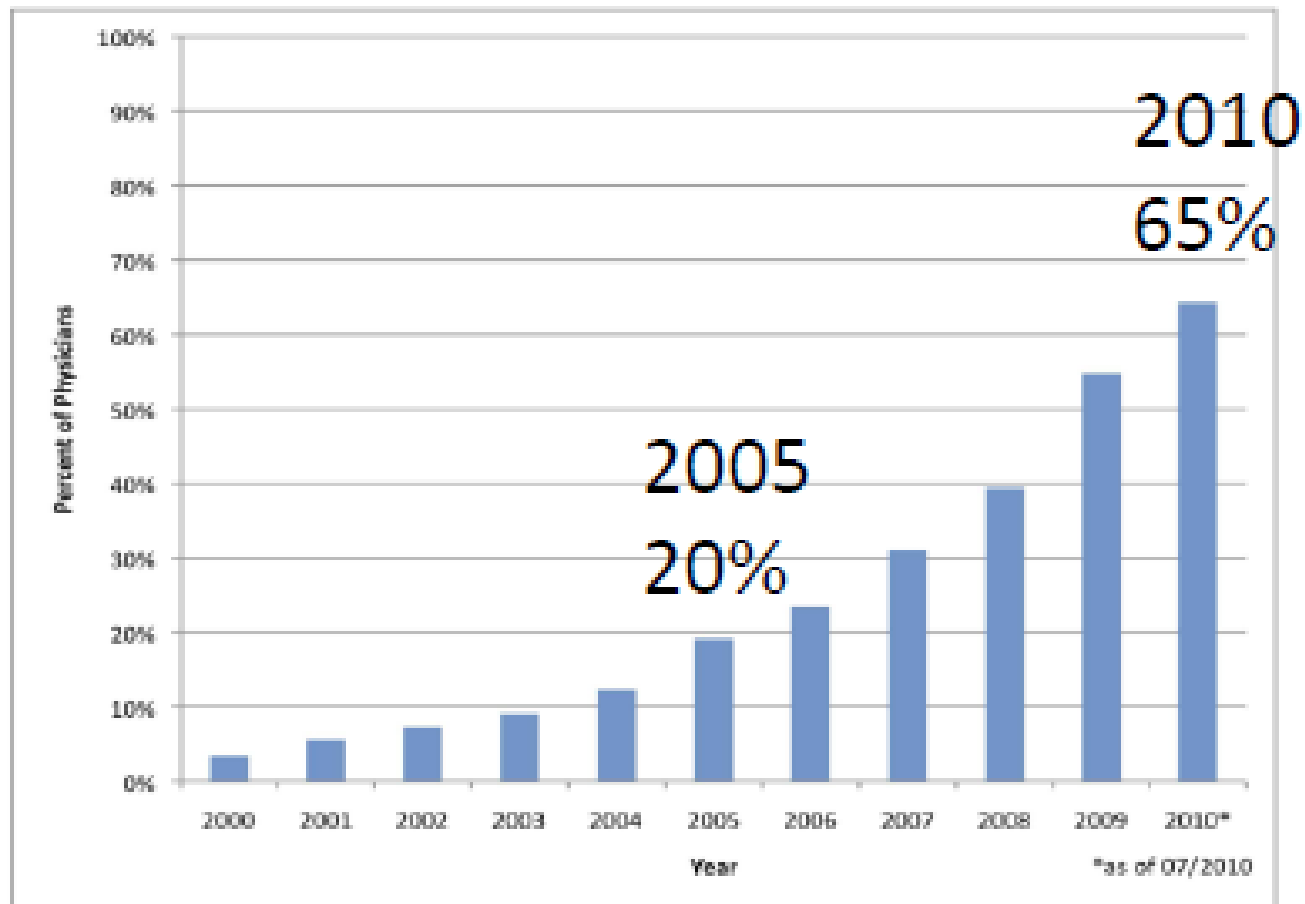


Figure 2. Cumulative adoption of stereotactic body radiation therapy (SBRT) for the treatment of any disease site.

NEDEN SRS/SBRT ?

	Primary lung cancer	Pancreas cancer	Prostate cancer	Spine/para-spinal lesions	Head & neck cancer	Primary Liver Cancer	Lung & liver metastases
Phase I	😊	😊		😊	😊	😊	😊
Phase II	😊	😊	😊	😊	😊	😊	😊
Knowledge-seeking analyses	😊	😊	😊	😊			😊
Registries or pooled analyses	😊		😊				😊
Randomized Phase II	😊						
Phase III				😊			

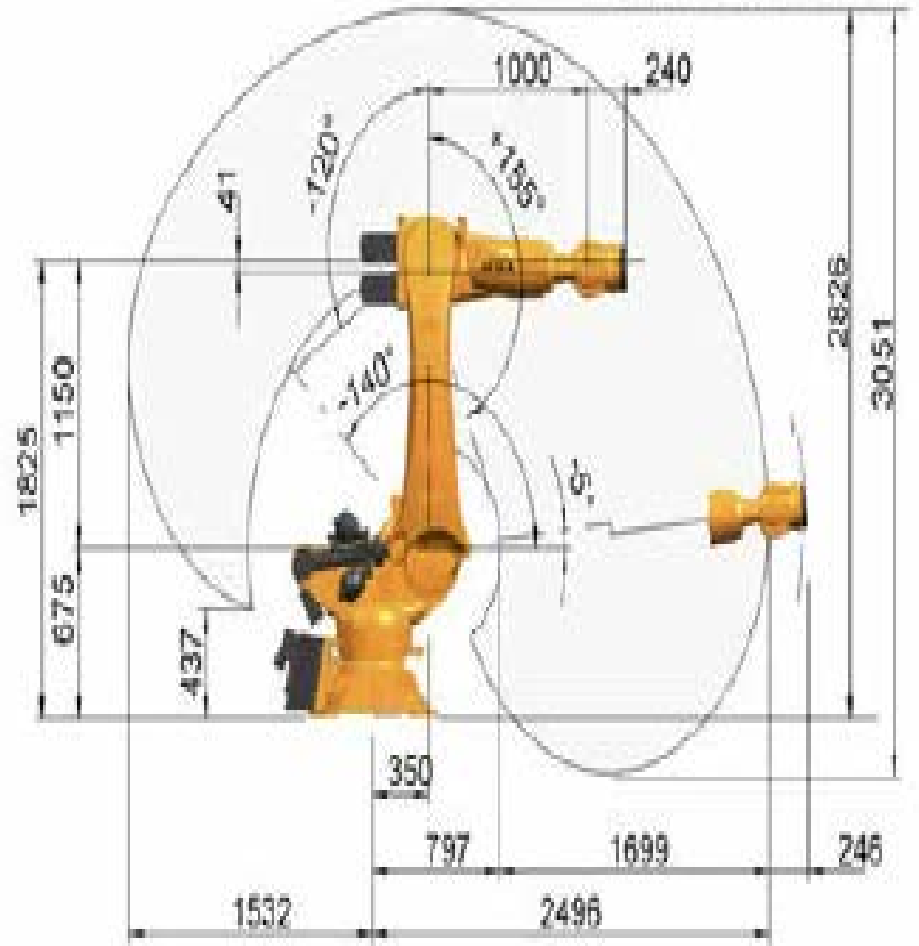
İÇERİK

- ❑ **Cyberknife Genel Bakış**
- ❑ **Cyberknife Tedavi Metodları**
- ❑ **İntrakraniyal Cyberknife Uygulamaları**
- ❑ **Ekstrakranial Cyberknife Uygulamaları**

Cyberknife Genel Bakış

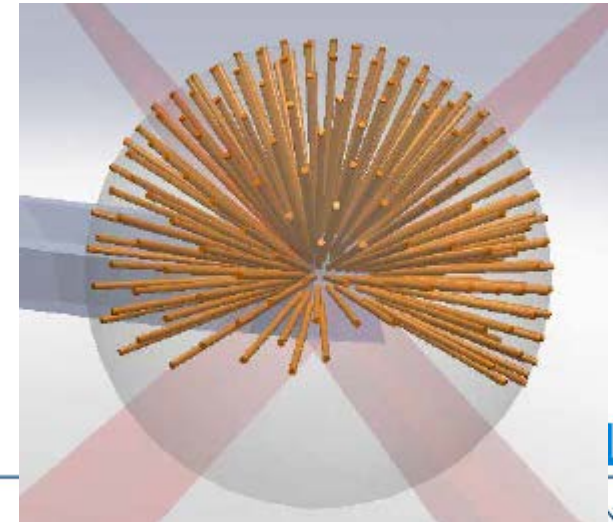
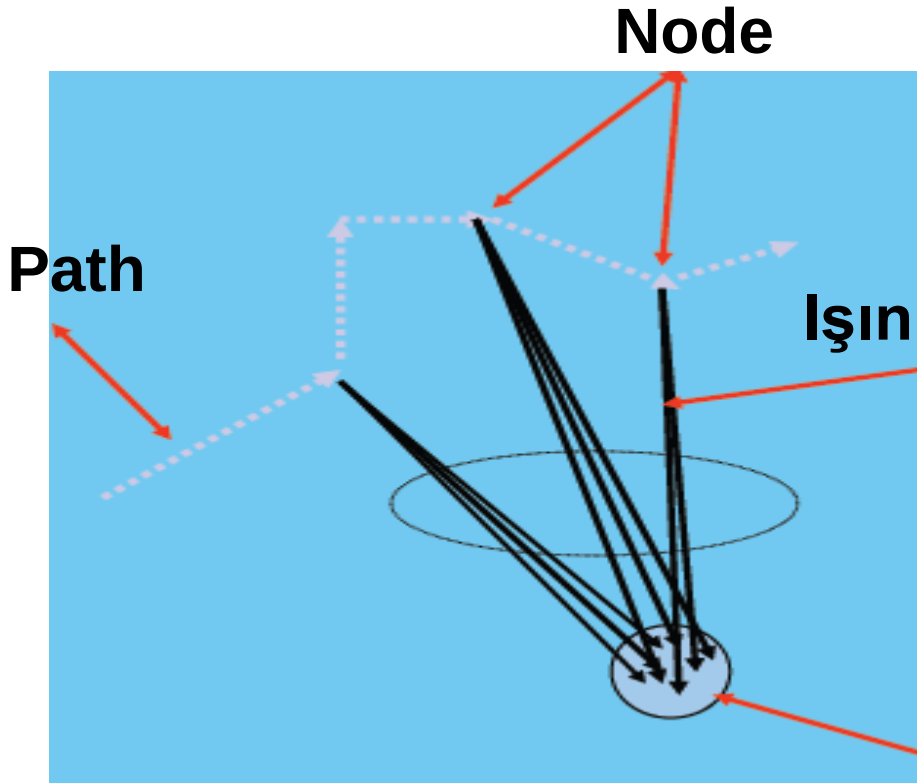
□ Temel mantık-1

- 6 eksenli robot
- Ortogonal görüntü alma kapasitesi
- CT DRR/ Gerçek DRR karşılaştırması
- Tedavi süresince ışının oluşan sapma kadar yeniden hedeflenmesi



Cyberknife Genel Bakış

□ Temel mantık-2

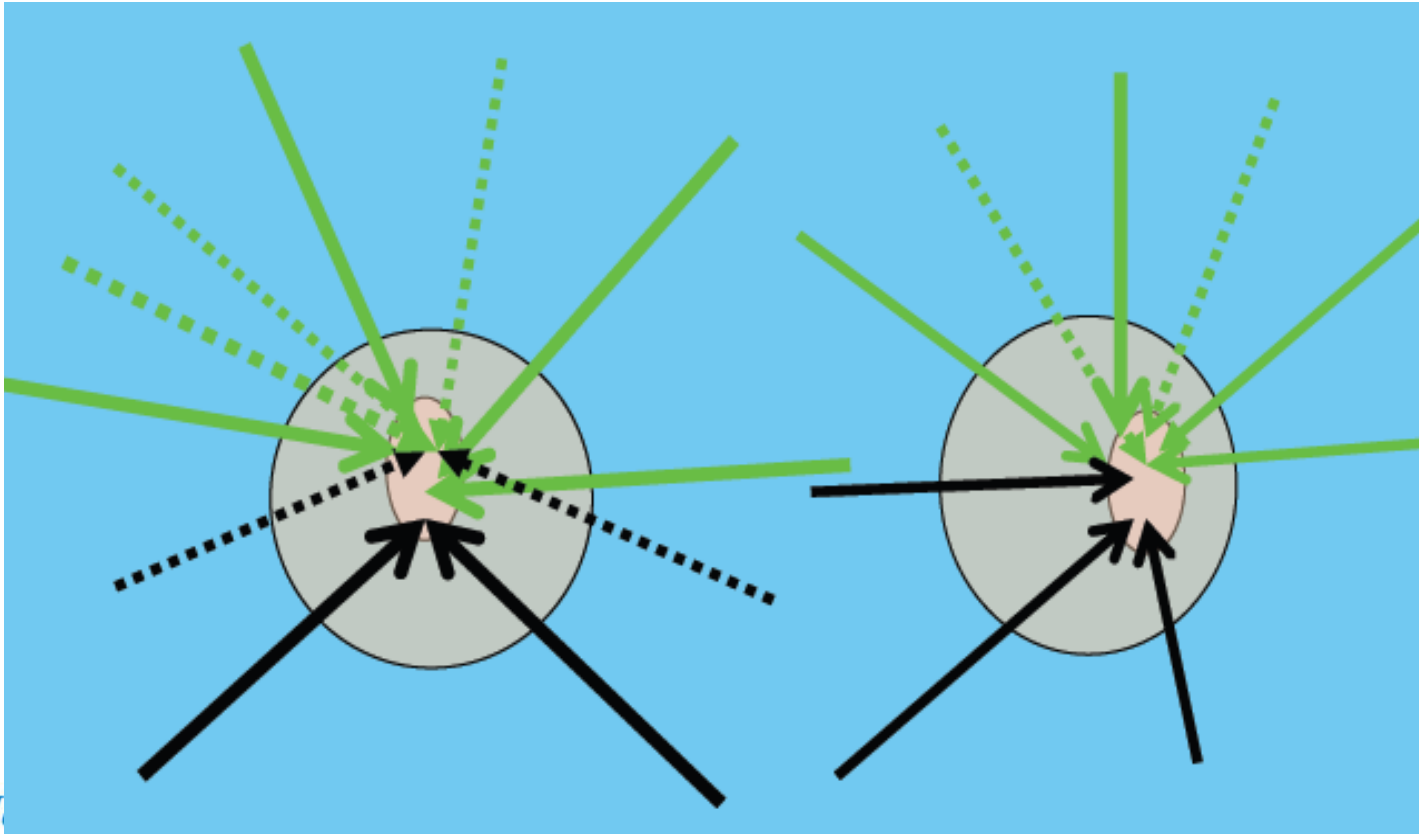


Tümör

Cyberknife Genel Bakış

□ Temel mantık-3

3D Non-İzosentrik Tedavi Yöntemi



Cyberknife Genel Bakış

□ Nereden başlasak?

AAPM Report #54 – Stereotactic Radiosurgery

AAPM Report #91 – The Management of Motion in Radiation Oncology (TG 76)

TG 68 – Intracranial Stereotactic Positioning Systems

TG 101 – Stereotactic Body Radiotherapy

TG 104 – kV Localization in Therapy

Efforts In Progress

TG 117 – Use of MRI in Treatment Planning and Stereotactic Procedures

TG 132 – Use of Image Registration and Data Fusion Algorithms and Techniques in Radiotherapy Treatment Planning

TG 135 – QA for Robotic Radiosurgery

TG 147 – QA for Non-Radiographic Radiotherapy Localization and Positioning Systems

TG 155 – Small Fields / Non-Equilibrium Condition Photon Beam Dosimetry

TG 176 – Task Group on Dosimetric Effects of Immobilization Devices

TG 178 – Gamma Stereotactic Radiosurgery Dosimetry and QA

TG 179 – QA for Image-Guided Radiation Therapy Utilizing CT-Based Technologies

Cyberknife Genel Bakış

□ Başladık ya sonra?

PRACTICE GUIDELINE FOR THE PERFORMANCE OF STEREOTACTIC BODY RADIATION THERAPY

The medical physicist is responsible for the technical aspects of radiosurgery and must be available for consultation throughout the entire procedure: imaging, treatment planning, and dose delivery. Those responsibilities shall be clearly defined and should include the following:

1. Acceptance testing and commissioning of the SBRT system, thereby assuring its geometric and dosimetric precision and accuracy. This includes:
 - a. Localization devices used for accurate determination of target coordinates.
 - b. The image-based 3D and/or intensity-modulated treatment planning system.
 - c. The SBRT external beam delivery unit.
2. Implementing and managing a quality control (QC) program for the SBRT system to monitor and assure proper functioning of:
 - a. The SBRT external beam delivery unit.
 - b. The image guidance system as well as all other imaging devices used for SBRT.
 - c. The image-based 3D and/or intensity-modulated treatment planning system.
3. Establishing a comprehensive QC checklist that acts as a detailed guide to the entire treatment process.



