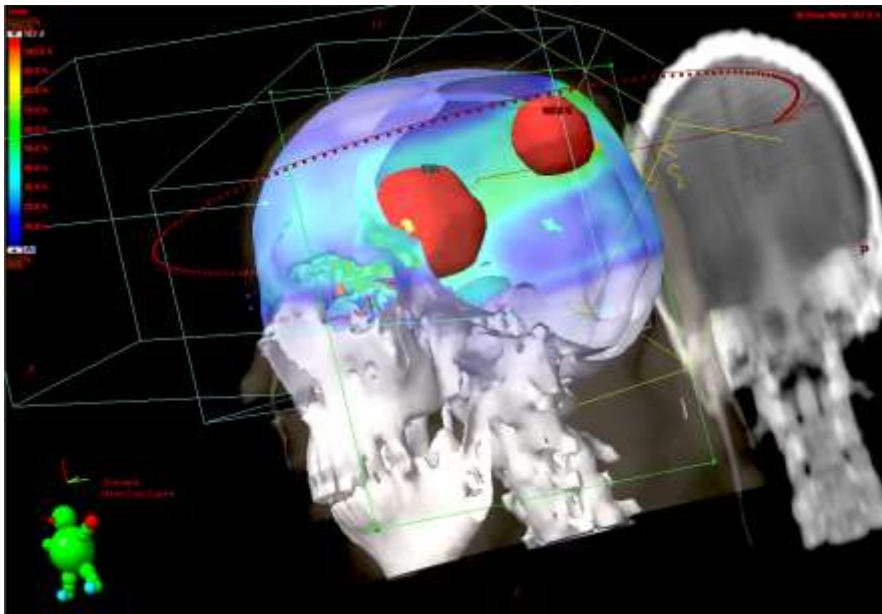


# Einzeitstereotaxie mit RapidArc im Kopfbereich



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# Einzeit-Kopfstererotaxie



## Häufige Indikationen

Hirnmetastasen  
Akustikusneurinome  
AVM

## Herausforderungen / Probleme:

- exakte Patientenpositionierung
- hohe Genauigkeit des Isozentrums
- exakte Online Lokalisation

# Technik-Möglichkeiten

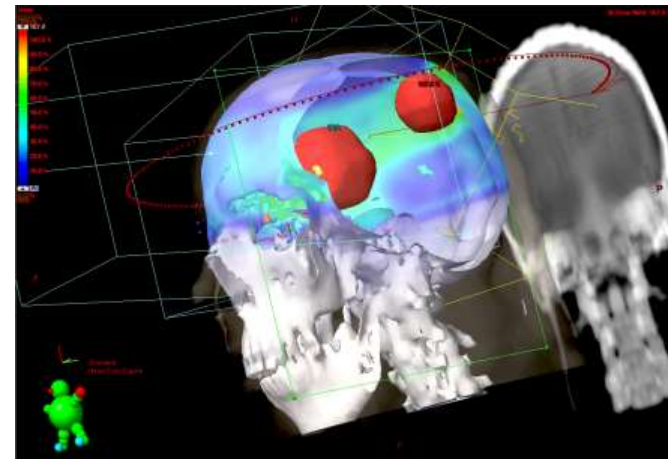
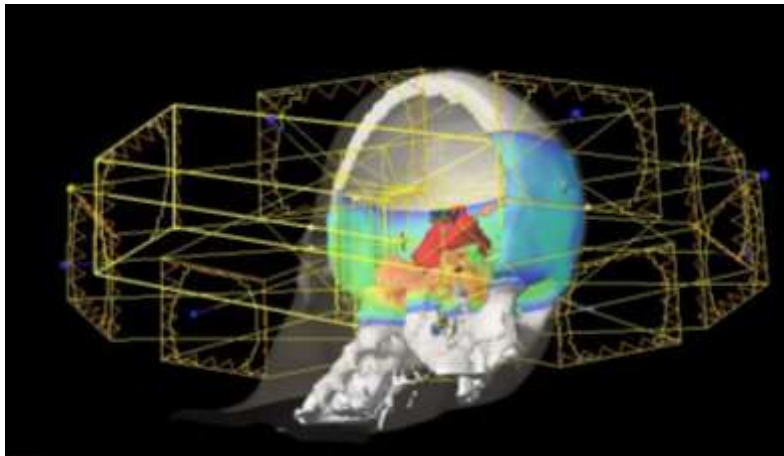
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Statisch konformale Technik

Dynamisch konformale Technik

Konventionelle IMRT

Volumetrische IMRT



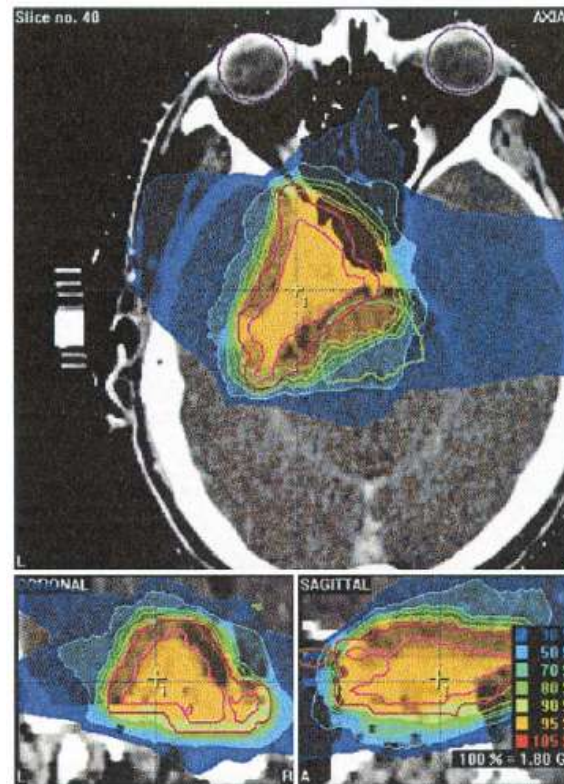
# Schädelbasismeningeome

## SCRT:

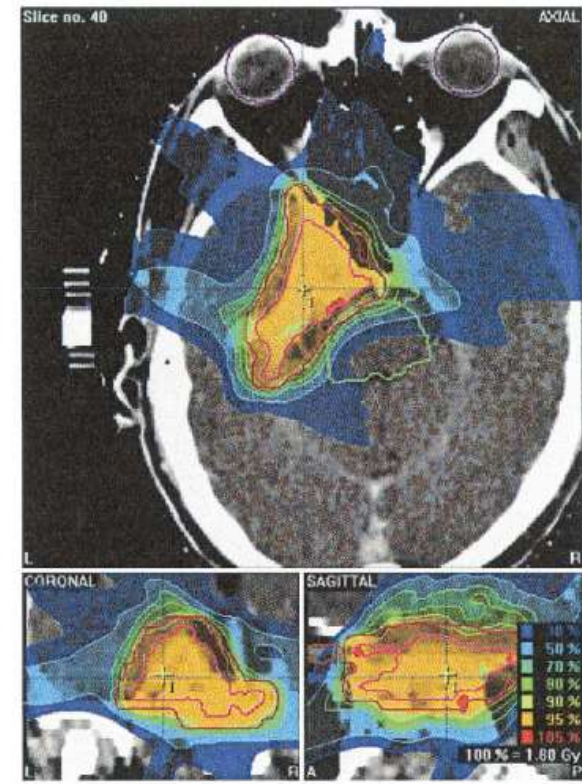
microMLC DKFZ und  
Clarkson Algorithmus

