

Preparation for cranial SRT & SRS

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Attributes of modern local RT delivery

refinements of conformal radiotherapy



precision

conformality

photons

protons

time factor (4D RT)

intrafraction patient and tumour motion

interfraction changes in tumour & normal tissue

quality assurance

imaging closer to treatment delivery (**IGRT**)

Radiotherapy technologies

immobilisation

target delineation

dose fractionation

plan evaluation

Preparation for high precision cranial RT

immobilisation

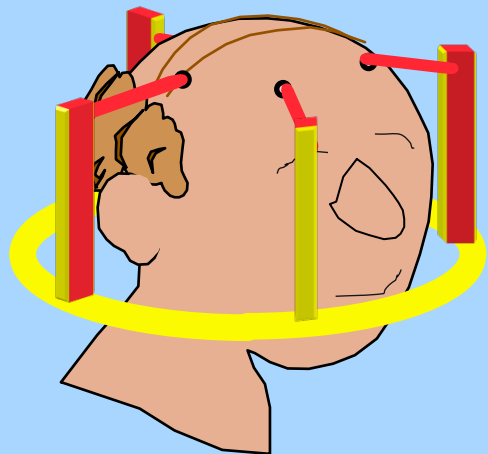
target delineation

dose fractionation

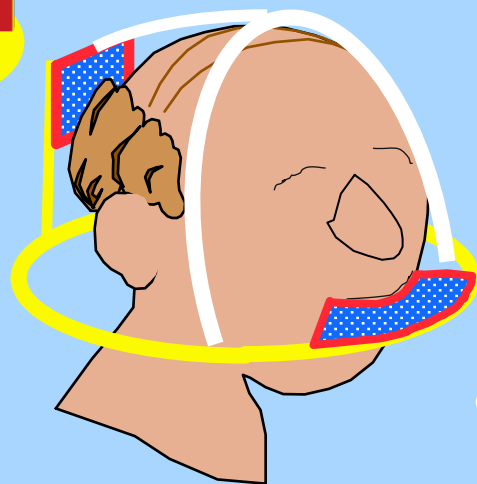
plan evaluation

Preparation for high precision cranial RT

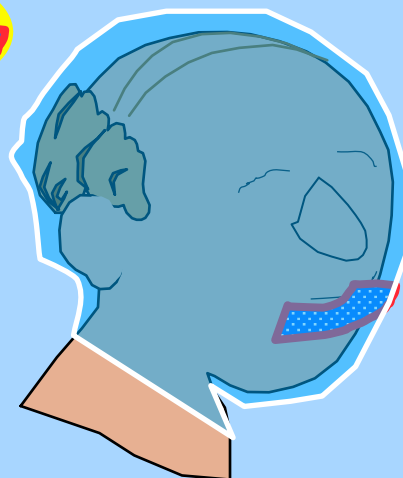
relocation accuracy



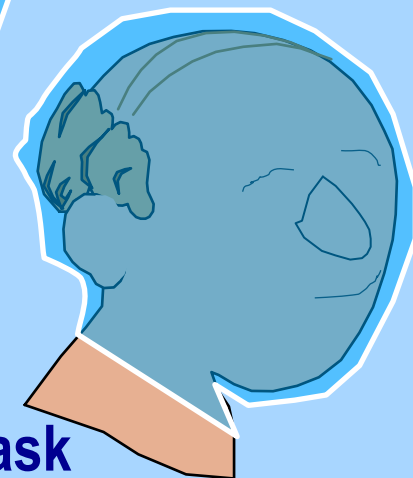
fixed frame



relocatable frame



precision mask

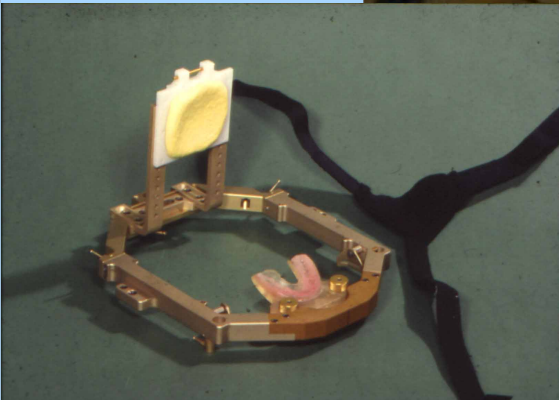


conventional mask

Methods of immobilisation

Frame system

GTC relocatable frame



Methods of immobilisation

Relocatable frame system with suction



Methods of immobilisation

Wroe et al 2015, Technol in Cancer Treatment, 14(1): 71-79

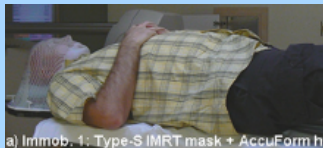
Mask systems



Methods of immobilisation

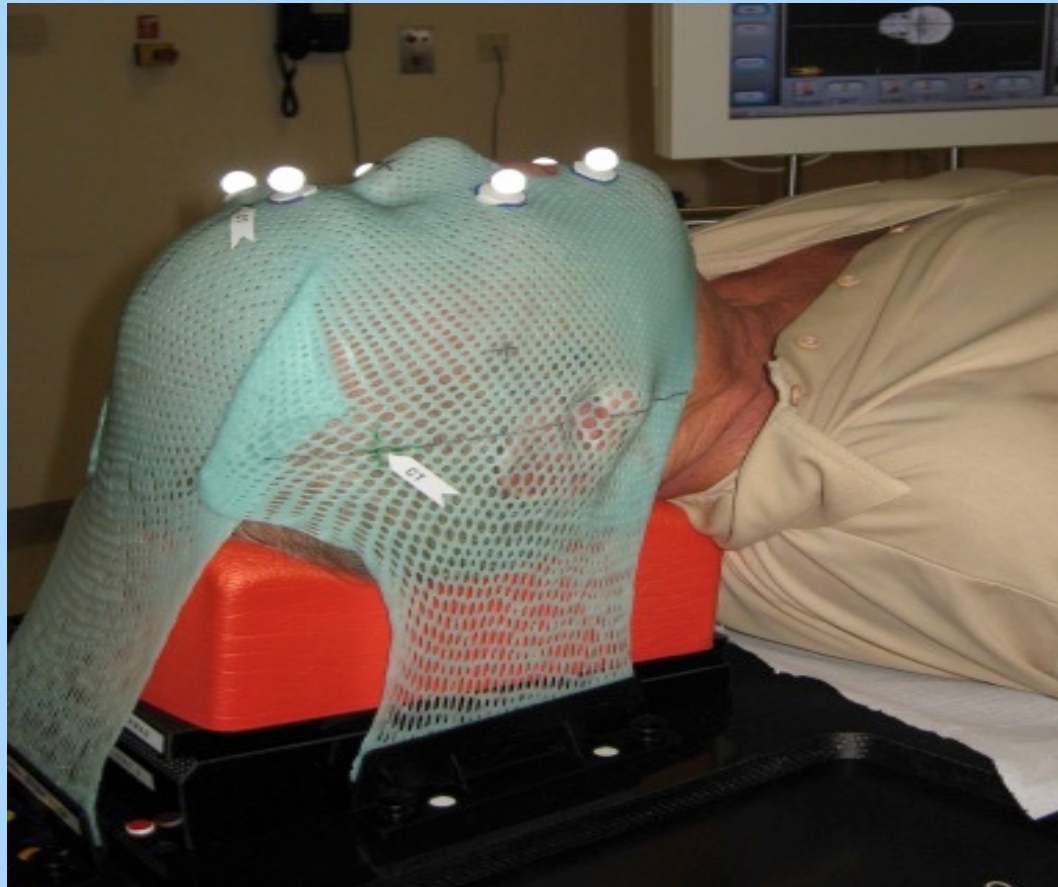
Mask systems

<i>mask system</i>	<i>translational shift</i> (mm) \pm SD	
	interfraction	intrafraction
1	2.3 (± 1.4)	1.1 (± 1.2)
2	2.2 (± 1.1)	1.1 (± 1.1)
3	2.7 (± 1.5)	0.7 (± 0.9)
4	2.1 (± 1.0)	0.7 (± 0.8)



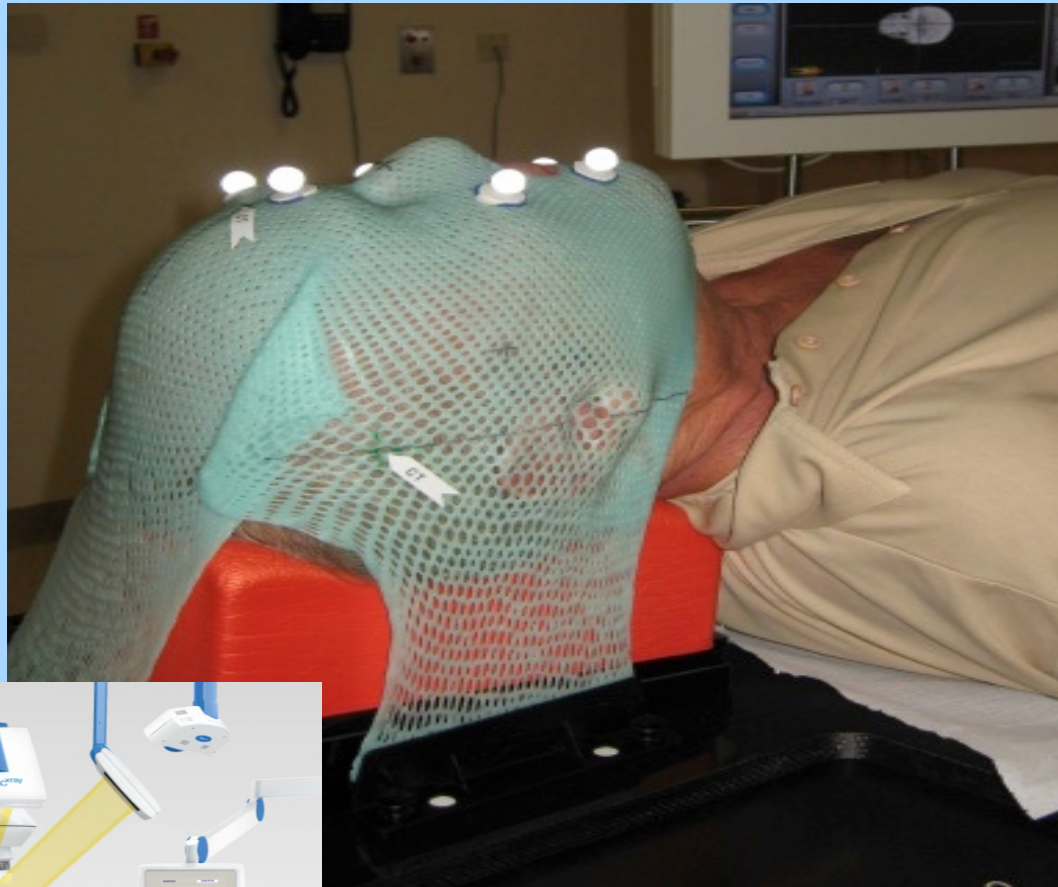
Methods of immobilisation

Mask system



Methods of immobilisation

Mask system with on line correction



Methods of immobilisation



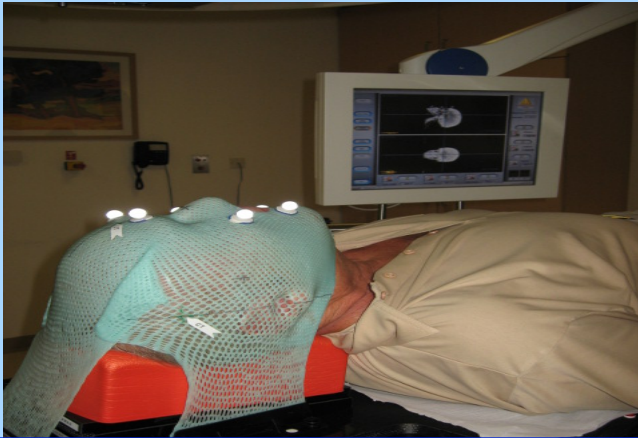
CTV-PTV margins 3mm

Specialized mouthbite (dentist)

Expensive

4 visits for planning (incl. CT verification)

Relocation accuracy < 2 mm



CTV-PTV margins 4mm

No specialist equipment

Less expensive

2-3 visits for planning

Relocation accuracy 3-5 mm

Comparison of immobilisation techniques

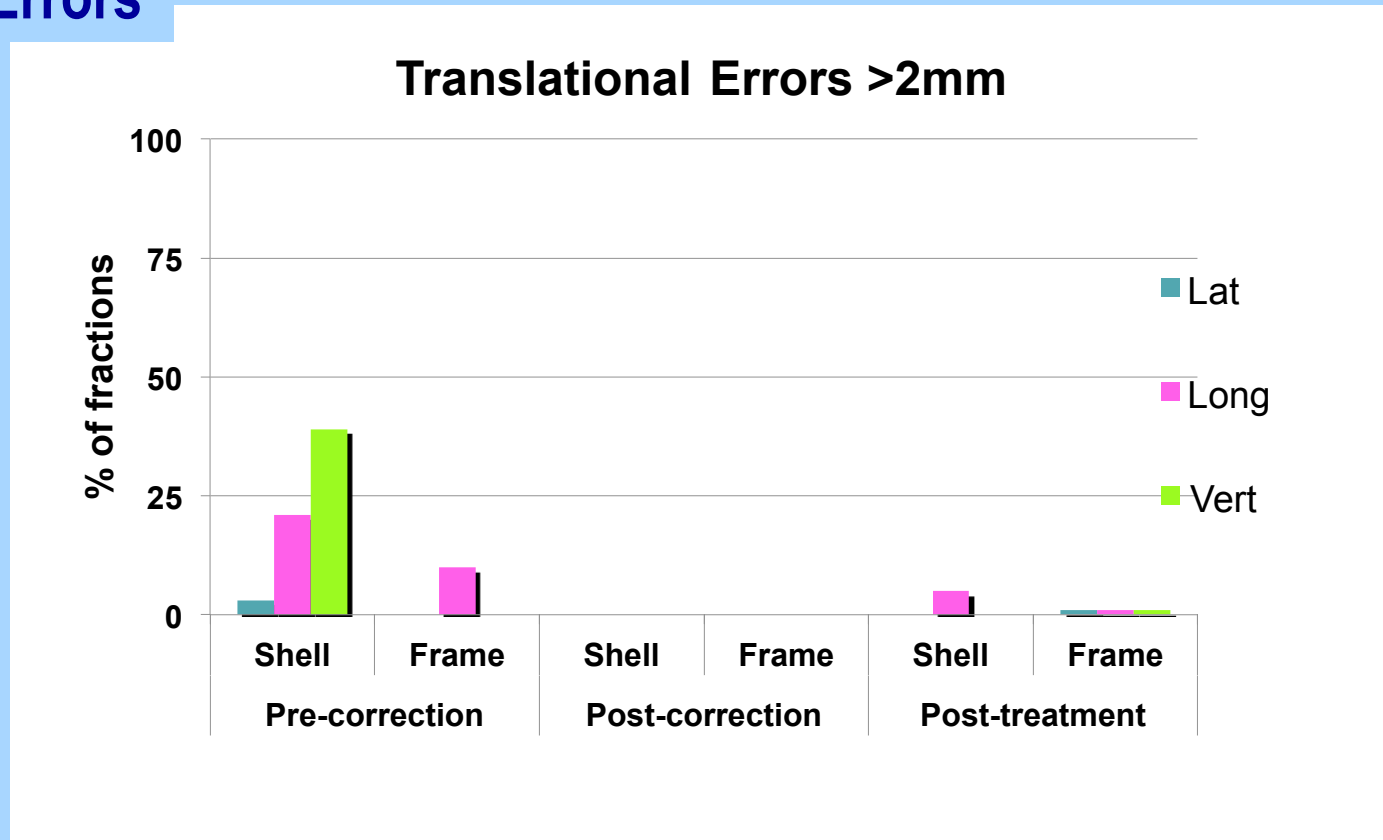
ExacTrac kV stereoscopic image verification system



