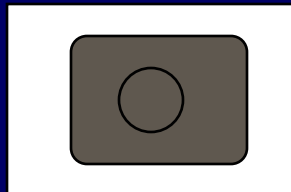
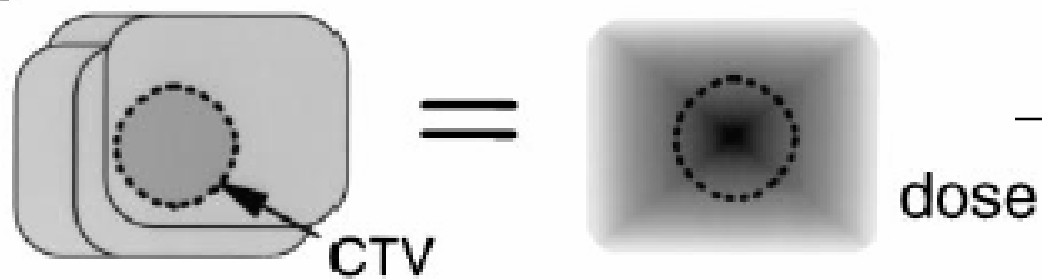


Set up error: is the difference between the intended and actual position of the part of the patient that is irradiated with respect to the treatment beams during the treatment

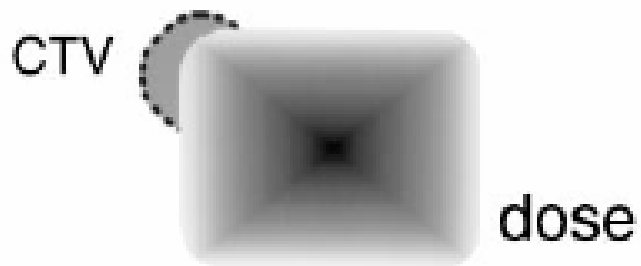


A



Random
Error

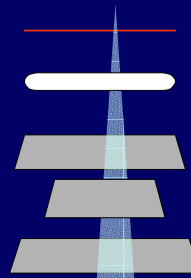
B



Systematic
Error

Geographical Miss

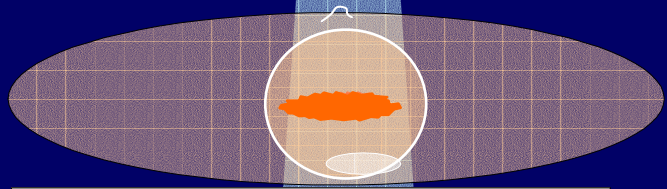
Focus



Asymmetric Jaws

*MLC / Custom
Field Shaping*

Patient



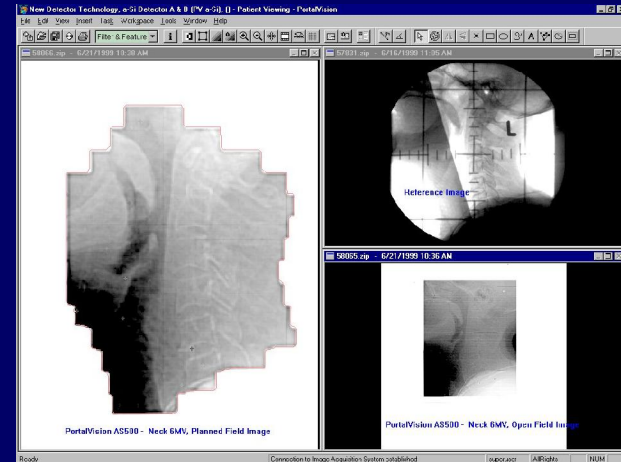
Couch



Detector

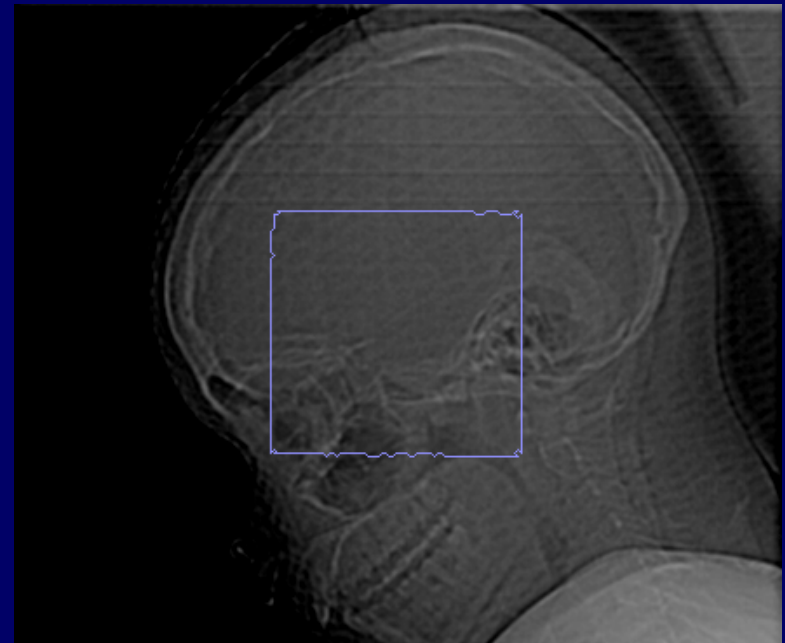
Methods of Treatment verification and Measurement of Errors in Clinical practice