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- ❑ Cyberknife Genel Bakış
- ❑ Cyberknife Tedavi Metodları
- ❑ İntrakraniyal Cyberknife Uygulamaları
- ❑ Ekstrakraniyal Cyberknife Uygulamaları

Cyberknife Tedavi Metodları

Skull tracking

Synthetic Image A **Camera Image A** **Overlay of Images A** **Couch Corrections**
Current Node
LFT: 3.4 mm
POS: 2.8 mm
INF: 1.1 mm
LFT: 1.4 deg
H-UP: 0.4 deg
CCW: 2.2 deg

Synthetic Image B **Camera Image B** **Overlay of Images B** **Tracking Mode**
6D Skull (6D)
Imaging Parameters
Patient Alignment

XRS A **KV: 125** **MA: 100** **EX: 100** **XRS B** **KV: 125** **MA: 100** **EX: 100** **Xray Parameters**

Window **Level** **Apply W/L To All** **Invert** **Max Contrast**

View Mode **Zoom**
X-Hairs 100%
☒ Display Fiducial Markers
☐ Display Blobs
☒ Display ROI
☐ Threshold

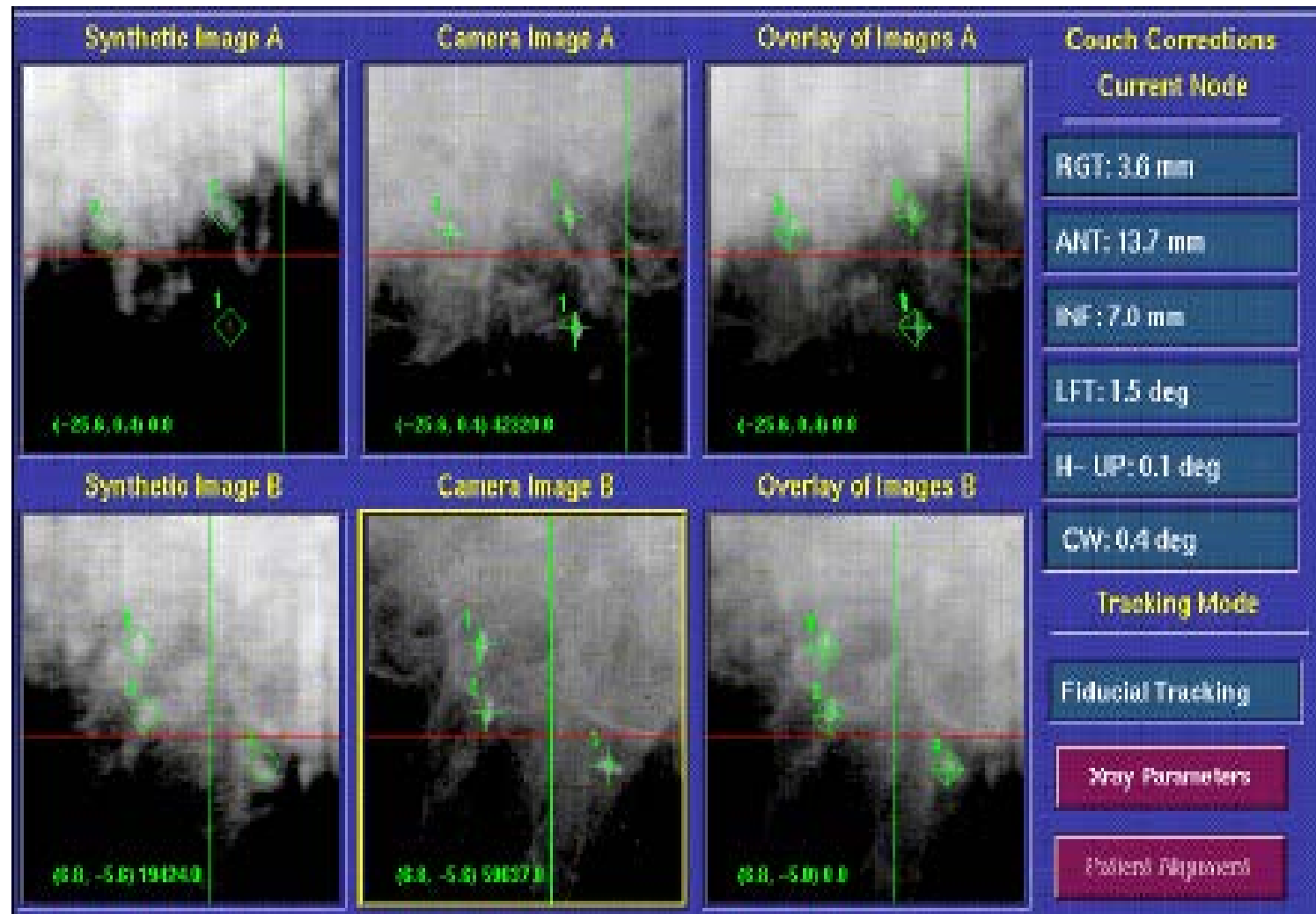
Fiducial Tracking **Fiducial Area** **Treatment Mode**
Search Search
☒ Search ☒ Track
Enable Offset
Use Identified Fiducial Properties
Search Parameters
Close

Reset Display **Align** **Add** **Subtract**

Scale
-3.4 -2.8 -1.1
LFT (mm) RGT (mm) POS (mm) ANT (mm) INF (mm) SUP (mm)

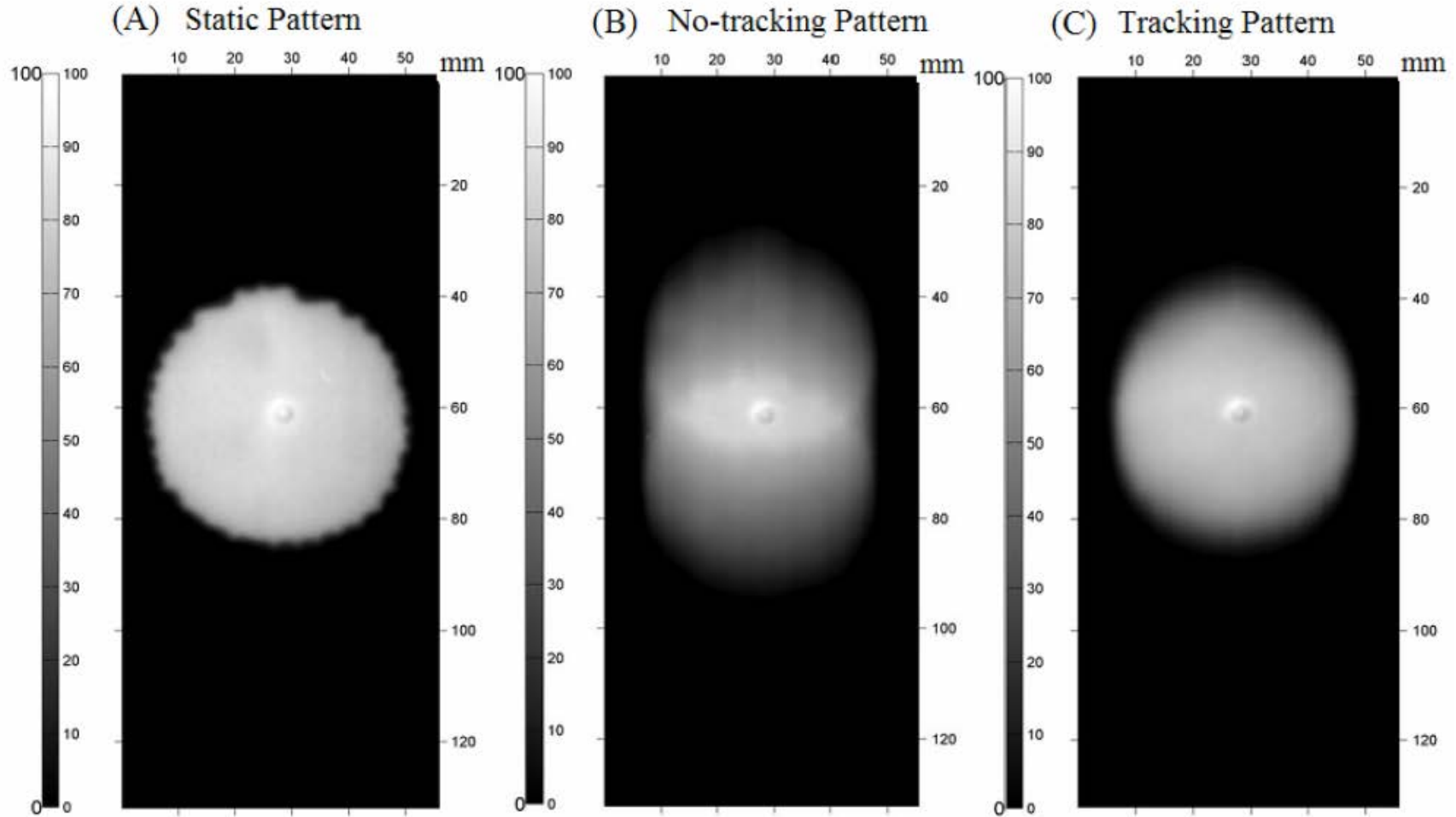
Cyberknife Tedavi Metodları

Fiducial tracking



Cyberknife Tedavi Metodları

Gerçek zamanlı Tümör Takibi



From Yaxi Liu, Astro 2008

ANADOLU^H

In Affiliation with
JOHNS HOPKINS MEDICINE

Cyberknife Tedavi Metodları

Static vs
Tracking(-)

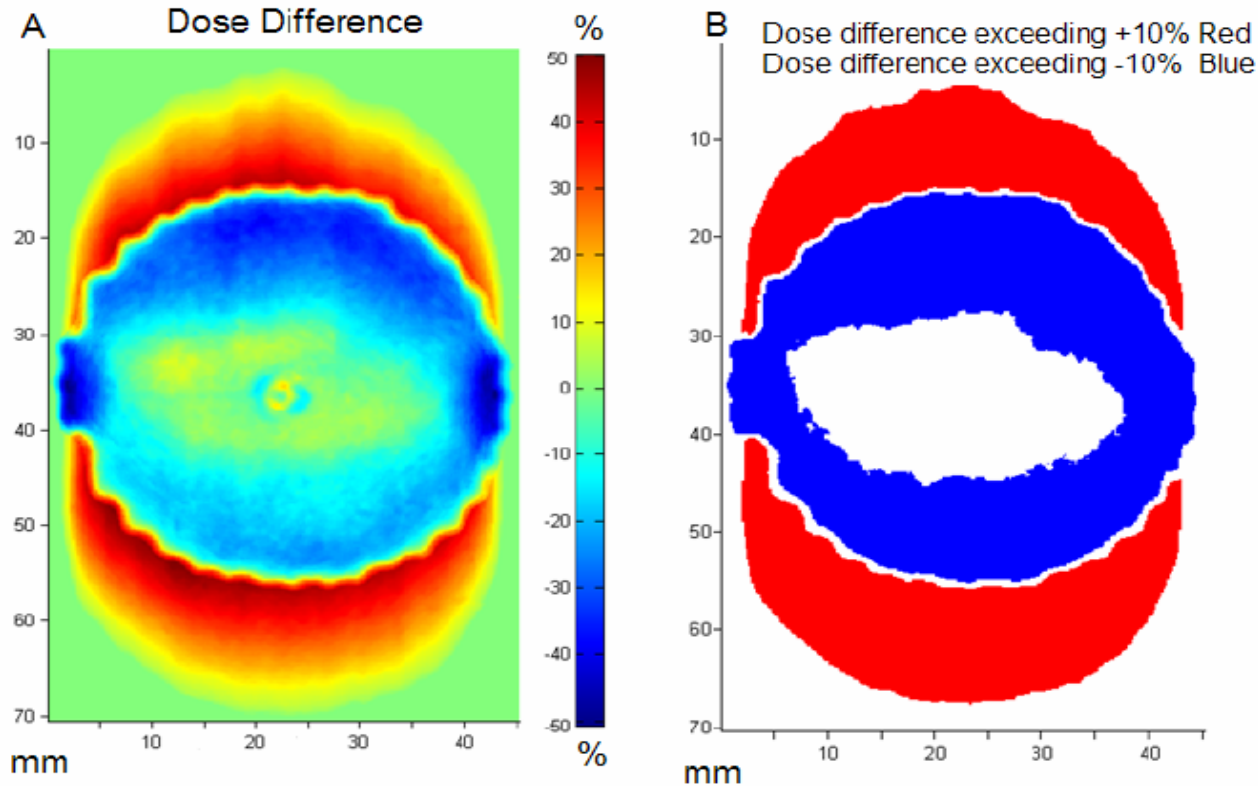


Figure 9 (A) Dose differences over the resulting irradiation field, and (B) film areas with 10% or more dose difference from subtracting dose maps of No-tracking from that of Static irradiation fields.

From Yaxi Liu, Astro 2008

Cyberknife Tedavi Metodları

Static vs real
time tracking

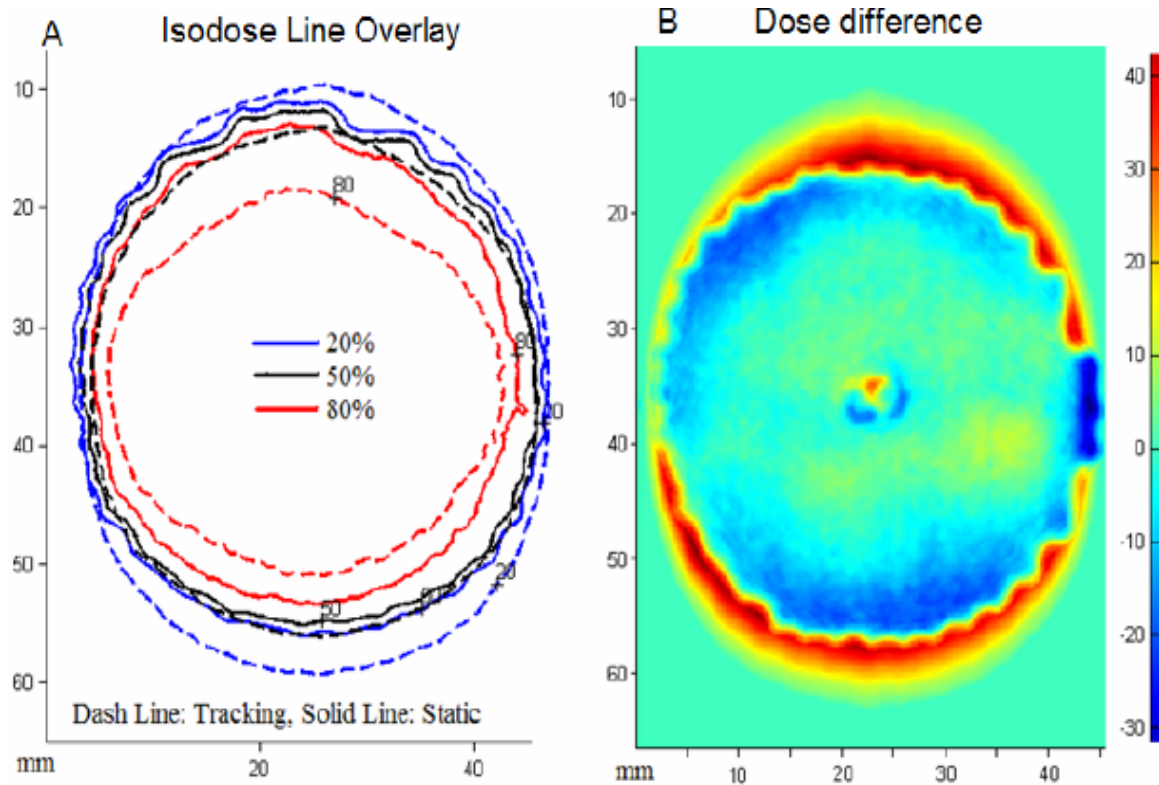
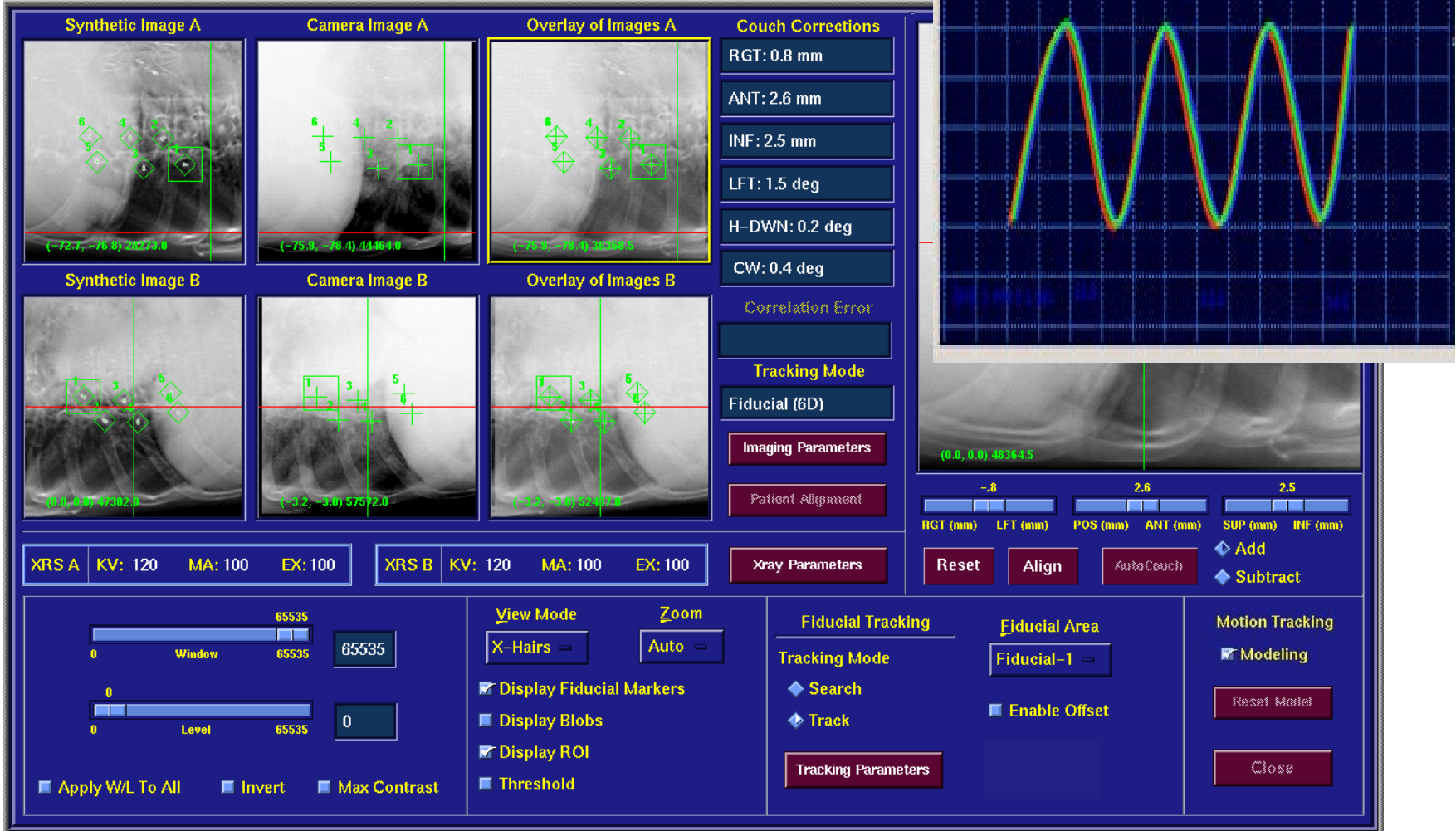


Figure 10 (A) Isodose line comparisons between real-time tumor Tracking (dashed line) and Static (solid line) situations, (B) Dose differences over the irradiation field resulting from the subtracting dose maps of real-time tumor Tracking from that of the Static irradiation field.

