

CyberKnife ve Uygulamaları



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Medikal Fizik Kongresi Kayseri-2005

1990

Accuray

John Adler

1994

Prototip Cyberknife

Stanford Uni.

1994

FDA gözetimi

Klinik deneyler(IKT)

1999

FDA gözetimi

Klinik deneyler(EKT)

2001

FDA onayı



CyberKnife

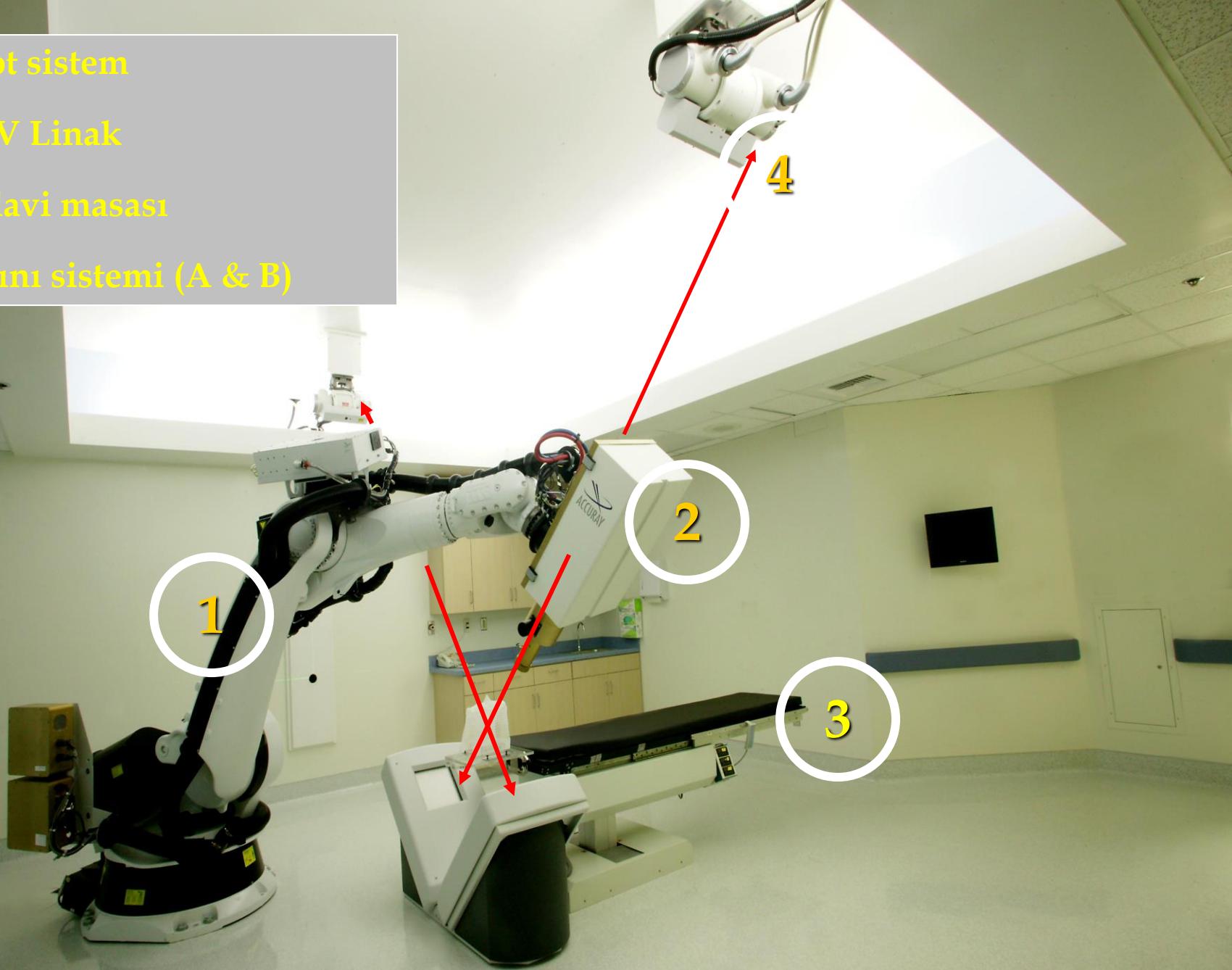
- ✓ Robot tekniği ile non-izosentrik & non-coplanar ışınlama
- ✓ Tedavinin başında ve tedavi süresince otomatik hasta setup'ı
- ✓ Yüksek konformaliti, riskli organların & sağlıklı dokunun maksimum korunması
- ✓ Organ hareketini gözönüne alarak ışınlama
- ✓ Hızlı doz düşüşü
- ✓ 1 mm altında hata ile ışınlama
- ✓ Bir veya birden fazla fraksiyon

1 robot sistem

2 6 MV Linak

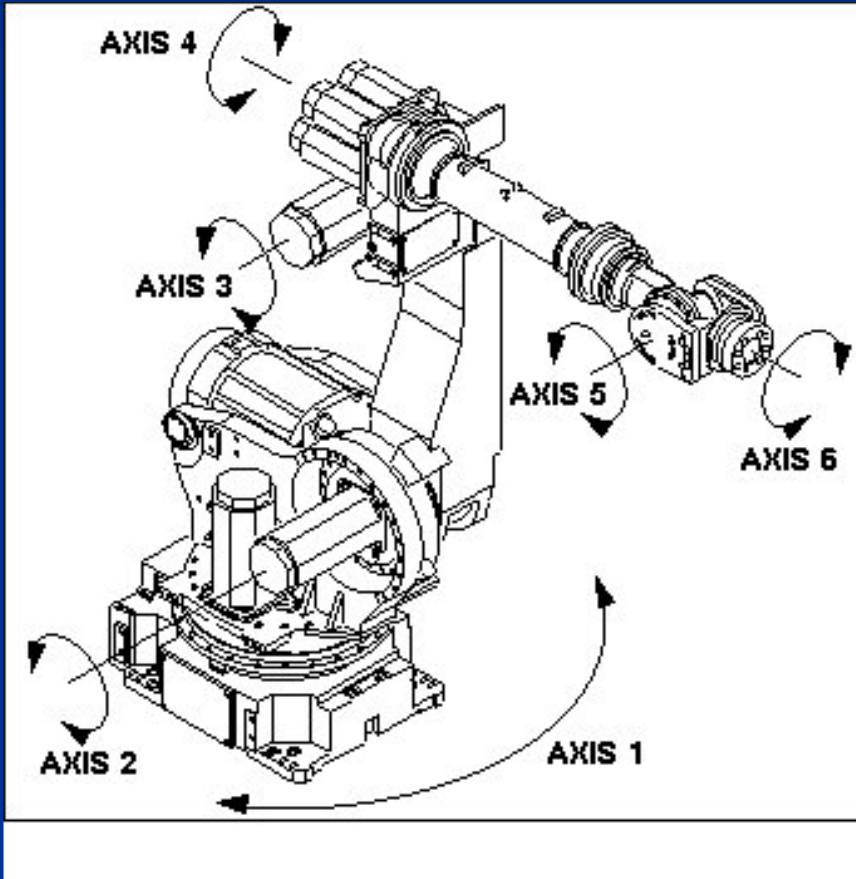
3 Tedavi masası

4 x-ışını sistemi (A & B)



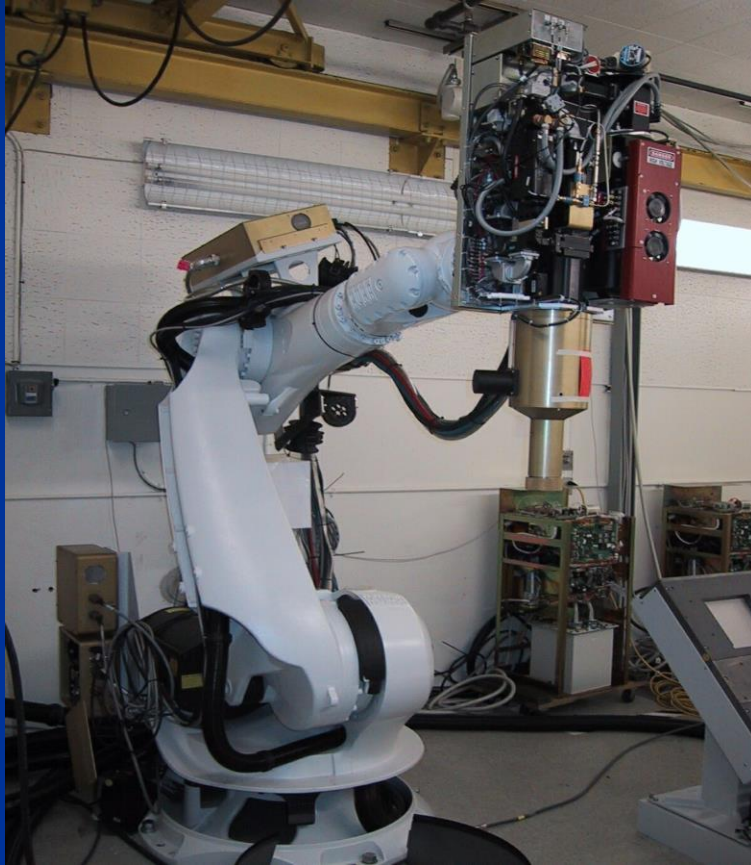


Robotun Özellikleri



- 6 akslı sanayi robotu
- 65 - 100 cm SSD
- 1525 kg ağırlık (LINAK dahil)
- 208-480 V, 54kW, 50/60 Hz
- Çalışma sıcaklığı: 0-45 °C
- relatif nem: < 75 %
- Çalışma alanı: 400 cm x 490 cm

HIZLANDIRICI



- Kompak 6 MV linak
- Doz hızı: 400cGy/min
- 1200 farklı doğrultudan ışın verebilme
- $D_{max} = 15 \pm 2$ mm
- $< 0.1\%$ sızıntı
- İkincil kolimatörlerin çapları:

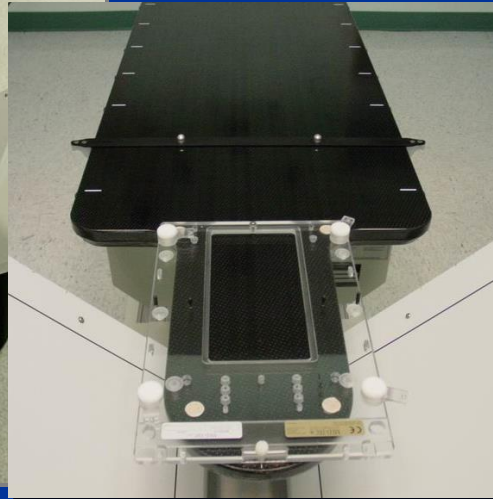
5.0 mm	15.0 mm	35.0 mm
7.5 mm	20.0 mm	40.0 mm
10.0 mm	25.0 mm	50.0 mm
12.5 mm	30.0 mm	60.0 mm



AXUM Tedavi Masası (1)

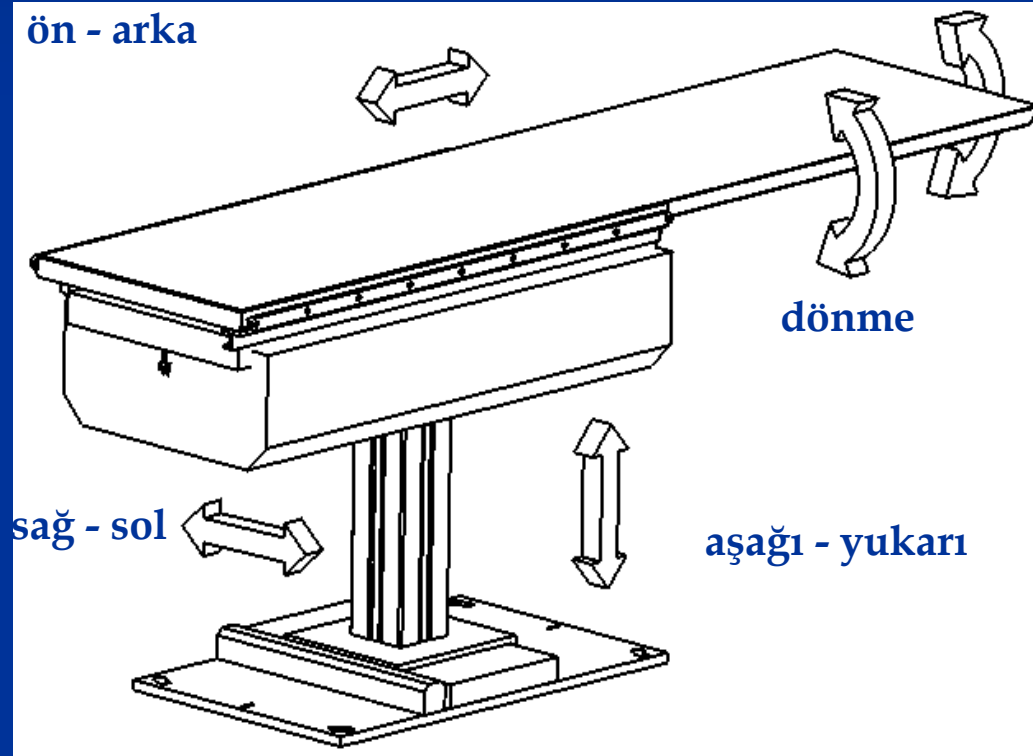


- Karbon fiber masa üstü
- maks. Hasta ağırlığı: 159 kg
- Otomatik hasta ayarlama
- 5 serbestlik dereceli dışarıdan hareket kontrolü:



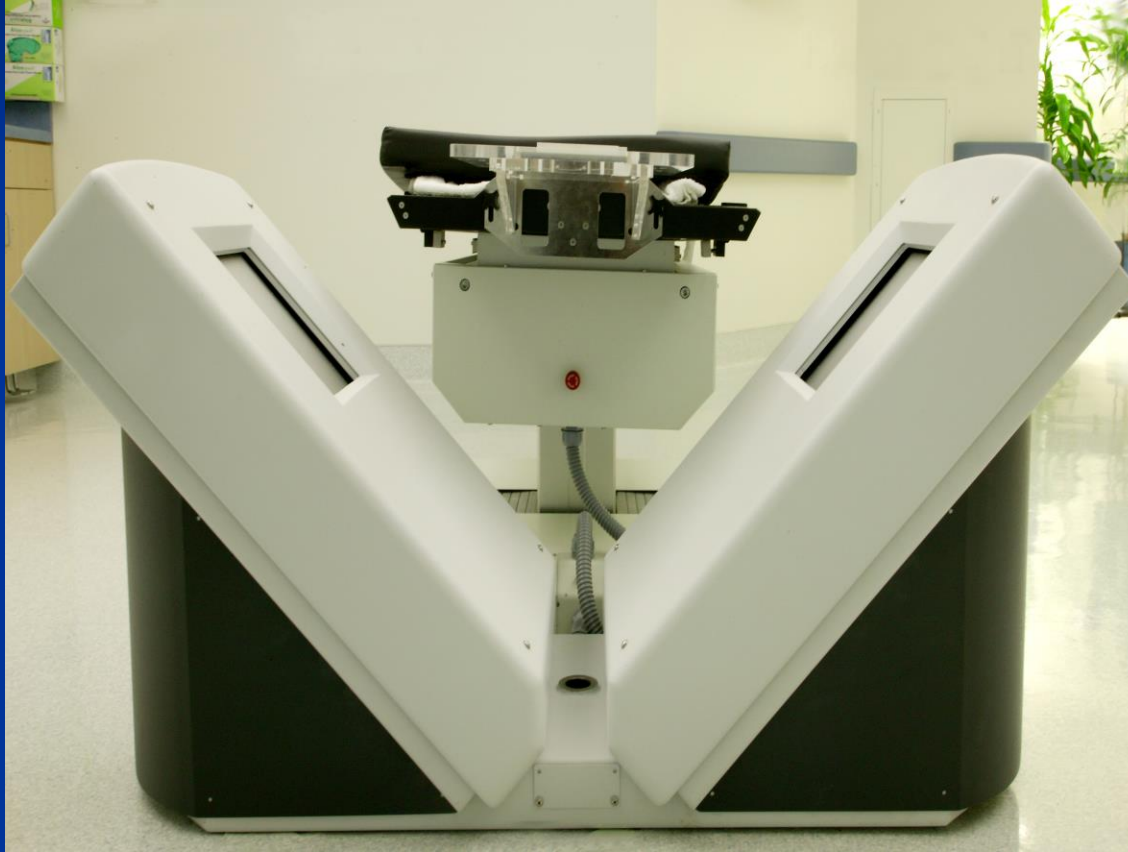
- ön-arka
- aşağı-yukarı
- sağ - sol
- Sag-sol dönme
- Öne-arkaya eğilme

AXUM Tedavi Masası (2)



maksimum hasta ağırlığı 160 kg

Dedektör paneli



- Amorf silikon panel
- 512x512 pixel
- 20x20 cm FOV
- İmaj merkezi cihaz izosentir'na ayarlı

X-ışını tüpü

- İki diagnostik X-ışını kaynağı
- İki görüntü dedektörü
- Gerçek zamanlı hasta görüntüleme
- DRR'lar ile karşılaştırılma