- ⌘ Film based Portal image
- ⌘ Electronic Portal Imaging Devices (EPID)
- ⌘ Ultrasound (BAT)
- ⌘ CT scan
- ⌘ IGRT

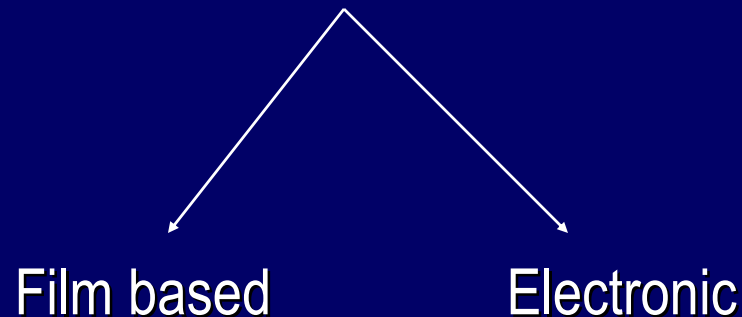


Portal Image:

Is the image of area being irradiated and is produced with the use of therapeutic X ray beam



Portal Image



Aim: To ensure correct patient position during the treatment

Electronic Portal Imaging



- ⌘ Images are available immediately
- ⌘ Images can be used to adjust the field or patient immediately-online correction
- ⌘ Digital images: can be enhanced by changing contrast and brightness
- ⌘ Can be used for matching with DRR or with simulator image.

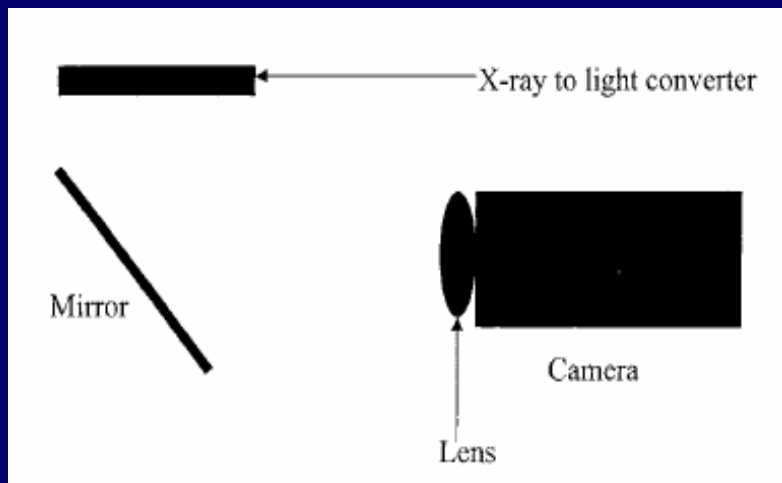
Electronic Portal Imaging Device (EPID)



