ESTRO School

ESTRO Course Book

Basic Treatment Planning

13 - 17 September, 2015
Lisbon, Portugal

NOTE TO THE PARTICIPANTS

The present slides are provided to you as a basis for taking notes during the course. In as many instances as practically possible, we have tried to indicate from which author these slides have been borrowed to illustrate this course.

It should be realised that the present texts can only be considered as notes for a teaching course and should not in any way be copied or circulated. They are only for personal use. Please be very strict in this, as it is the only condition under which such services can be provided to the participants of the course.

Faculty

David Sjöström

Disclaimer

EUROPEAN ACCREDITATION COUNCIL
FOR CONTINUING MEDICAL EDUCATION

Institution of the UEMS

The faculty of the teachers for this event has disclosed any potential conflict of interest that the teachers may have.

Programme

Sunday 13 September			
	08:15 – 09:00	Registration	
	09:00 – 09:15	Welcome and introduction	DS + all
	09:15 – 10:10	Introduction to treatment planning: Physicist perspective	DS
	10:10 – 10:30	Introduction to treatment planning: Oncologist perspective	PK
	10:30 – 10:50	**Coffee break**	
	10:50 – 11:30	ICRU recommendations on volume and dose	DS
	11:30 – 12:10	Treatment planning: tools and general principles part 1	SB + ML
	12:10 – 13:00	**Lunch**	
	13:00 – 13:30	Treatment considerations for palliative treatments	PK
	13:30 – 14:00	Introduction to practical treatment planning workshop for palliative cases	SB + ML
	14:00 – 14:30	Vendor: Introduction to TPS	Vendor
	14:30 – 14:50	**Coffee break**	
	14:50 – 17:00	Practical treatment planning workshop for palliative cases	All
	17:15	**Welcome reception**	

Monday 14 September			
	08:30 – 09:15	Feedback/discussion palliative workshop	SB/ML + All
	09:15 - 09:45	IGRT and margin determination; General introduction and IGRT in palliative treatment	MK
	09:45 – 10:10	Treatment considerations for pelvic cancers excluding prostate	CG
	10:10 – 10:30	**Coffee break**	
	10:30 – 10:50	Treatment considerations for pelvic cancers excluding prostate cont.	CG
	10:50 – 11:20	Treatment considerations for prostate cancer	PK
	11:20 – 12:00	Introduction and Practical OAR contouring workshop	DP + PK/CG
	12:00 – 12:50	**Lunch**	
	12:50 – 14:00	Practical OAR contouring workshop pelvis cont.	DP + PK/CG
	14:00 – 14:30	Introduction to practical treatment planning workshop for prostate cancers	DP
	14:30 – 14:50	**Coffee break**	
	14:50 – 15:20	Vendor: Introduction to TPS	Vendor
	15:20 – 17:00	Practical treatment planning workshop for pelvic (prostate) cancers	All
	19:00	**Social Dinner**	

Tuesday 15 September			
	09:00 – 09:45	Feedback/discussion pelvic workshop	DP + All
	09:45 – 10:10	IGRT and margin determination in Pelvic treatment	MK
	10:10 – 10:25	**Coffee break**	
	10:25 – 11:00	Treatment Planning: tools and general principles part 2	ML+SB
	11:00 – 11:50	Treatment considerations for breast cancer	CG
	11:50 – 12:40	**Lunch**	
	12.40 - 13.10	Introduction to practical treatment planning workshop for breast	DS
	13.10 - 13.40	Vendor: Introduction to TPS	Vendor
	13:40 – 14:40	Practical treatment planning workshop for breast	All
	14.40 – 15.00	**Coffee break**	
	15.00 – 17:00	Practical treatment planning workshop for breast workshop	All

Wednesday 16 September			
	08:30 – 09:30	Feedback/discussion breast workshop	DS + All
	09:30 – 09:50	IGRT for breast treatment	MK
	09.50 – 10:20	Treatment considerations for thorax	CG
	10:20 – 10:40	**Coffee break**	
	10:40 – 11:10	Treatment considerations for thorax cont.	CG
	11:10 – 12.00	Introduction and Practical OAR contouring workshop thorax	DP + PK/CG
	12:00 – 12:50	**Lunch**	
	12:50 – 13:20	Practical OAR contouring workshop thorax cont.	DP + PK/CG
	13.20 - 13.50	Introduction to practical treatment planning workshop for lung cancer	SB/ML
	13:50 – 14:20	Vendor: Introduction to TPS	Vendor
	14:20 – 15:00	Practical treatment planning workshop for lung	All
	15:00 – 15.20	**Coffee break**	
	15.20 – 17:00	Practical treatment planning workshop for lung	All

Thursday 17 September			
	08:30 – 09:30	Feedback/discussion lung workshop	ML/SB + All
	09:30 – 10: 00	Optimizing the treatment volume in Lung	MK
	10:00 – 10:40	Treatment considerations for Head and Neck	PK
	10:40 – 11:00	**Coffee break**	
	11:00 – 11:30	Treatment planning for Head and Neck	SB/DS
	11:30 – 12:10	Multiple Choice Question Test	DS + all
	12:10 – 12:30	Close and distribution of certificates	DS + all

Faculty

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Introduction to treatment planning

Physicist perspective

David Sjöström
Herlev Hospital, Denmark

The menu

Main course

Introduction to treatment planning

Starter

What do we irradiate with?

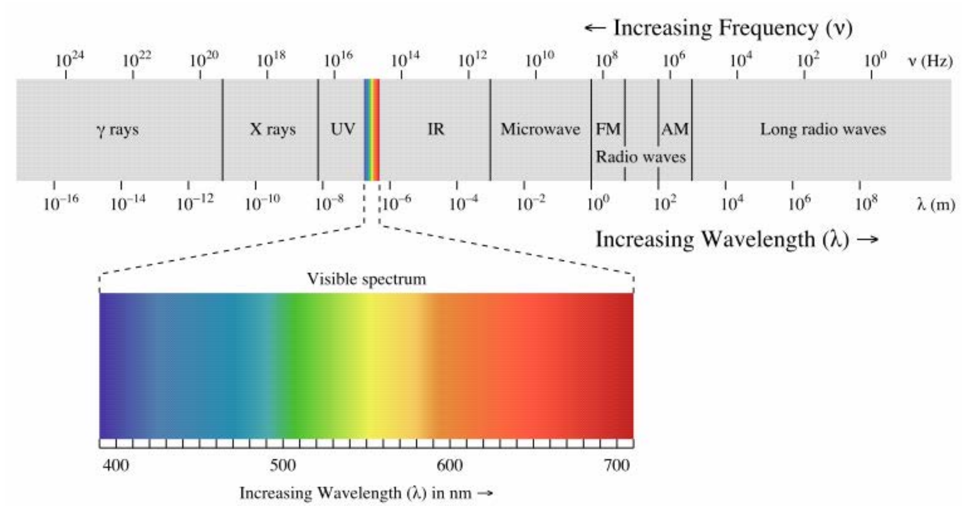
Where does the irradiation come from?

How does it work (interaction with matter)?

How is all this modeled in a treatment planning system?

Radiation in Radiotherapy?

- High energy (X-ray, Gamma) photons (=electromagnetic radiation)



- Particles
  - Electrons
  - Protons
  - Neutrons
  - Beta
  - Alfa

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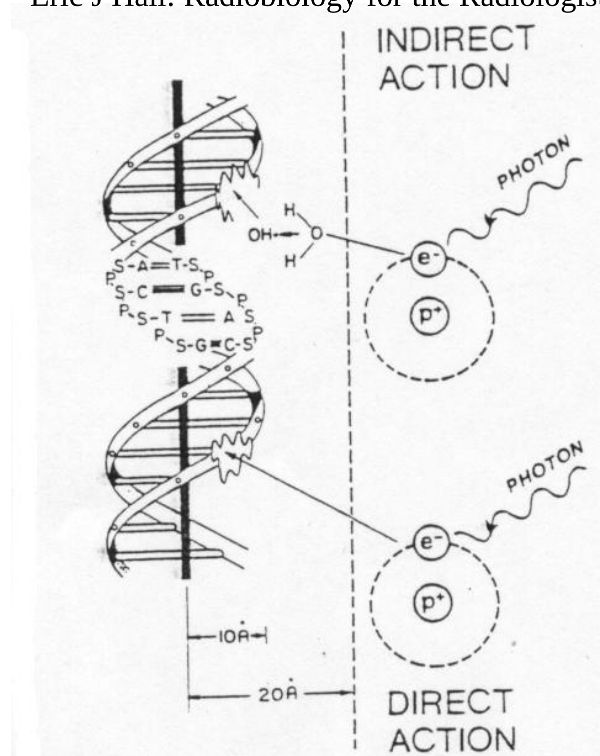
Radiation in Radiotherapy?

- Electromagnetic radiation = Photons (e.g X-ray, Gamma)

Eric J Hall: Radiobiology for the Radiologist



- Particles
  - Electrons
  - Protons
  - Neutrons
  - Beta
  - Alfa

- Ionizing radiation

ESTRO *LIVE* COURSE: BASIC CLINICAL RADIOBIOLOGY

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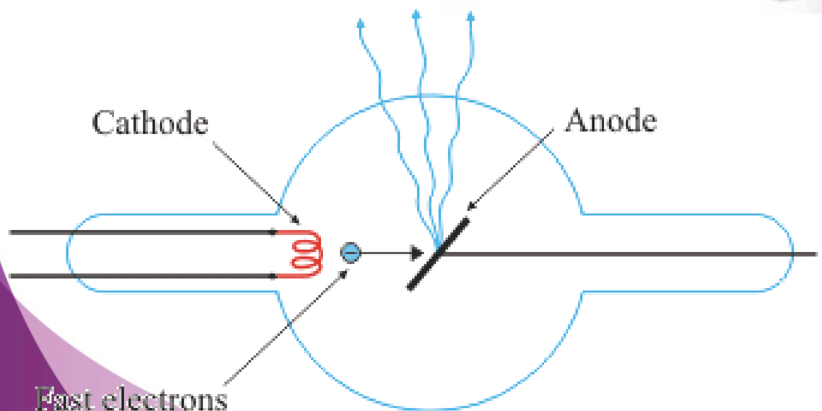
Ionizing
Radiation in Radiotherapy?

Generated radiation

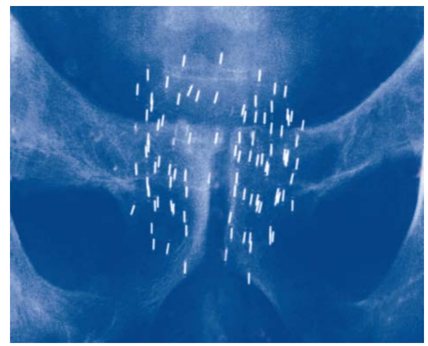


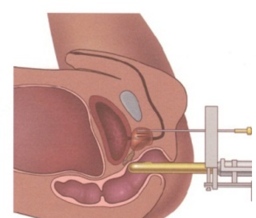
Radioactive sources

$$Co_{27}^{60} \xrightarrow[0.31\ \text{MeV}]{\beta} Ni_{28}^{*60}$$

$$Ni_{28}^{*60} \xrightarrow{\gamma\ 1.17\ \text{MeV}} Ni_{28}^{*60} \xrightarrow{\gamma\ 1.33\ \text{MeV}} Ni_{28}^{60}$$

$$T_{1/2} = 5.24Y$$





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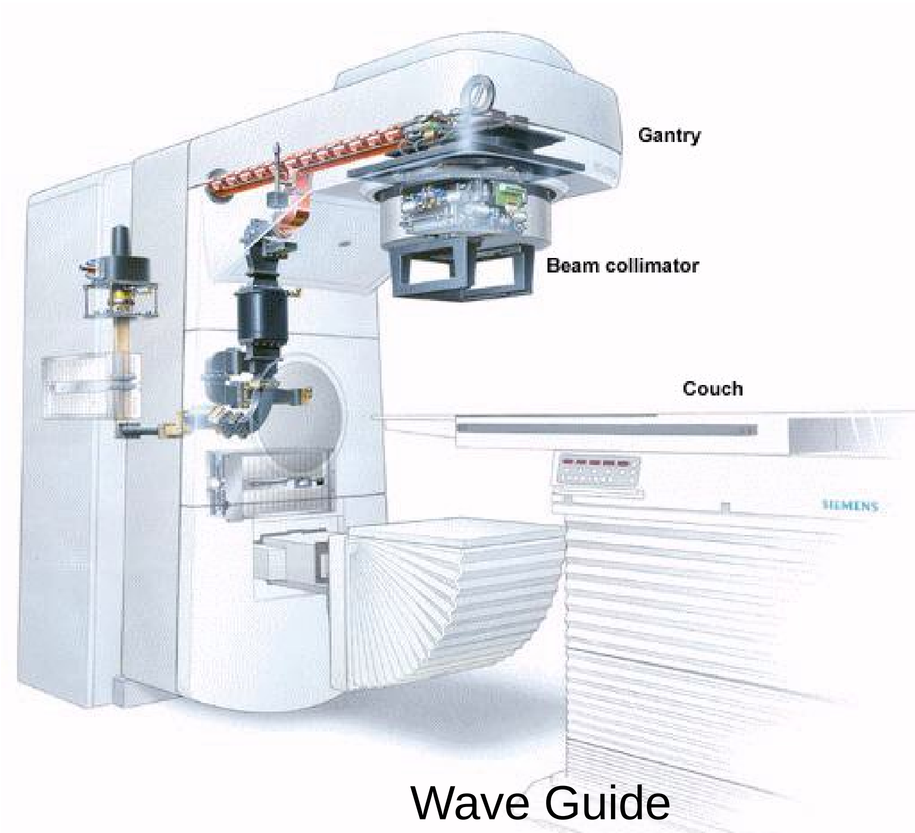
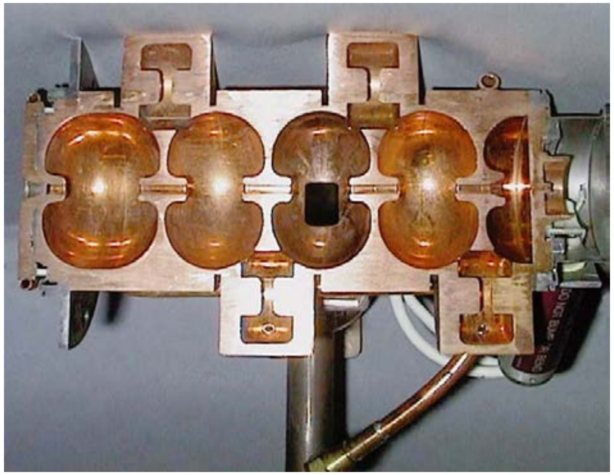
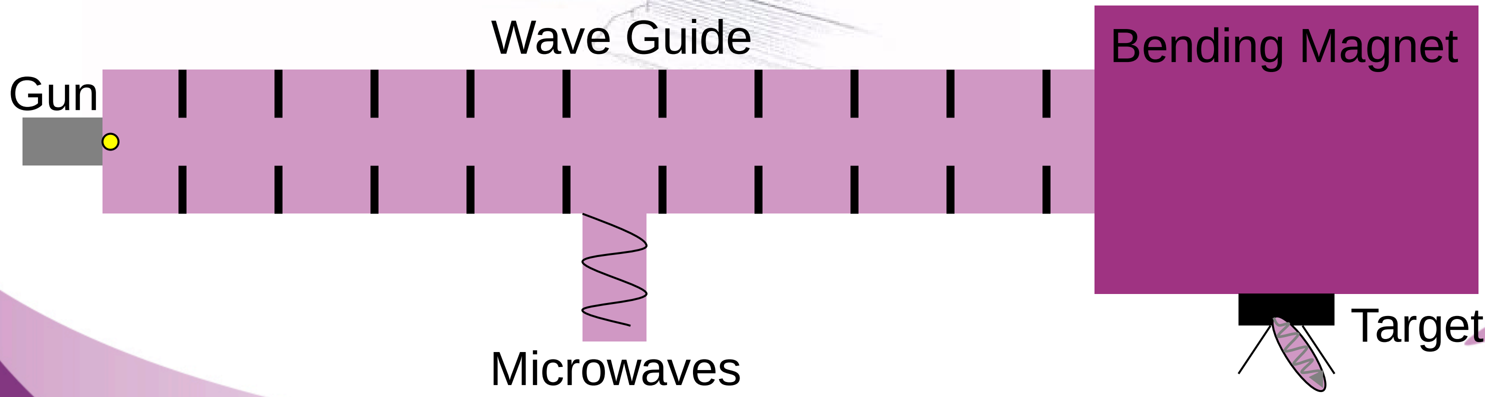
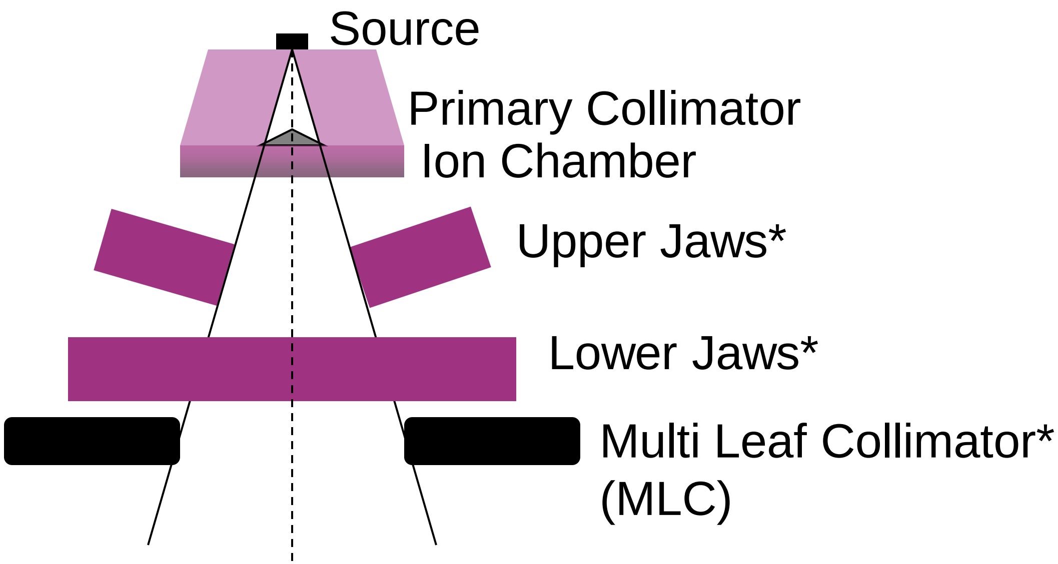
Linear accelerator



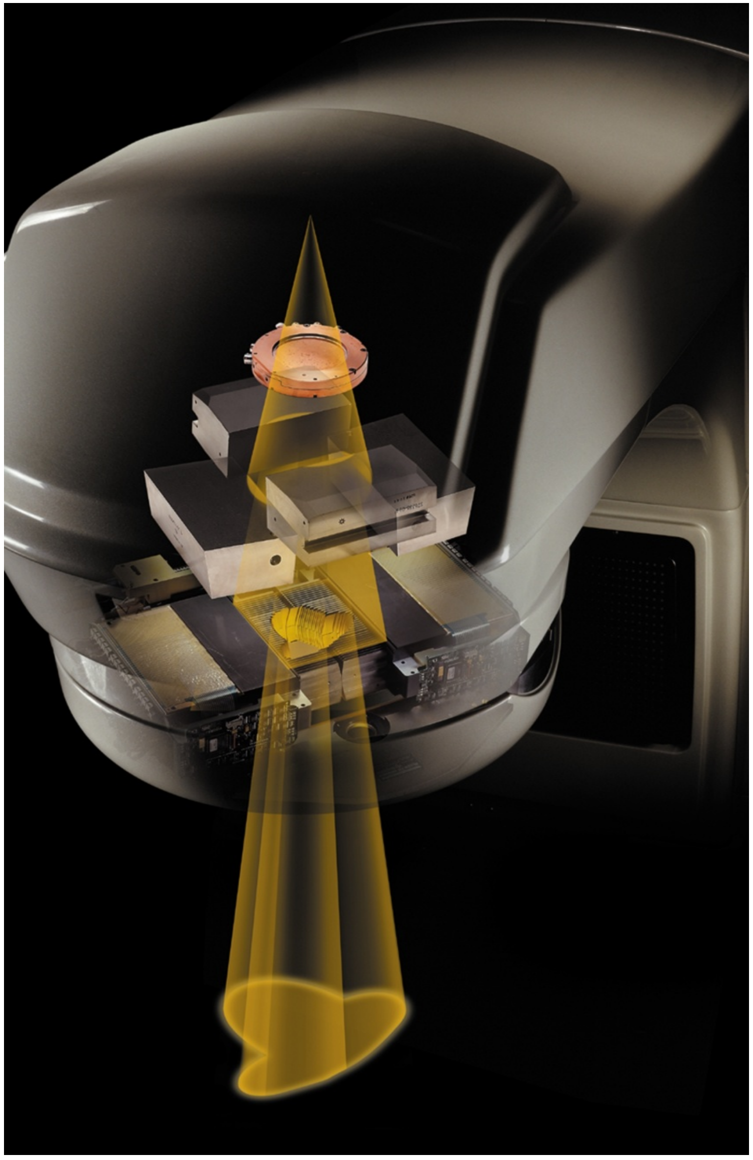




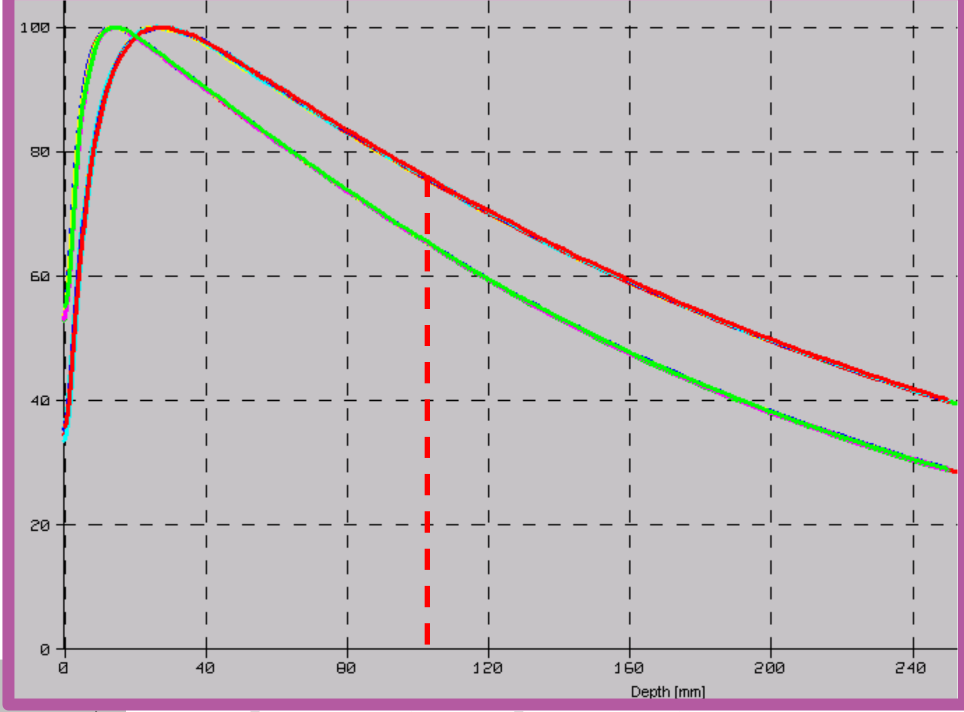
Treatment Unit Head Design



* Adjustable

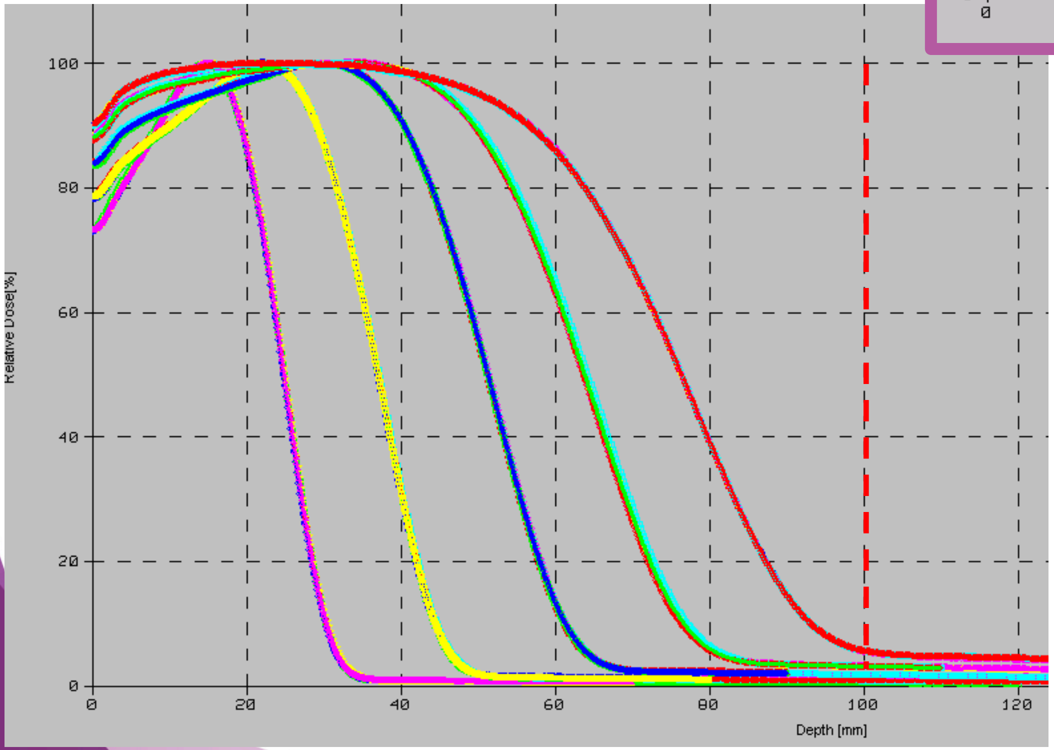


Photons and electrons



Photons (6 and 15 MV)

Electrons (6 to 18 MeV)



6 MeV

9 MeV

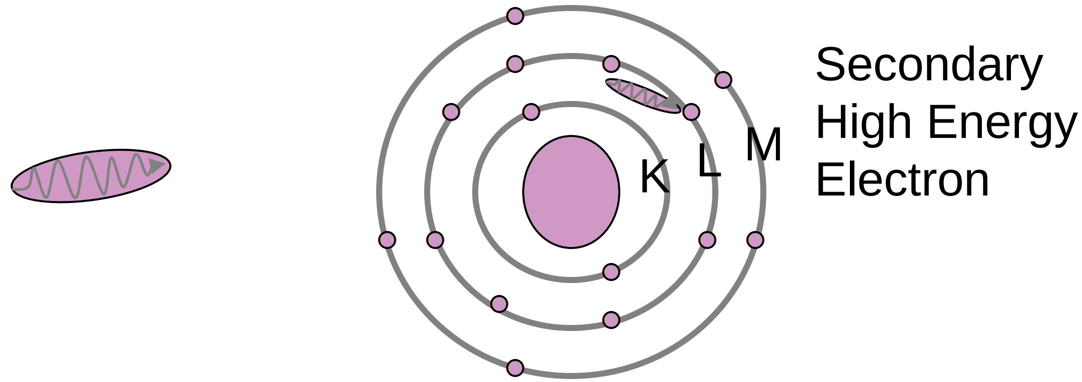
12 MeV

15 MeV

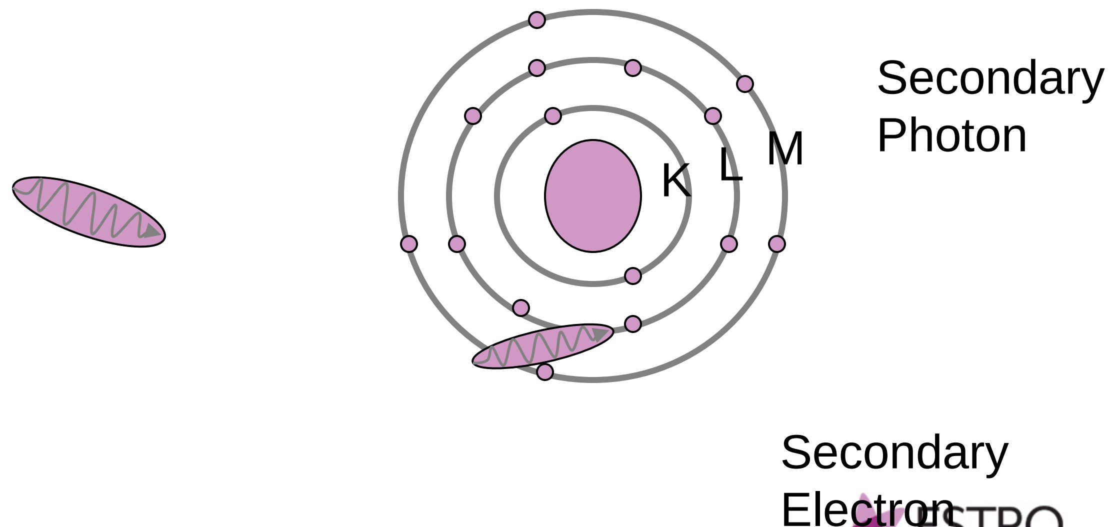
18 MeV

Photon interaction with matter (atoms)

- Photoelectric Effect
  - ➢ kV Photon Energy



- Compton Scatter
  - ➢ MV Photon Energy



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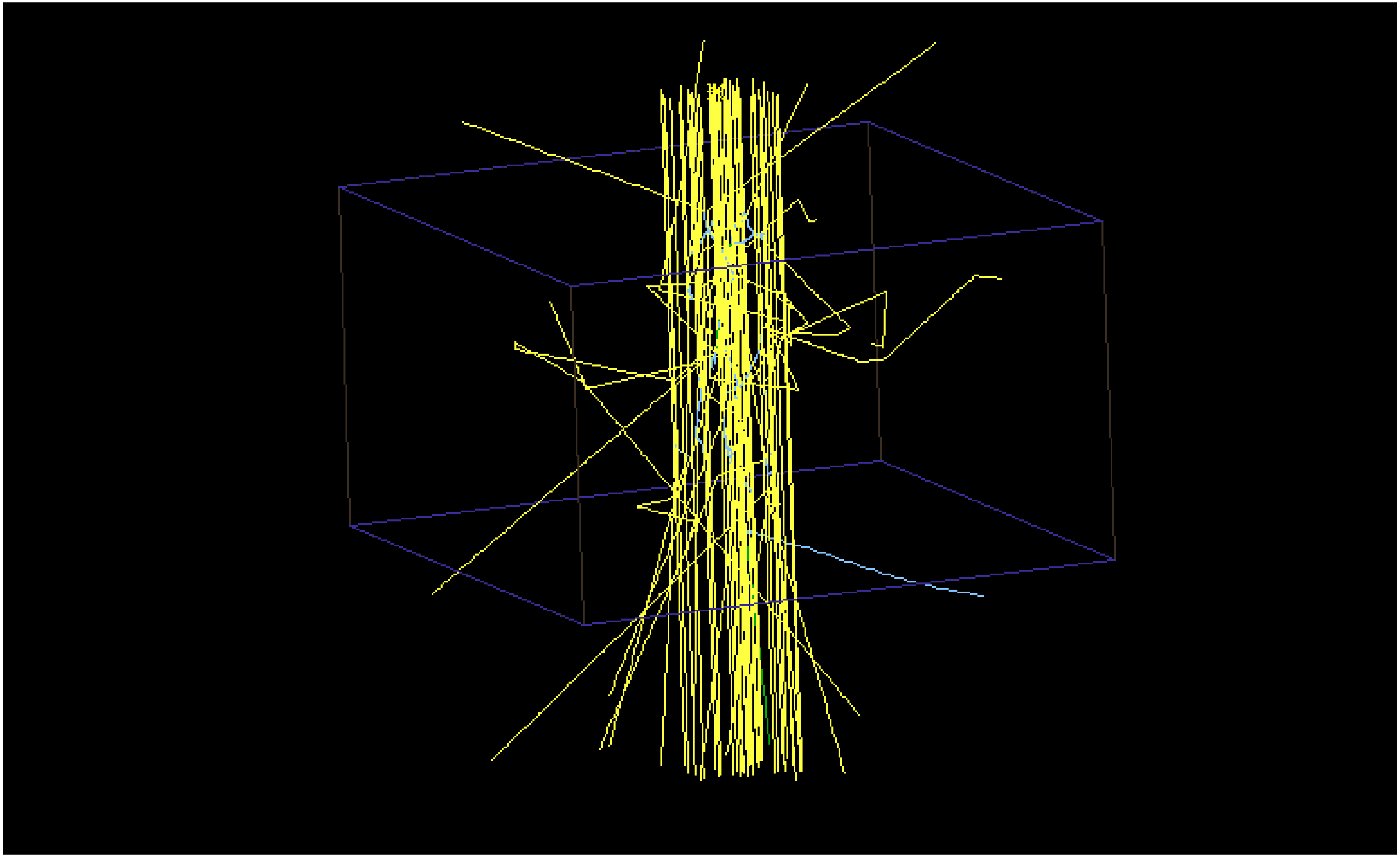
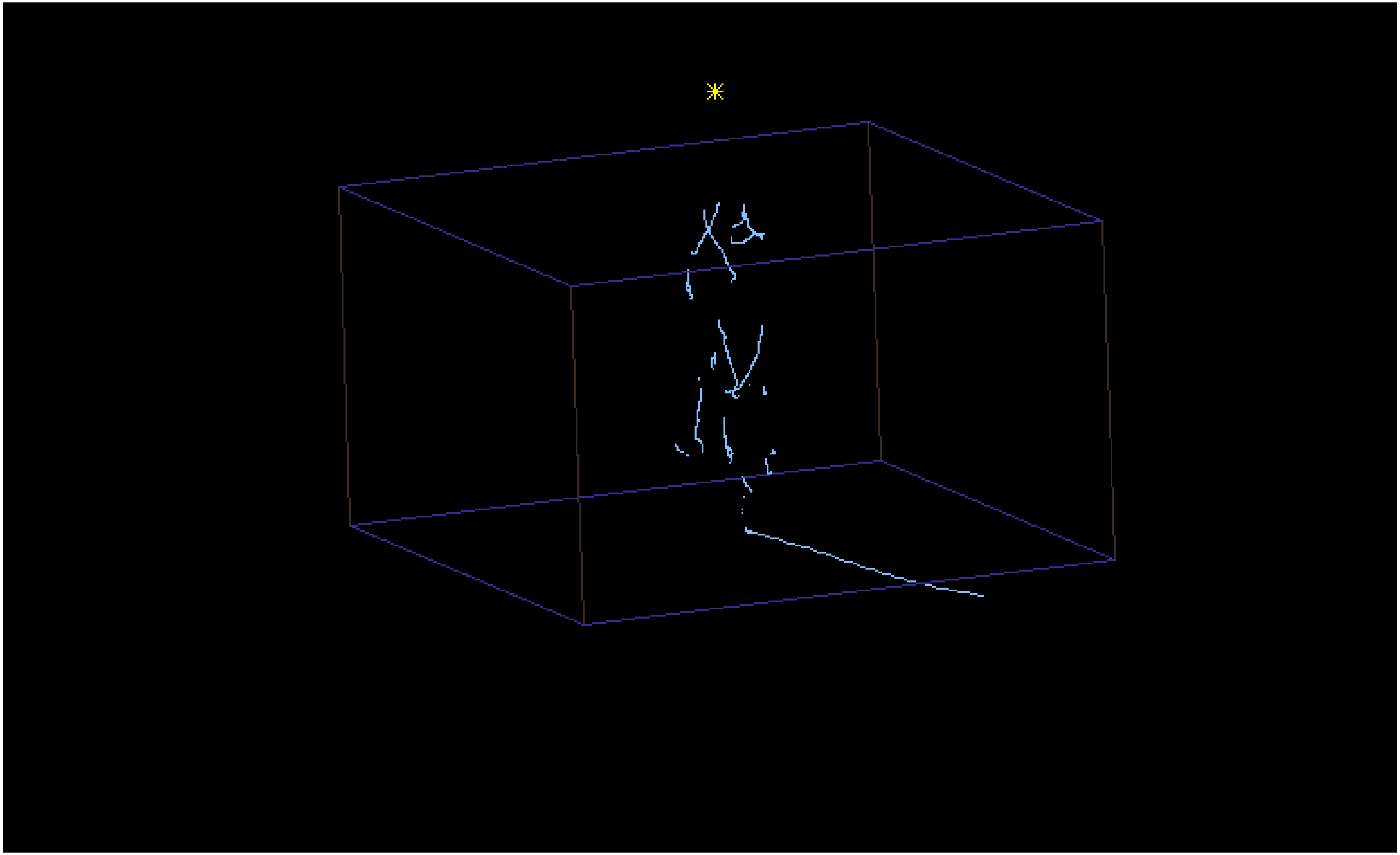
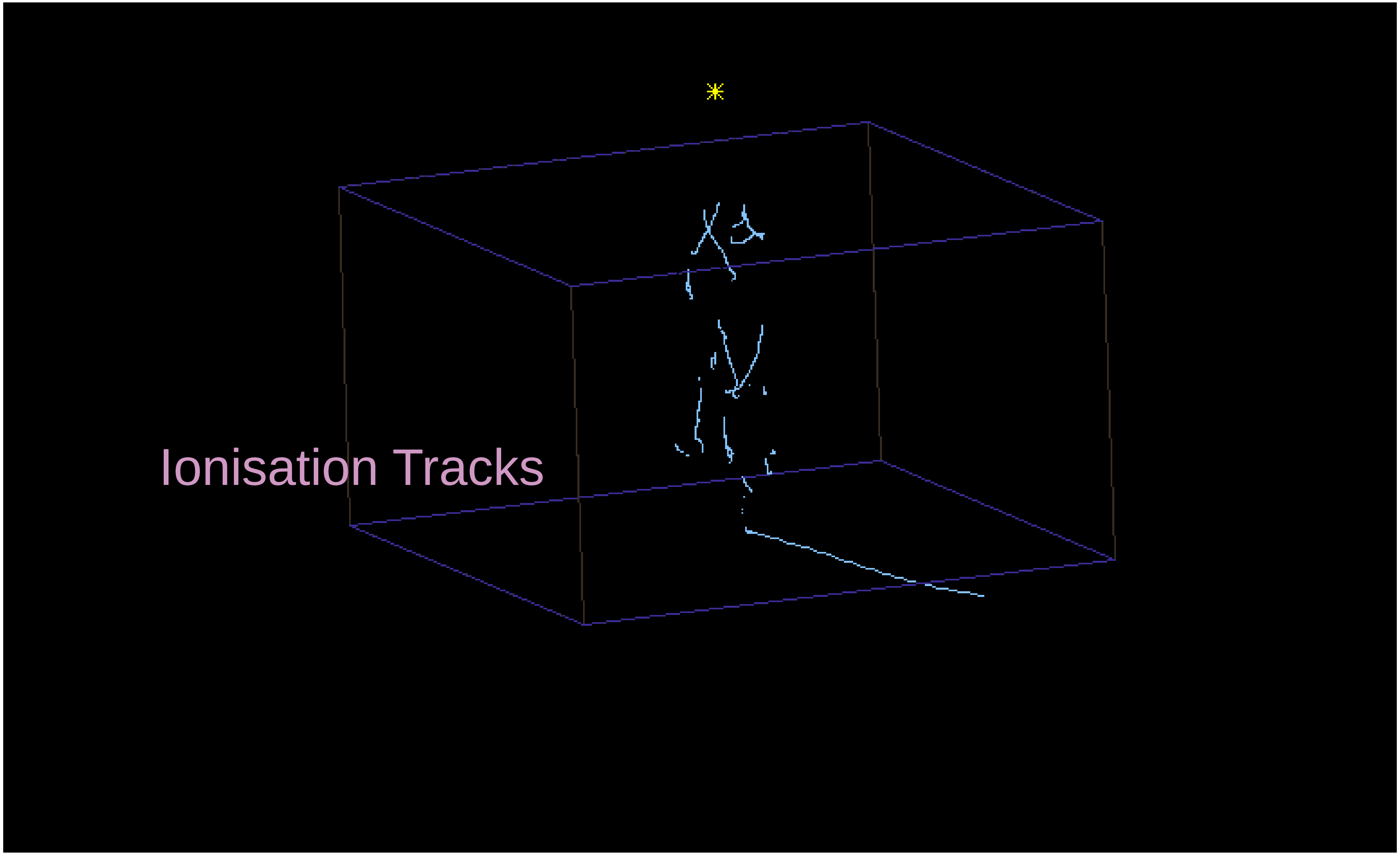
Photon interaction with matter (water)



Photon interaction with matter (water)

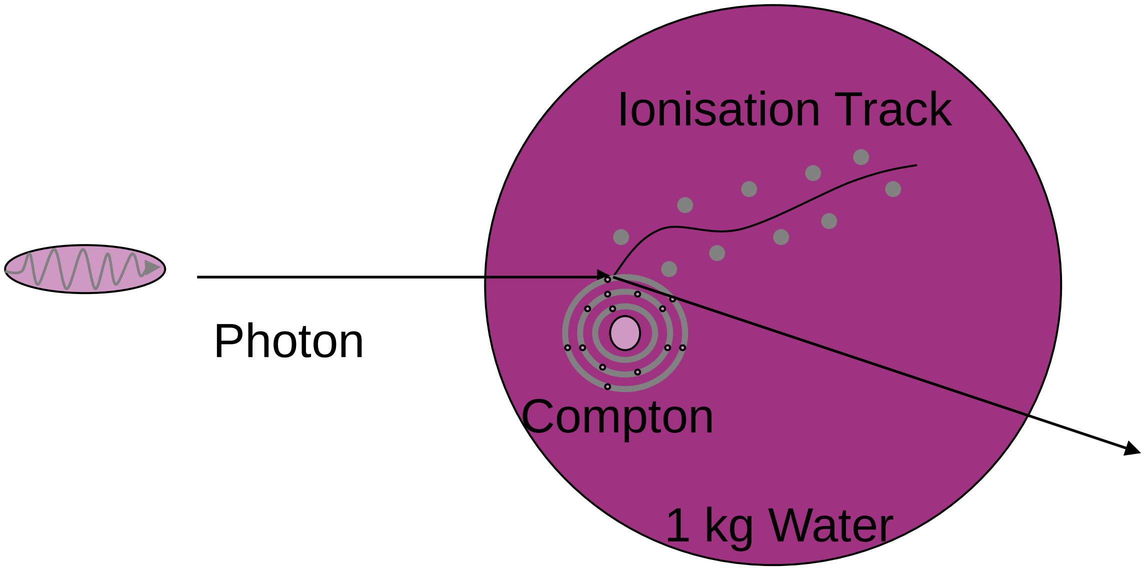


Photon interaction with matter (water)



Absorbed Dose – Gray [Gy]

Deposited Energy per Unit Mass

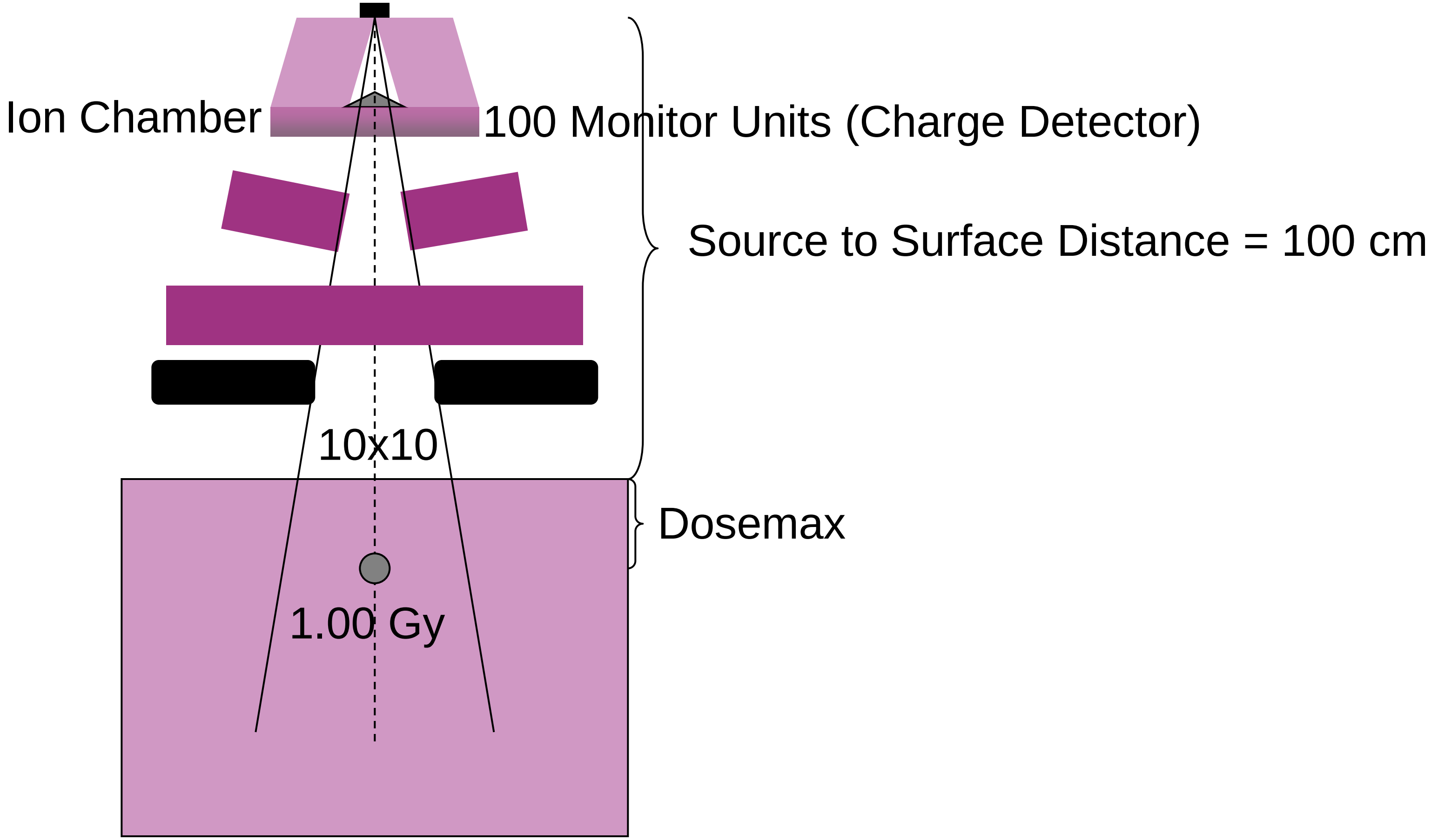


The SI unit – Gray [Gy]

$$Joule/kg$$

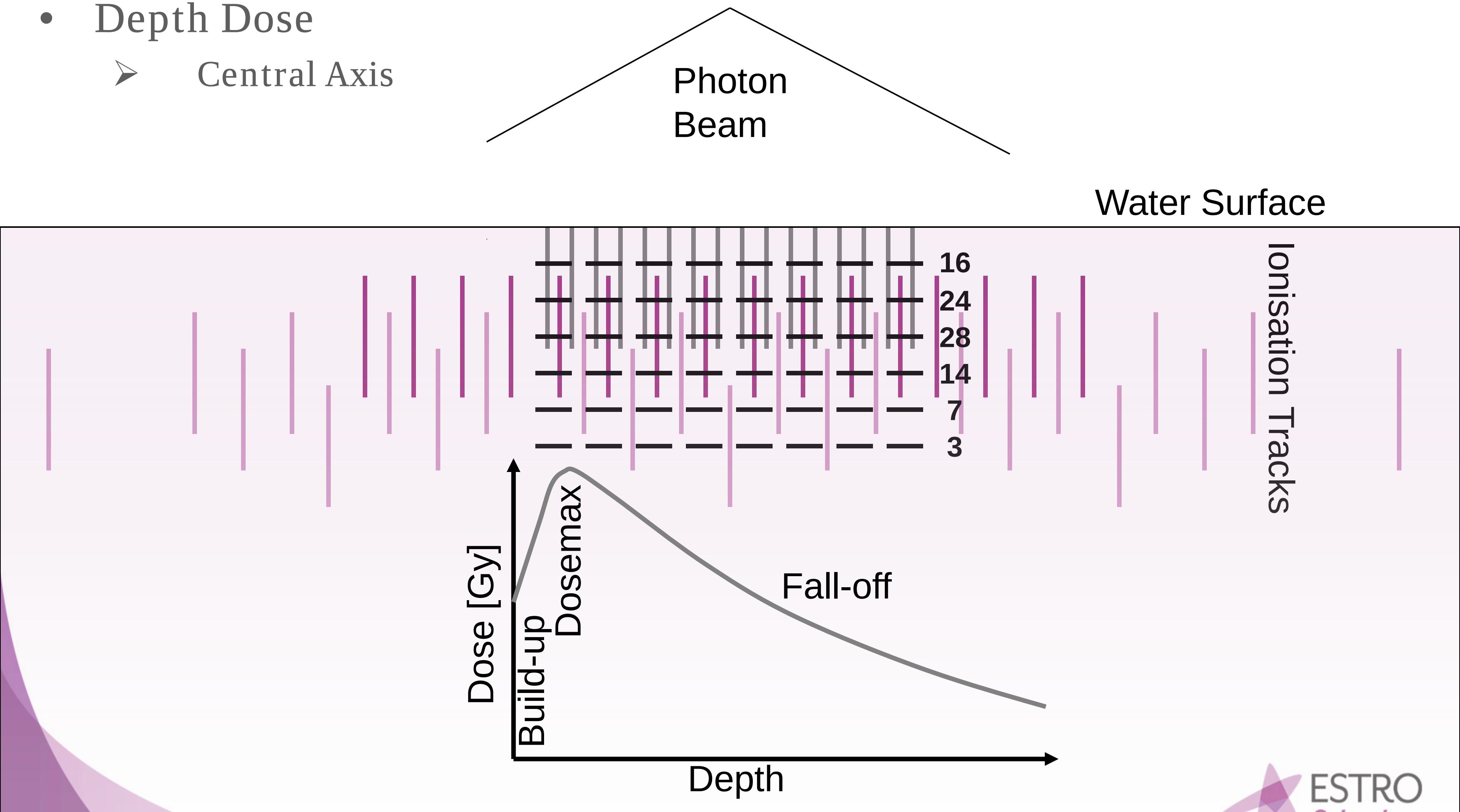
– 1 Gy – 1 Joule per kilogram

Absolute Dose - Linac

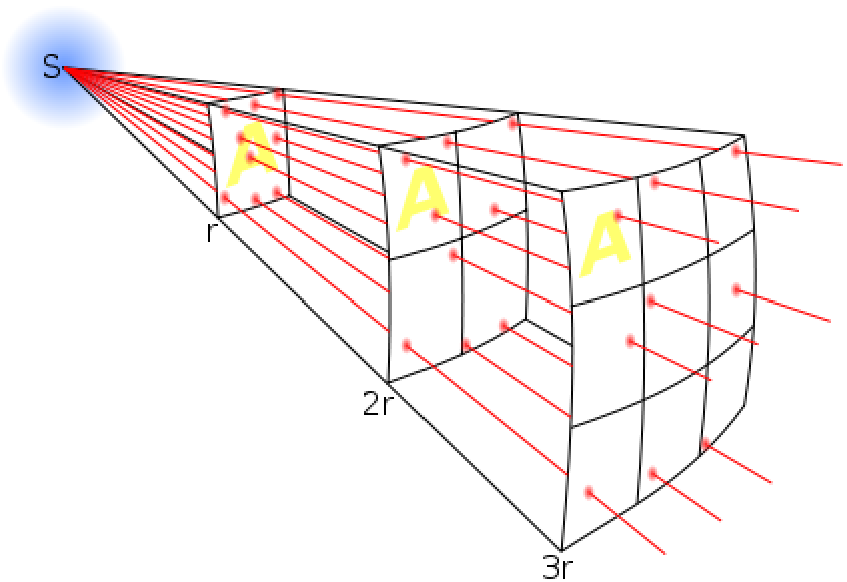


Dose distribution in water (depth dose)