## IMSRT:

Brainlab microMLC und  
Pencil beam Algorithmus



SCRT



IMSRT

# Schädelbasismeningeome

## SCRT:

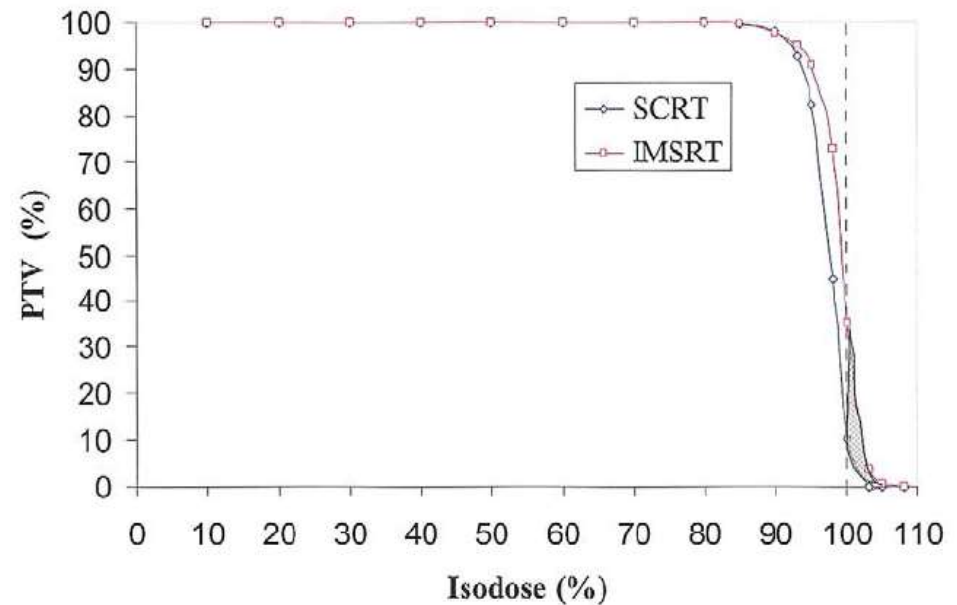
(microMLC DKFZ und Clarkson Algorithmus)

- kleinerer „Niedrig“dosisbereich ( $V_{30\%}$  kleiner)
- $D_{\max}$  geringer

## IMSRT:

(Brainlab microMLC und Pencil beam Algorithmus)

- schärferer Dosisgradient
- größerer Konformitätsindex
- bessere Anpassung der Isodosen bei unregelmäßigen ZV ( $V_{80\%}$  und  $V_{90\%}$  kleiner)
- bessere Risikoorganschonung (bes. in großer Nähe von ZV zu OAR)

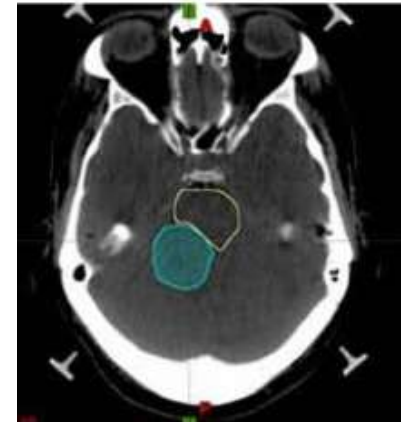


⇒ optimal ist IMRT

# Kopftumore

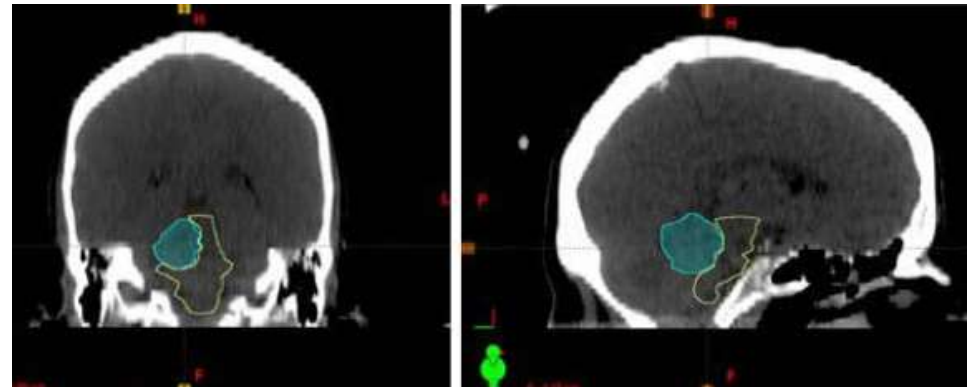
## 3D-statisch-konformal:

2,5mm MLC Novalis und  
5mm MLC Varian 2100Clinac  
6-12 Beams  
Eclipse Planning System



## 3D-dynamisch-konformal:

2,5mm MLC Novalis und  
5mm MLC Varian 2100Clinac  
4-7 Arcs  
Eclipse Planning System



## IMRT:

2,5mm MLC Novalis und  
5mm MLC Varian 2100Clinac  
4-12 static beams  
Eclipse Planning System

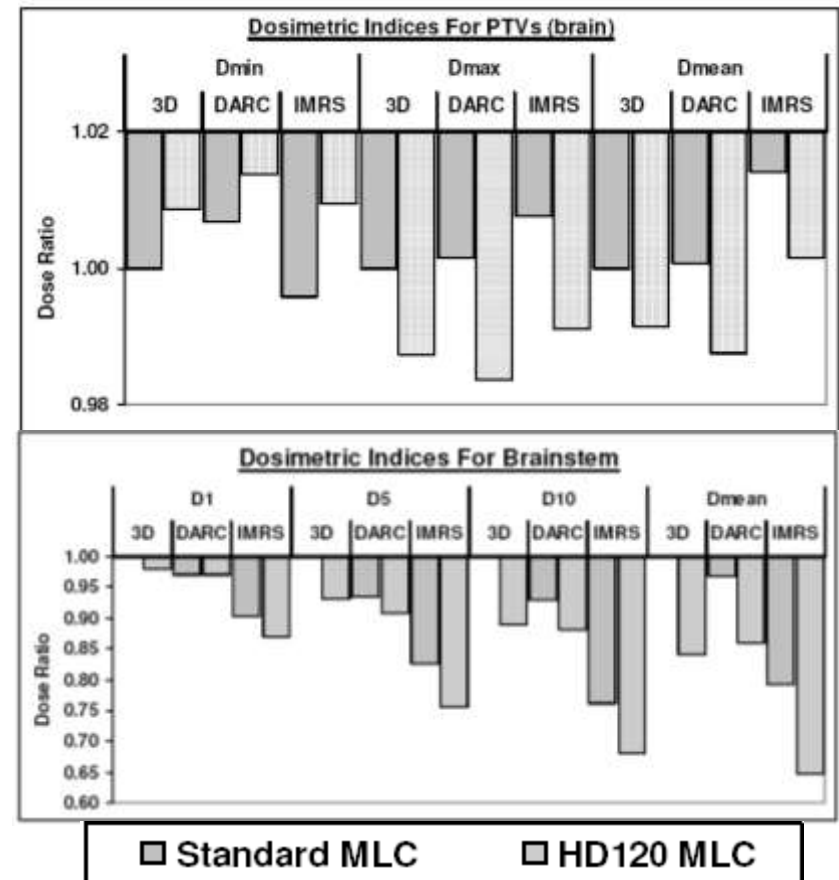
# Kopftumore

## Technik:

- bessere Risikoorganschonung mit IMRT vs. 3D-konformale Techniken (weniger Dosis am Hirnstamm)