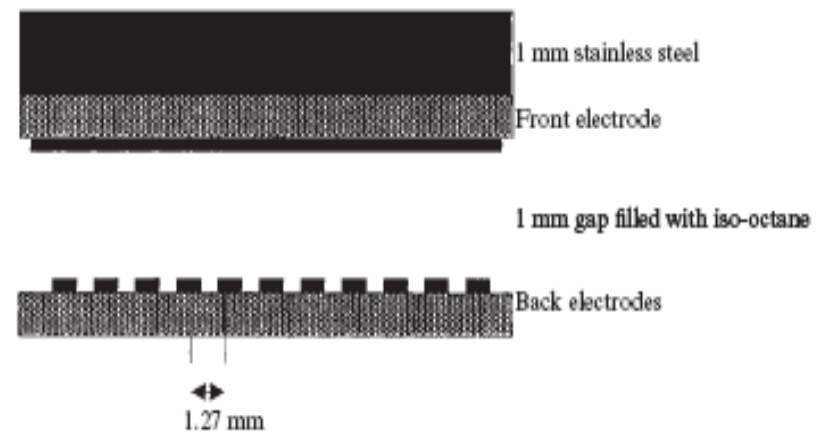
- 1980s.... *Norman Baily*
- Commercial EPIDs in 1990s

Types of EPID

- Liquid ionization chamber based
- Camera based
- Amorphous silicon based

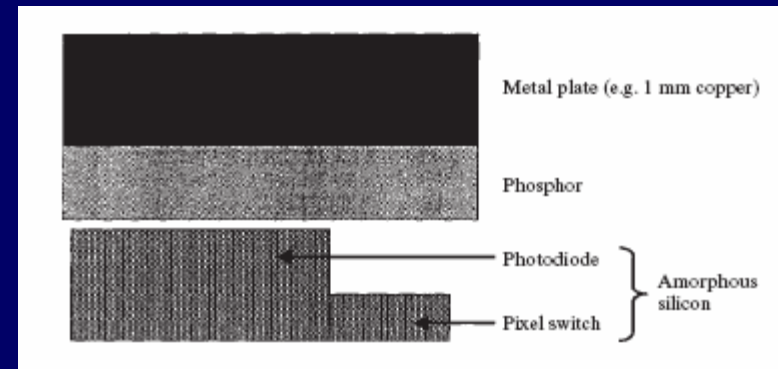
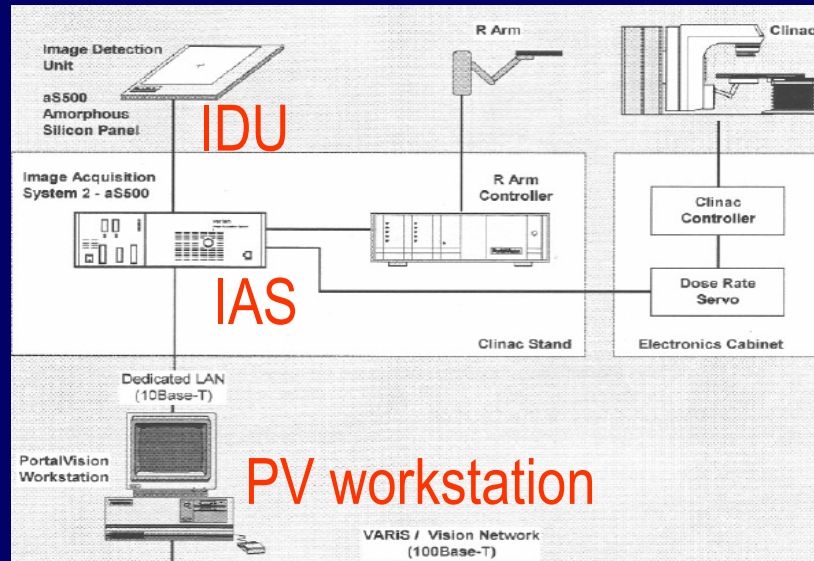


Camera based system



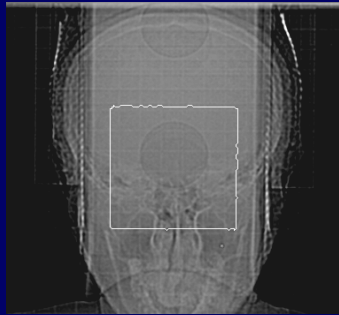
Liquid Ion chamber system

Amorphous Silicon System



- **Image Detection Unit (IDU) :**
featuring the detector and accessory electronics
- **Image Acquisition Unit (IAS2) :**
containing drive and acquisition electronics and interfacing hardware
- **A dedicated PortalVision workstation**