From Yaxi Liu, Astro 2008

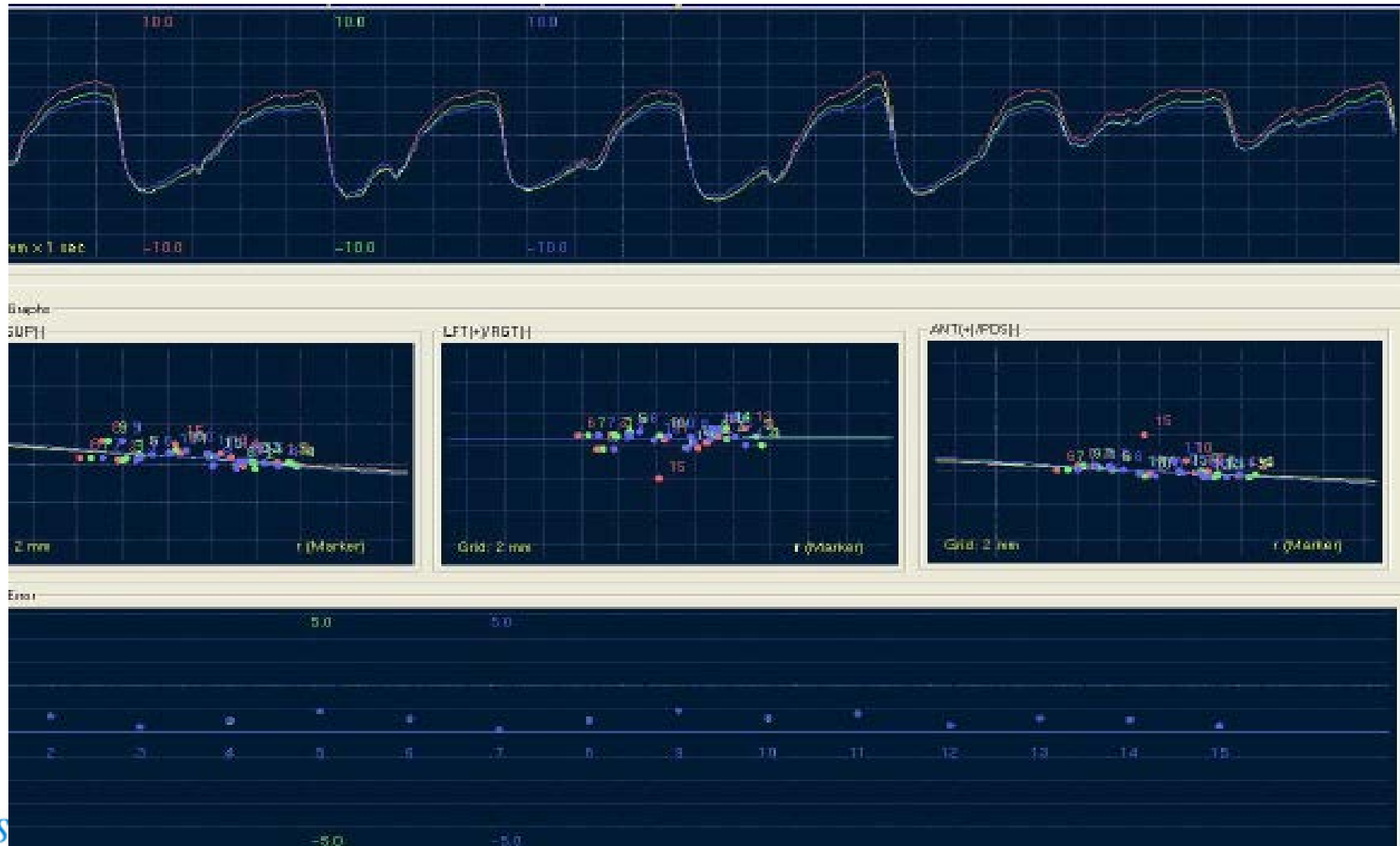
Cyberknife Tedavi Metodları

Synchrony Respiratory Tracking



Cyberknife Tedavi Metodlari

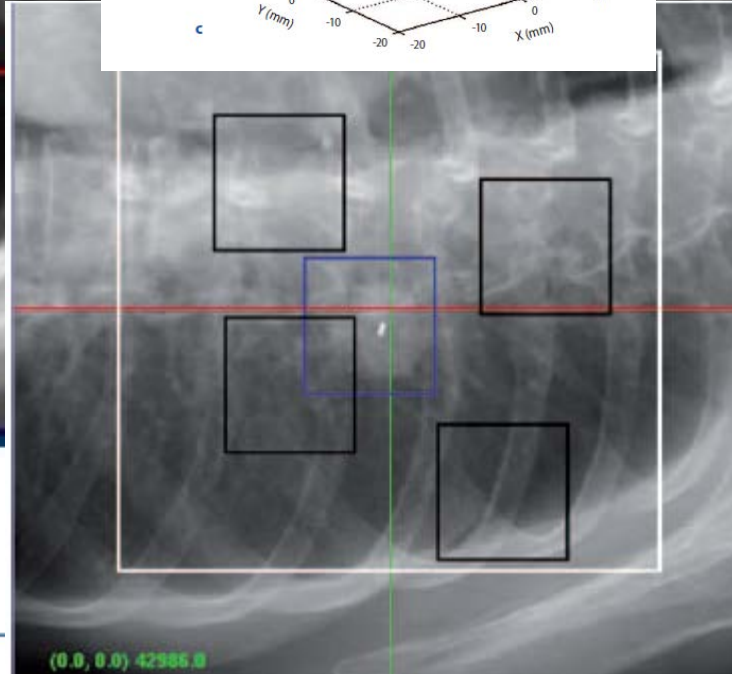
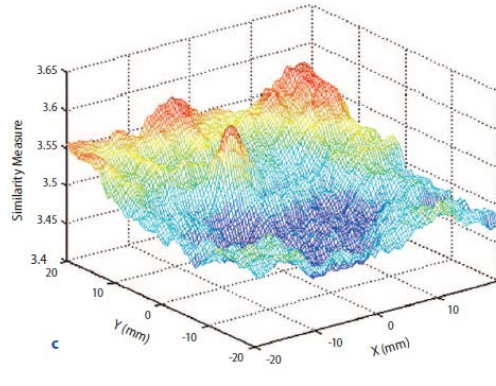
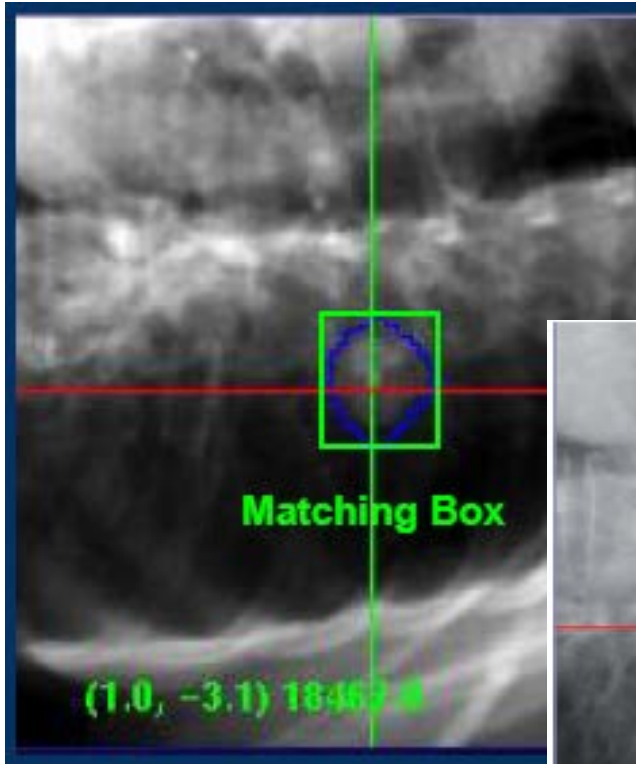
Synchrony Respiratory Tracking



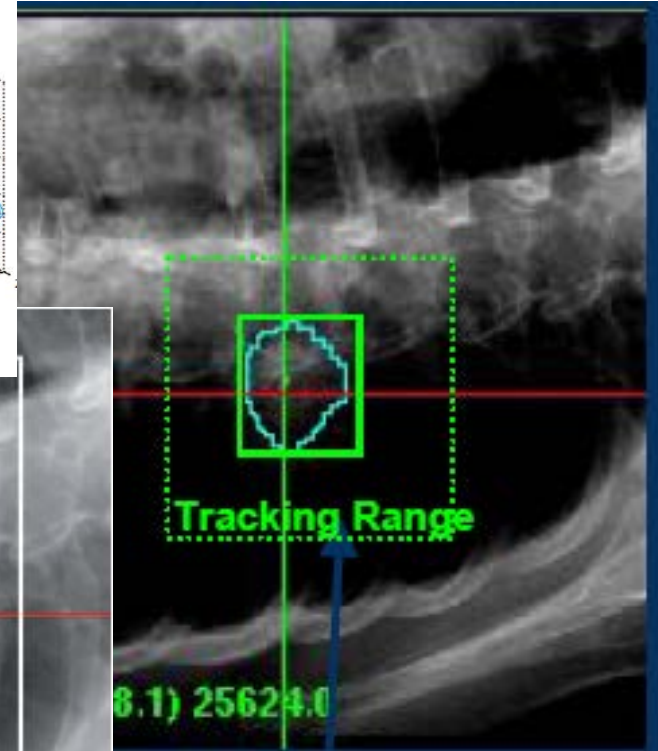
Cyberknife Tedavi Metodları

X Sight Spine/Lung/Optimized Lung

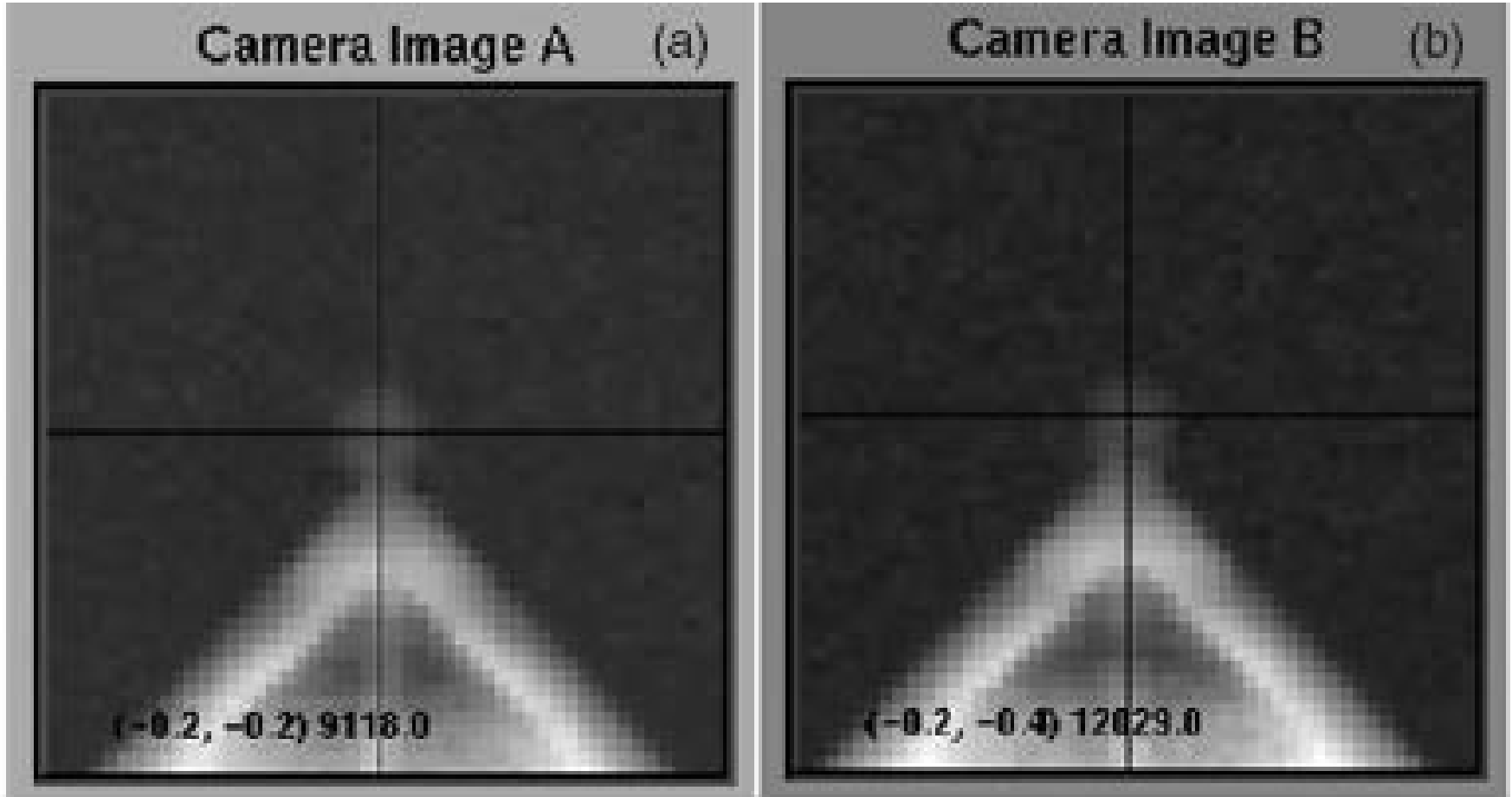
DRR görüntüsü



Gerçek zamanlı görüntü



Cyberknife Tedavi Metodları



Cyberknife Tedavi Metodları

- Her çift görüntü başına yüzey dozu

kVp	mA	ms	mAs	Dose (mGy)
100	100	100	10	0.15
100	320	100	32	0.50
120	100	100	10	0.24
120	320	100	32	0.80
150	100	100	10	0.38
150	320	100	32	1.24

Cyberknife Tedavi Metodları

- IGRT karşılaştırma/Hipofraksiyon

Diagnostic CT (Head)		1) Single-fraction Intracranial SRS					
		CyberKnife Image Guidance		MV portal Image-based set-up		CBCT based set-up	
# images	E (mSv)	# images	E (mSv)	# images	E (mSv)	# images	E (mSv)
1	1.9 – 2.2	54	0.24	1	No data	1	3.0
Diagnostic CT (Chest)		2) Hypofractionated (3 fractions) Lung SBRT					
		CyberKnife Image Guidance		MV portal Image-based set-up		CBCT based set-up	
# images	E (mSv)	# images	E (mSv)	# images	E (mSv)	# images	E (mSv)
1	5.8 – 6.4	138	3.56	3	25.8	3	24.3
Diagnostic CT (Pelvis)		3) Hypofractionated (4 fractions) Prostate SBRT					
		CyberKnife Image Guidance		MV portal Image-based set-up		CBCT based set-up	
# images	E (mSv)	# images	E (mSv)	# images	E (mSv)	# images	E (mSv)
1	8.2 - 11.4	196	16	4	5.3	4	12 (low dose) 92 (standard)

Cyberknife Tedavi Metodları

- IGRT konvansiyonel

Diagnostic CT		4) Conventionally Fractionated (N=40) Prostate IMRT							
		CyberKnife Image Guidance		MV portal Image-based set-up		CBCT based set-up		CBCT set-up + MV portal Image-based set-up	
# images	E (mSv)	# images	E (mSv)	# images	E (mSv)	# images	E (mSv)	# images	E (mSv)
1	8.2 - 11.4	600	48.9	40	52.8	40	120 (low dose) 920 (standard)	10 (CBCT) + 40 (MV EPID)	82.8 (low dose) 283 (standard)

Cyberknife Tedavi Metodları

- IGRT konvansiyonel

Diagnostic CT		4) Conventionally Fractionated (N=40) Prostate IMRT							
		CyberKnife Image Guidance		MV portal Image-based set-up		CBCT based set-up		CBCT set-up + MV portal Image-based set-up	
# images	E (mSv)	# images	E (mSv)	# images	E (mSv)	# images	E (mSv)	# images	E (mSv)
1	8.2 - 11.4	600	48.9	40	52.8	40	120 (low dose) 920 (standard)	10 (CBCT) + 40 (MV EPID)	82.8 (low dose) 283 (standard)

Cyberknife Tedavi Metodları

- Görüntüleme dozu

The management of imaging dose during image-guided radiotherapy: Report of the AAPM Task Group 75

Martin J. Murphy

Department of Radiation Oncology, Virginia Commonwealth University, Richmond, Virginia 23298

James Balter

Department of Radiation Oncology, University of Michigan, Ann Arbor, Michigan 48109

Stephen Balter

Departments of Medicine and Radiology, Columbia University Medical Center, New York, New York 10021

Jose A. BenComo, Jr.