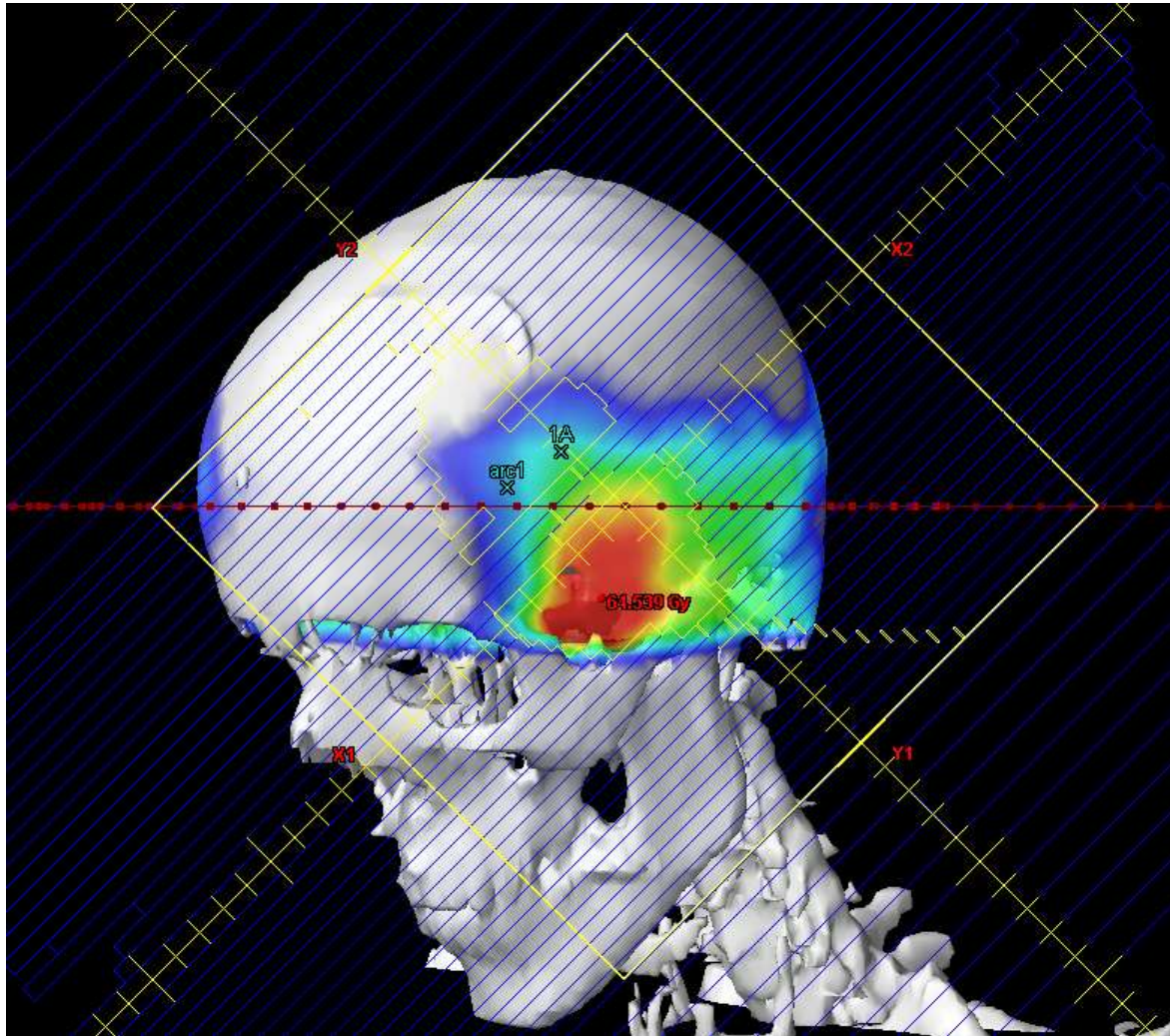
## MLC:

- HD MLC höhere Dosishomogenität ( $D_{\min}$  größer und  $D_{\max}$  kleiner)
- HD MLC weniger Dosis am Hirnstamm



⇒ optimal ist IMRT mit HD MLC

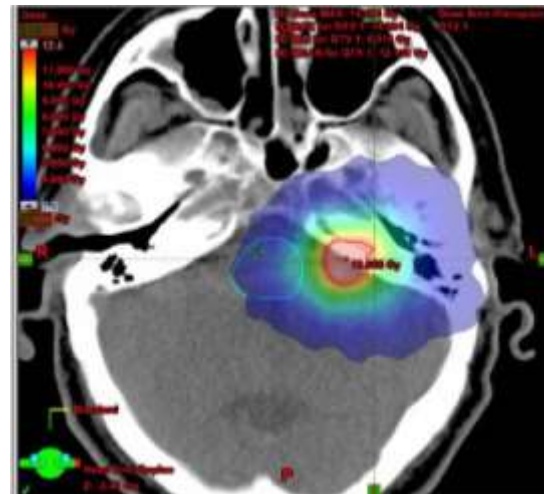
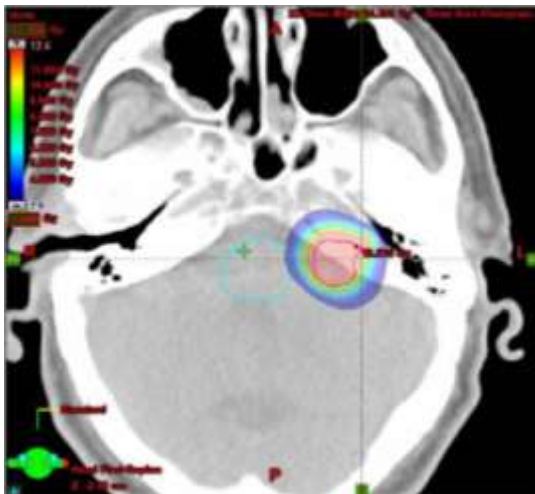
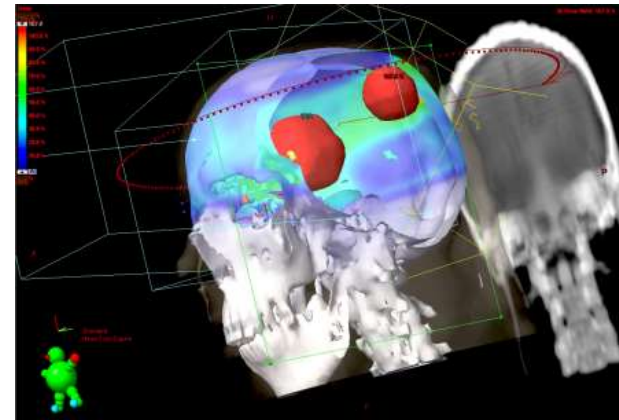
# IMRT die optimale Technik?