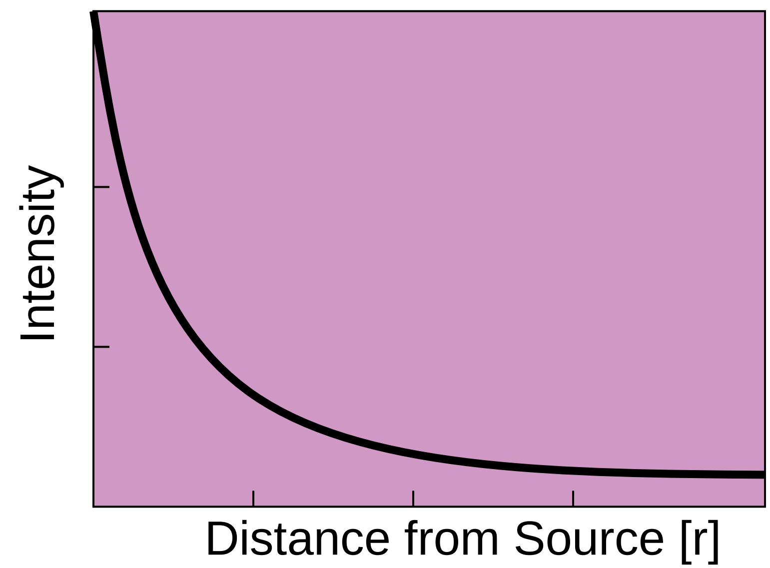
- Depth Dose
  - Central Axis



Photon Intensity Attenuation
- Inverse Square Law



$$Intensity \propto \frac{1}{r^2}$$

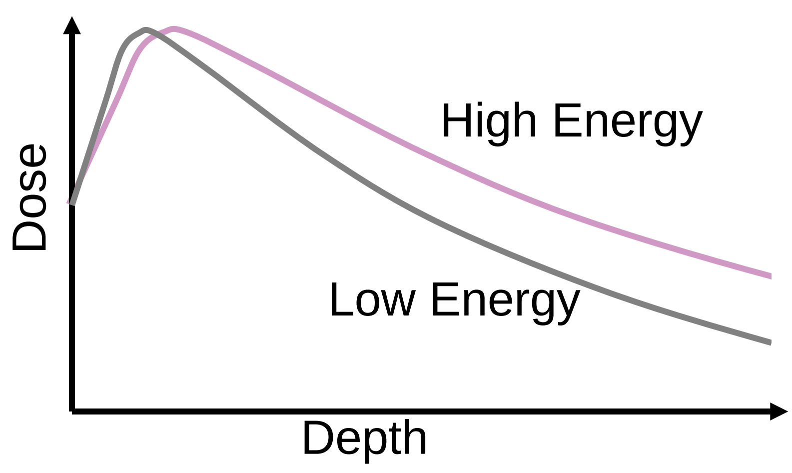


Depth dose (different engergy)

Higher energy

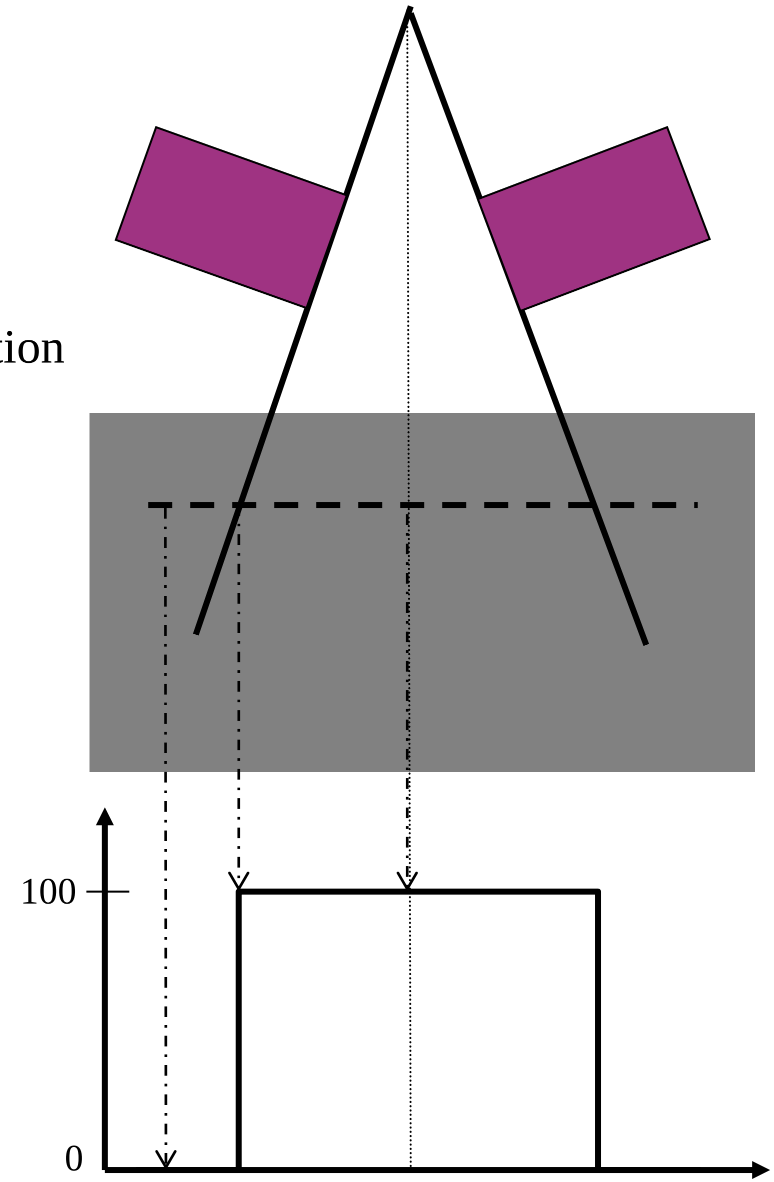
- Longer Ionisation Tracks
  - Deeper Dosemax
- Higher Penetrating Power
  - Less Fall-off

TREATMENT PLANNING: TOOLS AND GENERAL PRINCIPLES PART 1 (LATER TODAY)



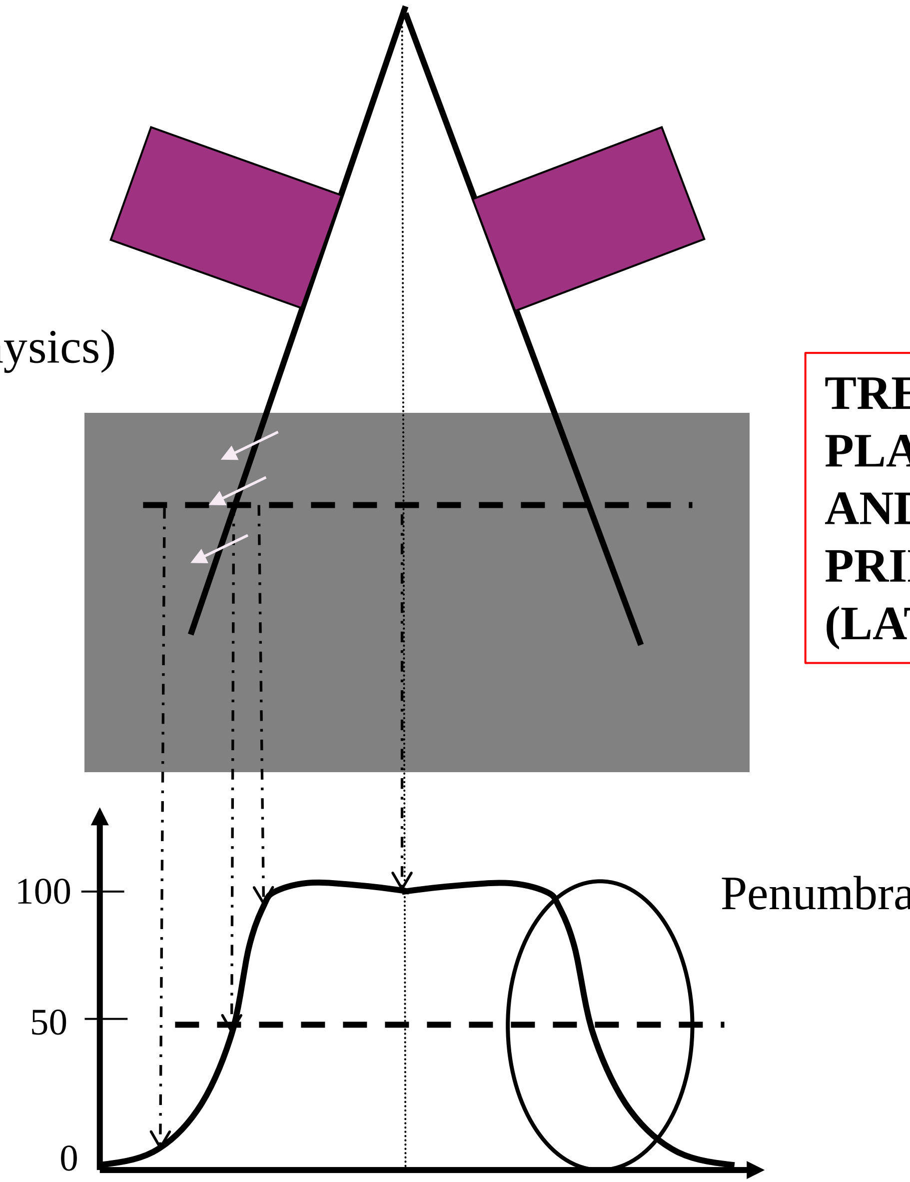
Dose Distribution in Water (profiles)

Ideal situation



Dose Distribution in Water (profiles)

Reality (Physics)



TREATMENT PLANNING: TOOLS AND GENERAL PRINCIPLES PART 1 (LATER TODAY)

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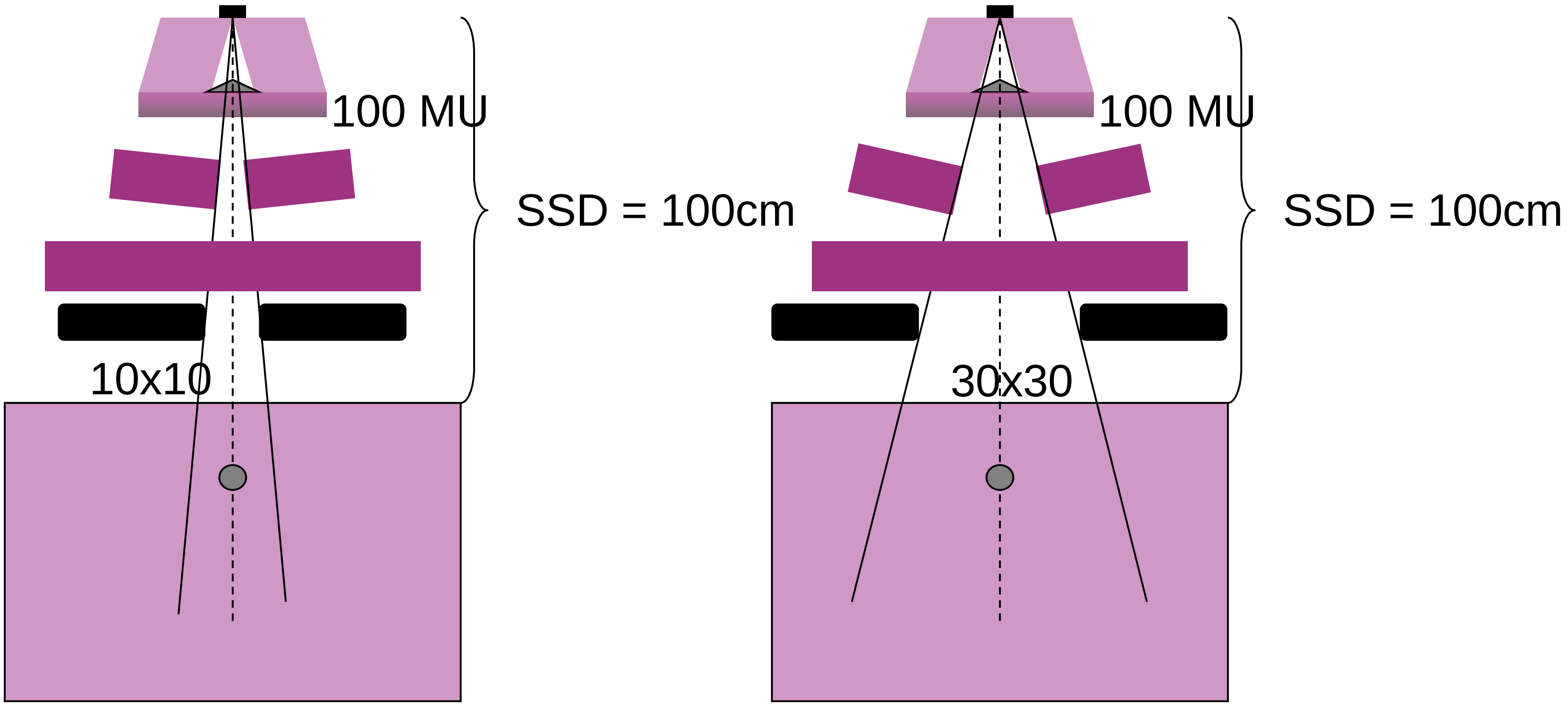
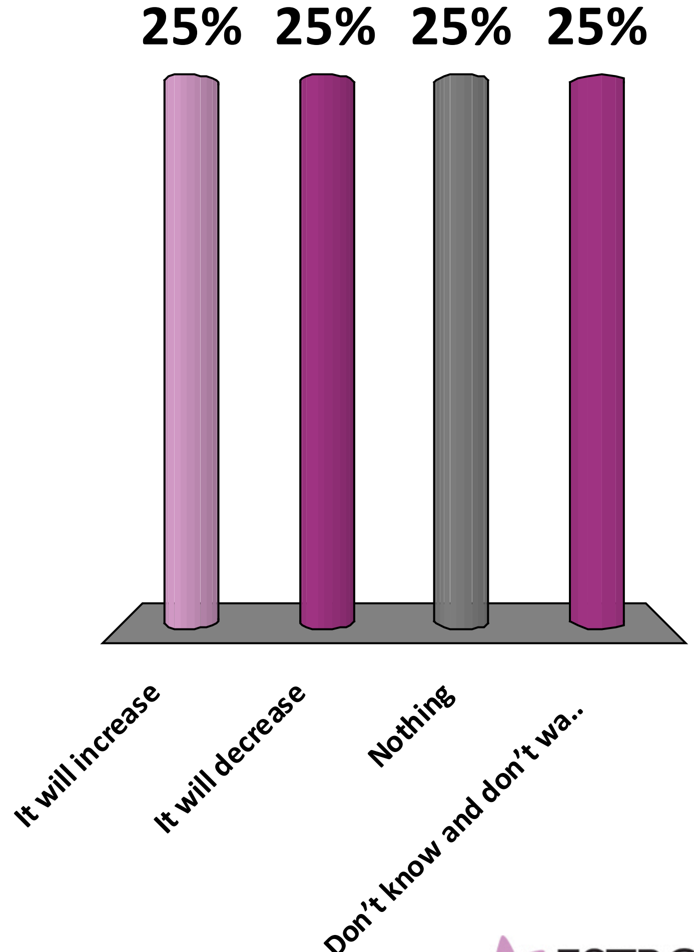
Dose dependence (field size)

- Output Factor



For the given situation what will happen with the dose?

A. It will increase
B. It will decrease
C. Nothing
D. Don’t know and don’t want to guess☺



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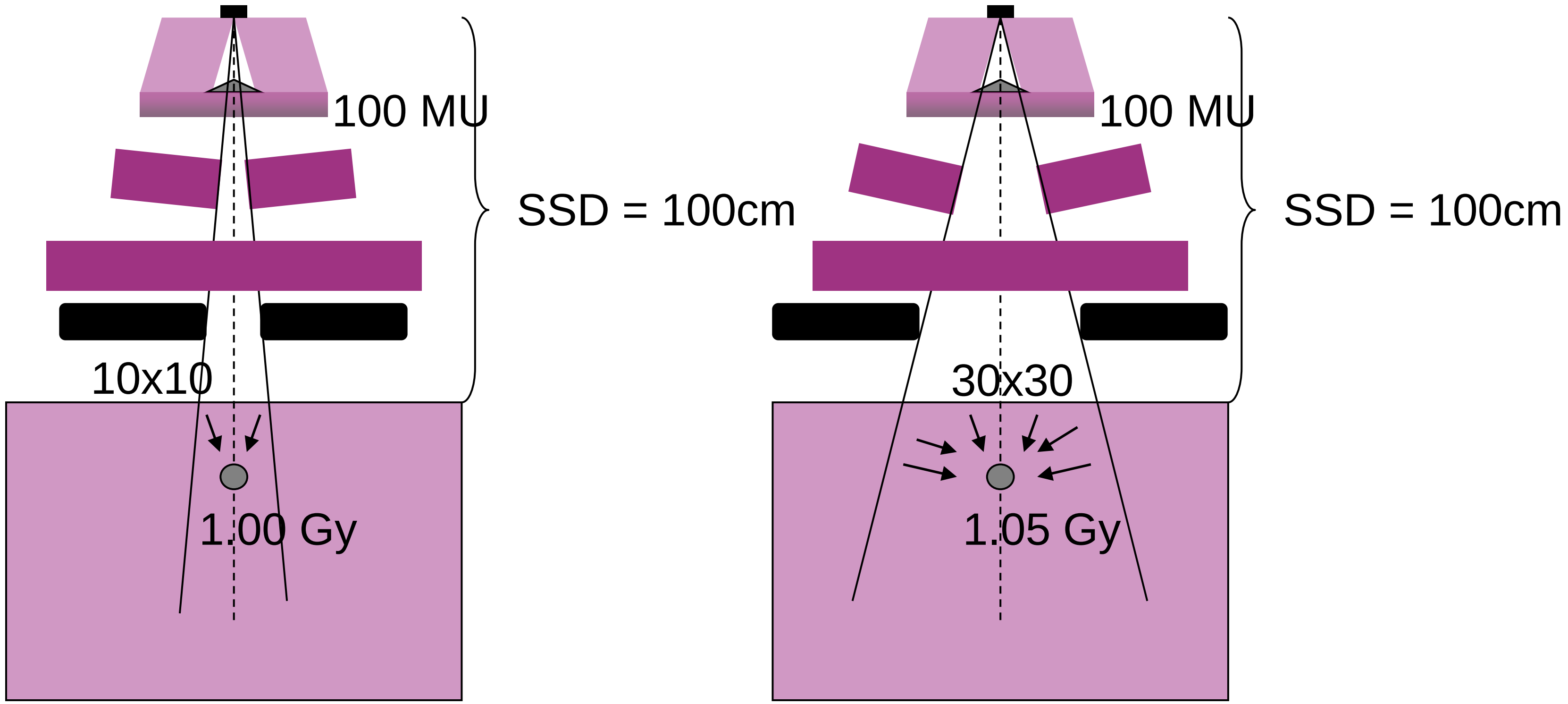
Dose dependence (field size)

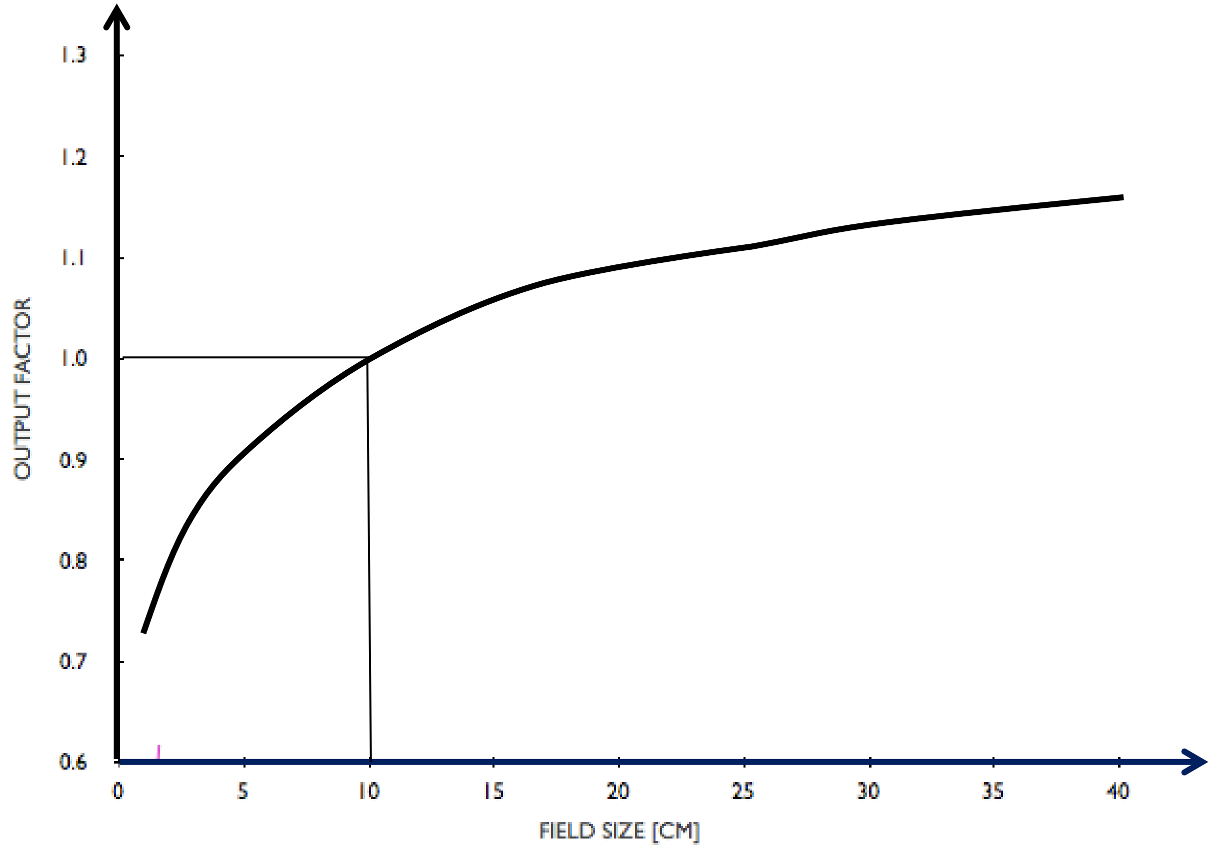
- Output Factor



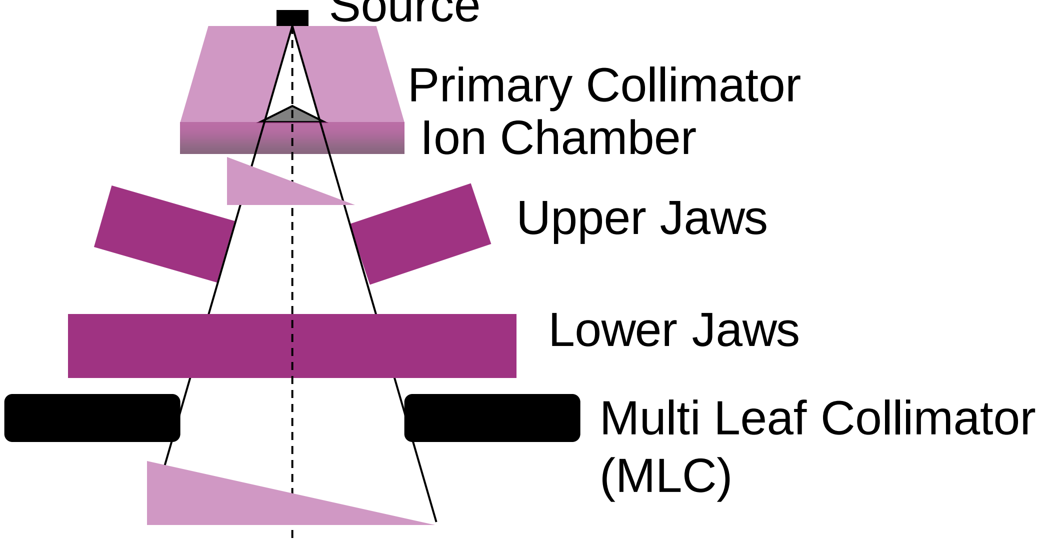
- 30x30 – 1.00 Gy (Dmax) → 95 MU

Dose dependence (field size)

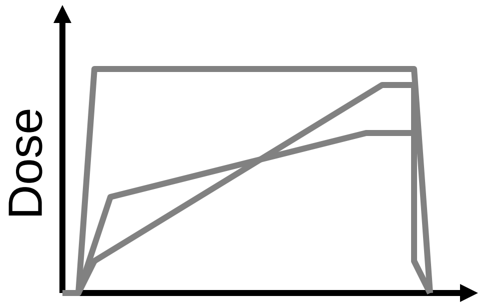
Output factors

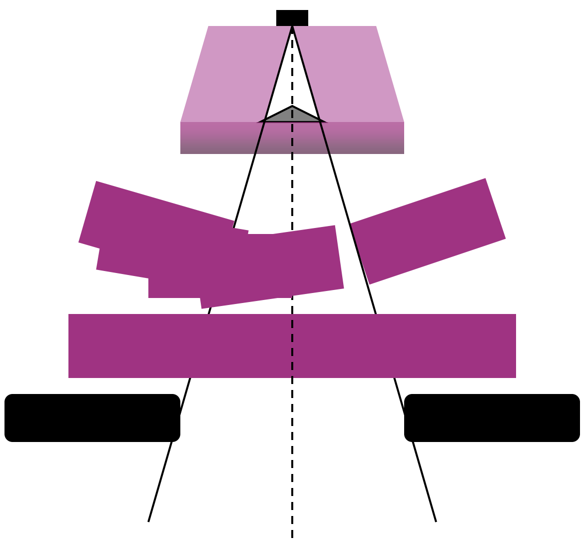


Beam Modifications - Wedges

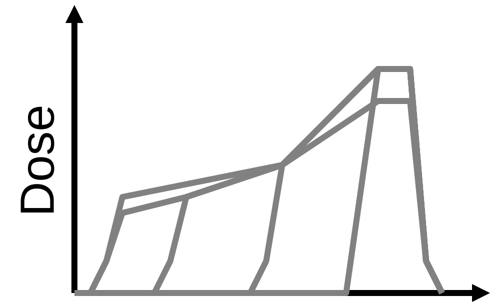


Physical Hard Wegde





Virtuel/Dynamic Wegde



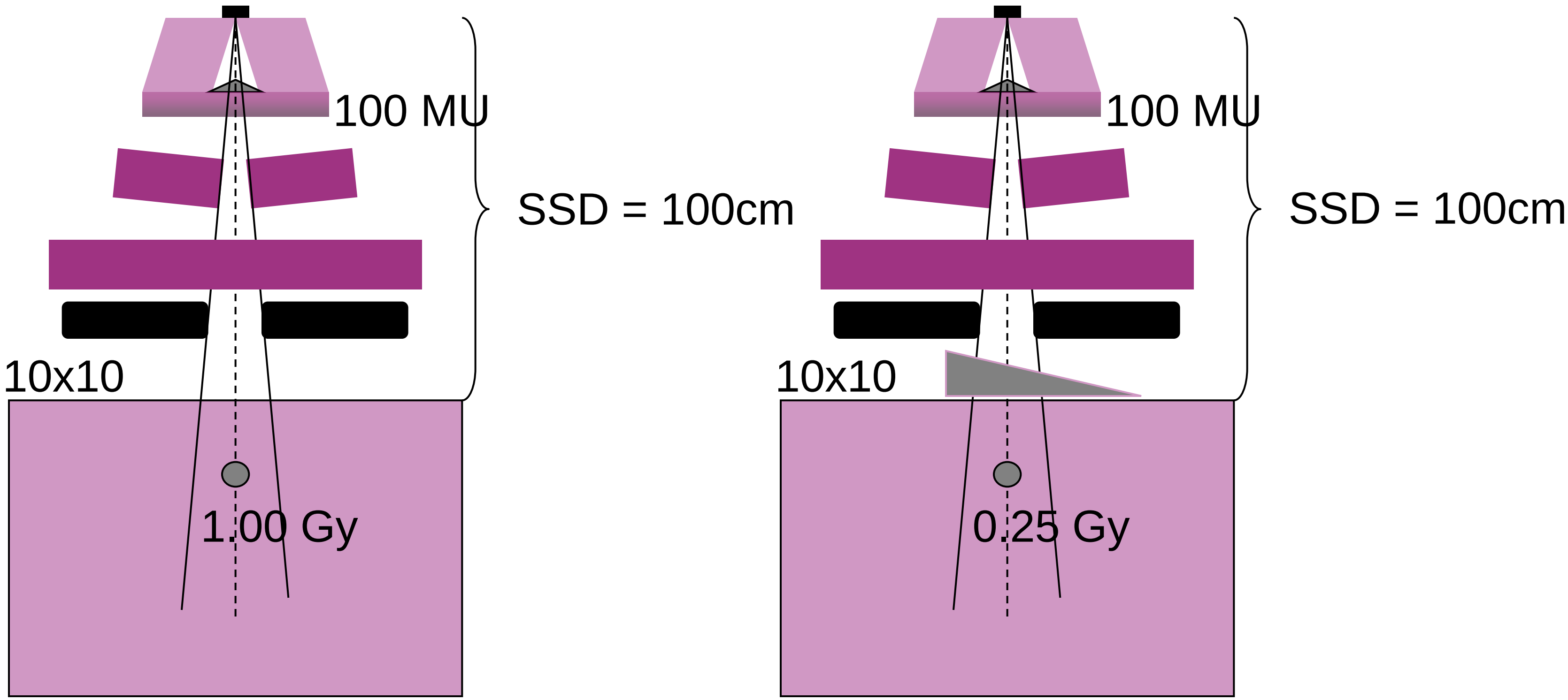
Wedge Angle

Adjust Jaw Speed
and Dose Rate

Beam Modifications – Wegdes

TREATMENT PLANNING: TOOLS AND GENERAL PRINCIPLES PART 1 (LATER TODAY)

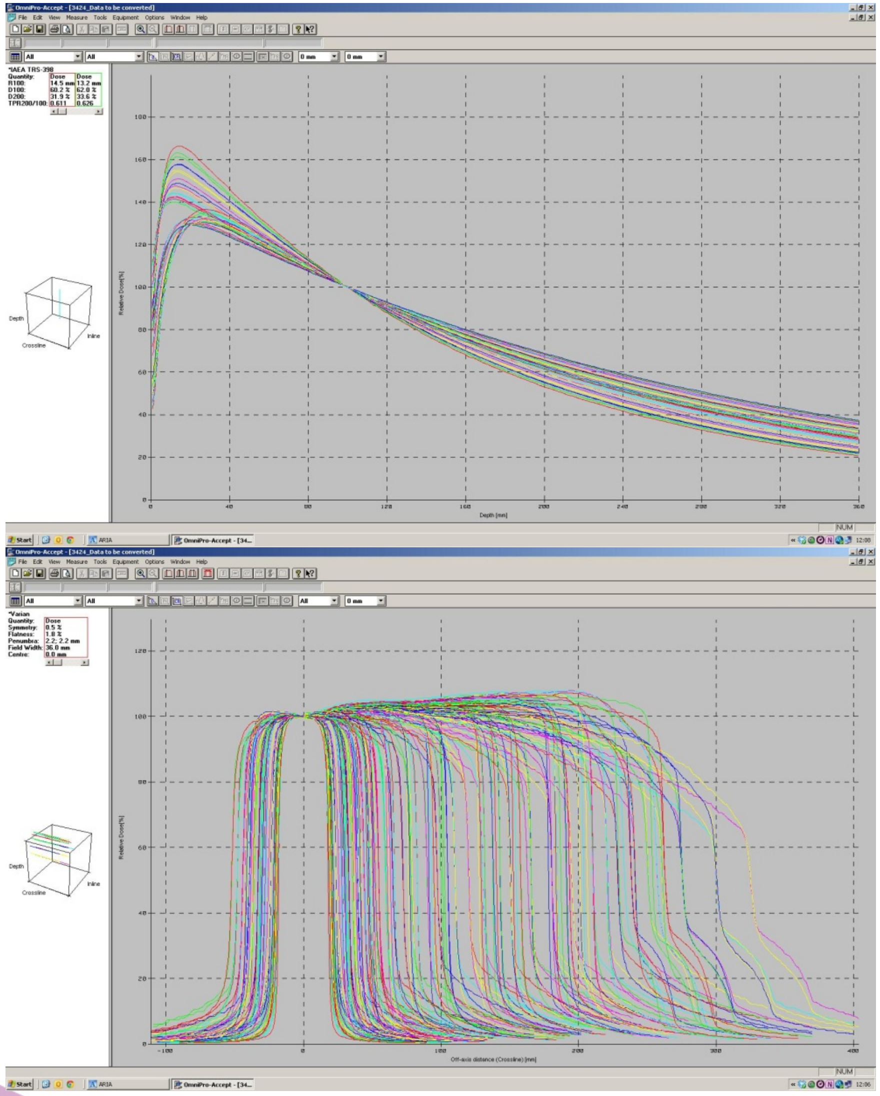
- Wegde Factor



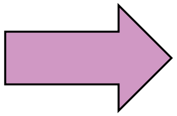
- Wedge - 10x10 1.00 Gy (Dmax) → 400 MU

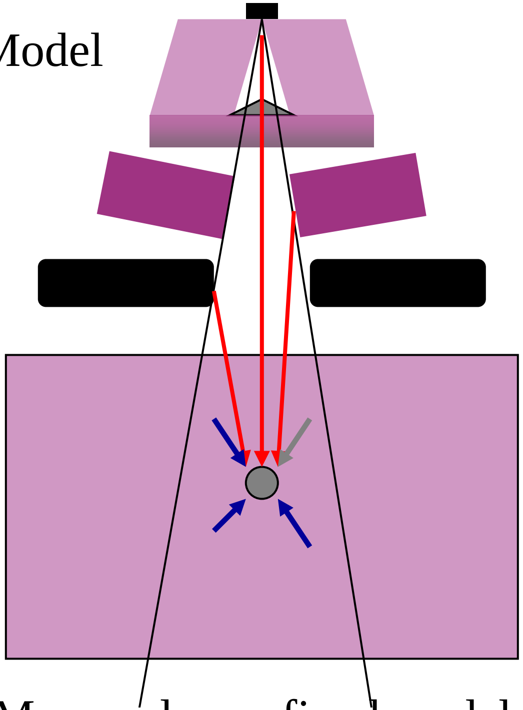
Dose Calculation Models

Input Measurements

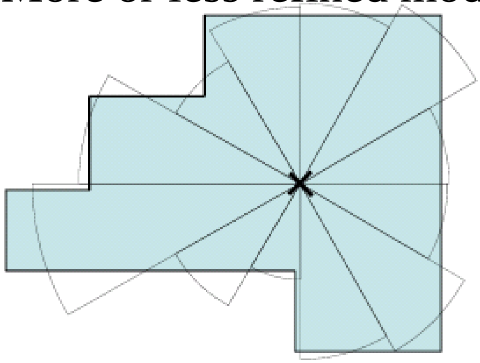


Model





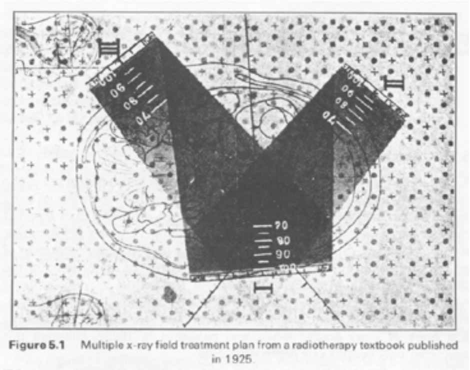
More or less refined model



Dose Calculation Models

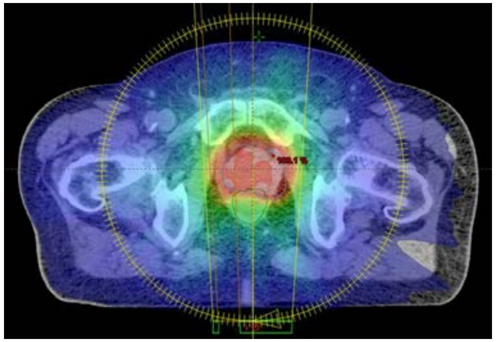
- Requirements:
  - General
  - Flexible
  - Accurate
  - fast
- => Changes in scattering due to e.g. beam shape, intensity, patient geometry, inhomogeneity should be incorporated to easy compute the "correct" 3D dose

Look-up tables



1925

Models



2010

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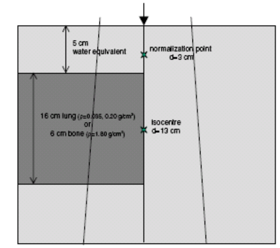
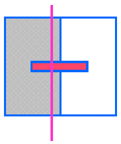
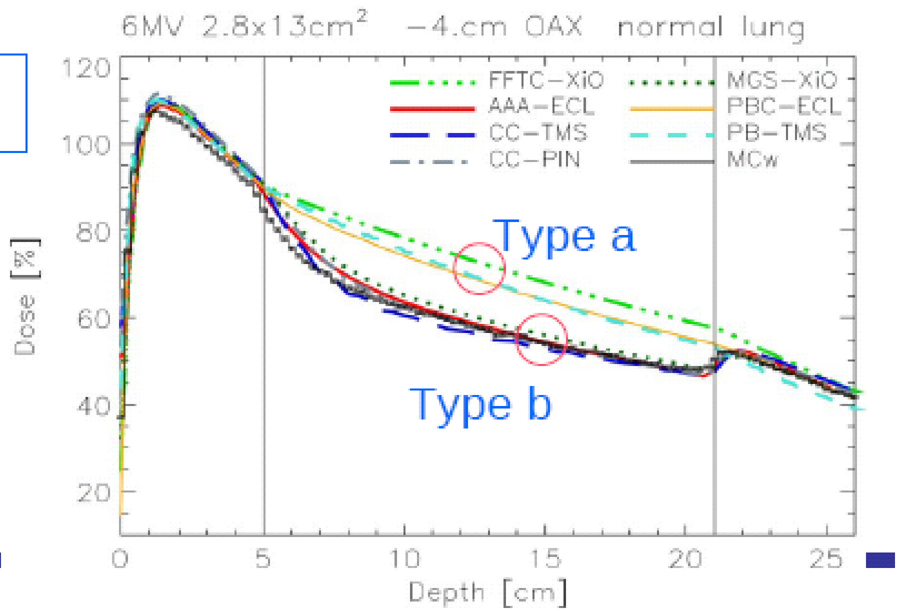
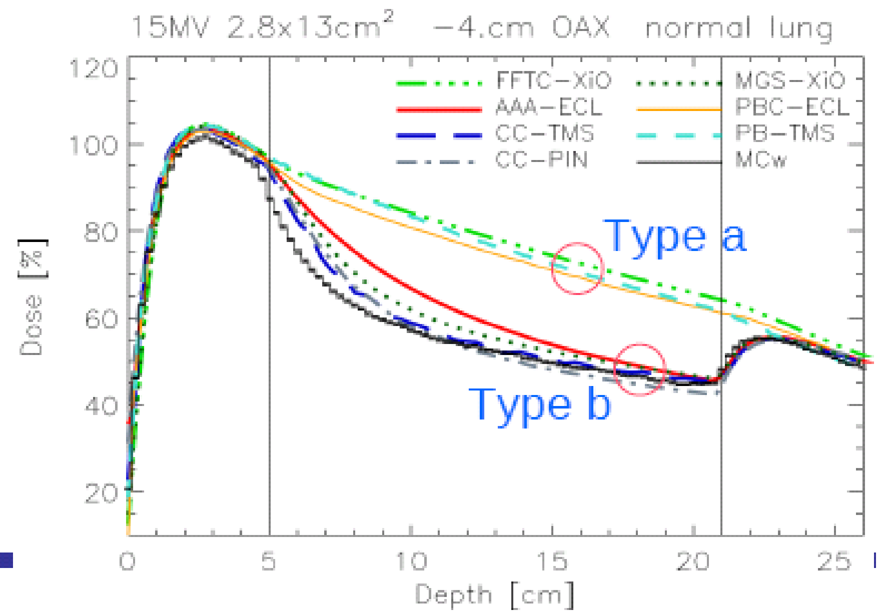
Dose Calculation Accuracy



Different dose calculation algorithms







Fogliata *et al.* Phys. Med. Biol. 52: 1363-1385 (2007)

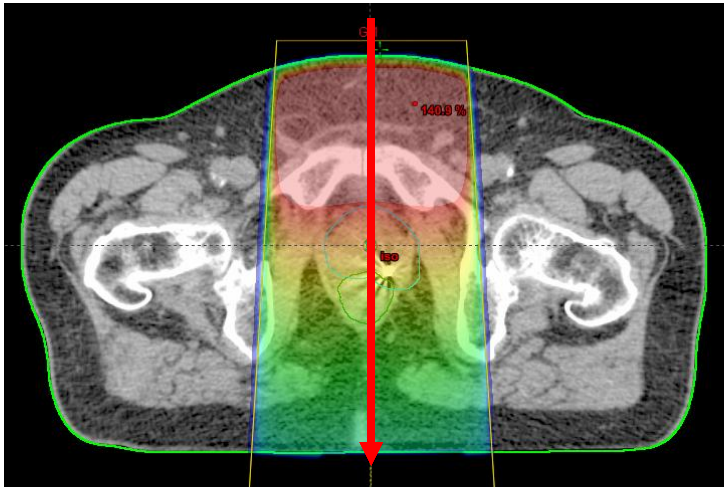
Dose calculation models

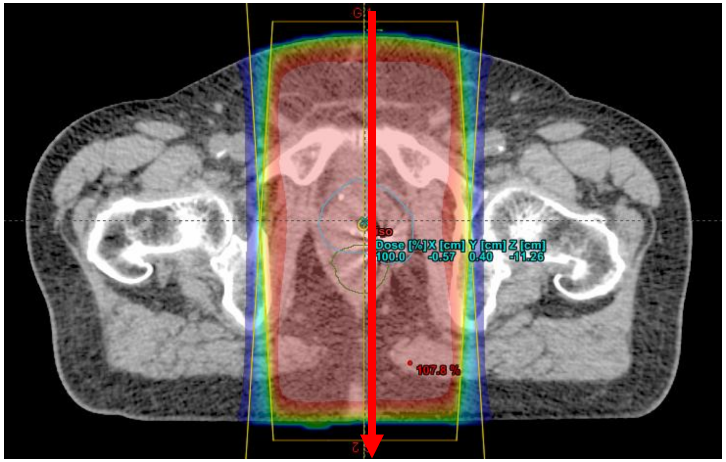
THIS COURSE:
TREATMENT PLANNING: TOOLS AND GENERAL PRINCIPLES PART 2 (TUESDAY)

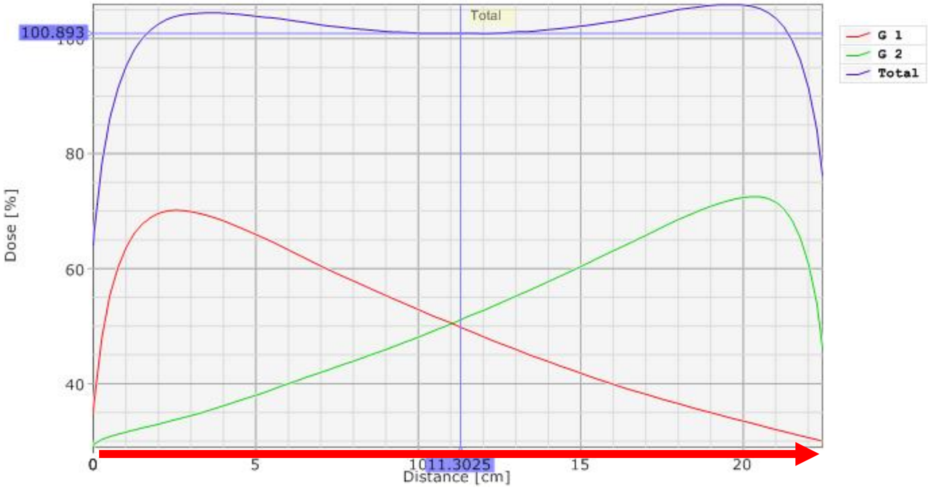
ESTRO *LIVE* COURSE:
DOSE MODELLING AND VERIFICATION FOR EXTERNAL BEAM RADIOTHERAPY