Set-up verification using EPID



Ant - EPID



Lat - EPID

Portal Imaging done: weekly, twice weekly, daily

Images obtained for fixed field sizes 8×8 or 10x10 at isocentre

Anterior and lateral portal images are taken irrespective of the treatment fields

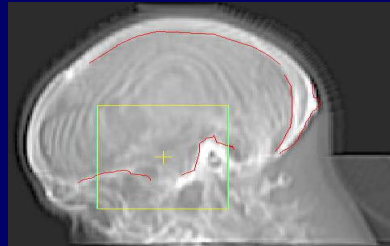
DRR of same field size is obtained from the planning system

Image matching/Registration

Image Matching

Image during treatment planning

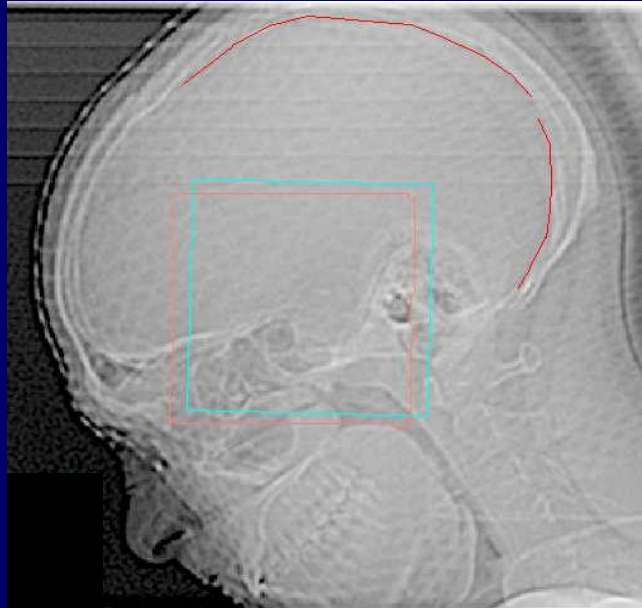
Image during treatment execution



Reference Image

- DRR
- Simulator Image
- First portal Image

Anatomy matching



Match Result Properties

General Image Mismatch History Comment

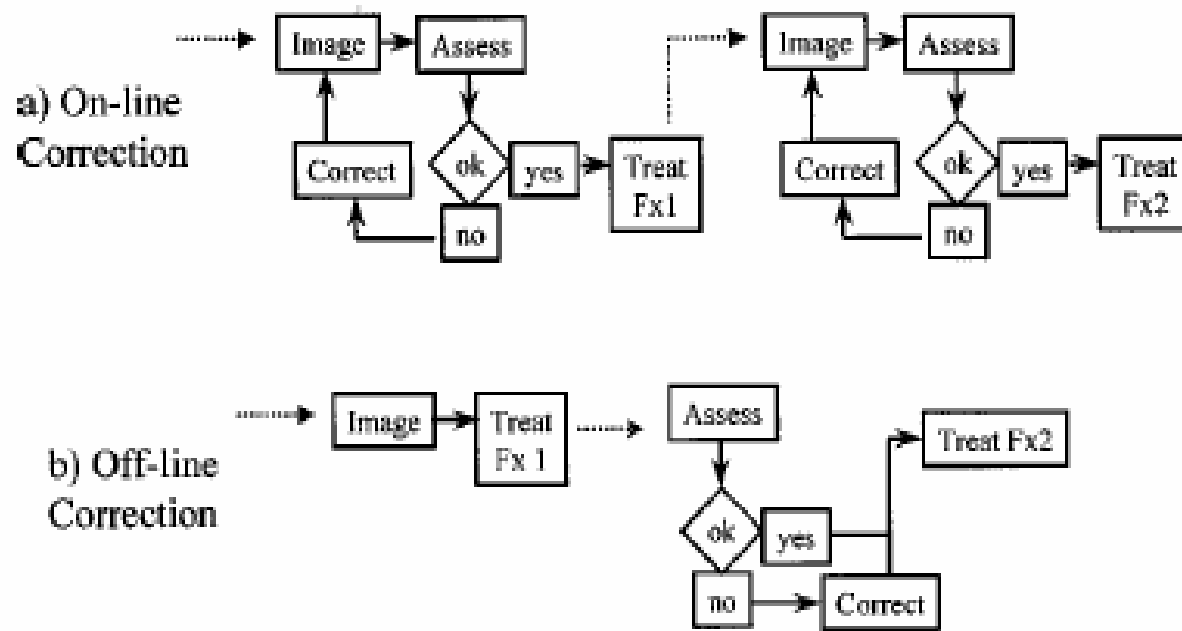
ID
Field Edge9

Mismatch in IEC1217 scale with respect to
Anatomy9

	Image		Couch	
X	+0.3	Lat	+0.3	cm
Y	-0.29	Lng	-0.29	cm
		Vit		cm
Rtn	+0.84	Rtn	+0.84	deg