# Technik-Möglichkeiten

## ConformalArcTherapy (CAT) vs. RapidArc-Technik



# Technik-Vergleich

Pat. no	Gender	Age (years)	Diagnosis	Summated GTV (cm <sup>3</sup> )	Number of isocenters	Prescribed SRS dose (Gy)	Prescription isodose CAT/RA (%)	Distance to nearest OAR (cm)
1	M	58	1 metastasis	0.1	1	11.0	80/95	3.7
2	M	76	Vestibularis schwannoma	0.9	2	13.0	70/95	0.6
3	F	44	2 metastases	0.3	2	22.0	80/95	4.2
4	M	55	1 metastasis	8.4	1	18.0	80/95	1.2
5	M	61	1 metastasis	3.2	1	18.0	80/95	2.8
6	M	60	1 metastasis	0.1	1	24.0	80/95	3.4
7	F	64	1 metastasis	0.7	1	24.0	80/95	4.0
8	M	72	Atypic meningeoma	2.7	1	14.0	70/95	2.8
9	F	64	4 metastases	2.0	4	22.0	80/95	3.5
10	M	60	2 metastases	0.3	2	24.0	80/95	3.6

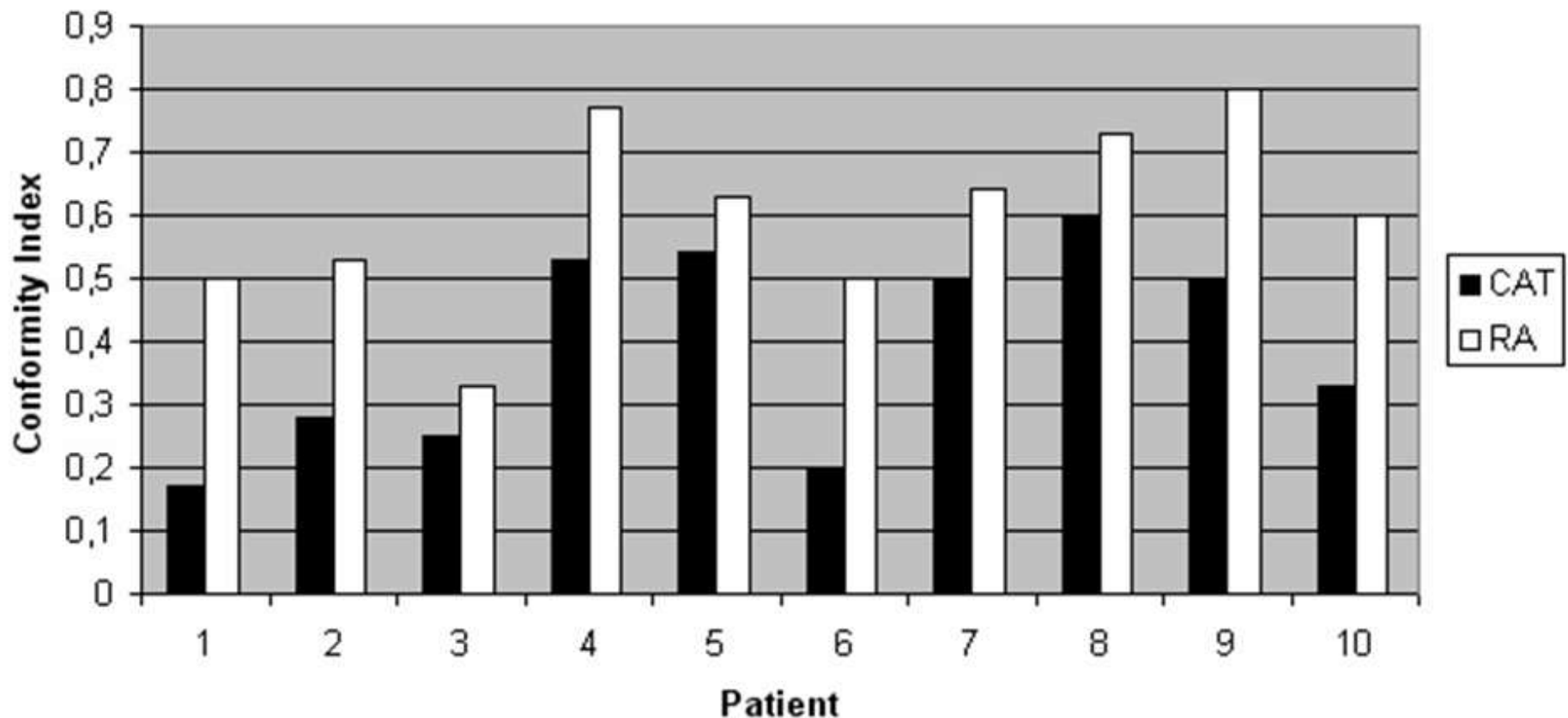
F: female, M: Male, GTV: Gross Tumour Volume, SRS: Stereotactic Radiosurgery, CAT: Conformal Arc Technique, RA: Rapid Arc, OAR: organ at risk.

- GTV mean Volume 0.8 cm<sup>3</sup> (0.1 - 8.4 cm<sup>3</sup>)
- GTV coverage 100% bei beiden Techniken und allen Patienten

# Conformity Index

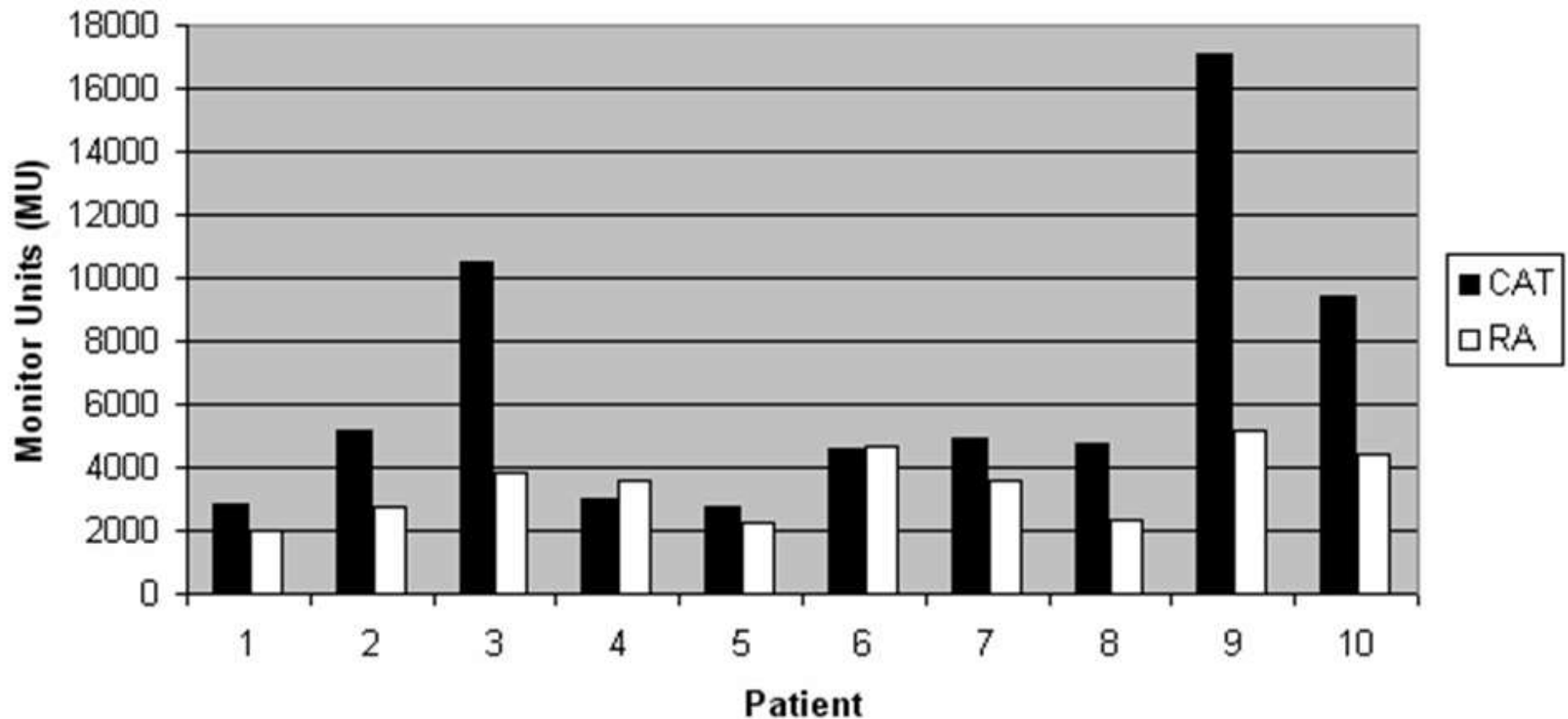
Höherer Conformity Index mit RadpiArc-Technik  
(Median 0.56 vs. 0.37)

$D_{\max}$  im GTV geringer mit RadpiArc-Technik  
(Mean 19.9Gy vs. 24.4 min.)