Treatment planning

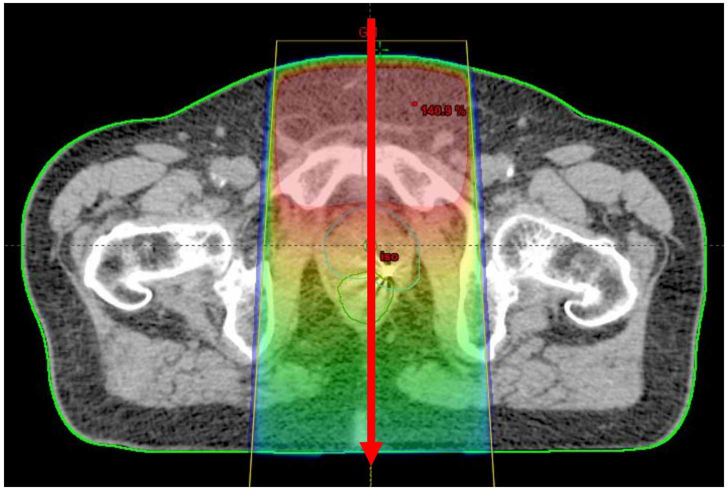
Treatment planning

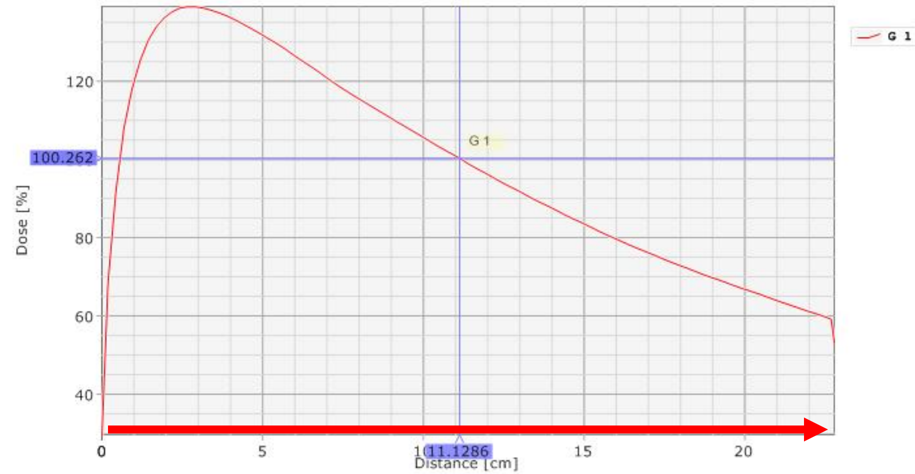


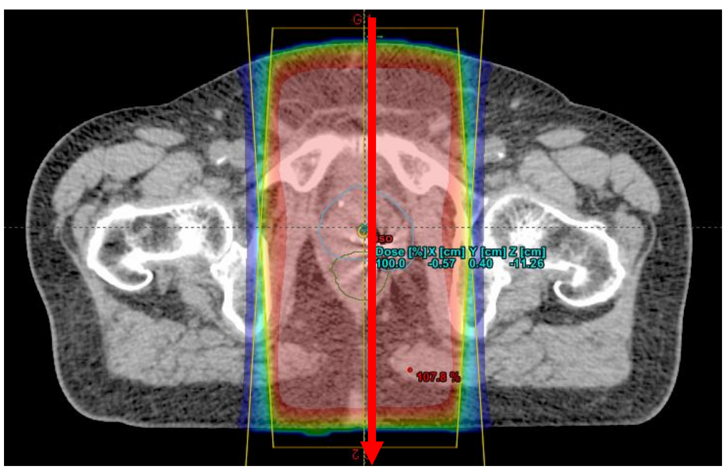


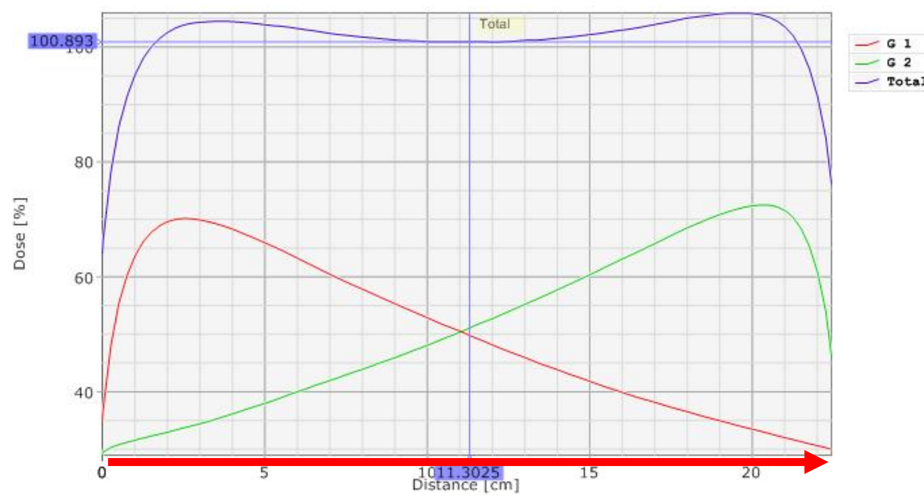


Treatment planning

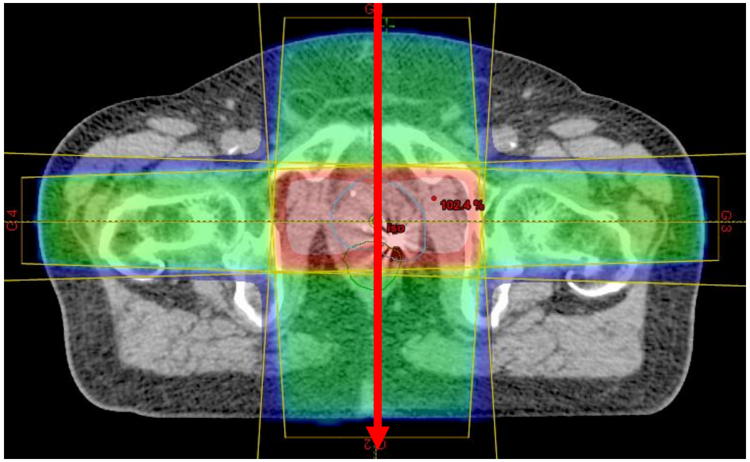


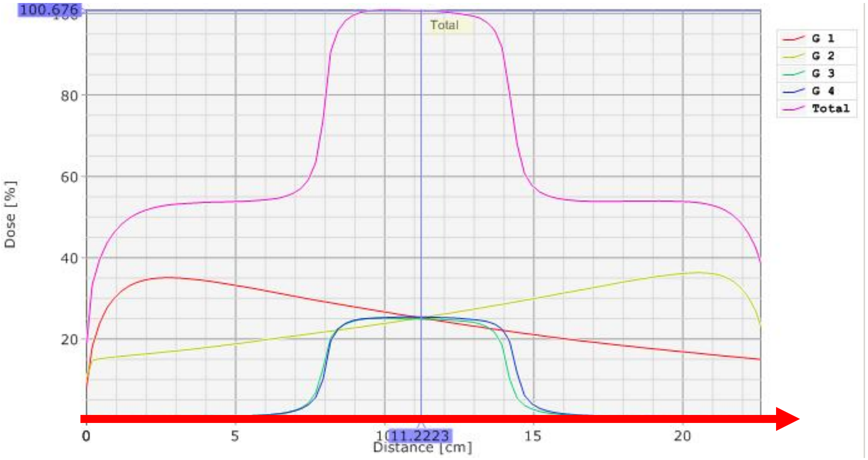


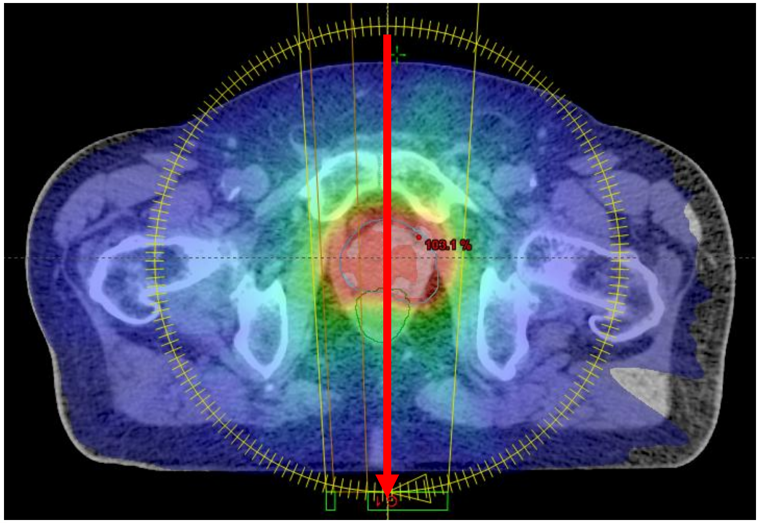


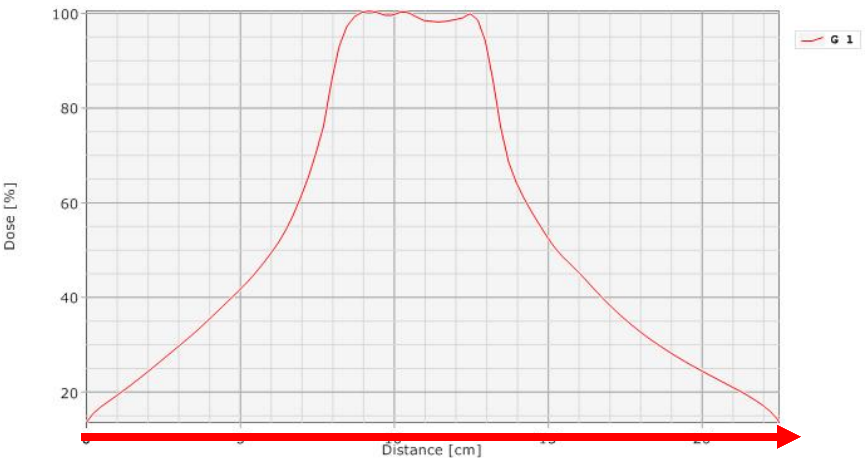


Treatment planning









2D vs. 3D Treatment Planning

2D planning:

- Single patient contour
- Volumes and dose drawn (calculated) on a single transverse contour through central axis.
- Simulation (Radiographs) to determine SSD, field size (and depth of volumes)

2D planning and 3D calculation:

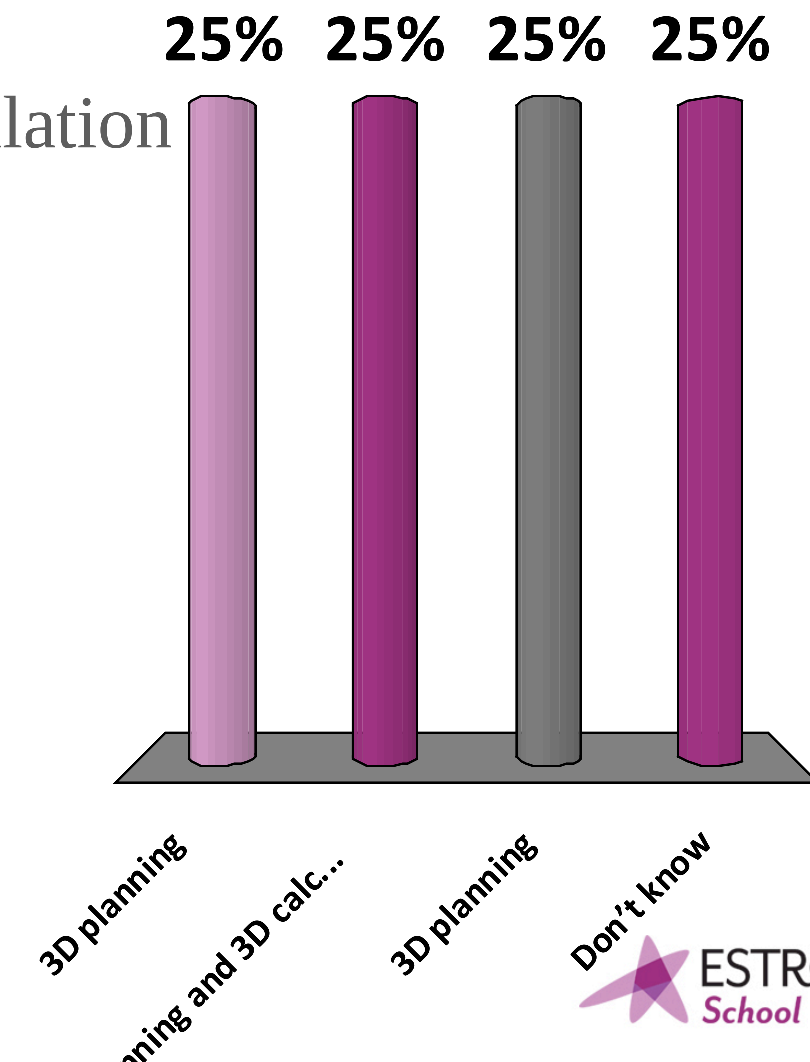
- Patient contour in 3D
- Dose calculated in 3D (tissue inhomogenity taken into account)

3D planning (3DCRT):

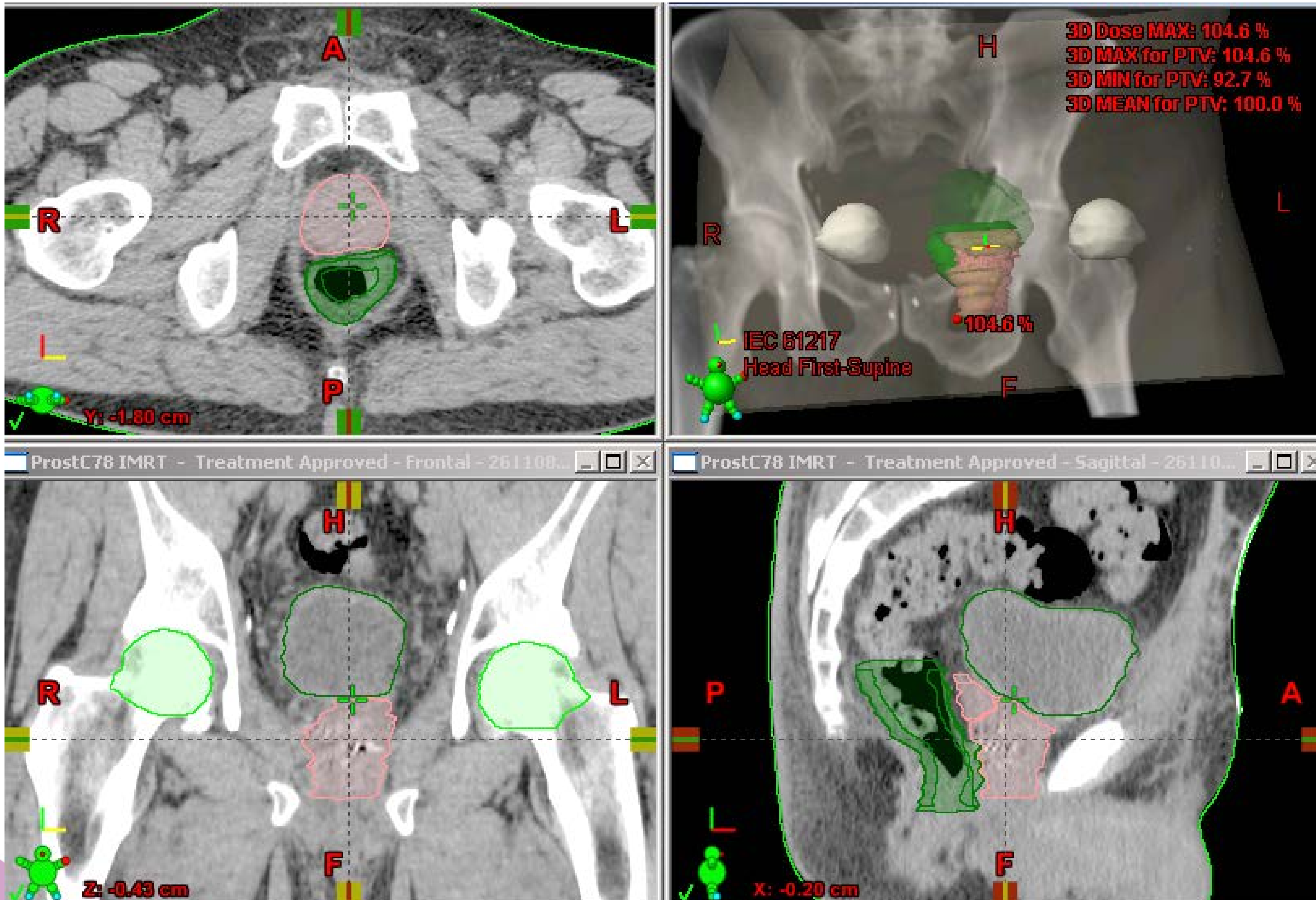
- Delineation of volumes
- Use of dose-volume histogram

How do you plan ”more simple” cases (e.g. palliative and breast) at your department?

A. 3D planning
B. 2D planning and 3D calculation
C. 3D planning
D. Don’t know



Delineation of structures (3D)



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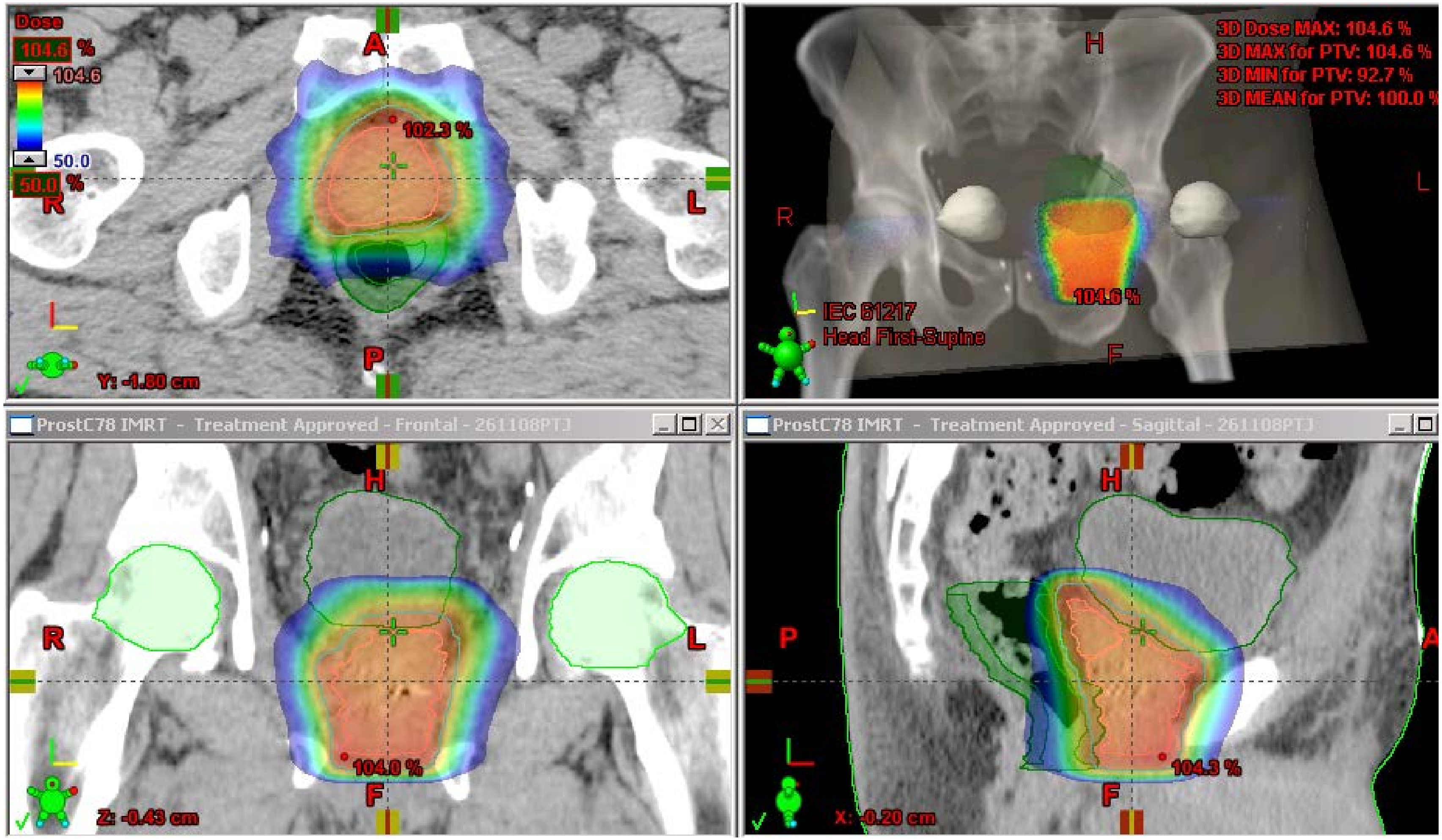
Evaluation of Dose (3D)



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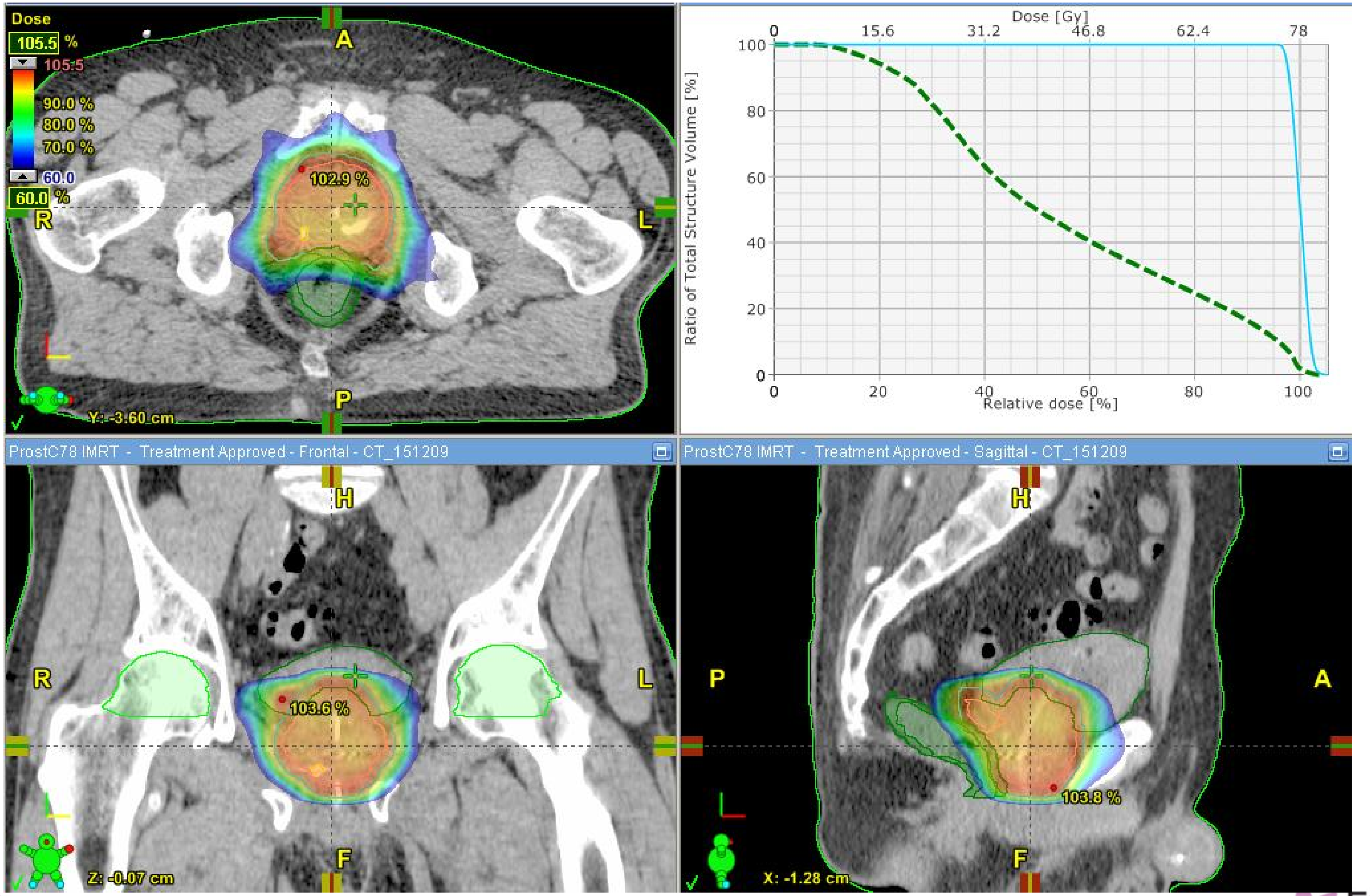
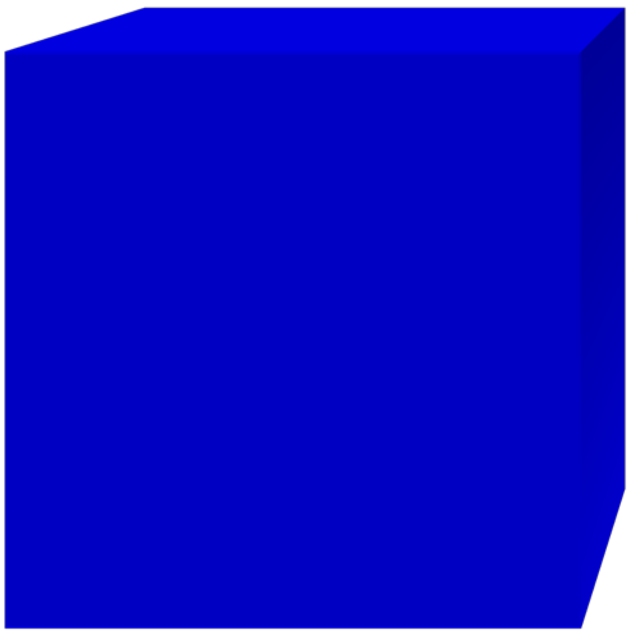
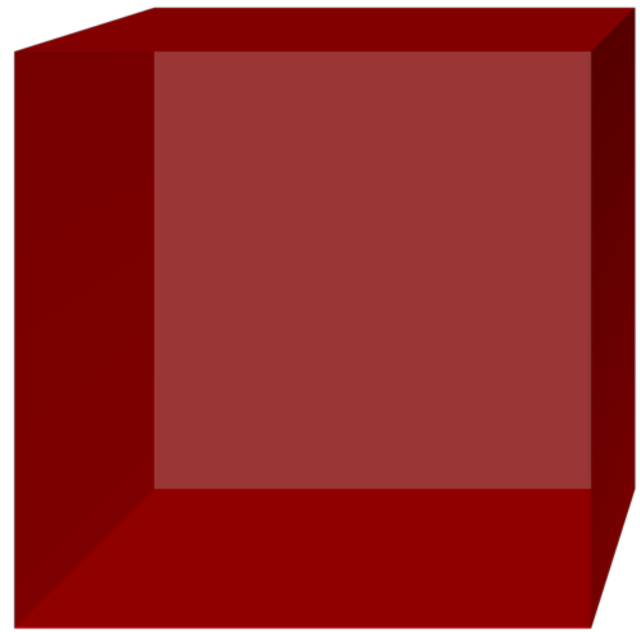
Evaluation of Dose Volume Histograms



Dose Volume Histogram



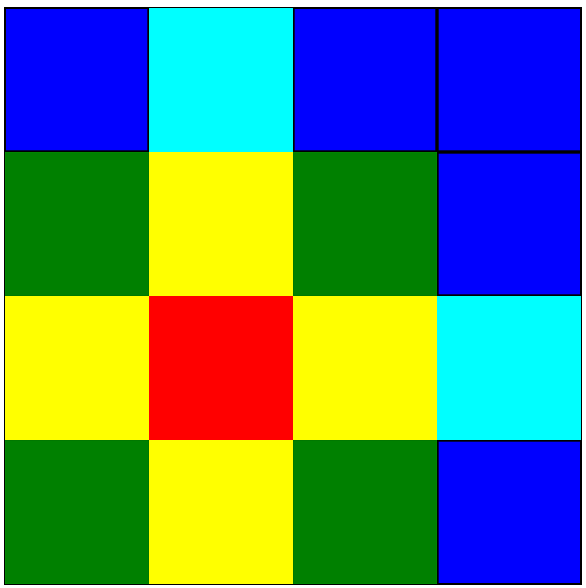
Volume matrix

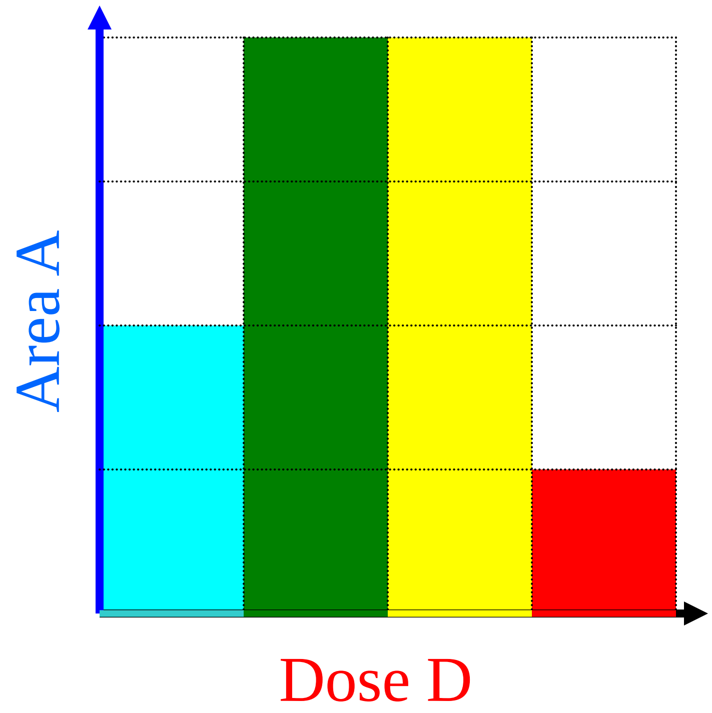


Dose matrix

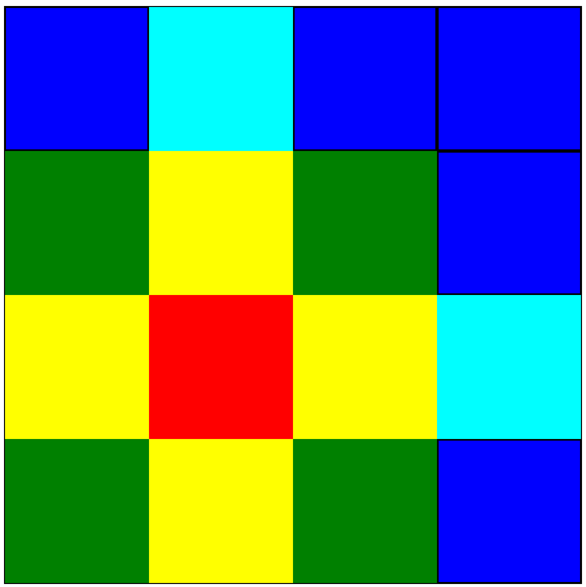
Dose Volume (Area) Histogram

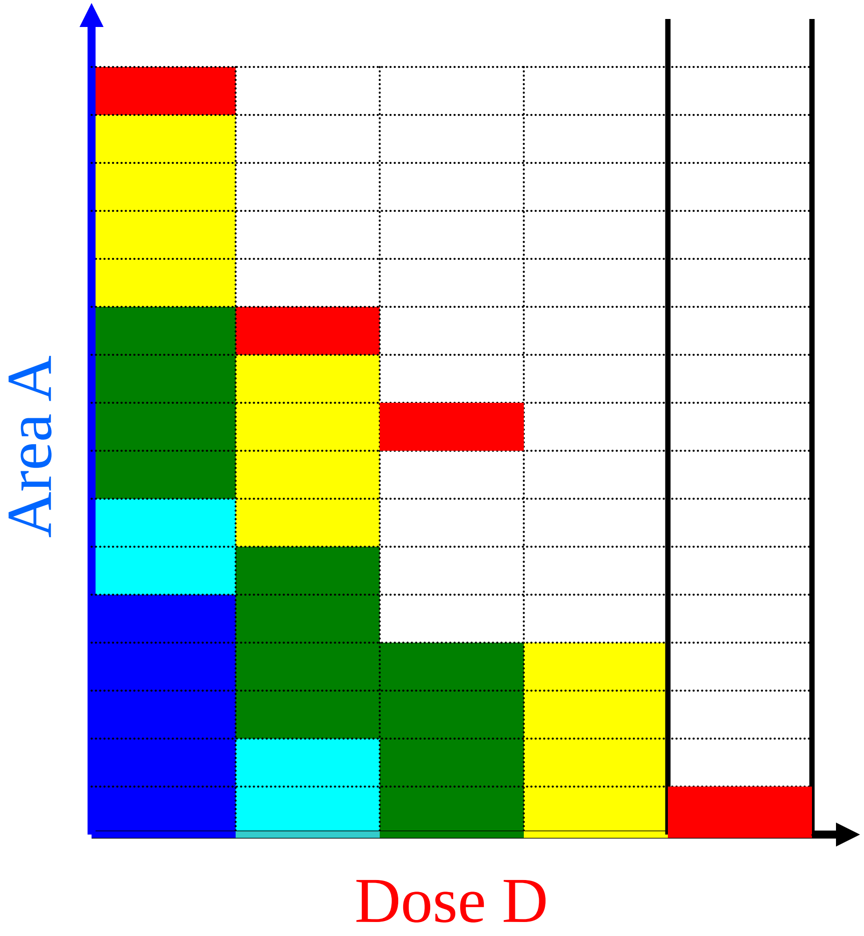
Differential Dose Volume (Area) Histogram





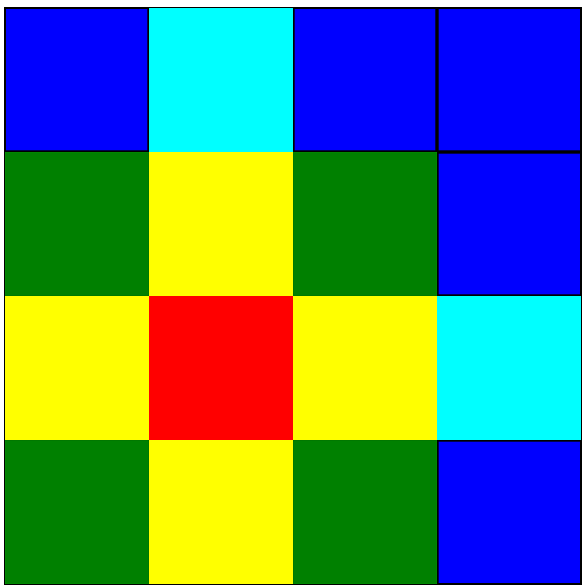
Dose Volume (Area) Histogram

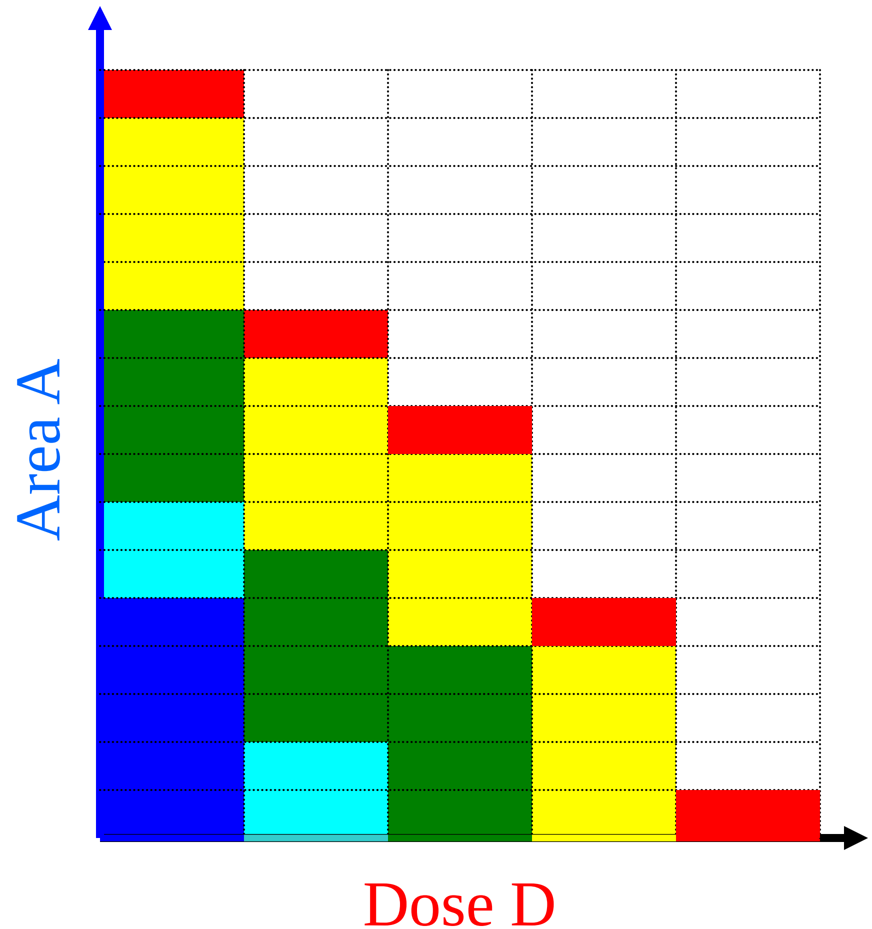




Dose Volume (Area) Histogram

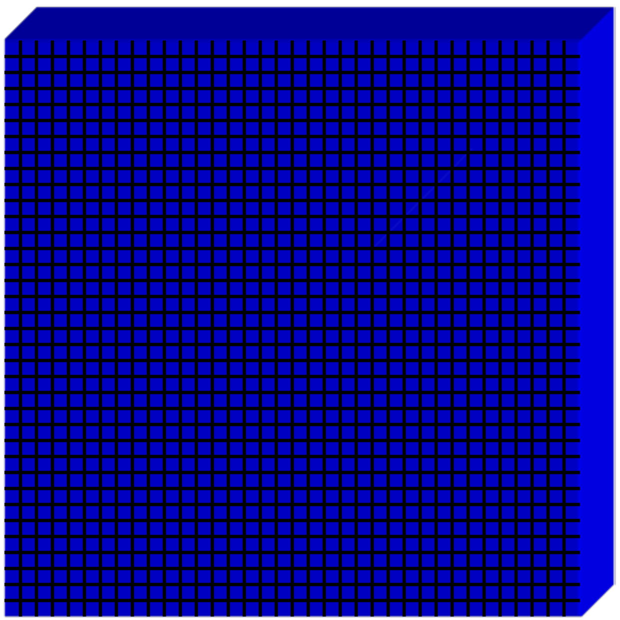
Cumulative DVH

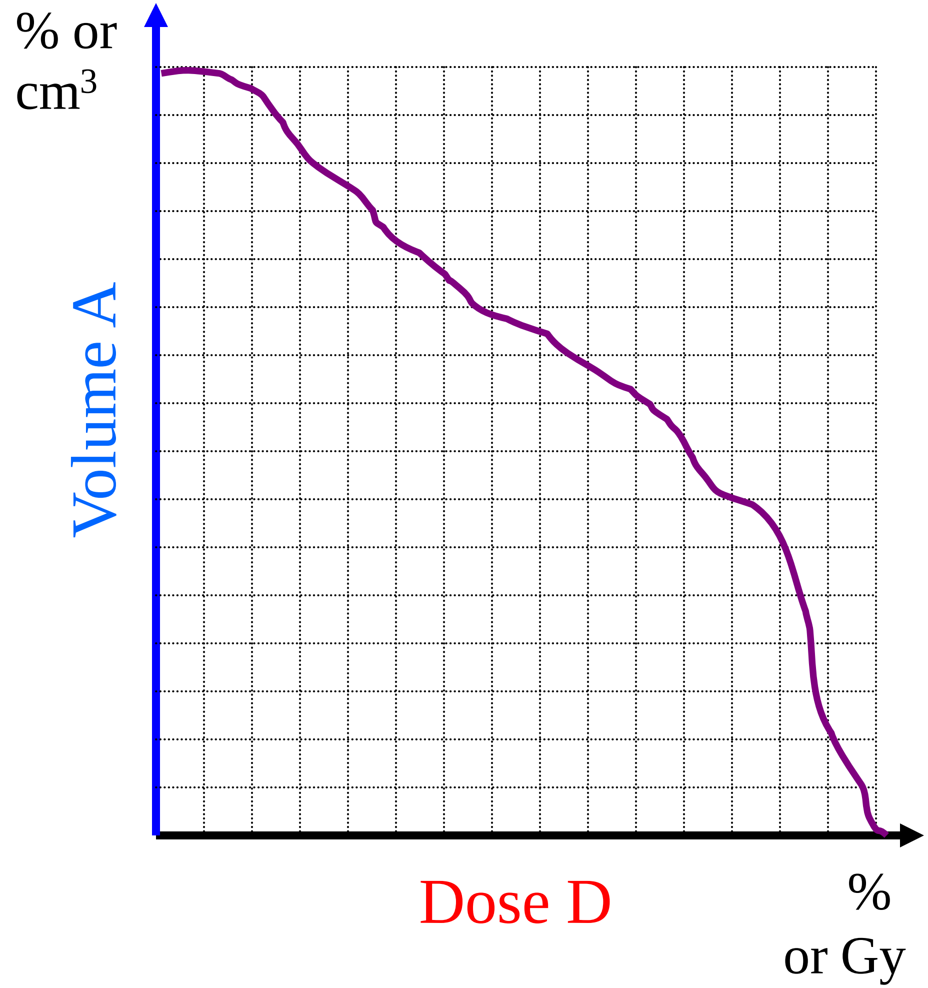




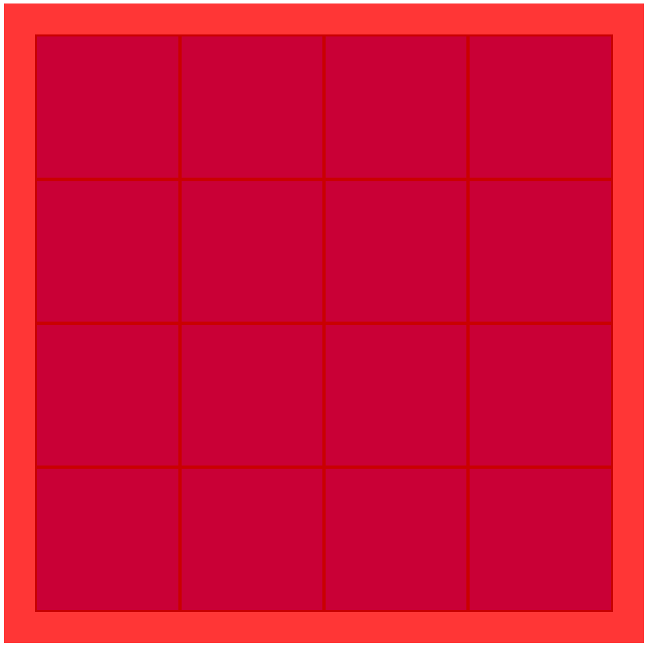
Dose Volume Histogram

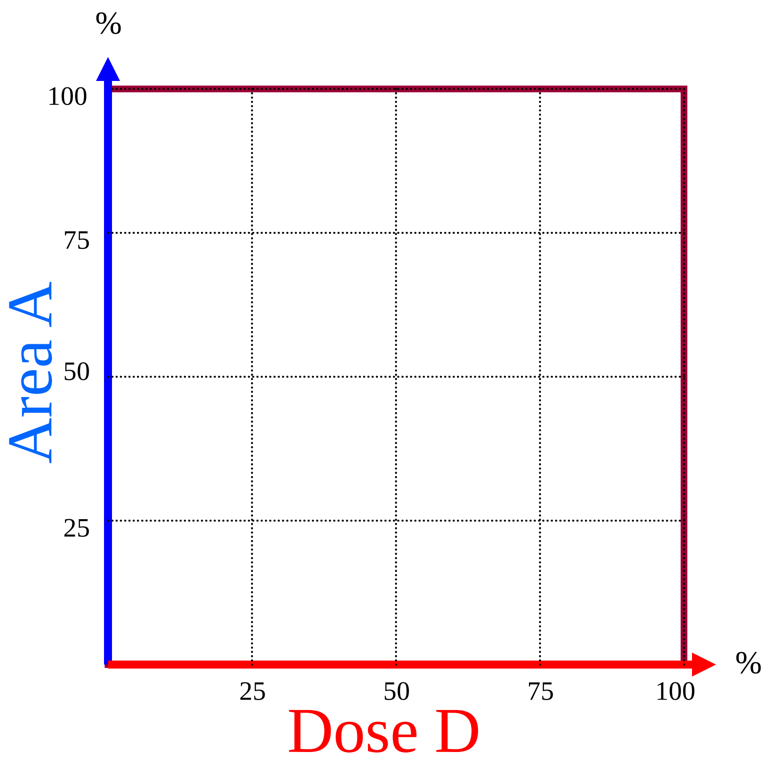
Relative or absolute Volume and Dose





Dose Volume Histogram





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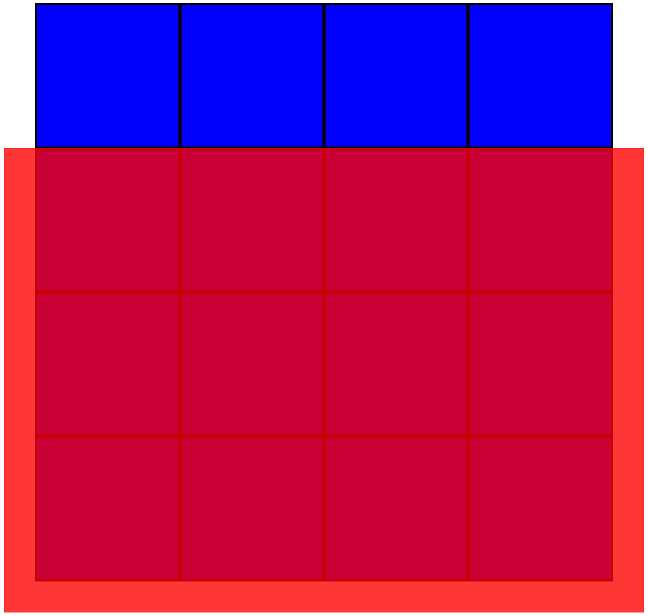
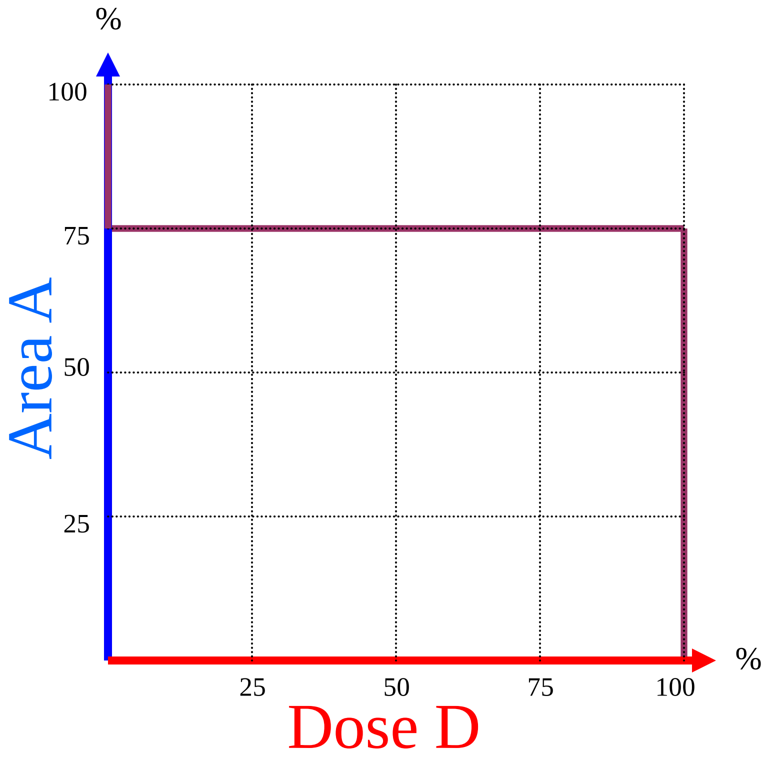
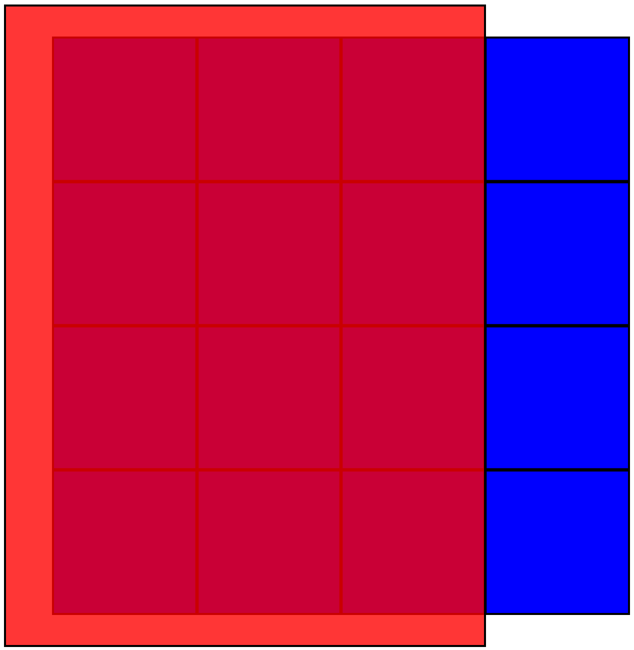
Dose Volume Histogram