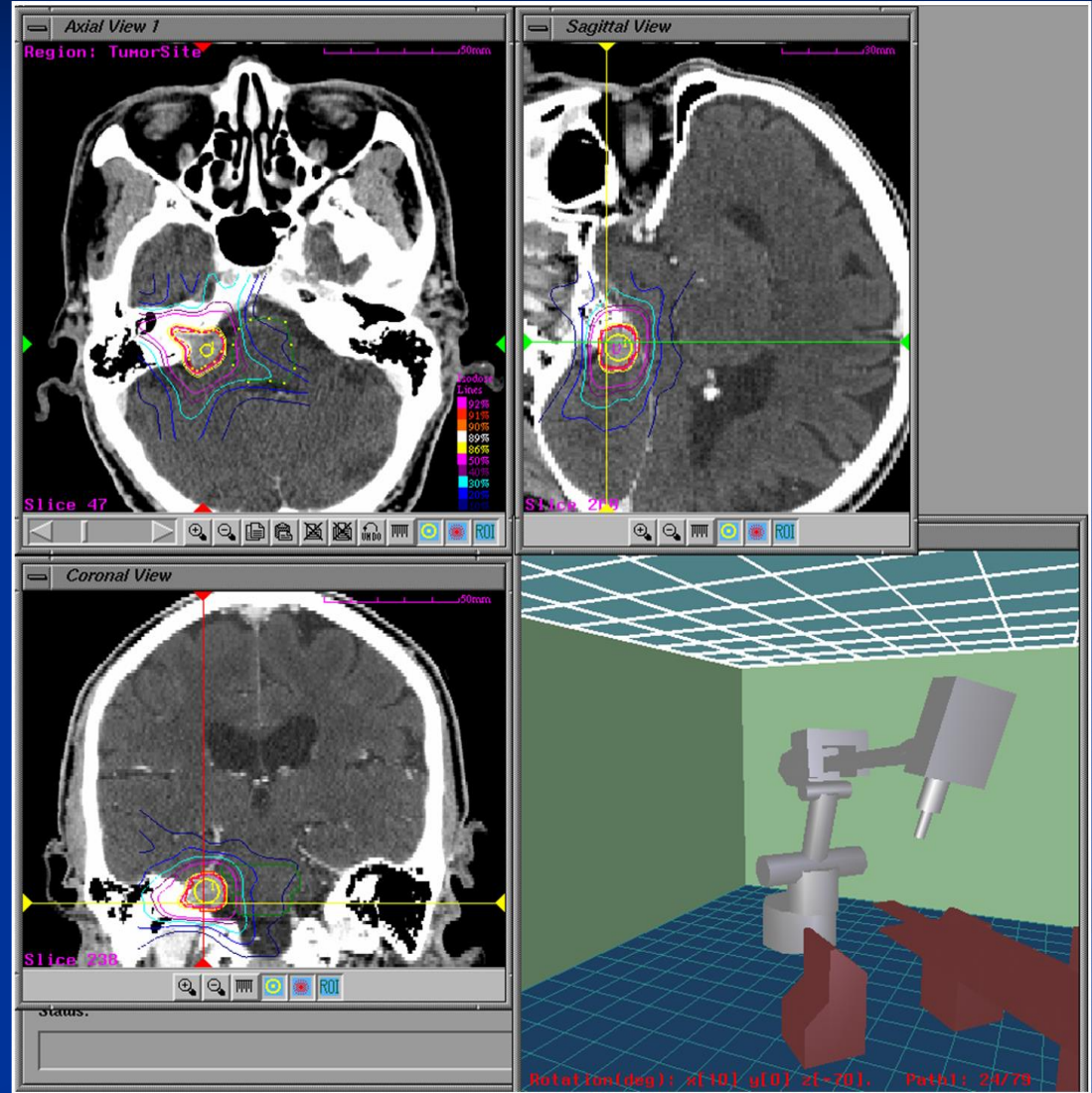
TPS

-Özel TPS

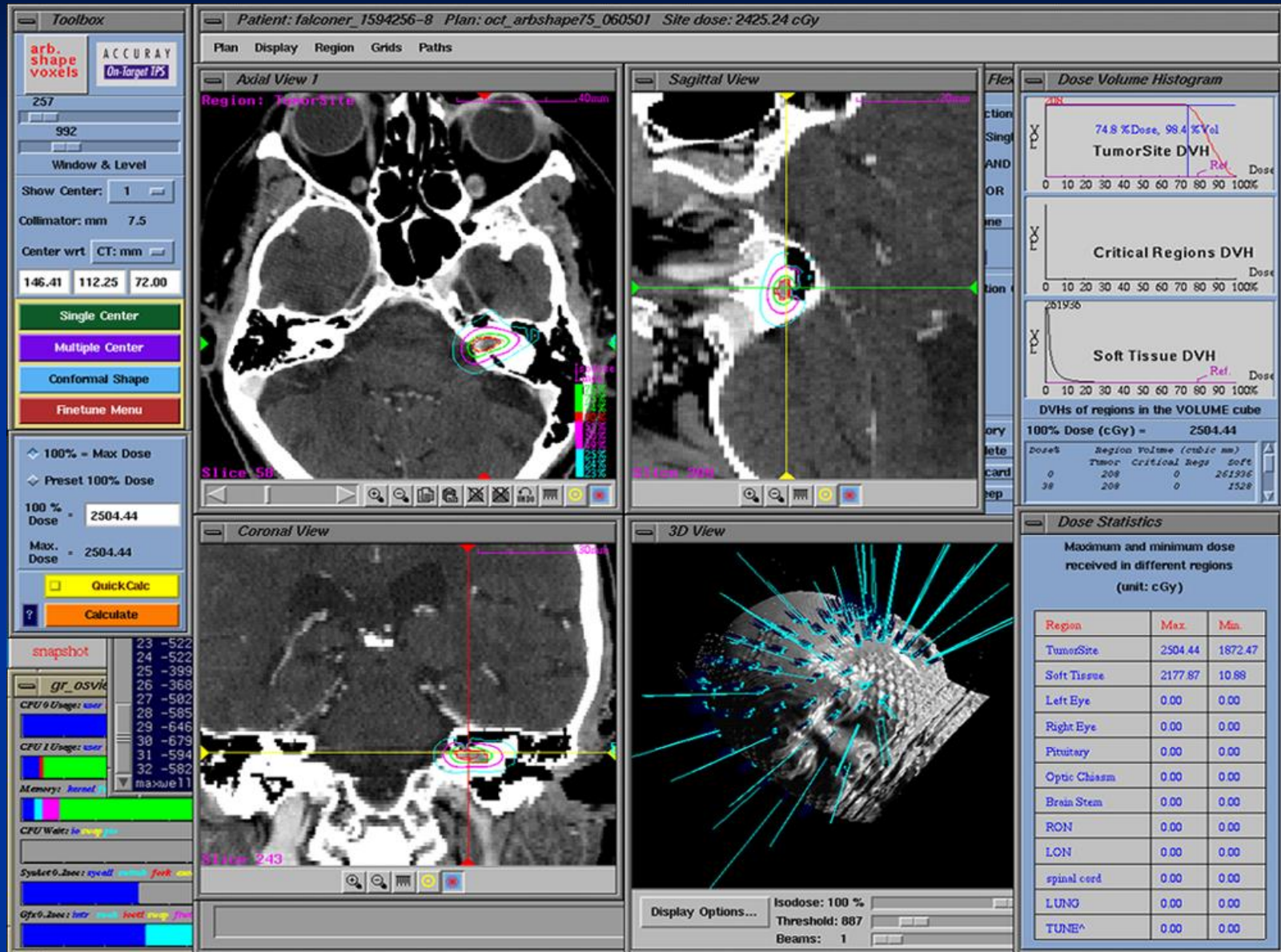
-Forward ve inverse planlama

-MRI,PET,Angio,CT aktarımı ve füzyonu

-QA araçları



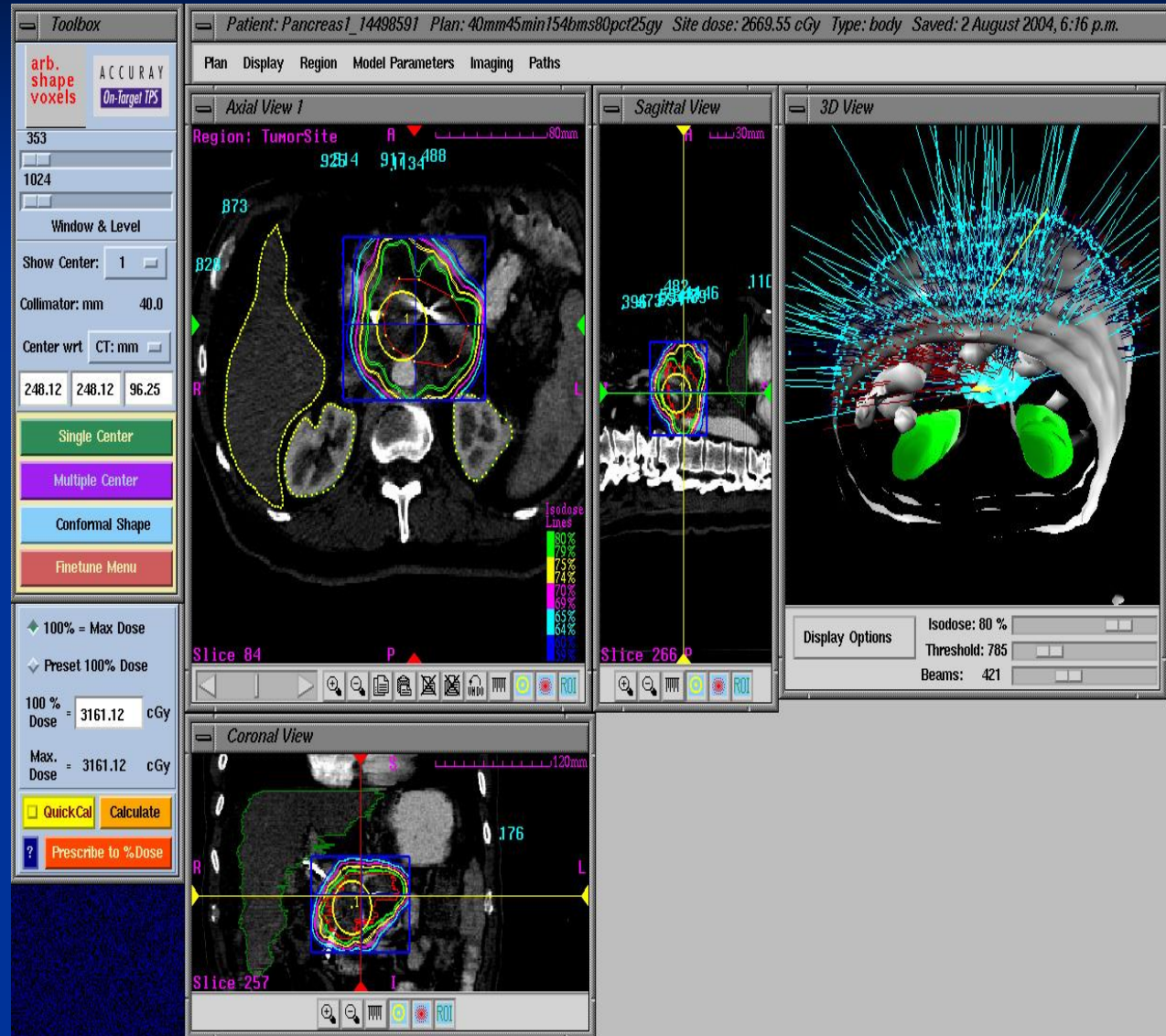
Tedavi Planlama Sistemi



TPS Dose Hesabı

-Suda
-800 mm SAD
-15 mm
derinlikte
-60 mm alan
boyutunda

1 cGy = 1 MU



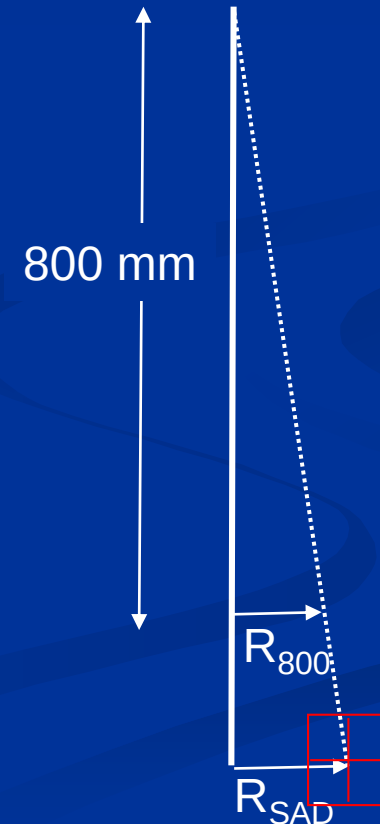
TPS doz hesabı

Diğer noktalarda:

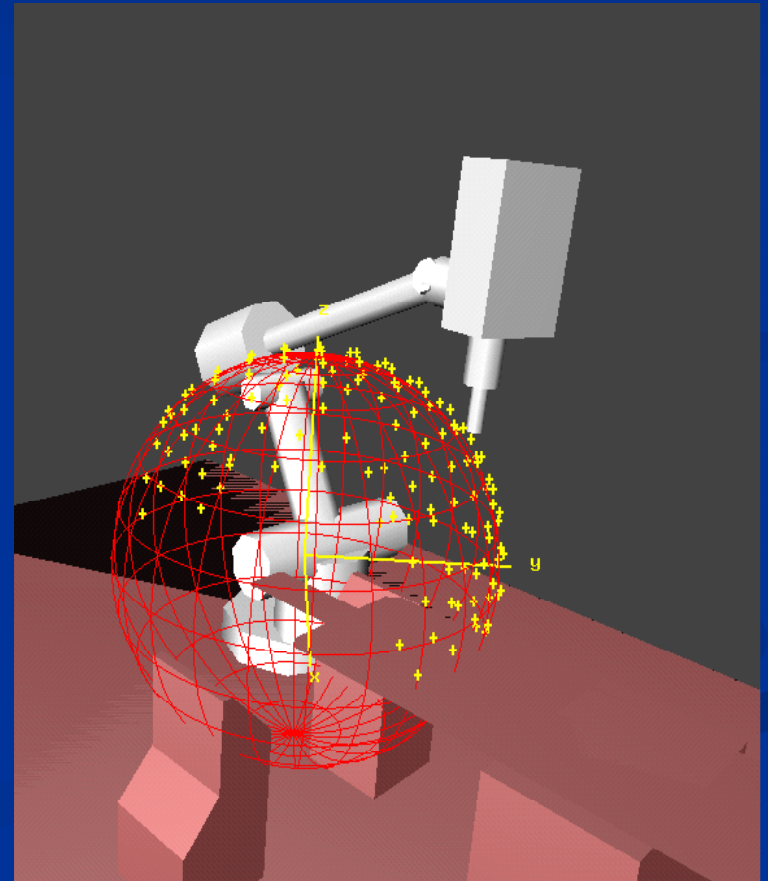
$$\text{RAD/MU} = \text{OCR}_{800}(\text{coll}, R_{800}, D_{\text{CAX}}) * (800/\text{SAD})^2 * \text{TPR}(\text{field size}, D_{\text{eff}}) * \text{DM}(\text{field size})$$

$$-R_{\text{SAD}} = R_{800}(\text{SAD}/800)$$

-TPR ve output faktor hesaplarında SAD düzeltmesi yapılmakta

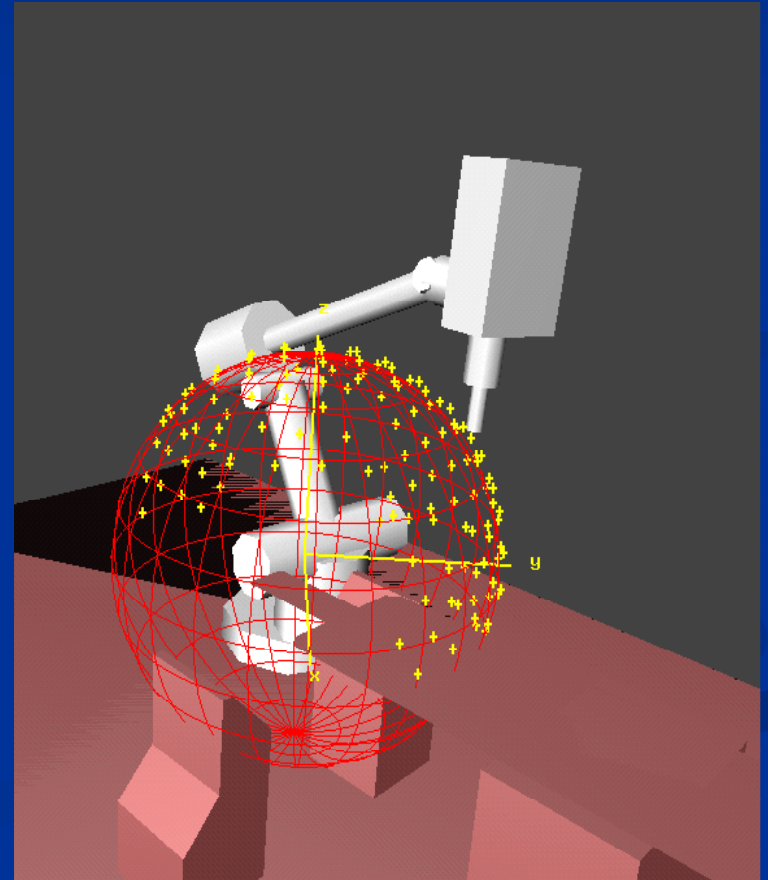


Tedavi sırasında robot hareketi

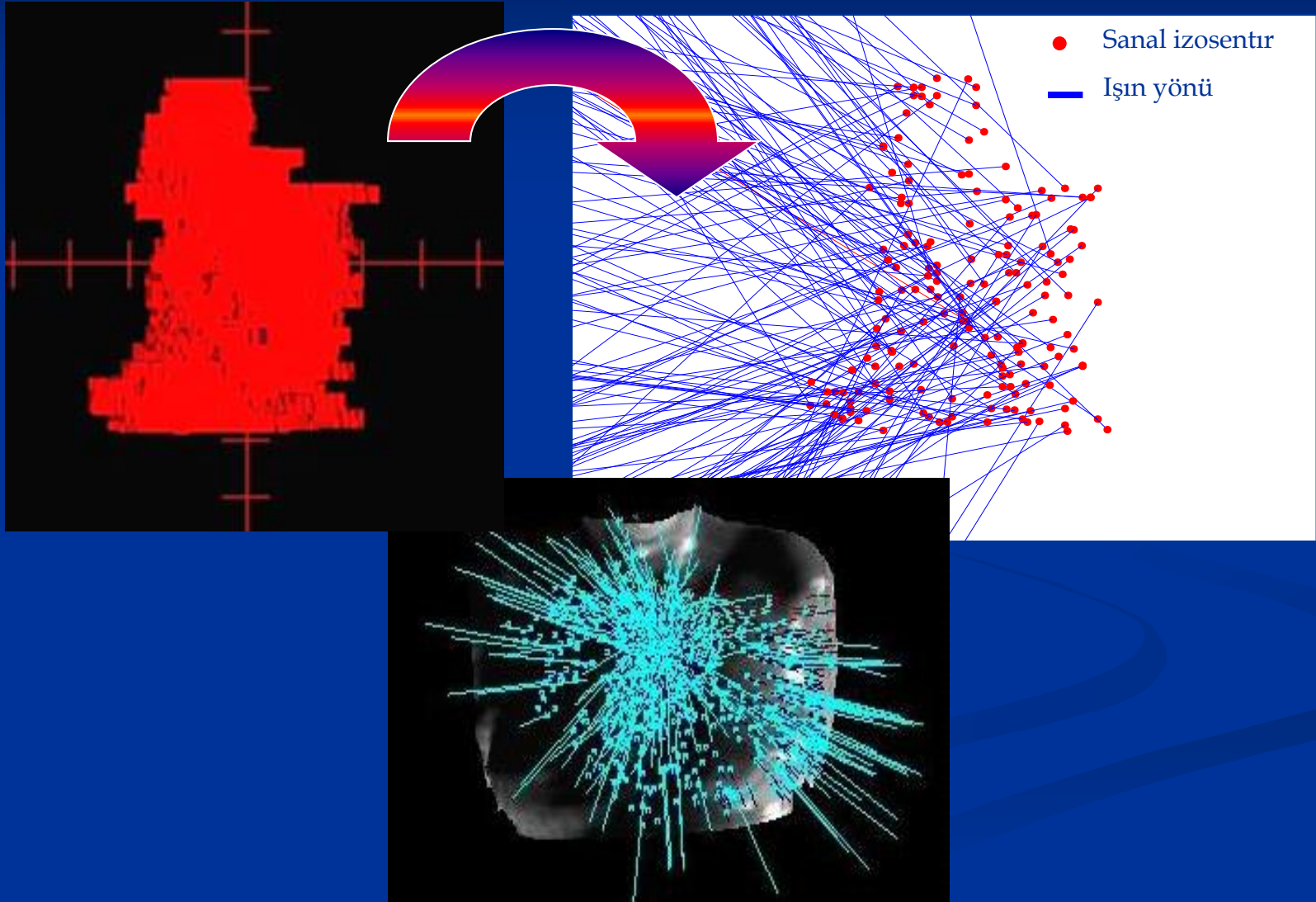


Tedavi sırasında robot hareketi

- 3 Paths veya tek path modeli
- 100-120 nod
- Nod başına 12 ışın doğrultusu
- Yaklaşık 1200 ışın
- Kafa ışınlamaları: 65,80 SAD
- Vücut ışınlamaları: 90-100 SAD



Hedef birçok sanal izosentirdan oluşur ve mümkün her yönden ışınlanabilir.