Correction Protocol

1. Online correction
2. Offline correction



PTV Margin

- ⌘ PTV is Planning target volume
- ⌘ Geometric margin depends upon the margin required for set up errors and organ motion
- ⌘ $PTV = ITV + \text{Set up margin (SM)}$
- ⌘ ITV is internal target volume
- ⌘ Internal Target Volume (ITV) = CTV + Internal margin (IM)



— GTV
— CTV
— PTV

External Motion: Patient Movement; Errors in reproducibility and Daily variations



Set Up Margin: SM

Internal Motion: Breathing, Swallowing, Peristalsis:

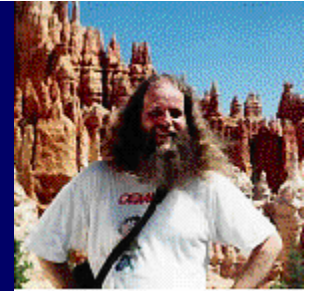


Internal Margin: IM-NOT SO IMPORTANT IN BRAIN TUMORS

Set up margin (SM)

- ⌘ Variations in patient positioning
- ⌘ Loosening / variation in Immobilisation devices
- ⌘ Mechanical uncertainty of equipment (sagging of gantry, collimators, couch, lasers)
- ⌘ Transfer errors from localisation CT scans / simulators to treatment units
- ⌘ Human factors: training, experience, concentration and time available for technologist
- ⌘ Patient's physical and mental state

PTV Generation



- ⌘ Several recipes; the 'Dutch' recipe is most common
- ⌘ An assessment of the standard deviation of the systematic error (Σ_{setup}) and the standard deviation of the random error (σ_{setup}) is required

- ⌘ Stroom's formula: CTV to PTV margin

$$\text{PTV} = 2\Sigma + 0.7\sigma$$

- ⌘ Van Herk's formula: CTV to PTV margin

$$\text{PTV} = 2.5\Sigma + 0.7\sigma$$

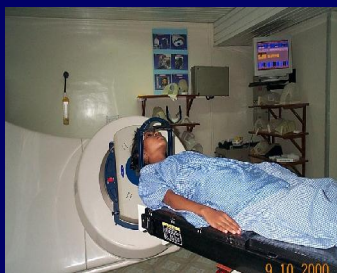
- ⌘ These generally guarantee that there is a 90% probability that 99% of the CTV will be encompassed by 95% isodose (assuming that the PTV is encompassed by the 95% isodose!)

Set-Up error in Head & neck region

Film or EPID	No. of patients	No. of images	Direction	σ_{sys} (mm)	σ_{random} (mm)	Ref.
Film	22	193	cc	2.1	2.1	[45]
EPID	21 (old mask)	470	ap	2.1	2.1	[5]
			ml	1.8	1.5	
			cc	1.7	1.8	
EPID	10 (new mask)	156	ap	2.0	1.6	[63]
			ml	1.8	1.5	
			cc	1.7	1.1	
			ap	2.0	1.6	
Film	27	234	cc	4.3	2.5	[63]
Film	29	136	ap	4.6	2	[103]
			ml	2.2	2.1	
EPID	26	356	cc	1.8	1.9	[98]
			ap	1.9	2.0	
			ml	1.8	1.6	
			cc	2.7	1.5	
			ap	1.7	1.2	
Film (85%); EPID (15%)	43	515	rot ap	1.2°	0.8°	[101]
			rot ml	0.7°	1.0°	
			cc (Orfit)	3.4	2.1	
			ap (Orfit)	3.4	2.1	
			cc (PVC)	3.6	2.1	
EPID	12	192	ap (PVC)	3.6	2.1	[104]
			cc	2.0	1.4	
EPID	12	290	ap	1.3	1.7	[32]
			ml	1.8 ^b	1.4	
			cc	2.2 ^b	1.4	
			ap	1.7 ^b	1.4	