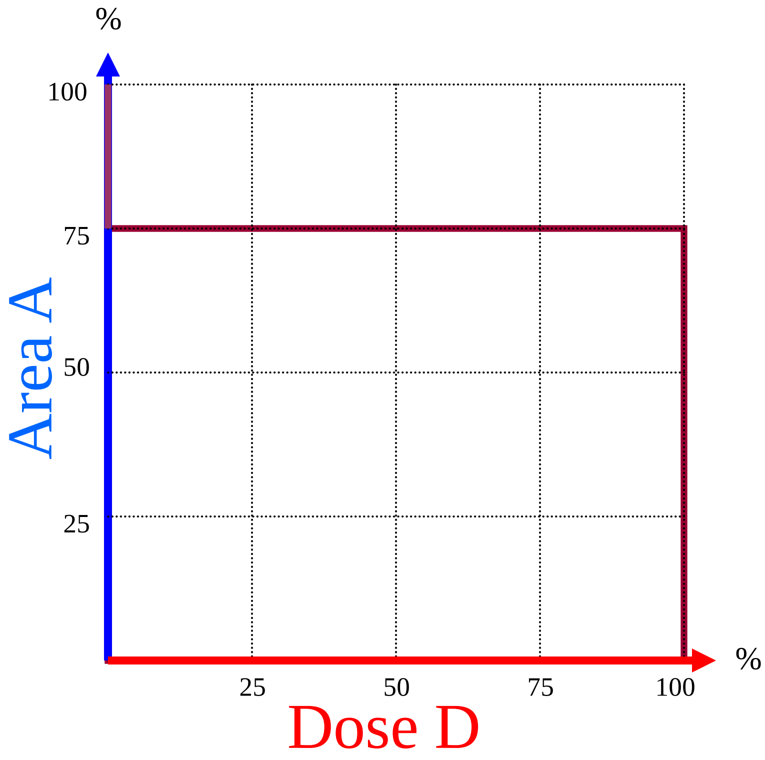




Dose Volume Histogram

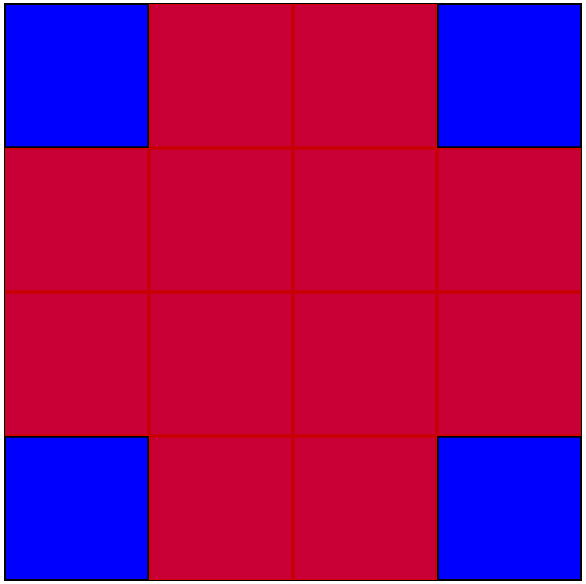
No spatial information

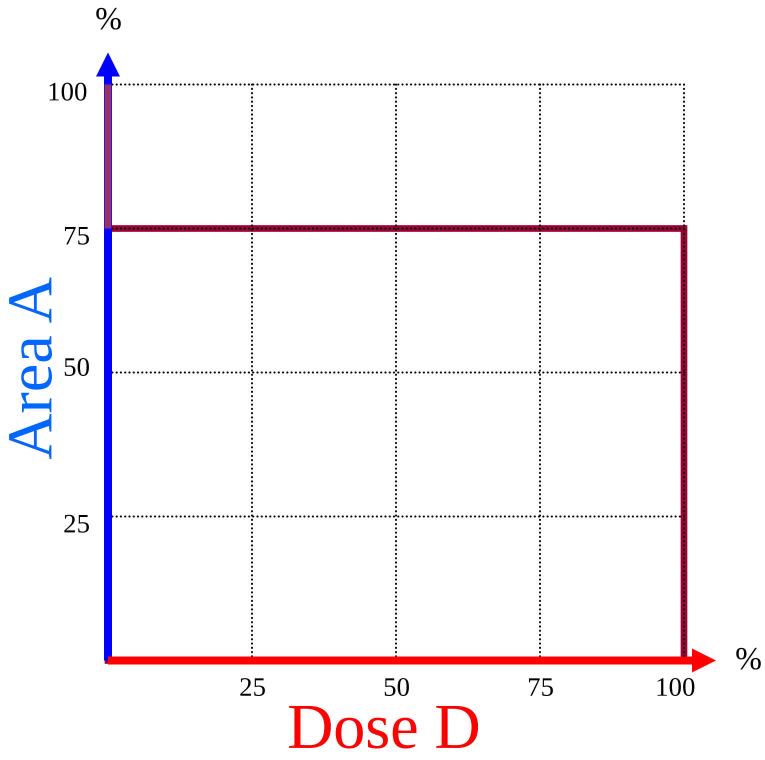




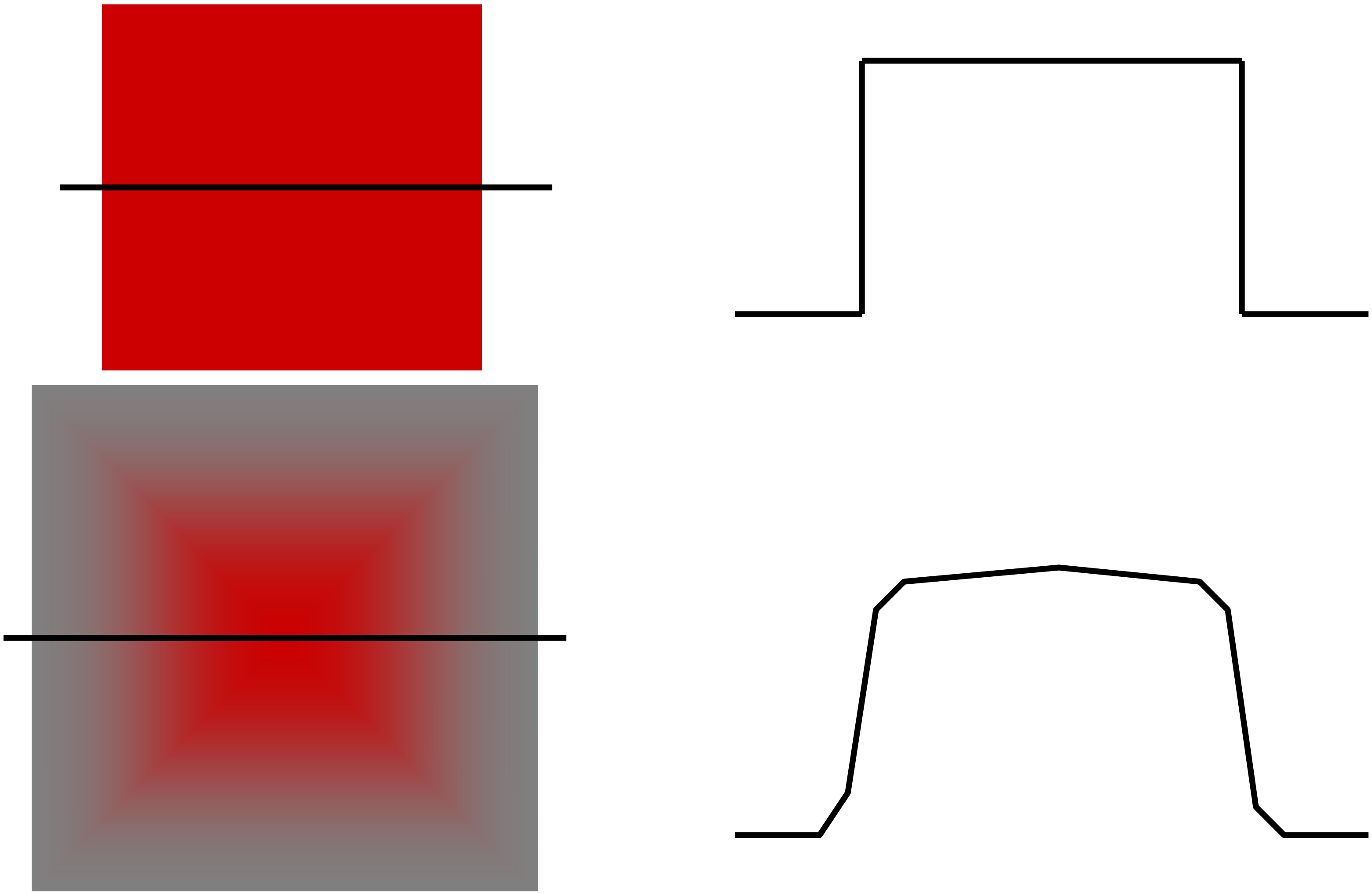
Dose Volume Histogram

No spatial information

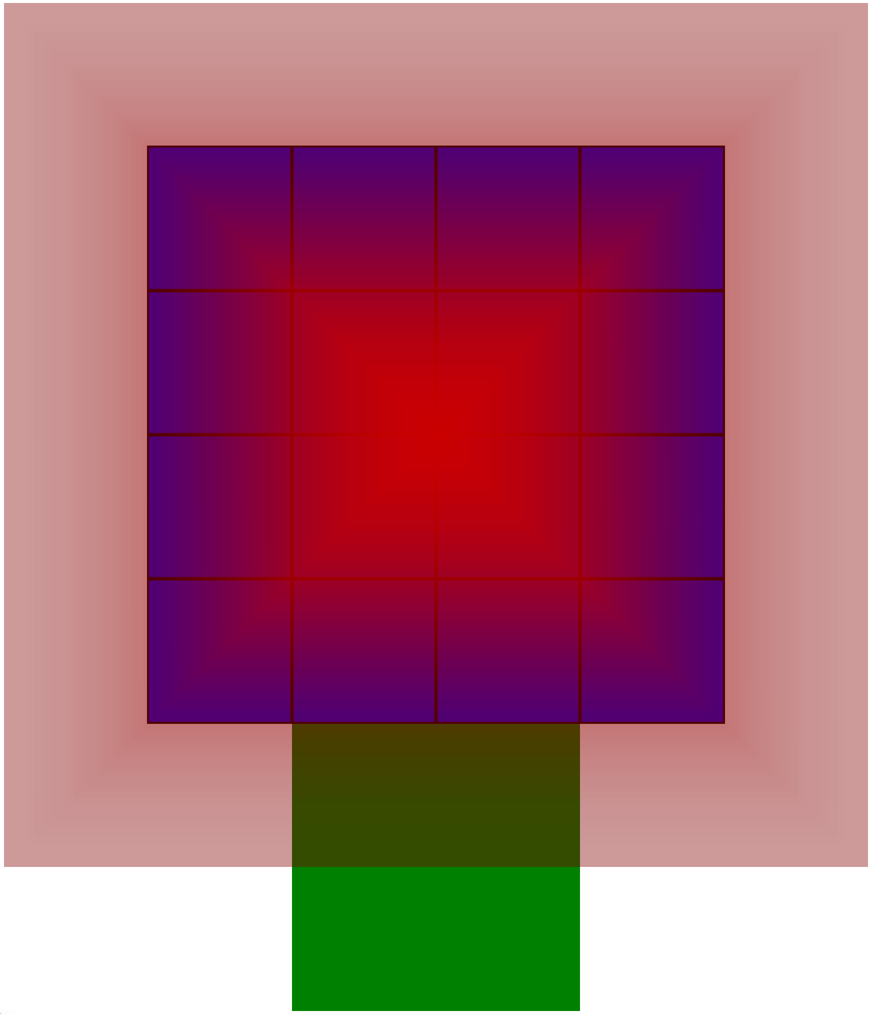


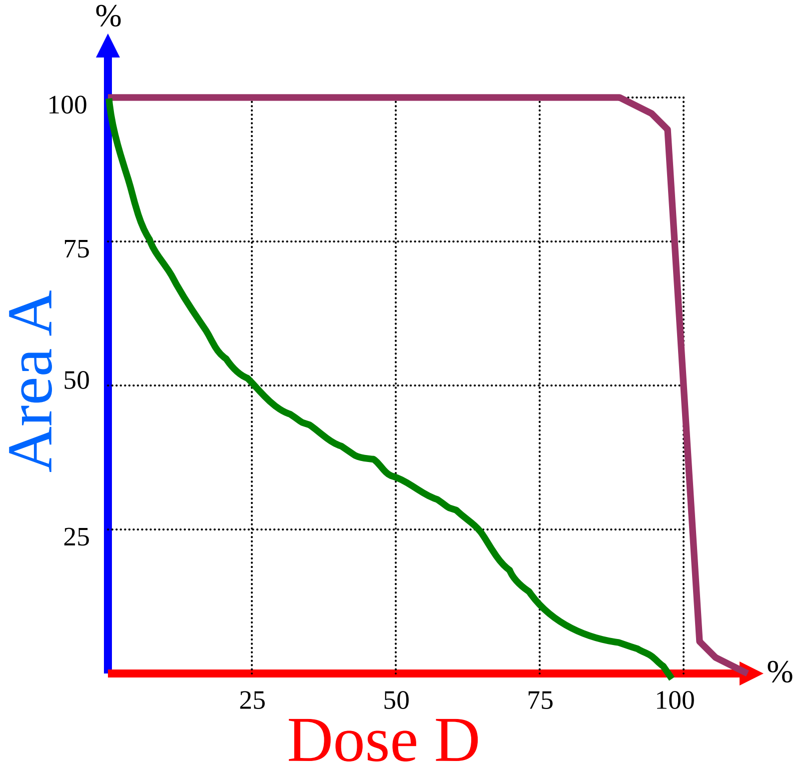


Dose Volume Histogram



Dose Volume Histogram





Dose Volume Histogram

D_{max} (serial organs)

D_{min}

$D_{50\%} = D_{median}$

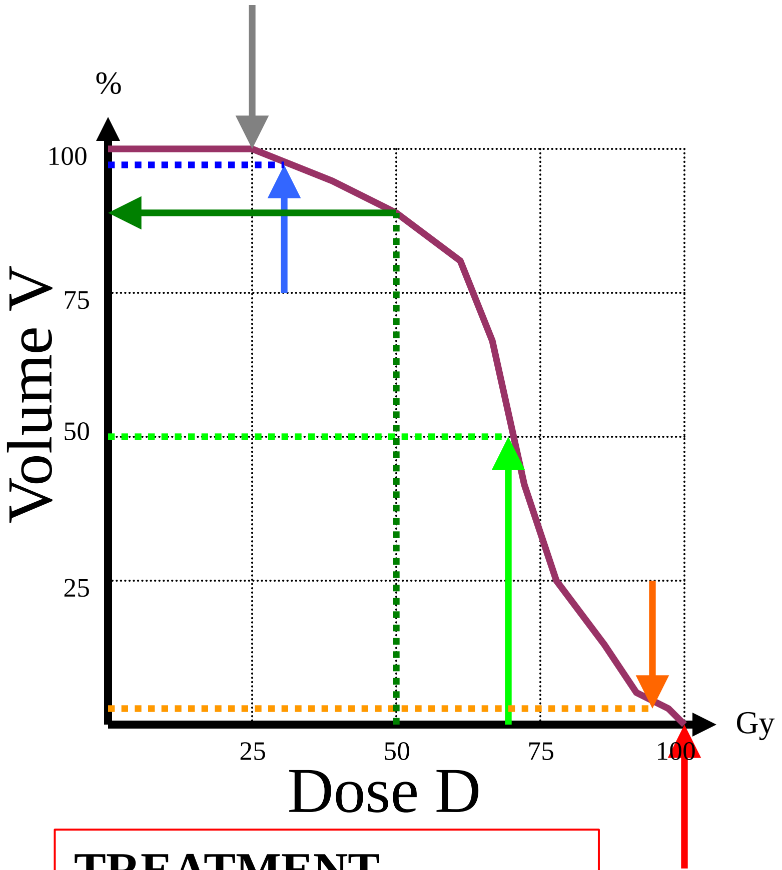
$D_{98\%}$ "close to min"

$D_{2\%}$ "close to max"

D_{mean}

V_{dose}

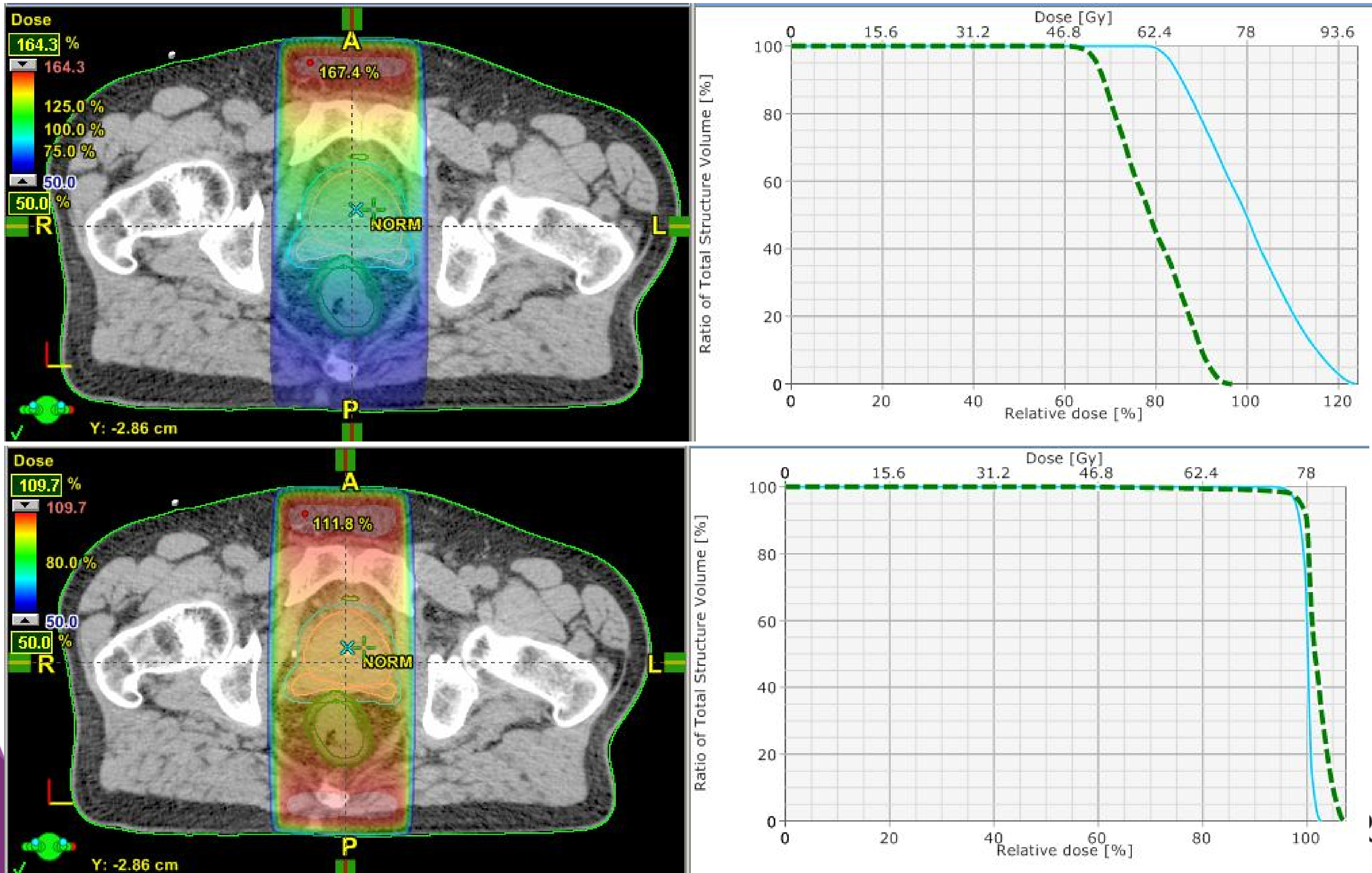
V_{50Gy} (parallel organs)



TREATMENT PLANNING: TOOLS AND GENERAL PRINCIPLES PART 1 (LATER TODAY)

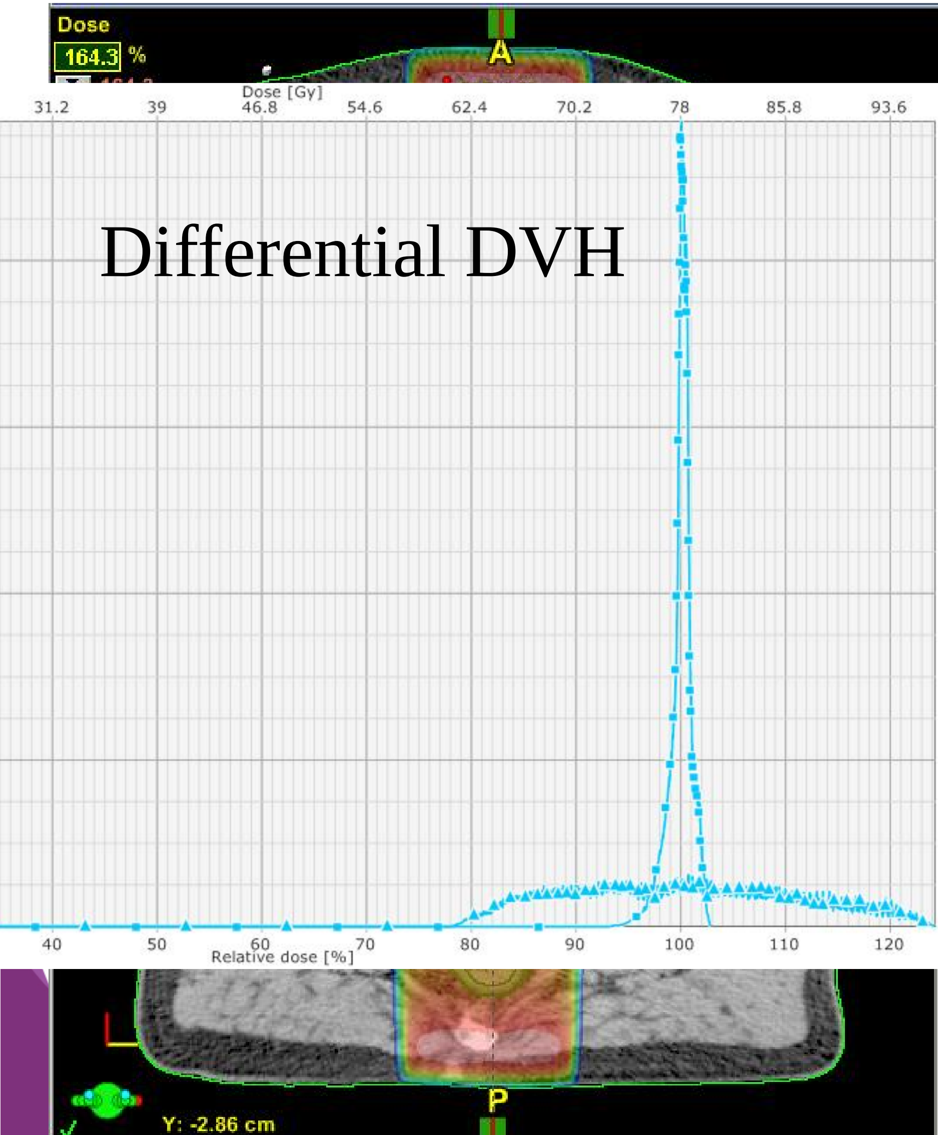
Dose Volume Histogram

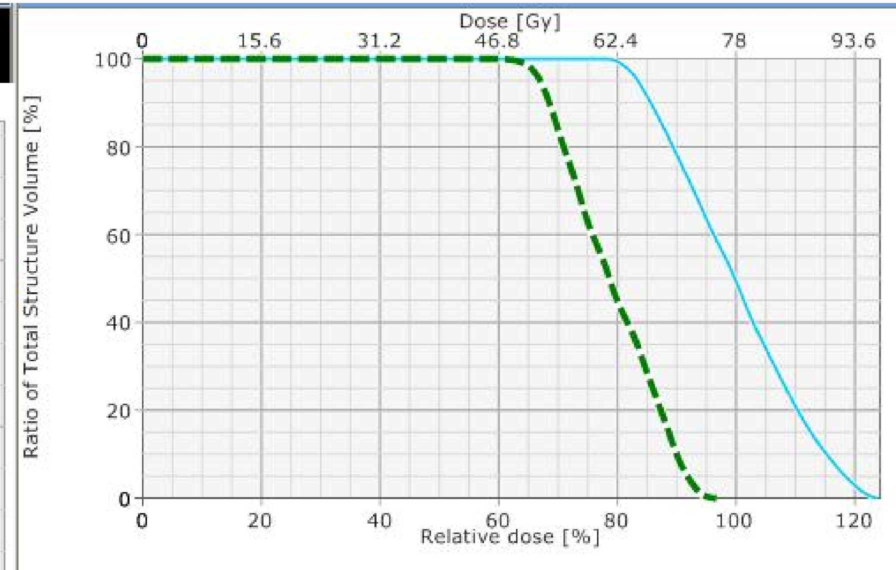
Some clinical example

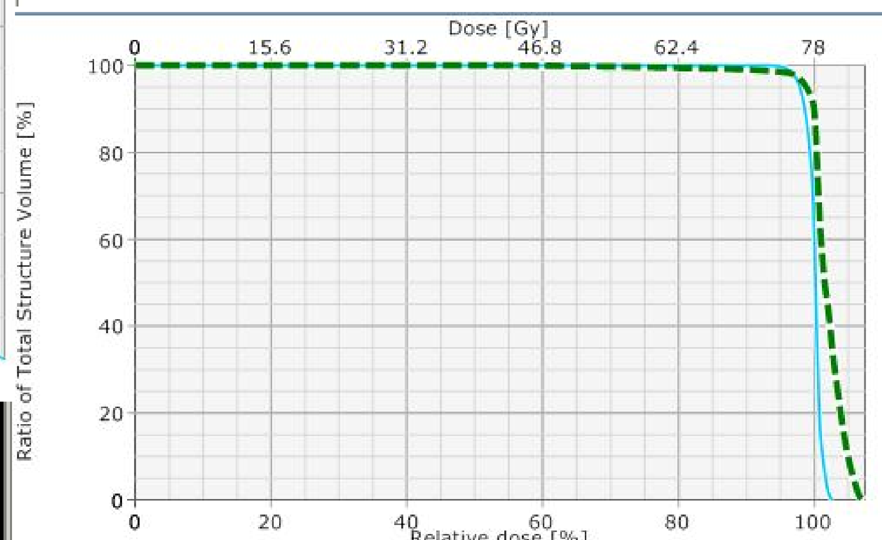


Dose Volume Histogram

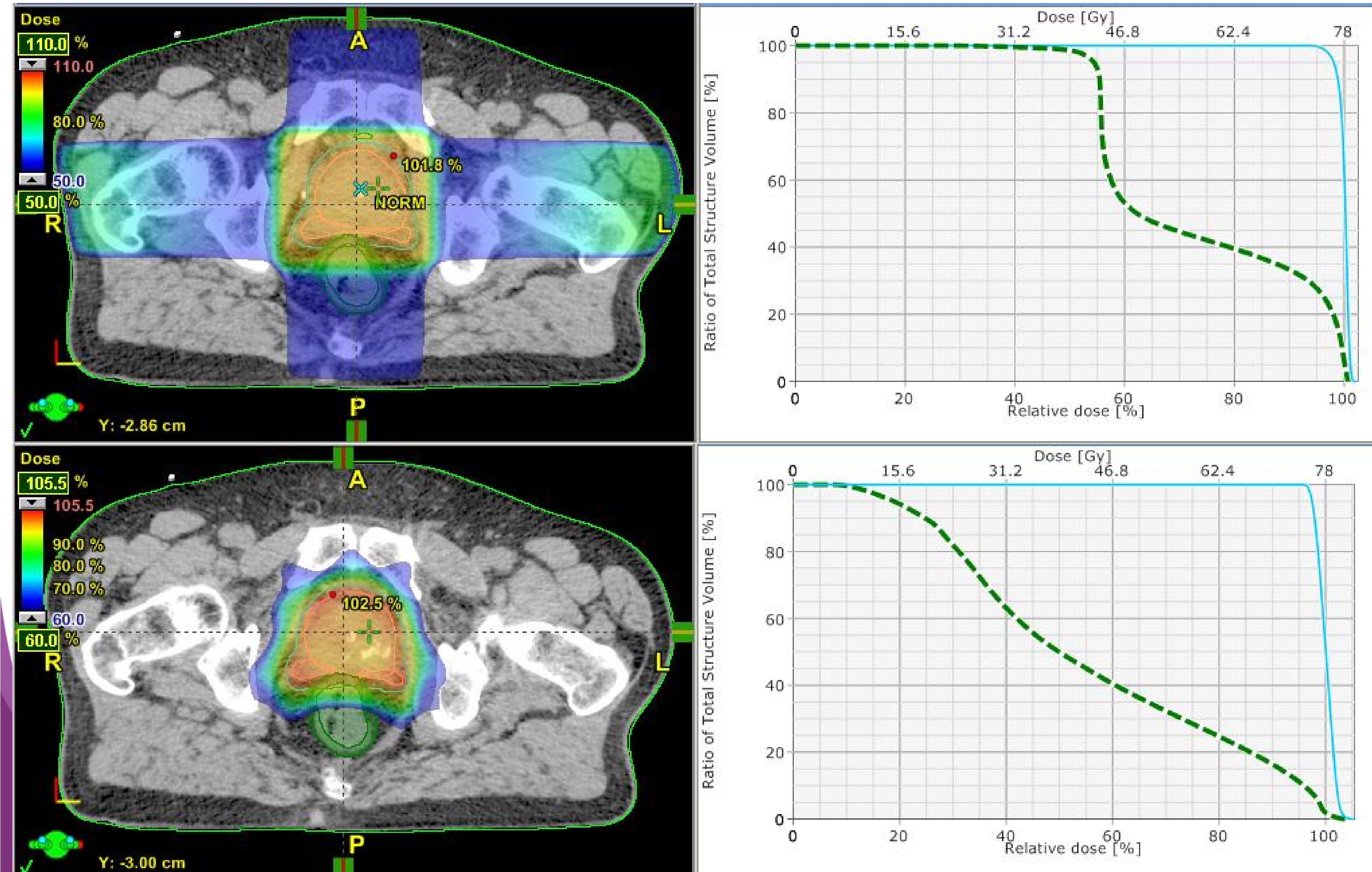
Some clinical example





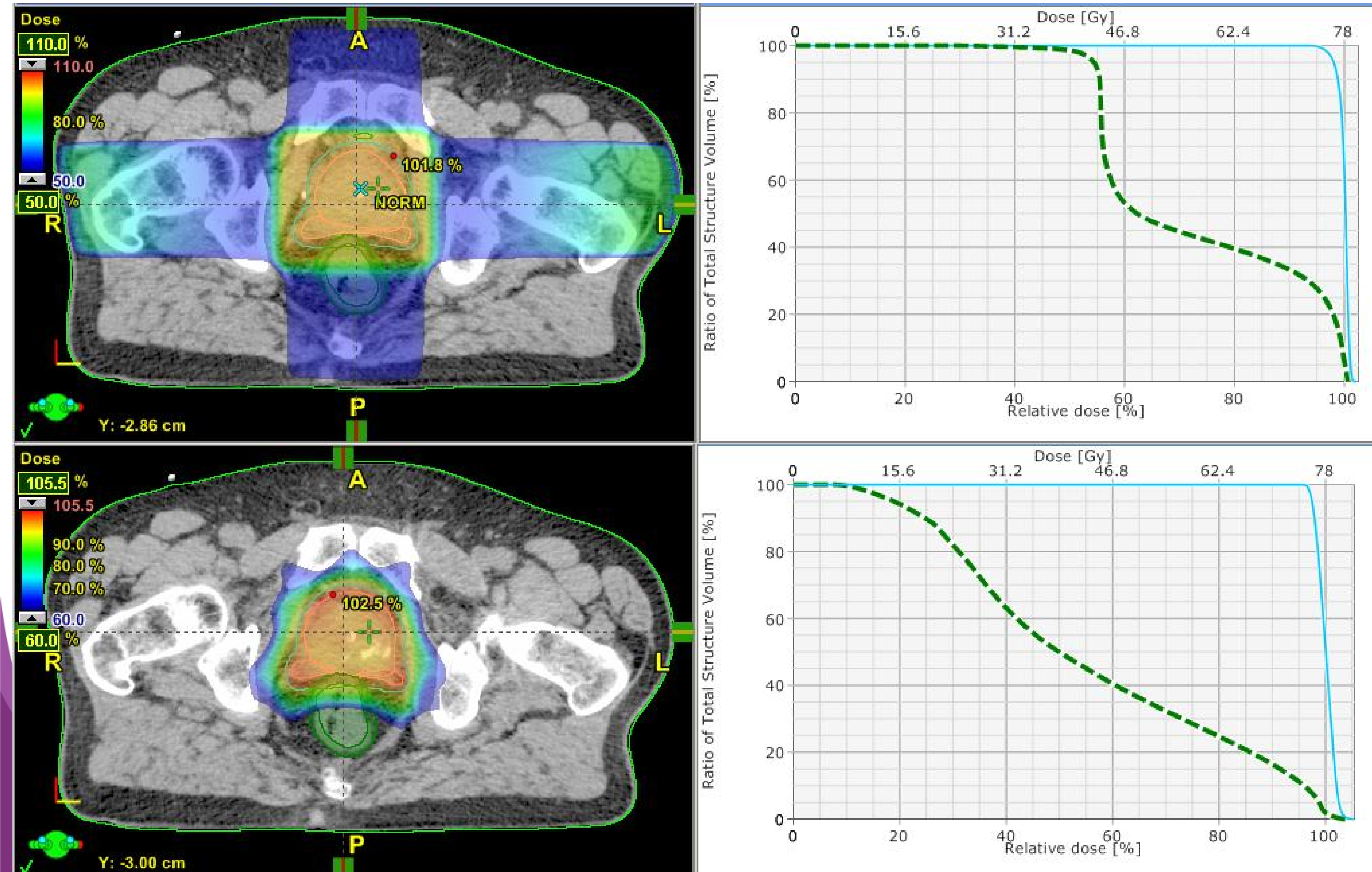


Dose Volume Histogram



Dose Volume Histogram

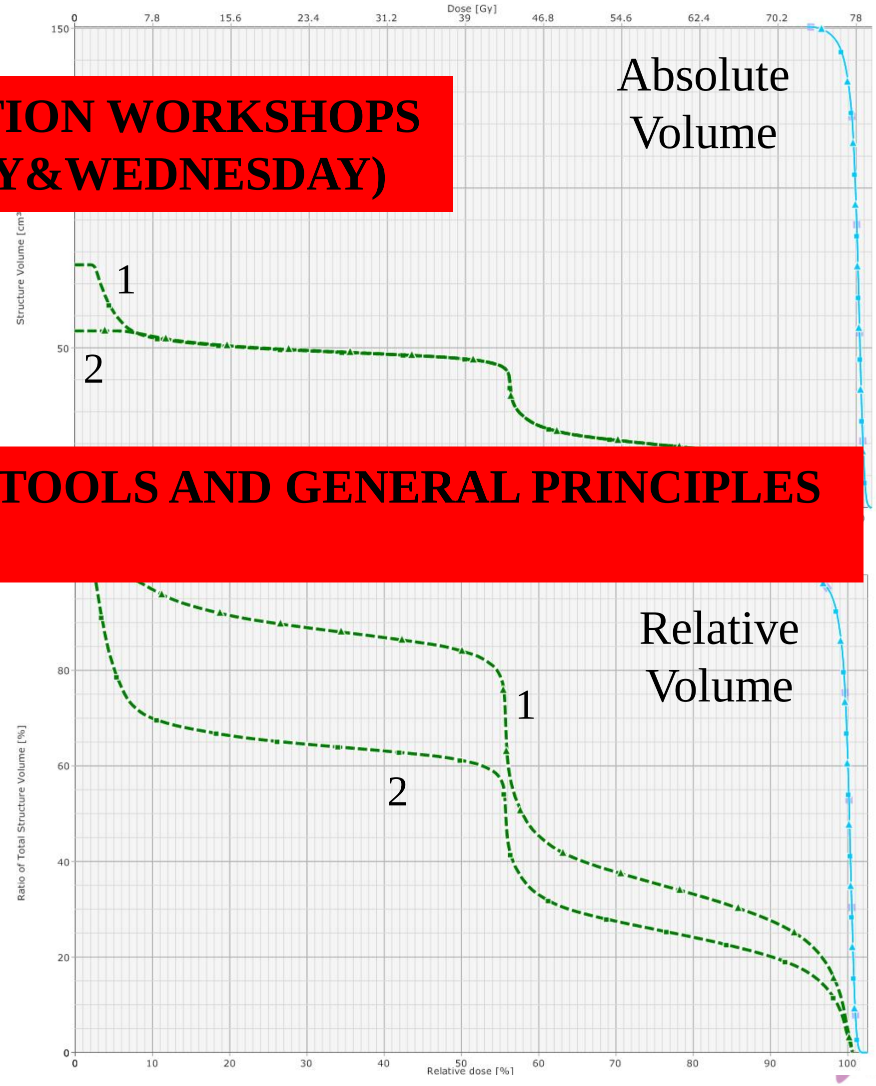
Some clinical example



Dose Volume Histogram

Relative or absolute volume – delineation is crucial

DELINEATION WORKSHOPS (MONDAY&WEDNESDAY)



TREATMENT PLANNING: TOOLS AND GENERAL PRINCIPLES PART 1 (LATER TODAY)

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Thank you for your attention

Questions?

Introduction to Treatment Planning

the Oncologist's Perspective

Paul Kelly

Cork University Hospital

Principles of Radiotherapy

All types of radiotherapy follow these general principles:

- Precisely locate the target
- Hold the target still
- Accurately aim the radiation beam
- Shape the radiation beam to the target
- Deliver a radiation dose that damages abnormal cells yet spares normal cells

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Clinical Relevance of the Radiotherapy Plan

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Clinical Relevance

- Treatment Intent: Radical versus Palliative
- Ideal Plan
- Reality: balance of competing priorities
- Concept of Therapeutic Index
- Dose Volume Constraints and their limitations
- Clinical relevance of:
  - Target coverage
  - Inhomogeneity
  - Side effects

Treatment Intent

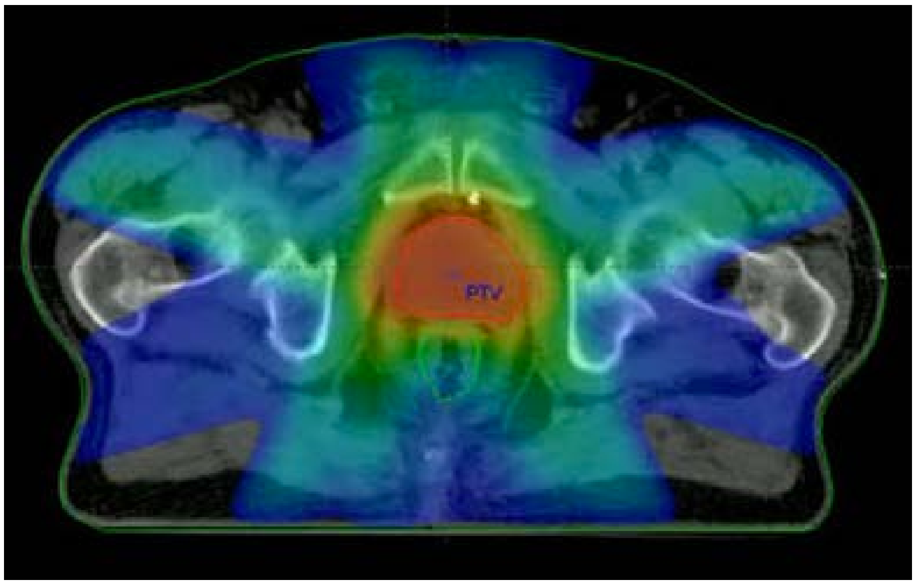
- **Radical**
  - Intended to cure, not palliate
  - Conventional fraction size, typically 1.8- 2Gy per fraction
  - Frequently high total dose
  - Frequently risk normal tissue tolerances
  - Concern regarding late normal tissue complications
  - Goal: cure whilst minimizing side effects

Treatment Intent

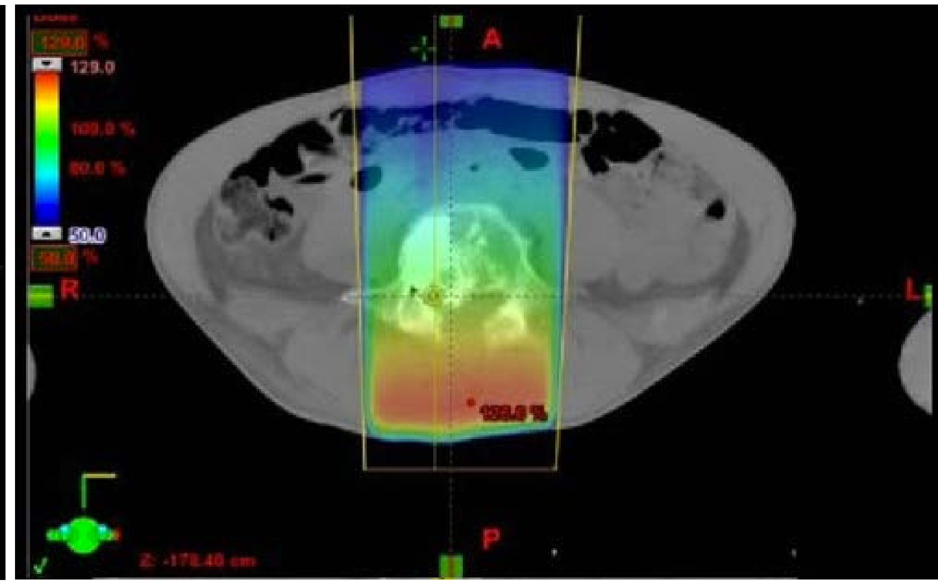
- **Radical**
  - Intended to cure, not palliate
  - Conventional fraction size, typically 1.8- 2Gy per fraction
  - Frequently high total dose
  - Frequently risk normal tissue tolerances
  - Concern regarding late normal tissue complications
  - Goal: cure whilst minimizing side effects
- **Palliative**
  - Intended to relieve symptoms
  - Typically hypofractionated eg >2Gy per fraction
  - Typically modest total dose
  - May cause acute side effects
  - Limited lifespan, less concern regarding late side effects
  - Goal: improve quality of life