5 adımda CyberKnife uygulaması



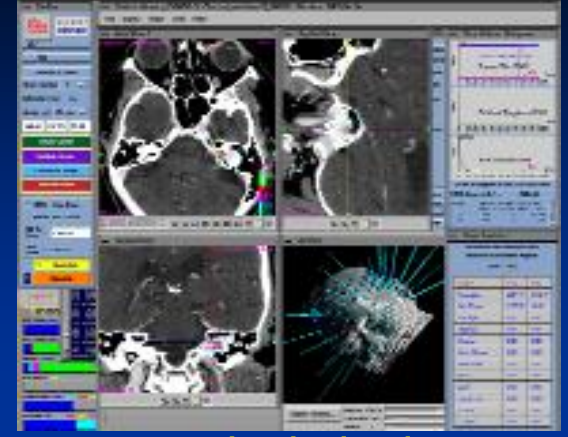
1. Hasta seçimi



2. Hastanın hazırlanması:
termoplastik maske, vakum
yatak vs.



3. BT taraması
Gerekirse füzyon için
MR, Angio vs.

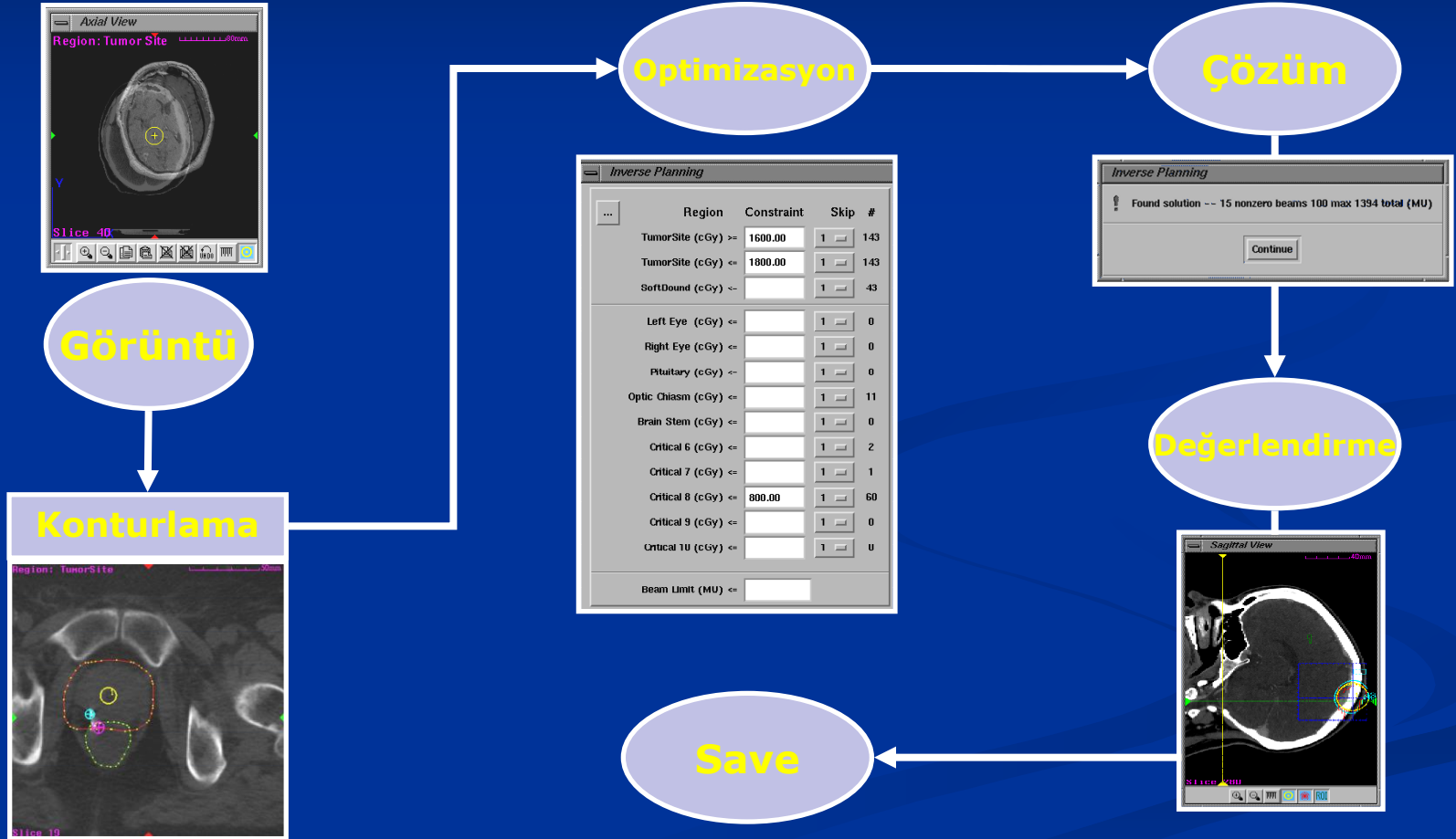


4. Tedavi planlaması

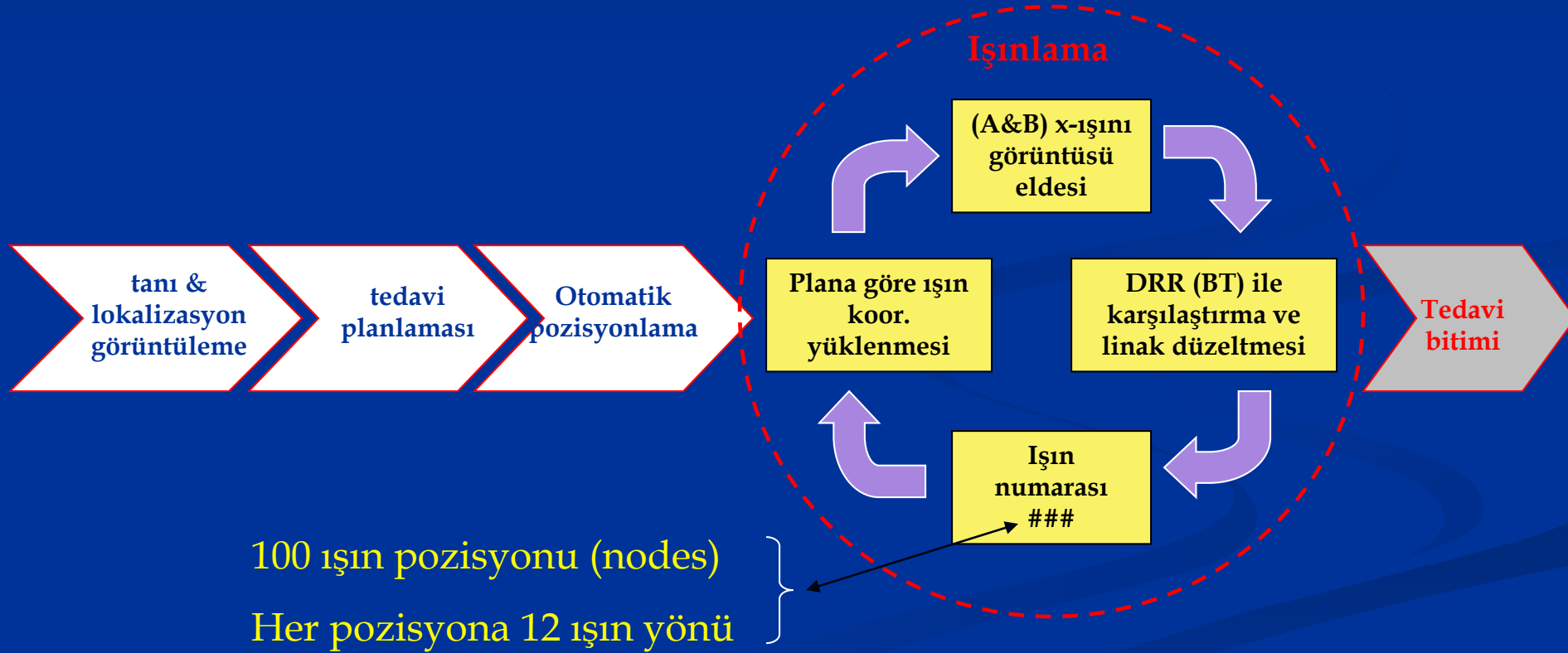


5. Işınlama

TPS işlemi

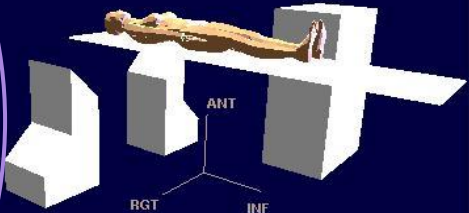
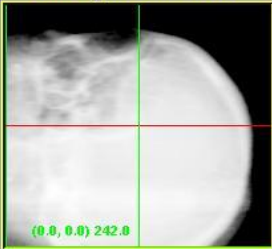
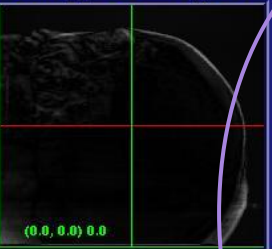
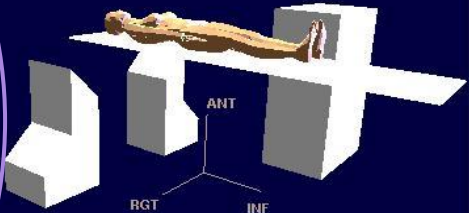
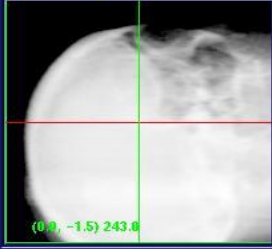
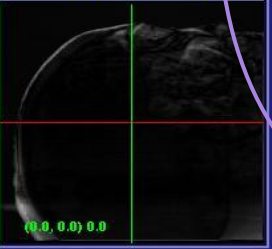
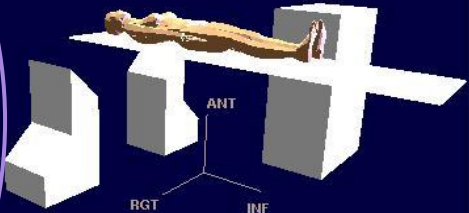
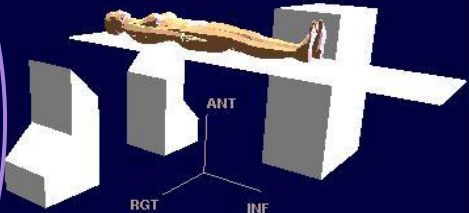
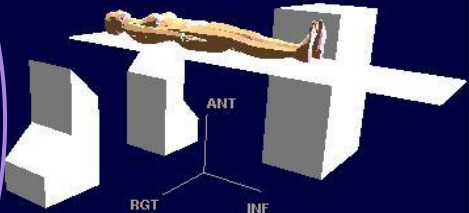
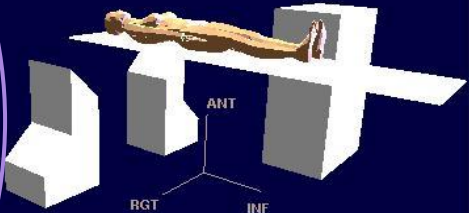
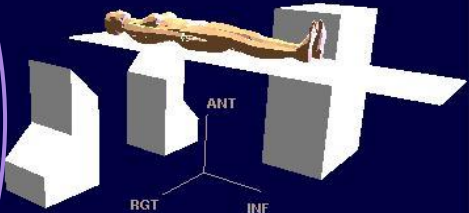


CyberKnife tedavi süreci



Tedavi

Treatment Data		Controls				
Name:	Bicron_Fiducial_P	Acquire	Correlate	Previous		
Medical ID:	021202	TREAT			Site Total: 0.00 cGy	Pat Pos: HFS
Physicians:	Me				Plan Total: 0.00 cGy	Time: 02/13/02 17:21:59
					Fraction: 1/1 : 99.44 cGy	Collimator: 7.5 mm

Immagine sintetica A			Immagine camera A			Sovrappos di immagini A			Correzioni lettino Nodo corrente					
 (0.0, 0.0) 242.0			 (0.0, 0.0) 240.0			 (0.0, 0.0) 0.0			Sn: 0.1 mm					
Immagine sintetica B			Immagine camera B			Sovrappos di immagini B			ANT : 2.0 mm					
 (0.0, -1.5) 243.0			 (0.0, -1.5) 243.0			 (0.0, 0.0) 0.0			SUP: 0.2 mm					
									Dx: 1.2 °					
									NasGiù: 1.1 °					
									AnOr: 1.4 °					
									Modalità Rilevam					
									Rilevam. cranico 6D					
									Parametri radiogr.					
									Allineamento paziente					
									Reset Display					
									Align					
									Add Subtract					

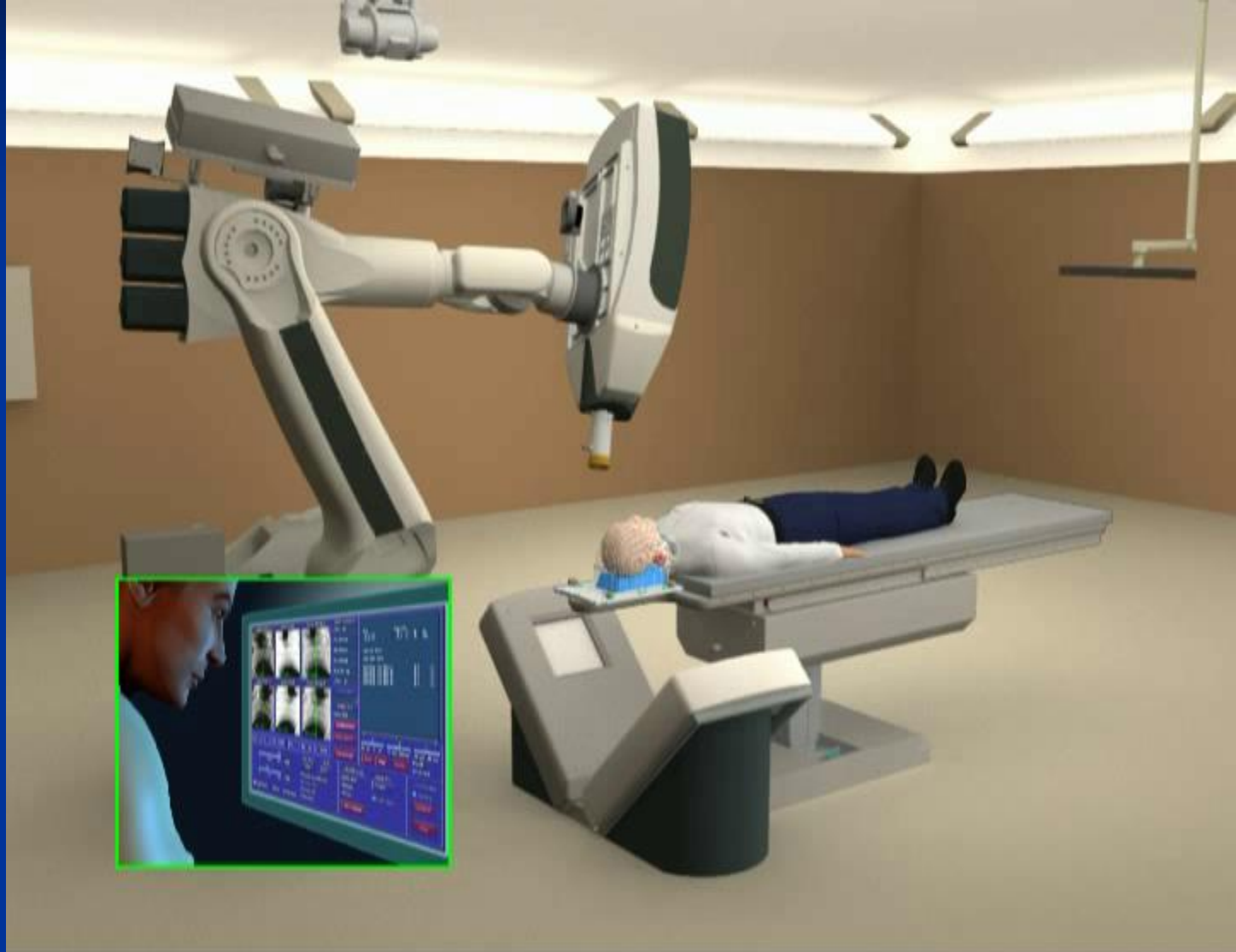
XRS A				XRS B			
KV: 120	MA: 100	EX: 50		KV: 120	MA: 100	EX: 50	
 Window 0 255 255				 Zoom 100%			
 Level 0 255 210				☒ Display Fiducial Markers			
☒ Apply W/L To All				☒ Display ROI			
☒ Invert				☒ Threshold			
☒ Max Contrast							

Fiducial Tracking		
Fiducial Area		
Search		
☒ Identify		
☒ Search ☒ Track		
Tracking Mode		
Search Parameters		
Tracking Parameters		
Close		

snapshot	PAUSE	Controls	Sites	Plans	Paths	EXIT
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CyberKnife

Görüntü Güdümlü Radyasyon Tedavisi (IGRT)

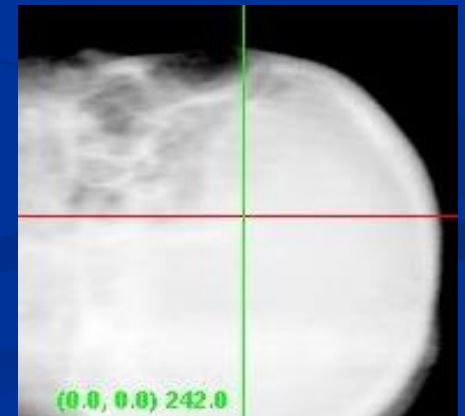
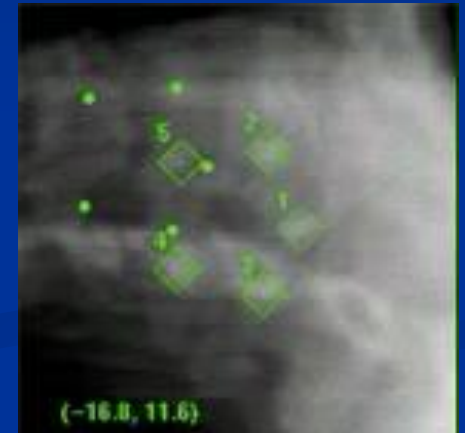