Comparison of immobilisation techniques

ExacTrac kV stereoscopic image verification system

Errors



Comparison of immobilisation techniques

Randomised trial of two systems

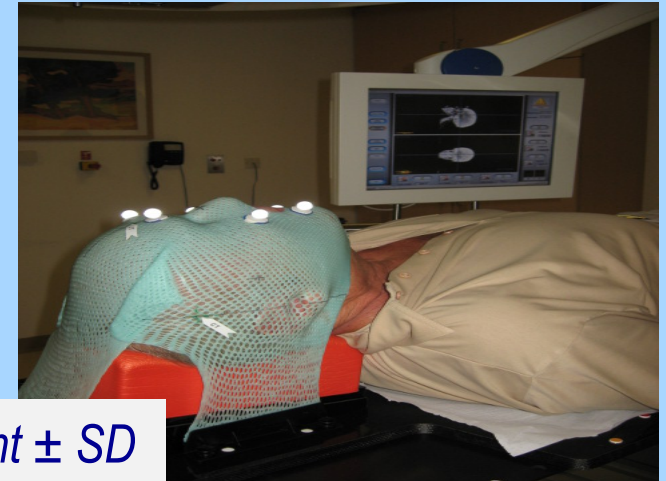
Patients undergoing SRT

randomise



mean 3D displacement \pm SD

2.00 ± 1.04 mm



3.17 ± 1.95 mm

Comparison of immobilisation techniques

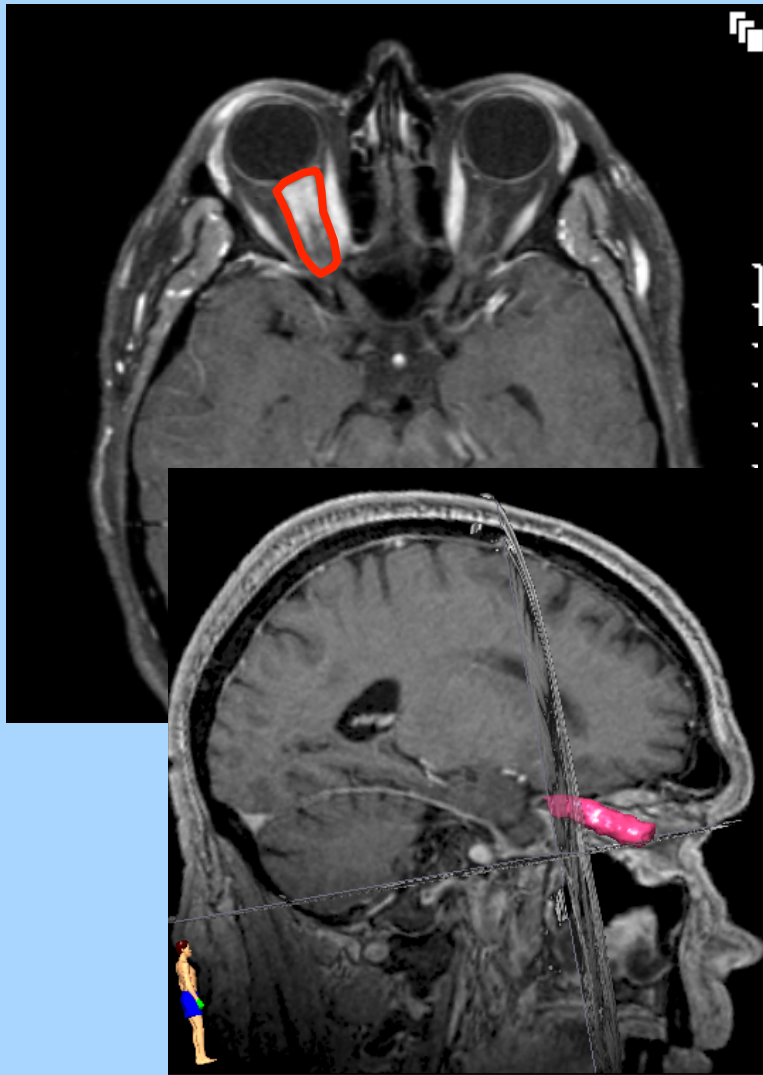
immobilisation

target delineation

dose fractionation

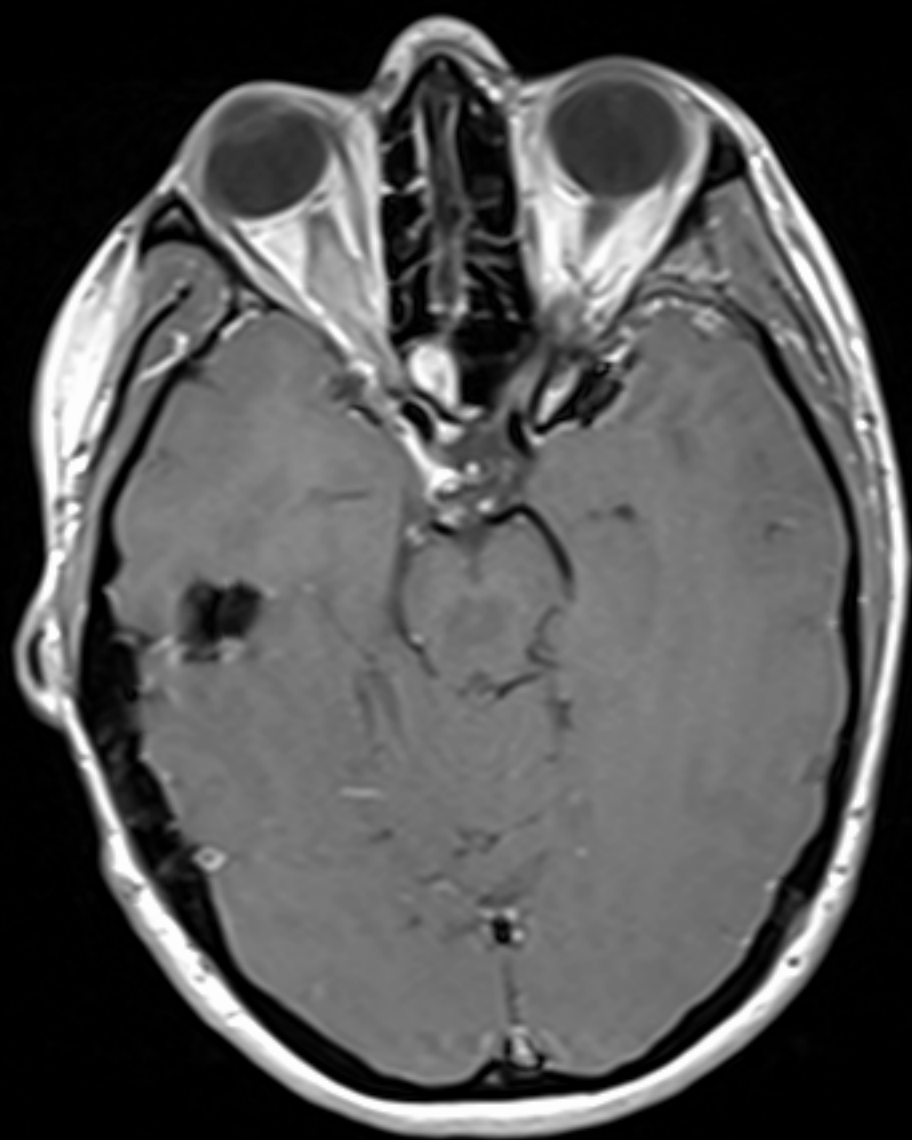
plan evaluation

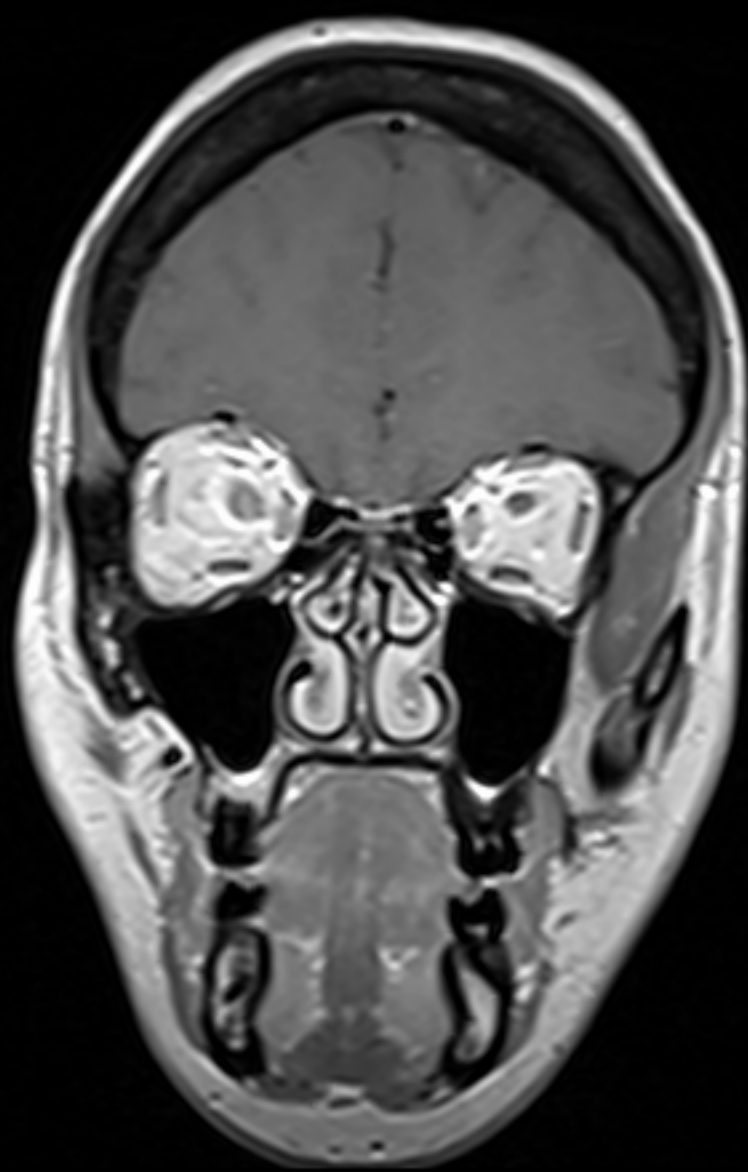
Preparation for high precision cranial RT