Treatment Intent

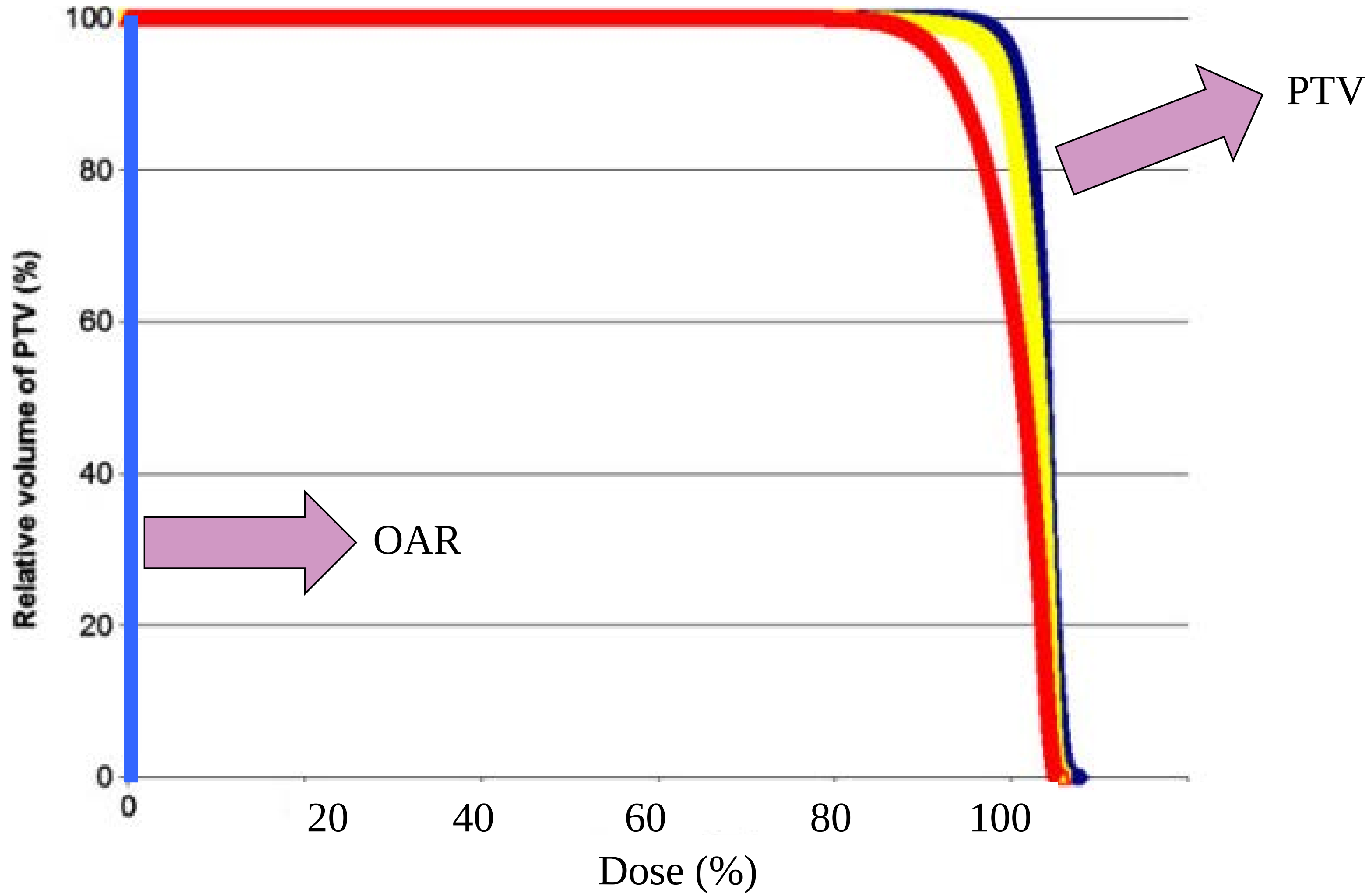
- **Radical**



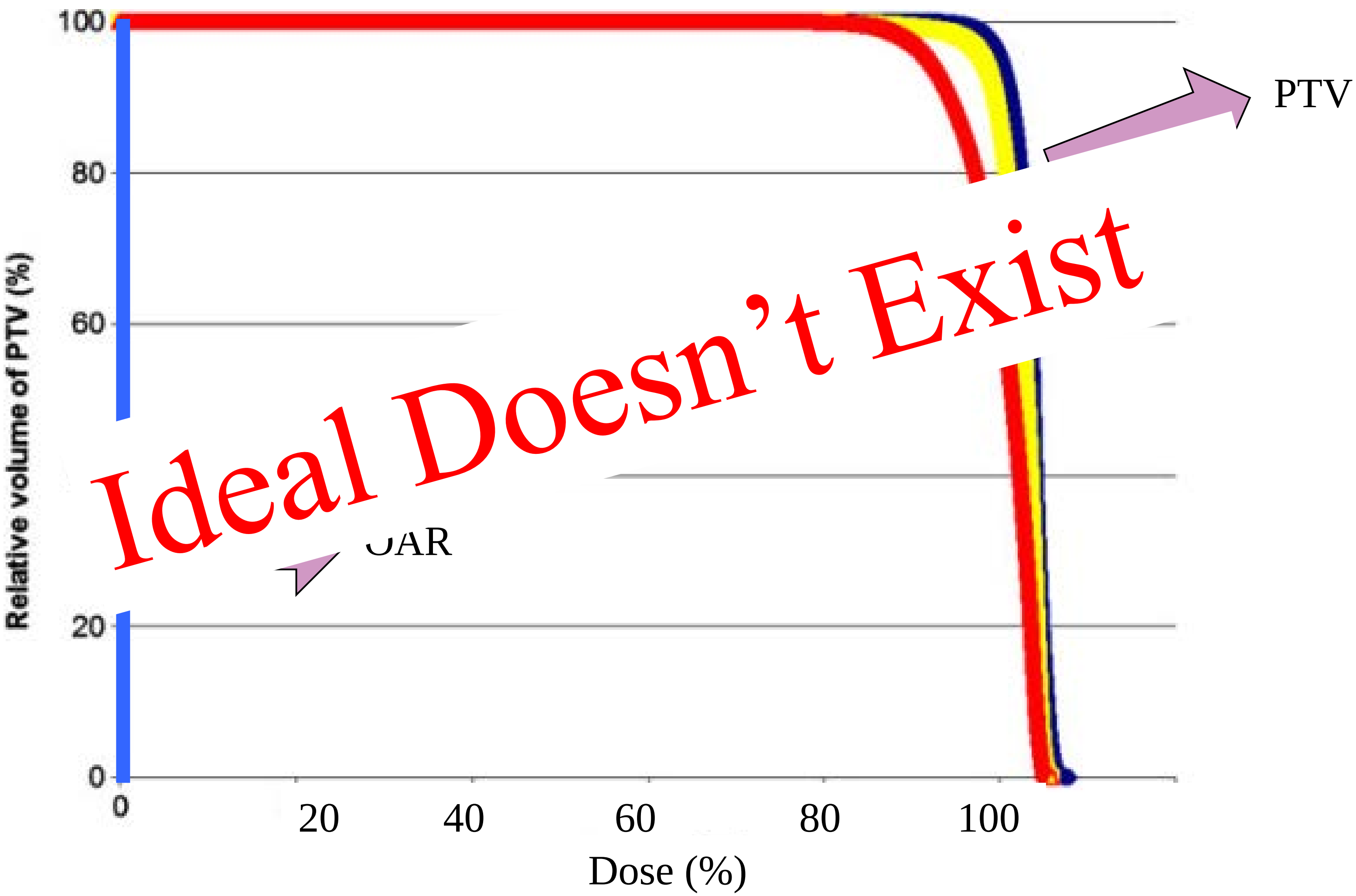
- **Palliative**



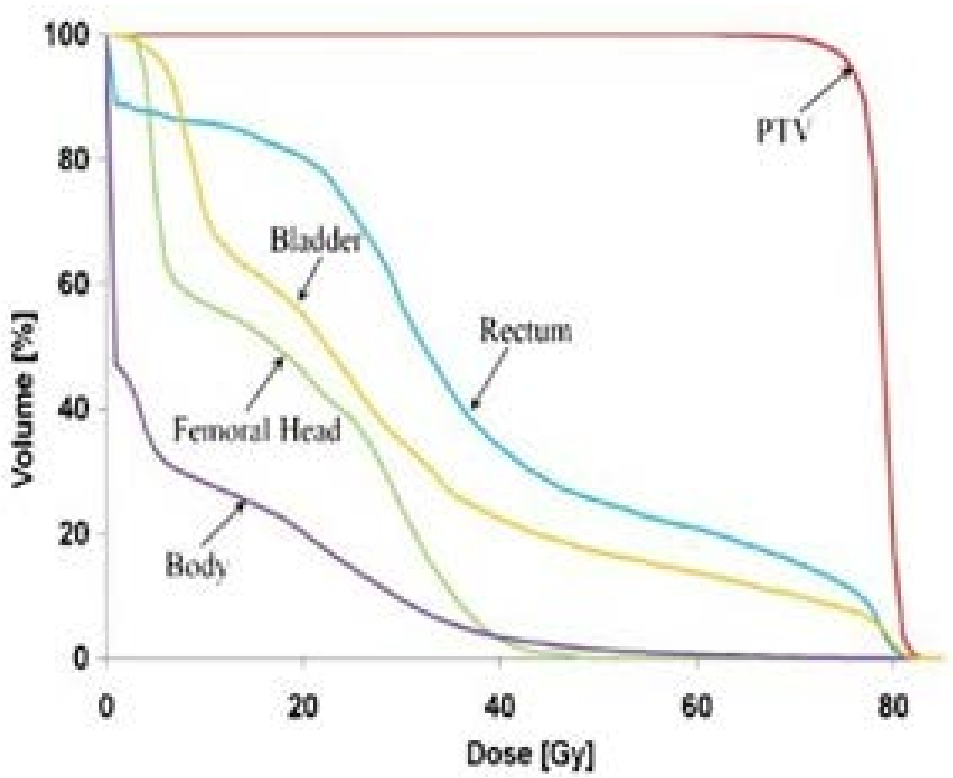
The Ideal Plan



The Ideal Plan



Typical DVH Prostate Radiotherapy



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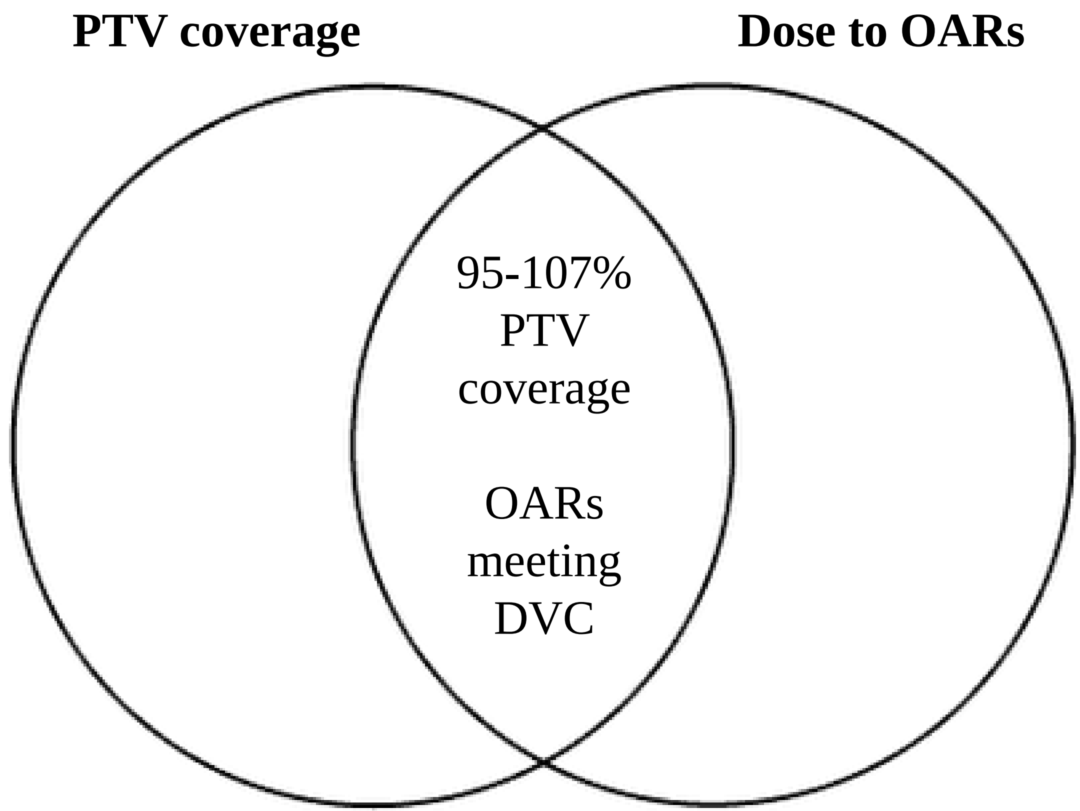
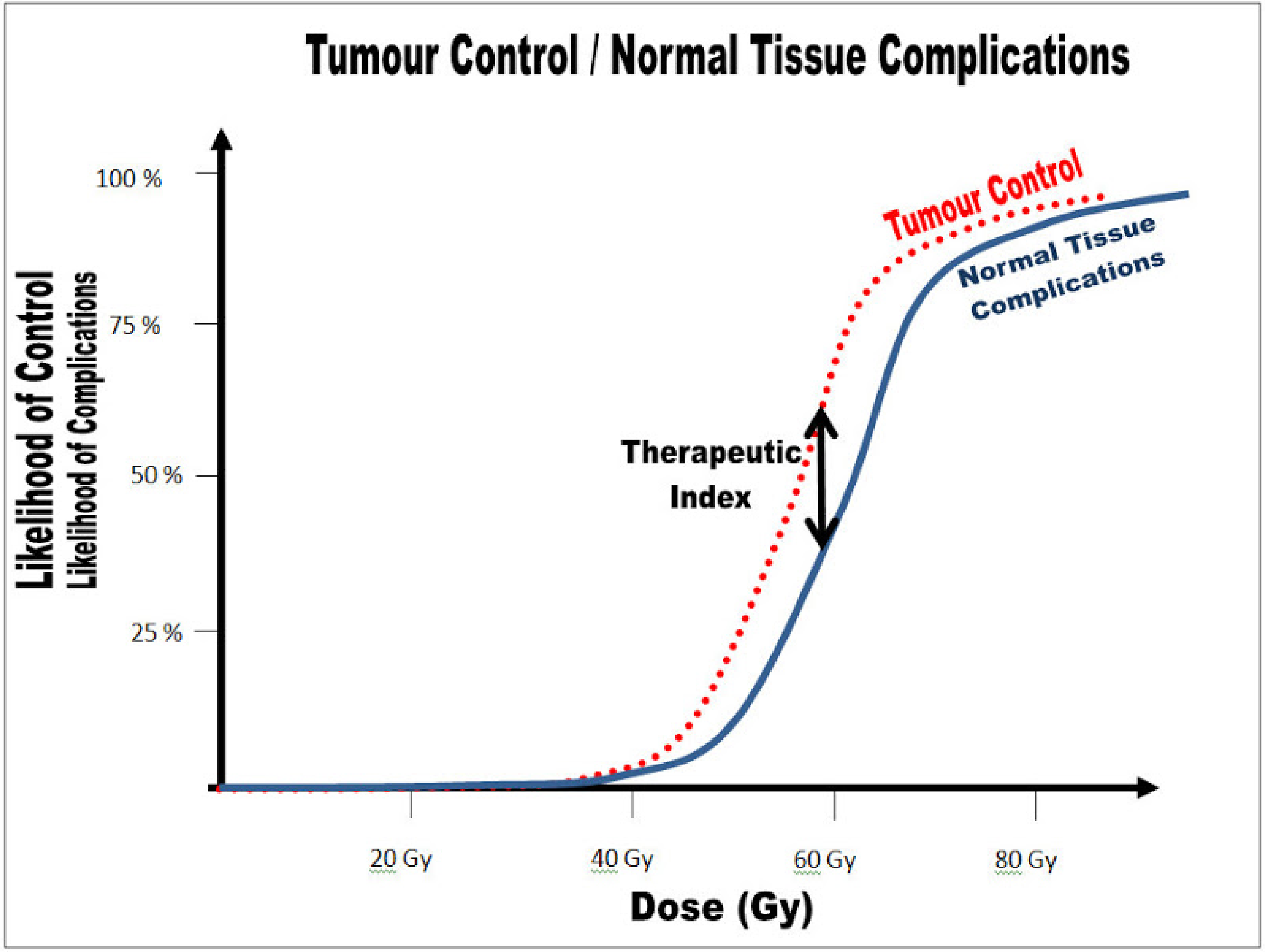
The reality: Competing priorities



OAR= Organ at Risk
DVC= Dose Volume Constraint

Concept of Therapeutic Index



Normal Tissue Tolerance

- "The Emami paper" (1991)
  - Committee of experts to review known data, provide guidelines
    - Some clinical data to suggest tissue tolerance
      - Comparatively poor ability to deliver dose
      - Poor ability to measure dose actually delivered
    - Some laboratory data (cell cultures, etc)
    - Some data "made up" based upon best-guess principles

Emami B, et al. Int J Radiat Oncol Biol Phys 1991; 21: 109-22.

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Emami "Out of Date?"

- Move from 2D to 3D treatment planning
- Higher energy beams/better penetration
- Improved ability to measure dose
- Increased use combined chemoradiotherapy
- Numerous additional studies of tissue tolerance subsequently published

QUANTEC

- Quantitative Analysis of Normal Tissue Effects in the Clinic
  - Large committee of experts (n=57)
  - Convened by ASTRO / AAPM
  - Updated guidelines published in Red Journal supplement (vol 76, No. 3)
  - 16 organ-specific papers
  - Several "general principle" papers

01 March 2010
Volume 76 , Issue 3

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QUANTEC-General Theme

- Importance of gathering prospective toxicity data on patients
- Standardized scale:
  - NCI Common Terminology for Criteria for Adverse Events (CTCAE) v4.0
  - LENT-SOMA
  - IIEF
  - etc

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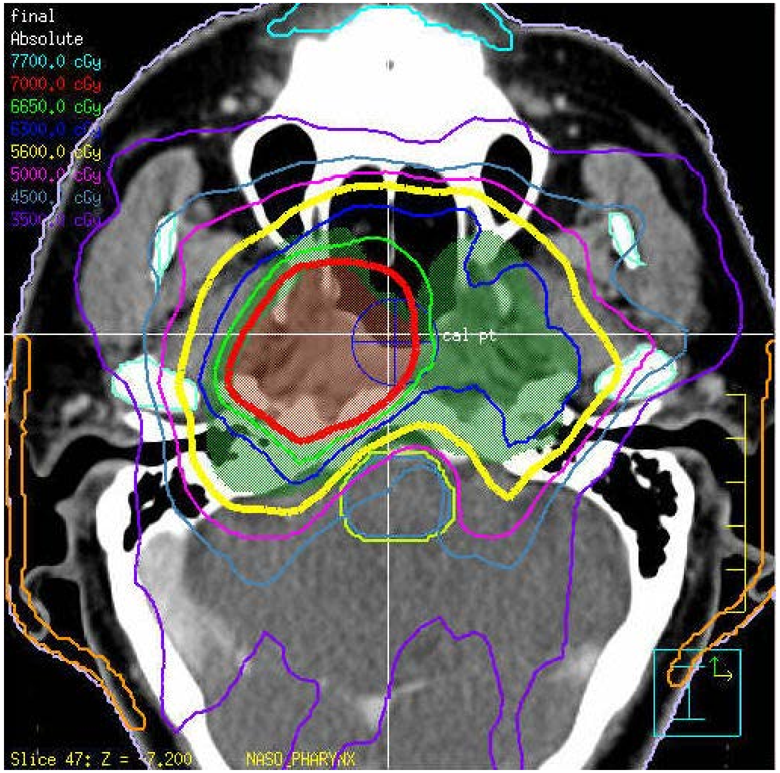
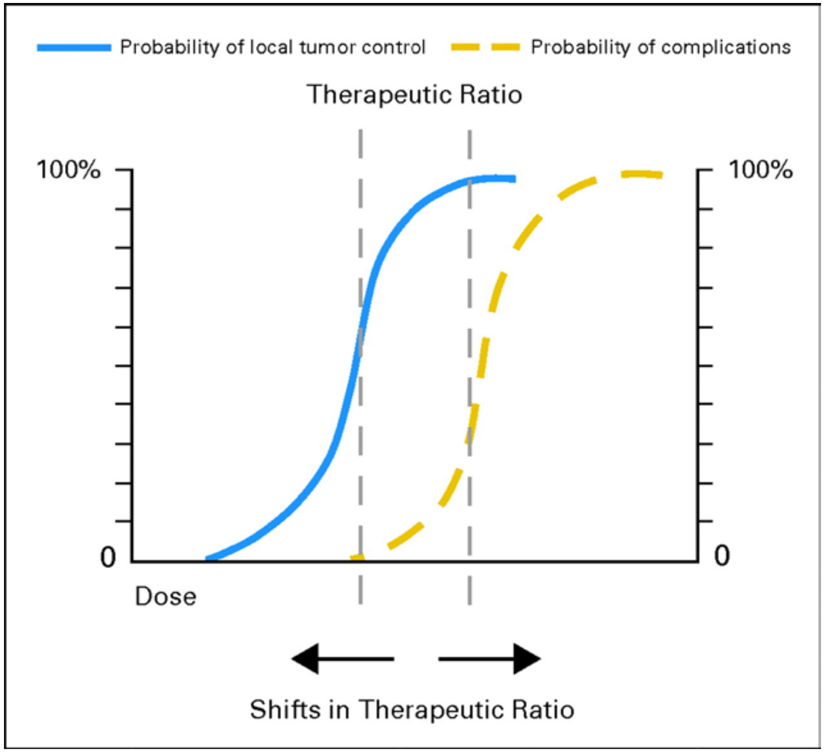
Dose Volume Constraints

- QUANTEC latest evidence-based dataset
- Not absolute
- Clinical context of utmost importance
- Clinical judgment required
- Risk of particular toxicities paramount in informed consent

Importance of Target Coverage





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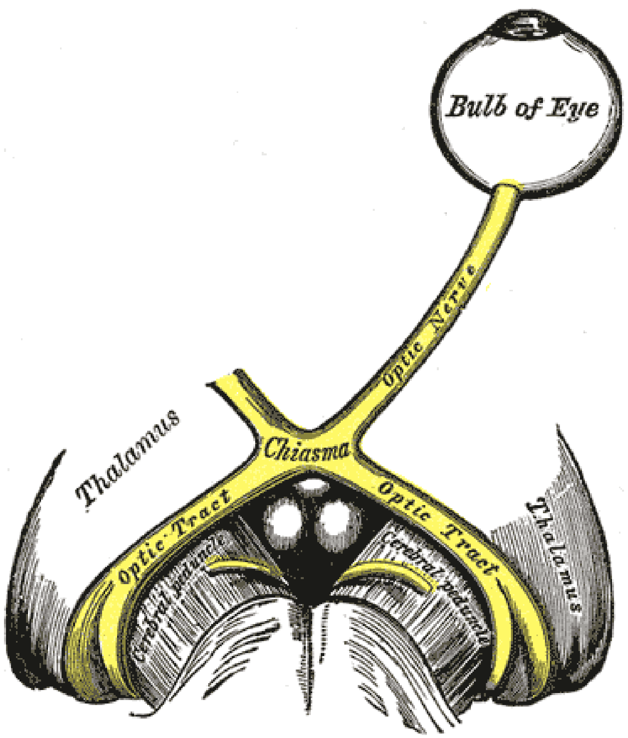
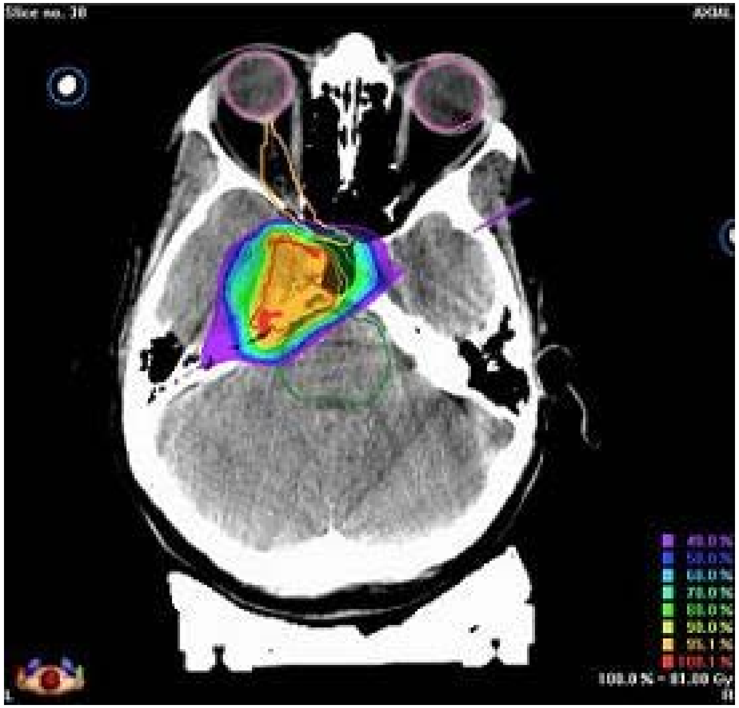
Risks of Poor Target Coverage

- Increased risk of local recurrence
- Increased risk of morbidity
- ? Increased risk of death

Importance of homogeneity [95-107%]





Importance of avoiding ‘hotspots’ within organs at risk

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Optic chiasm homogeneity

- Excessive dose to optic chiasm risks optic neuropathy, potential loss of sight, blindness

Clinical Scenario:

- Pituitary Tumour, prescribed dose 50 Gy in 25 fractions
- Maximum dose to optic chiasm 55 Gy
- QUANTEC 55Gy <3% risk of optic neuropathy ➔ ‘safe’?

Optic chiasm homogeneity

- Excessive dose to optic chiasm risks optic neuropathy, potential loss of sight, blindness

Clinical Scenario:

- Pituitary Tumour, prescribed dose 50 Gy in 25 fractions
- Maximum dose to optic chiasm 55 Gy
- QUANTEC 55Gy <3% risk of optic neuropathy ➔ 'safe'?
- However, 55 Gy ≈ 110% of the prescribed dose
- Each day, 2 Gy prescribed, however chiasm receives 2.2 Gy
- Biologically, higher dose per fraction increases risk of late side effect such as blindness
- 'Double Trouble'

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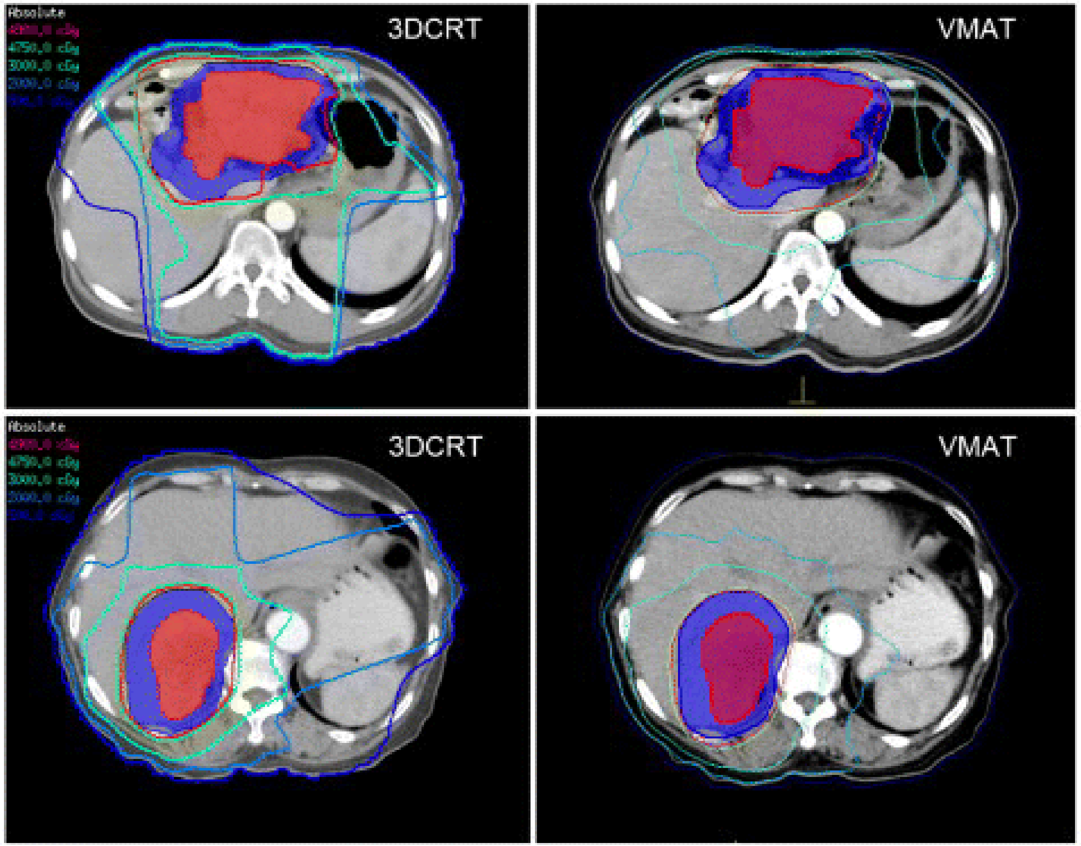
Acute side effects of radiation

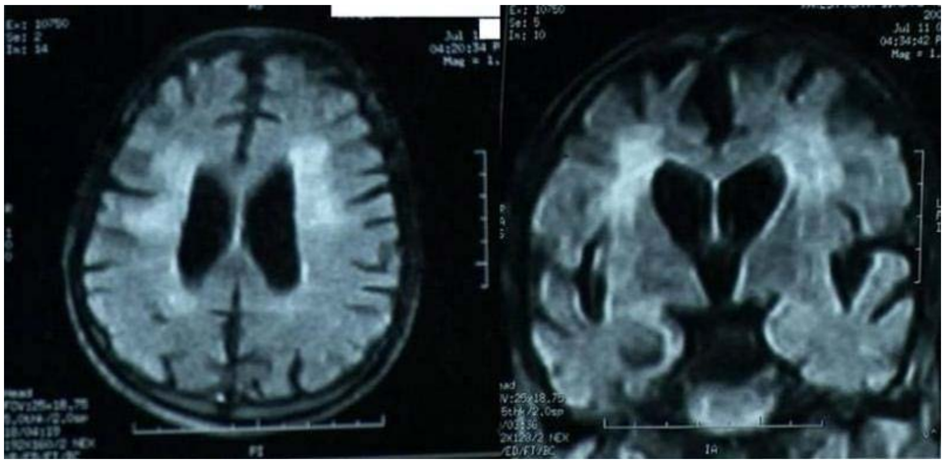
- Minimising acute side effects will improve the patient's experience of radiotherapy

eg nausea/vomiting in abdominal treatments



Late Effects in Radiation Oncology

Major source of morbidity in cancer survivors

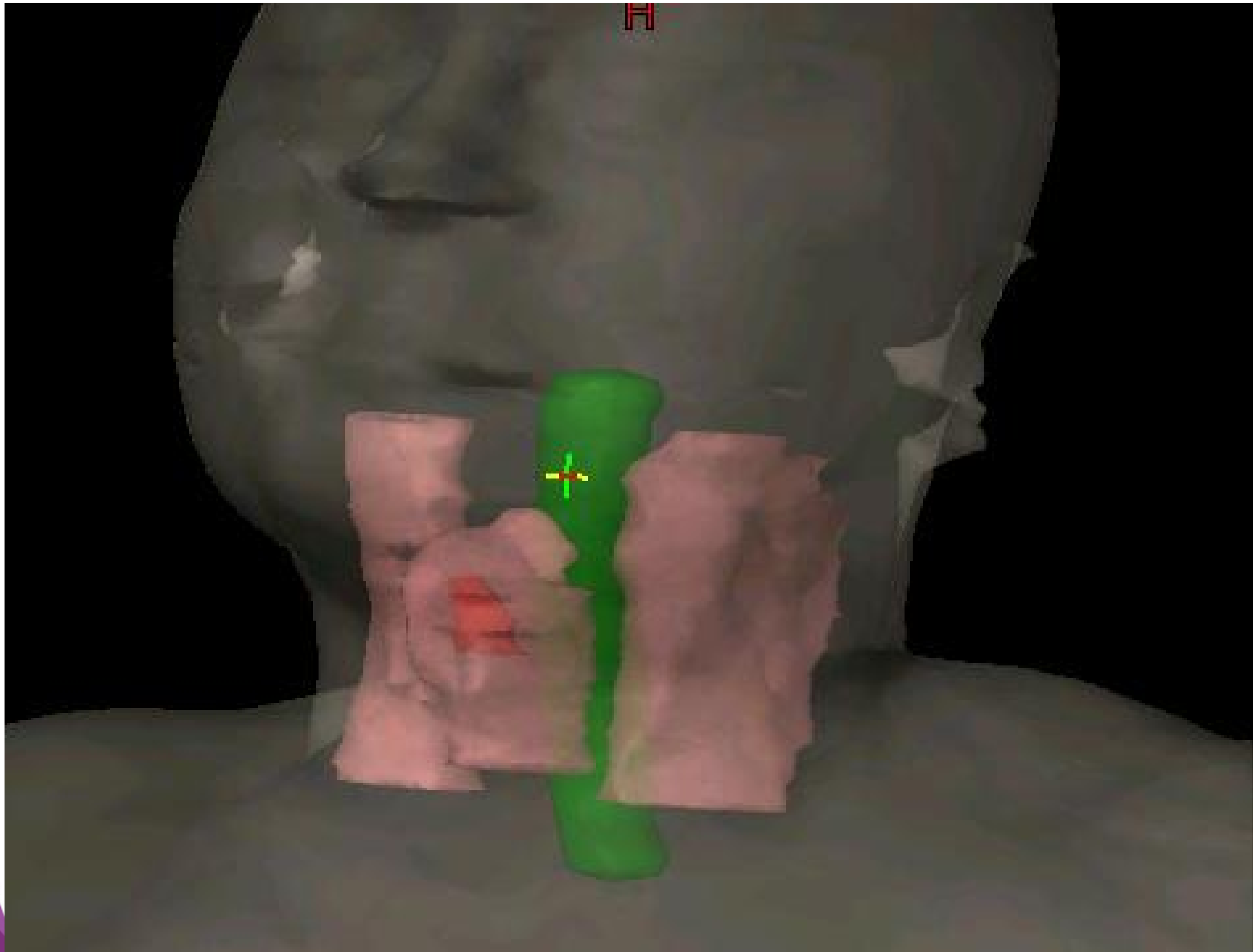


ICRU

recommendations on volume and dose

David Sjöström, Physicist
Herlev Hospital, Denmark

Background



Tumour cells contained in the red volume throughout the treatment course

Background

Tumour cells contained in the red volume throughout the treatment course

95% or more of the prescribed dose given to everything inside green area

Background

Tumour cells contained in the red volume throughout the treatment course

95% or more of the prescribed dose given to everything inside green area

How do we ensure that this picture reflects the reality of the treatment?

Background

Problem:

We need the same definitions of:

- **volume that has been treated**
- **dose given to this volume**
- **dose received by organs at risk**

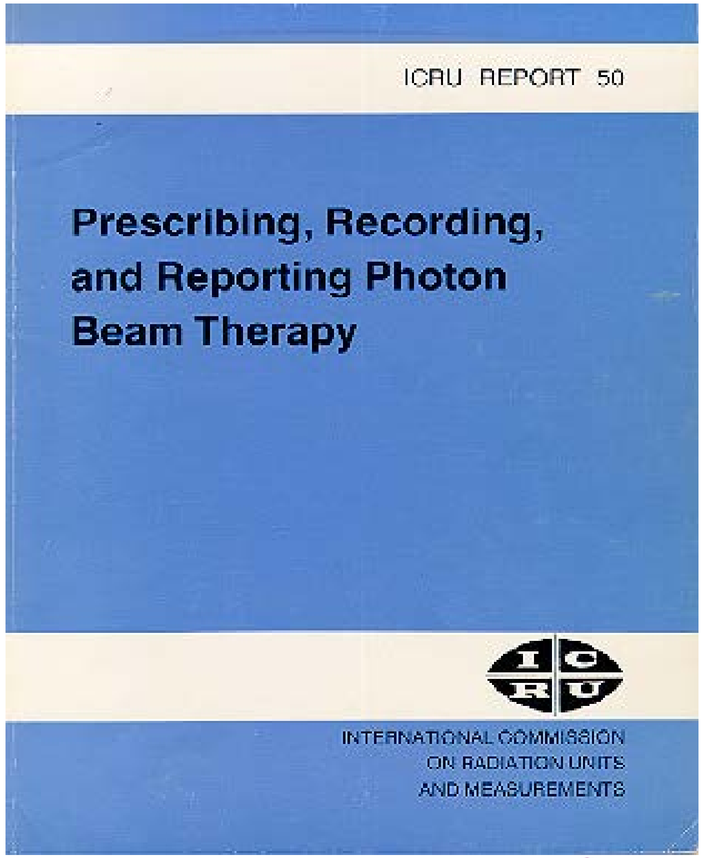
How to prescribe, record and report

Background

International Commission on Radiation Units and Measurements, Inc.

Solution:

ICRU reports - International recommendations for definitions of dose and volume in RT



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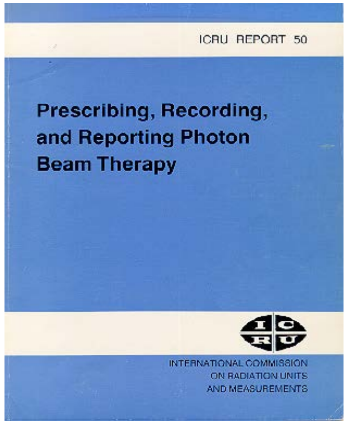
Background



ICRU Report No.29 (1978)

"Dose specification for reporting external beam therapy with photons and electrons"

ICRU Report No.50 (1993)

"Prescribing, recording and reporting photon beam therapy"

(Superseded ICRU Report No.29)

ICRU Report No.62 (1999)

"Supplement to ICRU Report No.50"

(Updated the ICRU Report No.50 with some new concepts. ICRU 50 still valid.)

Background

ICRU Report No.71 (2004)

“Prescribing, recording and reporting electron beam therapy”

(Extends concepts and recommendations from ICRU 50 and 62 from photons to electrons)

ICRU Report No.78 (2007)

“Prescribing, recording and reporting proton-beam therapy”

ICRU Report No.83 (2010)

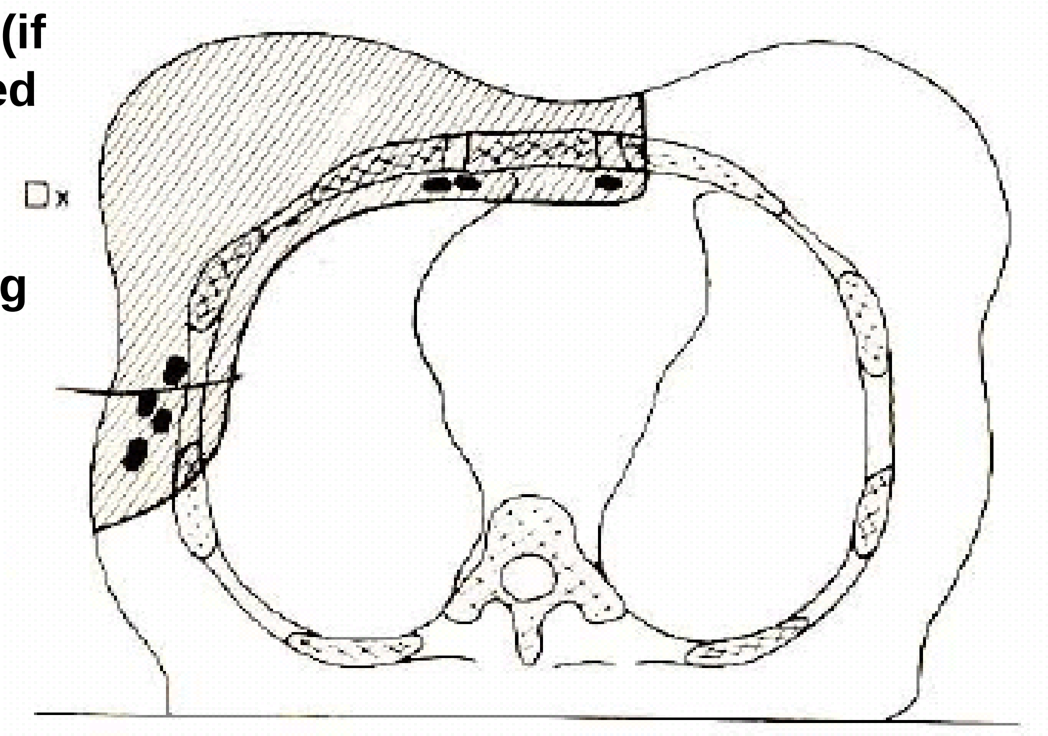
“Prescribing, Recording and Reporting intensity-modulated photon-beam therapy (IMRT)”

ESTRO School

Volumes in ICRU29 - 1978

“The Target Volume”

The *target volume* consists of the tumours (if present) and any other tissue with presumed tumour



- **expected movements of tissues containing the target volume**
- **variations in shape and size of the target volume**
- **variations in treatment set-up**

+ Organs at risk whose presence influence treatment planning

Volumes

Why all these updates?

Improvements in staging and imaging procedures

Improvements in the delivery and precision of radiotherapy

more detailed and accurate set of definitions to maximize the benefit of the development.

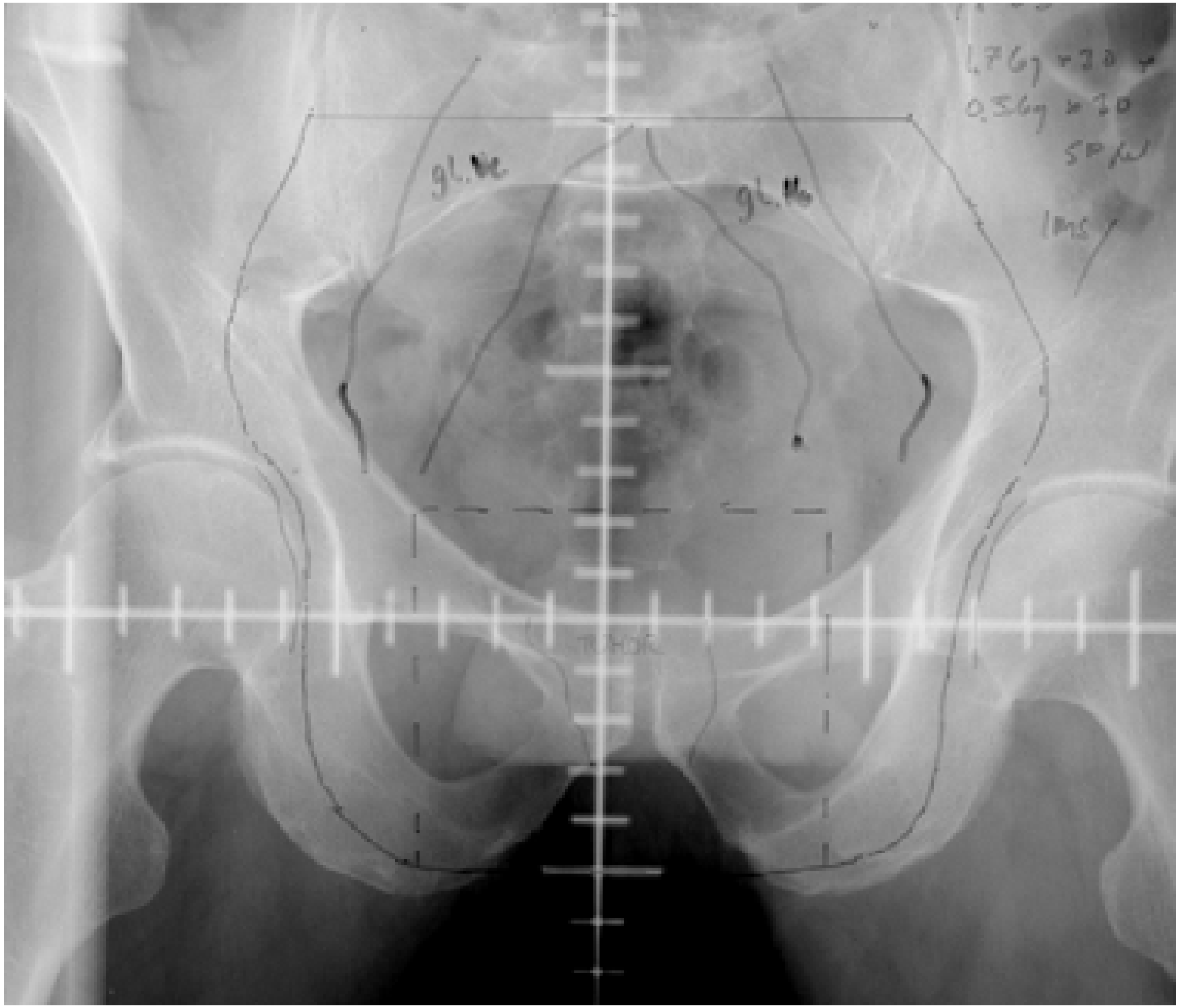
Volumes in ICRU29 - 1978

Example

Target volume

Primary + Boost

“Treatment fields defined from anatomical land marks in 2D”



Computerised Tomography (X Ray)

Possible to define and delineate

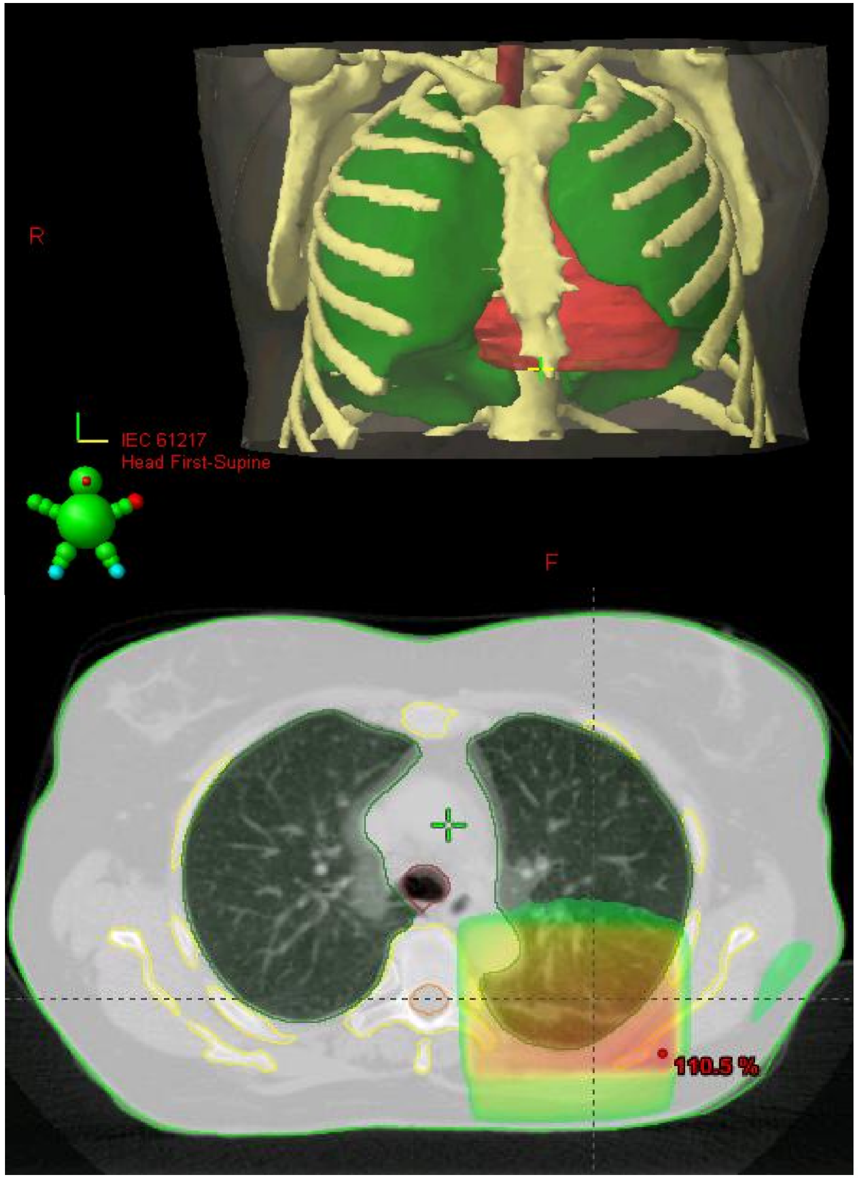
Outline of patient body

Tumour

Sensitive organs

Possible to

Optimize how to irradiate



Volumes

1978 ICRU29 **"The Target Volume"** **Organs at risk**

1993 ICRU50 ***… a realization that better tools were needed …***

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Volumes in ICRU50 - 1993

Gross Tumour Volume (GTV)

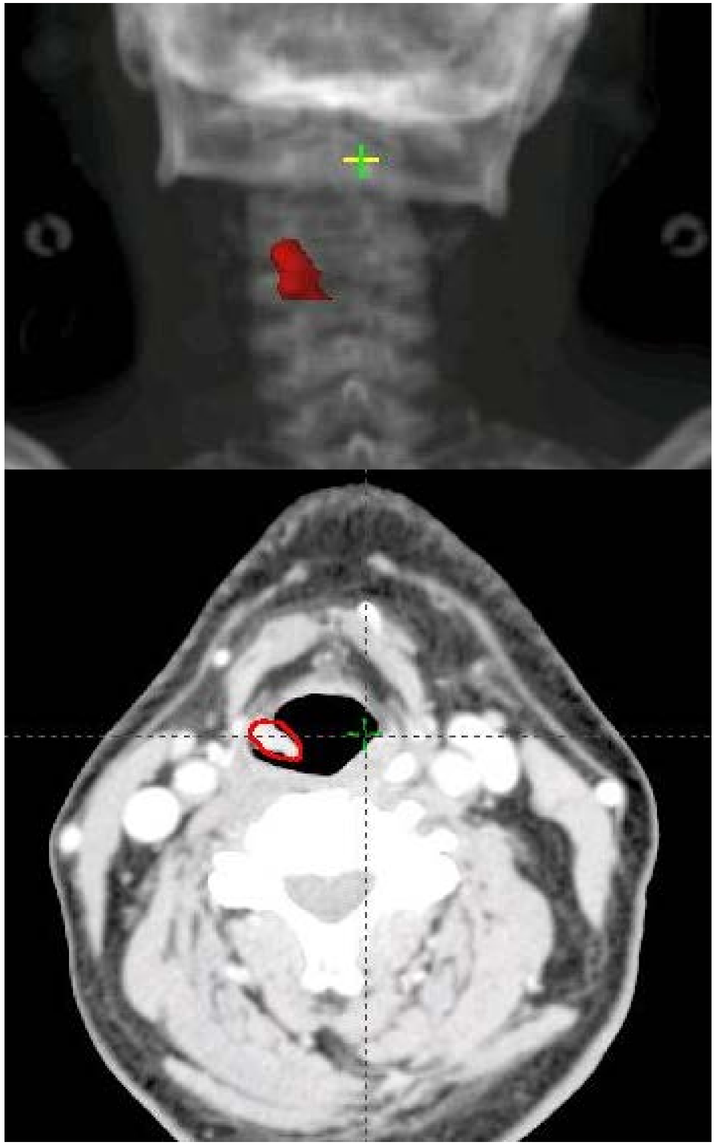
The GTV is the gross demonstrable extent and location of the malignant growth.

GTV consists of:

primary tumour

metastatic lymphnodes

other metastases



The demonstrated tumour

Volumes in ICRU50 - 1993

Clinical Target Volume (CTV)

The CTV is a tissue volume that contains a demonstrable GTV and/or subclinical, microscopical malignant disease.

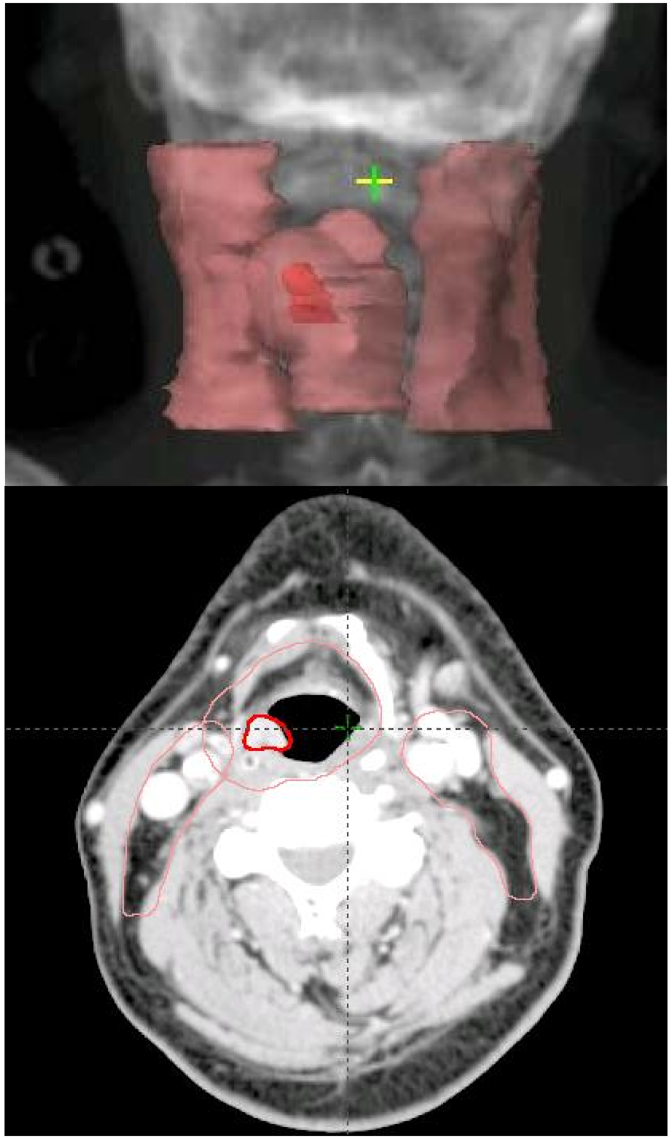
Suspected lymph nodes

Suspected disease around GTV

CTV = GTV (if there) + subclinical disease

Cannot be detected - “subclinical”.