Immobilisation for Stereotactic irradiation

Systematic errors



Direction <i>N</i> = 15	Mean	1 SD
<i>Anterior portal</i>		
Medial/lateral (mm)	0.8	0.7
Cranial/caudal (mm)	0.8	0.8
Rotation in coronal plane (°)	0.0	0.3
<i>Lateral portal</i>		
Anterior/posterior (mm)	-0.1	0.9
Cranial/caudal (mm)	0.0	1.0
Rotation in sagittal plane (°)	0.0	0.5



Random errors

Direction	1 SD
<i>Anterior portal (126 images)</i>	
Medial/lateral (mm)	0.6
Cranial/caudal (mm)	0.6
Rotation in coronal plane (°)	0.5
<i>Lateral portal (123 images)</i>	
Anterior/posterior (mm)	0.6
Cranial/caudal (mm)	0.7
Rotation in sagittal plane (°)	0.5



BrainLAB Relocatable mask/frame



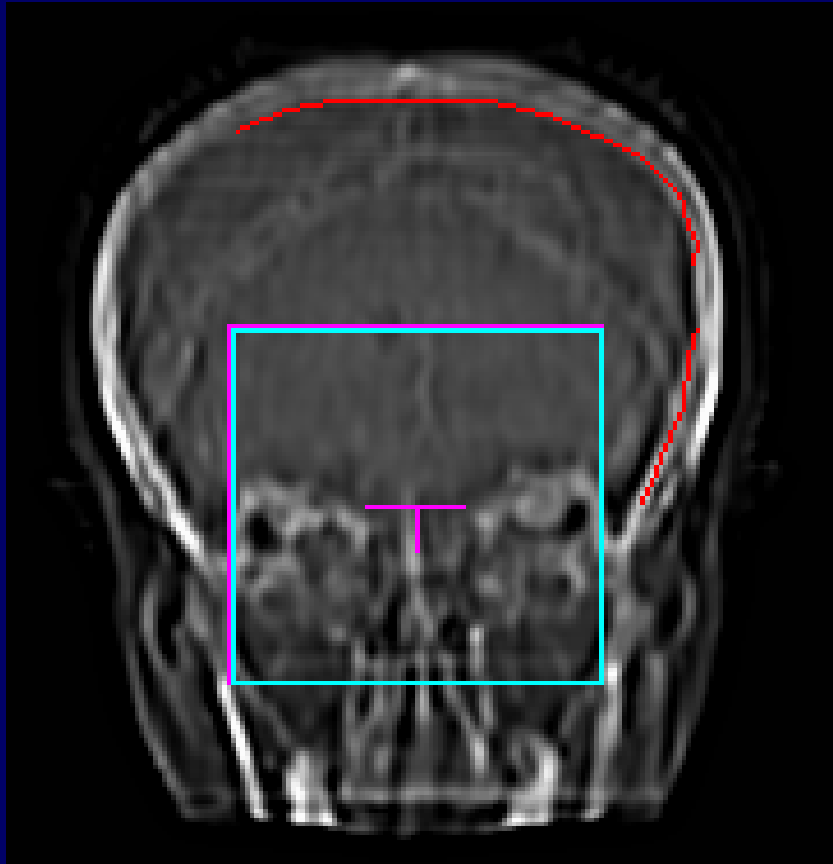
Comparison between simulator film and repeat simulator films	Mean	SD
Anterior film		
medial / lateral	0.0	0.8
cranial / caudal	0.4	1.4
rotation in coronal plane	0.1	1.2
Lateral film		
anterior /posterior	0.0	0.8
cranial / caudal	0.5	1.7
rotation in sagittal plane	0.4	1.5
3-D displacement	2.1	1.2