# Monitoreinheiten

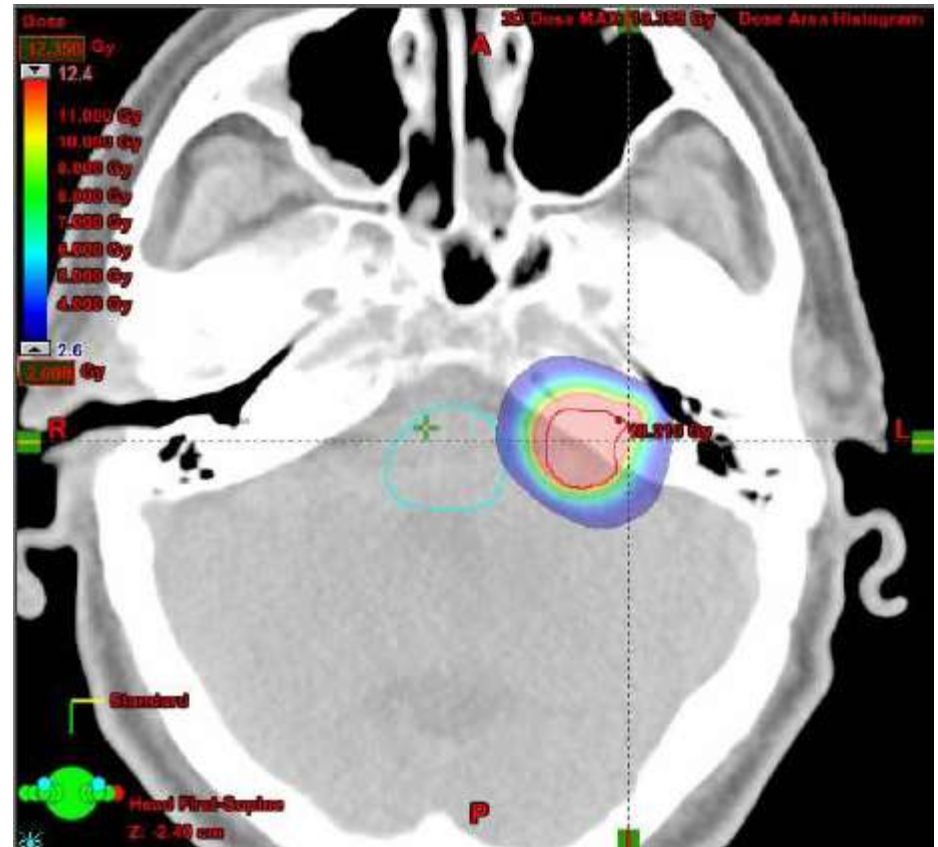
Weniger Monitoreinheiten mit RadpiArc-Technik  
(Median 3455 MU vs. 6504 MU)



# CAT-Technik

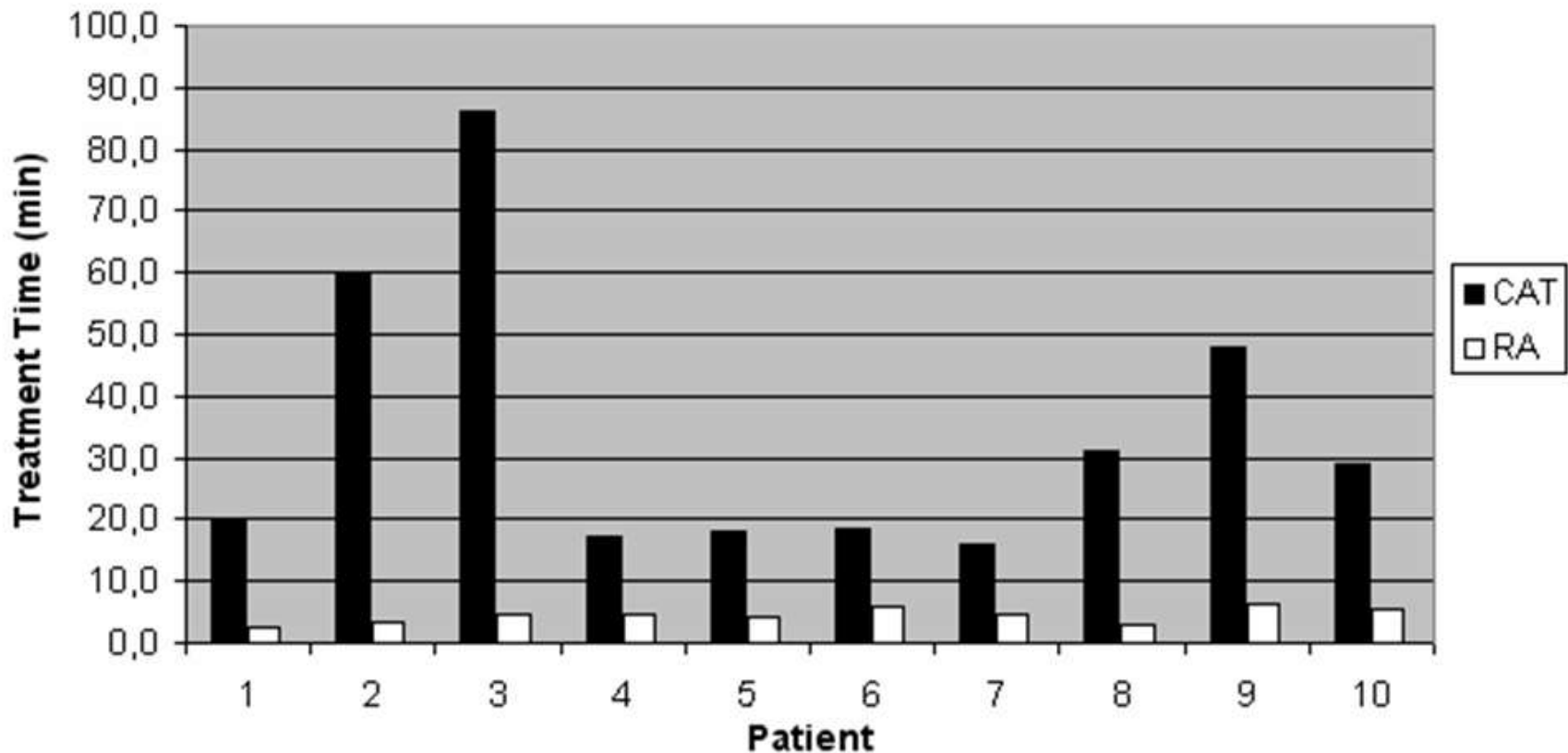
## Vorteile:

- scharfe Dosisgradienten



# Bestrahlungsdauer

Erheblich kürze Zeit mit RadpiArc-Technik  
(Median 4.5min. vs. 34.4 min.)