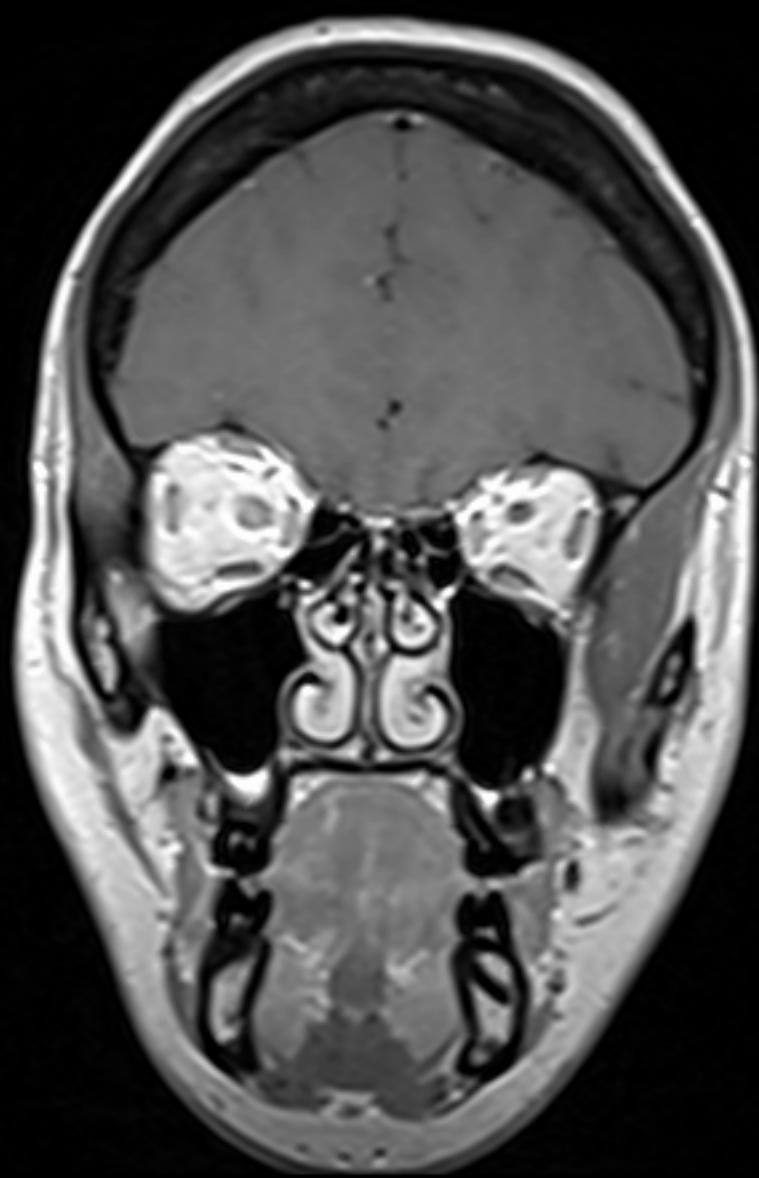


Optic nerve meningioma

Defining the target on MRI















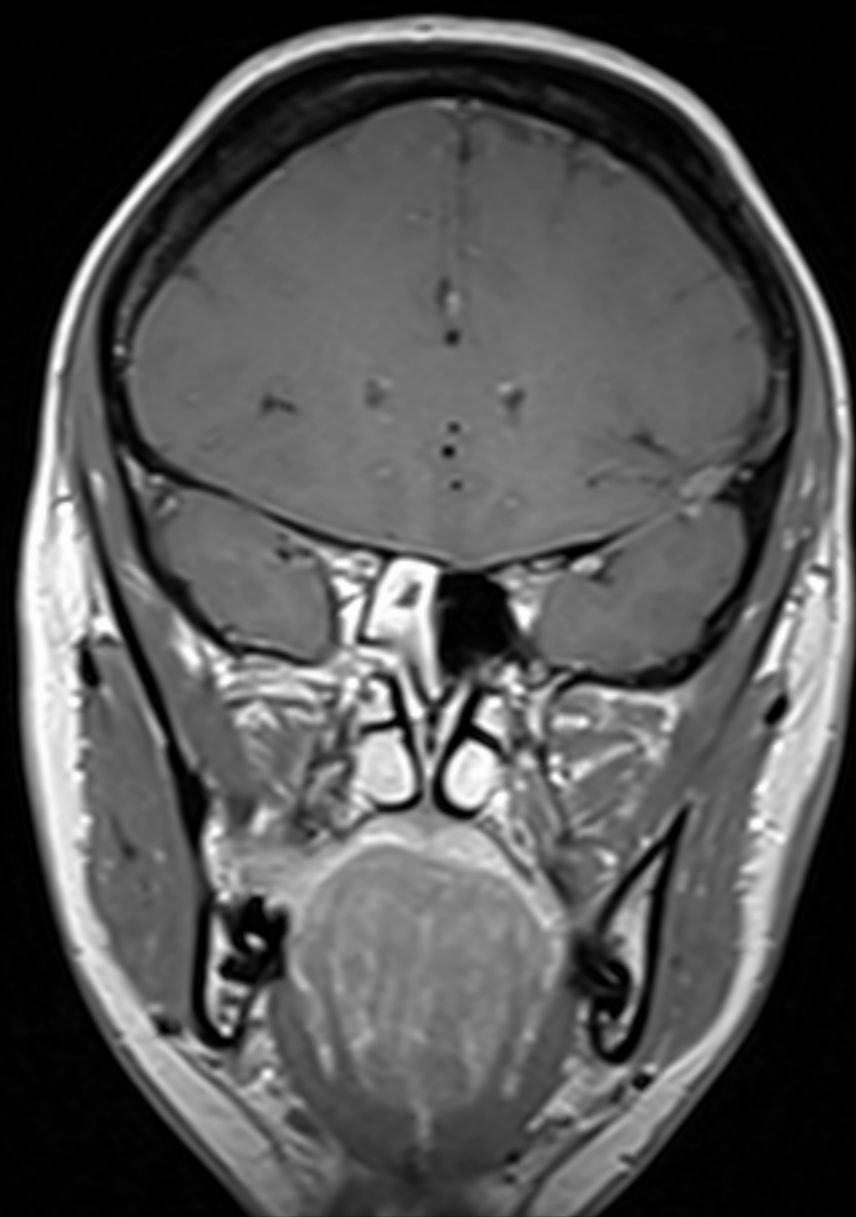


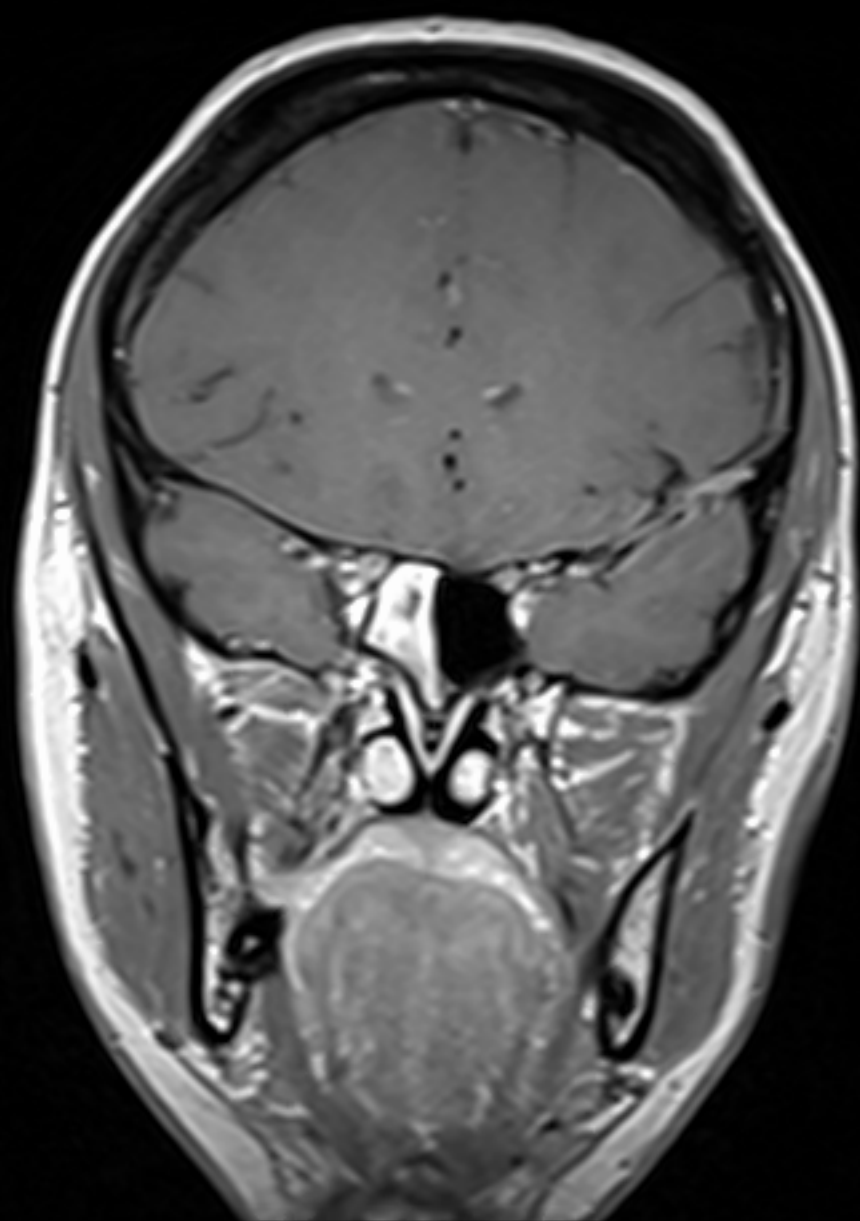


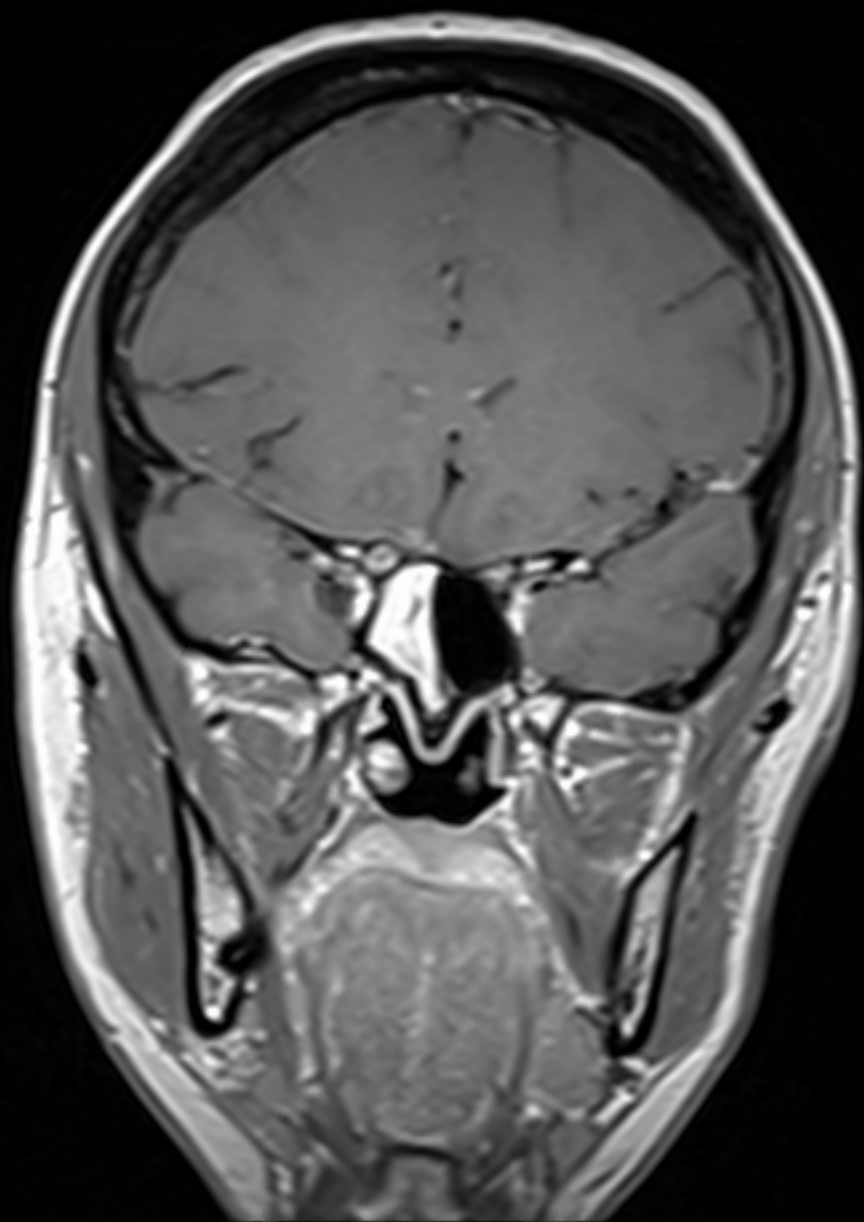


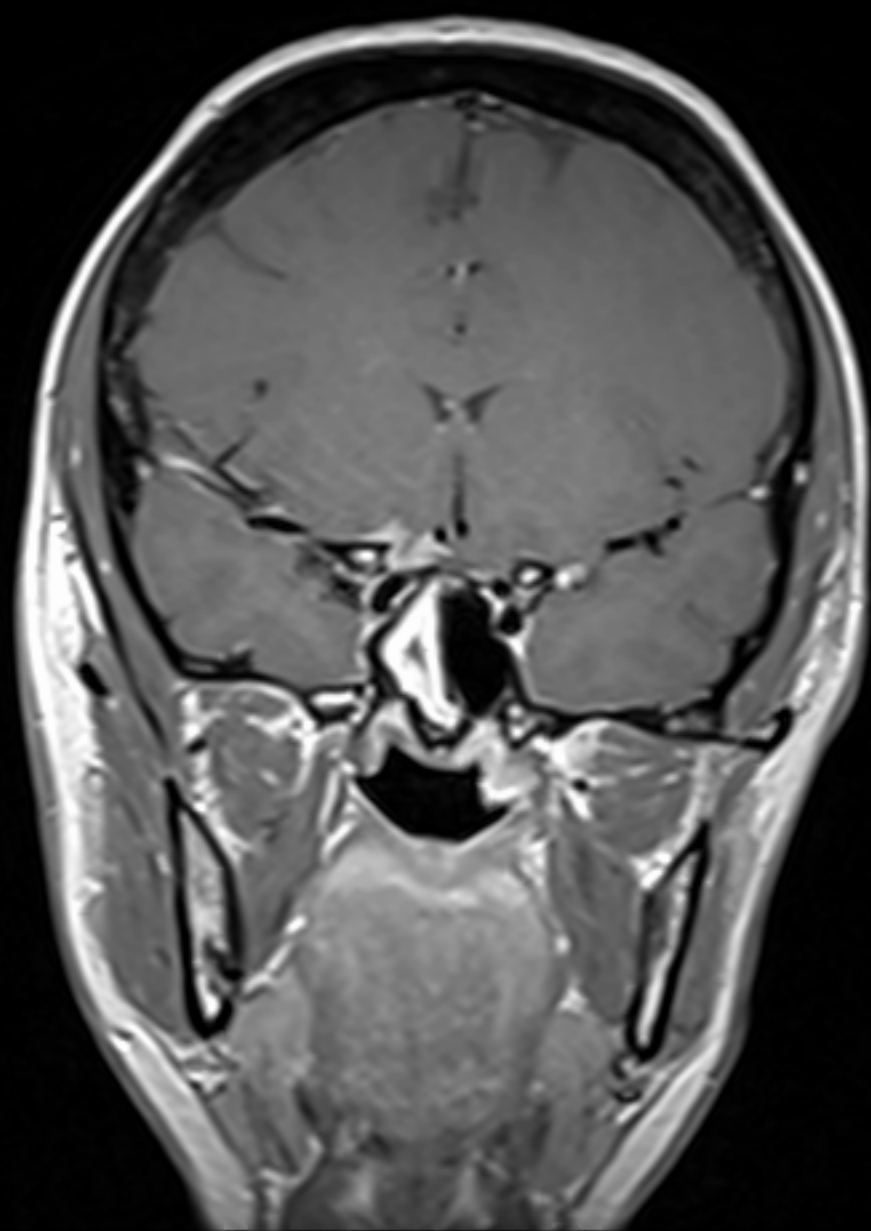