Based on clinical experience.



CTV I - GTV with margin, and CTV II – lymph nodes

Volumes in ICRU50 - 1993

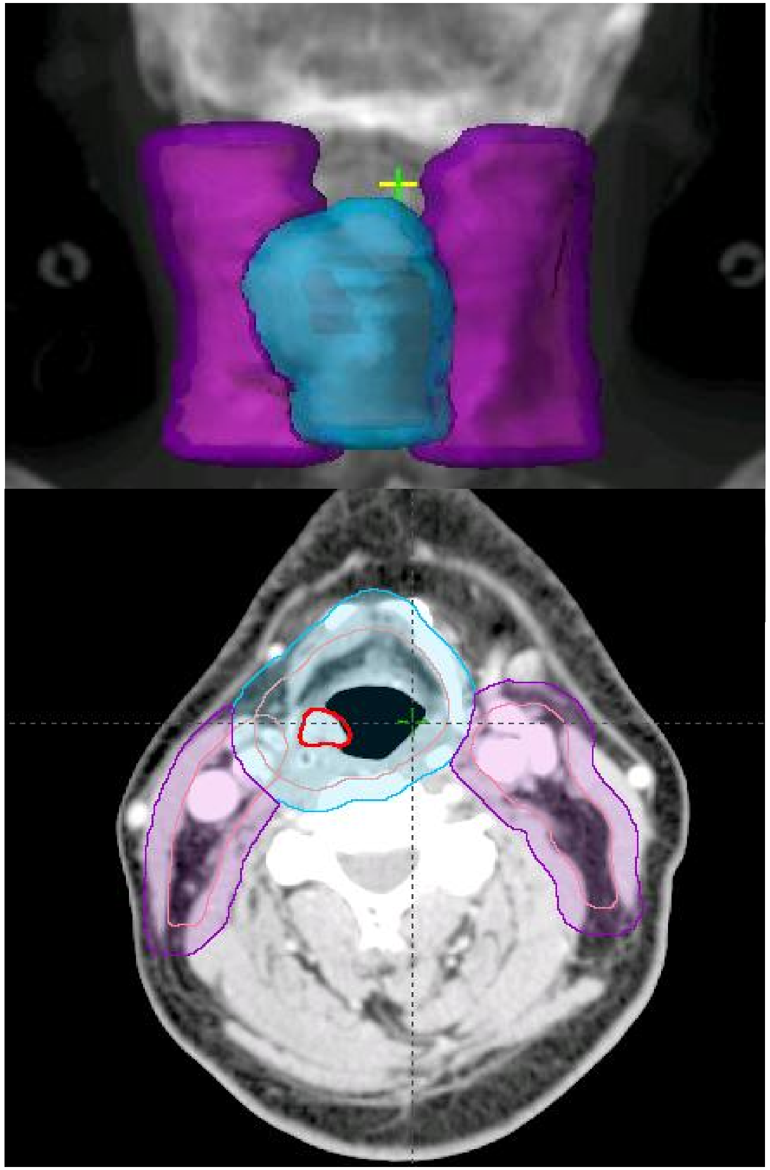
Planning Target Volume (PTV)

The PTV is a geometrical concept

Movements of tissues containing CTV
Movements of patient
Variations in size and shape
Variations in beam geometry characteristics

PTV = CTV + margin for geometrical variations

Aid for treatment planning; dose to PTV representing dose to CTV



CTV with margin forming the PTV

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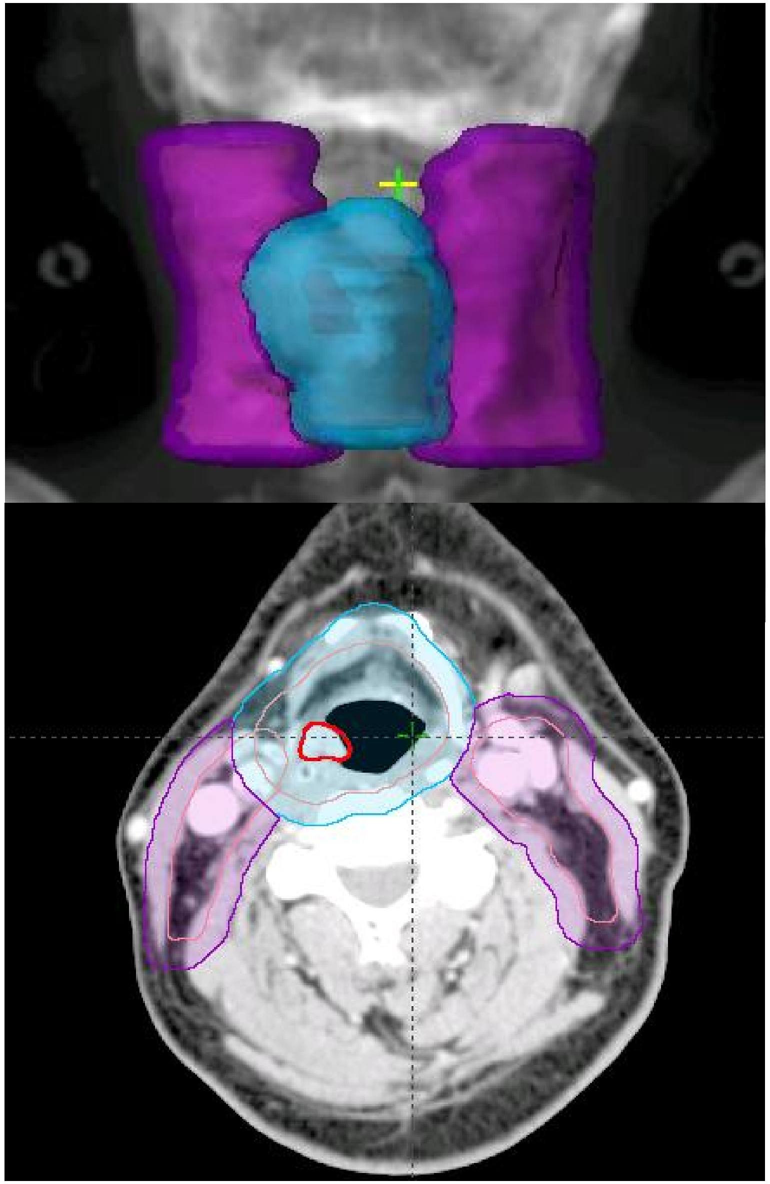
Volumes in ICRU50 - 1993

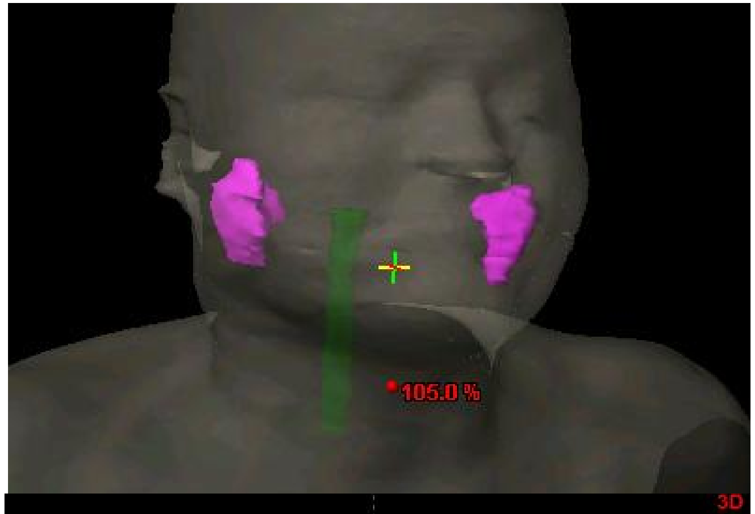


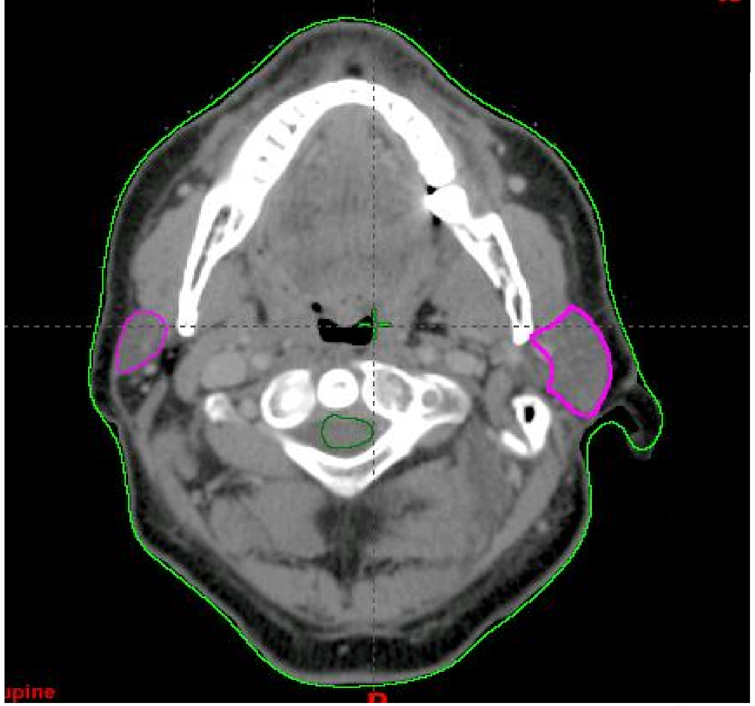
Volumes in ICRU50 - 1993

Organs at risk

The Organs at Risk are normal tissues whose radiation sensitivity may significantly influence treatment planning and/or prescribed dose

"Any possible movement of the organ at as well as uncertainties in the set up must be considered"





Volumes

1978 ICRU29 — **"The Target Volume"** — **Organs at risk**

1993 ICRU50 — **GTV** — **CTV** — **PTV** — **Organs at risk**

Volumes

1978 ICRU29 — **"The Target Volume"** — **Organs at risk**

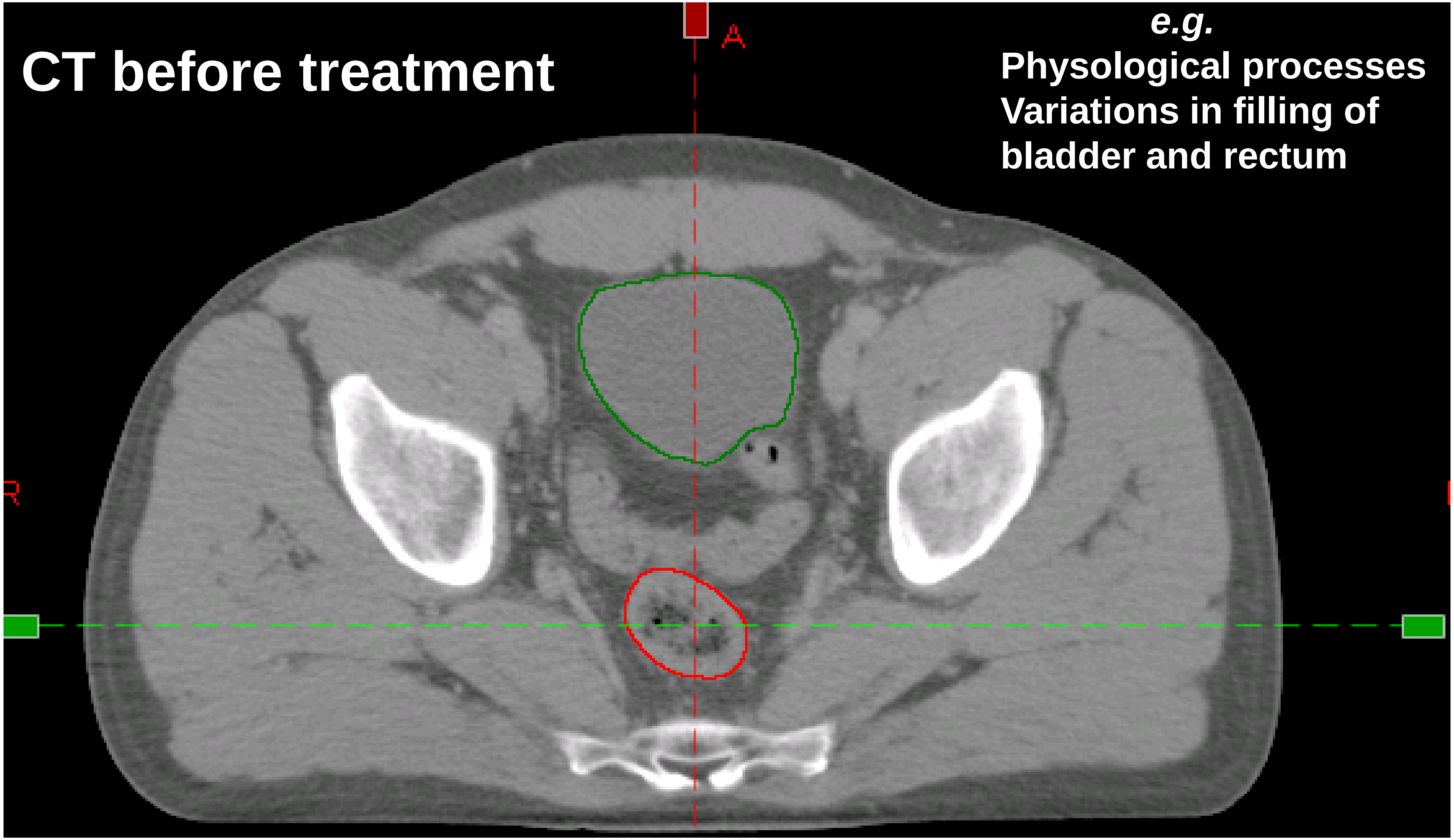
1993 ICRU50 — **GTV** — **CTV** — **PTV** — **Organs at risk**

1999 ICRU62 — ***… a lot of focus on geometrical variations in this time period…***

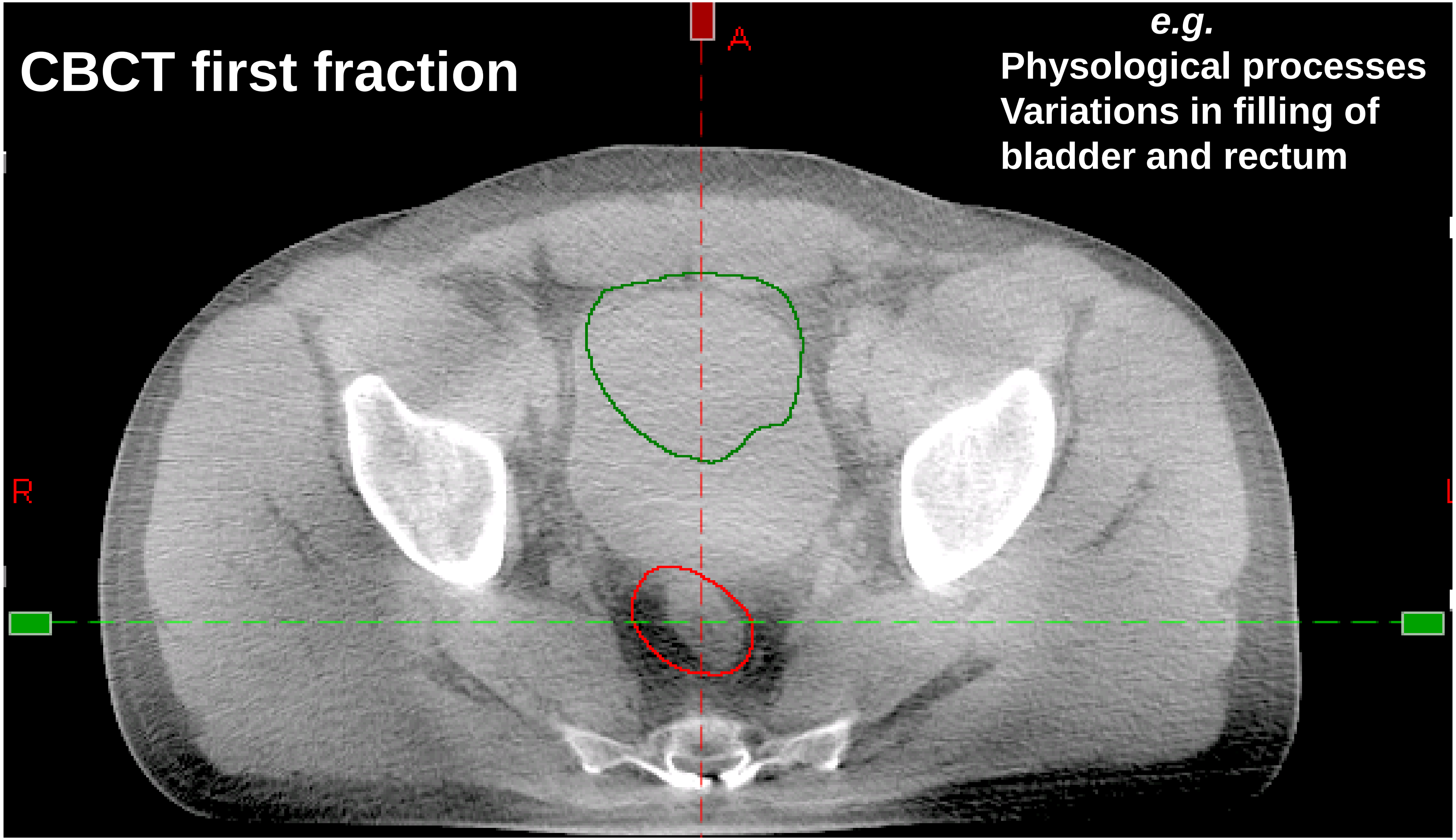
PROBLEM

Structures within a body are not static

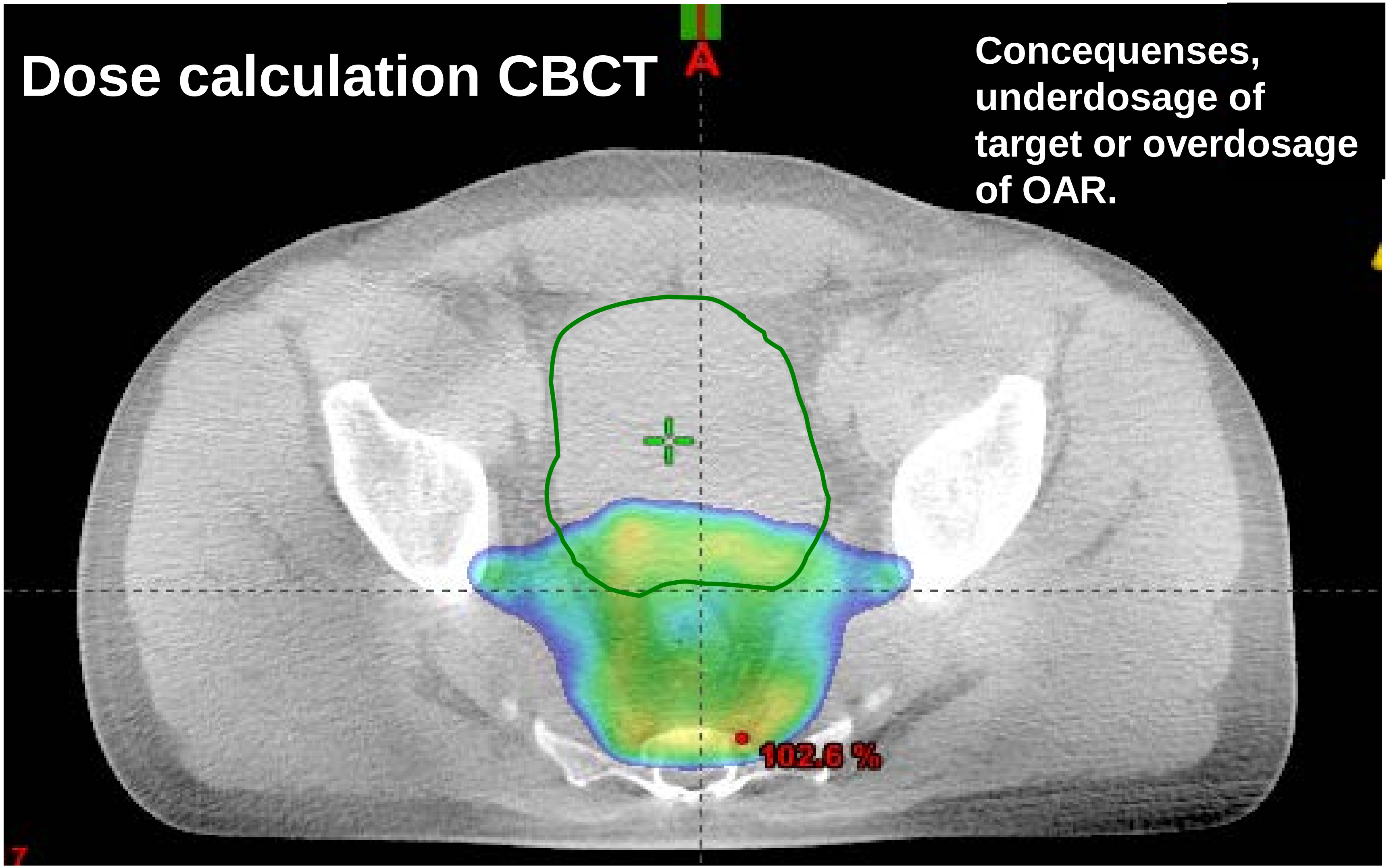
Positional variations



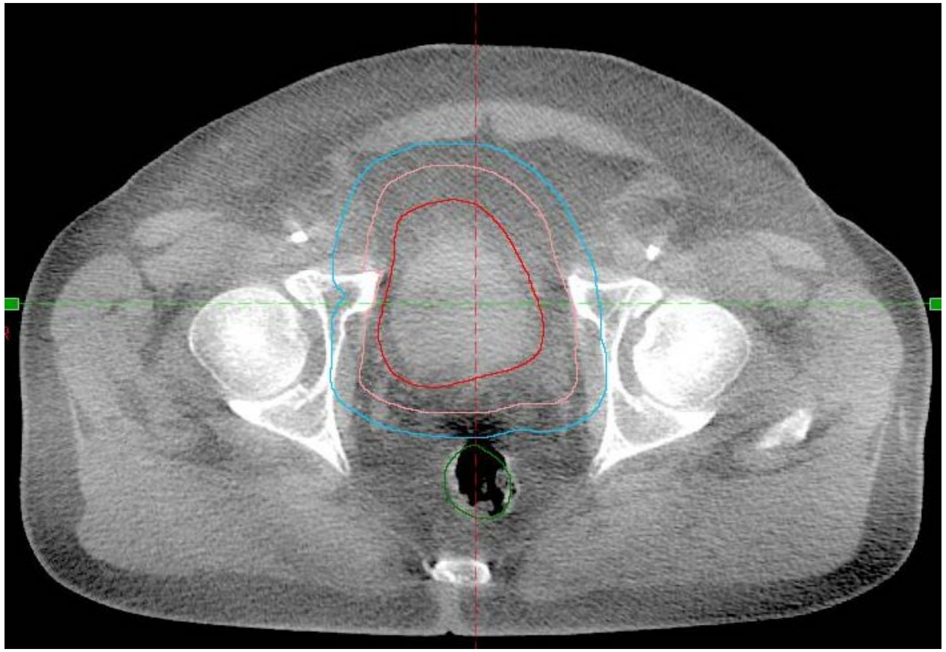
Positional variations



Positional variations



Positional variations



Organs and tumours in the pelvis region moves mainly due to changes in the digestive system and filling of bladder and rectum from day-to-day. Example: prostate, bladder, rectum, cervix.

Mainly inter-fraction positional variation

Typical values (1 SD) are 3 - 5 mm.

IGRT and margin determination: Pelvic treatment (Tuesday)

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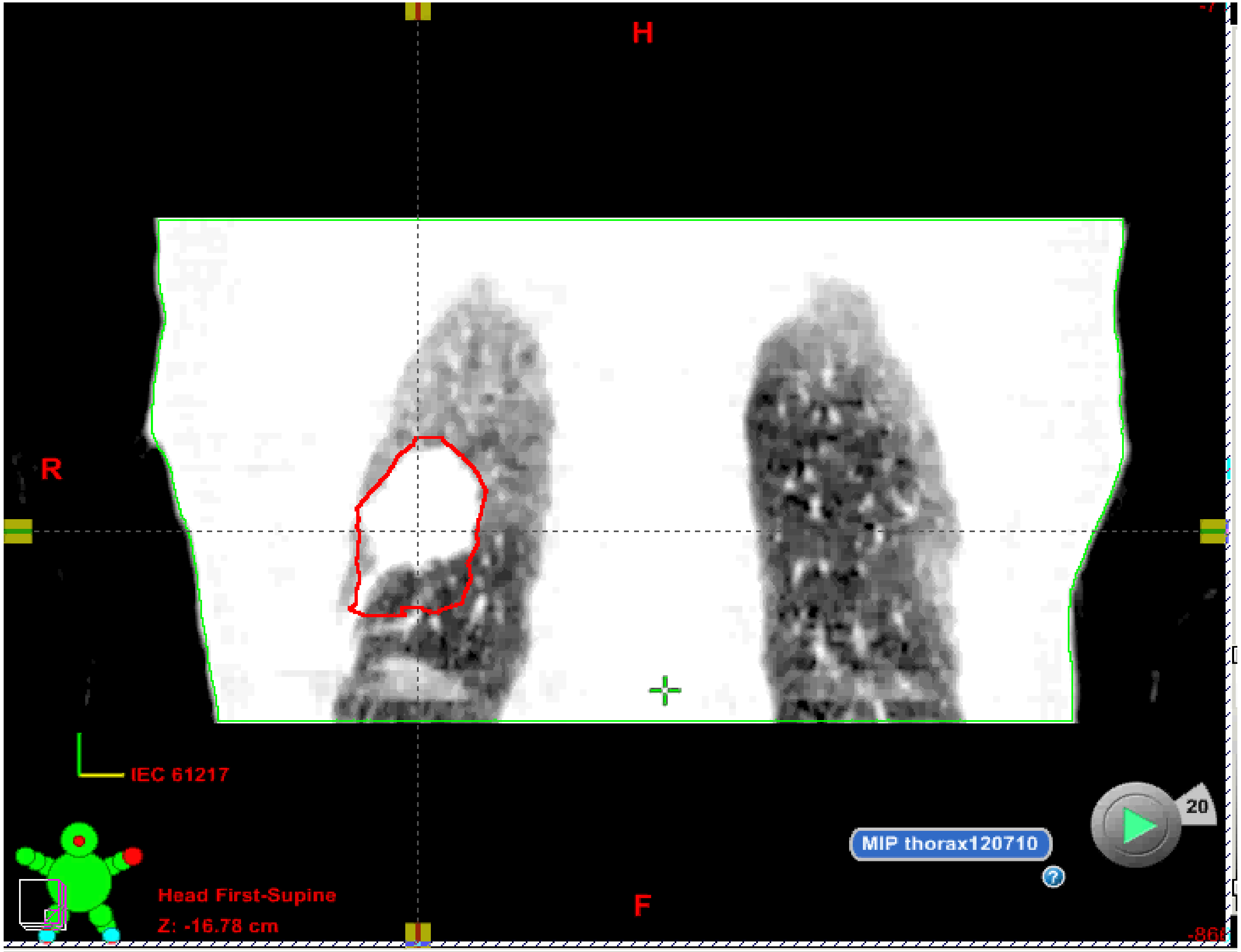
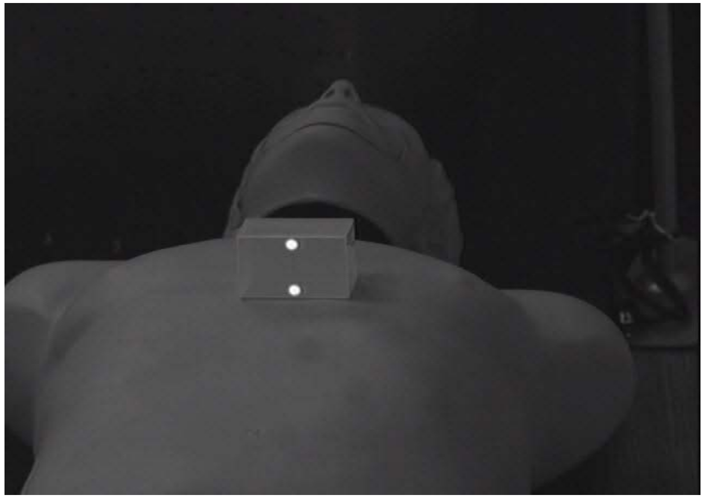
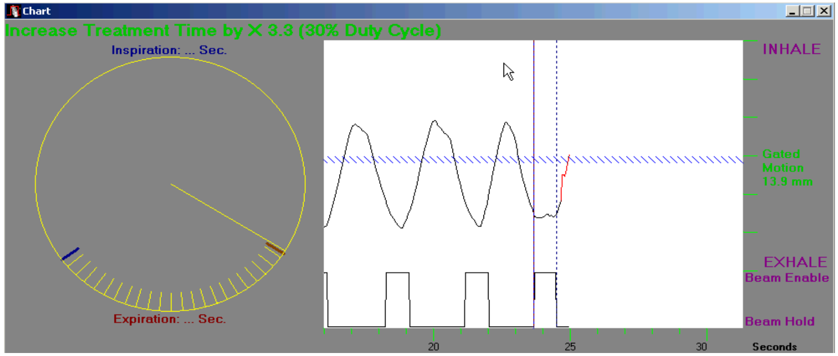
Breathing positional variations



Breathing positional variations





Breathing cycle (3-5 s) – during treatment (intra fraction variation)

Movement of organs and tumours in the abdomen region. Examples: lung tumours, kidneys, liver, breasts.

Example: Diaphragm moves 1 - 4 cm under normal free-breathing conditions. For deep-breathing, the corresponding figure can be 10 cm!

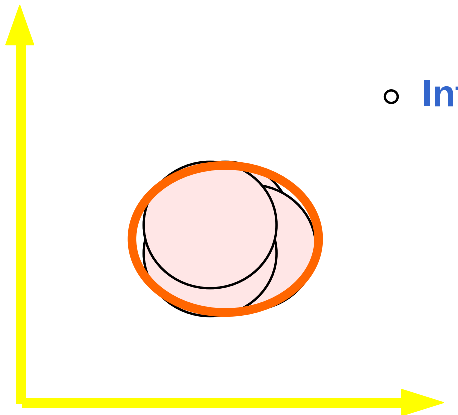
Necessary to quantify organ motion individually for "curative" lung cancer patients

Volumes in ICRU62 - 1999

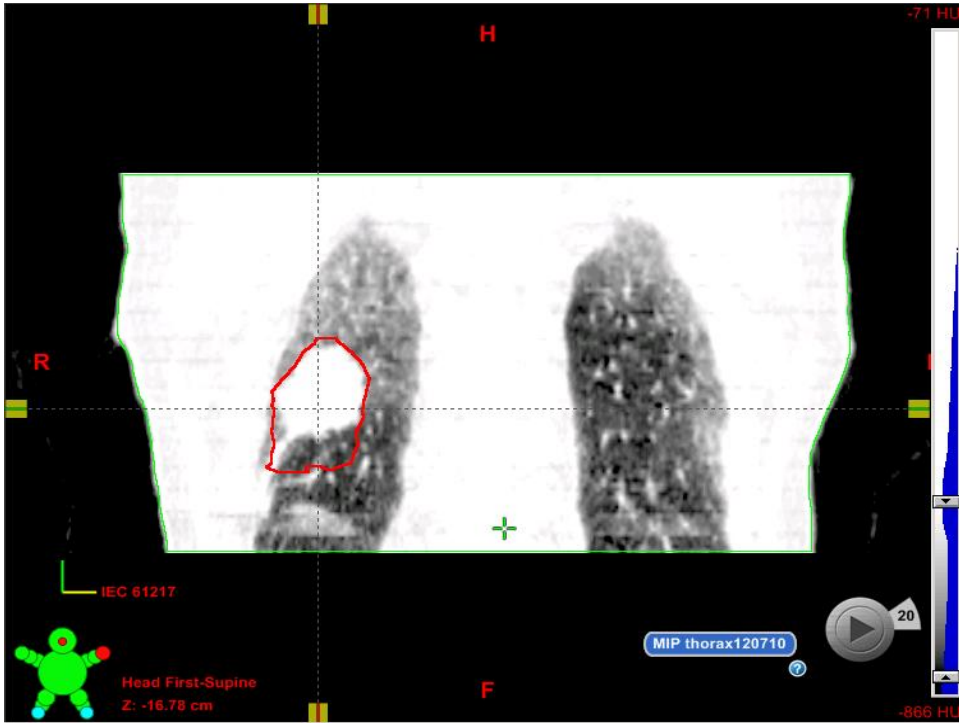
Internal Target Volume (ITV)

CTV with margin added to compensate for expected physiologic movements and variations in size shape and position of CTV in relation to Internal Reference Point.

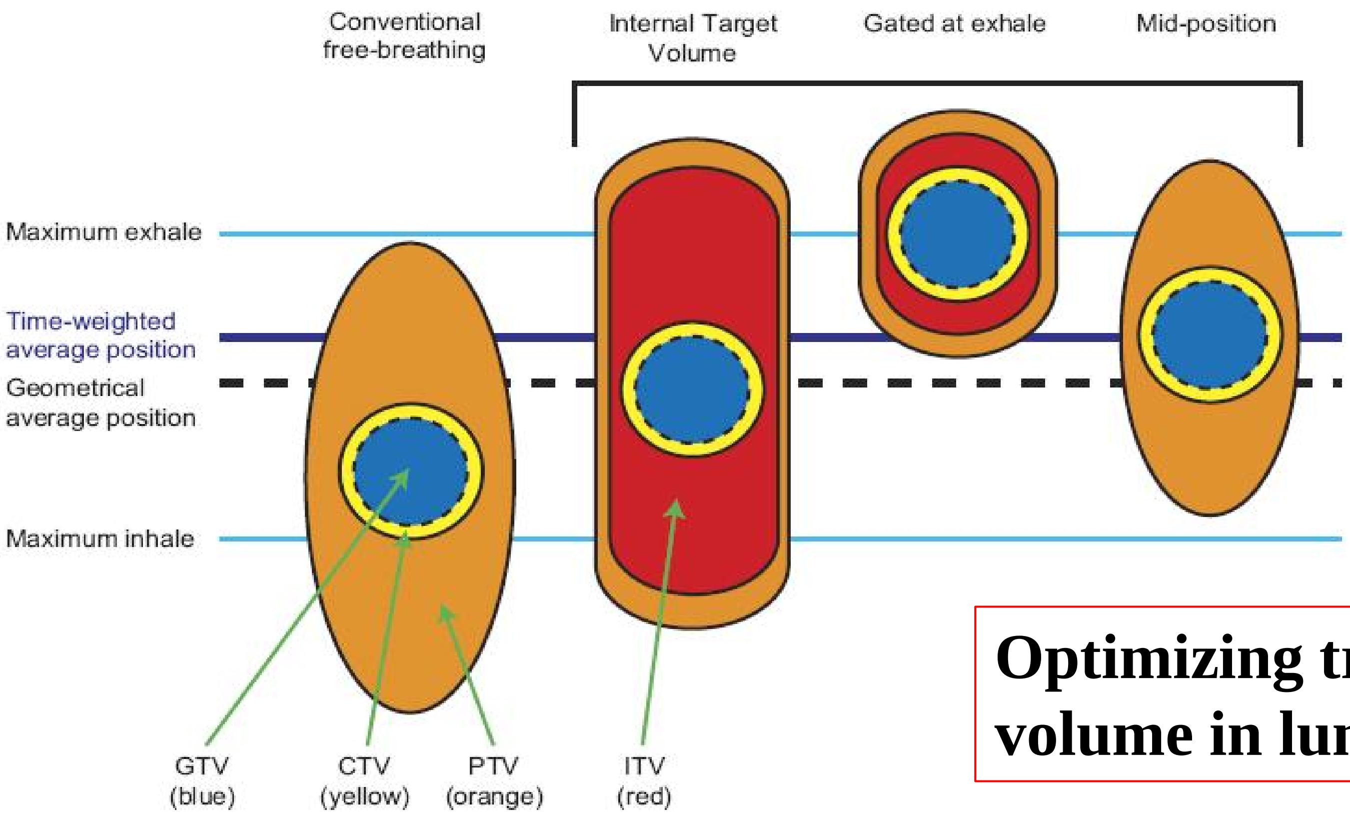
ITV = CTV + IM (Internal Margin)



- Internal reference point



New concepts replacing ITV



Optimizing treatment volume in lung (Thursday)

Fig. 1. Schematic overview of different treatment-planning concepts: conventional free-breathing, internal target volume (ITV), gating (at exhale), and mid-position. GTV = gross tumor volume; CTV = clinical target volume; PTV = planning target volume.

Wolthaus *et al.* Int. J. Radiation Oncology Biol. Phys 70 (4): 1229-1238, 2008

Summary of problem

Extent of geometric variations:

- **abdomen target – mm to cm (intra-fx amplitude)**
- **pelvis target – a few mm (1 SD inter-fx)**

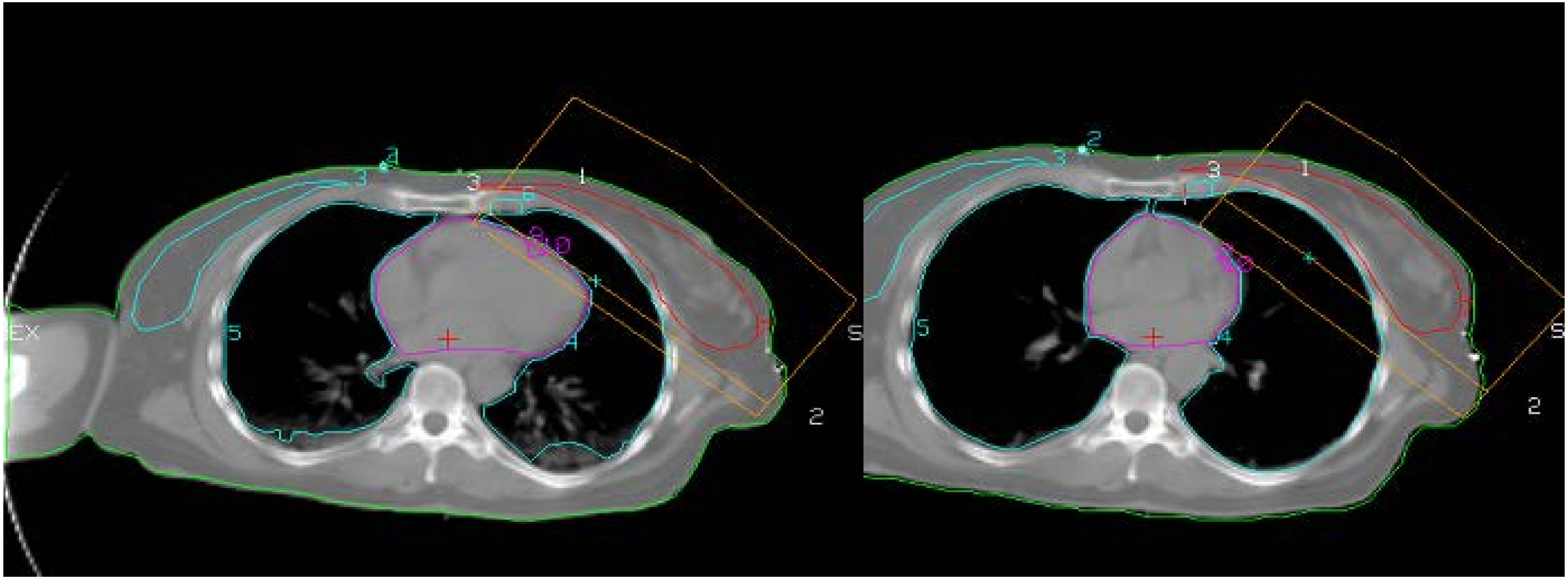
Strategies for dealing with geometric variations in practice:

- **breathing control**
- **real-time tumour tracking**
- **reproducible filling of bladder and rectum**
- **Adaptive treatment**

+ internal margin (IM)

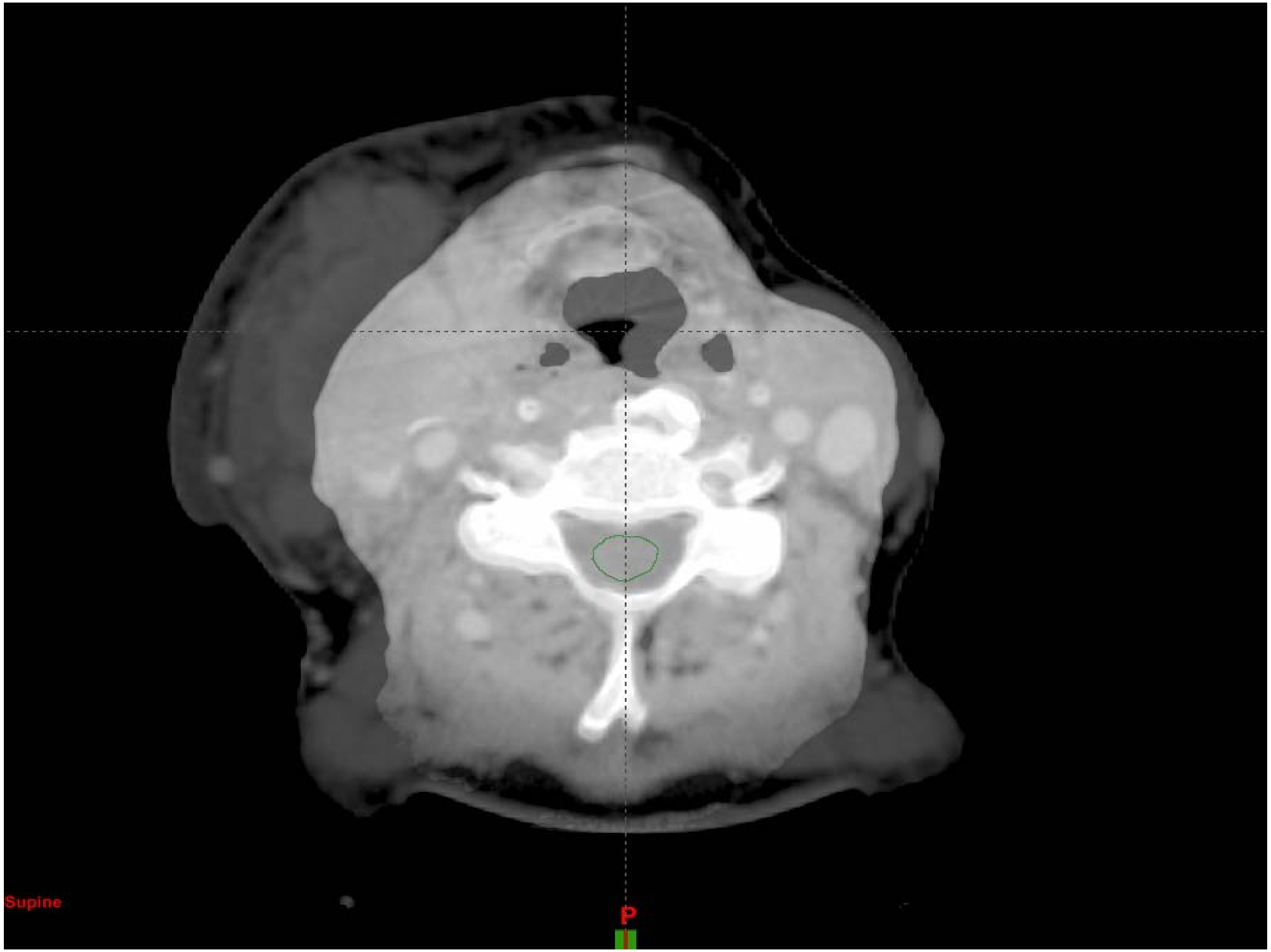
Example breathing control

Expiration | Deep inspiration



IGRT for breast cancer (Wednesday)

Example adaptation

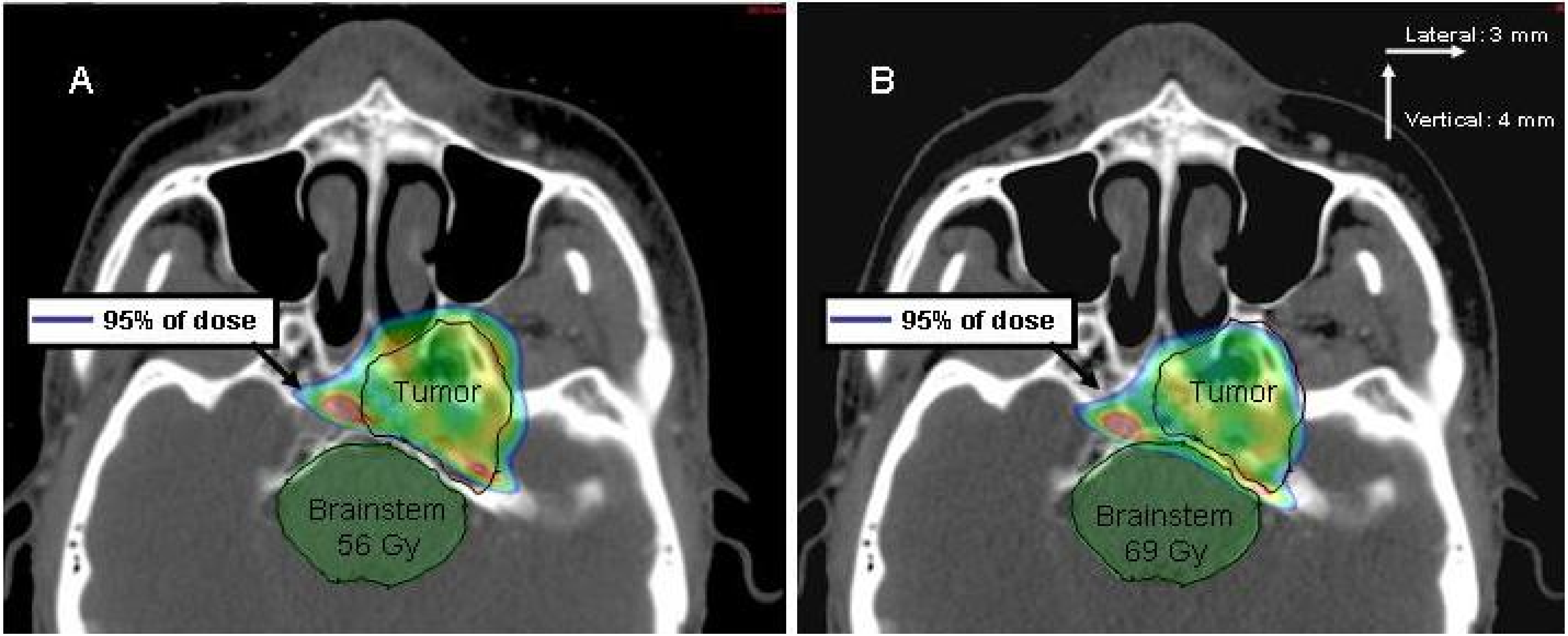


Example H&N patient with tumour shrinkage/weight loss.
Call for adaption?