# Risikoorganbelastung

Hirnelastung  $D_{\text{mean}}$  geringer mit CAT-Technik

Niedrigdosisbereich erheblich niedriger mit CAT-Technik

Risikoorganbelastung z.T. geringer mit CAT-Technik, z.T. vergleichbar mit beiden Techniken

Patient No.	1		2		3		4		5		6		7		8		9		10	
Technique	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA
Healthy brain $D_{\text{mean}}$ [Gy]	0.1	0.3	0.4	0.5	<b>0.6</b>	3	1.0	1.4	<b>2.1</b>	5.2	0.3	0.6	0.6	0.7	0.6	1	<b>1.3</b>	3.2	<b>0.5</b>	2.2
$V_{2\text{Gy}}$ [cm <sup>3</sup> ]	<b>8.6</b>	53	<b>59.5</b>	104.8	<b>68.7</b>	860.3	<b>316.8</b>	394.4	<b>92.3</b>	145.7	<b>37.6</b>	99.9	100.8	105.7	<b>99.6</b>	367.6	<b>223.7</b>	1057	<b>71.4</b>	601
OAR $D_{\text{max}}$ [Gy]																				
Lens left	0.0	0.5	0.0	0.1	<b>0.1</b>	1.3	<b>0.0</b>	1.3	0.6	0.1	0.3	0.2	0.0	0.0	<b>0.0</b>	<b>1.9</b>	0.6	0.3	0.3	0.6
Lens right	0.0	0.4	0.0	0.1	<b>0.0</b>	1.4	<b>1.1</b>	2.5	0.6	0.0	0.0	0.1	0.0	0.0	<b>0.0</b>	<b>1.3</b>	0.0	0.3	0.3	0.6
Brainstem	0.4	1.5	<b>3.7</b>	6.9	<b>0.5</b>	7.1	<b>2.3</b>	3.4	0.8	0.7	0.5	0.8	0.9	0.1	4.9	4.9	2.0	1.2	<b>0.9</b>	2.1
Chiasm	0.0	0.9	<b>0.5</b>	3.8	<b>0.1</b>	3.8	<b>0.7</b>	2.5	0.6	0.0	0.0	0.4	0.0	0.1	<b>1.2</b>	<b>4.2</b>	1.4	1.7	<b>0.0</b>	1.7
N. opticus right	0.0	0.6	0.0	0.2	<b>0.2</b>	3.2	2.4	1.4	0.7	0.1	0.0	0.3	0.0	0.0	<b>0.3</b>	<b>2.6</b>	0.5	1.0	0.4	1.3
N. opticus left	0.0	0.9	0.5	0.3	<b>0.2</b>	3.7	0.0	0.9	0.8	0.1	0.5	0.3	0.0	0.0	<b>1.2</b>	<b>4.6</b>	1.4	1.0	0.5	1.4

Healthy brain ( $D_{\text{mean}}$ ), low-dose volume ( $V_{2\text{Gy}}$ ) for all patients and both treatment techniques. The maximum dose to OAR is shown in Gy, the mean dose to healthy brain in Gy, and the low dose volume (volume which is irradiated with maximum of 2 Gy) in cm<sup>3</sup>.

OAR = organs at risk, CAT = conformal arc therapy, RA = Rapid Arc,  $D_{\text{mean}}$  = mean dose,  $V_{2\text{Gy}}$  = volume irradiated with 2 Gy or higher, Fat marked fields indicate a benefit for this value.

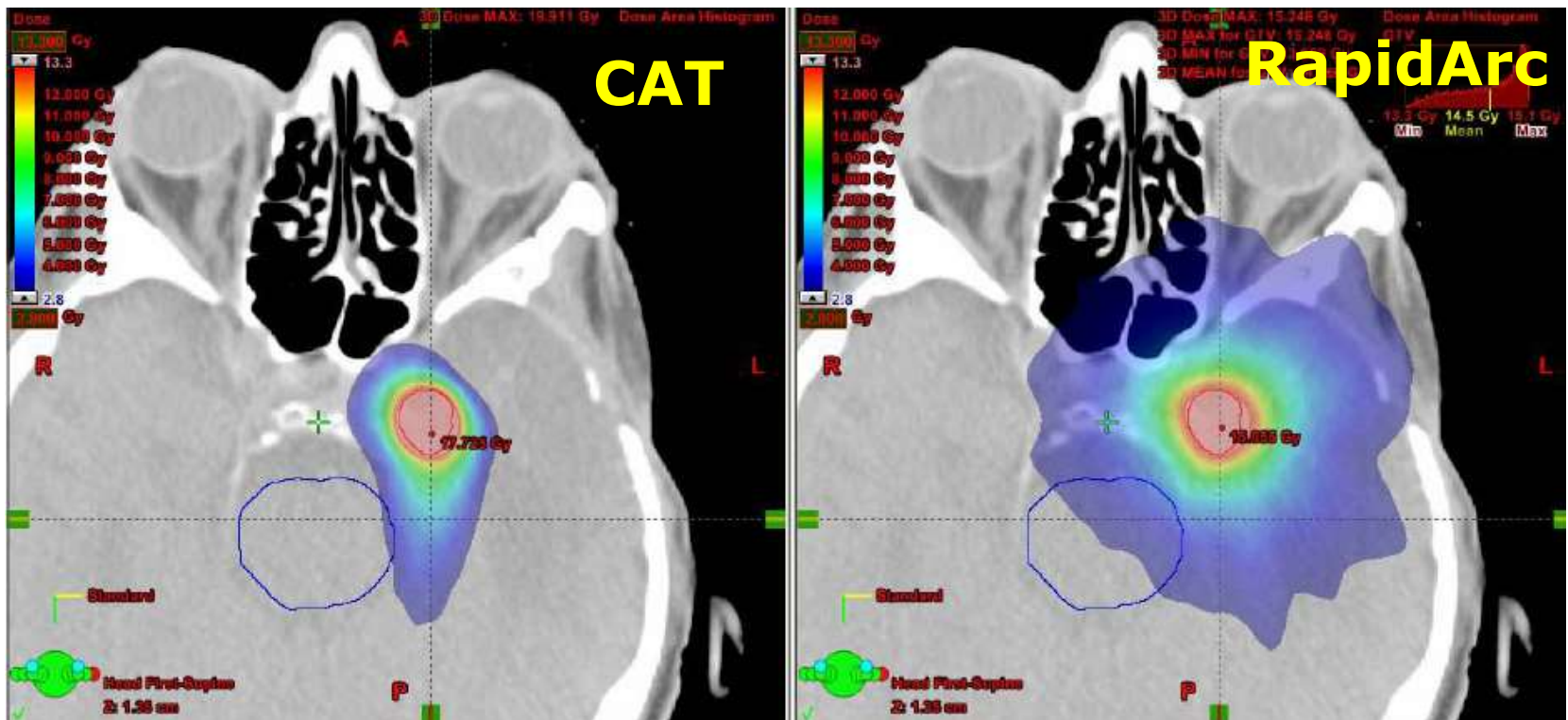
# Patient 8

N. optikus links niedrigere Dosis mit CAT-Technik

( $D_{\max}$  1.2Gy vs. 4.6Gy)

Chiasma niedriger Dosis mit CAT-Technik

( $D_{\max}$  1.2Gy vs. 4.2Gy)