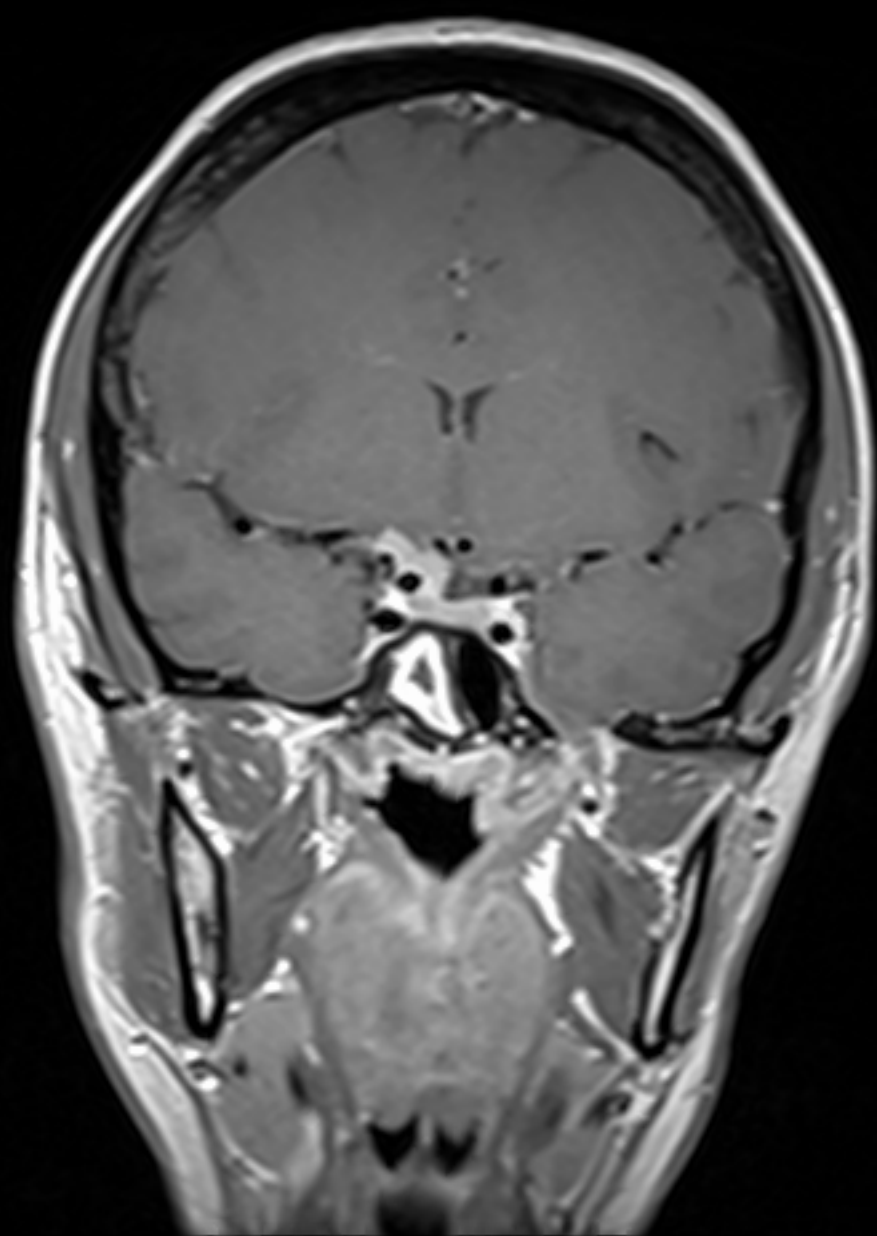


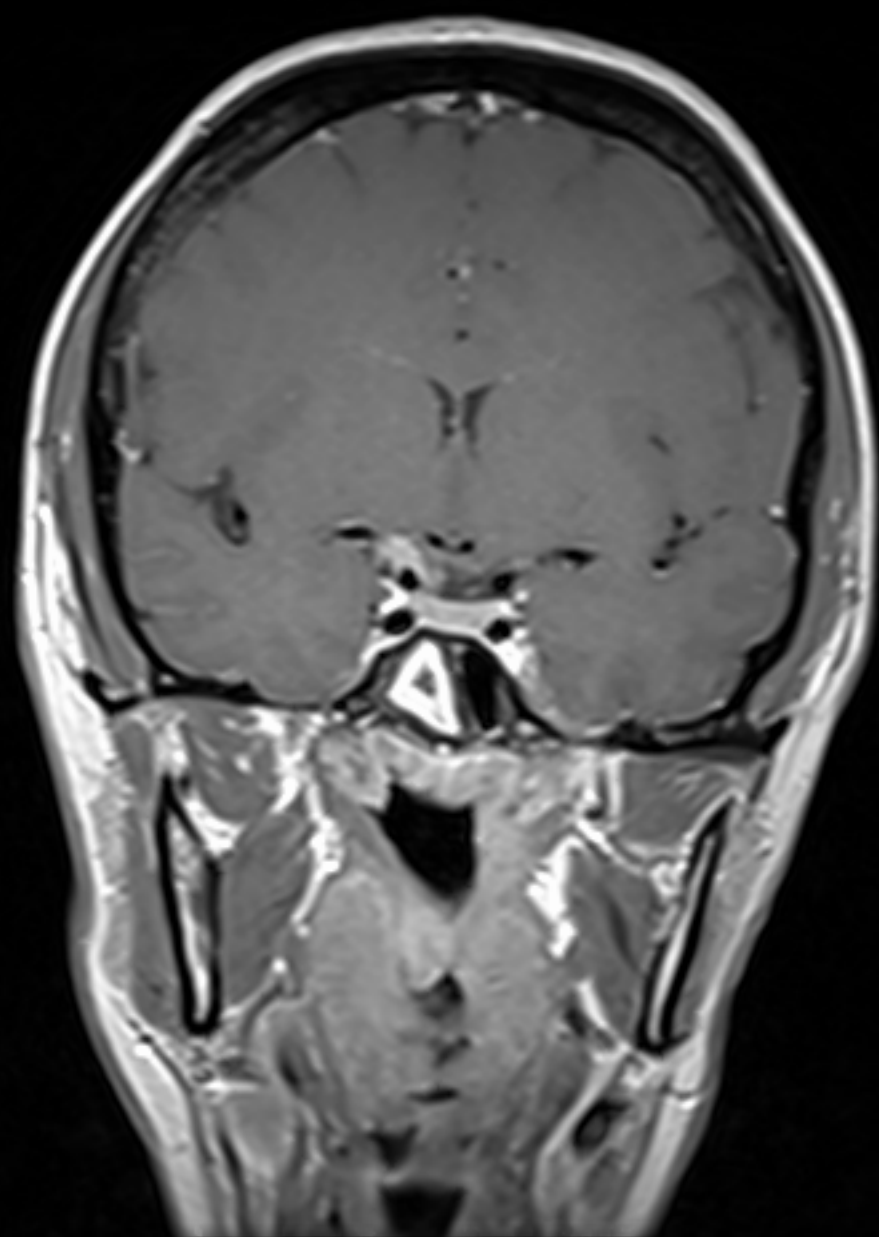


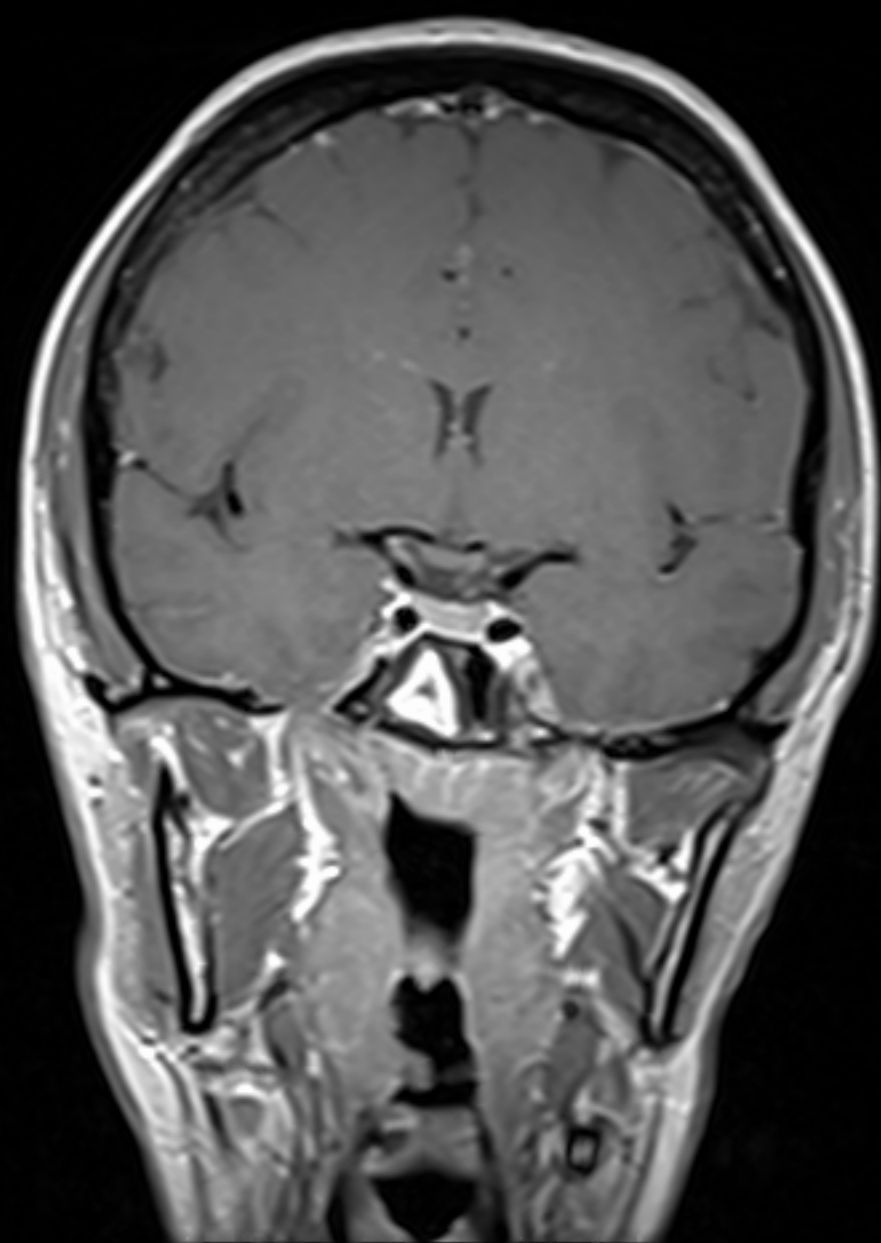


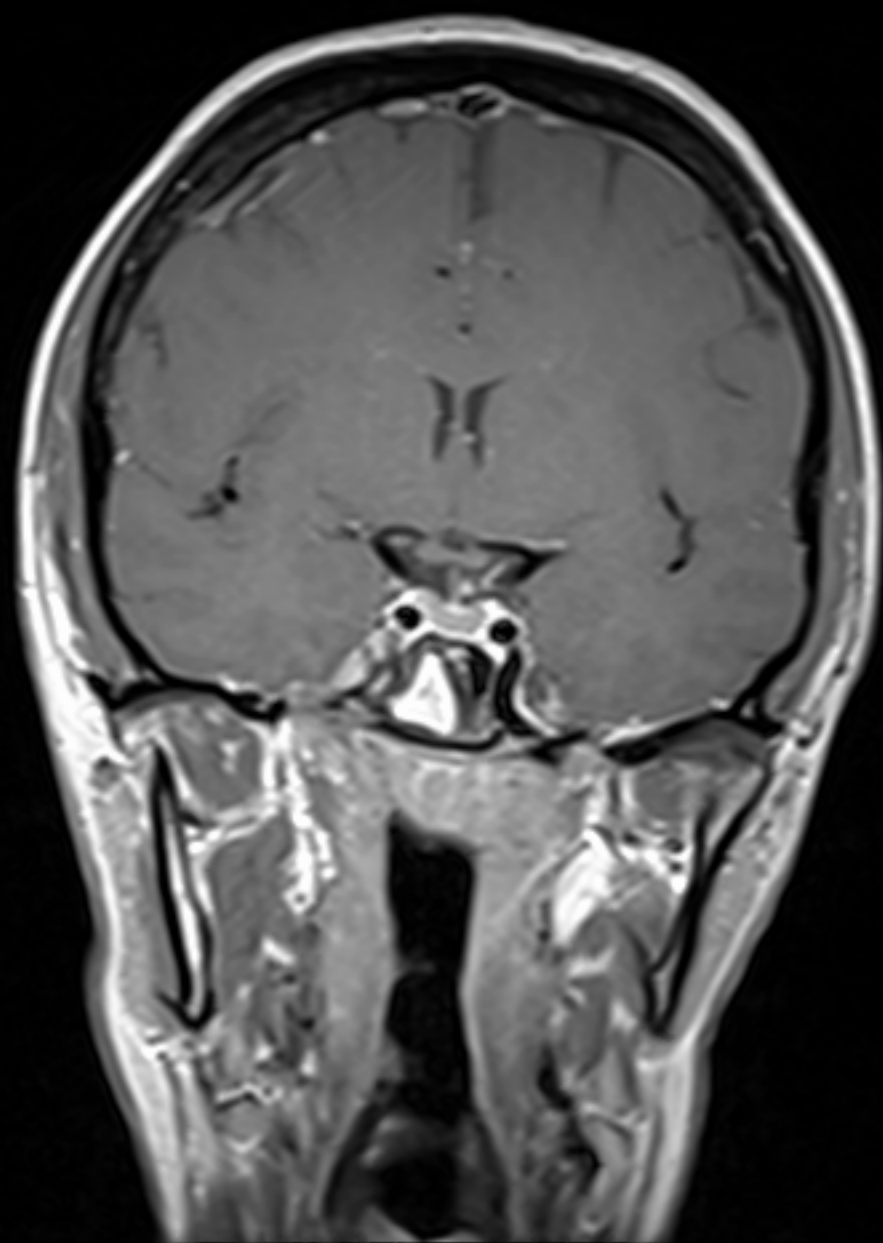




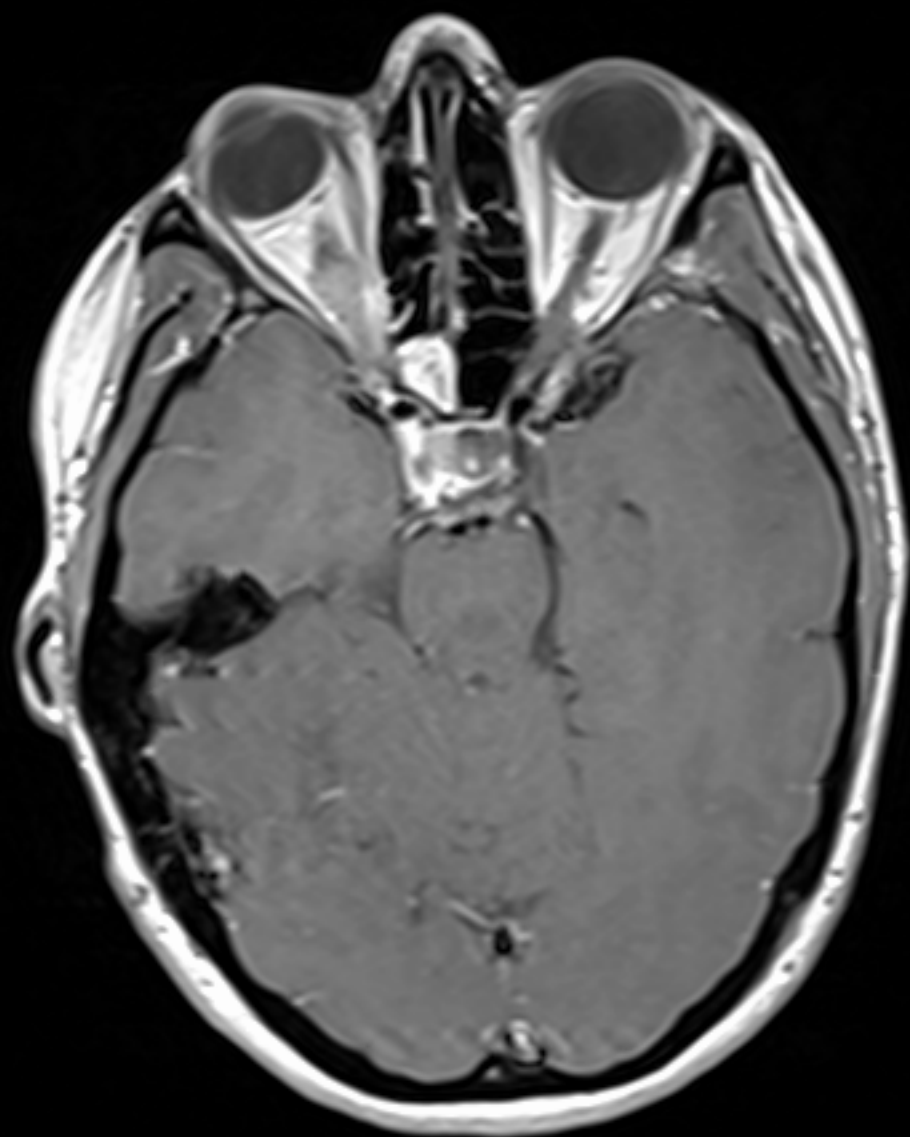


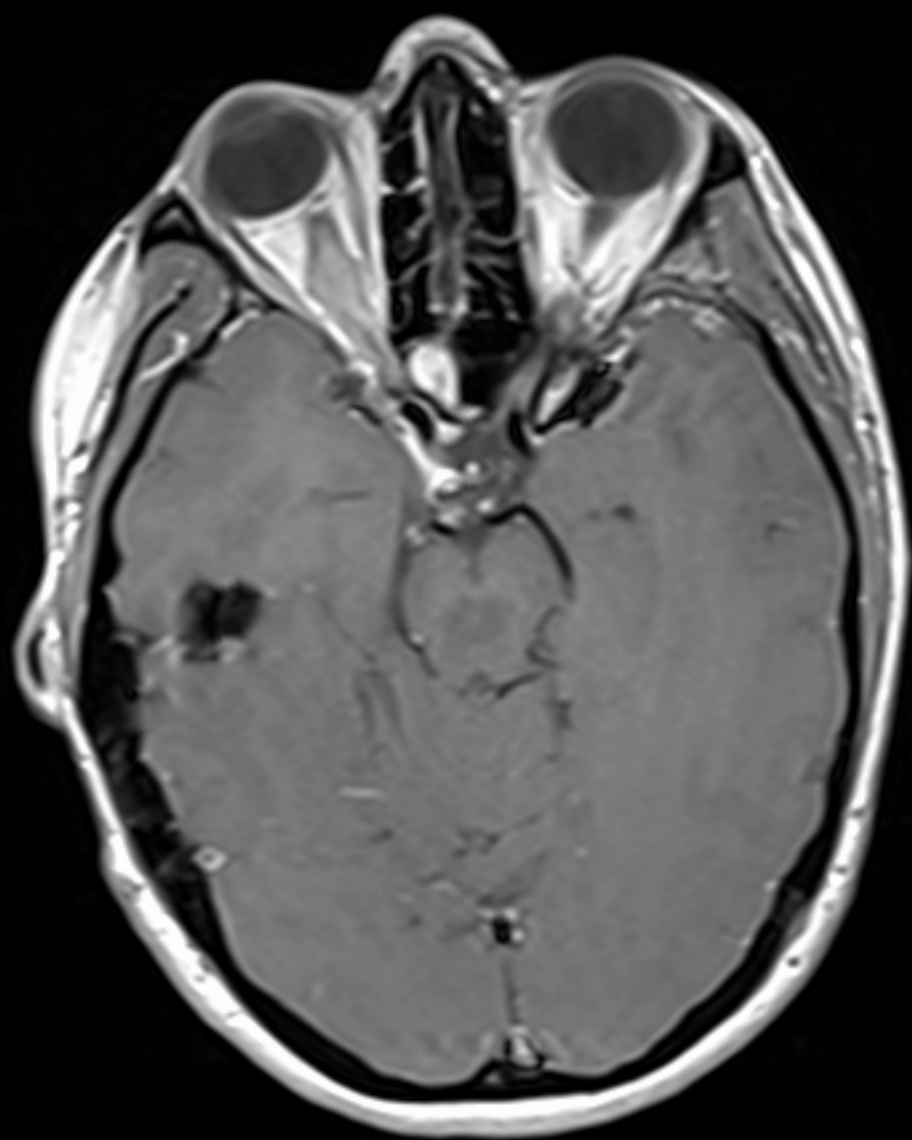


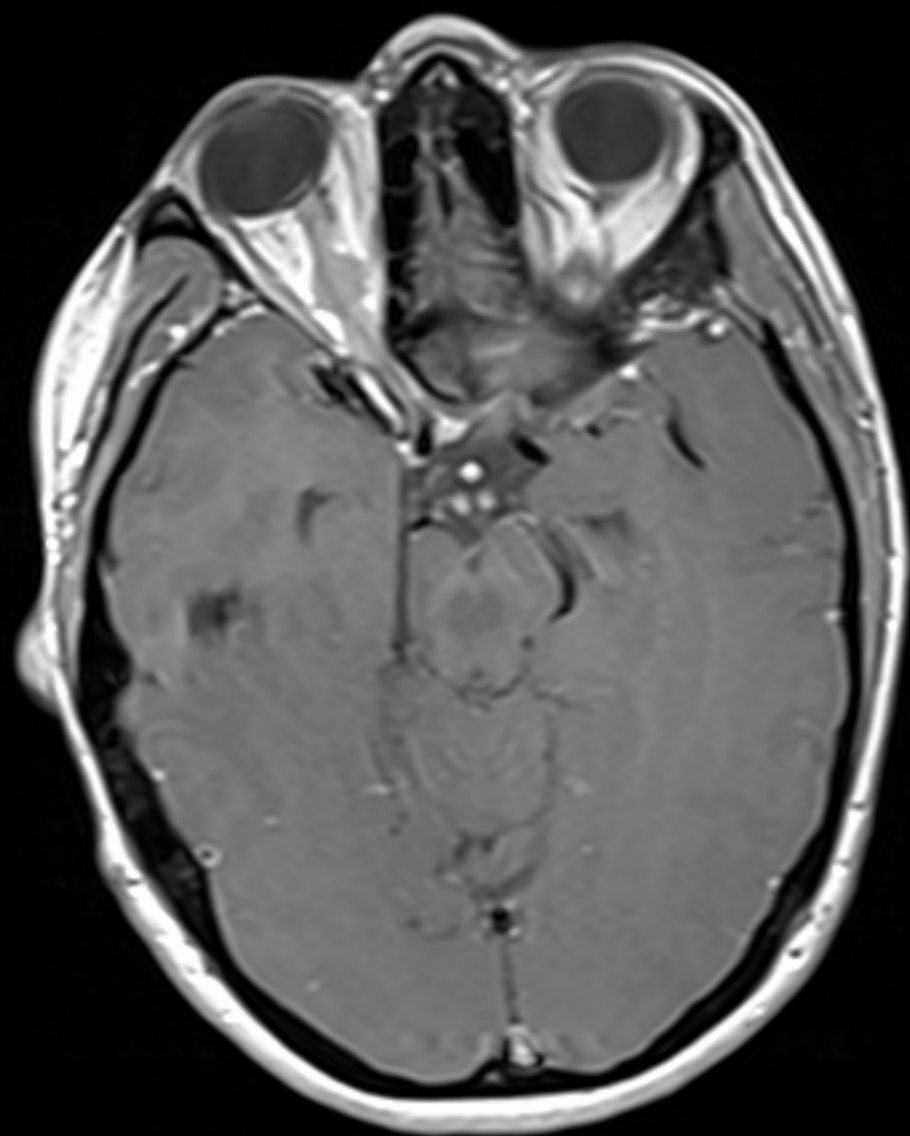