TMH EPID study for margin generation

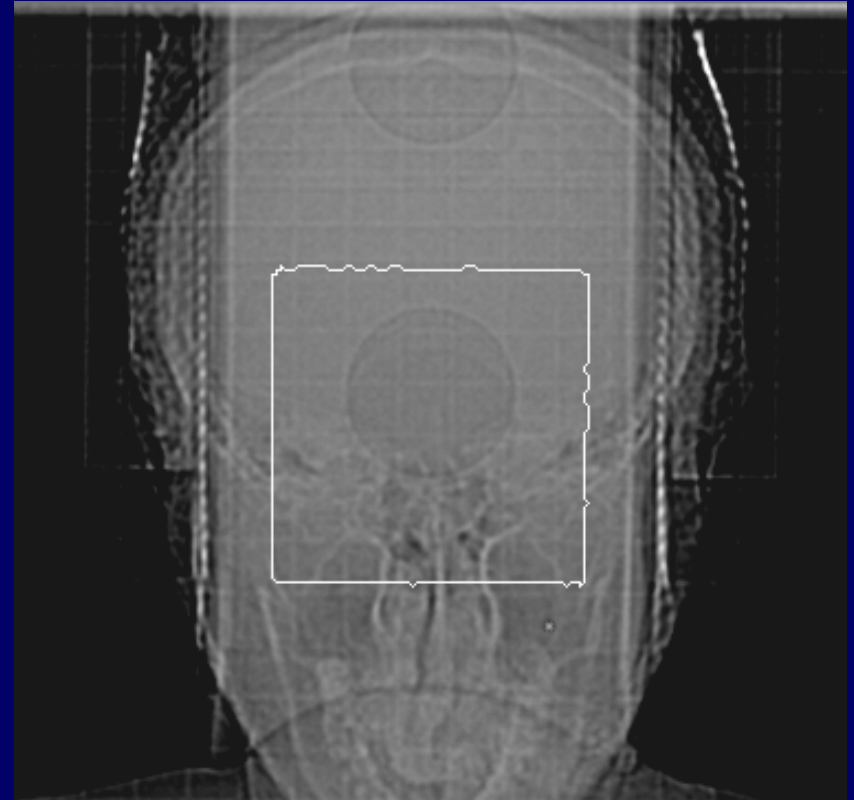


- Portal Vision: Amorphous silicon detector aS500 attached Varian 6 EX with retractable arm
- Anterior and lateral portal images of 8×8 Field size
- Portal Imaging done twice weekly