# Ergebnisse

Patient No.	1		2		3		4		5		6		7		8		9		10	
Prescribed Dose [Gy]	11		13		22		18		18		24		24		14		22		24	
Technique	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA
GTV D <sub>max</sub> [Gy]	13.7	11.2	17.3	14	27.5	22.6	22.4	19.2	22.5	19.4	30	24.9	30	25.8	19.9	15.2	31.4	23.1	30	24.1
GTV [cm <sup>3</sup> ]	0.1		0.9		0.3		8.4		3.2		0.1		0.7		2.7		1.0		0.3	
V <sub>95%</sub> [cm <sup>3</sup> ]	0.6	0.2	3.2	1.5	1.2	0.9	15.8	10.7	5.9	4.9	0.5	0.2	1.4	1.1	4.5	3.7	4.0	2.5	0.9	0.5
CI <sub>95%</sub>	0.17	0.50	0.28	0.53	0.25	0.33	0.53	0.77	0.54	0.63	0.20	0.50	0.50	0.64	0.60	0.73	0.25	0.40	0.33	0.60
Healthy brain D <sub>mean</sub> [Gy]	0.1	0.3	0.4	0.5	0.6	3	1.0	1.4	2.1	5.2	0.3	0.6	0.6	0.6	0.6	1	1.3	3.2	0.5	2.2
V <sub>2Gy</sub> [cm <sup>3</sup> ]	8.6	53	59.5	104.8	68.7	860.3	316.8	394.4	92.3	145.7	37.6	99.9	100.8	105.7	99.6	367.6	223.7	1057	71.4	601
OAR D <sub>max</sub> [Gy]																				
Lens left	0	0.5	0	0.1	0.1	1.3	0	1.3	0.6	0.1	0.3	0.2	0	0	0	1.9	0.6	0.3	0.3	0.6
Lens right	0	0.4	0	0.1	0	1.4	1.1	2.5	0.6	0	0	0.1	0	0	0	1.3	0	0.3	0.3	0.6
Brainstem	0.4	1.5	3.7	6.9	0.5	7.1	2.3	3.4	0.8	0.7	0.5	0.8	0.9	0.1	4.9	4.9	2.0	1.2	0.9	2.1
Chiasm	0	0.9	0.5	3.8	0.1	3.8	0.7	2.5	0.6	0	0.0	0.4	0.0	0.1	1.2	4.2	1.4	1.7	0.0	1.7
N. opticus right	0	0.6	0.0	0.2	0.2	3.2	2.4	1.4	0.7	0.1	0.0	0.3	0.0	0	0.3	2.6	0.5	1	0.4	1.3
N. opticus left	0	0.9	0.5	0.3	0.2	3.7	0.0	0.9	0.8	0.1	0.5	0.3	0.0	0	1.2	4.6	1.4	1	0.5	1.4
Treatment time [min]	20.37	2.35	59.5	3.46	86	4.82	17.2	4.47	18.2	4.36	18.3	5.83	16.07	4.5	31.3	2.87	48	6.44	28.9	5.47
Monitor units	2817	2025	5164	2771	10522	3856	2964	3577	2729	2241	4618	4663	4916	3595	4756	2294	17116	5151	9433	4377
Choice of treatment	RA		CAT		CAT		RA / CAT		RA		RA		RA		CAT		RA		RA	
Reason	Time / MU		V <sub>2Gy</sub> / OAR		V <sub>2Gy</sub> / OAR		-		Time / MU / D <sub>max</sub>		Time / D <sub>max</sub>		Time / MU / D <sub>max</sub>		V <sub>2Gy</sub> / OAR		Time / MU / D <sub>max</sub> / V <sub>2Gy</sub>		Time / MU / D <sub>max</sub> / V <sub>2Gy</sub>	

Green marked fields indicate a benefit for this item, whereas red fields show a disadvantage for each measured value. OAR = organs at risk, CAT = conformal arc therapy, RA = Rapid Arc, GTV = gross tumour volume, D<sub>mean</sub> = mean dose, V<sub>2Gy</sub> = volume irradiated with 2 Gy or higher. V<sub>95%</sub> = volume of 95% isodose in cm<sup>3</sup>, CI<sub>95%</sub> = ratio of the target volume covered by the 95% isodose line divided by the total volume covered by that isodose line.

# Ergebnisse

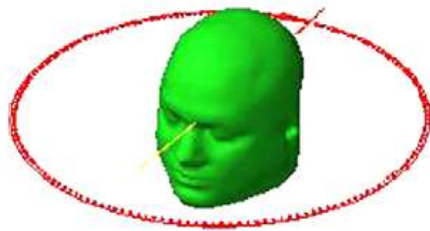
Patient No.	1		2		3		4		5		6		7		8		9		10	
Prescribed Dose [Gy]	11		13		22		18		18		24		24		14		22		24	
Technique	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA	CAT	RA
GTV D <sub>max</sub> [Gy]	13.7	11.2	17.3	14	27.5	22.6	22.4	19.2	22.5	19.4	30	24.9	30	25.8	19.9	15.2	31.4	23.1	30	24.1
GTV [cm <sup>3</sup> ]	0.1		0.9		0.3		8.4		3.2		0.1		0.7		2.7		1.0		0.3	
V <sub>95%</sub> [cm <sup>3</sup> ]	0.6	0.2	3.2	1.5	1.2	0.9	15.8	10.7	5.9	4.9	0.5	0.2	1.4	1.1	4.5	3.7	4.0	2.5	0.9	0.5
CI <sub>95%</sub>	0.17	0.50	0.28	0.53	0.25	0.33	0.53	0.77	0.54	0.63	0.20	0.50	0.50	0.64	0.60	0.73	0.25	0.40	0.33	0.60
Healthy brain D <sub>mean</sub> [Gy]	0.1	0.3	0.4	0.5	0.6	3	1.0	1.4	2.1	5.2	0.3	0.6	0.6	0.6	0.6	1	1.3	3.2	0.5	2.2
V <sub>2Gy</sub> [cm <sup>3</sup> ]	8.6	53	59.5	104.8	68.7	860.3	316.8	394.4	92.3	145.7	37.6	99.9	100.8	105.7	99.6	367.6	223.7	1057	71.4	601
OAR D <sub>max</sub> [Gy]																				
Lens left	0	0.5	0	0.1	0.1	1.3	0	1.3	0.6	0.1	0.3	0.2	0	0	0	1.9	0.6	0.3	0.3	0.6
Lens right	0	0.4	0	0.1	0	1.4	1.1	2.5	0.6	0	0	0.1	0	0	0	1.3	0	0.3	0.3	0.6
Brainstem	0.4	1.5	3.7	6.9	0.5	7.1	2.3	3.4	0.8	0.7	0.5	0.8	0.9	0.1	4.9	4.9	2.0	1.2	0.9	2.1
Chiasm	0	0.9	0.5	3.8	0.1	3.8	0.7	2.5	0.6	0	0.0	0.4	0.0	0.1	1.2	4.2	1.4	1.7	0.0	1.7
N. opticus right	0	0.6	0.0	0.2	0.2	3.2	2.4	1.4	0.7	0.1	0.0	0.3	0.0	0	0.3	2.6	0.5	1	0.4	1.3
N. opticus left	0	0.9	0.5	0.3	0.2	3.7	0.0	0.9	0.8	0.1	0.5	0.3	0.0	0	1.2	4.6	1.4	1	0.5	1.4
Treatment time [min]	20.37	2.35	59.5	3.46	86	4.82	17.2	4.47	18.2	4.36	18.3	5.83	16.07	4.5	31.3	2.87	48	6.44	28.9	5.47
Monitor units	2817	2025	5164	2771	10522	3856	2964	3577	2729	2241	4618	4663	4916	3595	4756	2294	17116	5151	9433	4377
Choice of treatment	RA		CAT		CAT		RA / CAT		RA		RA		RA		CAT		RA		RA	
Reason	Time / MU		V <sub>2Gy</sub> / OAR		V <sub>2Gy</sub> / OAR		-		Time / MU / D <sub>max</sub>		Time / D <sub>max</sub>		Time / MU / D <sub>max</sub>		V <sub>2Gy</sub> / OAR		Time / MU / D <sub>max</sub> / V <sub>2Gy</sub>		Time / MU / D <sub>max</sub> / V <sub>2Gy</sub>	

Green marked fields indicate a benefit for this item, whereas red fields show a disadvantage for each measured value. OAR = organs at risk, CAT = conformal arc therapy, RA = Rapid Arc, GTV = gross tumour volume, D<sub>mean</sub> = mean dose, V<sub>2Gy</sub> = volume irradiated with 2 Gy or higher. V<sub>95%</sub> = volume of 95% isodose in cm<sup>3</sup>, CI<sub>95%</sub> = ratio of the target volume covered by the 95% isodose line divided by the total volume covered by that isodose line.