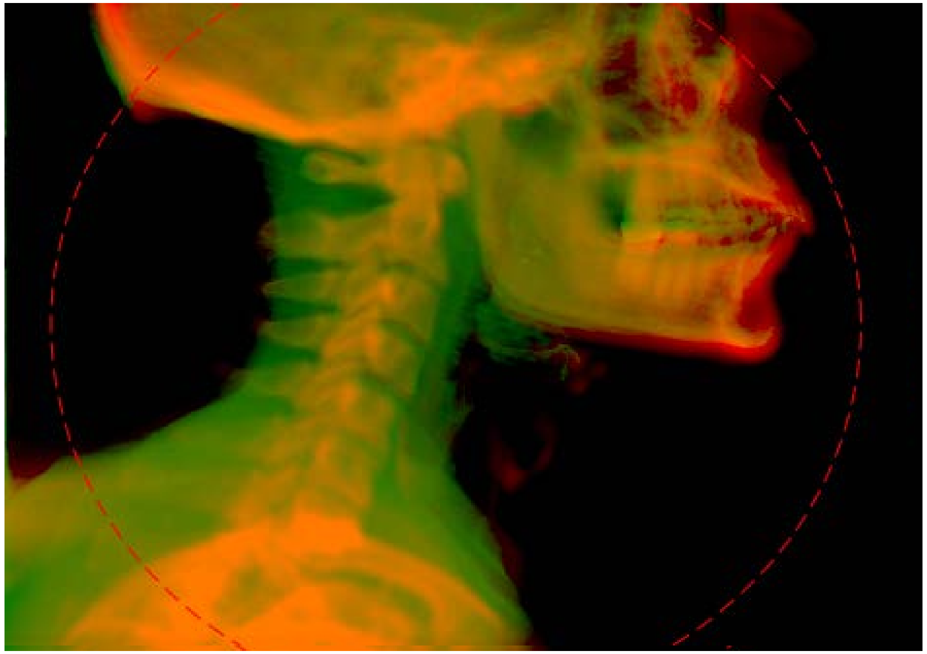
PROBLEM

Setting up the patient and the irradiation fields can not be done identically from day-to-day

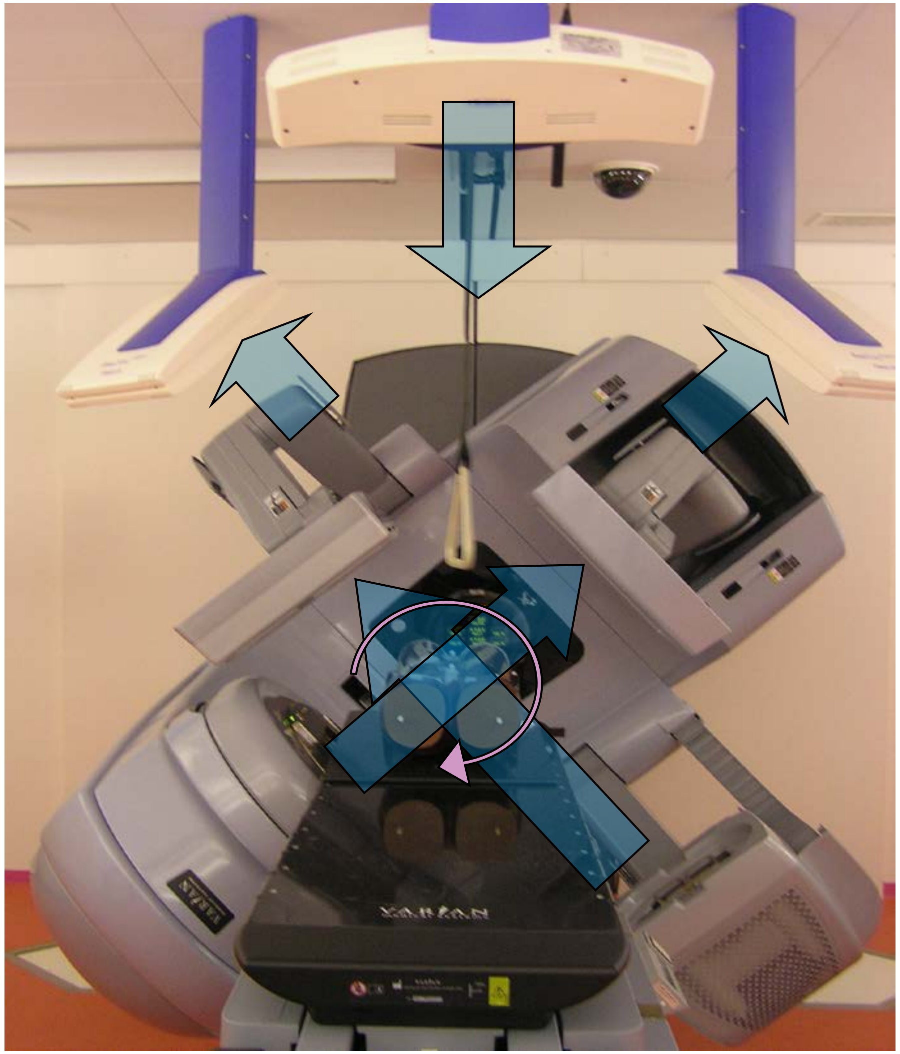
High/Low dose area is moving when set-up of patient is varying



Set-up variations

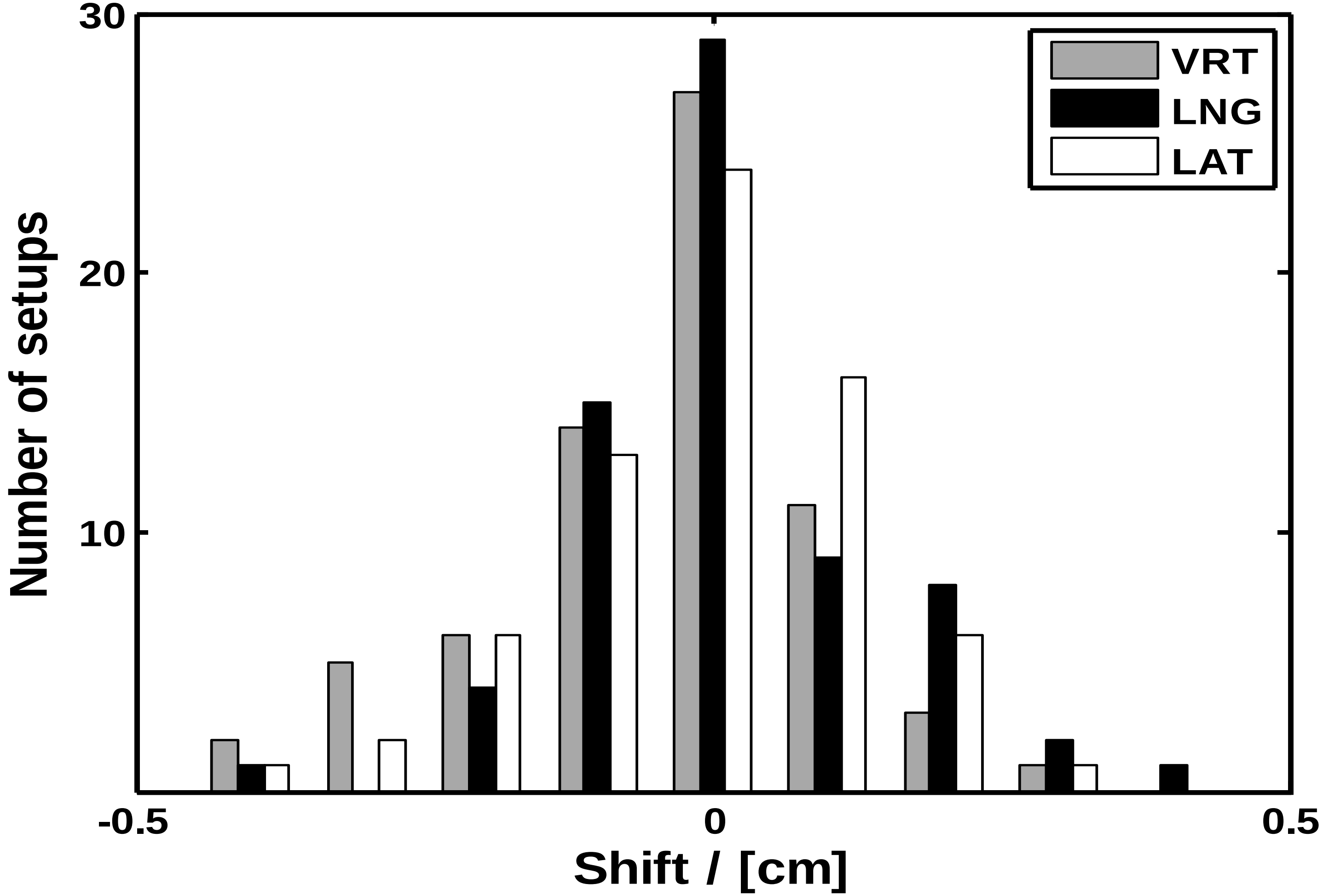


OBI 0 - OBI 270	
	*
Vrt	-0.5
Lat	0.3
Long	0.2
Pitch	-2.2
Roll	0.0
Rot	0.9



Martins IGRT lectures for the different sites (Monday-Thursday) morning lectures)

Set-up variations

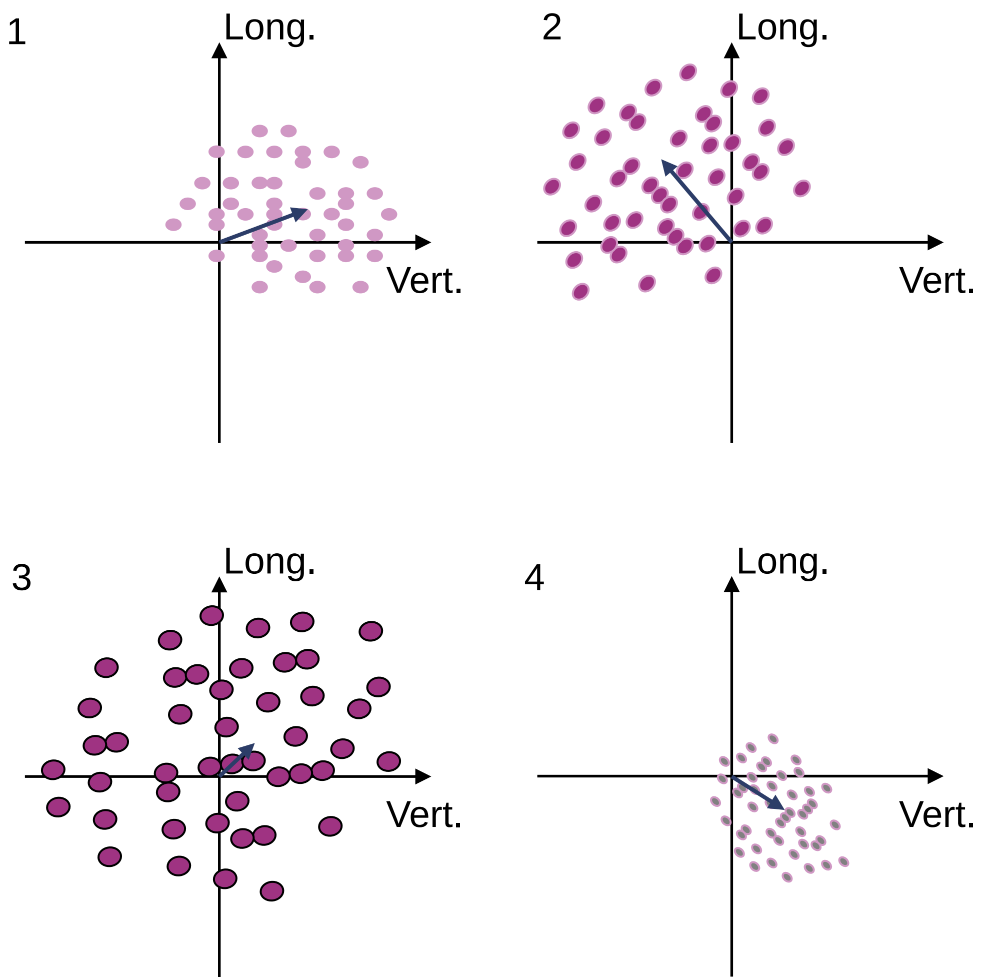


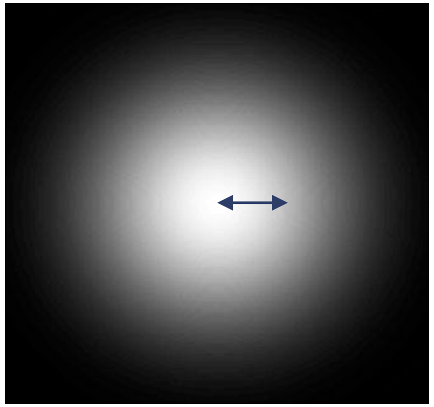
<u>NSCLC setup</u>

W. Ottosson, M. Baker, M. Hedman, C.F Behrens, D Sjöström "Evaluation of setup accuracy for NSCLC studying the impact of different types of cone-beam CT matches on whole thorax, columna vertibralis, and GTV" Acta Oncol. 2010; 49: 1184–1191

Set-up variations

Population Setup Errors

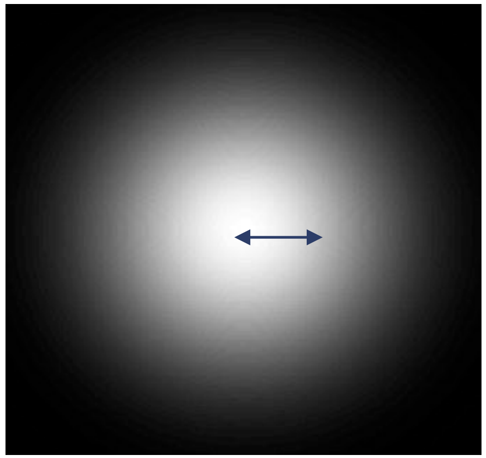




Systematic

Standard Deviation

Σ_{Pop}



Random

Standard Deviation

σ_{Pop}

$$M(CTV \rightarrow PTV) \approx 2.5\Sigma_{Pop} + 0.7\sigma_{Pop}$$

Set-up variations

CTV to PTV margin recipe

Author	Region	Recipe	Comments
Bel *et al.* (1996)	PTV	0.7σ	Statistical uncertainties only (linear approximation)—Monte Carlo.
Antolak and Rosen (1999)	PTV	1.65σ	Statistical uncertainties only, block margin?
Stroom *et al.* (1999a)	PTV	$2\,\Sigma + 0.7\sigma$	95 % absorbed dose to on average 99 % of CTV tested in realistic plans.
van Herk *et al.* (2000)	PTV	$2.5\,\Sigma + 0.7\,\sigma$ (or more correctly): $2.5\Sigma + 1.64\,(\sigma - \sigma_e)$	Minimum absorbed dose to CTV is 95 % for 90% of patients. Analytical solution for perfect conformation.
McKenzie (2000)	PTV	$2.5\,\Sigma + \beta + (\sigma - \sigma_e)$	Extension of van Herk *et al.* (2000) for fringe dose due to limited number of beams. The factor β depends on the beam organization.
Parker *et al.* (2002)	PTV	$\Sigma + \sqrt{(\sigma^2 + \Sigma^2)}$	95 % minimum absorbed dose and 100 % absorbed dose for 95 % of volume. Probability levels not specified.
van Herk *et al.* (2002)	PTV	$2.5 + \Sigma + 0.7\sigma + 3$ mm (or more correctly): $\sqrt{2.7^2\Sigma^2 + 1.6^2\sigma^2} - 2.8$ mm	Monte Carlo based test of 1 % TCP loss due to geometrical errors for prostate patients, fitted for various σ and Σ.
Ten Haken *et al.* (1997), Engelsman *et al.* (2001a, 2001b)	PRV (liver and lung)	0	No margin for respiration, but compensation by absorbed-dose escalation to iso-NTCP, reducing target-dose homogeneity constraints.
McKenzie *et al.* (2000)	PRV	A	Margin for respiration on top of other margins when respiration dominates other uncertainties.
van Herk *et al.* (2003)	PRV (lung)	$0.25\,A$ (caudally); $0.45\,A$ (cranially)	Margin for (random) respiration combined with random setup error of 3 mm SD, when respiration dominates other uncertainties ($A > 1$ cm).
McKenzie *et al.* (2002)	PRV	$1.3\,\Sigma \pm 0.5\,\sigma$	Margins for small and/or serial organs at risk in low (+) or high (−) absorbed-dose region.

Symbols: Σ, standard deviation of systematic uncertainties; σ, standard deviation of statistical (random) uncertainties; σ_e, describes width of beam penumbra fitted with a Gaussian function; A, peak-to-peak amplitude of respiration.

ICRU Report No.83 (2010)

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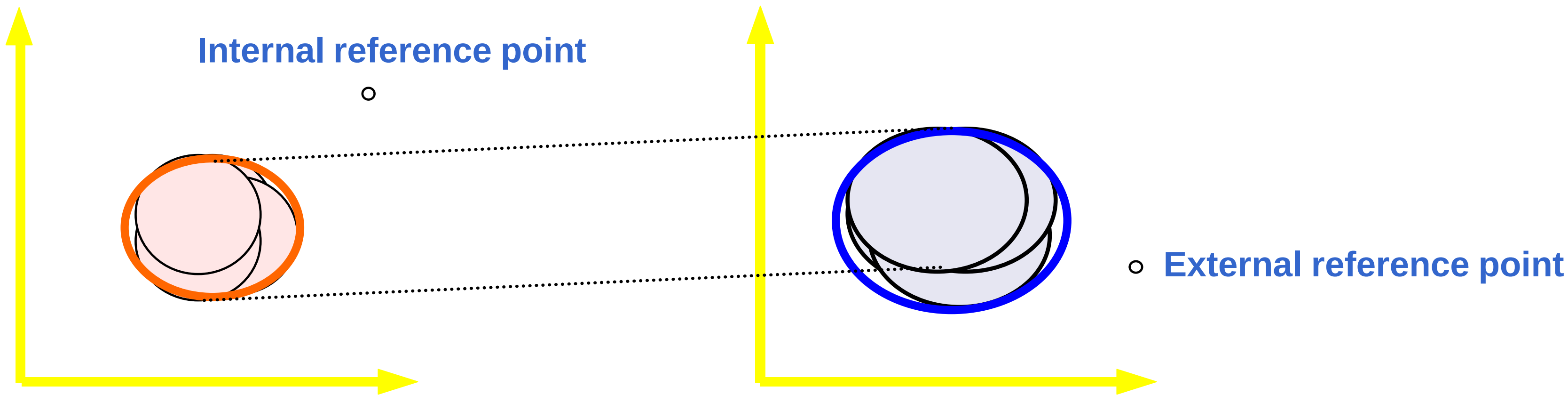
Volumes in ICRU62 - 1999

Planning Target Volume (PTV)

ITV with margin added to compensate for external geometric uncertainties in relation to External Reference Point.

PTV = ITV + SM (Set-up Margin)



Summary of problem

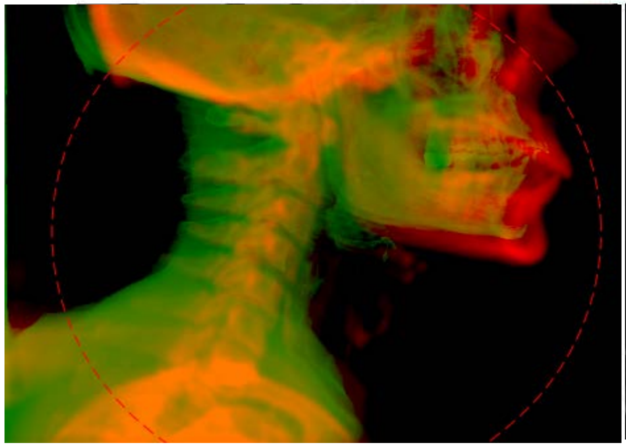
Extent of geometric variations:

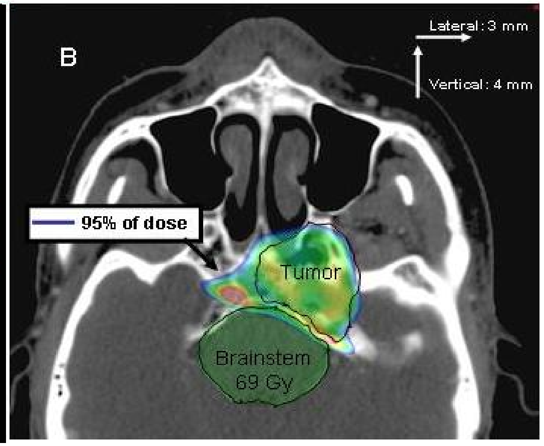
- **often a few mm (1 SD inter-fx)**

Strategies for dealing with geometric variations in practice:

- **fixation**
- **off-line portal imaging with decision rule protocols**
- **on-line portal imaging**
- **IGRT**

+ set-up margin (SM)





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Example IGRT

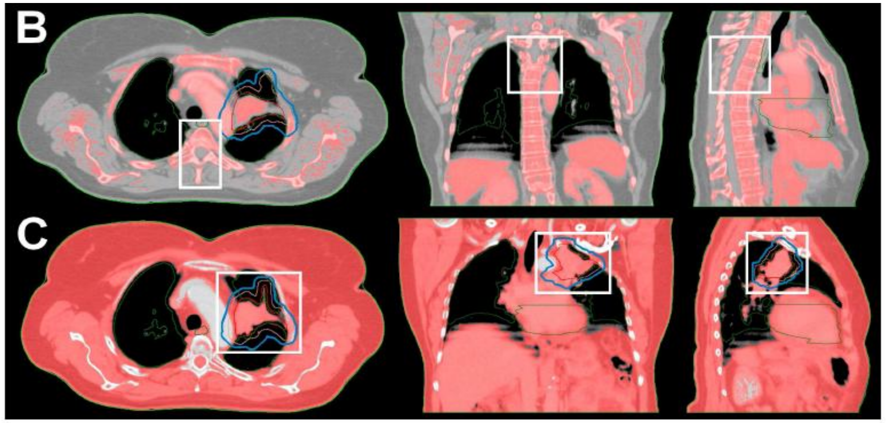

Table 2. Summary of the calculated CTV to PTV margins.

	CBCT IGRT				*2D kV planar IGRT*	*Non--IGRT*	
	CV / ST		*WT / ST*		*CV (2D) / ST*	*Tattoo / ST*	*Tattoo / CV*
DOF	*3 / 6*	*6 / 6*	*3 / 6*	*6 / 6*	*3 / 6*	*3 / 6*	*3 / 6*
VRT / [cm]	0.4	0.4	0.4	0.3	0.4	0.7	0.9
LNG / [cm]	0.4	0.2	0.6	0.5	0.3	1.0	1.0
LAT / [cm]	0.3	0.2	0.2	0.2	0.3	0.6	0.6

Ottosson et al. “Evaluation of setup accuracy for NSCLC studying the impact of different types of cone-beam CT matches on whole thorax, columna vertibralis, and GTV” Acta Oncol. 2010; 49: 1184–1191

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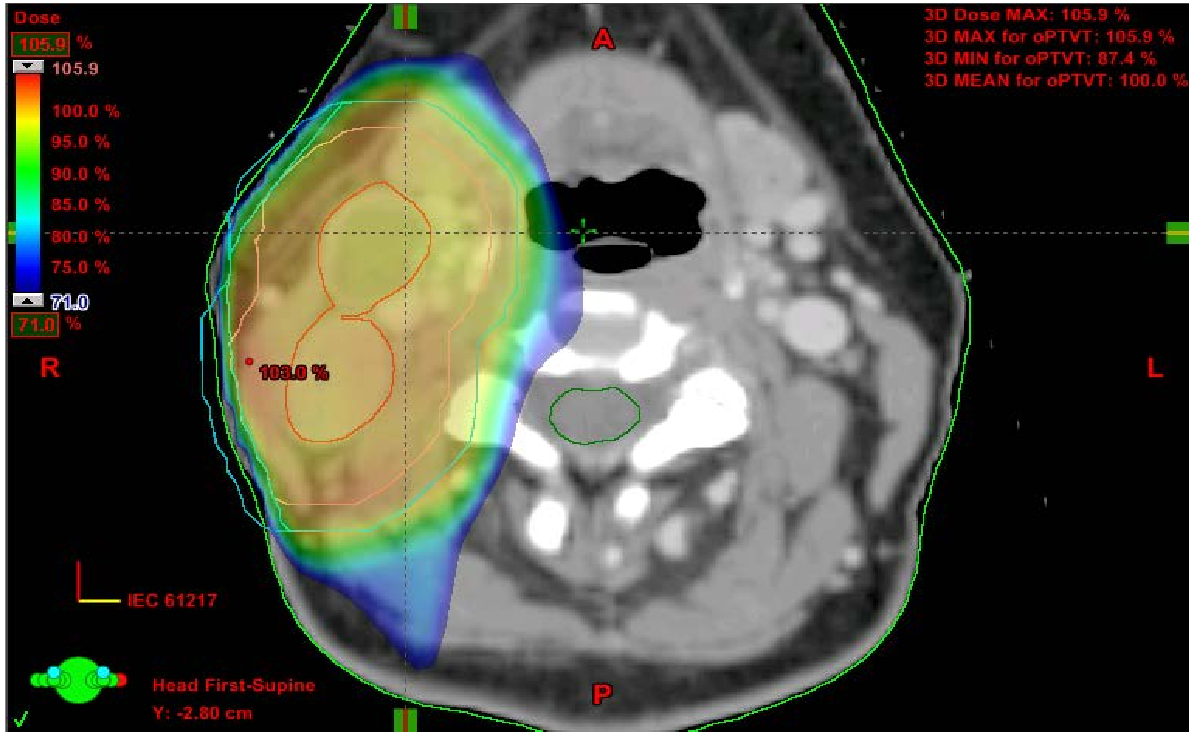
Volumes in ICRU62 - 1999

Organ at Risk (OR)

Organs at Risk are normal tissues whose radiation sensitivity may significantly influence treatment planning and/or prescribed dose.



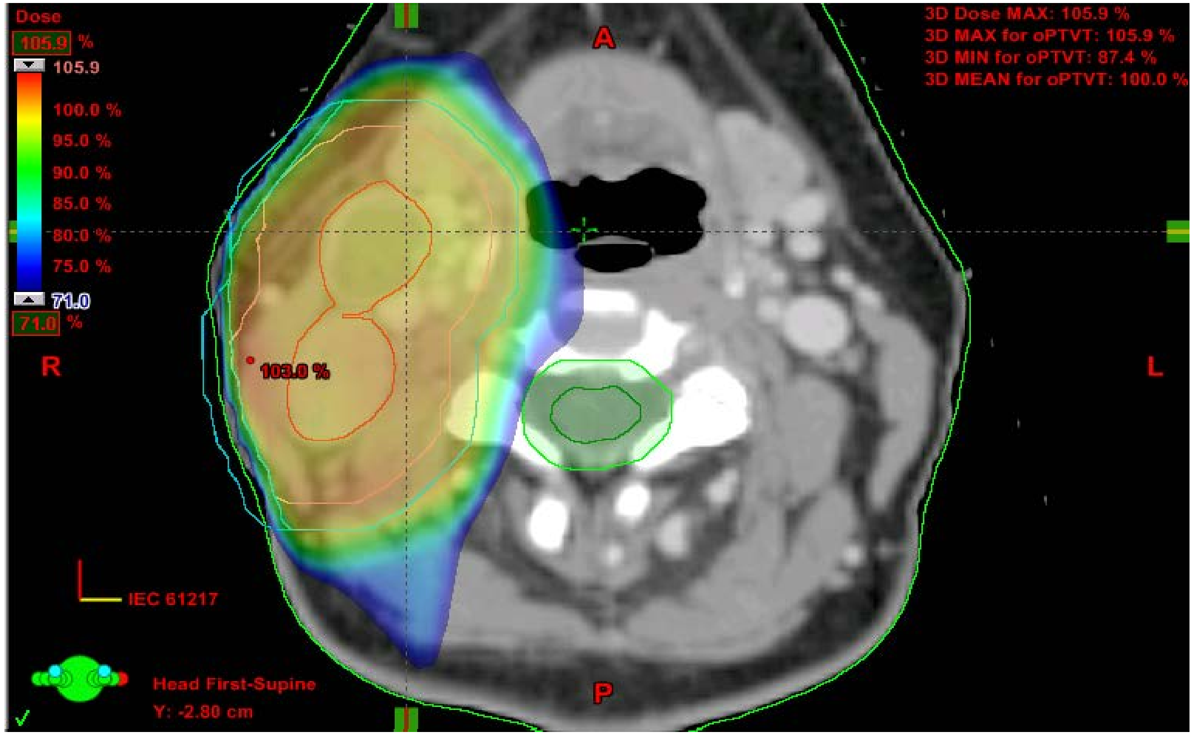
Volumes in ICRU62 - 1999

Organ at Risk (OR)

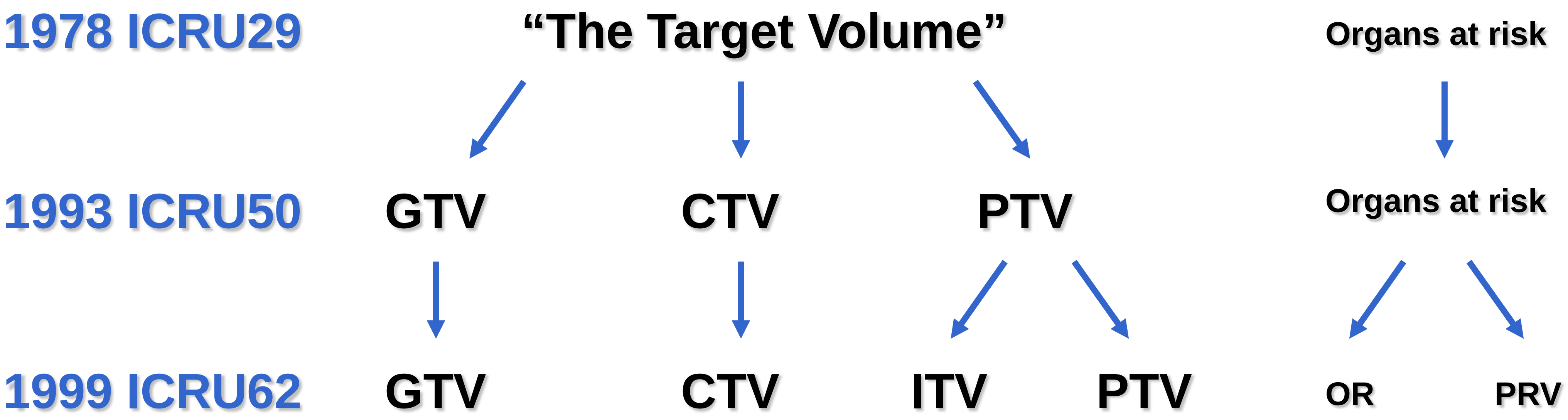
Organs at Risk are normal tissues whose radiation sensitivity may significantly influence treatment planning and/or prescribed dose.

Planning Organ at Risk Volume (PRV)

The PRV is the OR with an integrated geometric margin added, in analogue with the CTV-to-PTV expansion.



Volumes


1978 ICRU29
"The Target Volume"
Organs at risk
1993 ICRU50
GTV
CTV
PTV
Organs at risk
1999 ICRU62
GTV
CTV
ITV
PTV
OR
PRV

Volumes

1978 ICRU29 — **"The Target Volume"** — **Organs at risk**

1993 ICRU50 — **GTV** — **CTV** — **PTV** — **Organs at risk**

1999 ICRU62 — **GTV** — **CTV** — **ITV** — **PTV** — **OR** — **PRV**

2004 ICRU71

Volumes

1978 ICRU29	**"The Target Volume"**				**Organs at risk**	
1993 ICRU50	**GTV**	**CTV**	**PTV**		**Organs at risk**	
1999 ICRU62	**GTV**	**CTV**	**ITV**	**PTV**	**OR**	**PRV**
	GTV-T	**CTV-T**	**(ITV)**	**PTV-T**		
2004 ICRU71	**GTV-N**	**CTV-N**		**PTV-N**	**OAR**	**PRV**
	GTV-M	**CTV-M**		**PTV-M**		

Volumes

1978 ICRU29	**"The Target Volume"**				**Organs at risk**	
1993 ICRU50	**GTV**	**CTV**		**PTV**	**Organs at risk**	
1999 ICRU62	**GTV**	**CTV**	**ITV**	**PTV**	**OR**	**PRV**
	GTV-T	**CTV-T**	**(ITV)**	**PTV-T**		
2004 ICRU71	**GTV-N**	**CTV-N**		**PTV-N**	**OAR**	**PRV**
	GTV-M	**CTV-M**		**PTV-M**		

…ICRU…

… variations in delineation …

… a lot of work on imaging …

… "dose sculpting" is more readily done …

… the "dose-bath" might be a problem …

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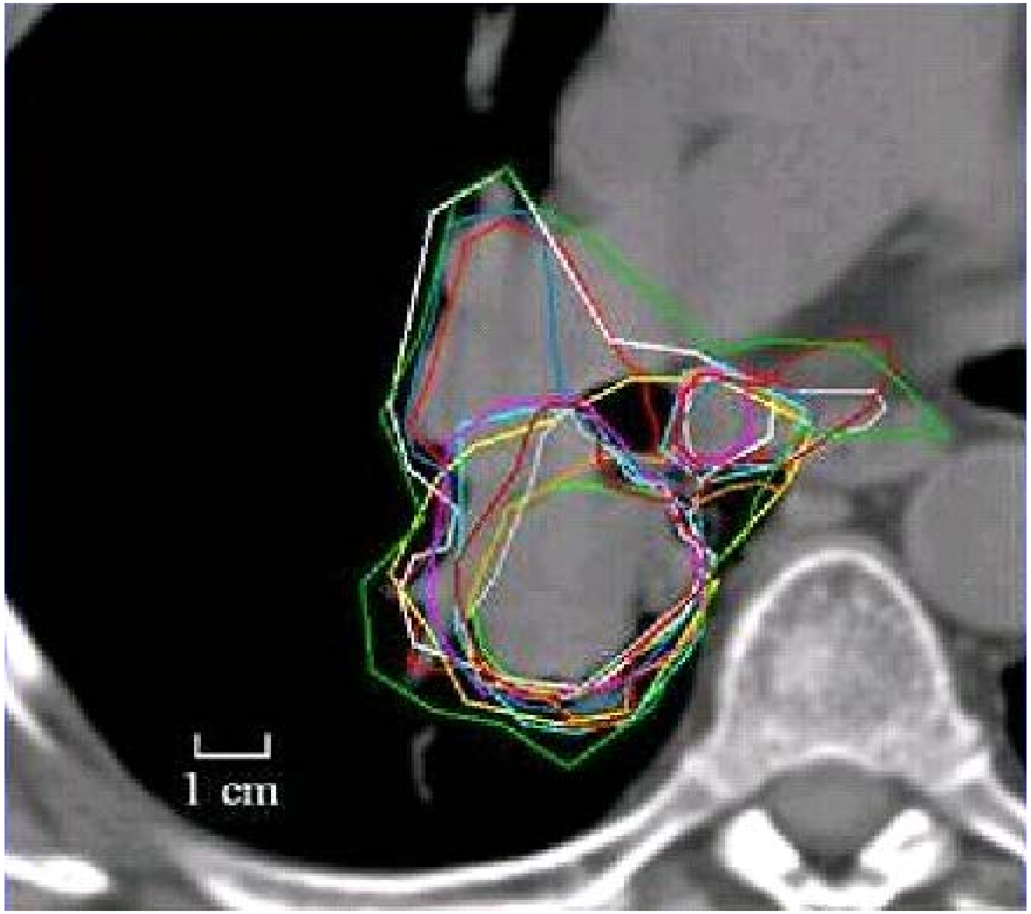
PROBLEM

Target-location might shift, depending on who is delineating it

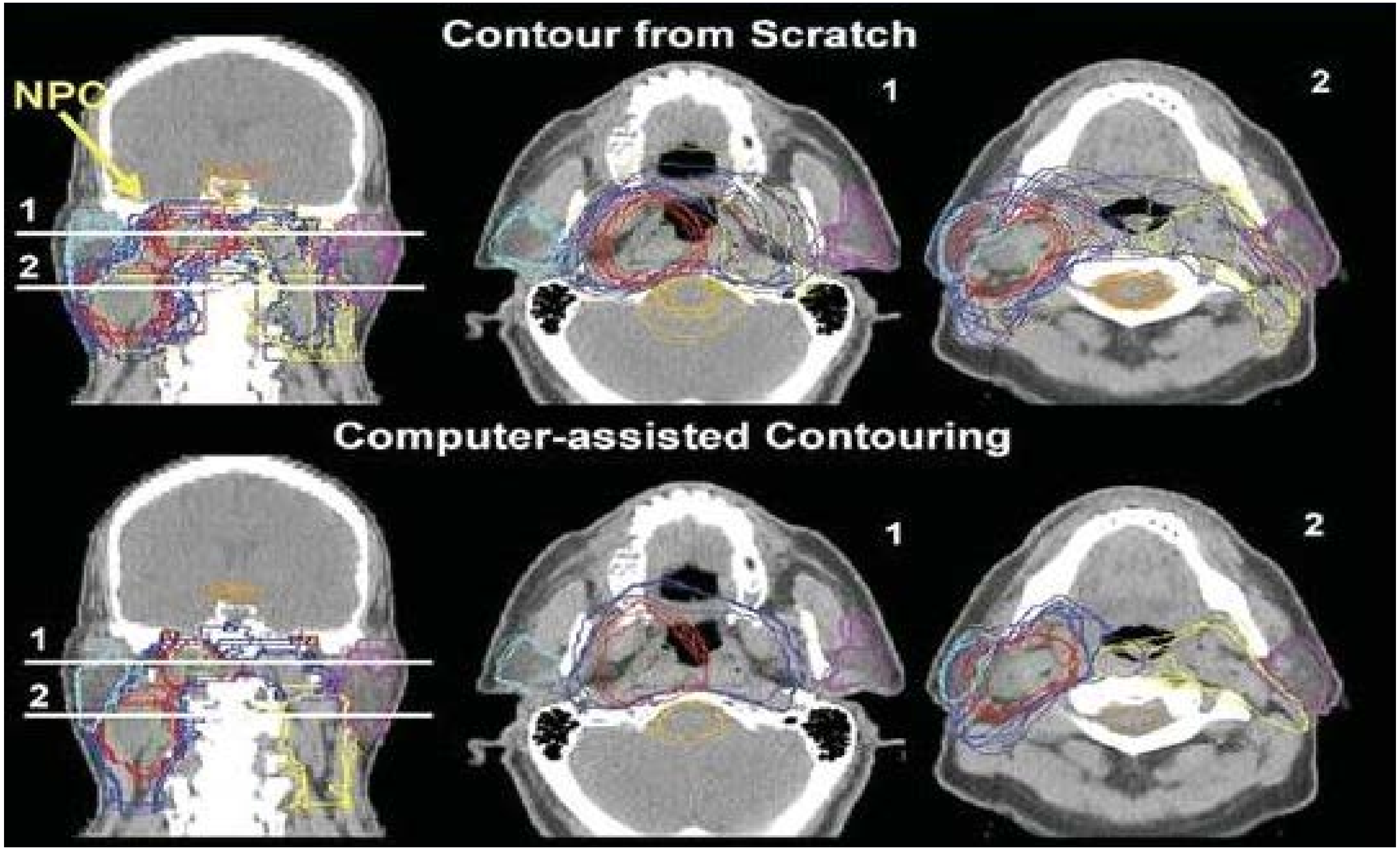
Target-location might shift, depending on who is delineating it



Stenbakkers *et al.* Int J Radiat Oncol Biol Phys 2005

DELINEATION WORKSHOPS (MONDAY&WEDNESDAY)

Target-location might shift, depending on who is delineating it

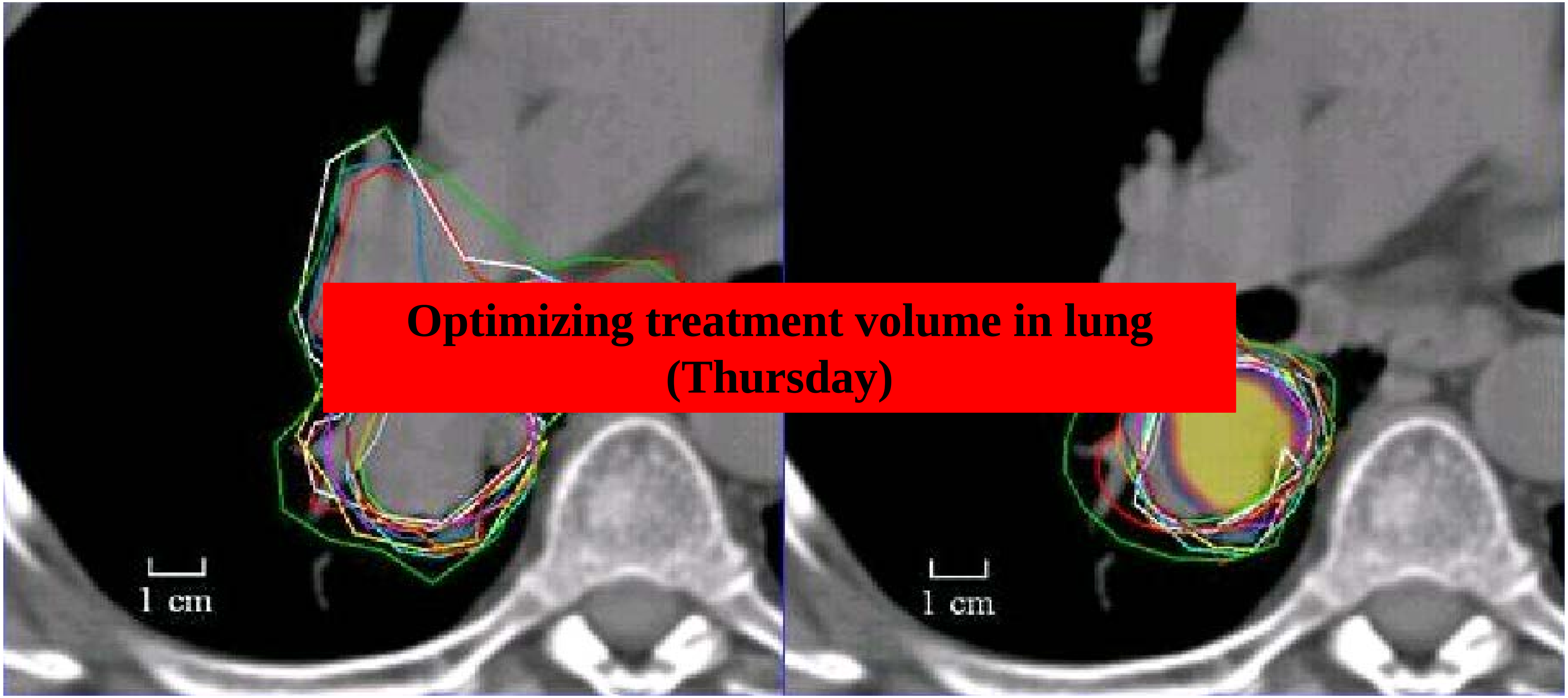


KC Chao *et al.* Int J Radiat Oncol Biol Phys 68(5):2007

PROBLEM

Target-location might shift, depending on imaging modality

Target-location might shift, depending on who is delineating it and imaging modality

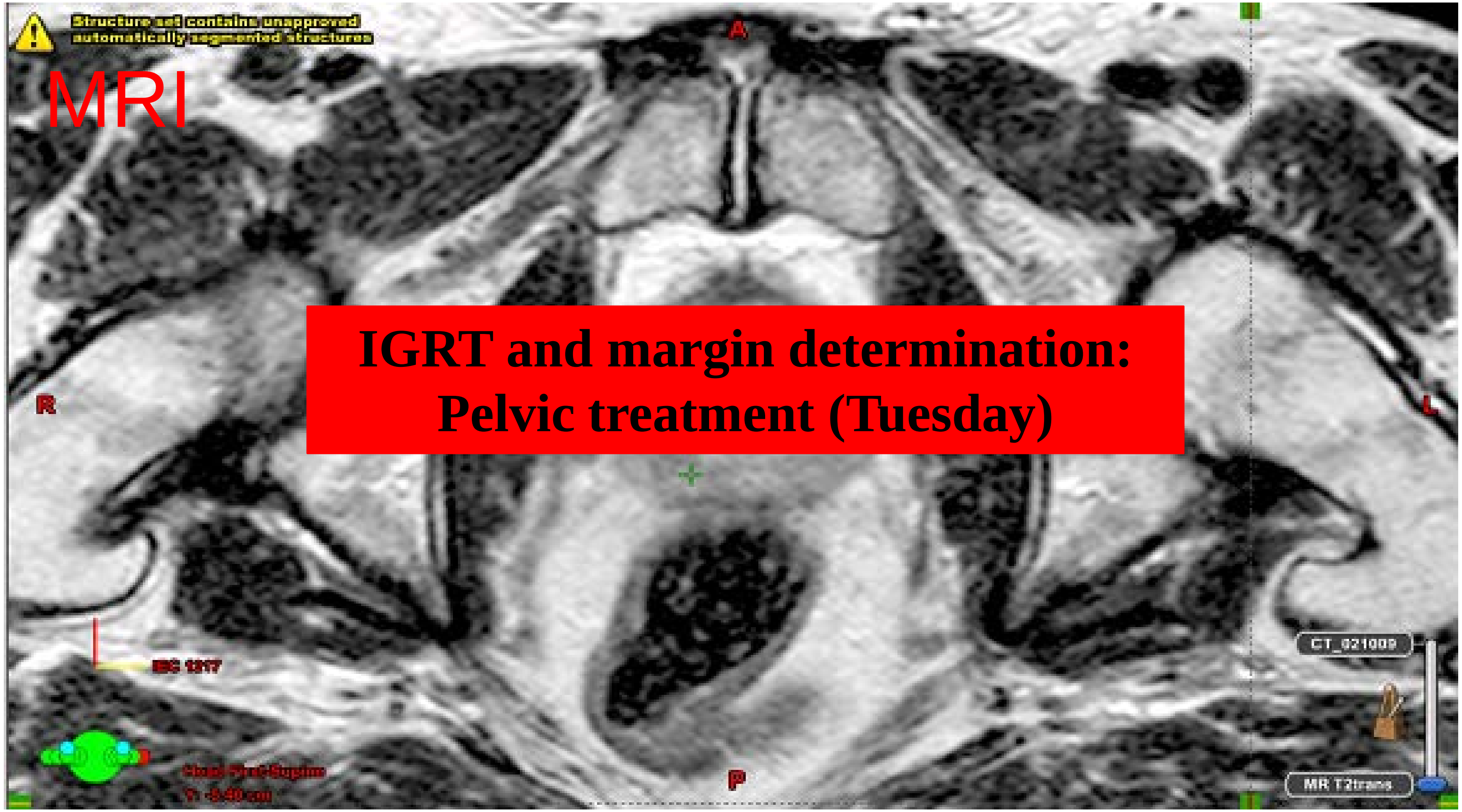


Optimizing treatment volume in lung (Thursday)

Stenbakkers *et al.* Int J Radiat Oncol Biol Phys 2005

Target-location might shift, depending on imaging modality

Target-location might shift, depending on imaging modality



IGRT and margin determination: Pelvic treatment (Tuesday)

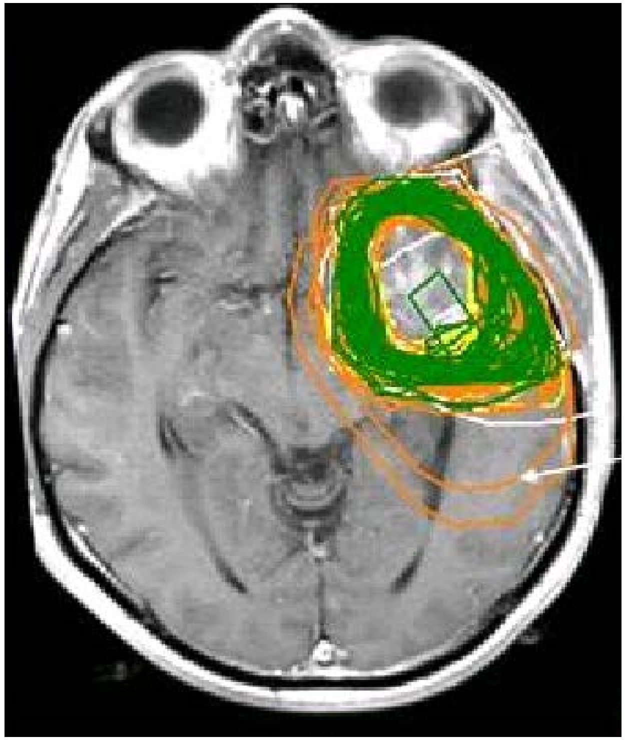
Summary of problem

Extent of geometric variations:

- **Delineation variation the largest geometrical variation in radiotherapy – often cm**

Strategies for dealing with geometric variations in practice:

- **radiologists input in GTV delineation**
- **use optimal imaging modalities**
- **e.g. contrast**
- **workshops/audits**
- **Autocontouring (?)**

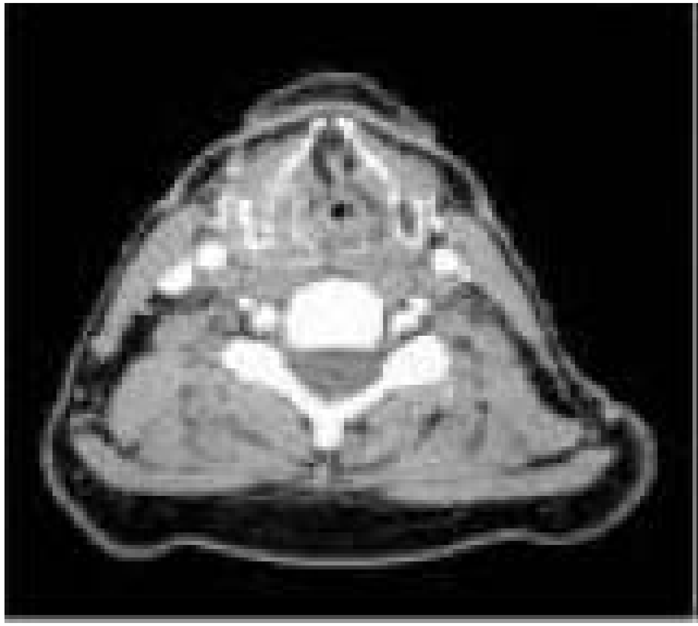


ICRU: "The uncertainty in the delineation *(of GTV and CTV)* should be included in margin considerations"

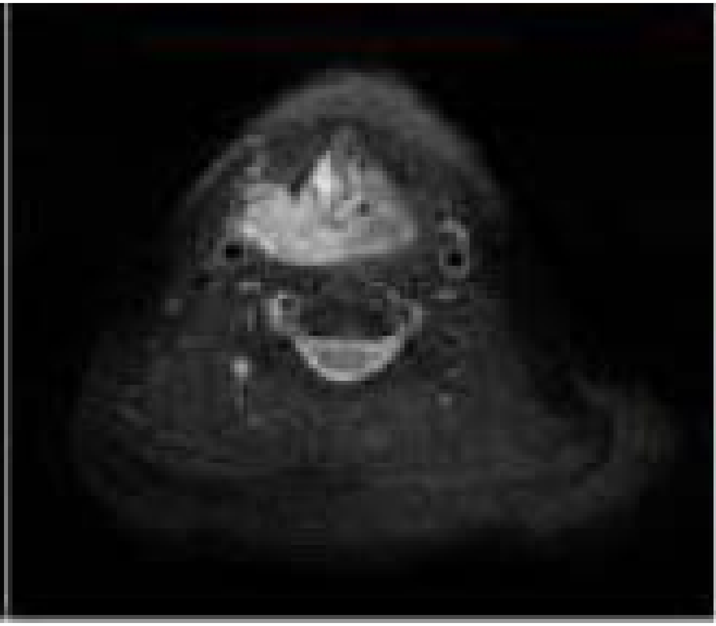
Volumes in ICRU78 and ICRU83

Definition of volumes depends on the imaging modality

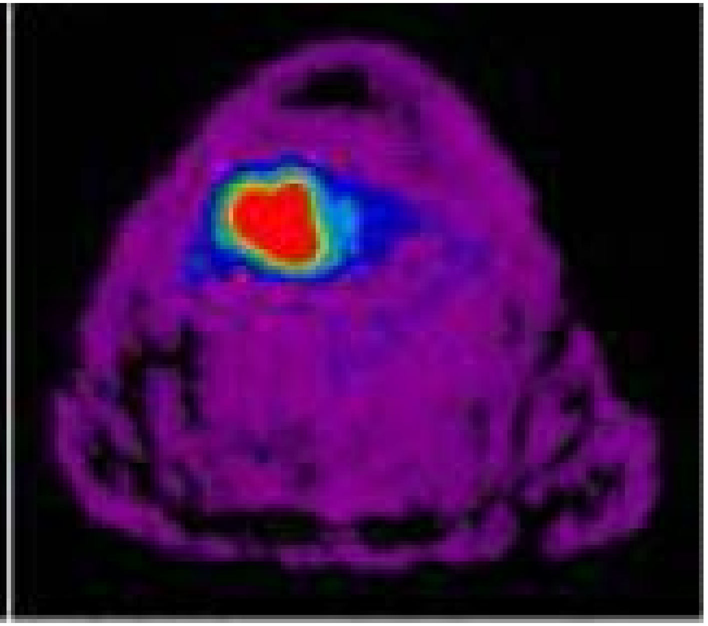
ICRU: “A clear annotation has to be used” e.g.