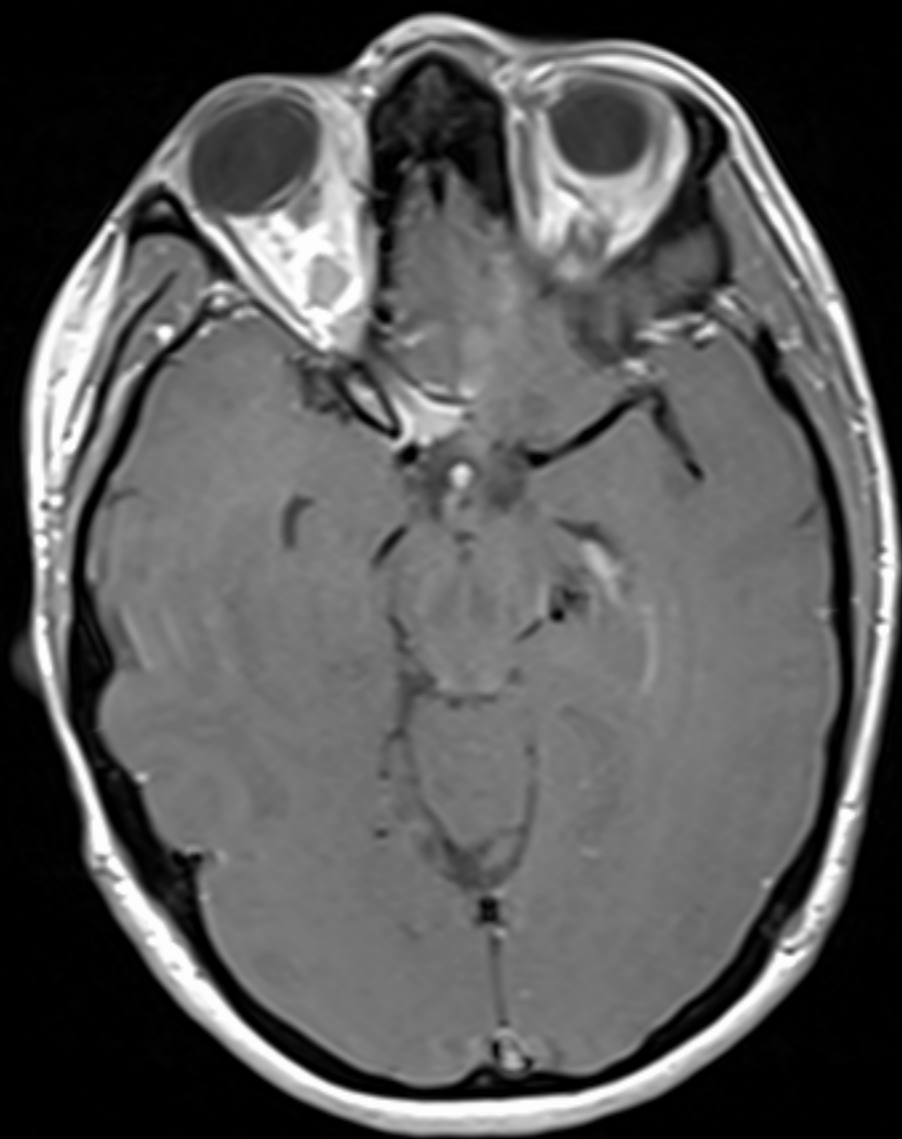


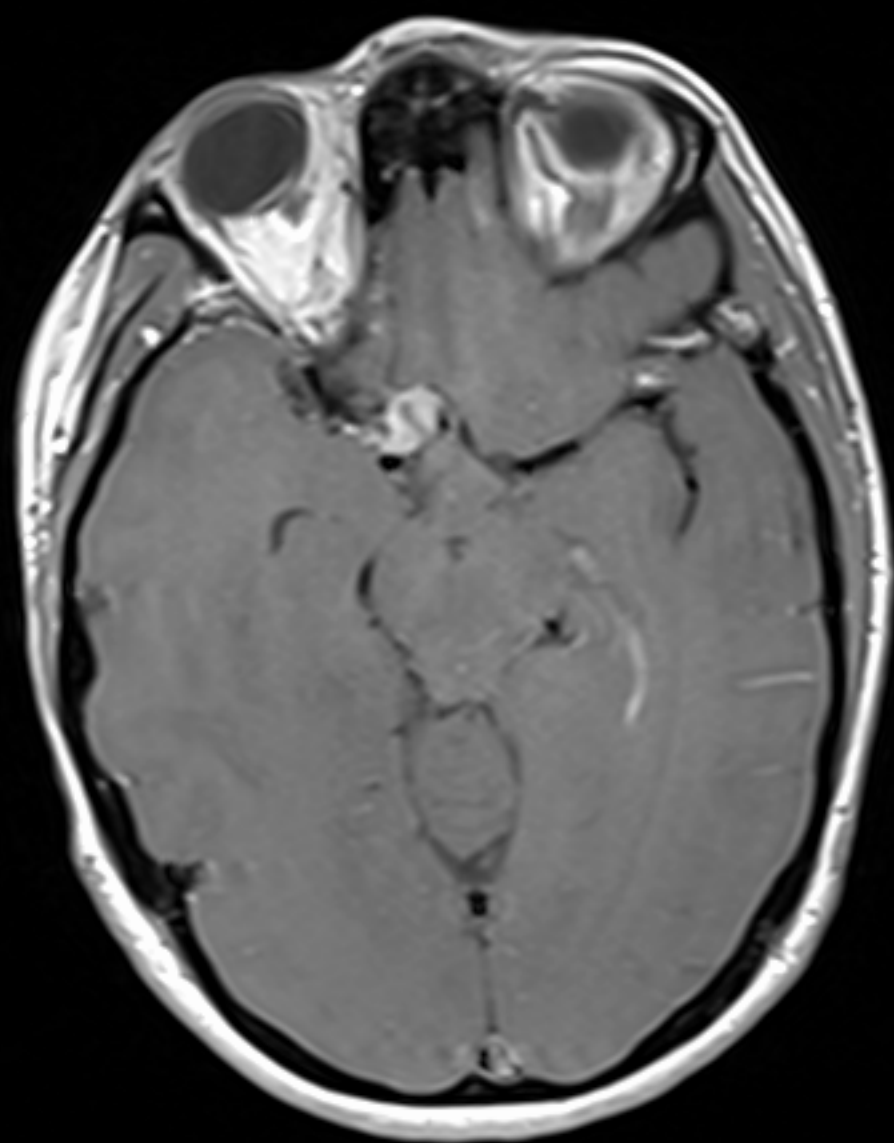


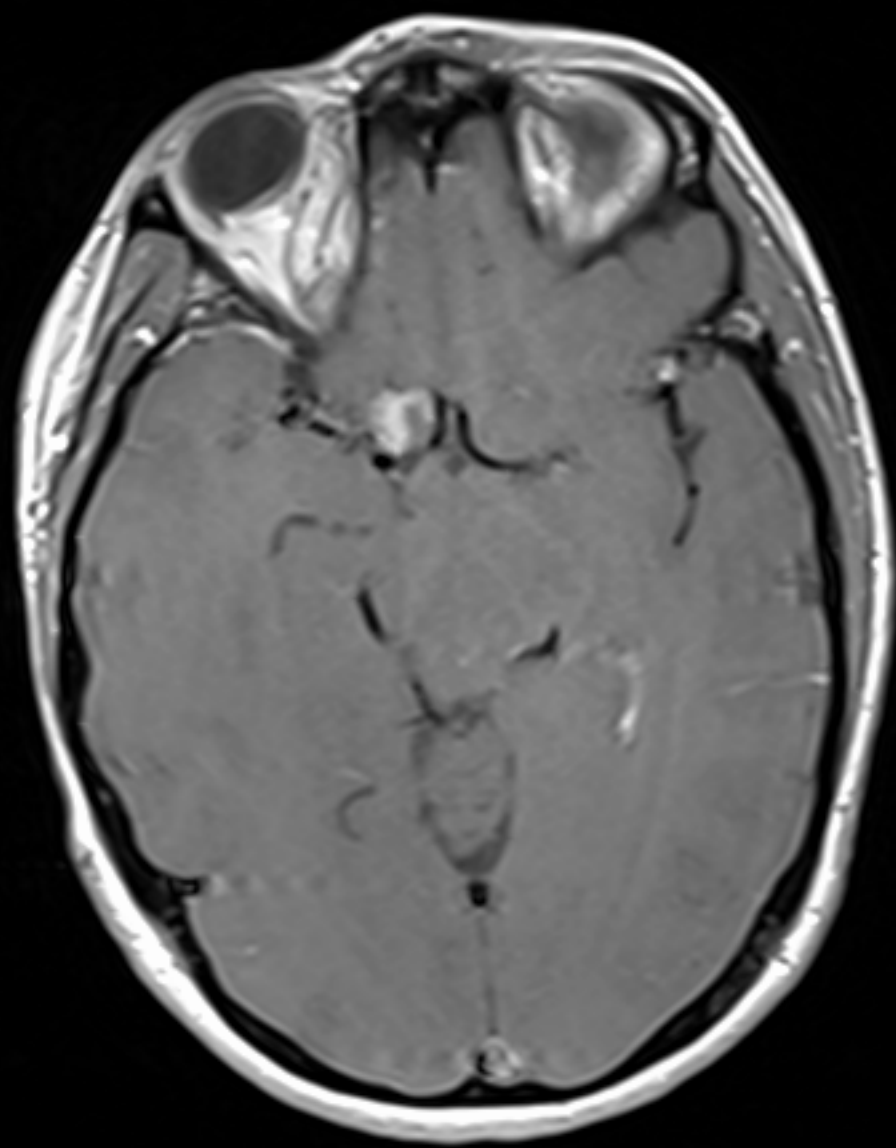


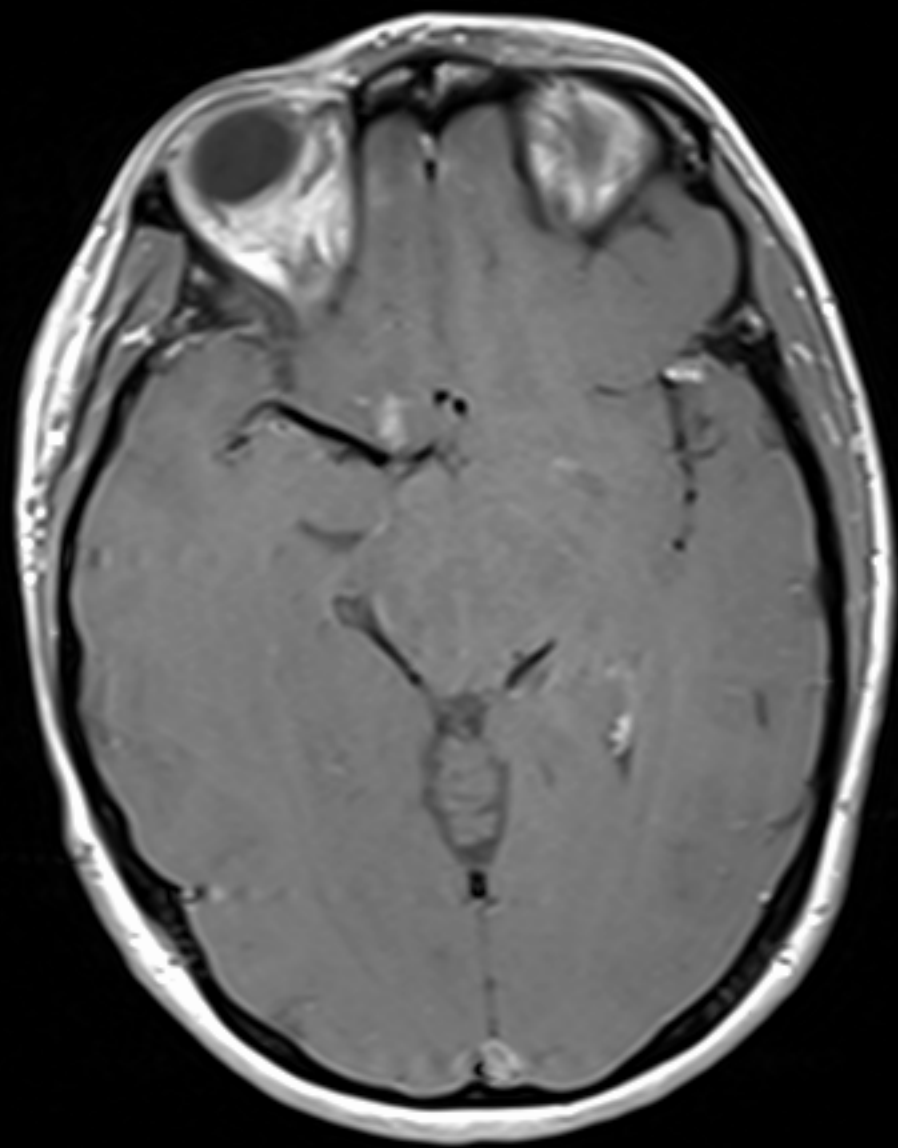




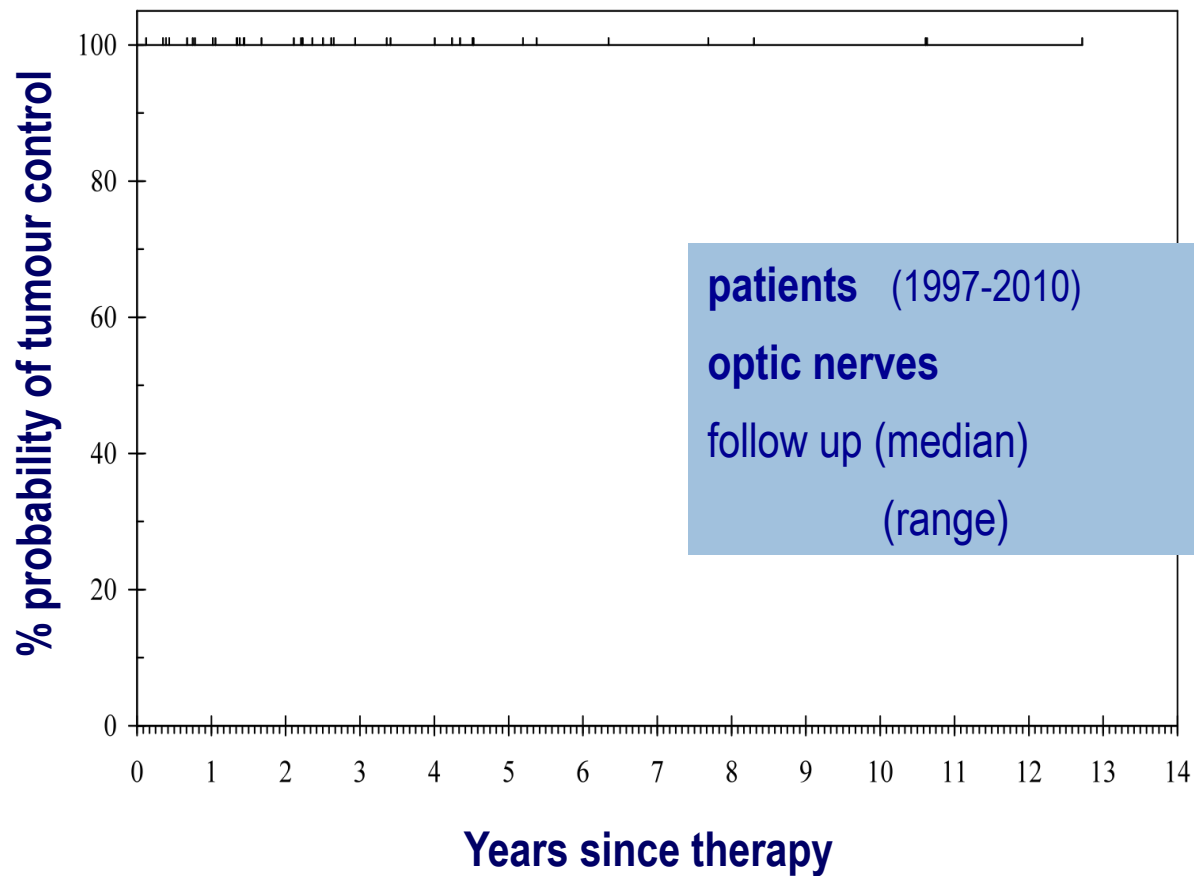
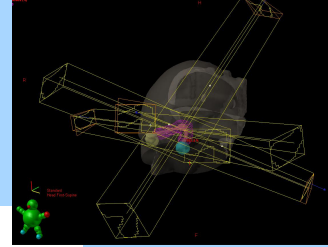