Anterior DRR

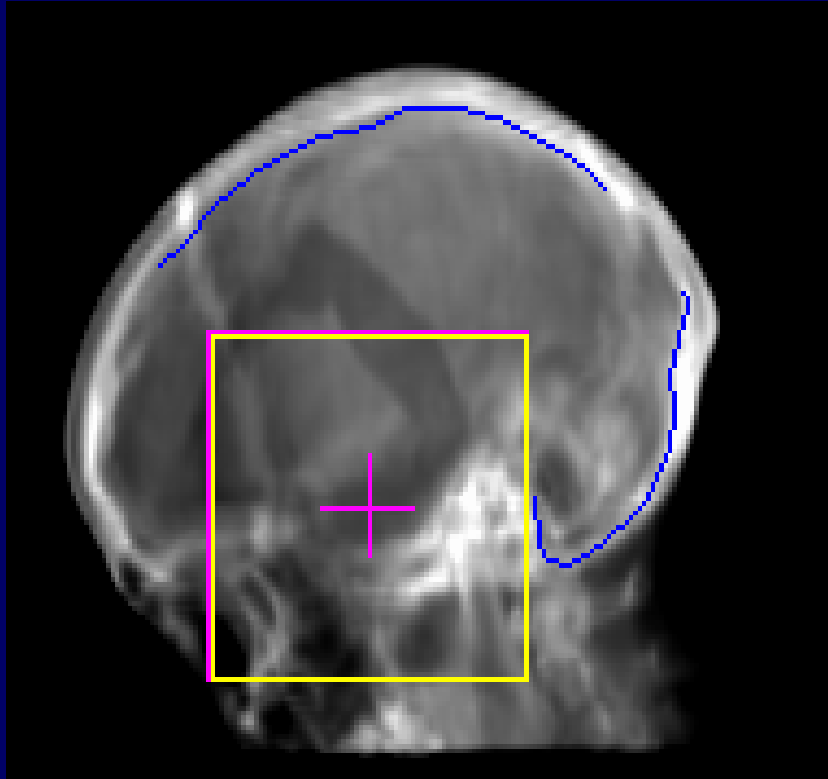


Anterior Portal image

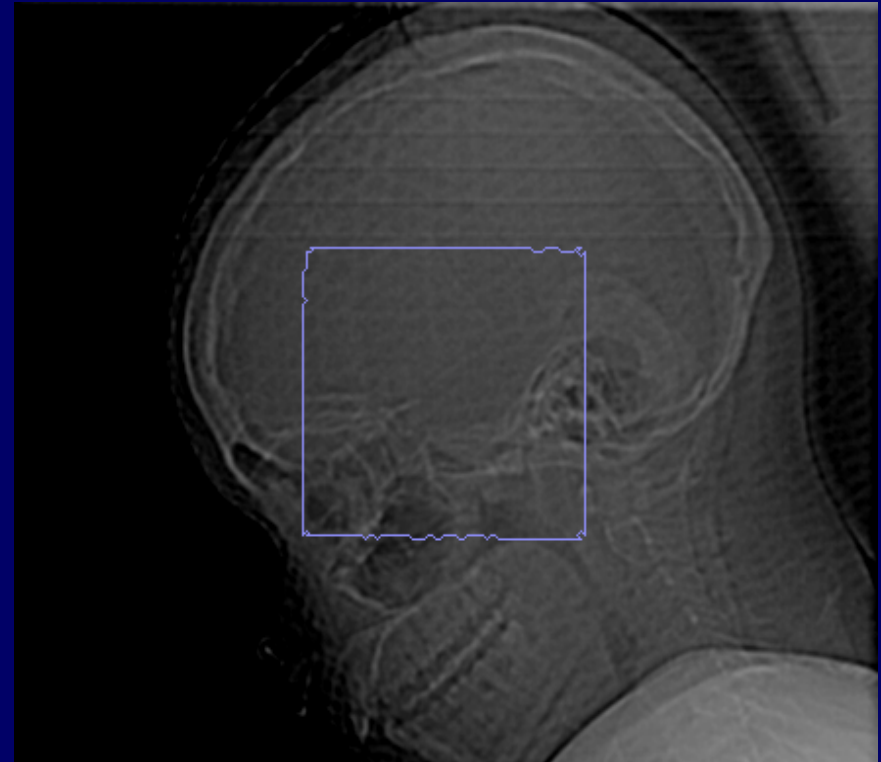


Total number of Images in 15 patients : 130

Lateral DRR



Lateral EPID Image



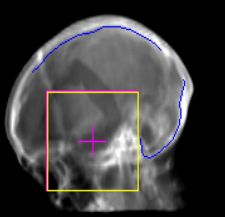
Total number of Images in 15 patients : 128



Systematic Errors

Random Errors

Direction	1 Standard Deviation	1 Standard Deviation
Anterior Portal		
Medial/Lateral (mm)	1.8	1.2
Cranial/Caudal (mm)	2.0	1.6
Rotation in coronal plane (°)	0.91	0.97
Lateral Portal		
Anterior/Posterior (mm)	2.1	1.5
Cranial/Caudal (mm)	2.0	2.0
Rotation in sagittal plane(°)	1.42	1.45



Total Errors



Direction	Mean mm	1 Standard Deviation
Anterior Portal (130 images)		
Medial/Lateral (mm)	1.233	2.0
Cranial/Caudal (mm)	-0.8	2.6
Rotation in coronal plane (°)	0.41	1.24
Lateral Portal (128 images)		
Anterior/Posterior (mm)	4.8	2.4
Cranial/Caudal (mm)	-0.9	2.8
Rotation in saggital plane(°)	0.65	2.04

Margin Generation Protocol

Generation of CTV to PTV margin Stroom IJROBP 1999 :

$$PTV = 2 \times \text{Systematic Error} + 0.7 \times \text{Random Error}$$

Direction	Formula	Margin (mm)
Medial/Lateral	$2 \times 1.8 + 0.7 \times .2$	4.4
Cranial/Caudal	$2 \times 2 + 0.7 \times 1.6$	5.12
Anterior/Posterior	$2 \times 2.1 + 0.7 \times 1.2$	5.25

*

Summary

- ⌘ Treatment verification using portal imaging is important especially for high precision techniques
- ⌘ Electronic Portal Imaging is the current standard
- ⌘ Accurate immobilization
- ⌘ Each institution should develop their own for portal vision and QA
- ⌘ Margin for PTV should ideally be derived from your own data.