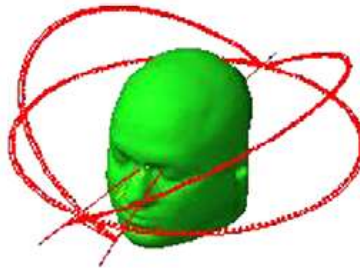
⇒ optimal ist eine individuelle Entscheidung zwischen CAT und RapidArc

# Multi-Isozenter-RapidArc

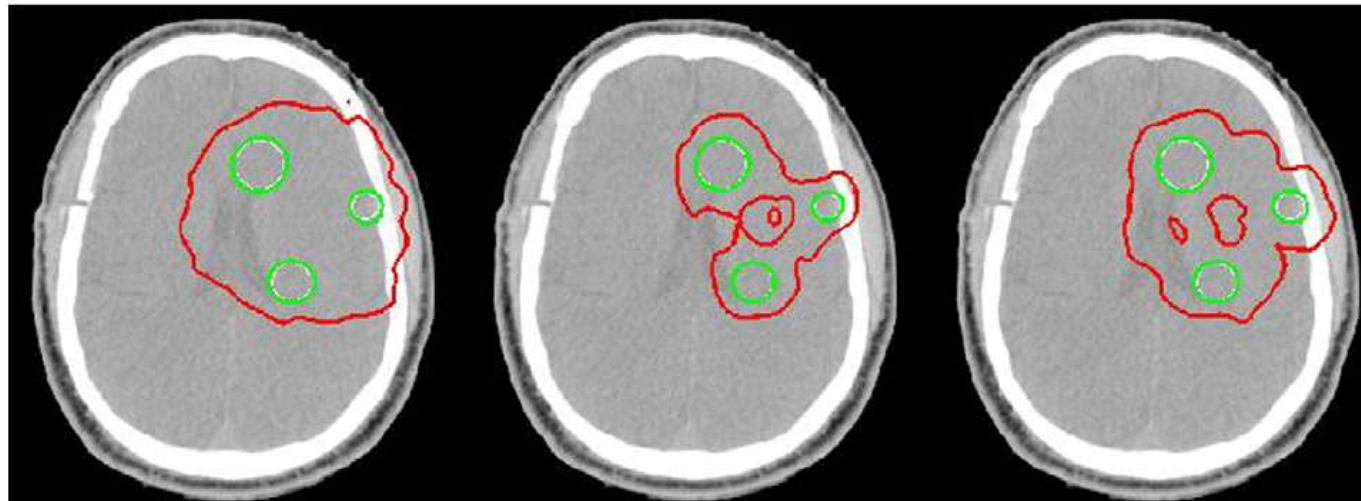
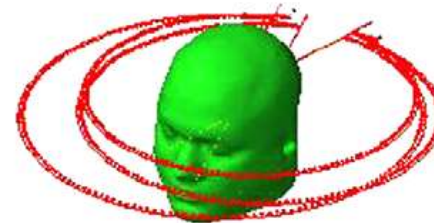
1 Arc +  
1 Isozentrum



3 Arcs +  
1 Isozentrum



3 Arcs +  
3 Isozentren



# Multi-Isozenter-RT

## 1 Arc + 1 Isozentrum:

- gute Konformität

## 3 Arcs + 1 Isozentren:

- große Konformalität

## 3 Arcs + 3 Isozentren:

- geringste Dosis am Gehirn ( $V_{12Gy}$ )
- längste Bestrahlungszeit

⇒ 1 Isozentrum reicht meist  
 ⇒ mehrere Arcs führen zu  
 einer höheren Konformität

Variable	SASI	TASI	TATI
Monitor units	5,615	5,994	13,785
Beam-on time (min)	5.62	5.94	13.79
Dose to GTV*			
Maximum	142.9	150.9	147.3
Minimum	102.3	101.9	102.5
Mean	122.6	125.4	125.3
Normal brain volume <sub>12Gy</sub> (%)	1.73	1.26	1.11
Brain volume <sub>12Gy</sub> (%)	2.18	1.71	1.55
Paddick CI	0.699	0.761	0.713
RTOG CI	1.45	1.33	1.44
Paddick GI	6.10	4.80	4.72

*Abbreviations:* SASI = single-arc/single-isocenter; TASI = triple-arc/single-isocenter; TATI = triple-arc/triple-isocenter; GTV = gross tumor volume; CI = conformity index; RTOG = Radiation Therapy Oncology Group; GI = gradient index.

\* Percentage of 20-Gy prescription dose.

- 1 Paddick CI =  $(TV_{PV})^2 / (TV \times PV)$ , where PV is the prescription volume,  $TV_{PV}$  is the target volume within the prescribed isodose surface, and TV is the target volume
- 2 RTOG CI =  $PV/TV$ , where PV is the prescription volume, and TV is the target volume
- 3 Paddick GI =  $PV_{50\%}/PV$ , where  $PV_{50\%}$  is 50% of the prescription volume isodose line, and PV is the prescription volume

# Zusammenfassung

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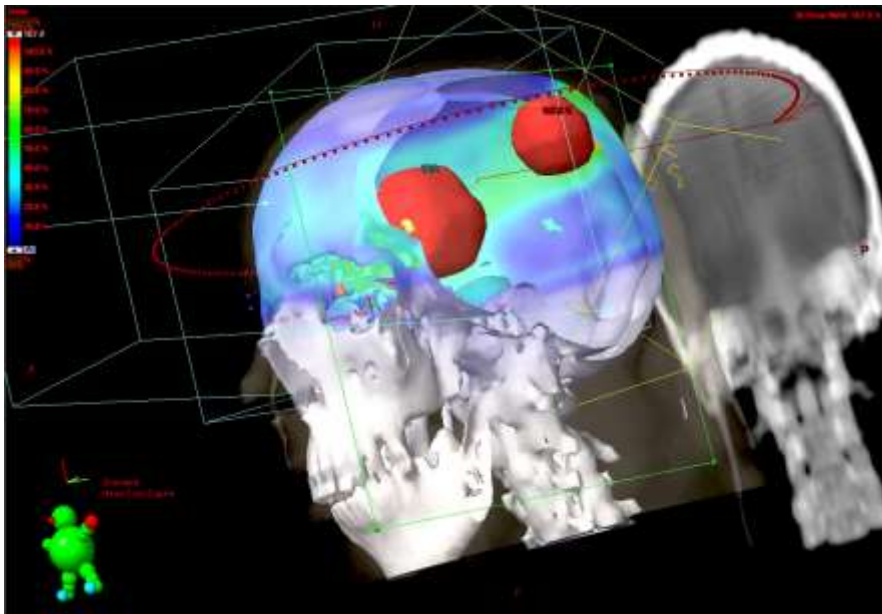
⇒ optimaler Ausstattung:

Kones und 2,5mm MLC

⇒ optimale Planung:

Planvergleich von CAT mit  
vol. IMRT, 1 Isozentrum, mehrere Arcs

# Einzeitstereotaxie mit RapidArc im Kopfbereich



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