TEDAVİ MODELLERİ

1. Kafatası izleme yöntemi
2. “Fiducial” izleme yöntemi
3. Hareket izleme (Synchrony) yöntemi
4. İskelet izleme yöntemi

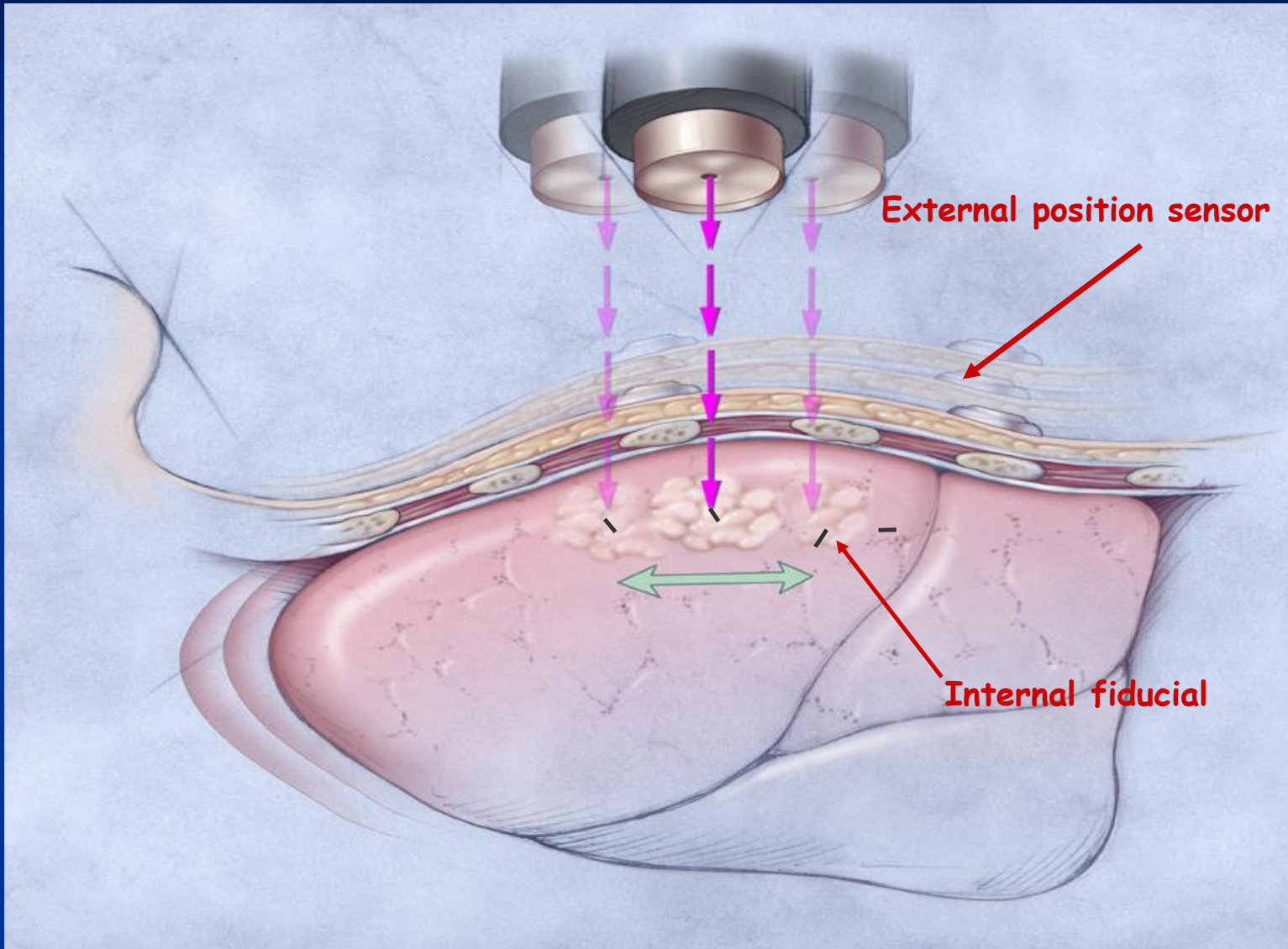
Lokalizasyonun Doğruluğu

- Altın markır kullanıldığında lokalizasyon doğruluğu 0.5-1 mm'dir. ("fiducial tracking") (SD = 0.15 mm)
- Kafatası görüntüsü kullanıldığında lokalizasyon doğruluğu 0.5-1mm'dir. ("skull tracking") (SD = 0.15 mm)



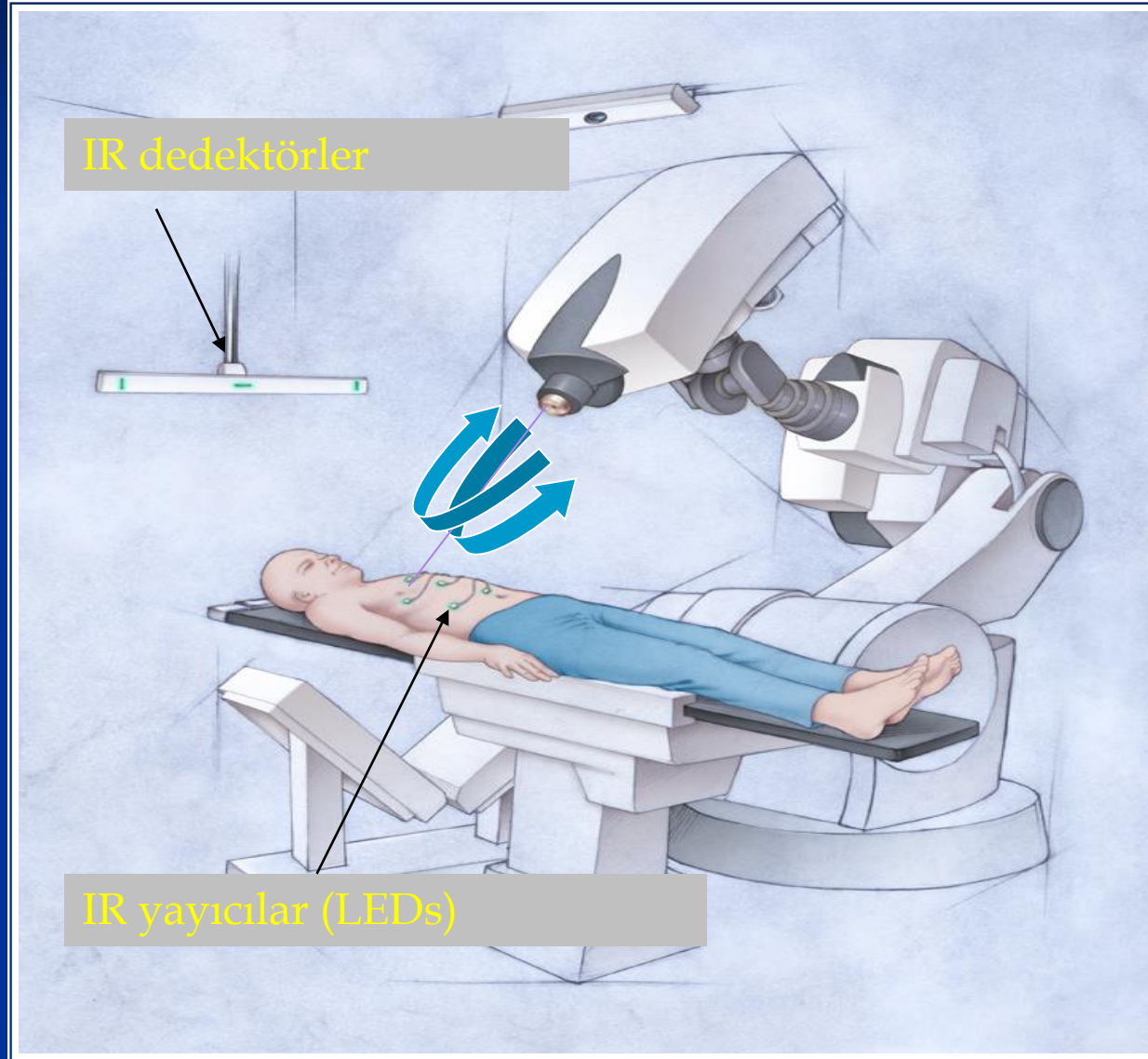
Synchrony™

hareketli organların dinamik izlenmesi (1)



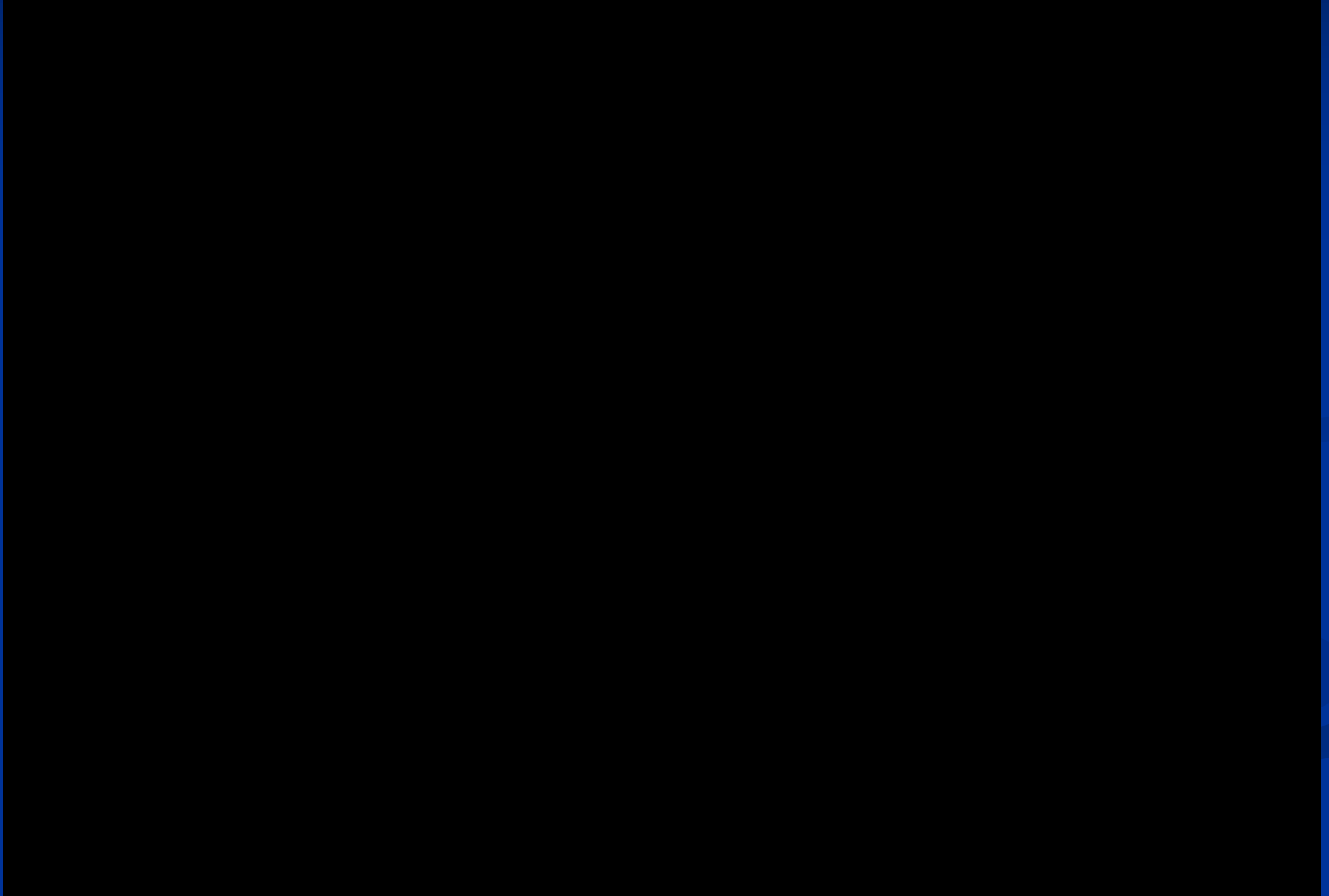
Synchrony™

hareketli organların dinamik izlenmesi (2)



Synchrony™

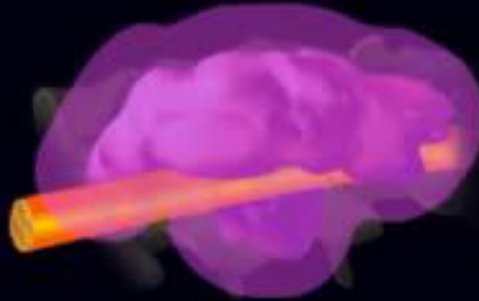
hareketli organların dinamik izlenmesi (3)



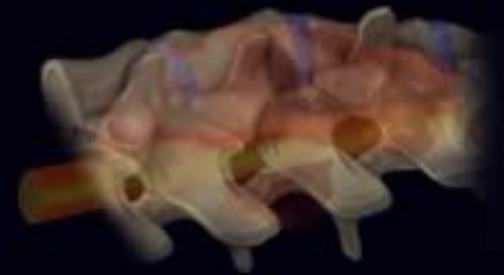
Hata Marjlarının Karşılaştırılması



Conventional RT

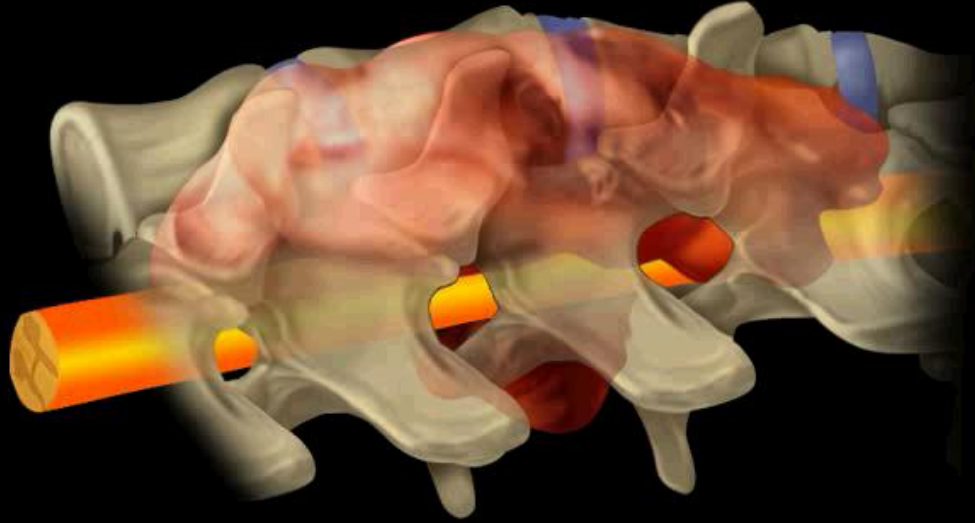


Conformal/IMRT



CyberKnife

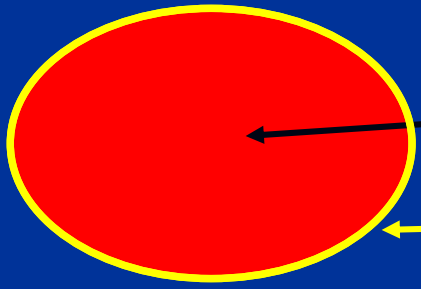
Radyocerrahi doęruluk



Konformalite İndeksi (CI)

$CI = \text{referans izodoz volyumu} / \text{hedef volyum}$

ideal tedavi planı:

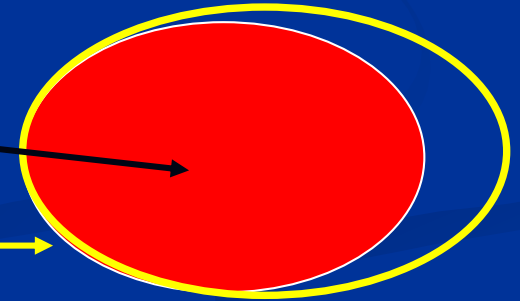


$CI = 1$

Hedef

Referans İzodoz

uygulamada:

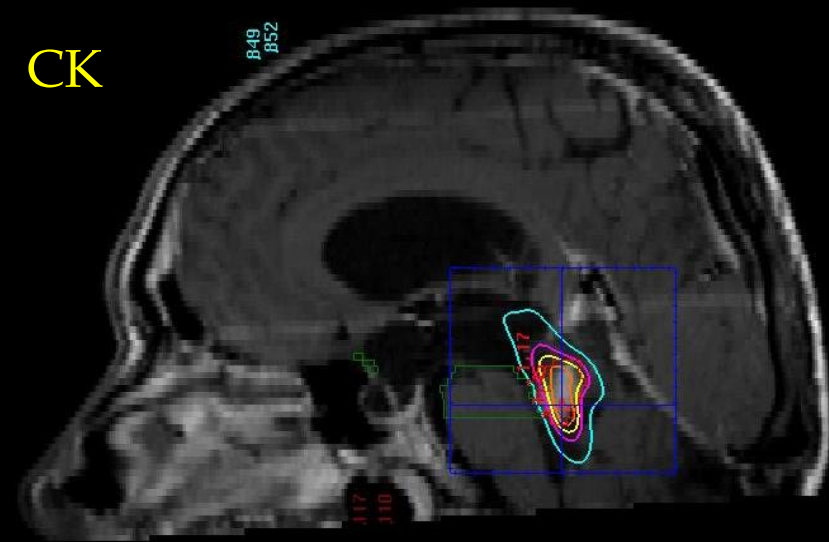


$CI > 1$

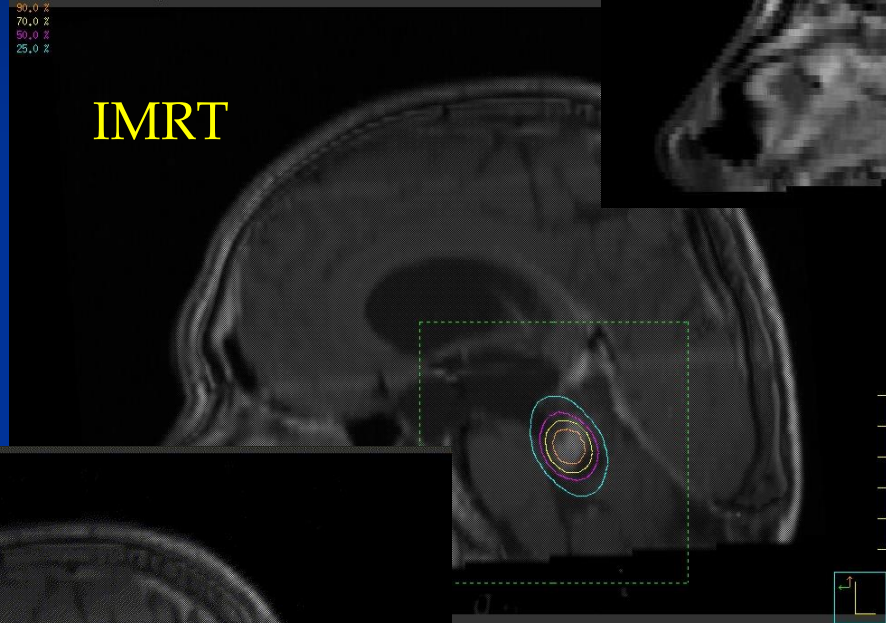


Konformalite Karşılaştırılması

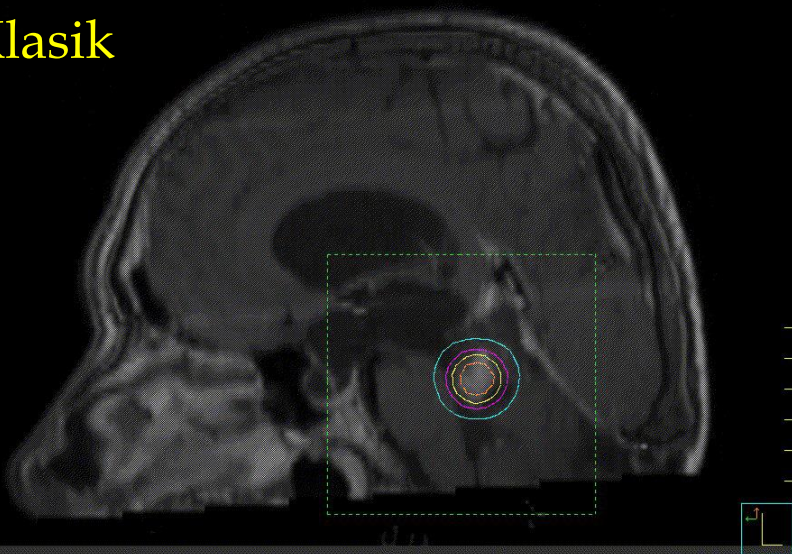
CK



IMRT



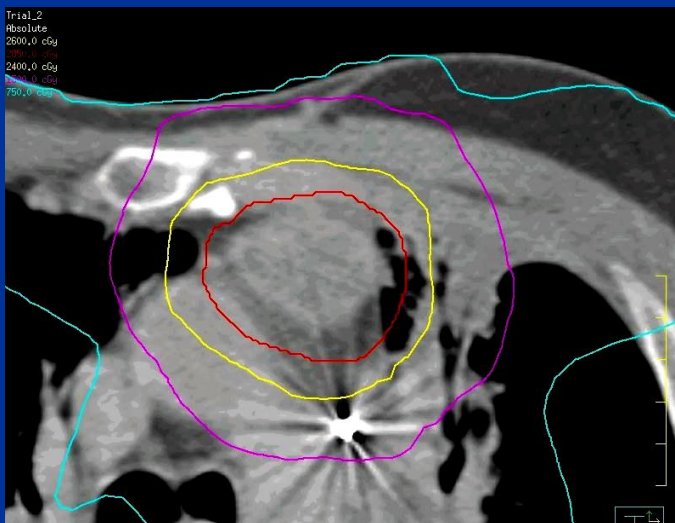
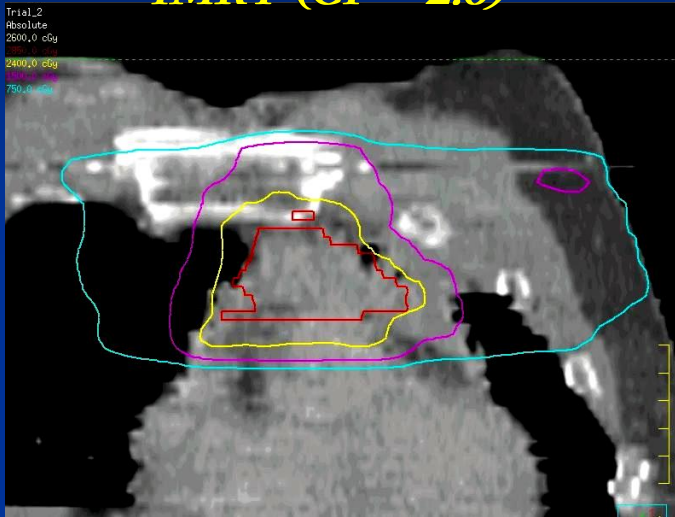
Klasik