Department of Radiation Physics, M.D. Anderson Cancer Center, Houston, Texas 77030

Indra J. Das

Department of Radiation Oncology, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania 19104

Steve B. Jiang

Department of Radiation Oncology, University of California, San Diego, La Jolla, California 92093

C.-M. Ma

Department of Radiation Oncology, Fox Chase Cancer Center, Philadelphia, Pennsylvania 19111

Gustavo H. Olivera

Department of Medical Physics, University of Wisconsin, Madison, Wisconsin 53706

Raymond F. Rodebaugh

St. Joseph's Hospital, Phoenix, Arizona 85013

Kenneth J. Ruchala

TomoTherapy, Inc., Madison, Wisconsin 53717

Hiroki Shirato

Department of Radiology, Hokkaido University Hospital, Hokkaido, Japan

Fang-Fang Yin

Department of Radiation Oncology, Duke University Medical Center, Durham, North Carolina 27710

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**Task Group 75
2007**

Cyberknife Tedavi Metodları

Table 7. Clinical accuracy results for the 6D skull tracking, fiducial tracking and Xsight spine tracking algorithms of our CyberKnife system.

Trial	A/P (mm)	L/R (mm)	S/I (mm)	Accuracy (mm)
6D skull tracking—clinical accuracy				
1	0.25	−0.52	−0.16	0.60
2	0.23	0.40	−0.04	0.46
3	0.24	−0.25	−0.19	0.40
4	0.29	0.09	−0.36	0.47
5	0.20	0.11	−0.16	0.28
Average	0.24	−0.04	−0.18	0.44
SD	0.03	0.35	0.11	0.12
Fiducial tracking—clinical accuracy				
1	0.17	−0.22	−0.07	0.29
2	0.06	−0.06	−0.38	0.39
3	−0.03	0.11	0.03	0.12
4	0.31	−0.14	−0.07	0.34
5	−0.13	−0.06	−0.29	0.32
Average	0.08	−0.07	−0.16	0.29
SD	0.17	0.12	0.17	0.10
XSS spine tracking—clinical accuracy				
1	−0.42	0.27	−0.22	0.54
2	−0.09	−0.57	−0.12	0.59
3	0.04	−0.24	−0.04	0.24
4	0.01	−0.61	0.06	0.61
5	0.13	0.25	−0.59	0.65
Average	−0.06	−0.18	−0.18	0.53
SD	0.21	0.43	0.25	0.16

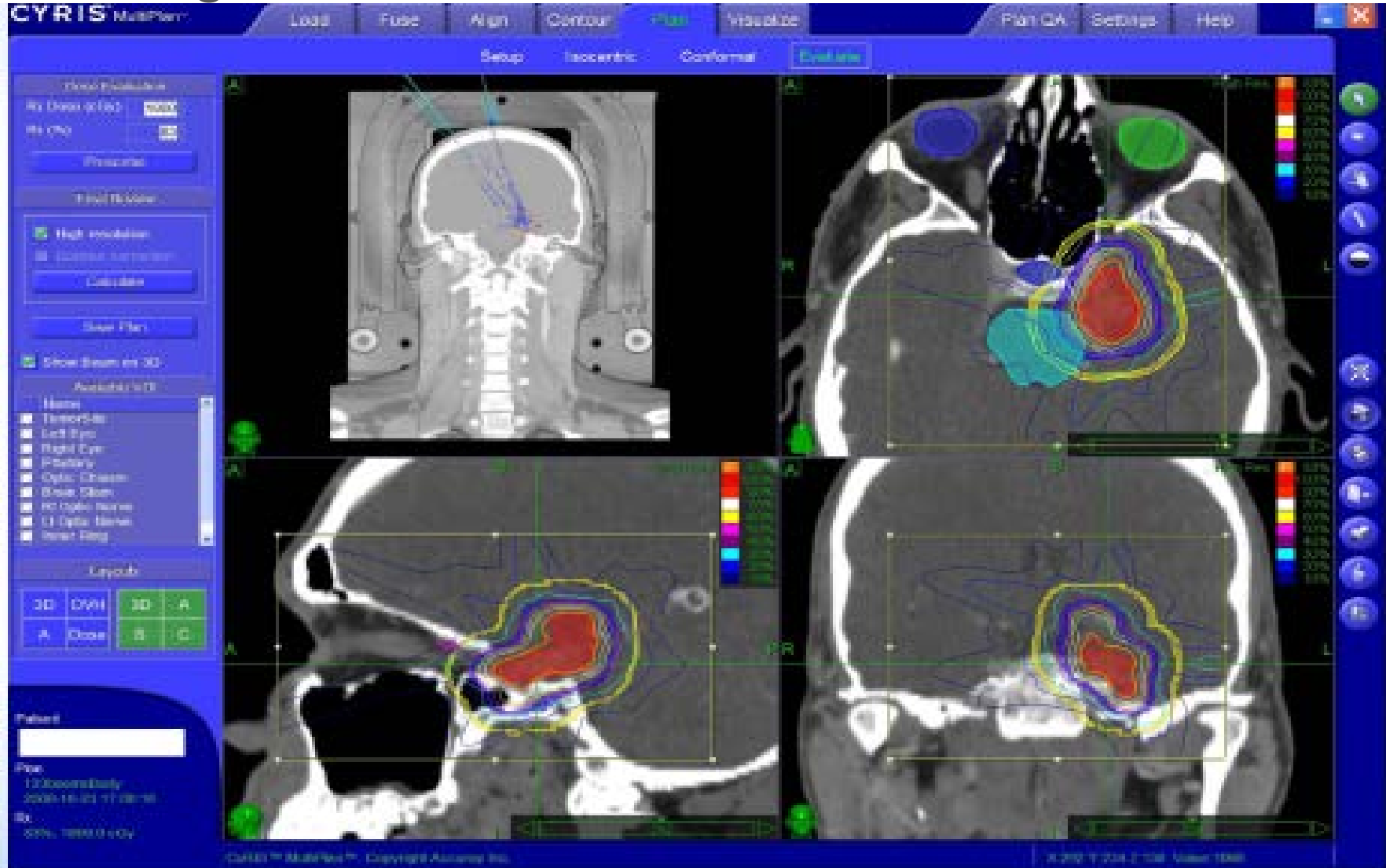
End to End Test

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- ❑ Cyberknife Tedavi Metodları
- ❑ **Intrakraniyal Cyberknife Uygulamaları**
- ❑ Ekstrakranial Cyberknife Uygulamaları
- ❑ Avantaj ve Dezavantajlarıyla Cyberknife

Intrakraniyal Cyberknife Uygulamaları

- Meningioma



İntrakraniyal Cyberknife Uygulamaları

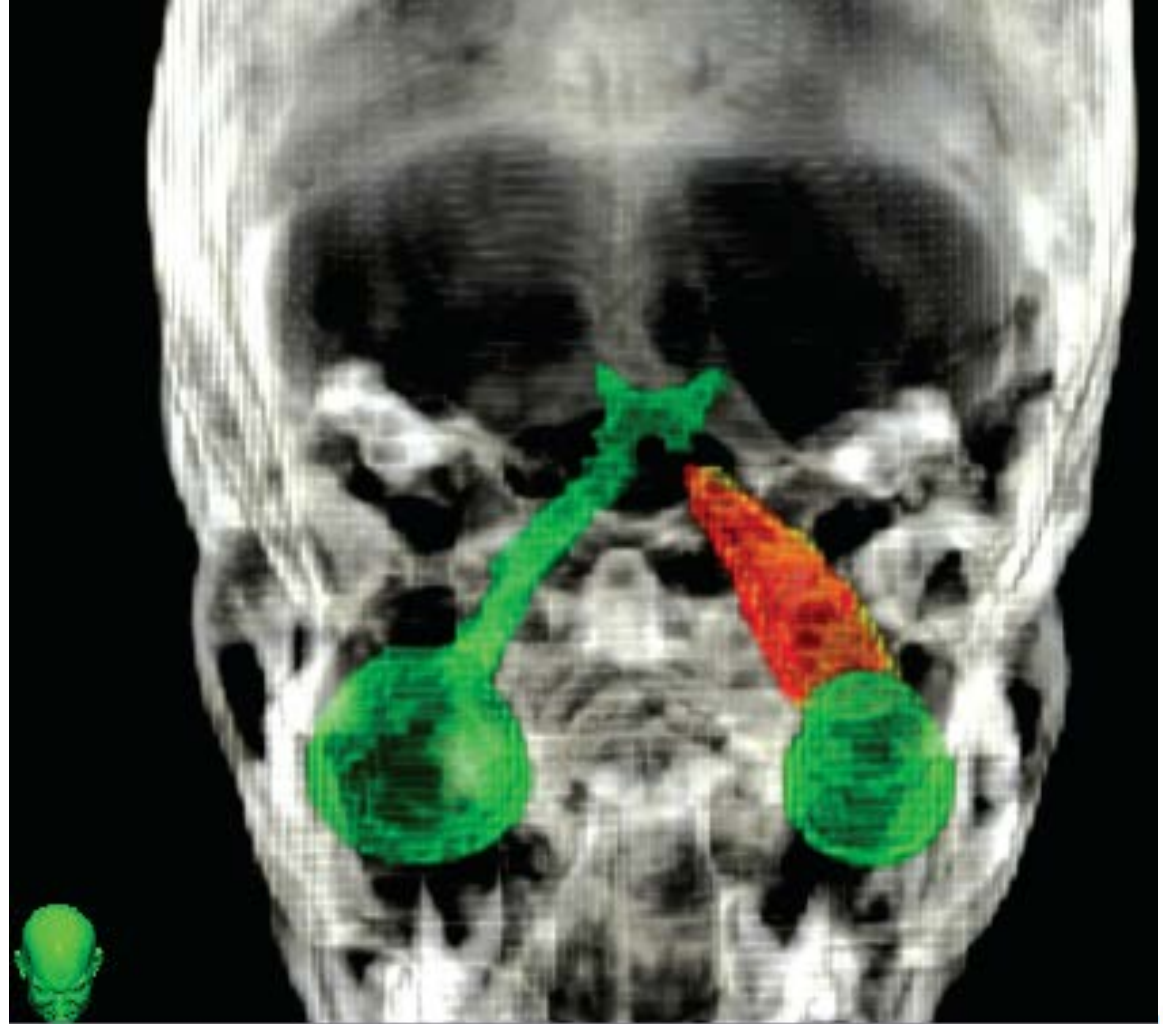
- Optik Sinir Meningioma



İntrakraniyal Cyberknife Uygulamaları

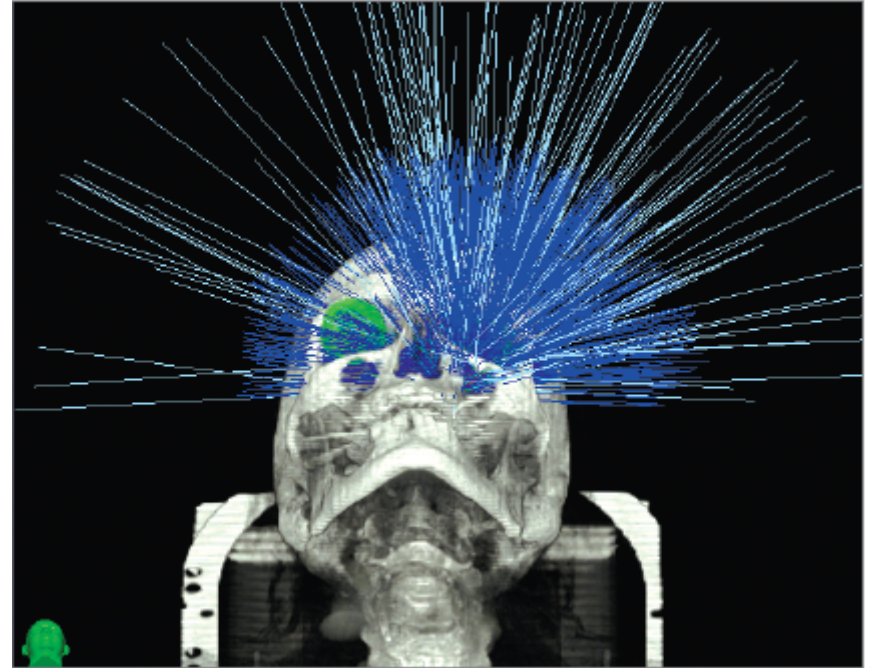
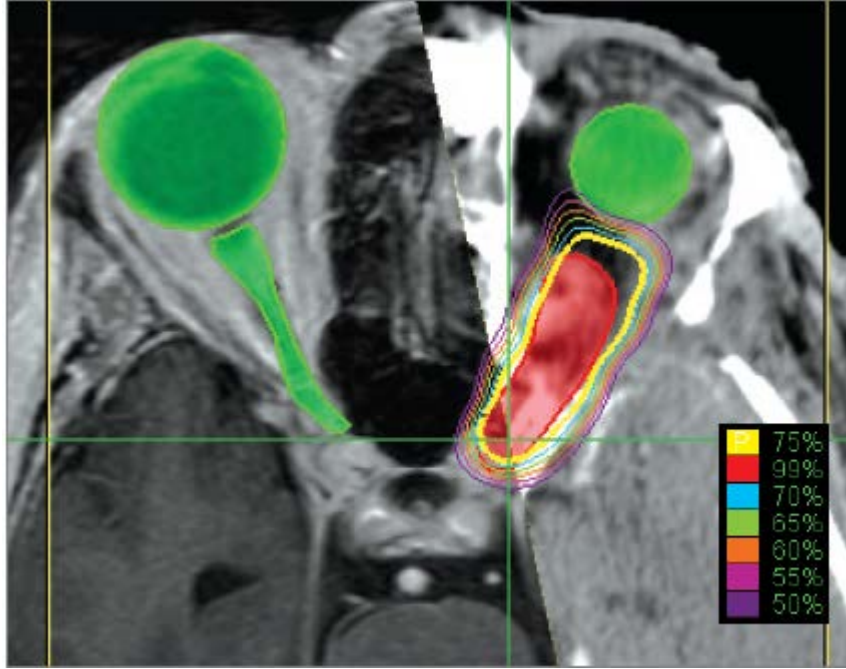
- Optik Sinir Meningioma

- Tümör hacmi 3.1 cc
- Doz: %75/25 Gy/5 fx
- CI: 1.3
- %95.7 kapsama
- 170 ışın
- 10 mm kolimatör