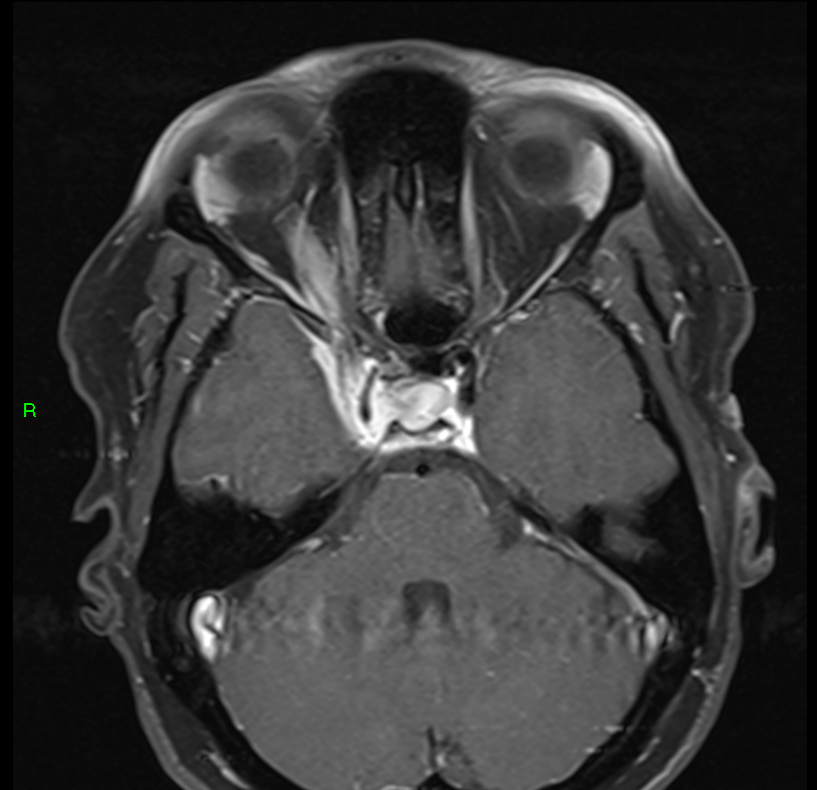
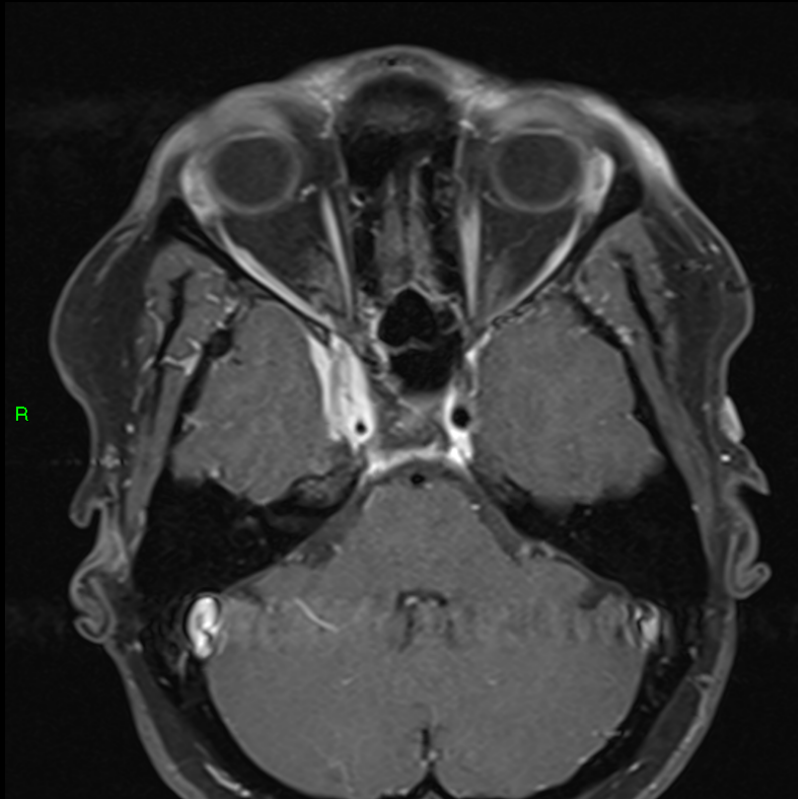


Tumour control (optic nerve sheath meningioma)

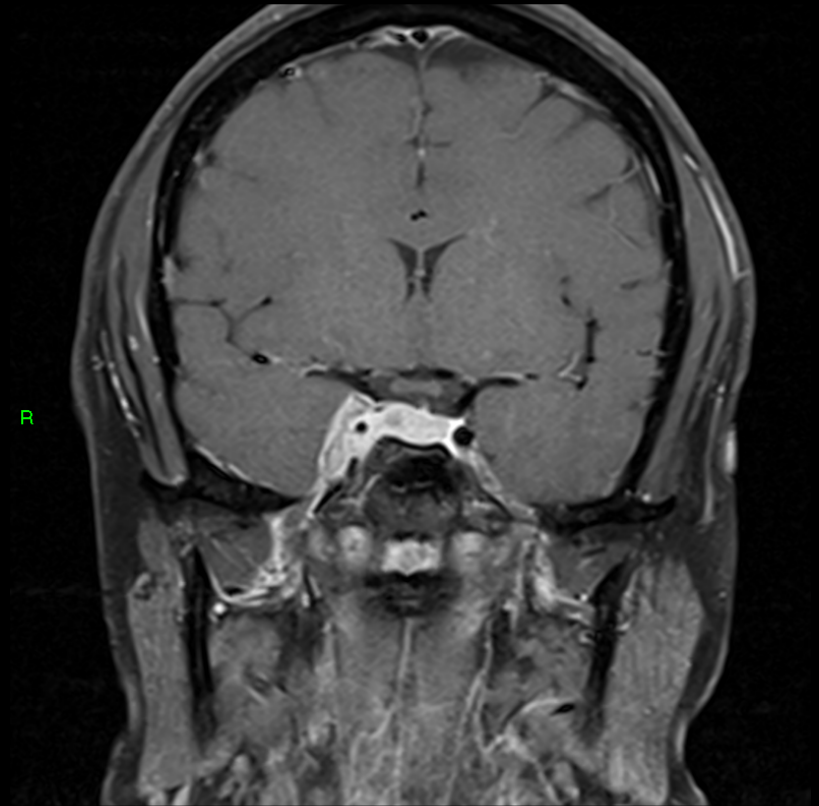
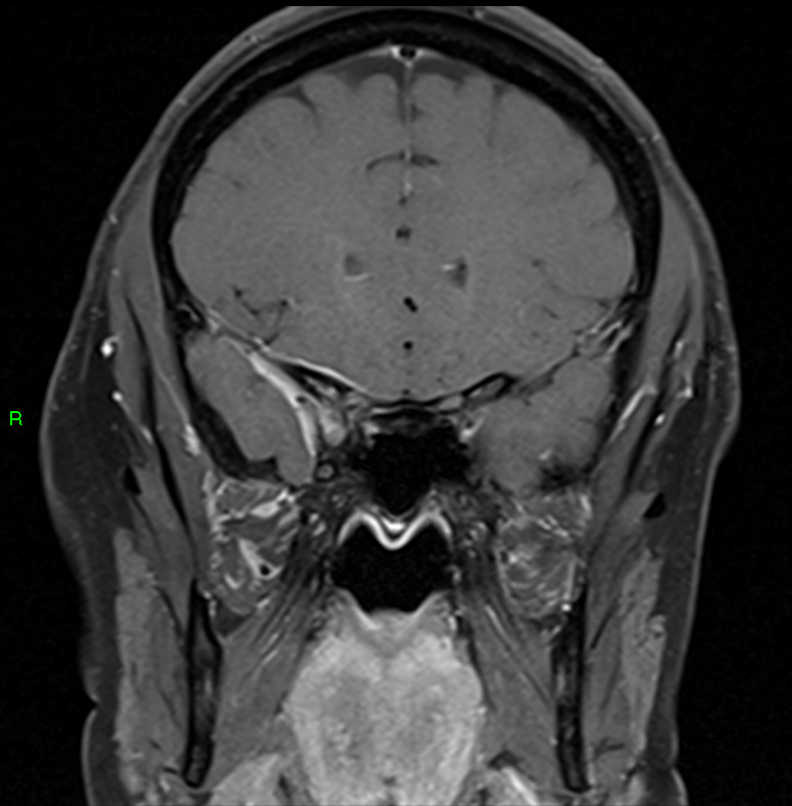