Uygulama 1: Akciğer Adonekarsinomu

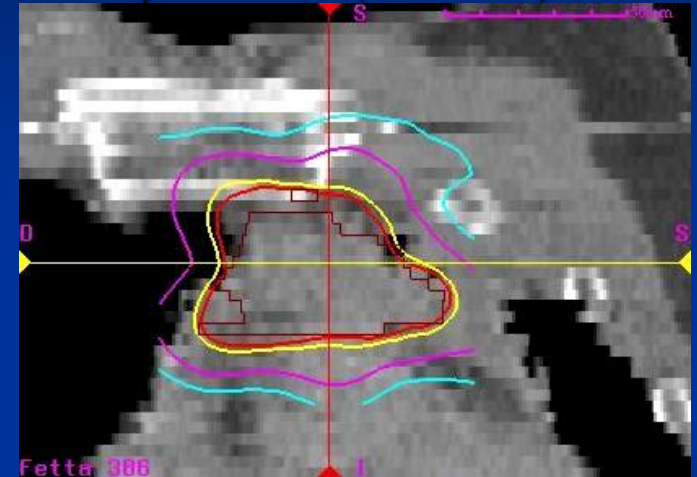
Cyberknife: 30 Gy tek fraksiyon

IMRT (CI = 2.6)



95 %
75 %
50 %
25 %

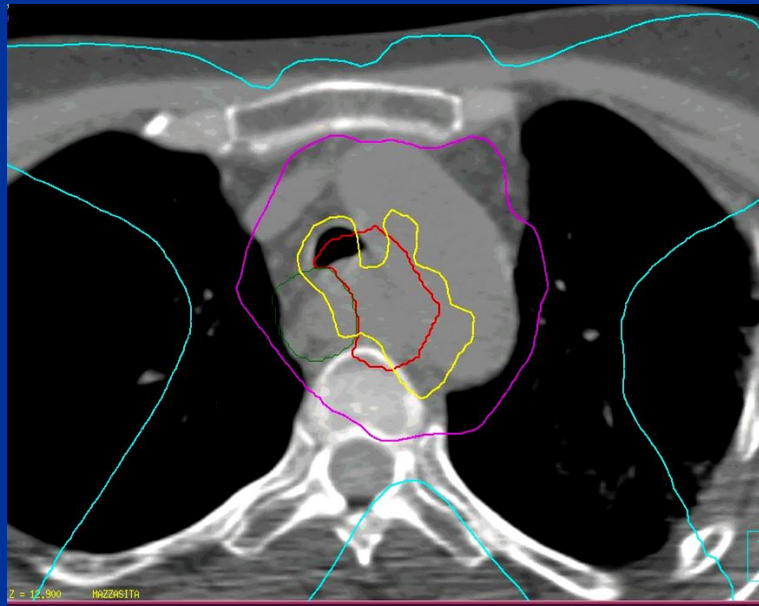
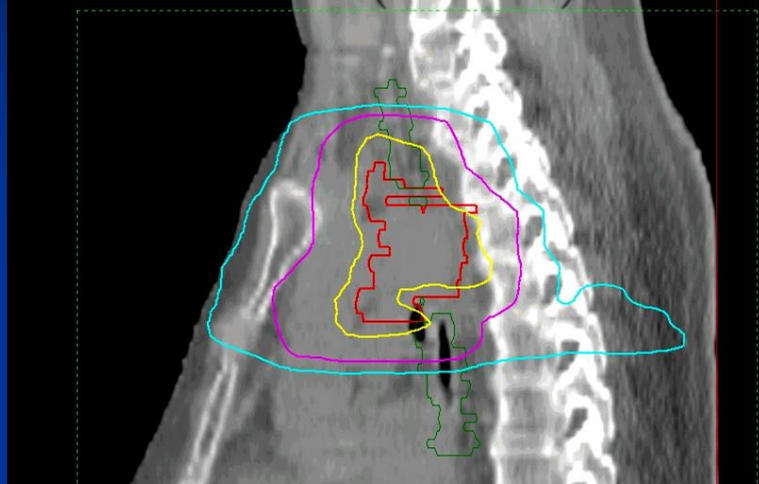
Cyberknife (CI = 1.3)



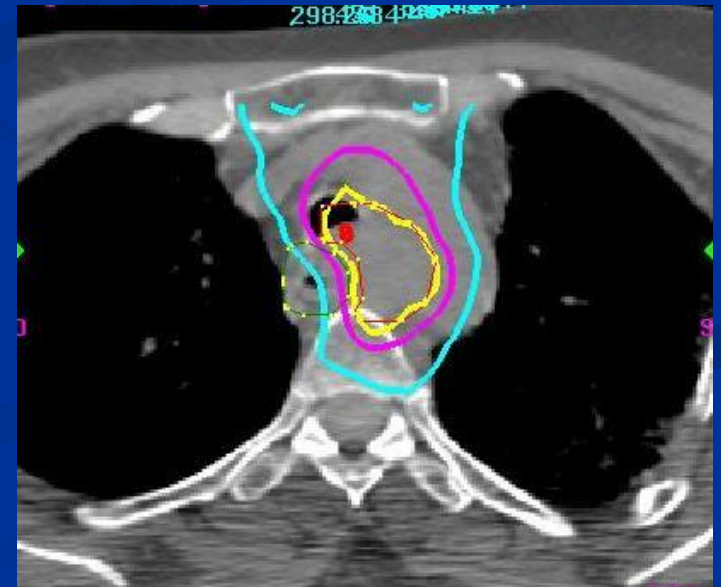
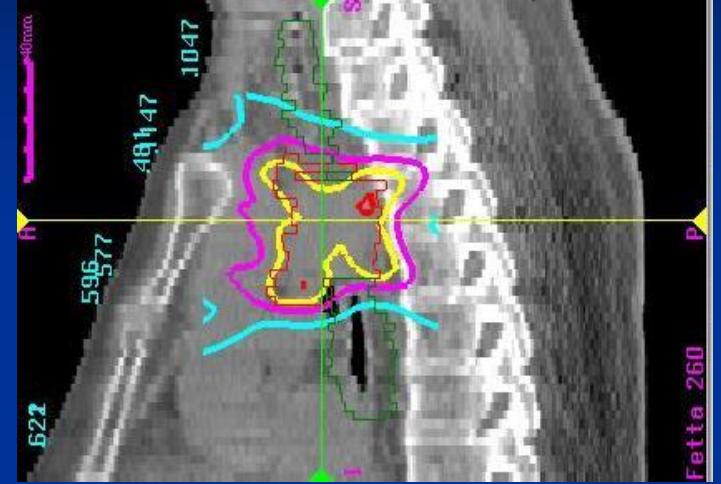
Uygulama 2: Akciğer Kanseri

Cyberknife: 30 Gy 3 fraksiyon

IMRT (CI = 1.9)



Cyberknife (CI = 1.0)

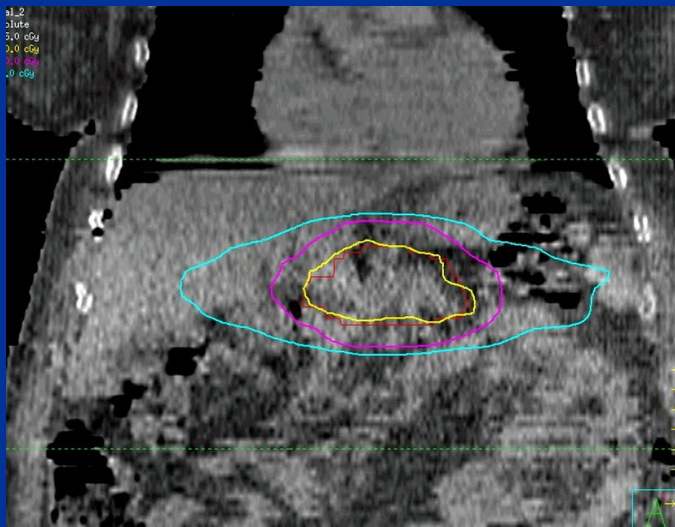
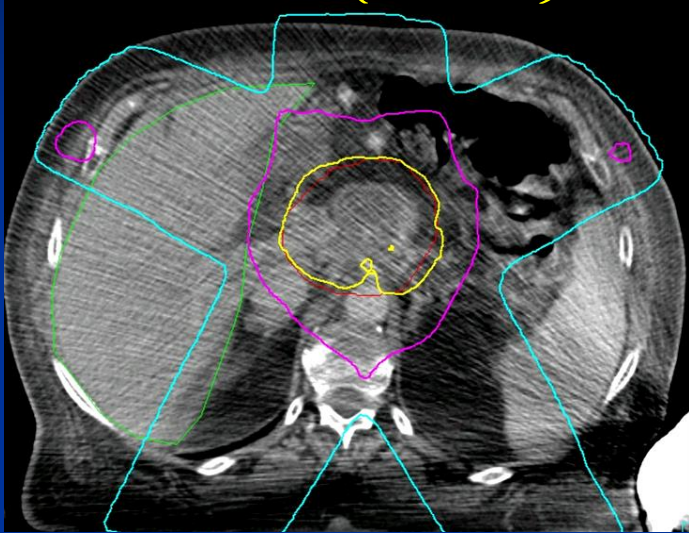


- 95 %
- 75 %
- 50 %
- 25 %

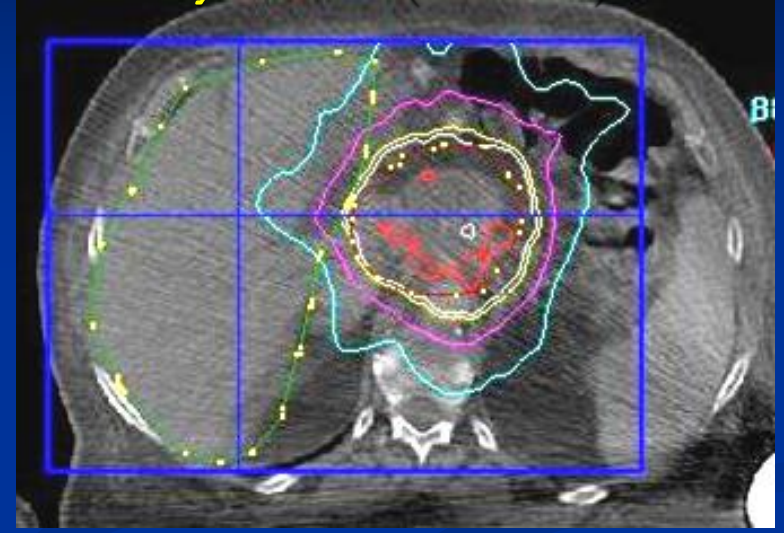
Uygulama 3: Pankreas kanseri

Cyberknife: 27 Gy 3 fraksiyon

IMRT (CI = 1.0)



Cyberknife (CI = 0.9)



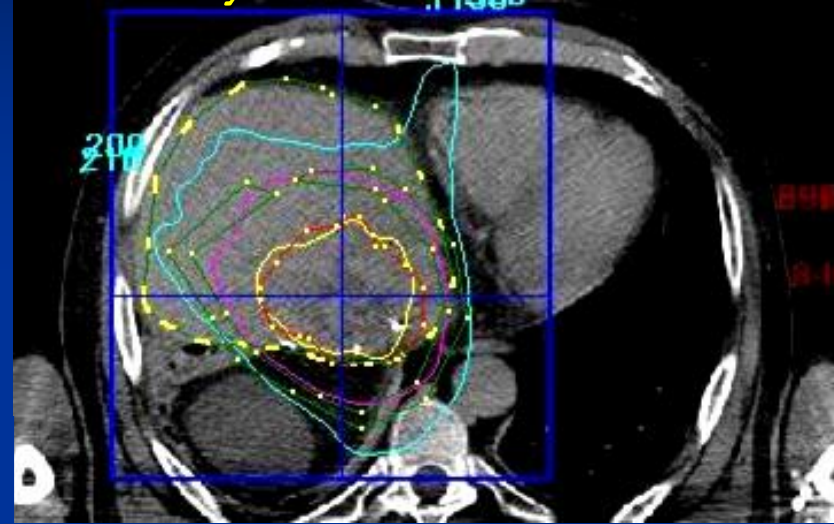
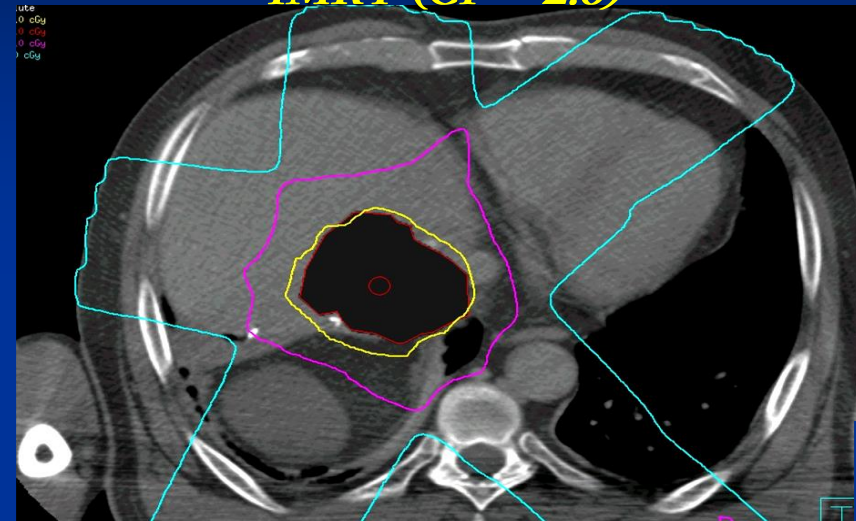
— 95 %
— 80 %
— 50 %
— 25 %

Uygulama 4: Karaciğer Metaztazı

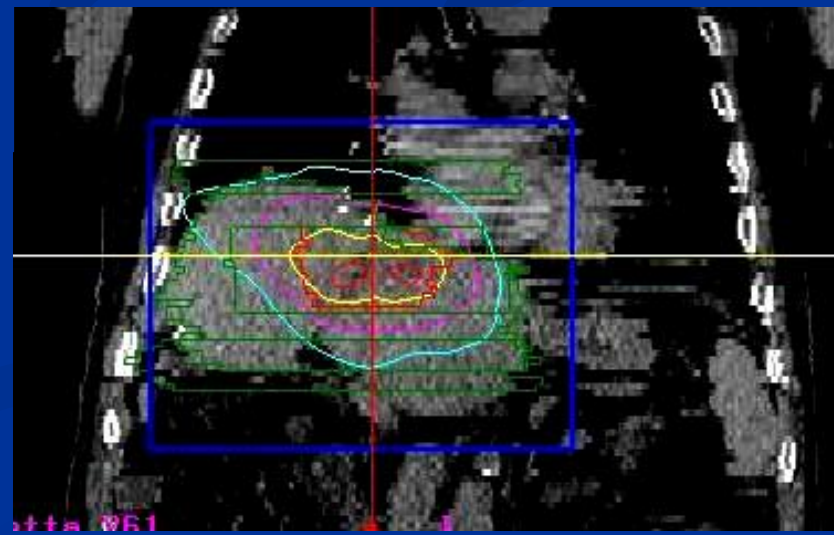
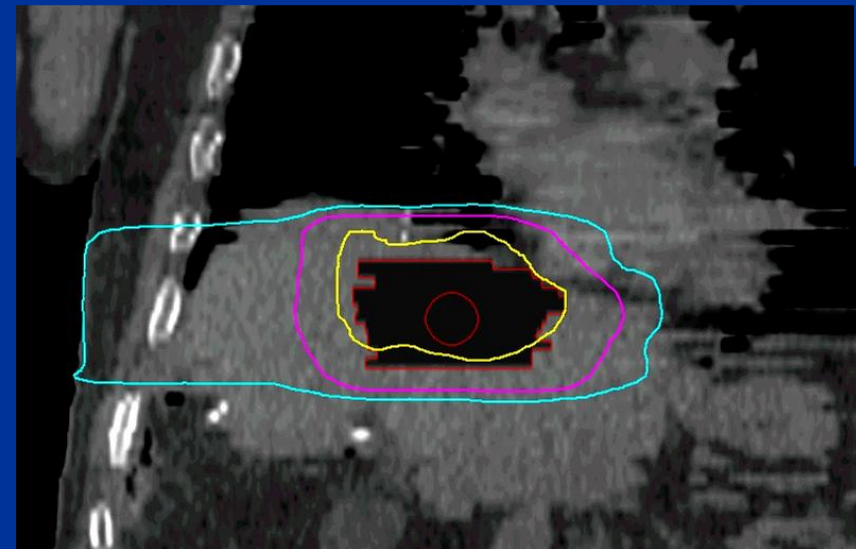
Cyberknife: 33.75 Gy 3 fraksiyon

IMRT (CI = 2.6)

Cyberknife (CI = 0.9)



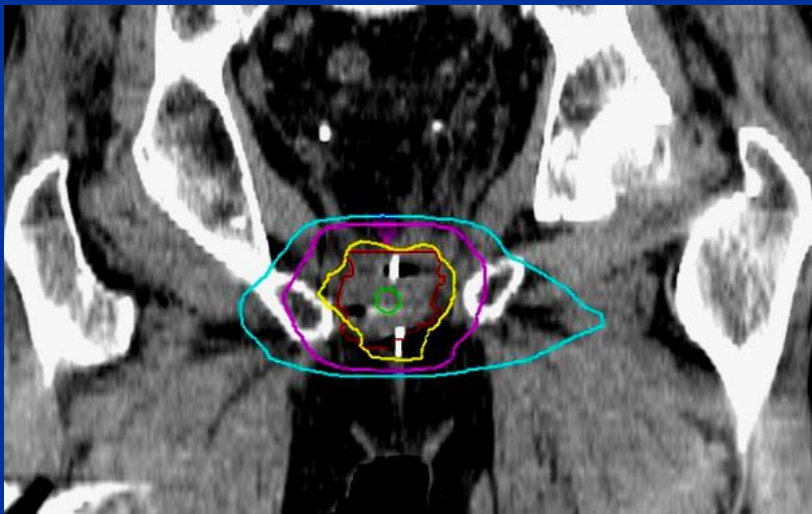
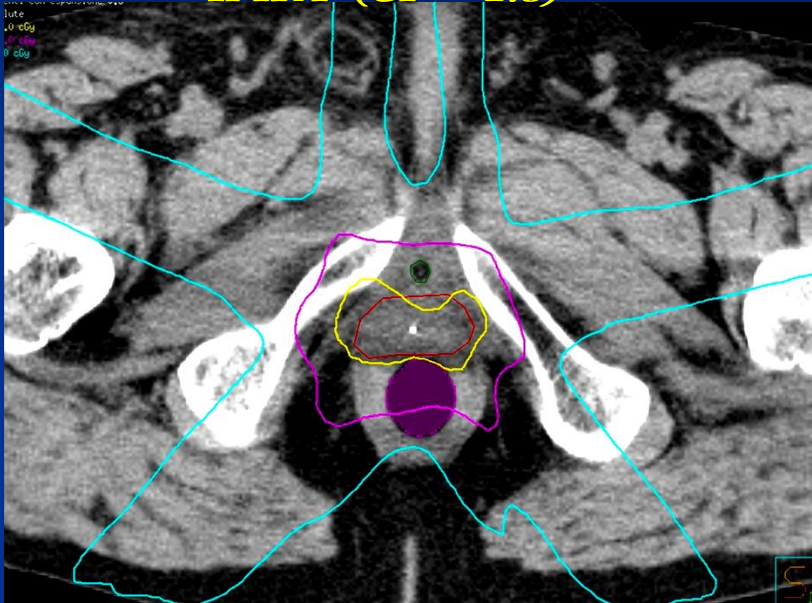
95 %
80 %
50 %
25 %