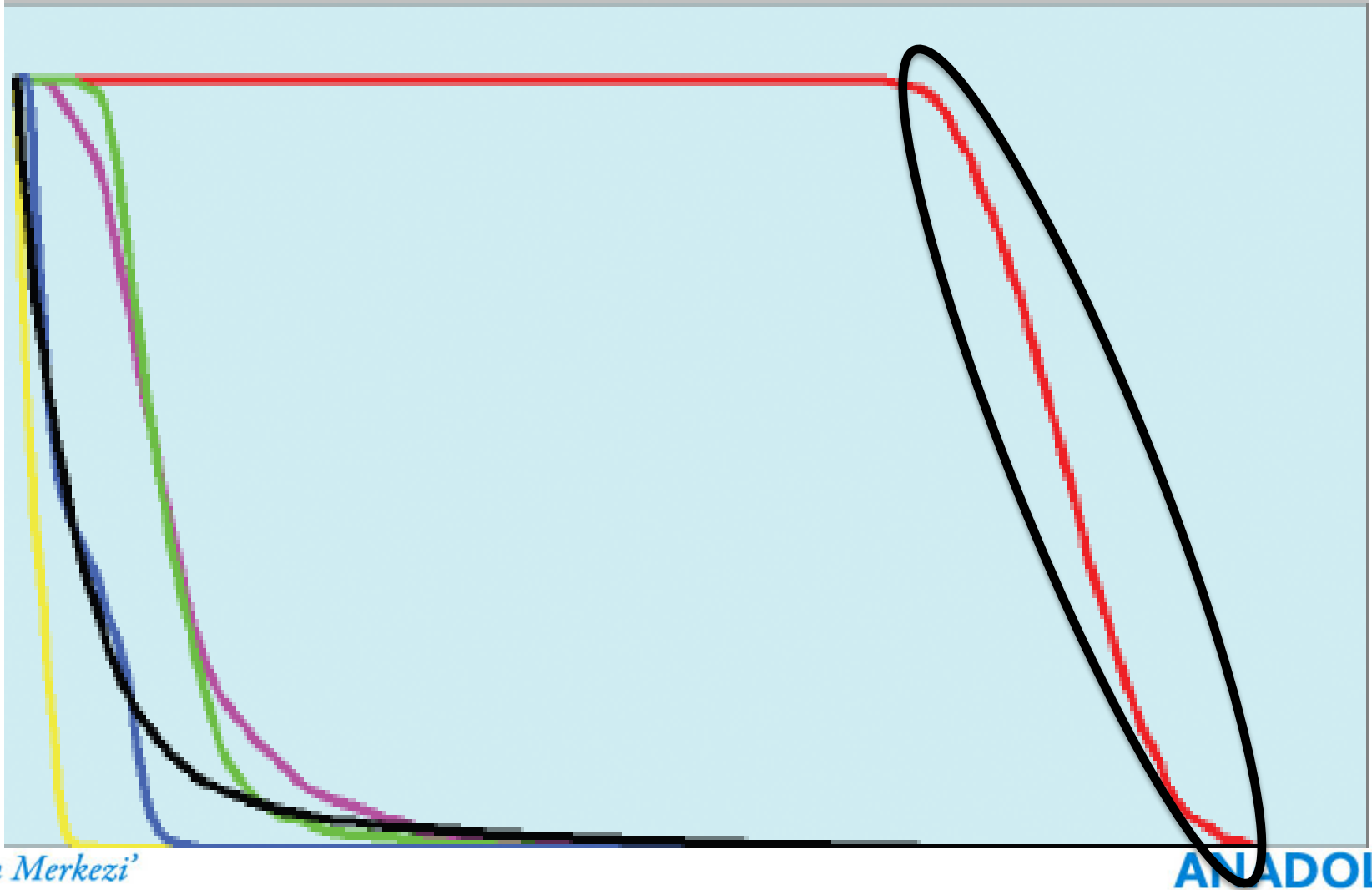
İntrakraniyal Cyberknife Uygulamaları

- Optik Sinir Meningioma



İntrakraniyal Cyberknife Uygulamaları

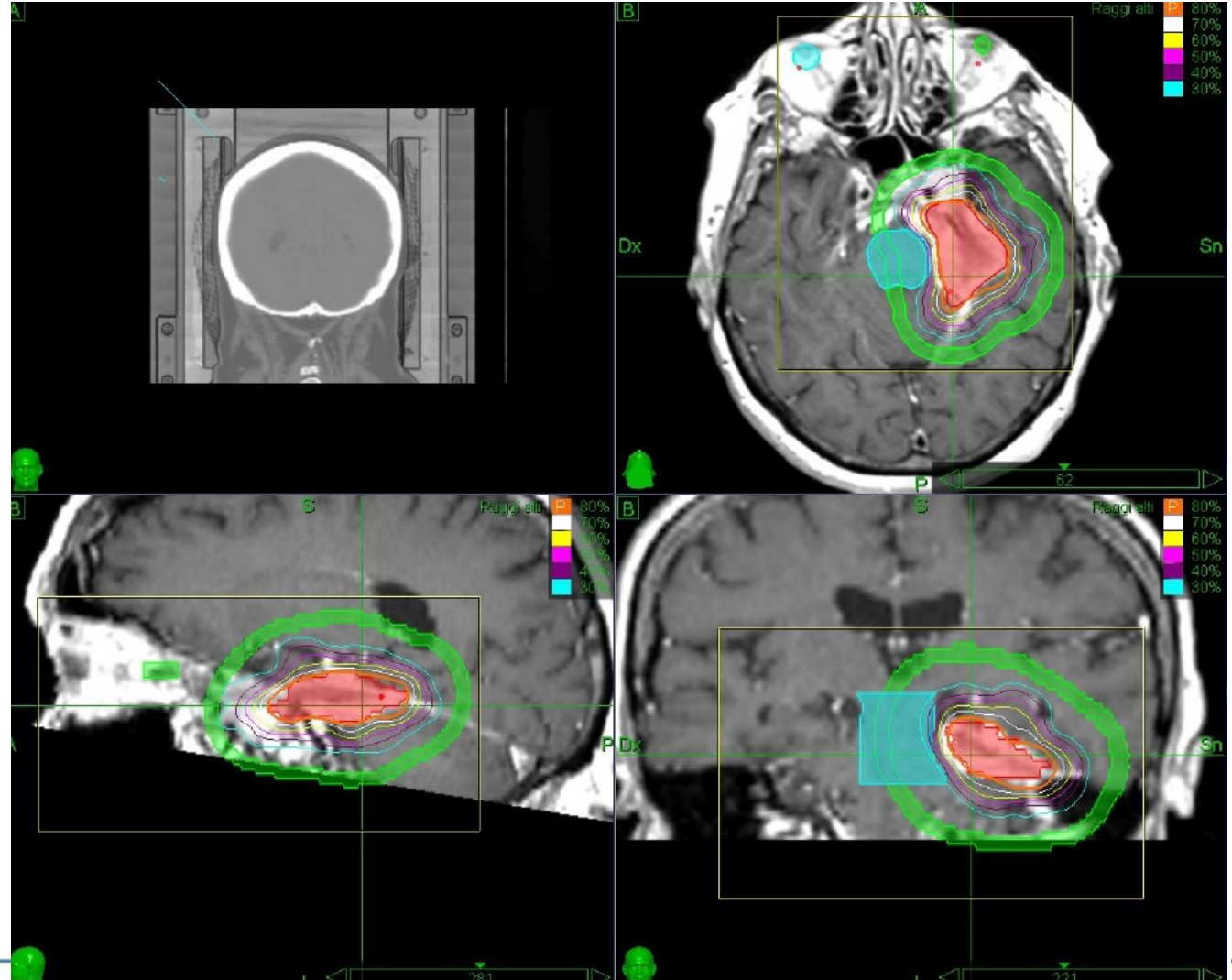
- Optik Sinir Meningioma



İntrakraniyal Cyberknife Uygulamaları

- Kavernoz Sinir Meningioma

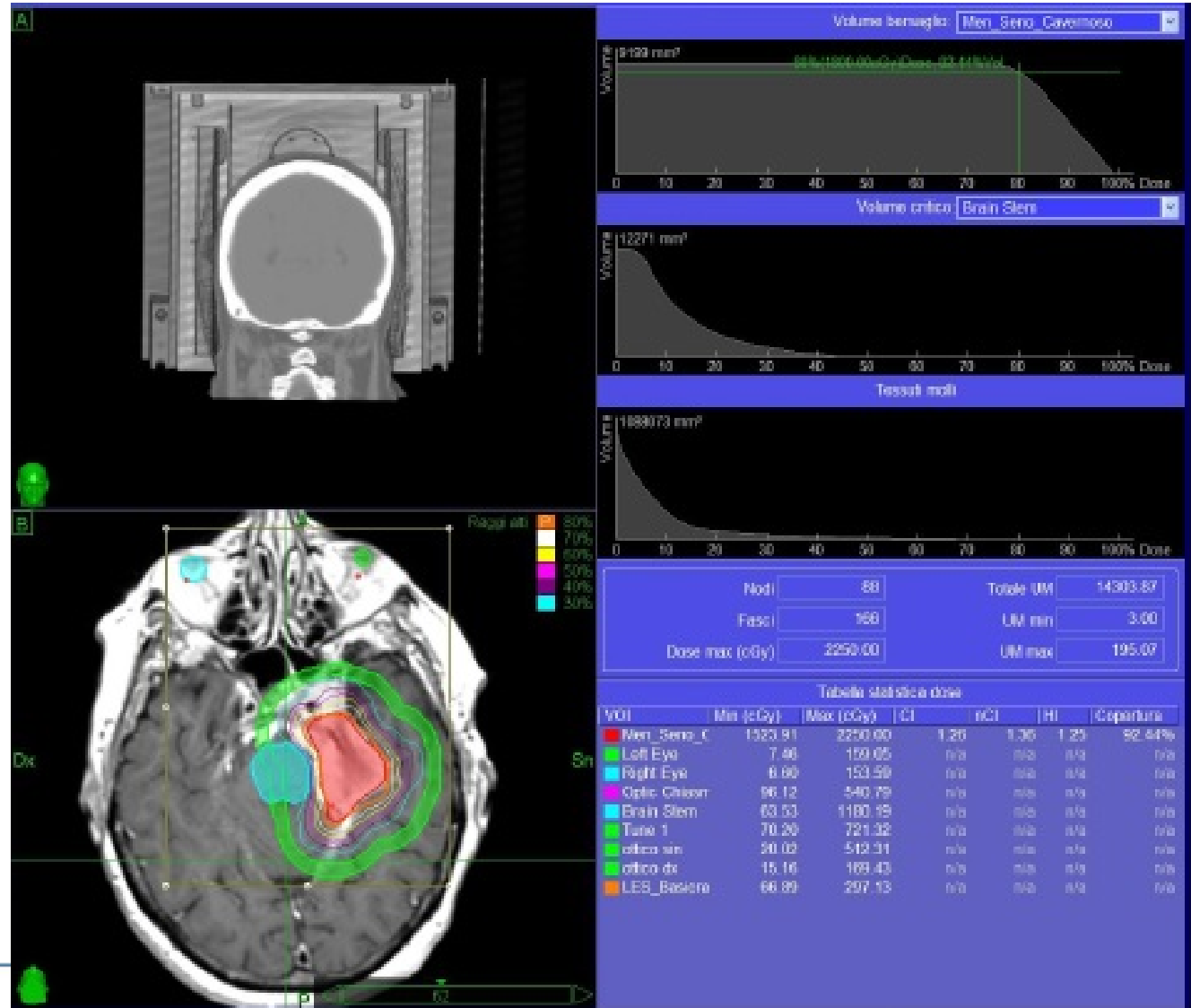
22 Gy/3 fx



İntrakraniyal Cyberknife Uygulamaları

- Kavernoz Sinir Meningioma

Beyin sapı
max doz:11 Gy



İntrakraniyal Cyberknife Uygulamaları

Türk Onkoloji Dergisi 2009;24(4):159-165

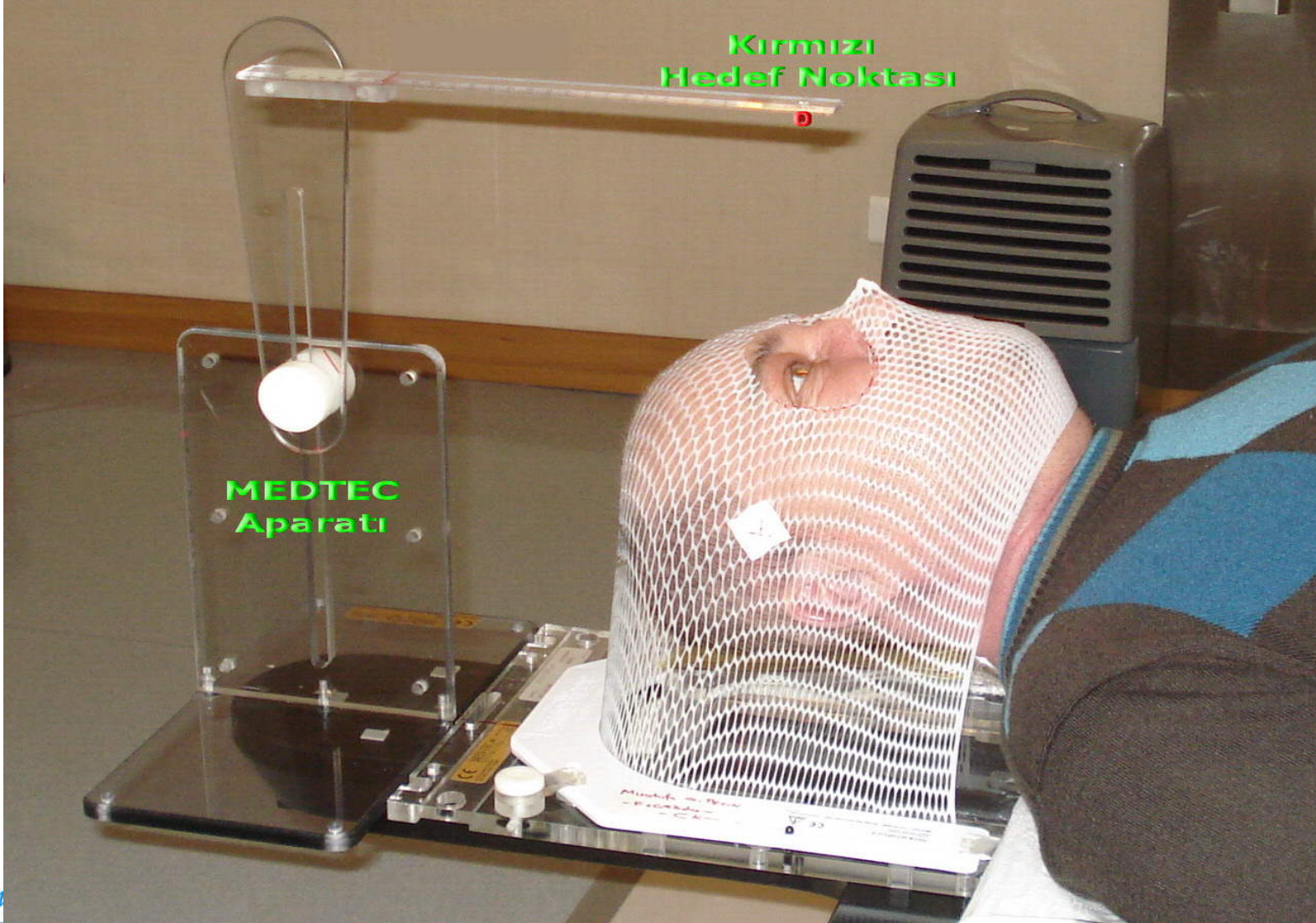
Klinik Çalışma - Araştırma / Original Article

Göz çukuru ve göz içi tümörlerinin CyberKnife® ile tedavisinde basit bir sabitleme ve izleme yöntemi

A simple fixation and monitoring method for treating choroidal and orbital tumors using the CyberKnife® system

İntrakraniyal Cyberknife Uygulamaları

Orbital tümörler



İntrakraniyal Cyberknife Uygulamaları

Orbital tümörler



İntrakraniyal Cyberknife Uygulamaları

Orbital tümörler

Planlama Parametreleri	1.Hasta	2.Hasta
Hedef volüm(mm ³)	1521	1485
Doz(Gy)	20	21
%Referans hedef dozu	84	85
Konformalite indeksi	1,21	1,38
Homojenite indeksi	1,19	1,18
Maksimum plan dozu(Gy)	23,8	24,7
Fraksiyon Sayısı	2	3
Kolimator(mm)	7,5	7,5
Toplam Işın sayısı	173	183
Ort. Fraksiyon süresi(dk.)	38	38
Path sayısı	1	1

İntrakranyal Cyberknife Uygulamaları

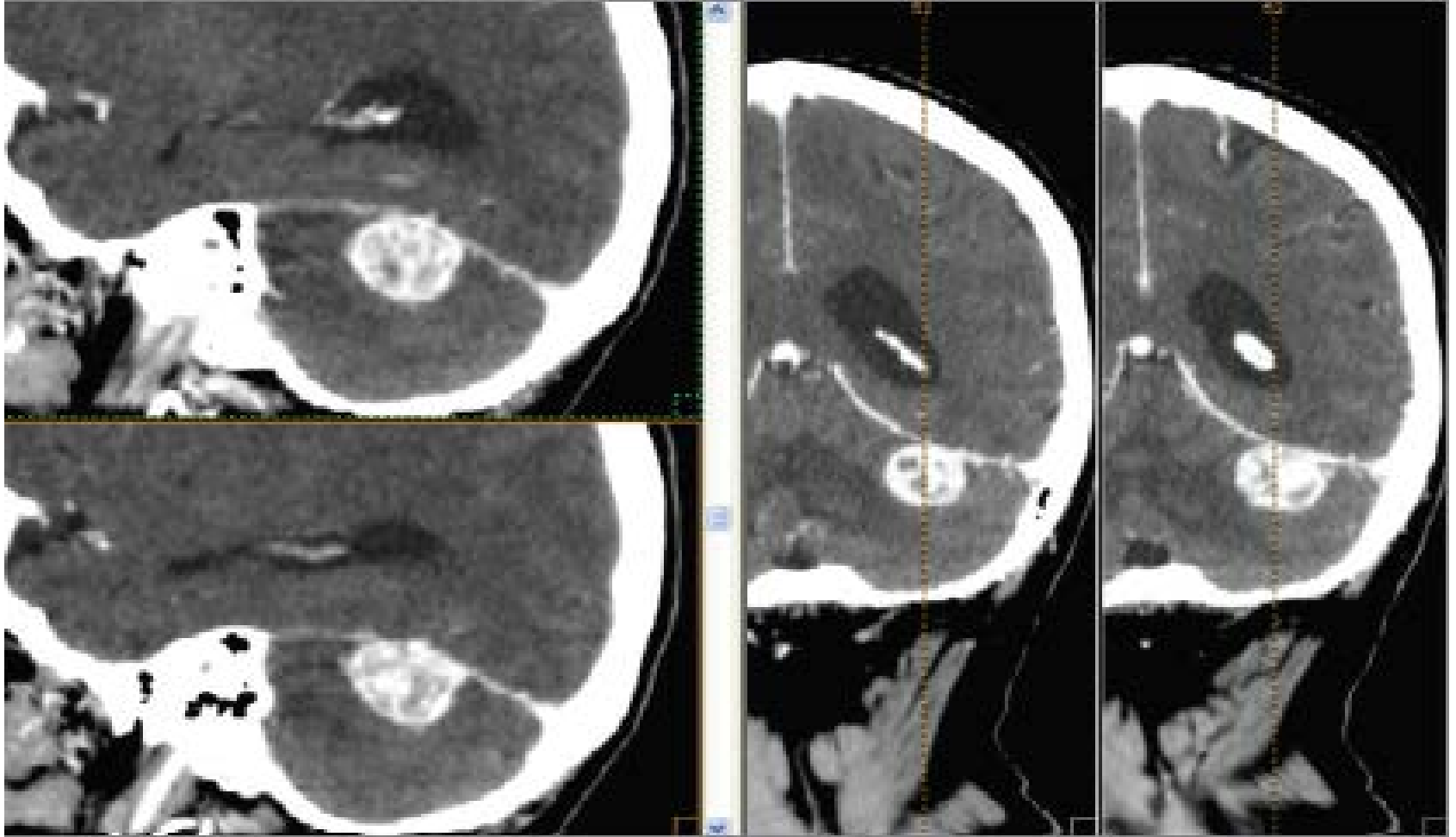
Orbital tümörler



Şekil 5. Tedaviye başlamadan önce kontrol odasındaki monitör üzerine yerleştirilen saydama çizilen hasta lensinin görüntüsü.