Optic nerve sheath meningioma

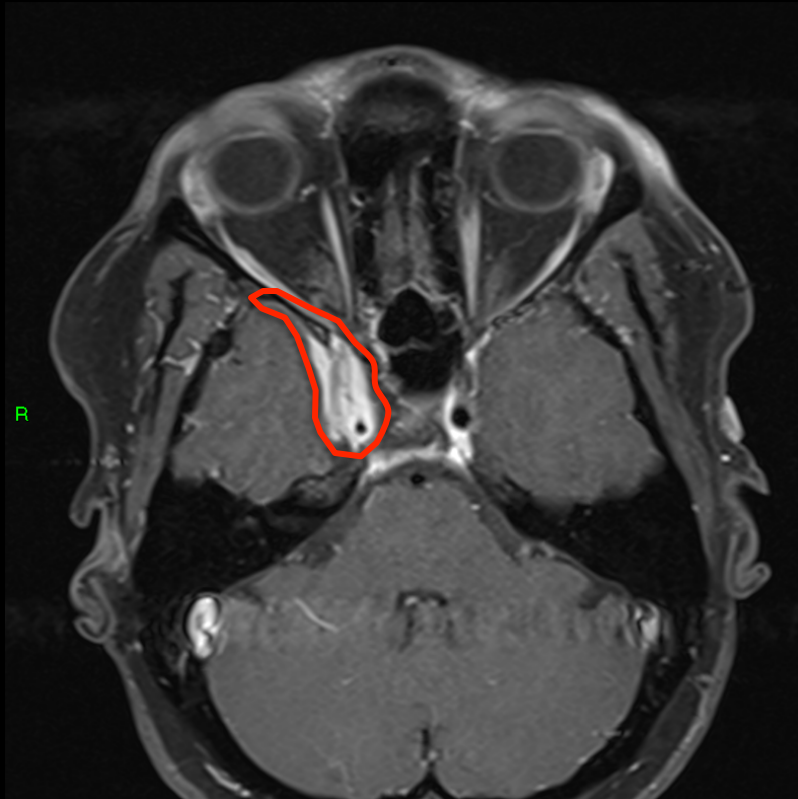
cavernous meningioma

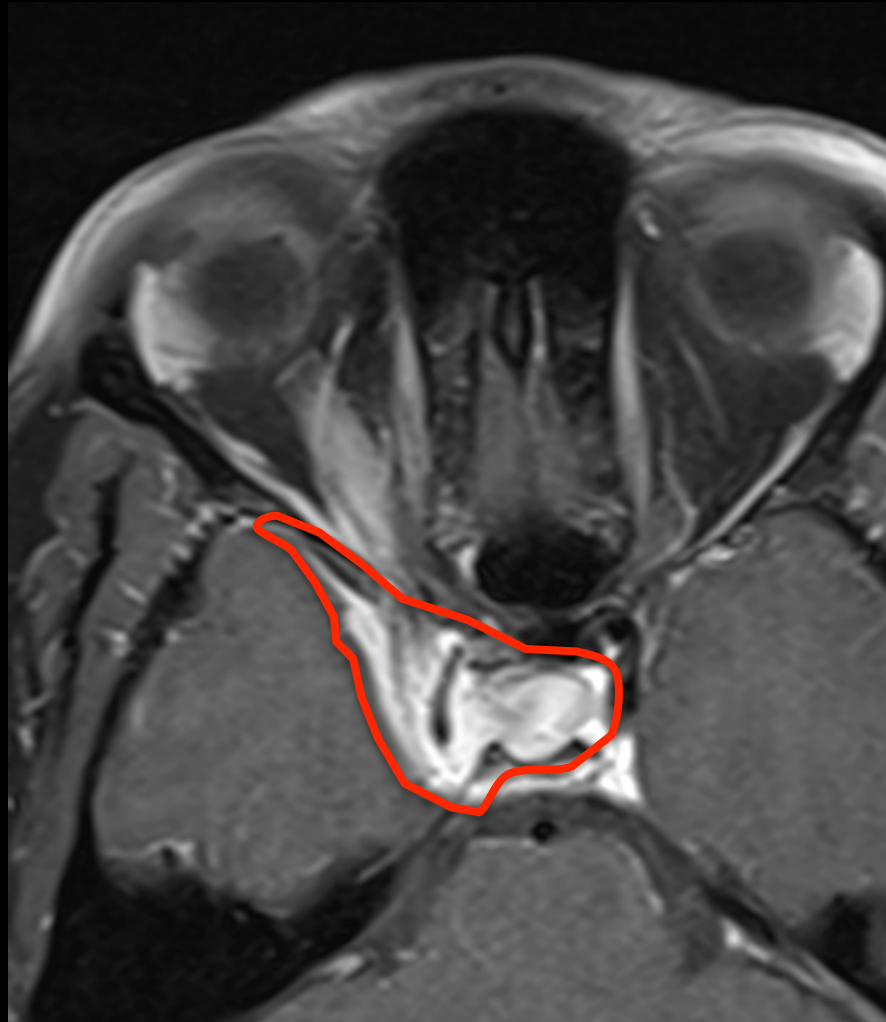


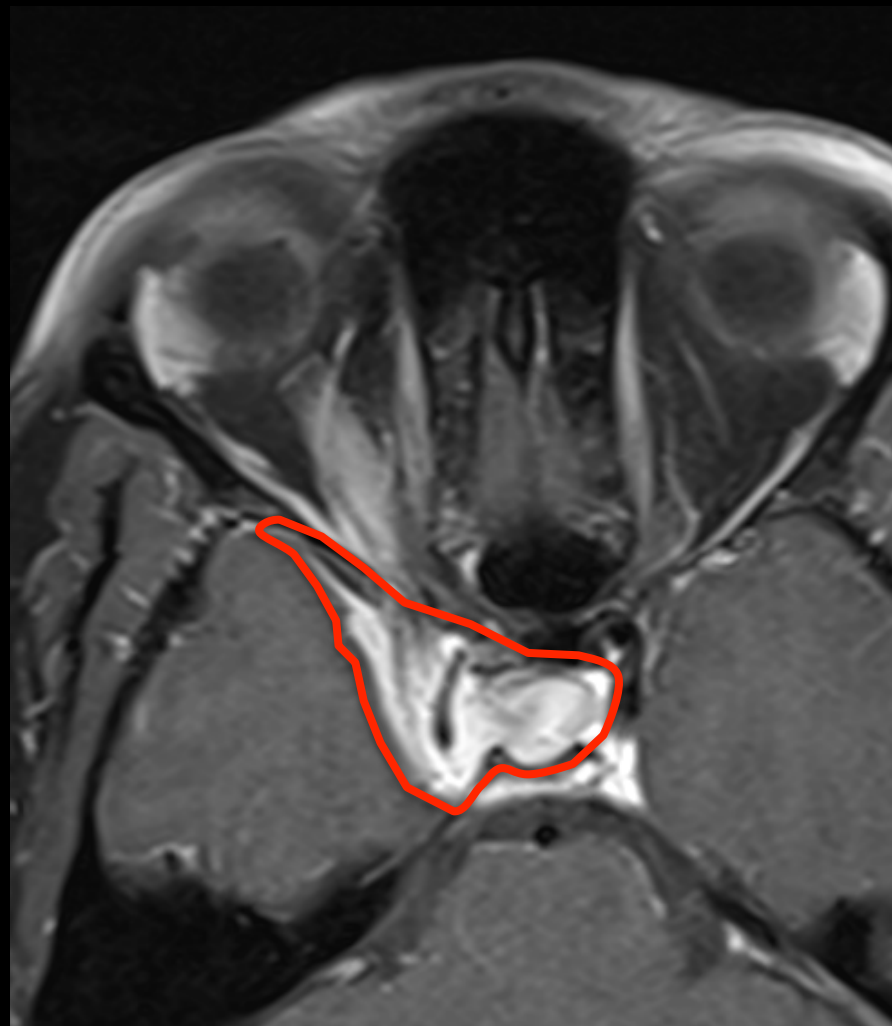
cavernous meningioma

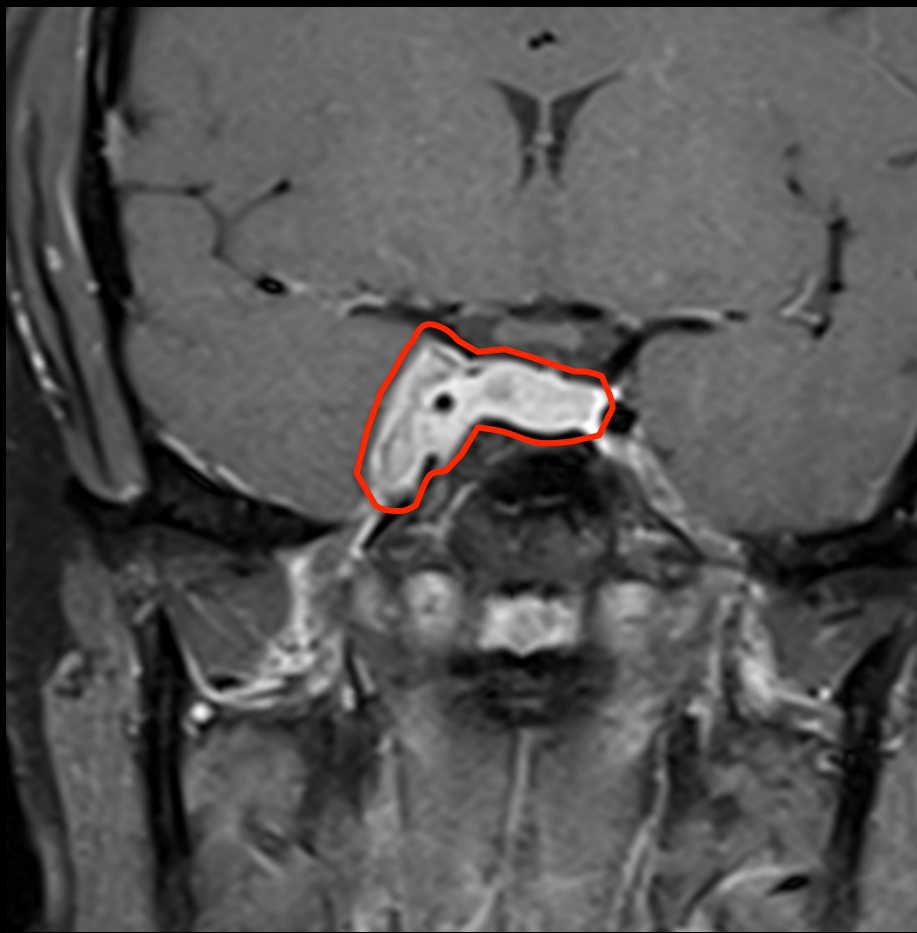


cavernous meningioma









immobilisation

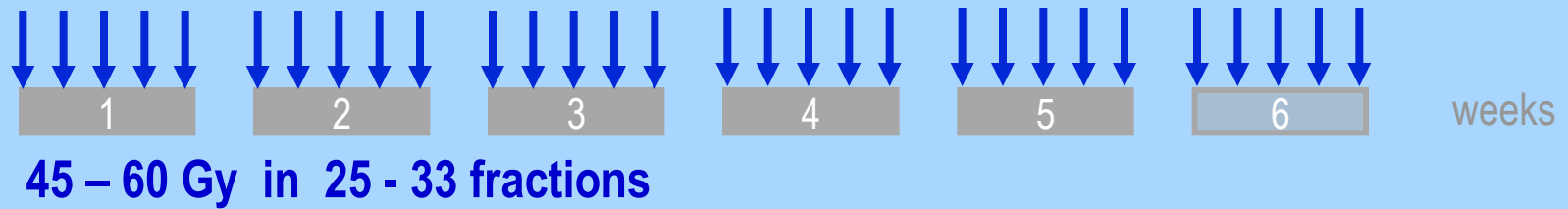
target delineation

dose fractionation

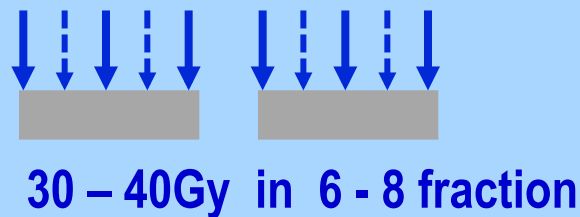
plan evaluation

Preparation for high precision cranial RT

Fractionated radiotherapy



Hypofractionated radiotherapy



Single fraction radiotherapy (radiosurgery)



Dose fractionation

Fractionated radiotherapy for benign intracranial tumours

pituitary adenoma	45Gy in 25f
meningioma	50 - 60Gy on 25-30f
acoustic neuroma	45 - 50Gy in 25-30f
craniopharyngioma	50Gy in 30f
pilocytic astrocytoma	50Gy in 30f
optic pathway glioma	50Gy in 30f

Dose fractionation

immobilisation

target delineation

dose fractionation

plan evaluation

Preparation for high precision cranial RT

<i>Metric</i>	
conformity index (RTOG)	rCI
conformity index (Paddick)	pCI
homogeneity index	HI
gradient index	GI

Metrics for high precision RT

<i>Metric</i>		<i>calculation</i>
conformity index (RTOG)	rCI	V_{Rx} / V_{PTV}
conformity index (Paddick)	target delivery	
homogeneity index	HI	D_{max} / D_{Rx}
gradient index	normal tissue avoidance noncritical adjacent normal tissue	

- V_{Rx} - volume covered by prescription isodose
 V_{PTV} - PTV volume
 $V_{PTV,Rx}$ - overlapping volume
 D_{max} - maximum dose at the PTV
 D_{Rx} - prescription dose in the PTV

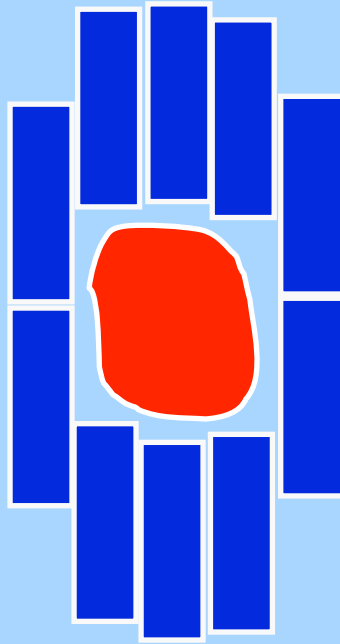
Metrics for high precision RT

<i>Metric</i>		<i>calculation</i>
conformity index (RTOG)	rCI	V_{Rx} / V_{PTV}
conformity index (Paddick)	target delivery	
homogeneity index	HI	D_{max} / D_{Rx}
gradient index	GI	$V_{50\%} / V_{100\%}$

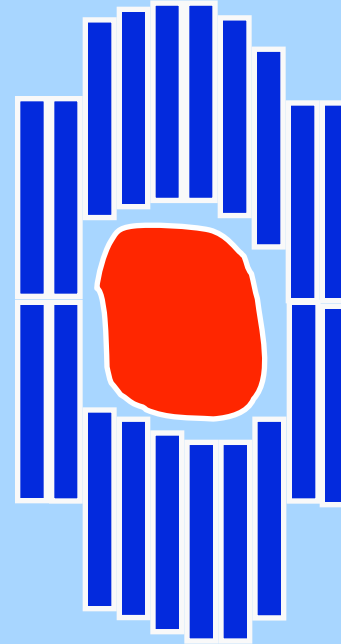
- V_{Rx} - volume covered by prescription isodose
 V_{PTV} - PTV volume
 $V_{PTV,Rx}$ - overlapping volume
 D_{max} - maximum dose at the PTV
 D_{Rx} - prescription dose in the PTV

Metrics for high precision RT

conformal treatment delivery



5 mm



2.5 mm

multi-leaf collimator leaf size

Collimation

<i>Metric</i>		<i>calculation</i>
conformity index (RTOG)	rCI	V_{Rx} / V_{PTV}
conformity index (Paddick)	target delivery	
homogeneity index	HI	D_{max} / D_{Rx}
gradient index	normal tissue avoidance noncritical adjacent normal tissue	

- V_{Rx} - volume covered by prescription isodose
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Metrics for high precision RT

<i>Metric</i>		<i>calculation</i>
conformity index (RTOG)	rCI	V_{Rx} / V_{PTV}
conformity index (Paddick)	target delivery	
homogeneity index	HI	D_{max} / D_{Rx}
gradient index	normal tissue avoidance noncritical adjacent normal tissue critical OARs	

- V_{Rx} - volume covered by prescription isodose
 V_{PTV} - PTV volume
 $V_{PTV,Rx}$ - overlapping volume
 D_{max} - maximum dose at the PTV
 D_{Rx} - prescription dose in the PTV

Metrics for high precision RT

<i>Metric</i>		<i>calculation</i>
conformity index (RTOG)	rCI	V_{Rx} / V_{PTV}
conformity index (Paddick)	pCI	$V_{PTV,Rx}^2 / V_{PTV} \times V_{Rx}$
homogeneity index	HI	D_{max} / D_{Rx}
gradient index	GI	$V_{50\%} / V_{100\%}$
normal tissue volume (brain/ROIs) irradiated to Dx (DVH)		

- V_{Rx} - volume covered by prescription isodose
- V_{PTV} - PTV volume
- $V_{PTV,Rx}$ - overlapping volume
- D_{max} - maximum dose at the PTV
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Metrics for high precision RT

<i>Metric</i>		<i>calculation</i>
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homogeneity index	HI	D_{max} / D_{Rx}
gradient index	GI	$V_{50\%} / V_{100\%}$
normal tissue volume (brain/ROIs) irradiated to Dx (DVH)		
planning time, treatment time etc.		

- V_{Rx} - volume covered by prescription isodose
- V_{PTV} - PTV volume
- $V_{PTV,Rx}$ - overlapping volume
- D_{max} - maximum dose at the PTV
- D_{Rx} - prescription dose in the PTV

Metrics for high precision RT

<i>Metric</i>		<i>calculation</i>	<i>worse</i>	<i>ideal value</i>
conformity index (RTOG)	rCI	V_{Rx} / V_{PTV}	low	1.0
conformity index (Paddick)	pCI	$V_{PTV,Rx}^2 / V_{PTV} \times V_{Rx}$	low	1.0
homogeneity index	HI	D_{max} / D_{Rx}	high	1.0
gradient index	GI	$V_{50\%} / V_{100\%}$	high	1.0

V_{Rx} - volume covered by prescription isodose

V_{PTV} - PTV volume

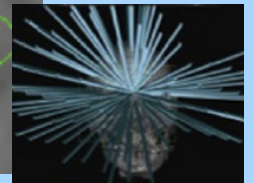
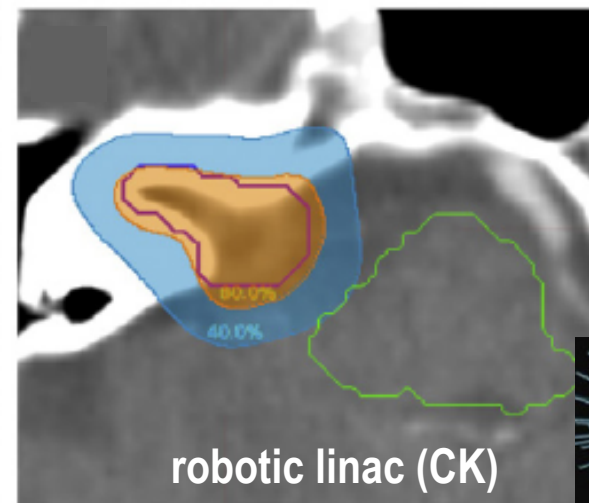
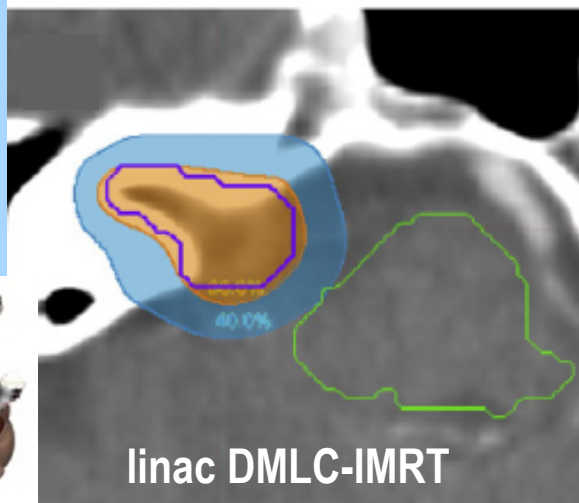
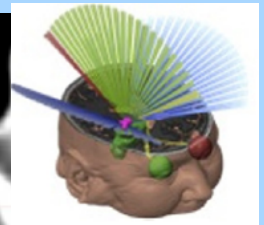
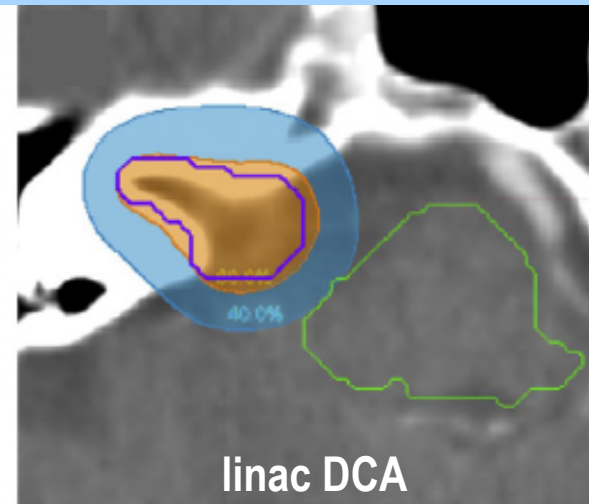
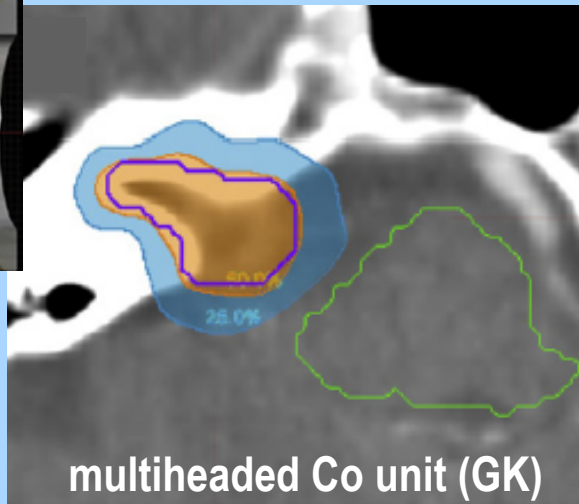
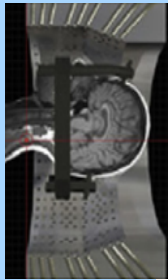
$V_{PTV,Rx}$ - overlapping volume

D_{max} - maximum dose in the PTV

D_{Rx} - prescription dose in the PTV

Metrics for high precision RT

example of acoustic neuroma



- DCA - dynamic conformal arcs
- DMLC - dynamic MLC
- GK - gamma knife
- CK - cyberknife