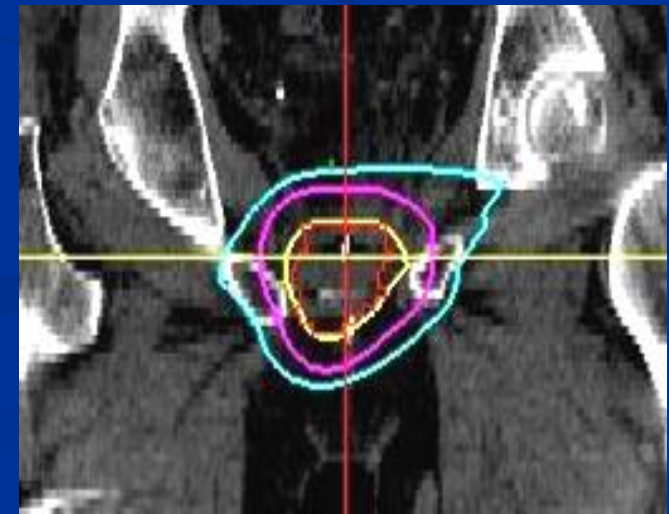
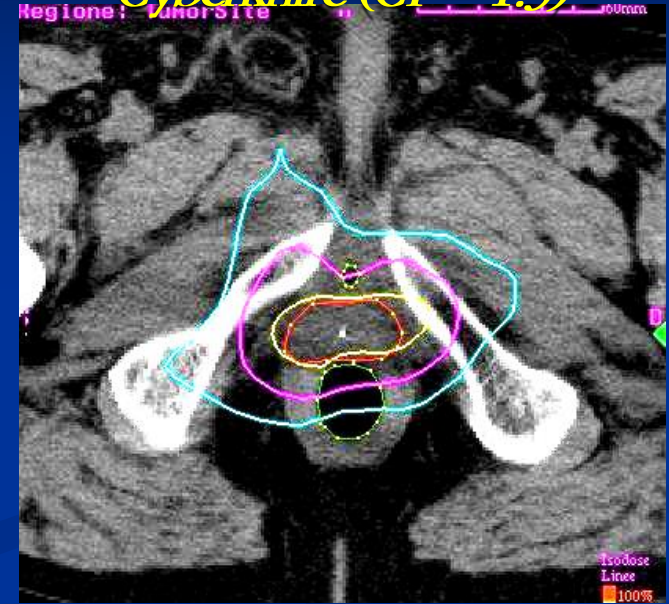
Uygulama 5: Prostat Kanseri

Cyberknife: 30 Gy 3 fraksiyon

IMRT (CI = 1.8)



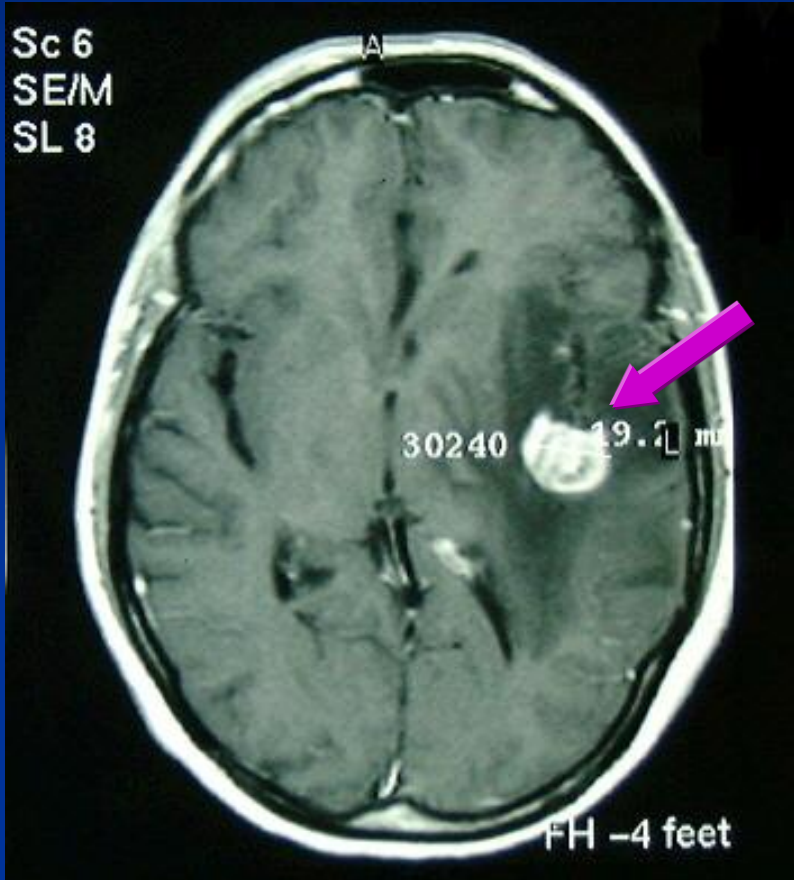
Cyberknife (CI = 1.3)



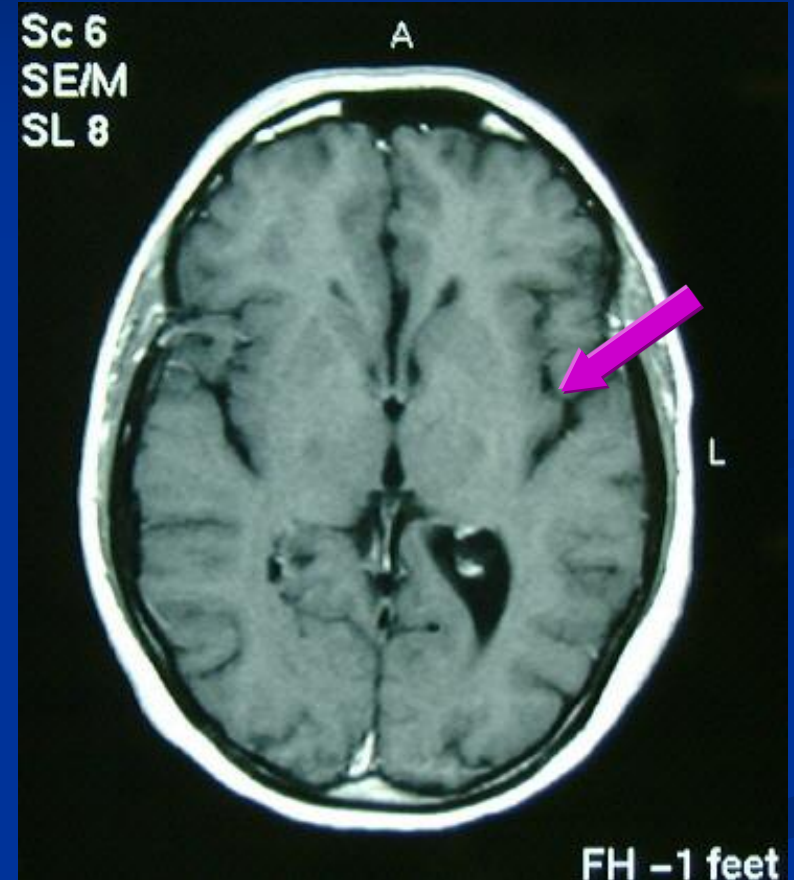
- 95 %
- 75 %
- 50 %
- 25 %

CyberKnife® : Sonuçlar

68 yaşında bayan hasta: akciğer adenokarsinomu metaztazı
22 Gy, tek fraksiyon



Tedaviden önce



3 ay follow-up

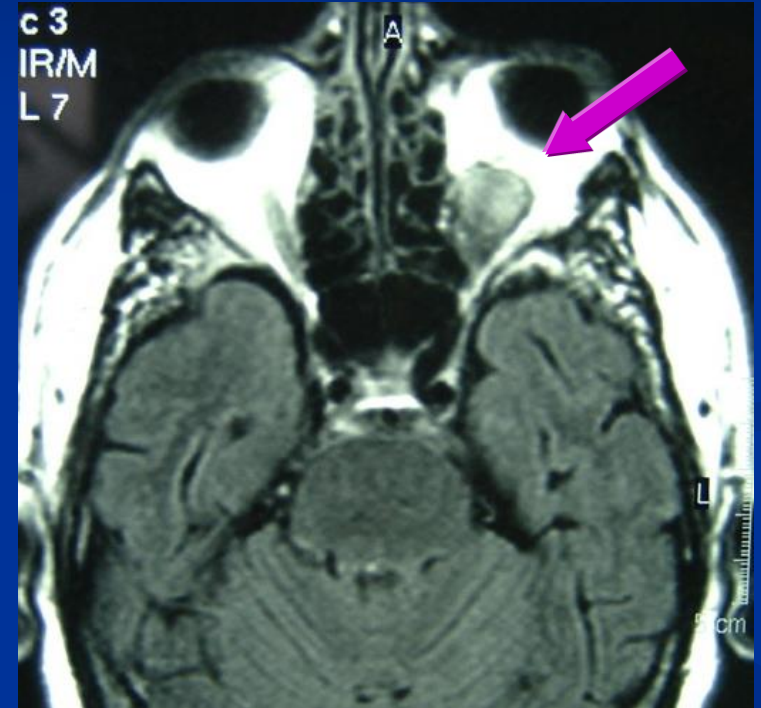
Courtesy of San.Bortolo Hospital - Vicenza - Italy

CyberKnife® : Sonuçlar

69 yaşında erkek hasta: orbit sarkoma not-resectable
22 Gy, 2 fraksiyon



Tedaviden önce



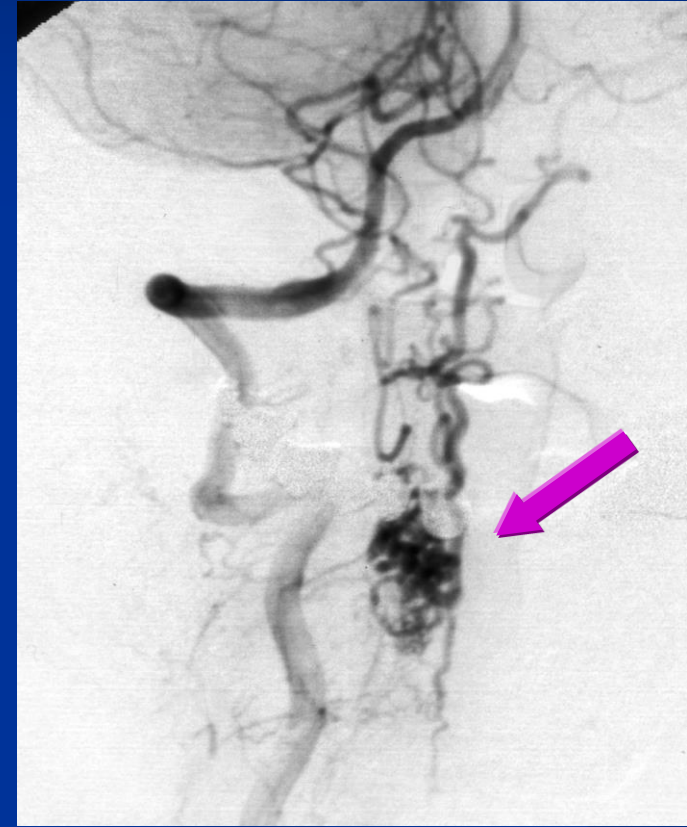
4 ay follow-up

CyberKnife® : Sonuçlar

C2-C3 Spinal AVM Ekstrakranial tedavi



Tedaviden önce

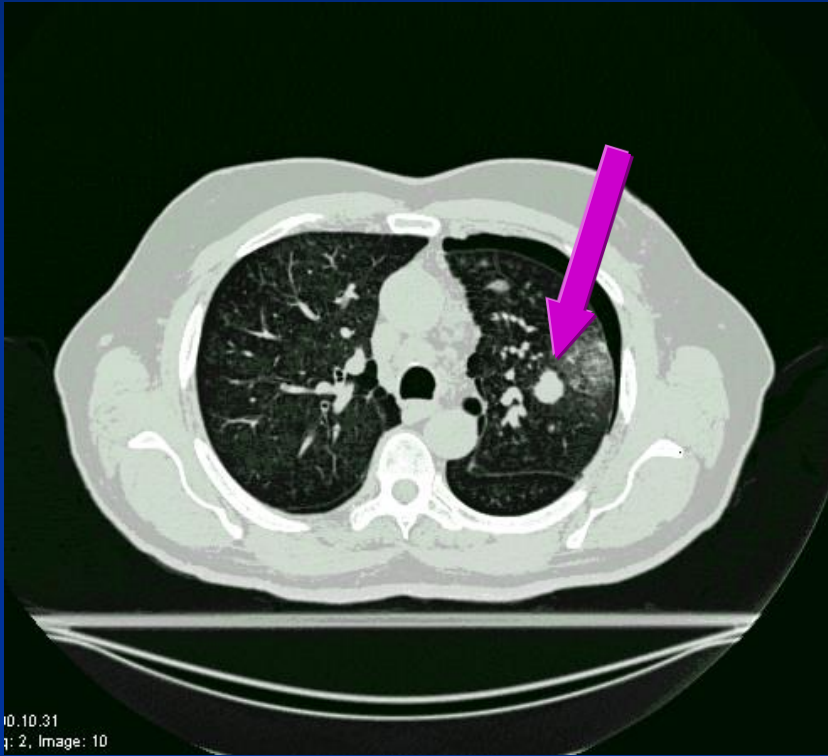


4 yıl Follow-up

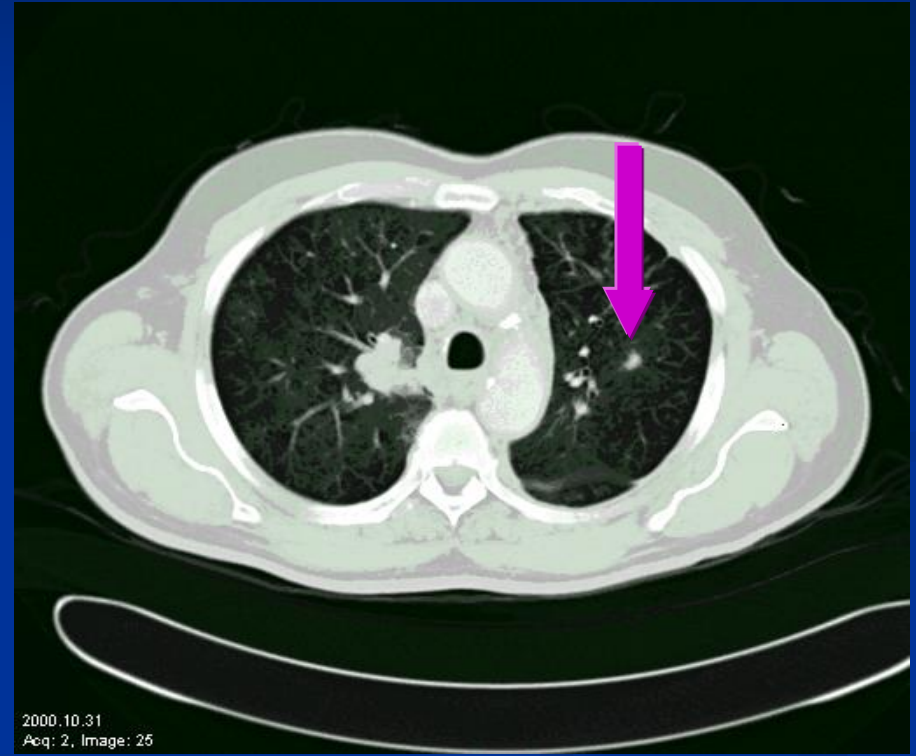
Courtesy of Stanford University – California (USA)

CyberKnife® : Sonuçlar

Ekstrakranial tedavi : Akciğer Kanseri
15 Gy tek fraksiyon



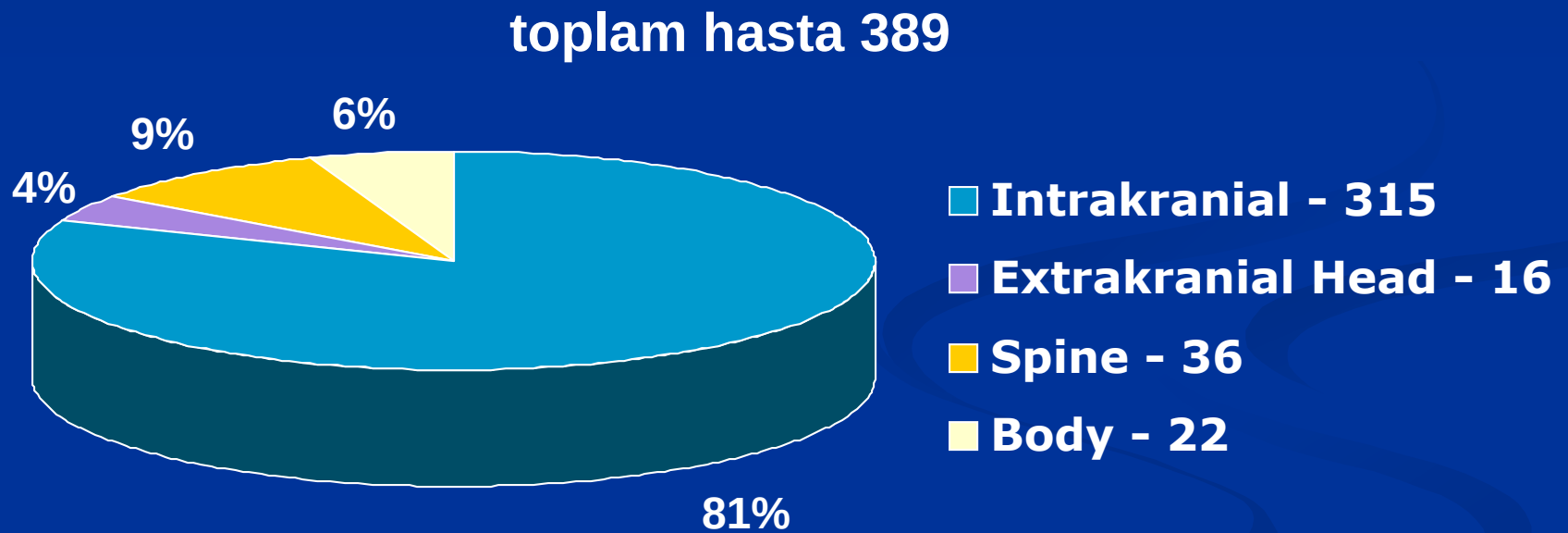
Tedaviden önce



Tedaviden sonra

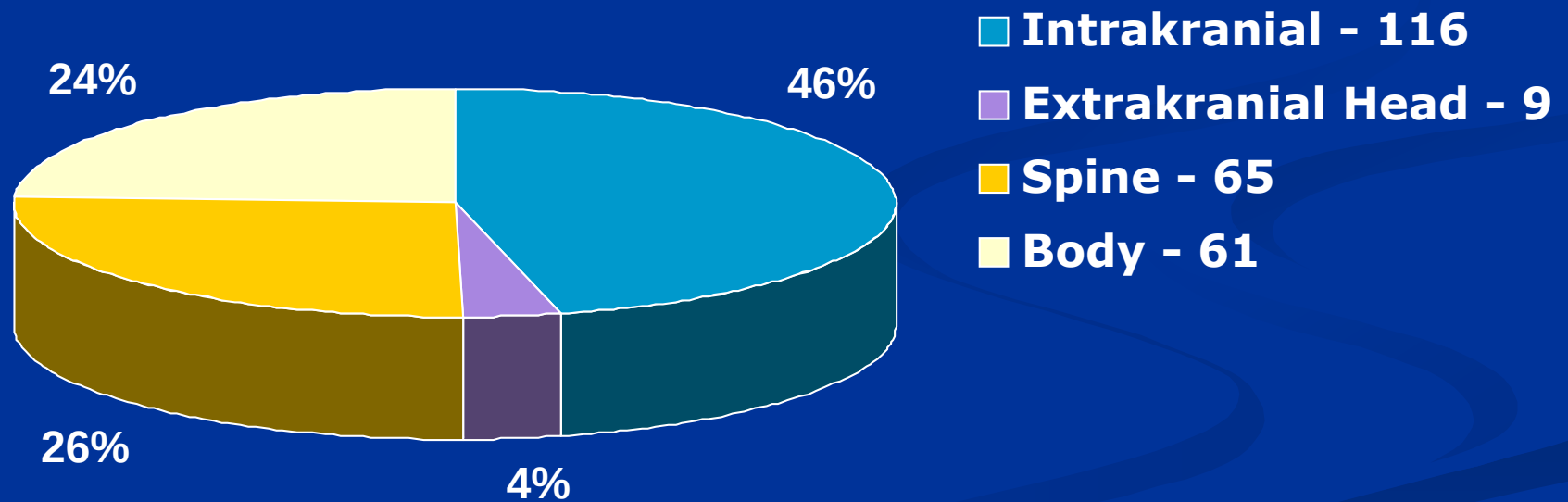
Courtesy of Boudler – Colorado (USA)