İntrakranyal Cyberknife Uygulamaları

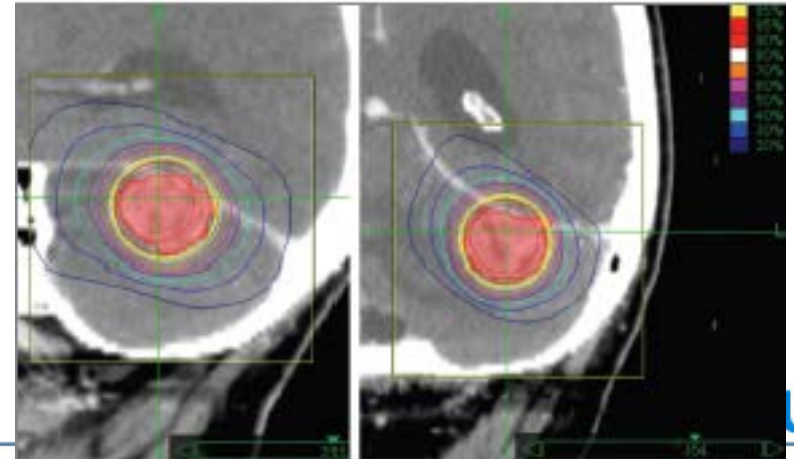
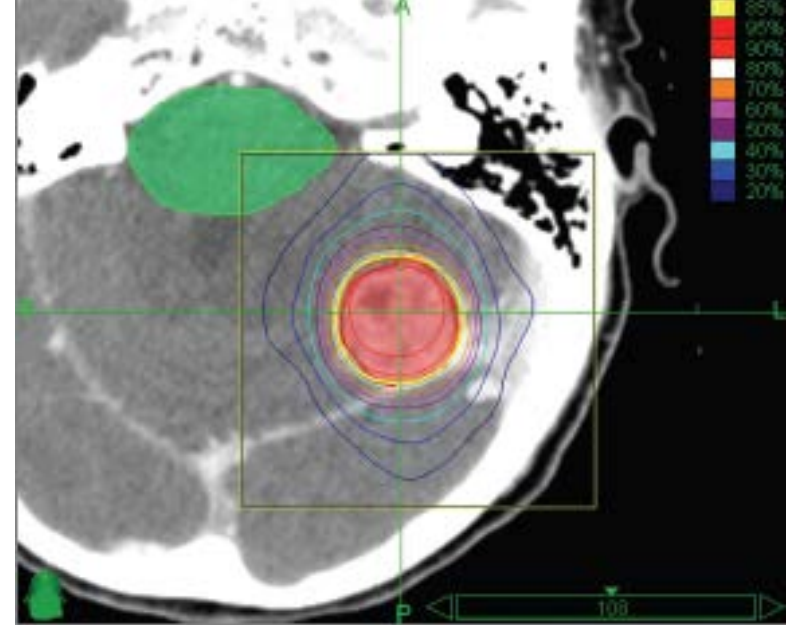
Renal tümör Beyin mtz.



İntrakranyal Cyberknife Uygulamaları

Renal tümör Beyin mtz.

- Tümör hacmi 5 cc
- Doz:%85/18 Gy/1 fx
- CI:1.36
- %95.6 kapsama
- 90 ışın
- 25 mm kolimatör

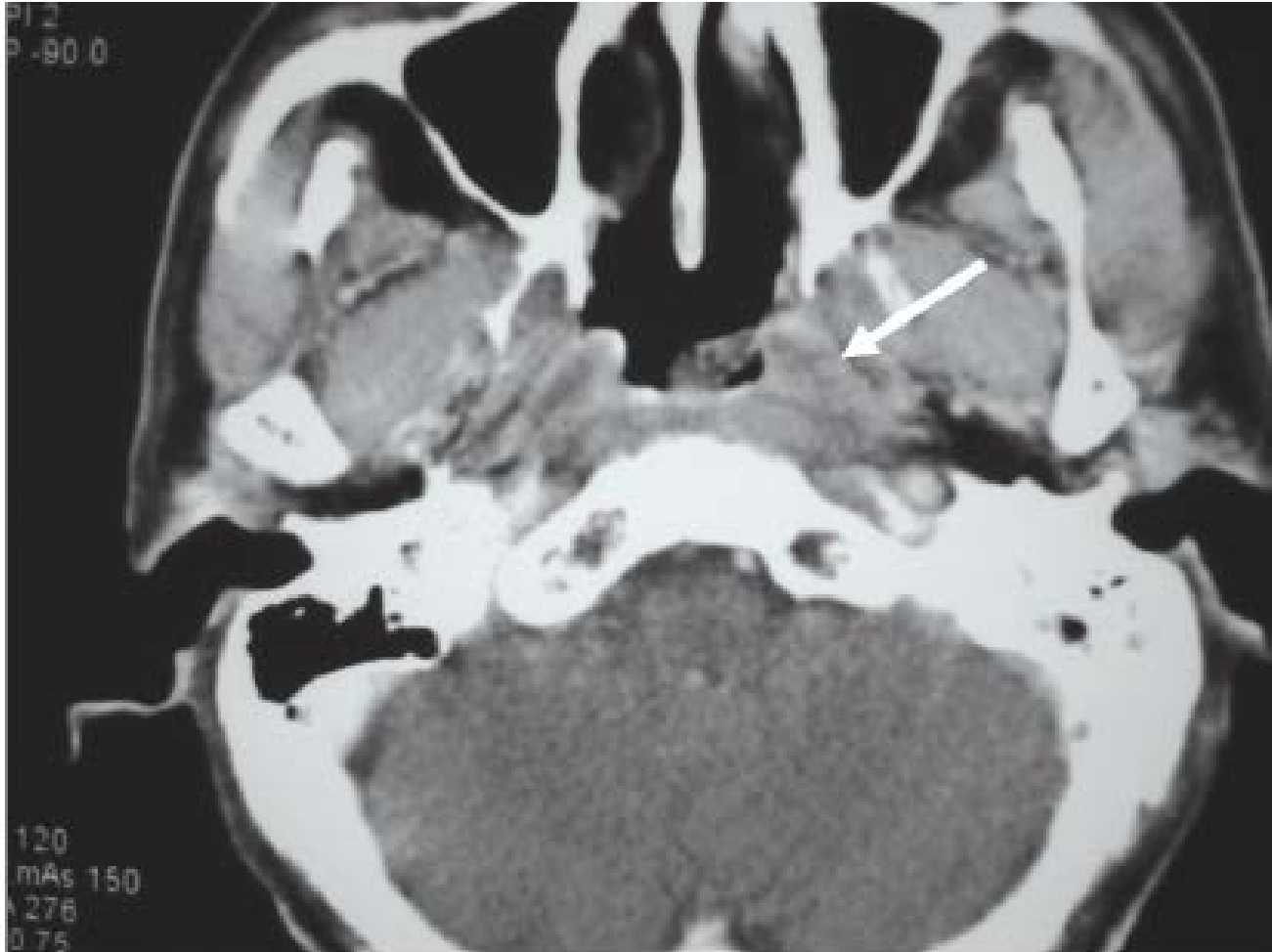


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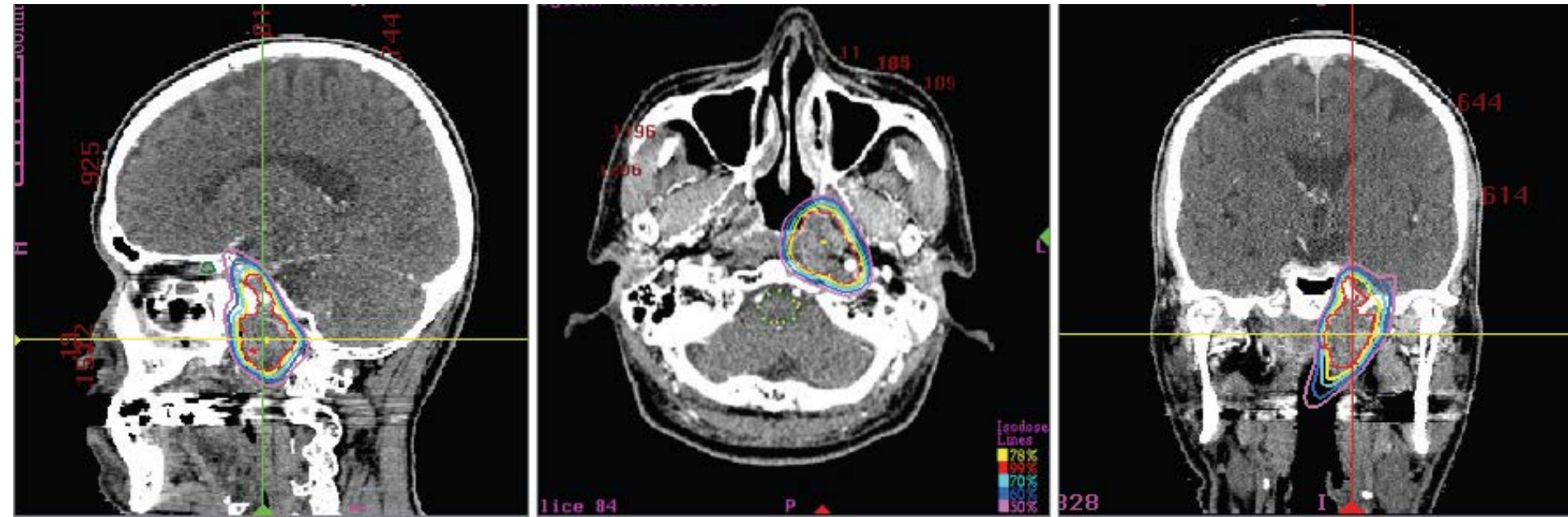
Ekstrakranial Cybernife Uygulamaları

- Nzf nüks



Ekstrakranial Cybernife Uygulamaları

- Nzf nüks

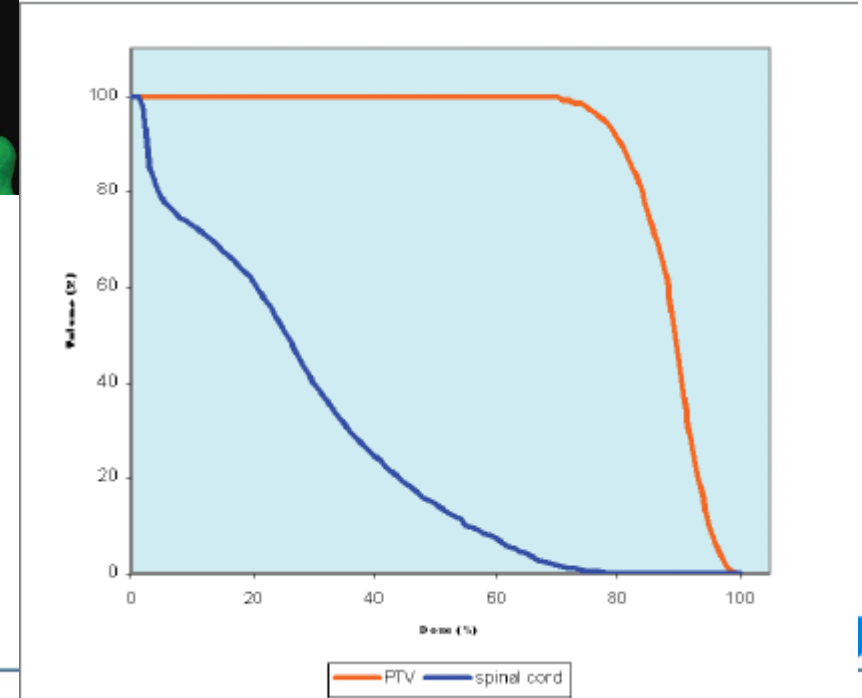
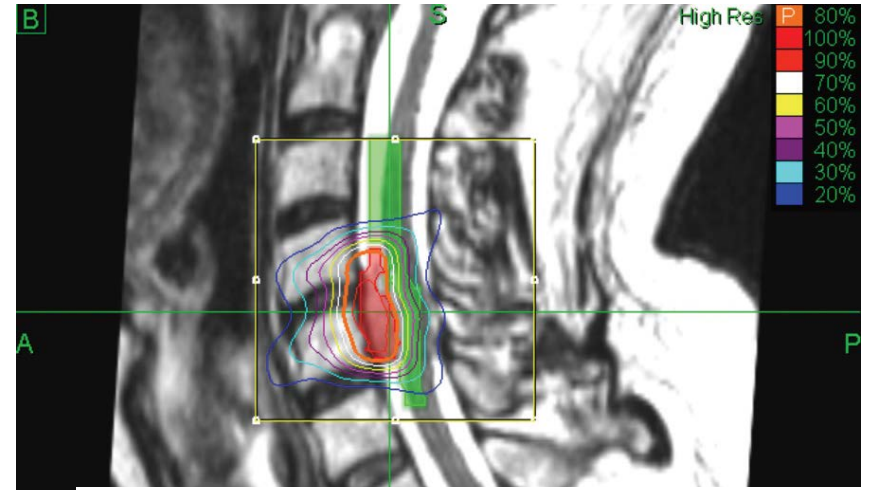
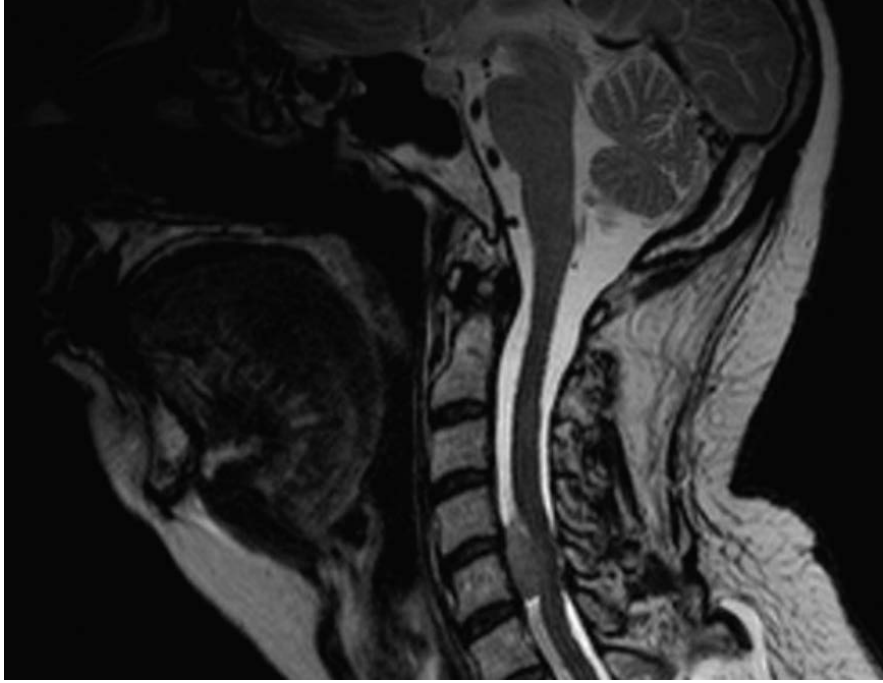


- 27 Gy/3 fx/%78

- 184 ışıın

Ekstrakranial Cybernife Uygulamaları

- Spinal tümörler

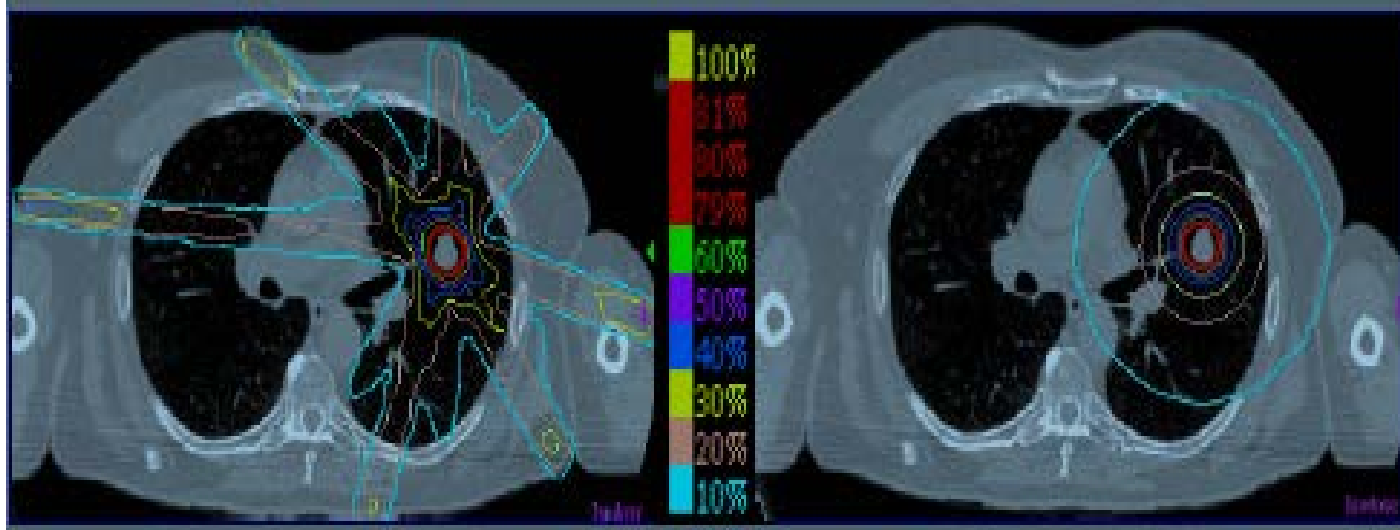


- 5 mm,
- 13 Gy
- %80 izodoz hattı
- Max doz SC 10,5 Gy

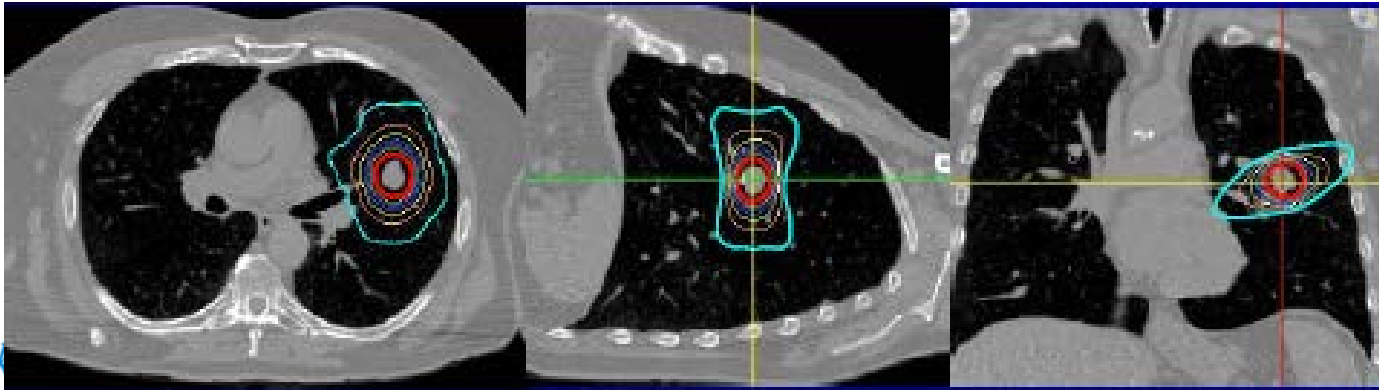
'Sağlığın Merkezi'