Comparison of techniques

		GK	DCA	IMRT	CK
Paddick conformity index	Mean	0.77	0.66	0.68	0.77
	SD	0.04	0.04	0.04	0.06
	Min	0.68	0.59	0.52	0.67
	Max	0.84	0.74	0.89	0.85
	Mean acoustic neuromas	0.76	0.67	0.66	0.75
	SD	0.04	0.05	0.06	0.06
	Mean arteriovenous malformation	0.80	0.65	0.70	0.80
	SD	0.04	0.03	0.06	0.04
Dose heterogeneity index	Mean	0.84	0.30	0.18	0.22
	SD	0.05	0.03	0.05	0.02
	Min	0.71	0.25	0.09	0.21
	Max	0.92	0.35	0.28	0.26
	Mean acoustic neuromas	0.83	0.29	0.18	0.22
	SD	0.05	0.03	0.06	0.02
	Mean arteriovenous malformation	0.86	0.32	0.18	0.21
	SD	0.03	0.03	0.04	0.01
Gradient index	Mean	2.59	3.16	3.94	3.48
	SD	0.10	0.55	0.92	0.47
	Min	2.47	2.48	2.74	2.81
	Max	2.81	4.45	6.00	4.54
	Mean acoustic neuromas	2.55	3.00	3.52	3.41
	SD	0.07	0.36	0.64	0.46
	Mean arteriovenous malformation	2.68	3.77	4.78	3.62
	SD	0.07	0.36	0.64	0.46

DCA - dynamic conformal arcs

DMLC - dynamic MLC (IMRT)

GK - gamma knife

CK - cyberknife

Comparison of techniques

Paddick conformity index

pCI

GK DCA IMRT CK

Mean acoustic neuromas
SD

GK

DCA

IMRT

CK

0.76
0.04

0.67
0.05

0.66
0.06

0.75
0.06

Dose heterogeneity index

Mean

SD

Min

Max

Mean acoustic neuromas

SD

Mean arteriovenous malformation

SD

Gradient index

Mean

SD

Min

Max

Mean acoustic neuromas

SD

Mean arteriovenous malformation

0.84

0.05

0.71

0.92

0.83

0.05

0.86

0.03

2.59

0.10

2.47

2.81

2.55

0.07

2.68

0.30

0.03

0.25

0.35

0.29

0.03

0.32

0.03

3.16

0.55

2.48

4.45

3.00

0.36

3.77

0.18

0.05

0.09

0.28

0.18

0.06

0.18

0.04

3.94

0.92

2.74

6.00

3.52

0.64

4.78

0.22

0.02

0.21

0.26

0.22

0.02

0.21

0.01

3.48

0.47

2.81

4.54

3.41

0.46

3.62

DCA - dynamic conformal arcs

DMLC - dynamic MLC

GK - gamma knife

CK - cyberknife

Comparison of techniques

Gevaert et al 2013 Radiother Oncol 106,192–197

		GK	DCA	IMRT	CK
Paddick conformity index	Mean	0.77	0.66	0.68	0.77
	SD	0.04	0.04	0.04	0.06
	Min	0.68	0.59	0.52	0.67
	Max	0.84	0.74	0.89	0.85
	Mean acoustic neuromas	0.76	0.67	0.66	0.75
	SD	0.04	0.05	0.06	0.06
	Mean arteriovenous malformation	0.80	0.65	0.70	0.80
Dose heterogeneity index	SD	0.04	0.03	0.06	0.04
	Mean	0.84	0.30	0.18	0.22
	SD	0.05	0.03	0.05	0.02
	Min	0.71	0.25	0.09	0.21
	Max	0.92	0.35	0.28	0.26
	Mean acoustic neuromas	0.83	0.29	0.18	0.22
	SD	0.05	0.03	0.06	0.02
Gradient index	Mean arteriovenous malformation	0.86	0.32	0.18	0.21
	SD	0.03	0.03	0.04	0.01
	Mean	2.59	3.16	3.94	3.48
	SD	0.10	0.55	0.92	0.47
		Min			
		Max			
		GK	DCA	IMRT	CK
Mean acoustic neuromas		2.55	3.00	3.52	3.41
SD		0.07	0.36	0.64	0.46

GI

DCA - dynamic conformal arcs
DMLC - dynamic MLC
GK - gamma knife
CK - cyberknife

Comparison of techniques

		GK	DCA	IMRT	CK
Paddick conformity index	Mean	0.77	0.66	0.68	0.77
	SD	0.04	0.04	0.04	0.06
	Min	0.68	0.59	0.52	0.67
	Max	0.84	0.74	0.89	0.85
	Mean acoustic neuromas	0.76	0.67	0.66	0.75
	SD	0.04	0.05	0.06	0.06
	Mean arteriovenous malformation	0.80	0.65	0.70	0.80
	SD	0.04	0.03	0.06	0.04
Dose heterogeneity index	Mean	0.84	0.30	0.18	0.22
	SD	0.05	0.03	0.05	0.02
	Min	0.71	0.25	0.09	0.21
	Max	0.92	0.35	0.28	0.26
	Mean acoustic neuromas	0.83	0.29	0.18	0.22
	SD	0.05	0.03	0.06	0.02
	Mean arteriovenous malformation	0.86	0.32	0.18	0.21
	SD	0.03	0.03	0.04	0.01
Gradient index	Mean	2.59	3.16	3.94	3.48
	SD	0.10	0.55	0.92	0.47
	Min	2.47	2.48	2.74	2.81
	Max	2.81	4.45	6.00	4.54
treatment time (mins)		GK	DCA	IMRT	CK
Mean		68.1	16.8	21.7	28.4
SD		27.5	2.2	3.4	8.1

DCA - dynamic conformal arcs

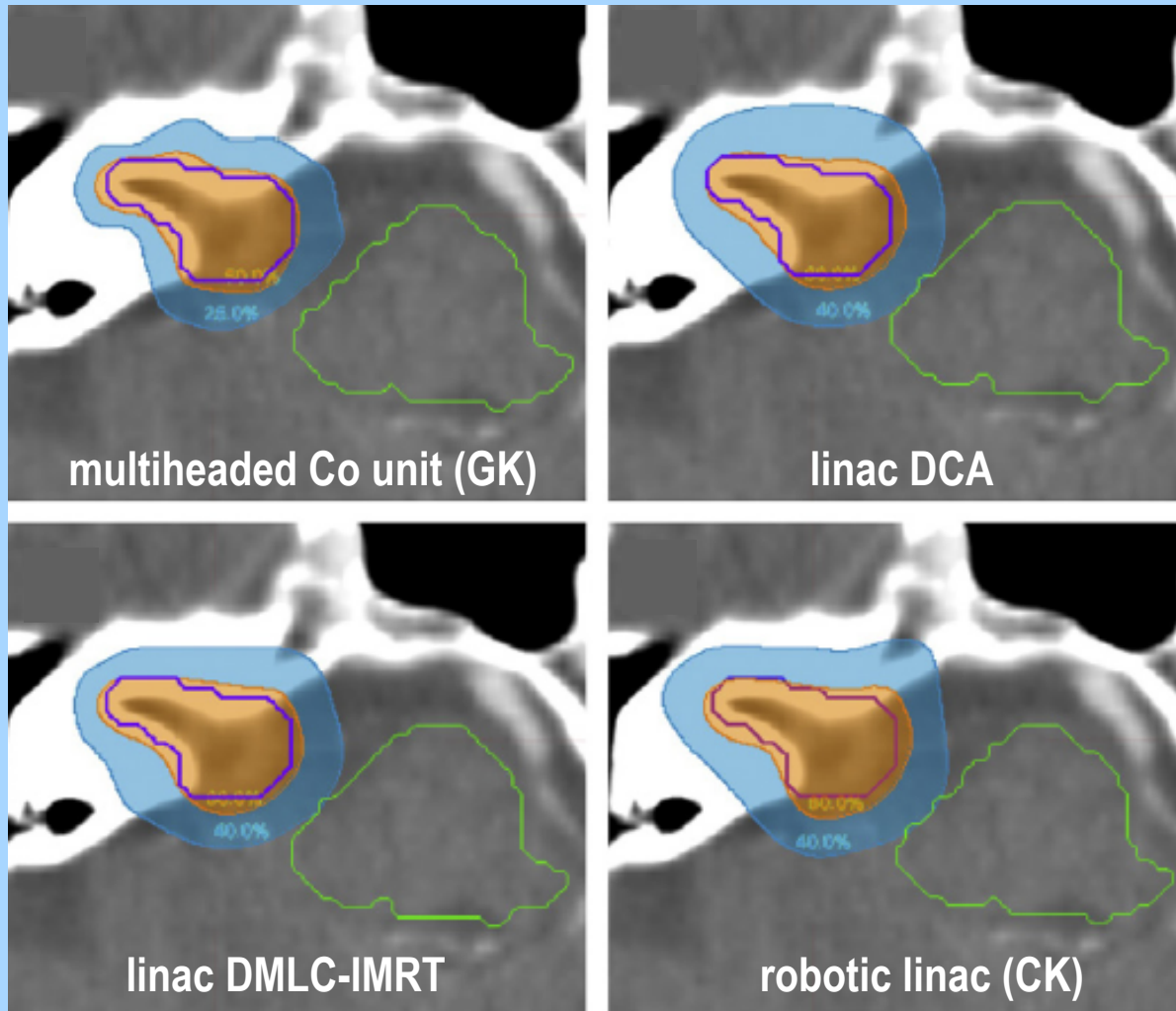
DMLC - dynamic MLC

GK - gamma knife

CK - cyberknife

Comparison of techniques

example of acoustic neuroma



- DCA - dynamic conformal arcs
- DMLC - dynamic MLC
- GK - gamma knife
- CK - cyberknife

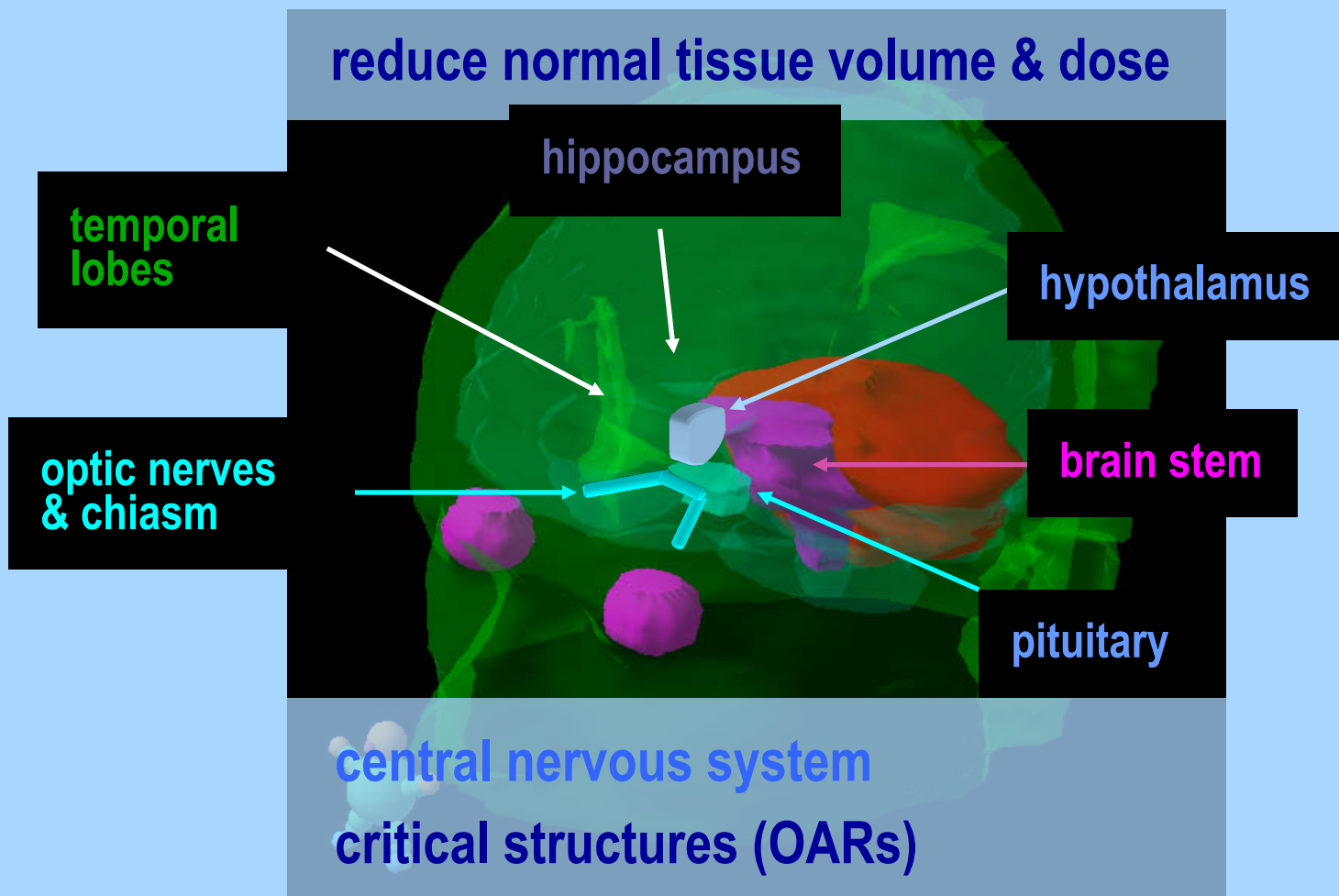
Comparison of techniques

<i>Metric</i>		<i>calculation</i>
conformity index (RTOG)	rCI	V_{Rx} / V_{PTV}
conformity index (Paddick)	pCI	$V_{PTV,Rx}^2 / V_{PTV} \times V_{Rx}$
homogeneity index	HI	D_{max} / D_{Rx}
gradient index	GI	$V_{50\%} / V_{100\%}$
normal tissue volume (brain/ROIs) irradiated to Dx (DVH)		

- V_{Rx} - volume covered by prescription isodose
- V_{PTV} - PTV volume
- $V_{PTV,Rx}$ - overlapping volume
- D_{max} - maximum dose at the PTV
- D_{Rx} - prescription dose in the PTV

Metrics for high precision RT

Avoidance in the treatment of skull base tumours



Evaluation of local radiotherapy techniques

Attributes of modern local RT delivery

refinements of conformal radiotherapy



precision

conformality

photons

protons

time factor (4D RT)

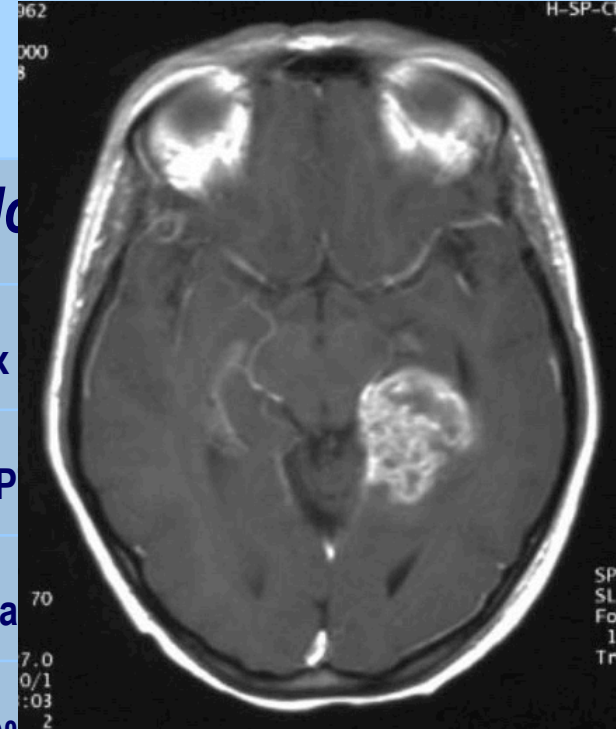
technical and clinical skill

quality assurance

imaging closer to treatment delivery (IGRT)

Classification of radiotherapy technologies

<i>Metric</i>		<i>calc</i>
conformity index (RTOG)	rCI	V_{Rx}
conformity index (Paddick)	pCI	V^2_p
homogeneity index	HI	D_{max}
gradient index	GI	$V_{50\%}$ 100%
normal tissue volume (brain/ROIs) irradiated to Dx (DVH)		
planning time, treatment time etc.		



application to daily practice

- V_{Rx} - volume covered by prescription isodose
- V_{PTV} - PTV volume
- $V_{PTV,Rx}$ - overlapping volume
- D_{max} - maximum dose at the PTV
- D_{Rx} - prescription dose in the PTV

Metrics for high precision RT

Preparation for cranial SRT & SRS

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