Son 12 ay Stanford CK tedavisi



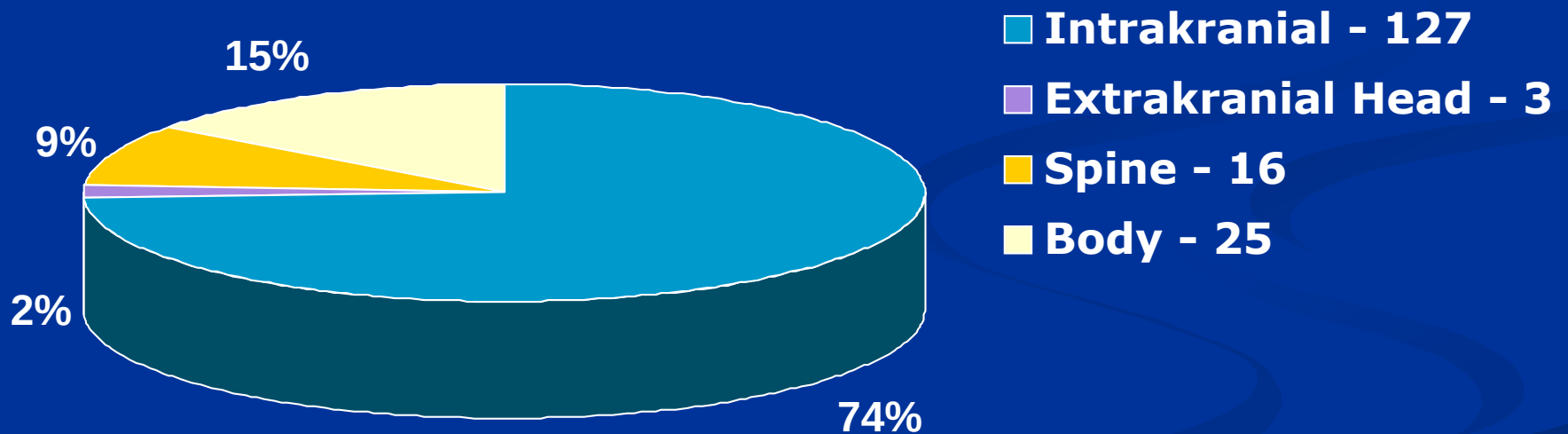
2004 Georgetown CK tedavisi

Toplam hasta - 251



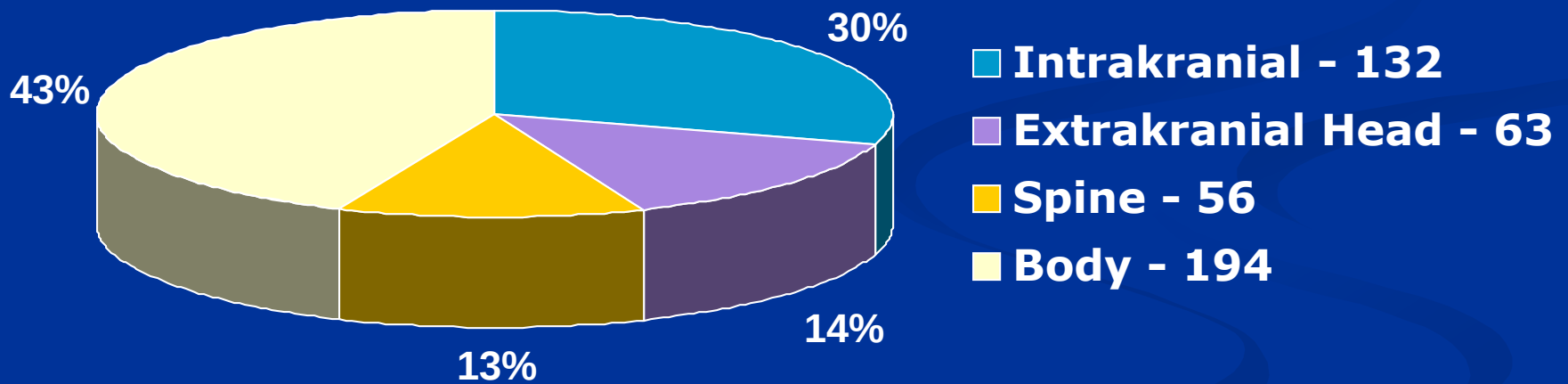
Boulder (USA) CK tedavisi

Toplam hasta - 171



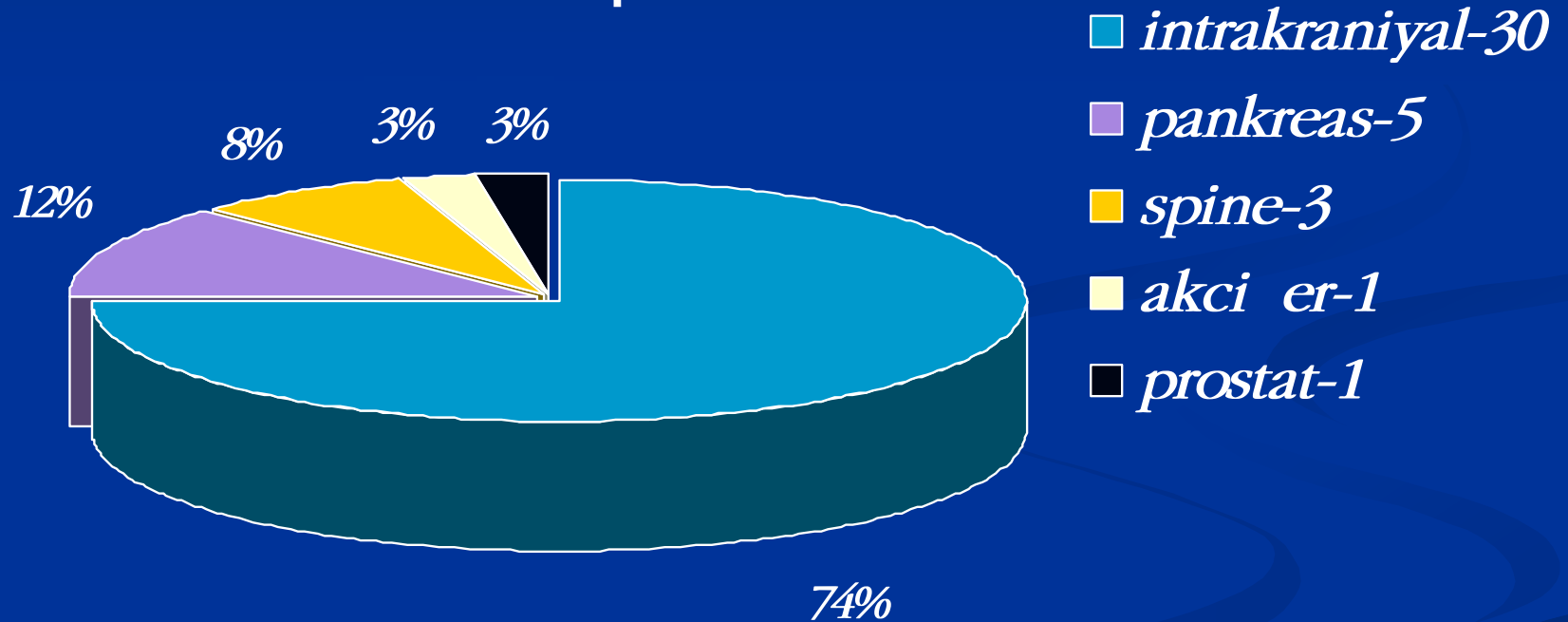
İlk 19 ay KCC CK tedavisi

Toplam hasta - 445



İlk 5 ay ASM CK tedavisi

Toplam Hasta - 40



ASM Cyberknife uygulaması

CYRIS™ InView™

Load

Fuse

Contour

Review

Settings

Help

Seed Points

Register

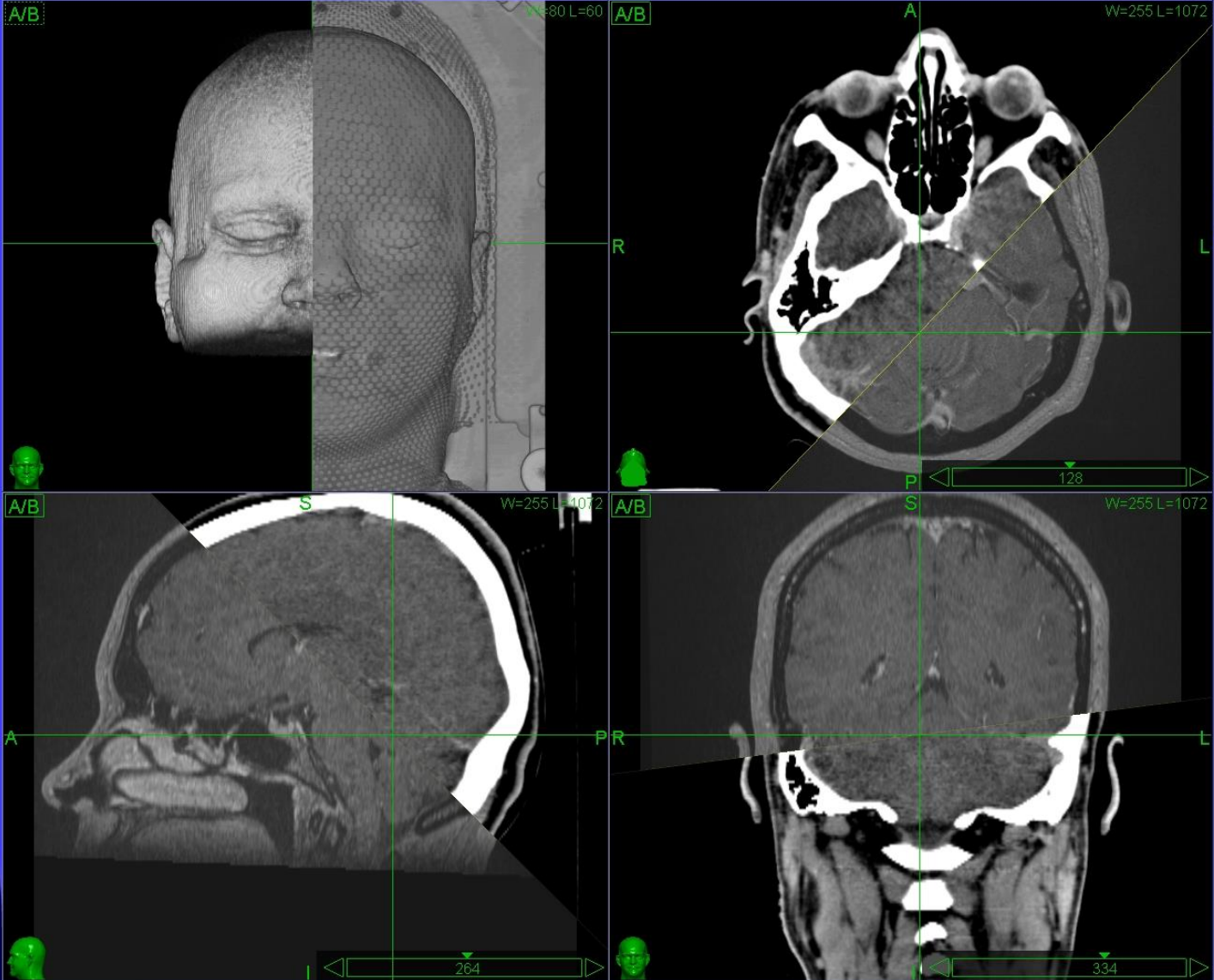
Start

Pause

Progress:



☐ Seed point transform



Patient Name

Deringoz^Hesna

Patient ID

1141

Dataset A CT/RTSS

Dataset B MR

CyRIS™ InView™ Version 1.1.0. Copyright© 2004, Accuray Inc.

X:264 Y:334 Z:128 Value:1034

ASM Cyberknife uygulaması



ASM Cyberknife uvculaması

CYRIS™ InView™

Load Fuse **Contour** Review Settings Help

Delineate Properties

Select VOI
TumorSite
Rename
Type: Target
Color:
☒ Auto interpolation

Edit Commands
Undo Redo
Delete All Delete
3D Copy Dilate
Copy Paste

Drawing Tools

Options
☐ Smart curve fitting
☒ Display all VOIs

Patient Name: Aydin^Bayram
Patient ID: 1933
Dataset A: CT/RTSS
Dataset B: MR

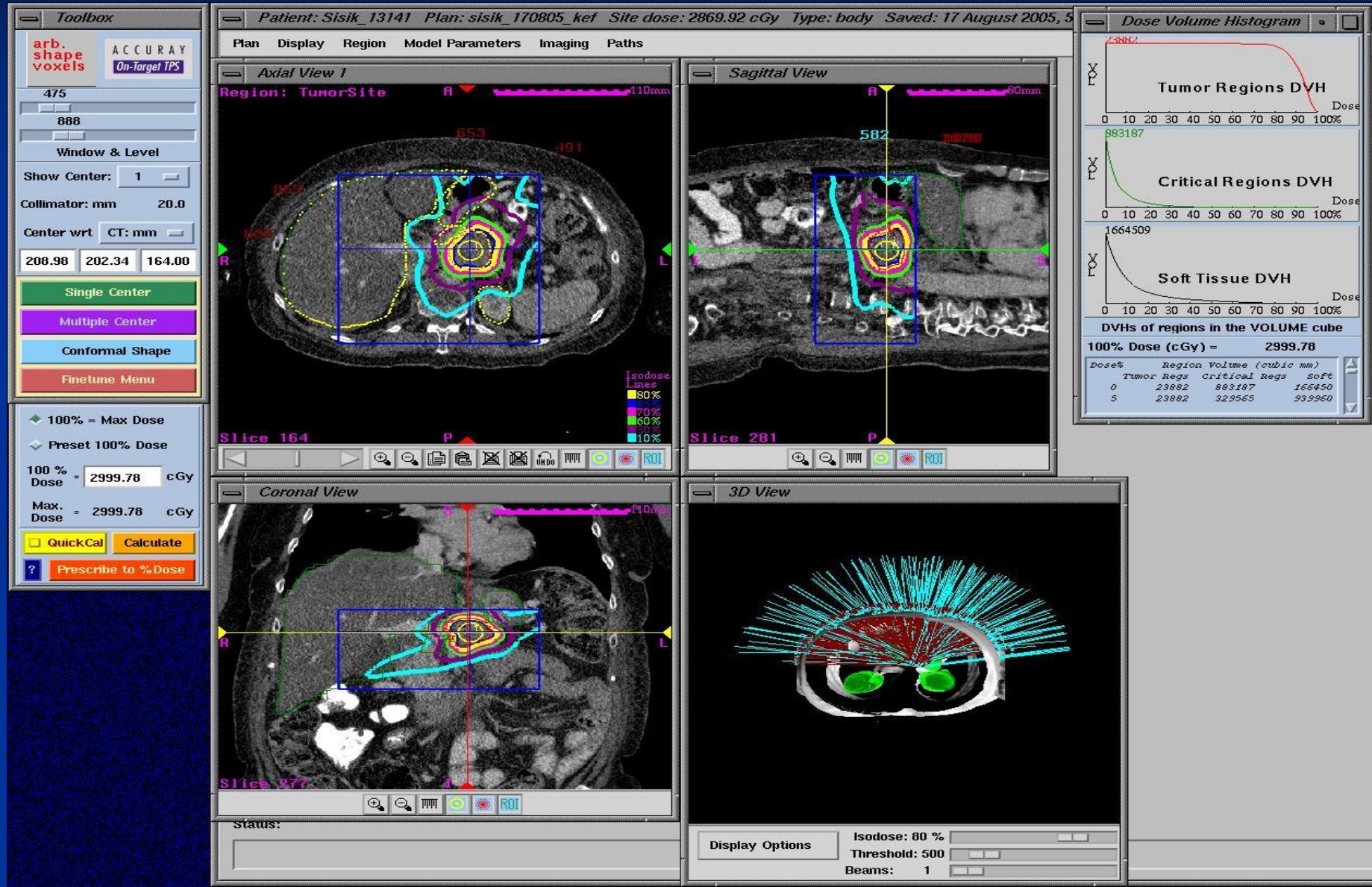
Dataset A **Dataset B**

X:228 Y:353 Z:194 Value:1013

CYRIS™ InView™ Version 1.1.0. Copyright© 2004, Accuray Inc.