Ekstrakranial Cybernife Uygulamaları

- Akciğer



CK

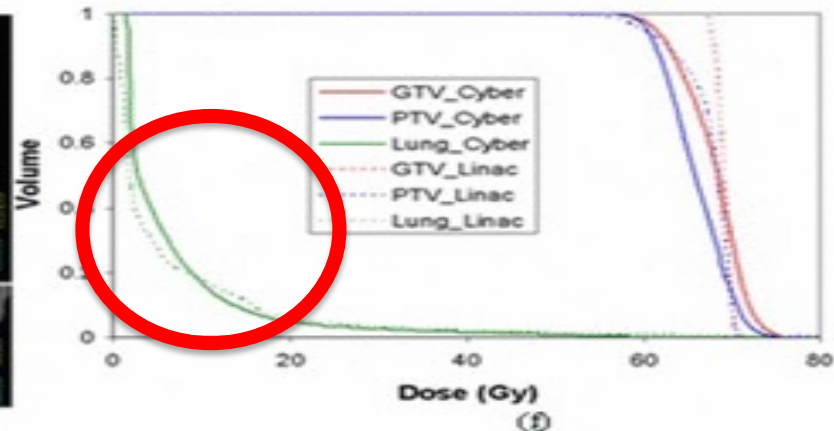
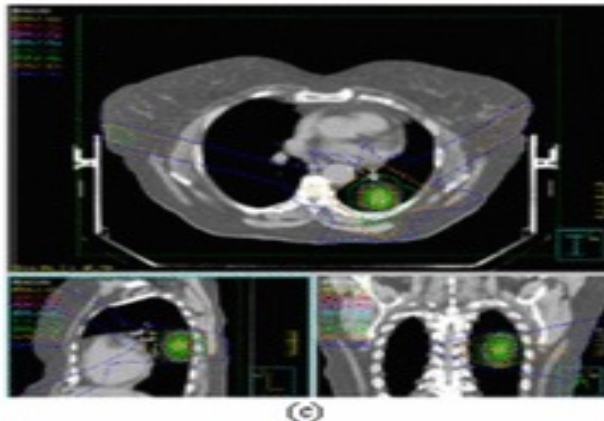
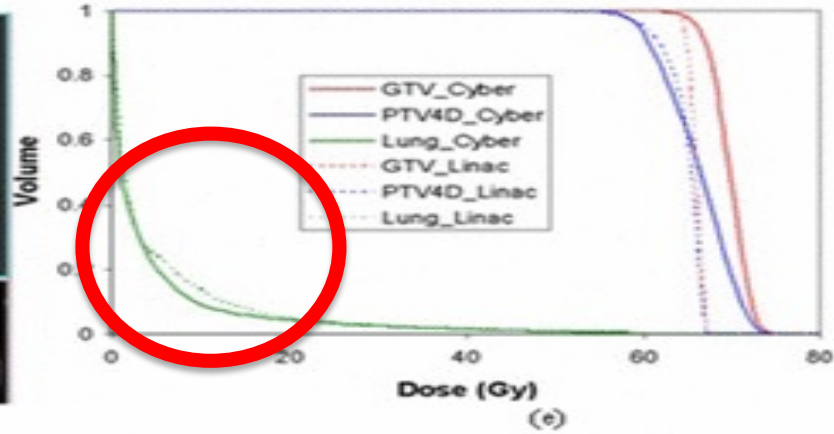
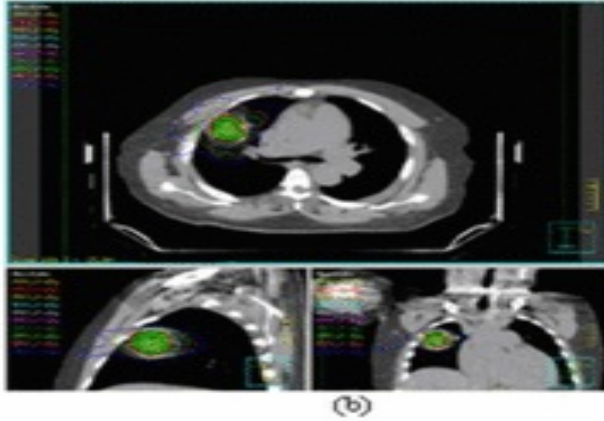
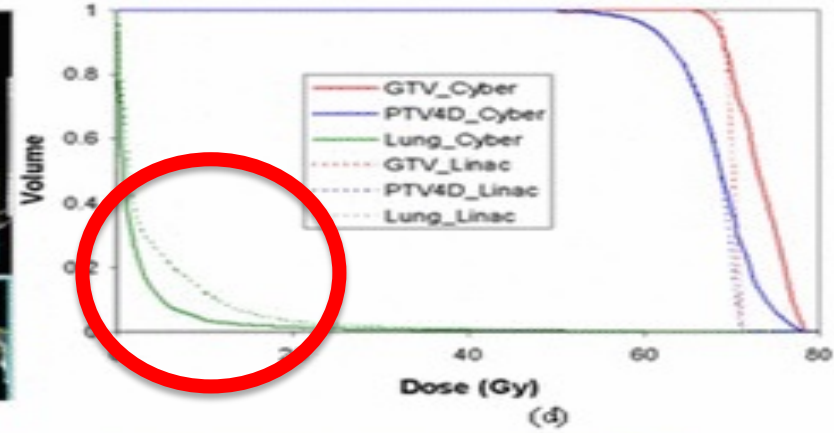
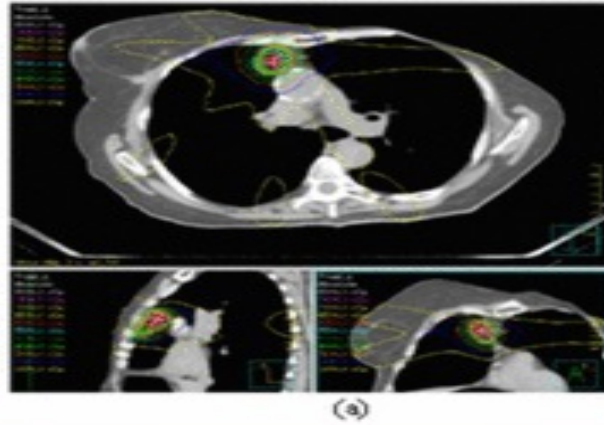


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Ekstrakranial Cybernife Uygulamaları

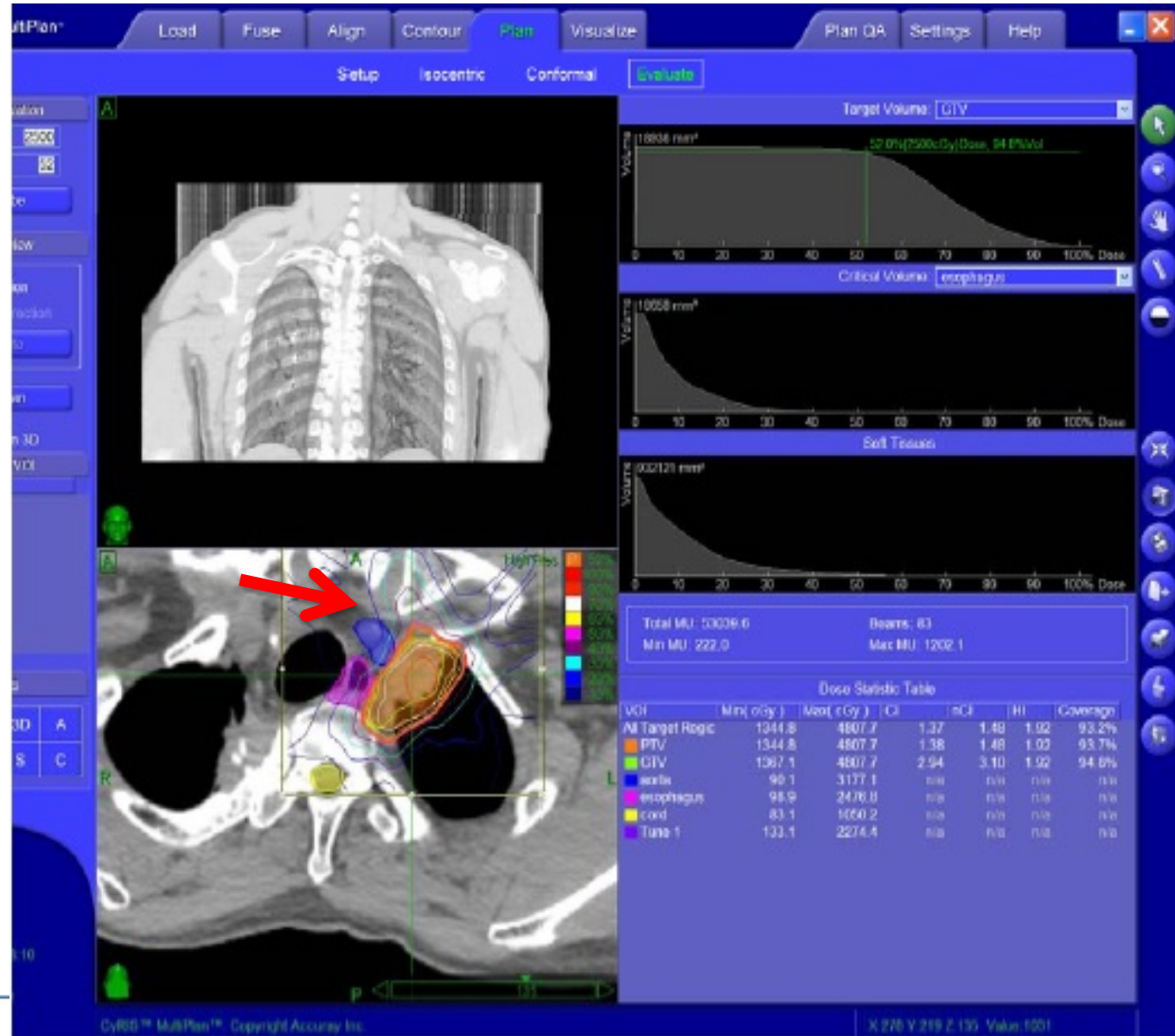
Tümör lokalizasyonu



Ekstrakranial Cybernife Uygulamaları

-Apikal
rekürrens

-Brakial
Pleksus
dozu:
15Gy



Ekstrakranial Cyberknife Uygulamaları

- **Karaciğer metastazları**

ROBOTIC RADIOSURGERY FOR LIVER METASTASES

Kayihan Engin^a, Nadir Kucuk^a, Murat Dokdok^b, Tayfun Enunlu^c, Kezban Berberoglu^d, Hande Ayata^a, Cemile Ceylan^a, Ayhan Kılıc^a, Metin Guden^a

^aRadiation Oncology, ^bRadiology, ^cStatistic Department, ^dNuclear Medicine,
Anadolu Medical Center, Kocaeli, Turkey

www.cureus.com

Ekstrakranial Cyberknife Uygulamaları

- Karaciğer metastazları**

Table 2. Patients and tumor characteristics

Characteristic	Value
# of Patients	55
# of treated lesions	84
Single lesion	37 pts (67%)
2 lesions	7 pts (13%)
3 lesions	11 pts (20%)
Gender	
Male	32 pts (58%)
Female	23 pts (42%)
Age	
Median	59 years
Mean	60.7 years
Range	22-86 years
Time from primary diagnosis to first metastasis	
Median	17 months
Range	0-151months
Time from first liver metastasis to rSBRT	
Median	6 months
Range	0-15 months
Metastases except liver during rSBRT	
None	33 pts (60%)
Multiple (≥2 different sites)	4 pts (7%)
Lung	9 pts (17%)
Bone	5 pts (9%)
Other sites (single location)	4 pts (7%)
Received chemotherapy during rSBRT	
Yes	44 pts (80%)
No	11 pts (20%)
Tumor volume	
Mean	40,48 cc
Range	3.8 cc-336 cc

Ekstrakranial Cyberknife Uygulamaları

- Karaciğer metastazları**

Table 3. Dose constraints for OARs

Critical Structure	Dose Constraint
Liver	≥ 700 cc ≤ 15 Gy
Kidneys	$V_5 < \%75$, $D_{max} < 15$ Gy
Spinal cord	$D_{max} < 18$ Gy
Stomach	$V_{20} < \%5$, $D_{max} < 25$ Gy
Duodenum	$V_{20} < \%5$, $D_{max} < 25$ Gy
Bowel	$V_{20} < \%5$, $D_{max} < 25$ Gy
Lungs	$V_{15} < \%5$, $D_{max} < 18$ Gy
Heart	$D_{max} < 25$ Gy

V_n -Organ volume that receives a dose of n Gy or less,
 D_{max} - Maximum point dose in the organ

Table 4. Dose-volume characteristics of rSBRT

Characteristic	Value	
Total liver volume	Mean	1571,8 cc
Collimator size	Median	20 mm
	Range	10 mm-35 mm
Prescription dose	Median	45 Gy
	Range	24 Gy-45 Gy
# of fraction	Median	3
	Range	3-6
Prescribed isodose line	Median	80%
	Range	70%-85%
Conformality index	Median	1.22
	Range	1.06-1.94
Homogeneity index	Median	1.25
	Range	1.18-1.43

Ekstrakranial Cyberknife Uygulamaları

- Karaciğer metastazları**

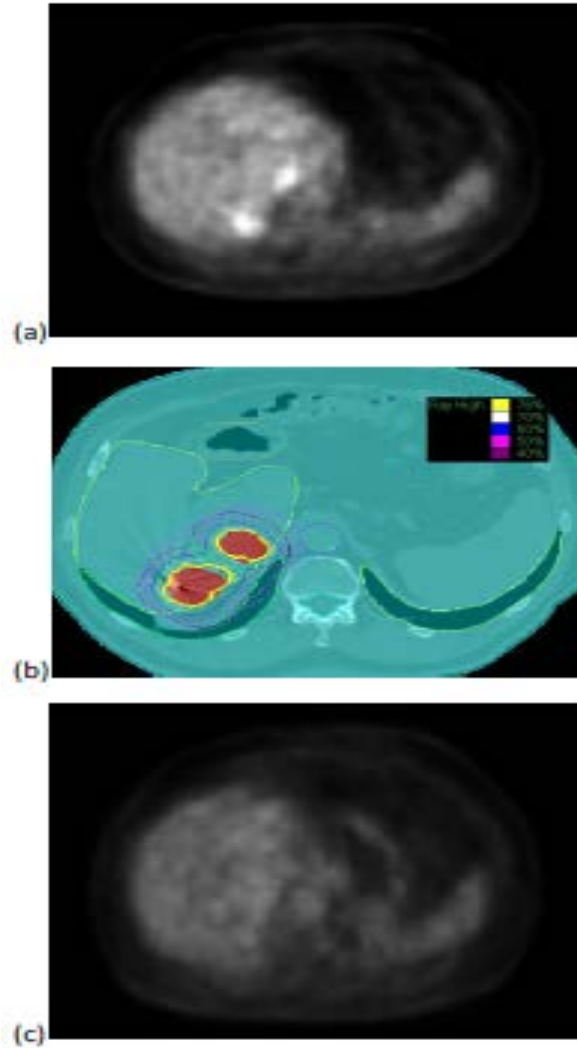
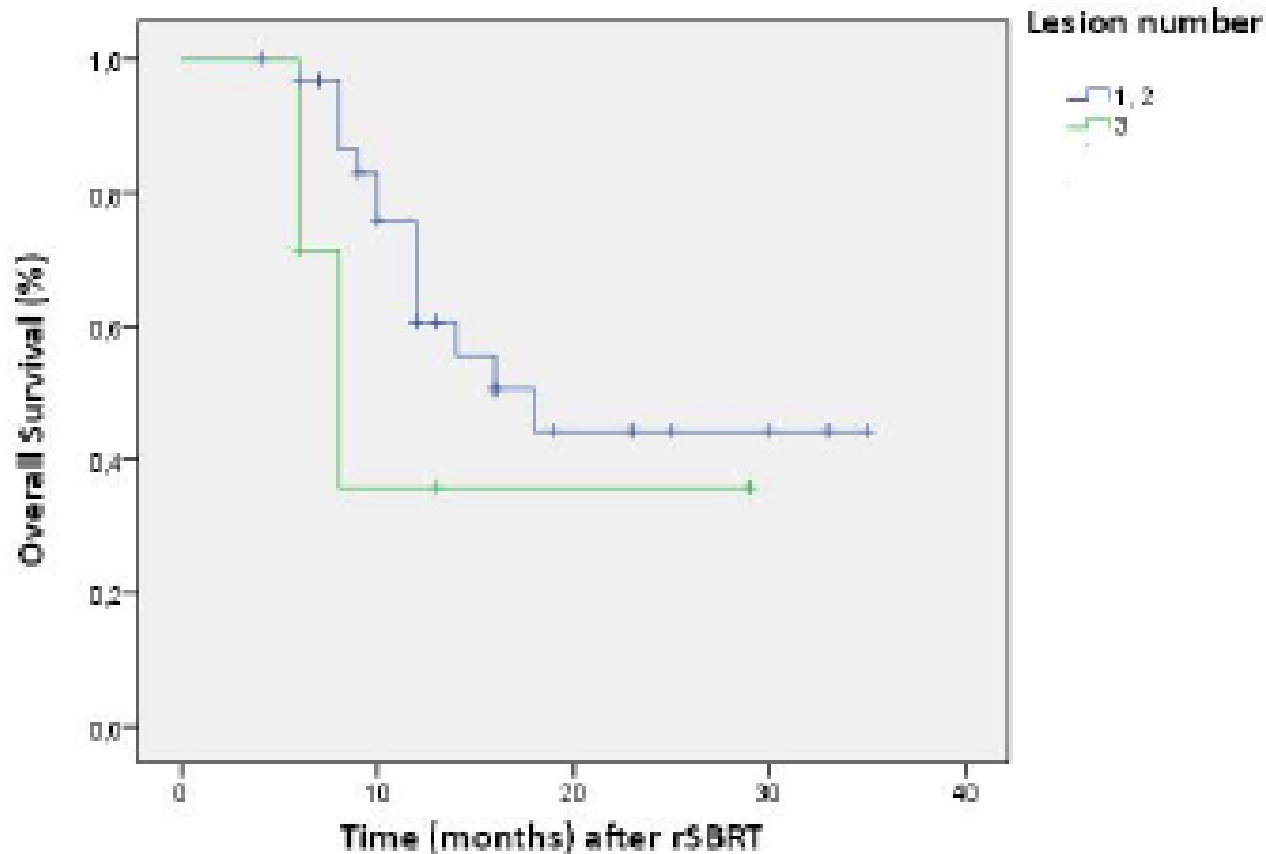


Figure 1. An example of CR with continued local control in a patient with metastatic colorectal cancer (a) axial view of lesions in PET before rSBRT, (b) treatment planning showing dose distribution, (c) PET image after 6 months from rSBRT

Ekstrakranial Cyberknife Uygulamaları

- Karaciğer metastazları



Ekstrakranial Cyberknife Uygulamaları

- Prostat

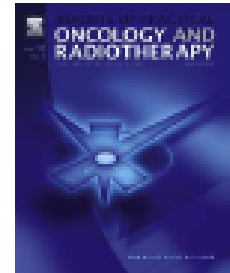
REPORTS OF PRACTICAL ONCOLOGY AND RADIOTHERAPY 15 (2010) 181–189



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Original article

Dosimetric and physical comparison of IMRT and CyberKnife plans in the treatment of localized prostate cancer

Cemile Ceylan*, Nadir Kucuk, Hande Bas Ayata, Metin Guden, Kayihan Engin

Anadolu Medical Center, Radiation Oncology, Anadolu Caddesi, No. 1 Gebze, 41400 Kocaeli, Turkey

Ekstrakranial Cyberknife Uygulamaları

- Prostat

Table 1 – IMRT plan dose prescription of PTV, bladder, rectum and femoral heads.

Structure	Type	Rank	Objective	Dose (cGy)	Volume (%)	Weight	Power
PTV	Target	1	Max	7550	0	100	2.4
			Min	7474	100	200	2.9
Bladder	OAR	2	Dose volume	5000	25	100	2
			Dose volume	3100	50	100	
Rectum	OAR	3	Dose volume	5000	17	100	2
			Dose volume	3100	35	100	
Right femoral heads	OAR	4	Max	5000	0	100	2
Left femoral heads	OAR	4	Max	5000	0	100	2
Patient	OAR	5	Max	4500	0	100	2

IMRT

Table 2 – An accepted IMRT plan index PTV and OAR's according to defined criteria.

PTV	Bladder	Rectum	Right femoral head	Left femoral head	Global max of the plan	Segment number
Max Dose (Gy): 79.40	77.45	78.44	39.21	39.42	79.40	67
Min Dose (Gy): 71.96	0.52	1.11				
Mean dose (Gy): 75.63	20.12	25.92				
CI: 0.97 ^a	>70 Gy V7%	>70 Gy V7%				
HI: 0.91 ^b						

^a CI: conformity index of plans according to Eq. (1).

^b HI: homogeneity index of plans according to Eq. (2).

CK

Table 3 – The CyberKnife plan dose prescription index.

Structure	Type	Objective
PTV	Target	Max Dose (cGy): 48 Min Dose: 36.25
Bladder	OAR	Max Dose (Gy): 32
Rectum	OAR	Max Dose (Gy): 32
Urethra	OAR	Max Dose (Gy): 41.69

Ekstrakranial Cyberknife Uygulamaları

- Prostat

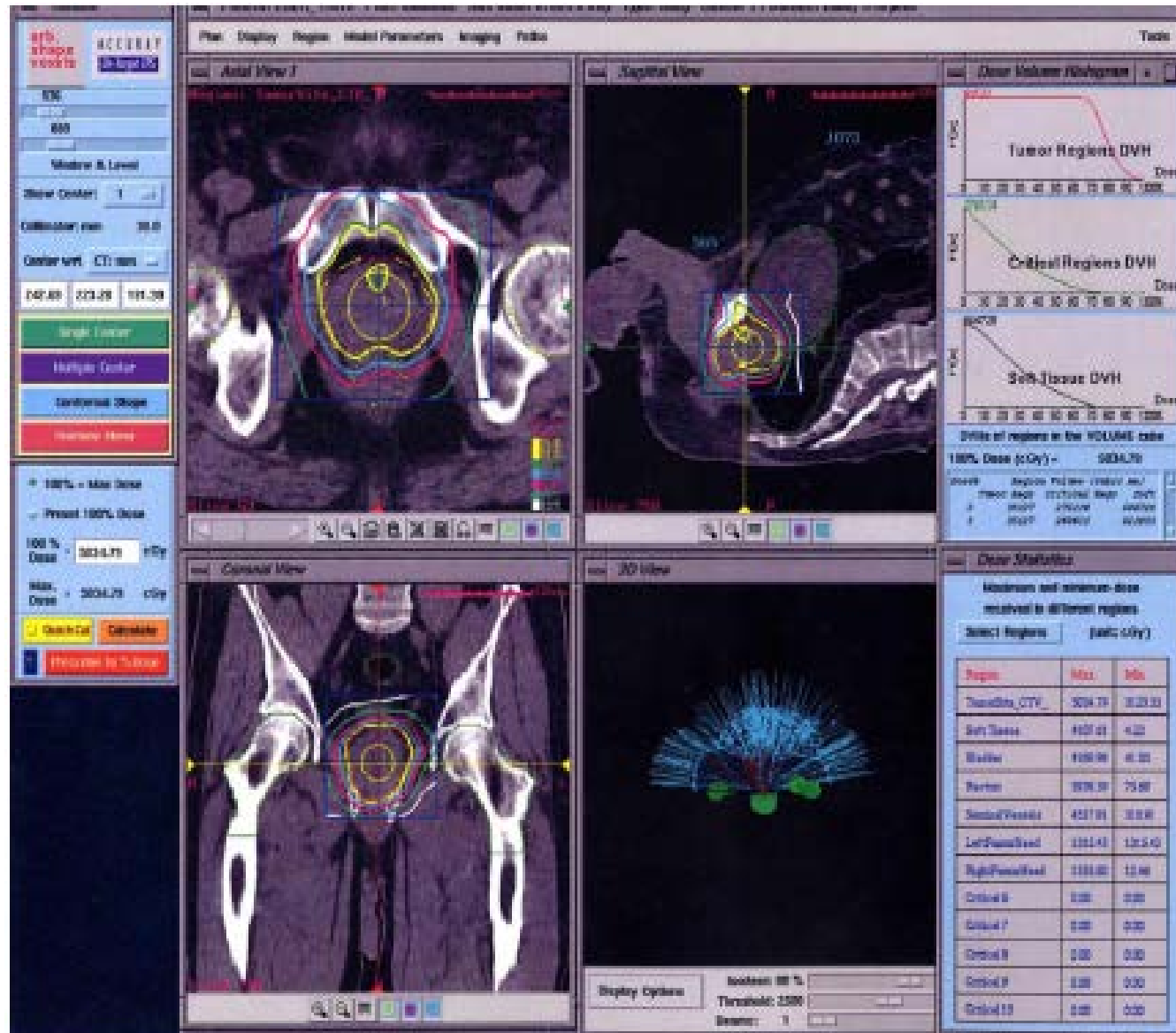


Fig. 4 – Treatment plan screen of the CyberKnife.

Ekstrakranial Cyberknife Uygulamaları

- Prostat

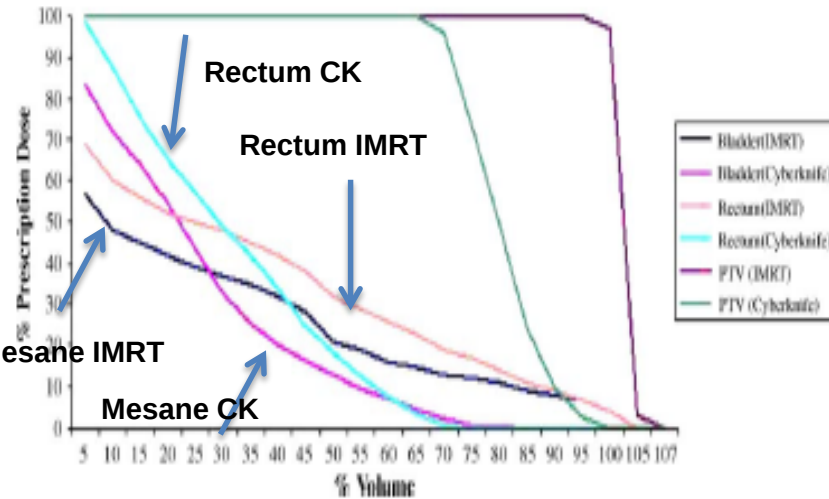


Fig. 7 - DVH comparison of the CyberKnife and IMRT plans for a patient.

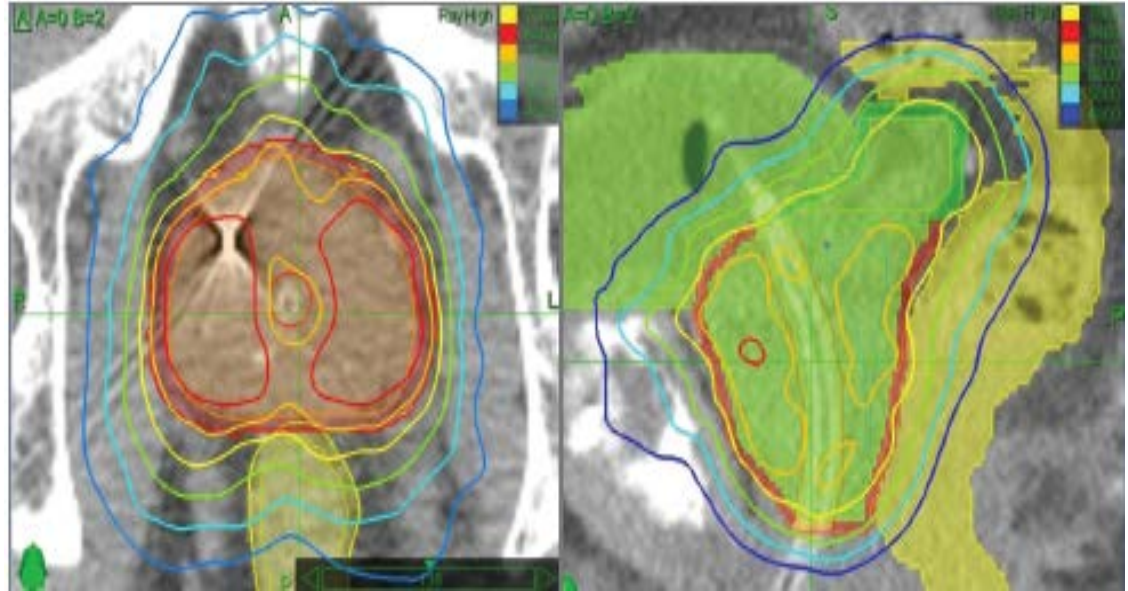
Table 4 – Median percent doses for bladder and rectum volumes in all patients. V10, V33, V50, V66 and V100 denote percentage volumes of organs that 10%, 33%, 50%, 66% and 100% of volumes, respectively. Table presents CI, HI and maximum and minimum doses for PTV as a percent of prescription dose.

	Median doses		p Value
	IMRT	CK	
%Bladder volume			
V10	96.25%	47.80%	<0.001
V33	33.75%	23.75%	0.047
V50	5.40%	13.40%	0.432
V66	3.45%	8.05%	0.198
V100	0.85%	0.10%	0.02
%Rectum volume			
V10	96.30%	57.05%	<0.001
V33	59.00%	35.10%	<0.001
V50	38.48%	27.45%	0.019
V66	12.73%	20.95%	0.287
V100	2.05%	2.60%	0.049
PTV			
CI	0.94	1.23	<0.001
HI	1.08	1.33	<0.001
Maximum percentage dose	108%	133%	
Minimum percentage dose	95.30%	86%	

Ekstrakranial Cyberknife Uygulamaları

- **Cyberknife Prostat IMRT, Cleveland**

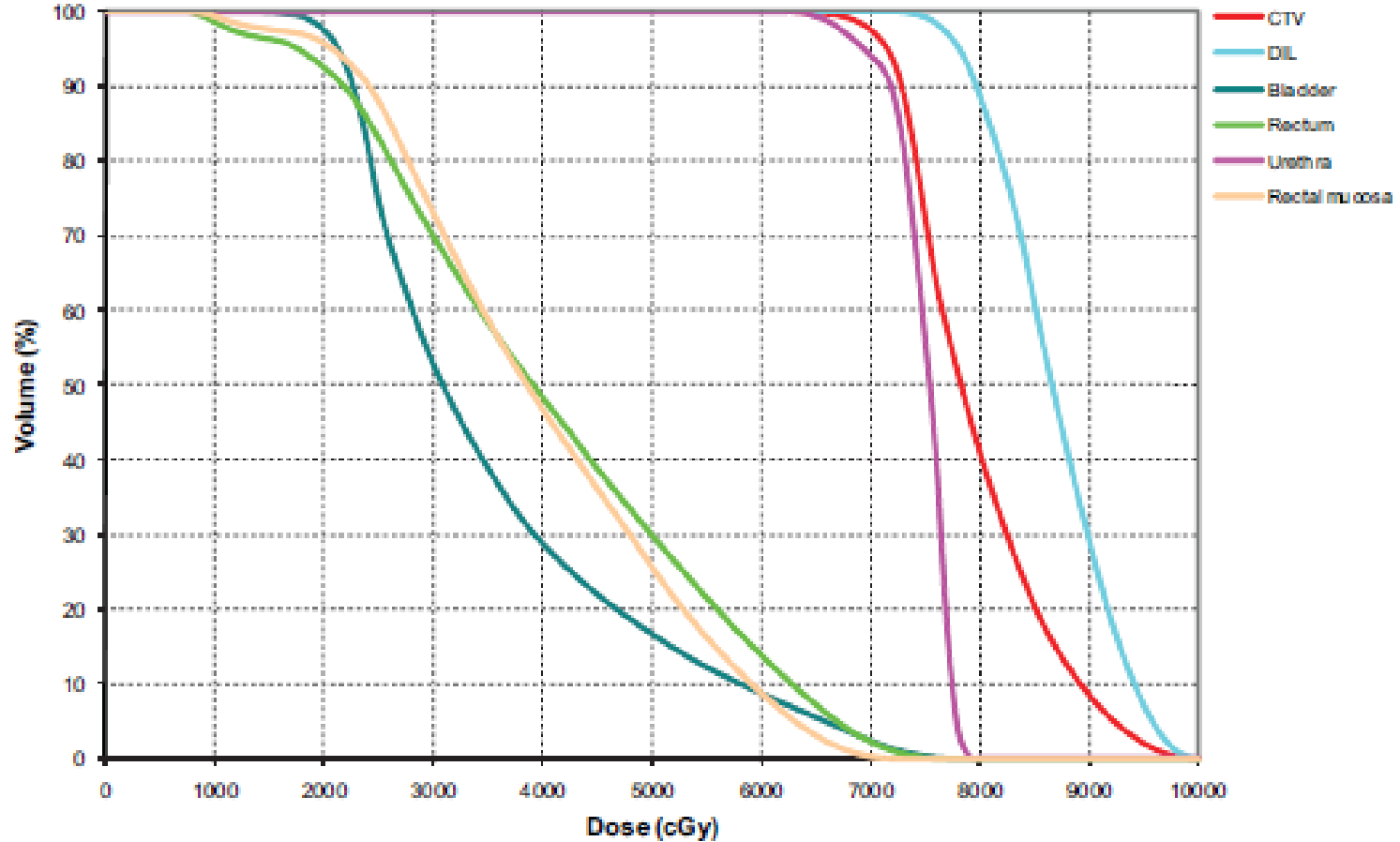
- GTVdozu>84 Gy
- CTV=SV+3mm
Ap/Pa,5 mm lateral
- CTV dozu=70
Gy/%70 PD/28 fx
- SIB



Dosimetric parameter	Current case	Cleveland Clinic ^{1,2}
Mean prostate dose	80 Gy	75 Gy
Mean urethra dose	75 Gy	Not reported
Rectal V70Gy	1.7 cc	8 cc
Bladder V70Gy	4 cc	7 cc

Ekstrakranial Cyberknife Uygulamaları

- Cyberknife Prostat IMRT, Cleveland



SONUÇ

- **Cyberknife SRS ve SBRT tedavilerinde doz hedeflemesini mükemmel yapan yazılımlara sahiptir.**
- **Hareketli organlarda gerçek zamanlı tümör takibi yapabilmektedir.**
- **Birçok vakada OAR koruması çok daha iyidir.**
- **Son dönemde yeni konsepti ile IMRT tedavilerine olanak sağlanmıştır.**

SON SÖZ

- Bu sunum için ilgili firmadan hiçbir maddi veya manevi destek alınmamıştır.
- Firma tarafından slayt önerisi yapılmamış ve slayt sürümünden haberleri olmamıştır.