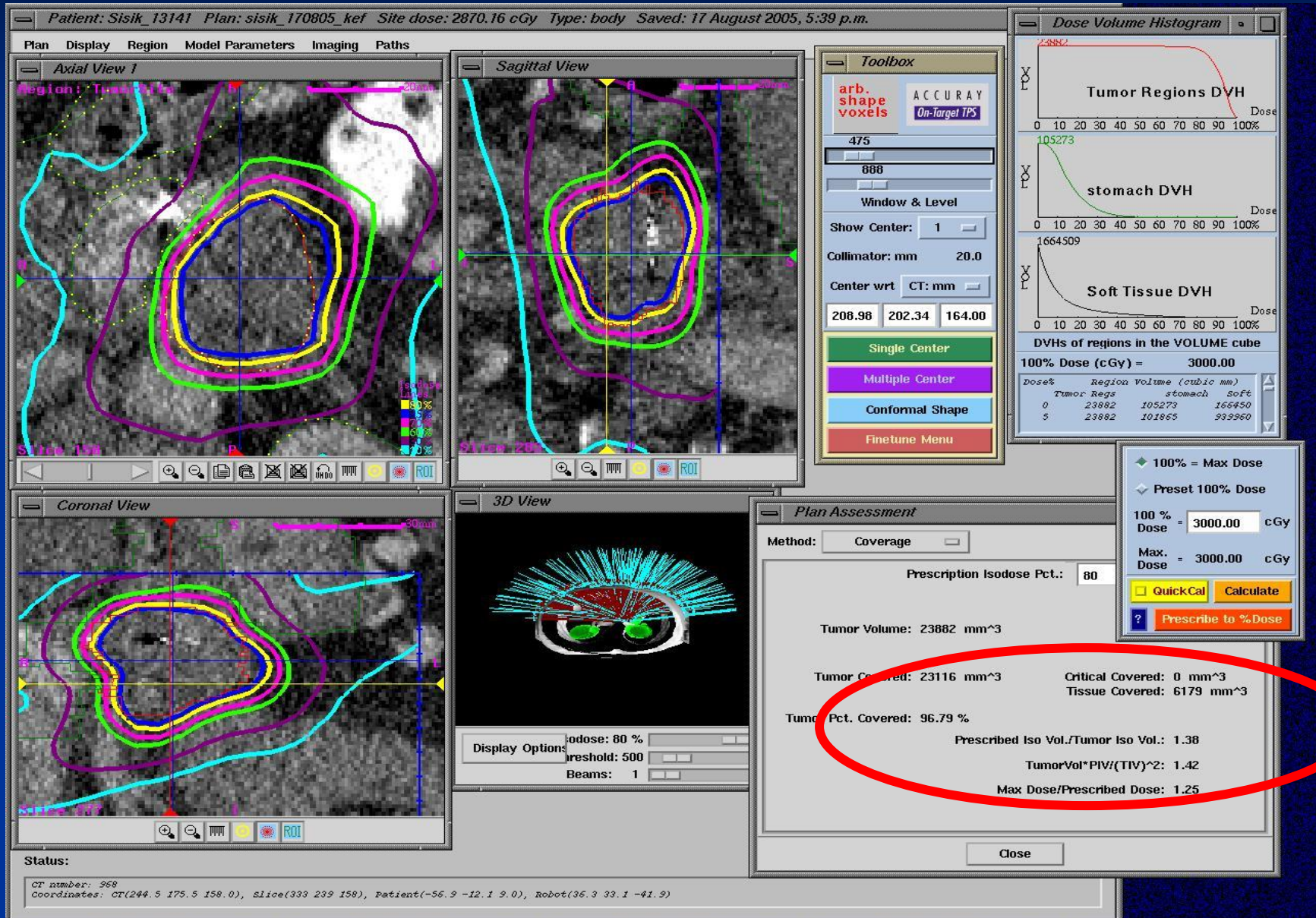
ASM Cyberknife uygulaması

Pancreas tm: 2 fx toplam 25 Gy CI:1,38 HI: 1,25



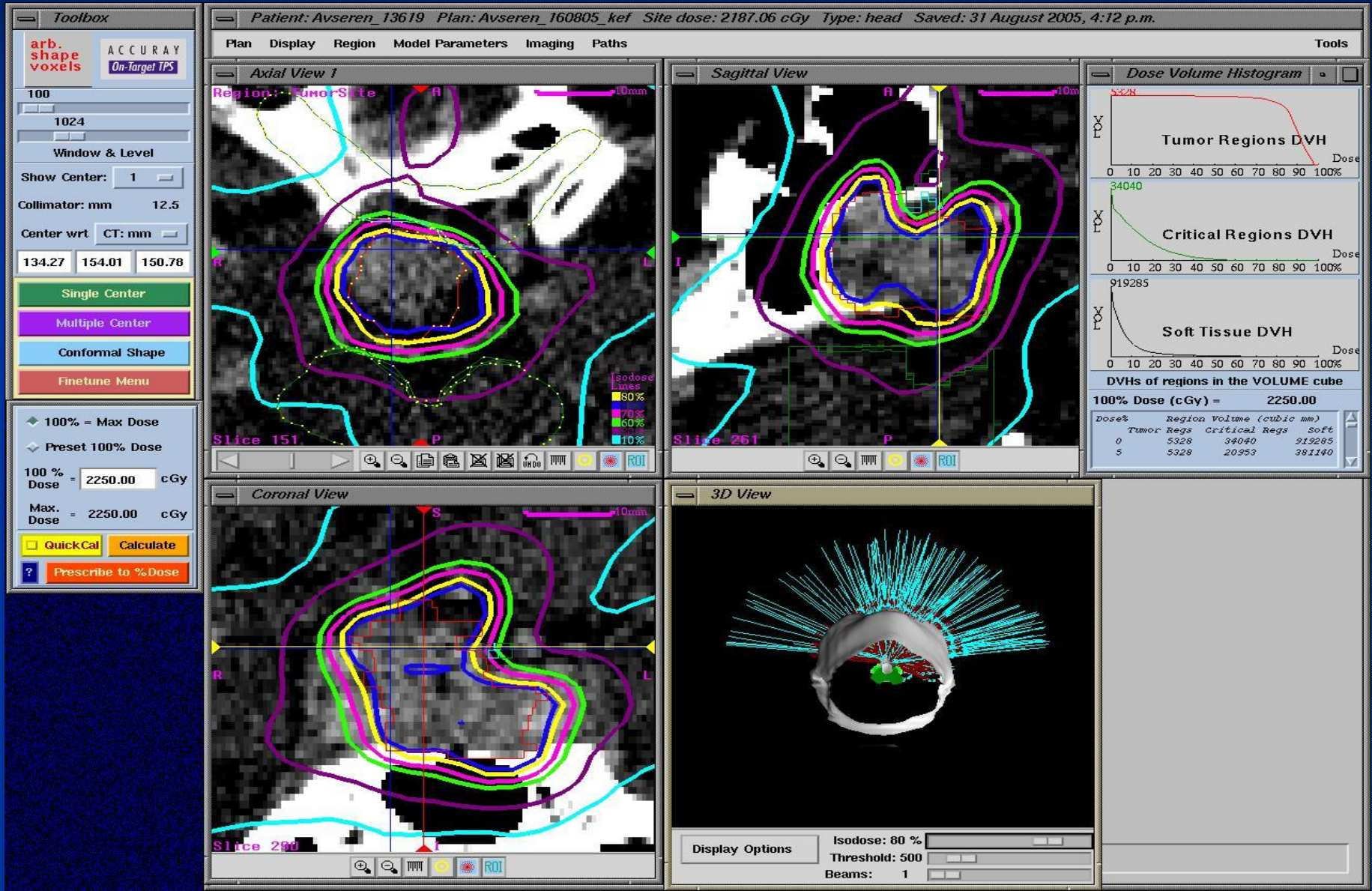
ASM Cyberknife uygulaması

Pancreas tm: 2 fx toplam 25 Gy CI:1,38 HI: 1,25



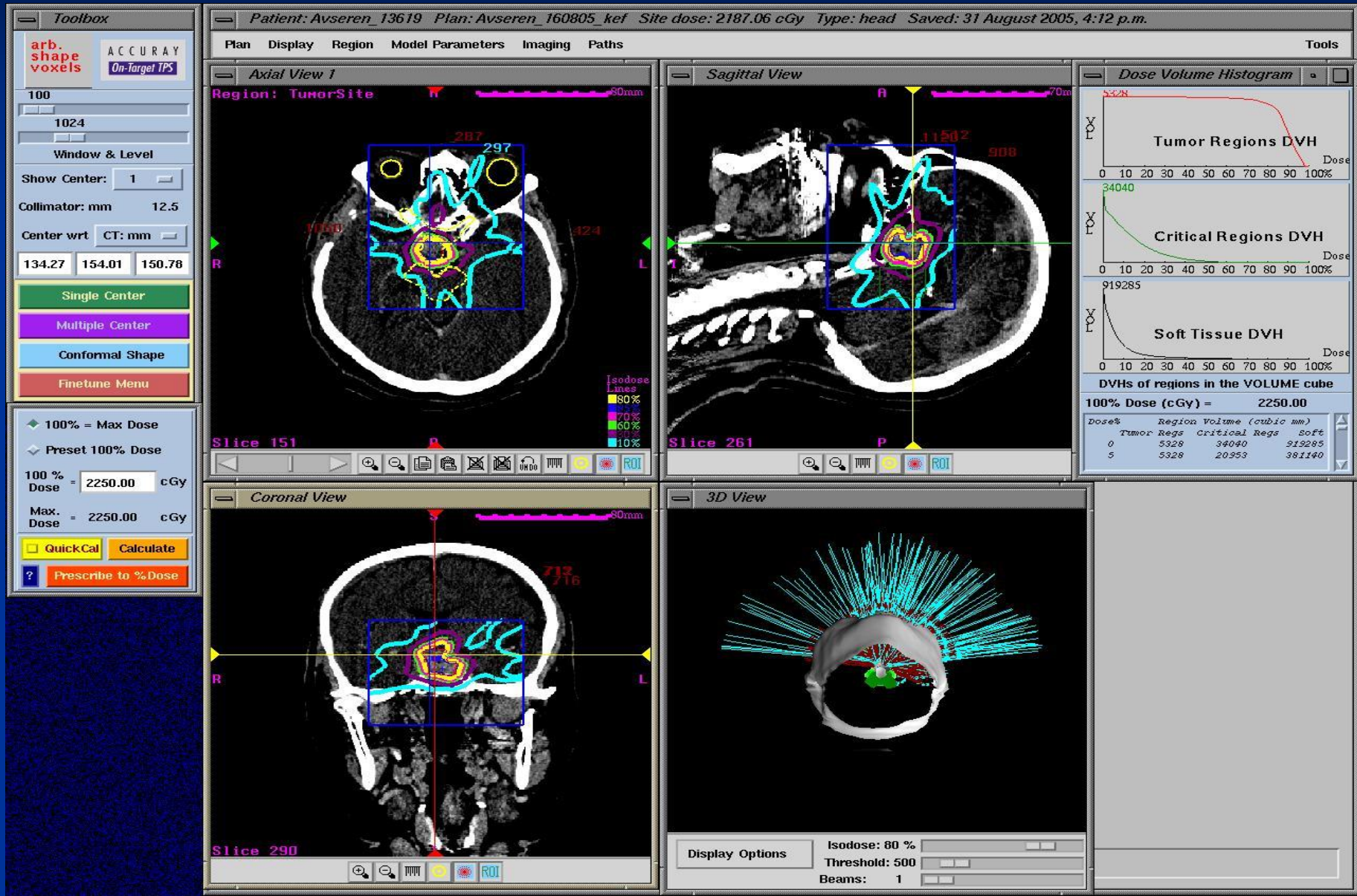
ASM Cyberknife uygulaması

Hipofiz tm: 2 fx toplam 18 Gy CI:1,53 HI: 1,25



ASM Cyberknife uygulaması

Hipofiz tm: 2 fx toplam 18 Gy CI:1,53 HI: 1,25



CyberKnife® ASM

Erken Sonuçları

Bayındır, Deniz
ID:13724
DoB:1989-10-17
2005-08-10
16:27:45
No. 93

A

Q: 95%



Bayındır*Deniz***
ID:13724
ANADOLU SAĞLIK MERKE. DoB:1989-10-17
Avant 2005-08-31
12:30:10
No. 83

ANADOLU SAĞLIK MERKE.

Avant

12:30:10

No. 83

A

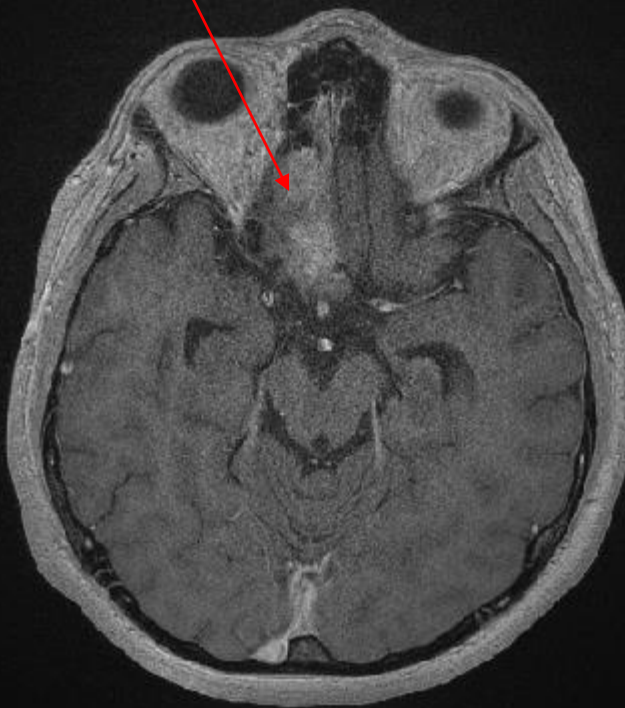
Q: 95%



ANADOLU SAĞLIK MERKEZI

Avanto

RF

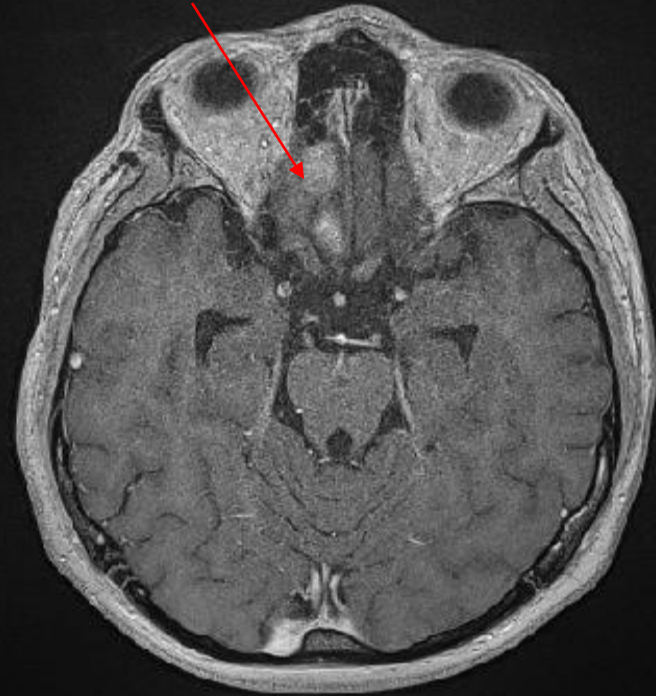


GR
TR:9
TE:3.98
SP:2.43784
SL:1
CM:

P

C: 86 SL:1
W: 180 CM:

Tedavi öncesi



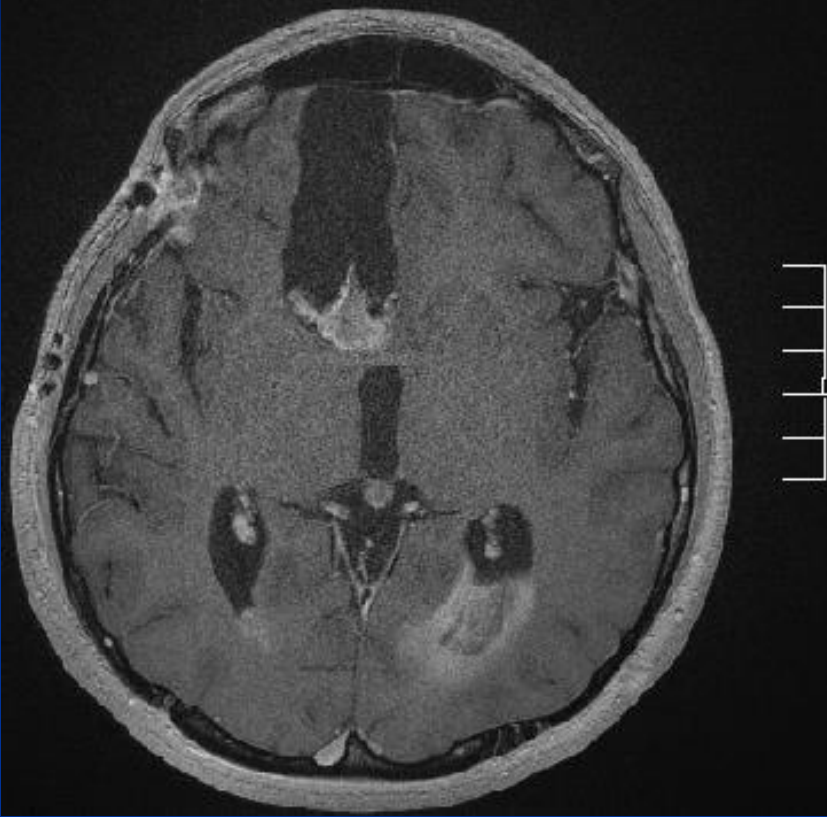
GR
TR:9
TE:3.98
SP:26.1477

P

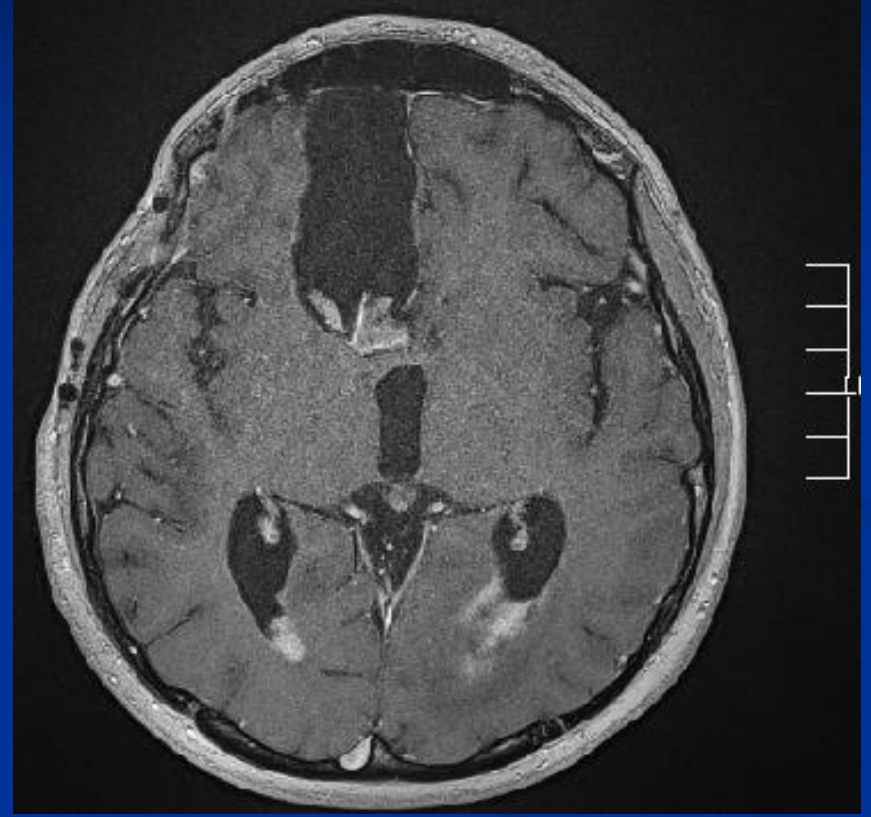
C: 765
W: 1581

Tedavi sonrası
20.gün

CyberKnife® ASM Erken Sonuçları



Tedavi öncesi



Tedavi sonrası 20.gün

SONUÇ

- Dünya genelinde 9000'den fazla hasta tedavisi
- Günde 7-8 hasta tedavi etmek mümkün
- Toplam klinik doğruluk 0.95 mm'den az.
- %75 beyin lezyonu
- %25 spine ve vücut lezyonu
- Ortalama fraksiyon sayısı 2.4
- Uygulama alanlarında hızlı artış