GTV-T (CT, 0 Gy)



GTV-T (MRI T2, fat sat, 0 Gy)



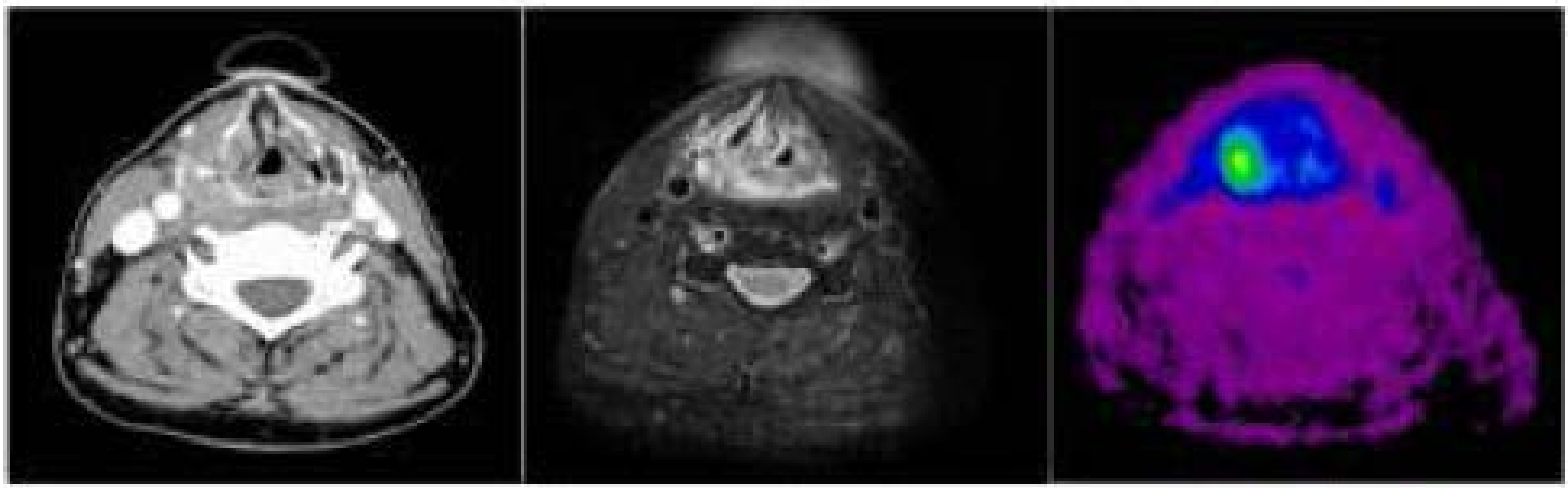
GTV-T (FDG-PET, 0 Gy)

ICRU Report No.83 (2010)

Volumes in ICRU78 and ICRU83

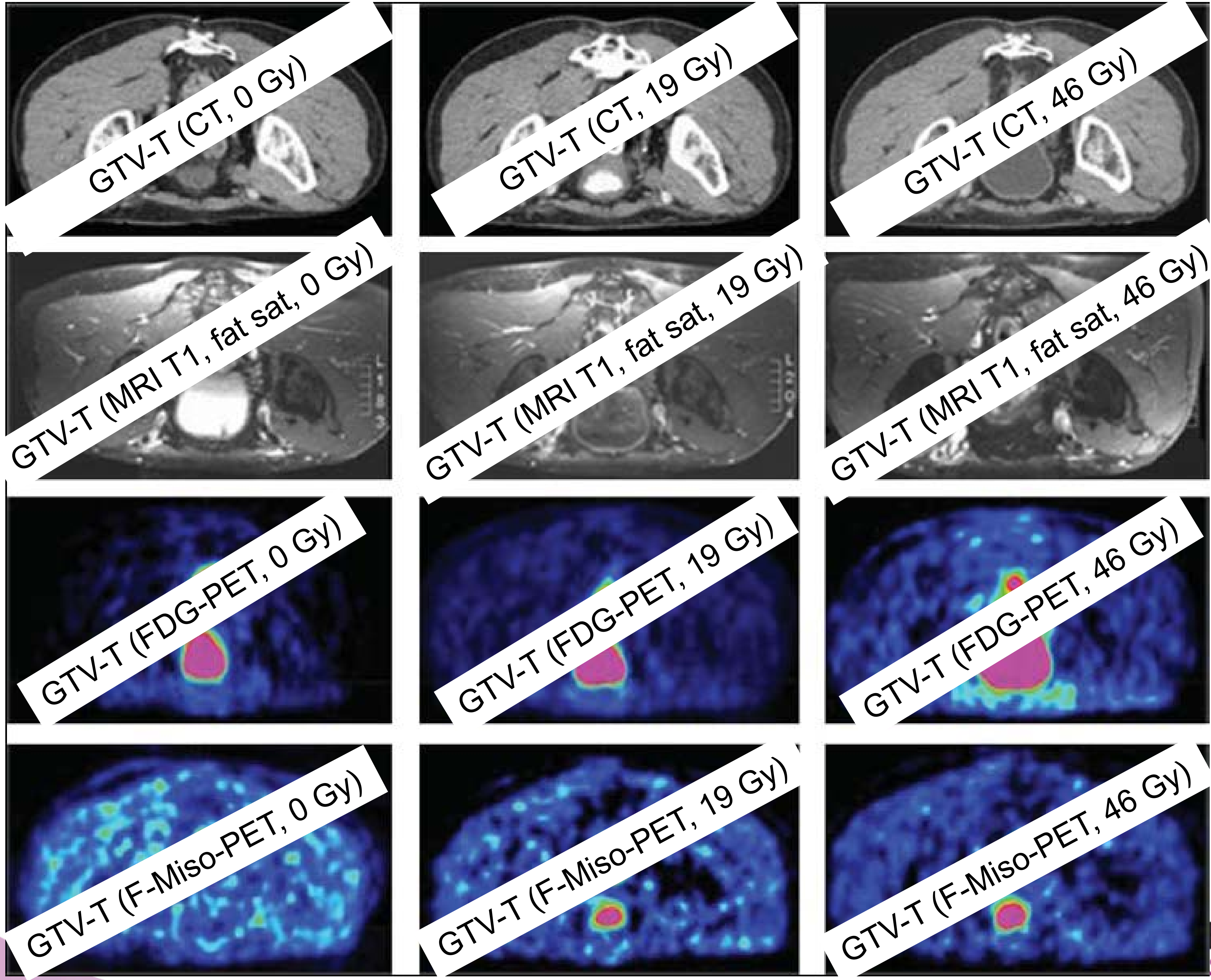
Definition of volumes depends on when imaging is done

ICRU: "… recommended to indicate the dose and/or the time when the GTV has been evaluated/measured…"



GTV-T (CT, 20 Gy) GTV-T (MRI T2, fat sat, 20 Gy) GTV-T (FDG-PET, 20 Gy):

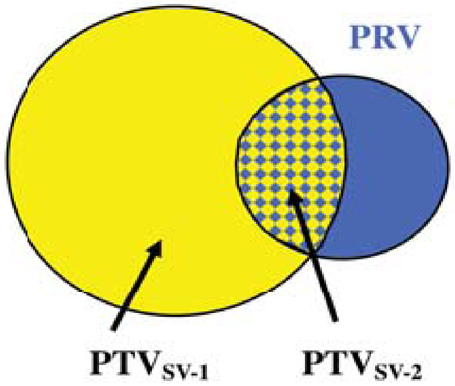
ICRU Report No.83 (2010)


GTV-T (CT, 0 Gy)
GTV-T (CT, 19 Gy)
GTV-T (CT, 46 Gy)
GTV-T (MRI T1, fat sat, 0 Gy)
GTV-T (MRI T1, fat sat, 19 Gy)
GTV-T (MRI T1, fat sat, 46 Gy)
GTV-T (FDG-PET, 0 Gy)
GTV-T (FDG-PET, 19 Gy)
GTV-T (FDG-PET, 46 Gy)
GTV-T (F-Miso-PET, 0 Gy)
GTV-T (F-Miso-PET, 19 Gy)
GTV-T (F-Miso-PET, 46 Gy)

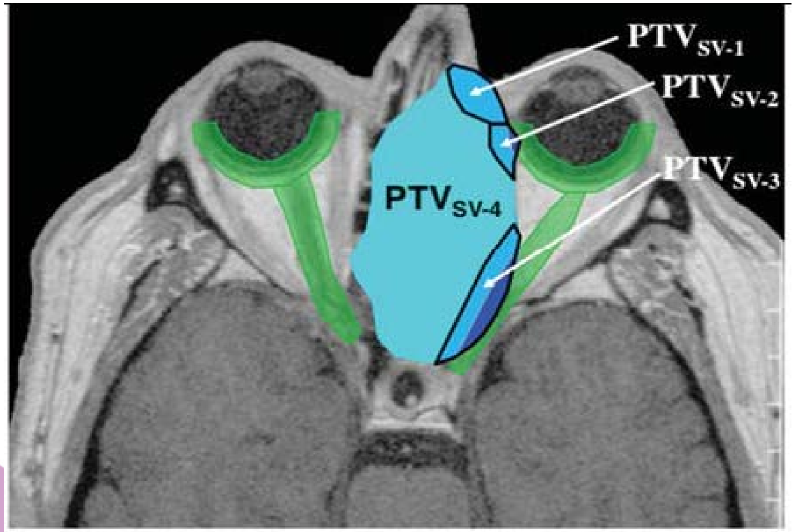
Volumes in ICRU78 and ICRU83

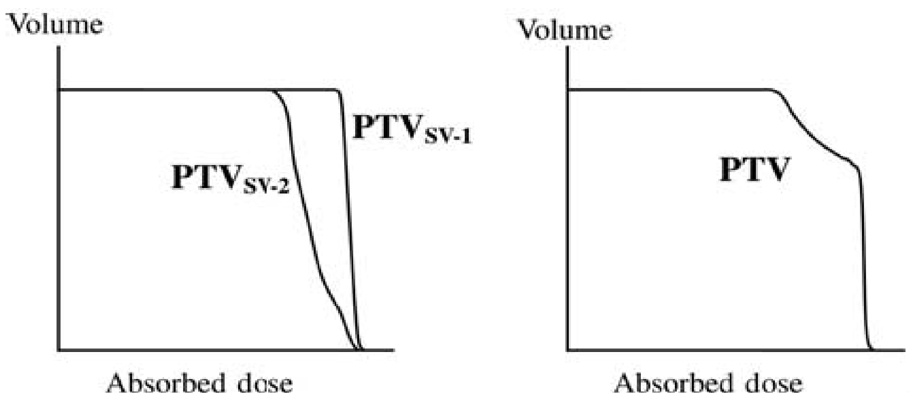
The PTV might overlap an adjacent PRV or there might be other reasons to subdivide the PTV

ICRU: "… the delineation of the PTV margins should not be compromised" "… subdivision of the PTV into regions with different prescribed doses (so-called PTV sub-volumes, PTV_{SV}) may be used"



$$PTV = PTV_{SV\text{-}1} + PTV_{SV\text{-}2}$$





ICRU Report No.83 (2010)

Volumes in ICRU78 and ICRU83

With new techniques, carcinogenesis needs to be monitored; there might also be unsuspected regions of high dose within the patient

ICRU: "… The volume within the patient excluding any delineated OAR and the CTV(s) should be identified as the "remaining volume at risk" (RVR)"

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Volumes

- **1978 ICRU29** — "The Target Volume" | Organs at risk
- **1993 ICRU50** — GTV | CTV | PTV | Organs at risk
- **1999 ICRU62** — GTV | CTV | ITV | PTV | OR | PRV
- **2004 ICRU71** — GTV-T, GTV-N, GTV-M | CTV-T, CTV-N, CTV-M | (ITV) | PTV-T, PTV-N, PTV-M | OAR | PRV
- **2007 ICRU78 / 2010 ICRU83** — OAR | PRV | RVR

e.g.

GTV	CTV	PTV
GTV-T (MR, 0 Gy)	CTV-T (MR, 0 Gy) (ITV)	PTV-T (MR, 0 Gy)
GTV-T (CT, 0 Gy)	CTV-T (CT, 0 Gy)	PTV-T (CT, 0 Gy)
GTV-T (PET, 16 Gy)	CTV-T (PET, 16 Gy)	PTV-T (PET, 16 Gy)
GTV-TN (PET, 16 Gy)	CTV-TN (PET, 16 Gy)	PTV-TN (PET, 16 Gy)
GTV-N (MR, 16 Gy)	CTV-N (MR, 16 Gy)	PTV-N (MR, 16 Gy)
GTV-N (CT, 0 Gy)	CTV-N (CT, 0 Gy)	PTV-N (CT, 0 Gy)

→ PTV-T$_{SV-1}$ (…)
→ PTV-T$_{SV-2}$ (…)
→ PTV-T$_{SV-3}$ (…)

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Volumes – Does it matter?

Dirk Verellen *et al*

***Nature Reviews Cancer* 7, 949-960 (December 2007)**

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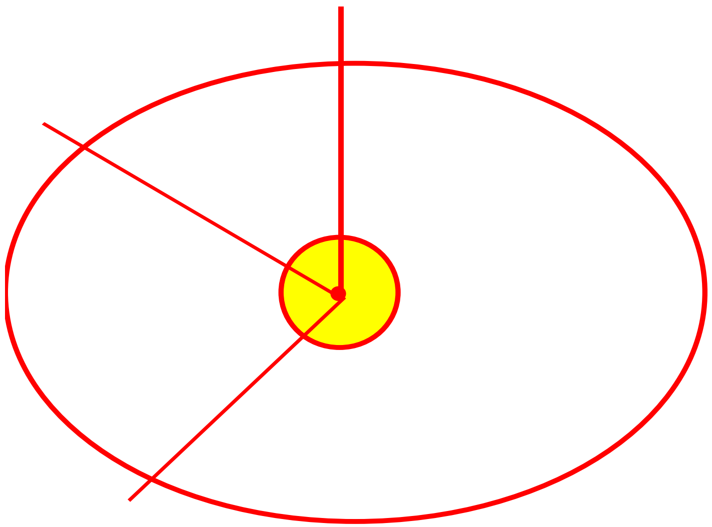
ICRU recommendations on Dose

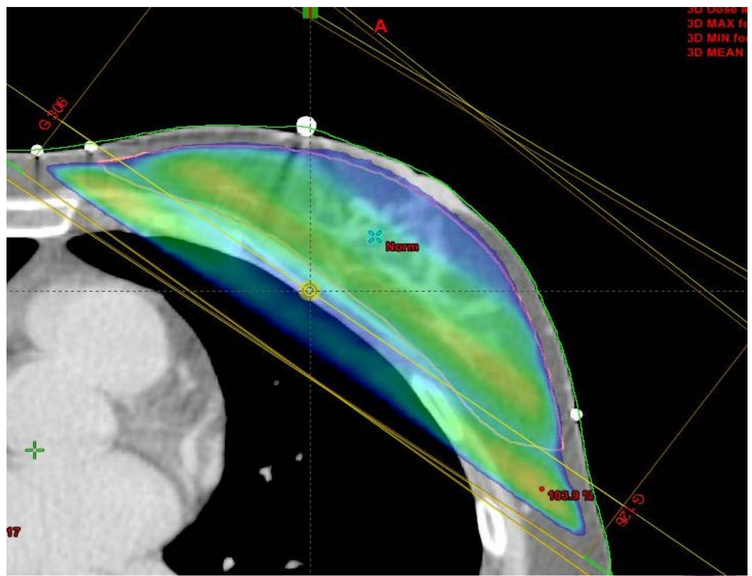
Dose in ICRU50 and ICRU62

ICRU Reference Point

- The dose at the point should be clinically relevant
- The point should be easy to define in a clear and unambiguous way
- The point should be selected so that the dose can be accurately determined
- The point should be in a region where there is no steep dose gradient

In central part of PTV at intersection of beam axes!





Dose in ICRU50 and ICRU62

Level 1. Minimum level of reporting dose

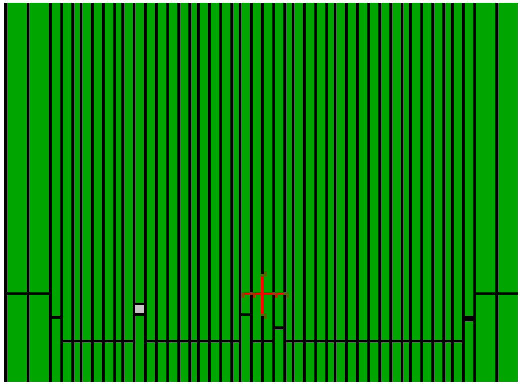
- The dose at the ICRU Reference Point

- Maximum dose to the PTV (D_{max})

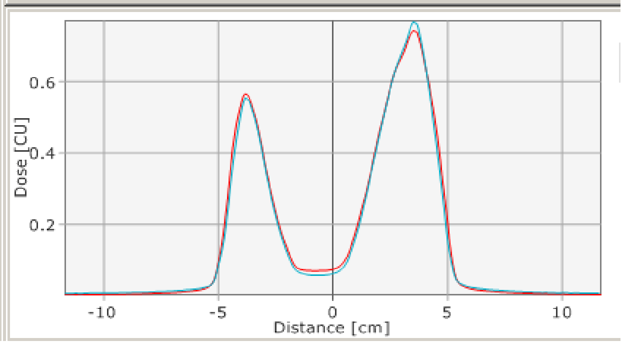
- Minimum dose to the PTV (D_{min})

- Maximum dose to the OR/PRV:s

Dose in ICRU83



Level 1. Why is it not adequate today?



-The absorbed dose distribution for IMRT can be less homogeneous then in CRT

-Each beam can produce absorbed dose with large dose gradients

- Large dose gradients (10%/mm) in the PTV boundary i.e. small shifts in delivery can affect the reliability of using a single point to report the dose

- Because modern TPS have evaluation tools that makes it possible.

- Monte Carlo calculations have statistical fluctuation in the results for small volumes which makes it difficult and uncertain to determine an absorbed dose to a point.

Dose in ICRU83

Leval 2. Minimum level of reporting dose in IMRT

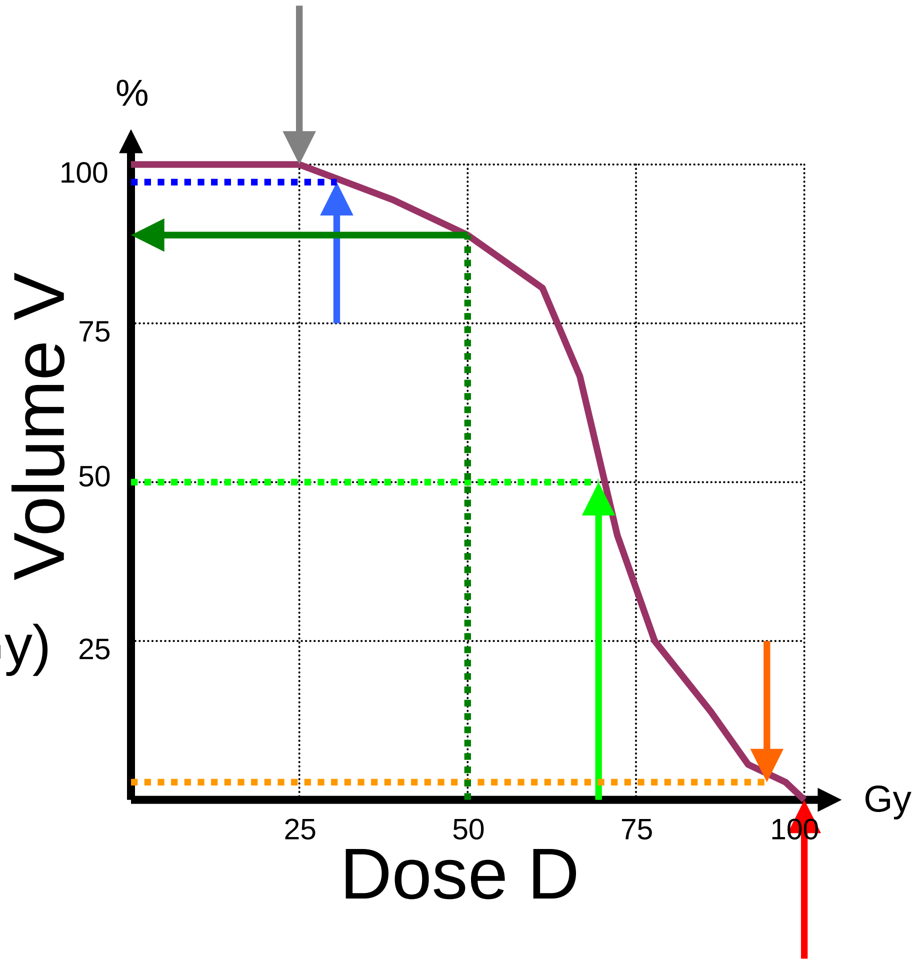
PTV and CTV

$D_{2\%}$ "close to max" replaces D_{max}

$D_{98\%}$ "close to min" replaces D_{min}

$D_{50\%} = D_{median}$

D_{mean}



OAR and PRV

V_D (e.g volume receiving more than 50 Gy)

V_{50Gy} (parallel organs)

D_{mean} (parallel organs)

$D_{2\%}$ (serial organs)

…AND…

-State the treatment planning system and algorithm used for planning and delivery system used for treatment

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Dose in ICRU83

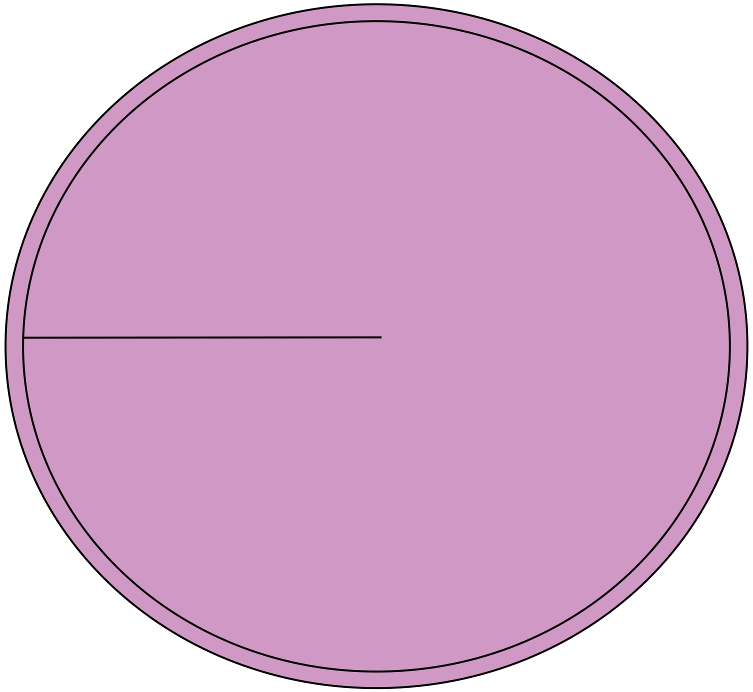
Reporting of absorbed dose

Why not $D_{100\%}$ and $D_{0\%}$(the earlier definition of min and max absorbed dose)?

E.g. PTV of 0.5 litres (radius 49.2 mm).

radius changed by less than 0.2 mm =>
1% change in volume

D98% and D2% serve the purpose to report an absorbed dose that is not reliant on a single computation point.



Dose in ICRU83

Level of reporting for IMRT

Leval 3. Techniques and concepts that are under development

-Dose Homogeneity
characterizes the uniformity of the absorbed dose distribution within the target

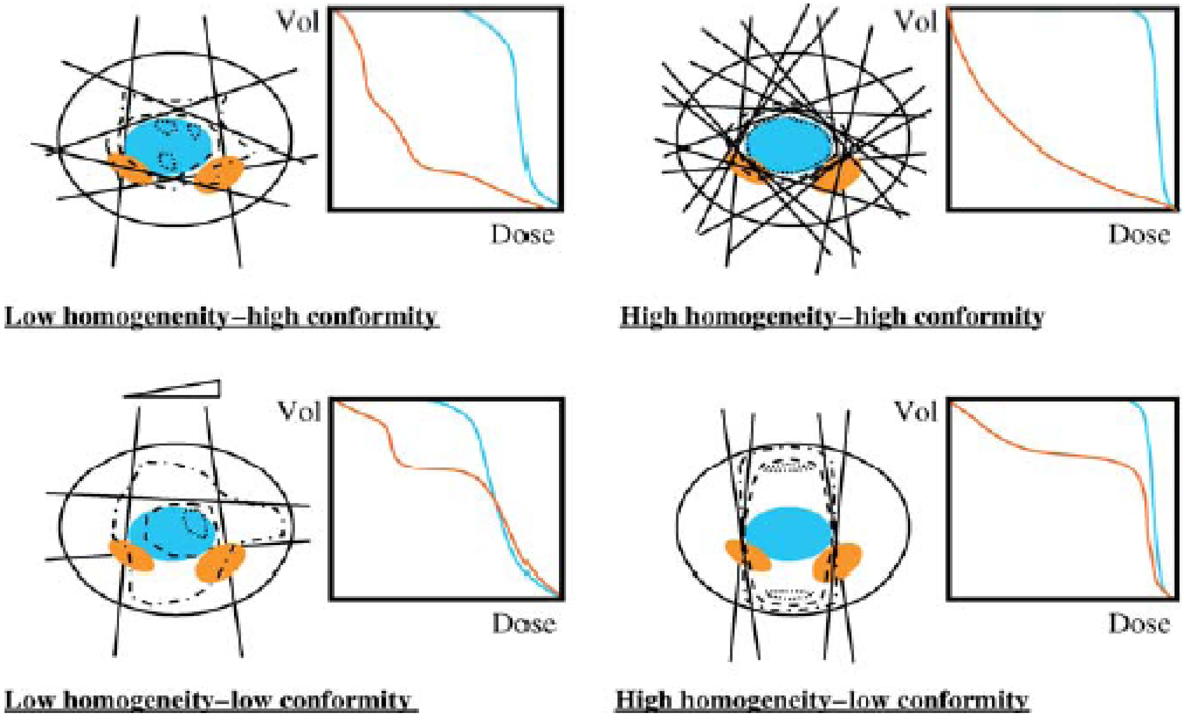
-Dose Conformity
characterizes the degree to which the high dose region conforms to the target volume

-Clinical and Biological evaluation (e.g. TCP, NTCP, EUD)

-Confidence interval (e.g. including systematic and random uncertainties)

Dose in ICRU83

Dose Homogeneity and Dose Conformity



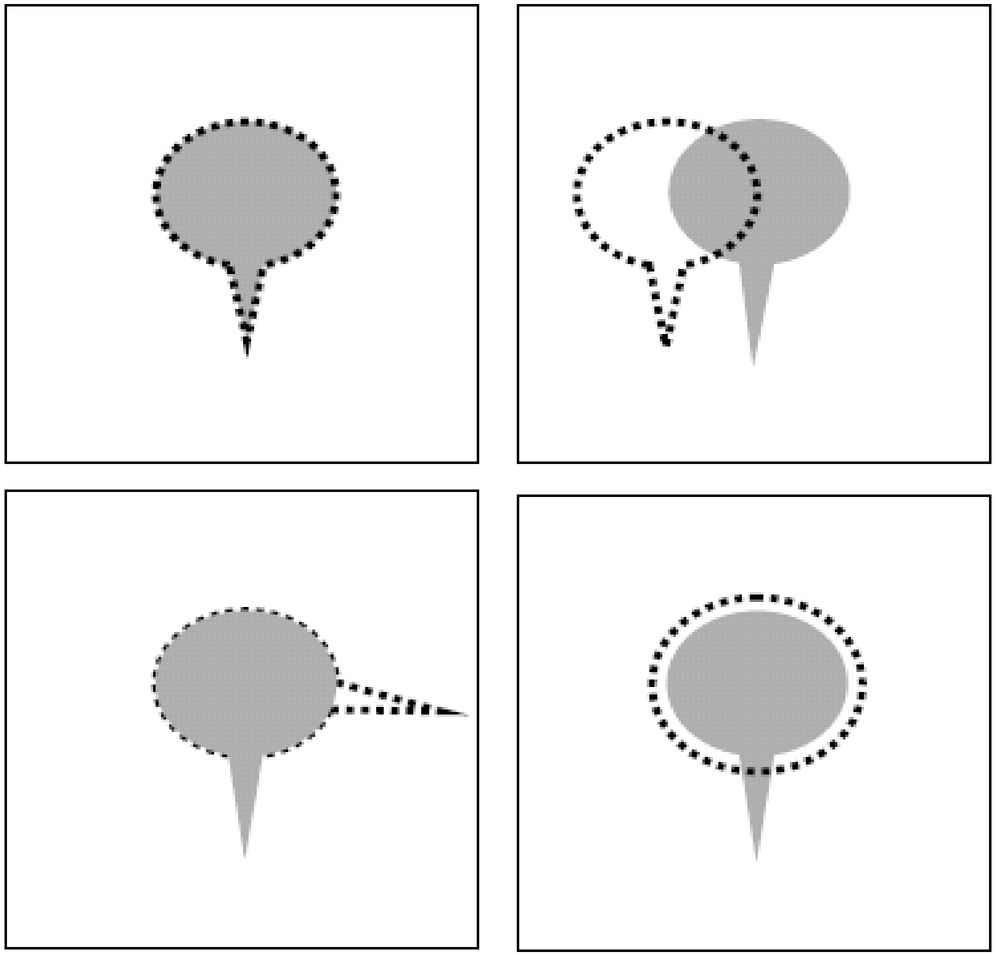
Homogeneity Index

$$HI = \frac{D_{2\,\%} - D_{98\,\%}}{D_{50\,\%}}.$$

ICRU Report No. 83 (2010)

Dose in ICRU83

Dose Homogeneity and Dose Conformity



$$Conformity\ index_{RTOG} = \frac{V_{RI}}{TV}$$

V_{RI}: Volume of the reference isodose

TV: Target volume

Loic Feuvret et al.
Int. J. Radiation Oncology Biol. Phys., 64 (2) 2006

Conformity index = 1

Dose in ICRU83

Quality assurance for IMRT treatment plans

Previous

5% point dose accuracy specification

Replaced by volumetric dose accuracy specification for IMRT

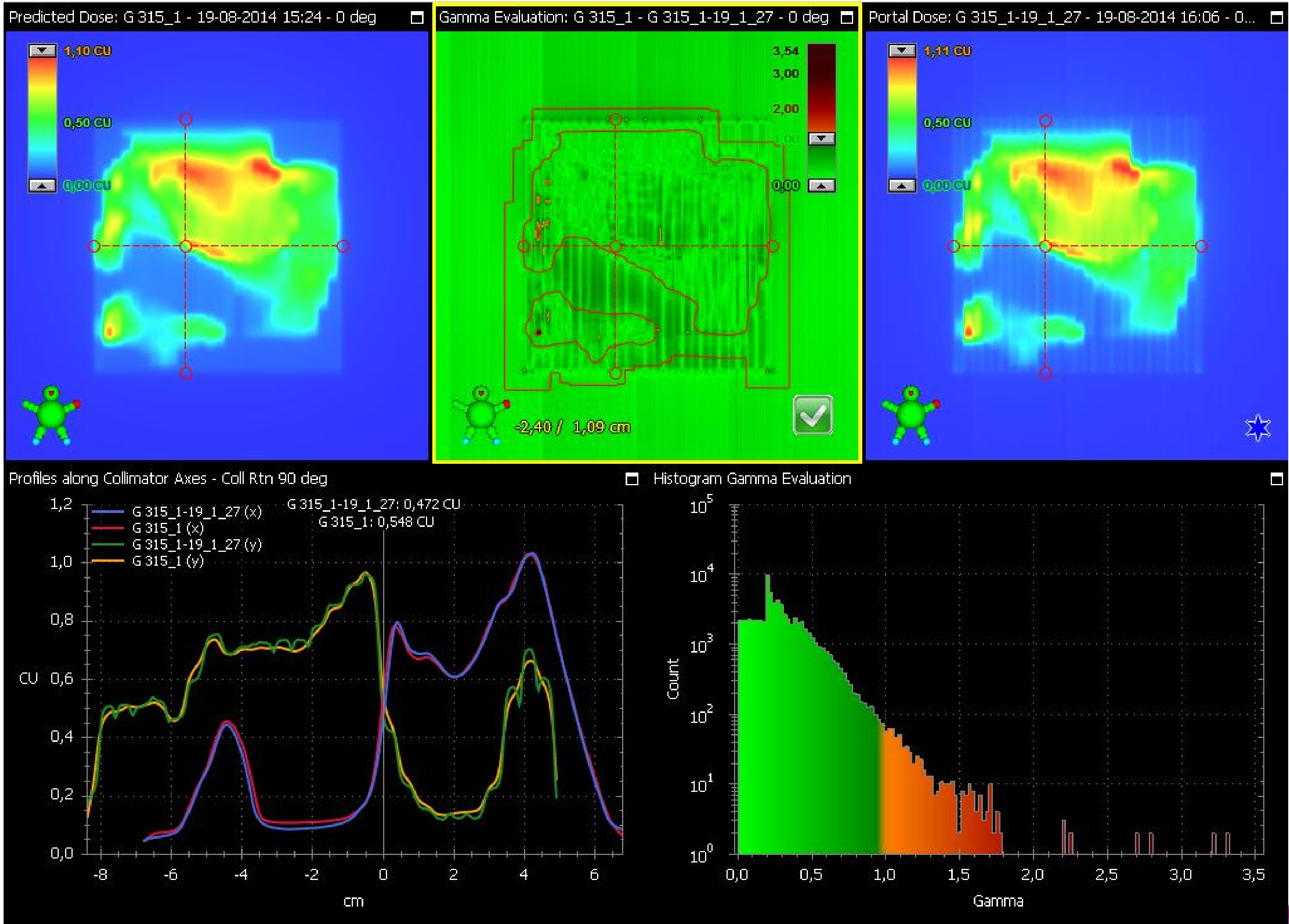
Not limited to single point

High gradient (≥20%/cm):85% of points within 5 mm (1 SD of 3.5 mm)

Low gradient (<20%/cm): 85% of points within 5% of predicted dose normalized to the prescribed dose

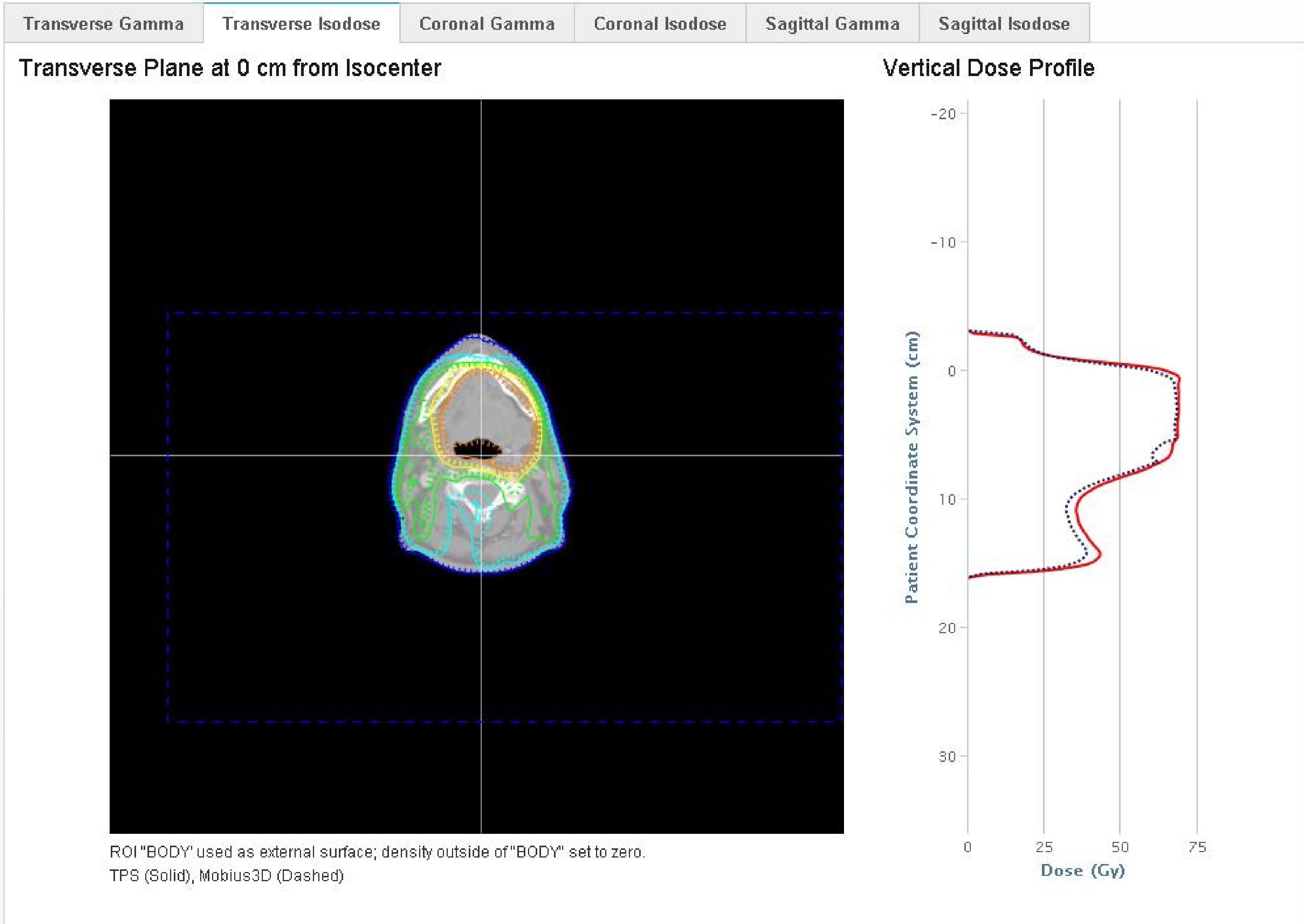
Dose in ICRU83

Example – Quality Assurance measurement



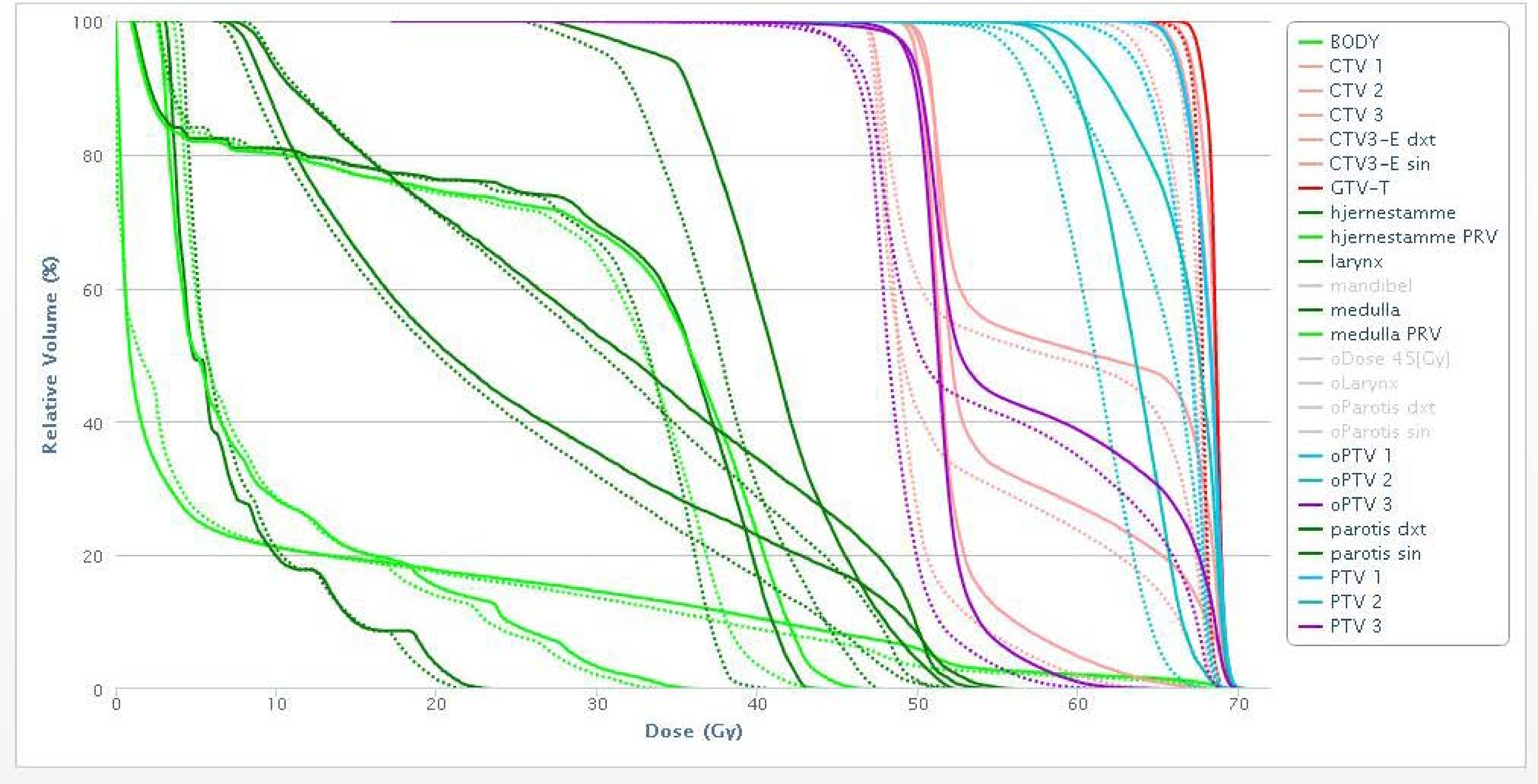
Dose in ICRU83

Example – Quality Assurance Independent calculation



Dose in ICRU83

Example – Quality Assurance Independent calculation



Summary

Volumes	**GTV-T (…)**	**CTV-T (…)**	**(ITV)**	**PTV-T (…)**	
	GTV-N (…)	**CTV-N (…)**		**PTV-N (…)**	**OAR PRV RVR**
	GTV-M (…)	**CTV-M (…)**		**PTV-M (…)**	

Dose

PTV and CTV

$D_{2\%}$ "close to max"

$D_{98\%}$ "close to min"

$D_{50\%} = D_{median}$

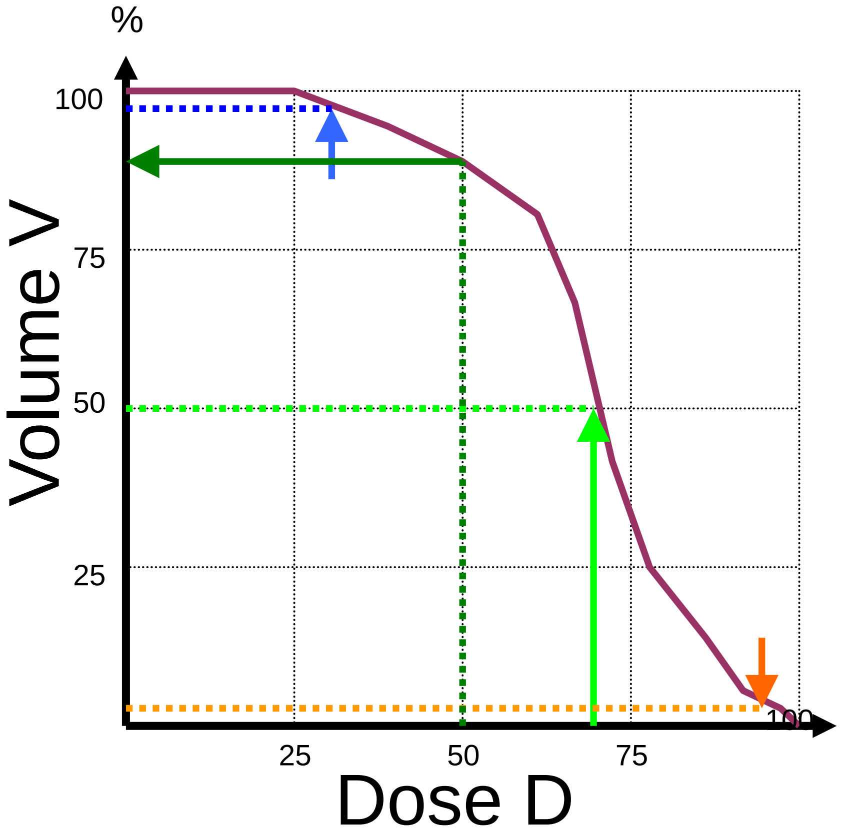
D_{mean}

OAR and PRV

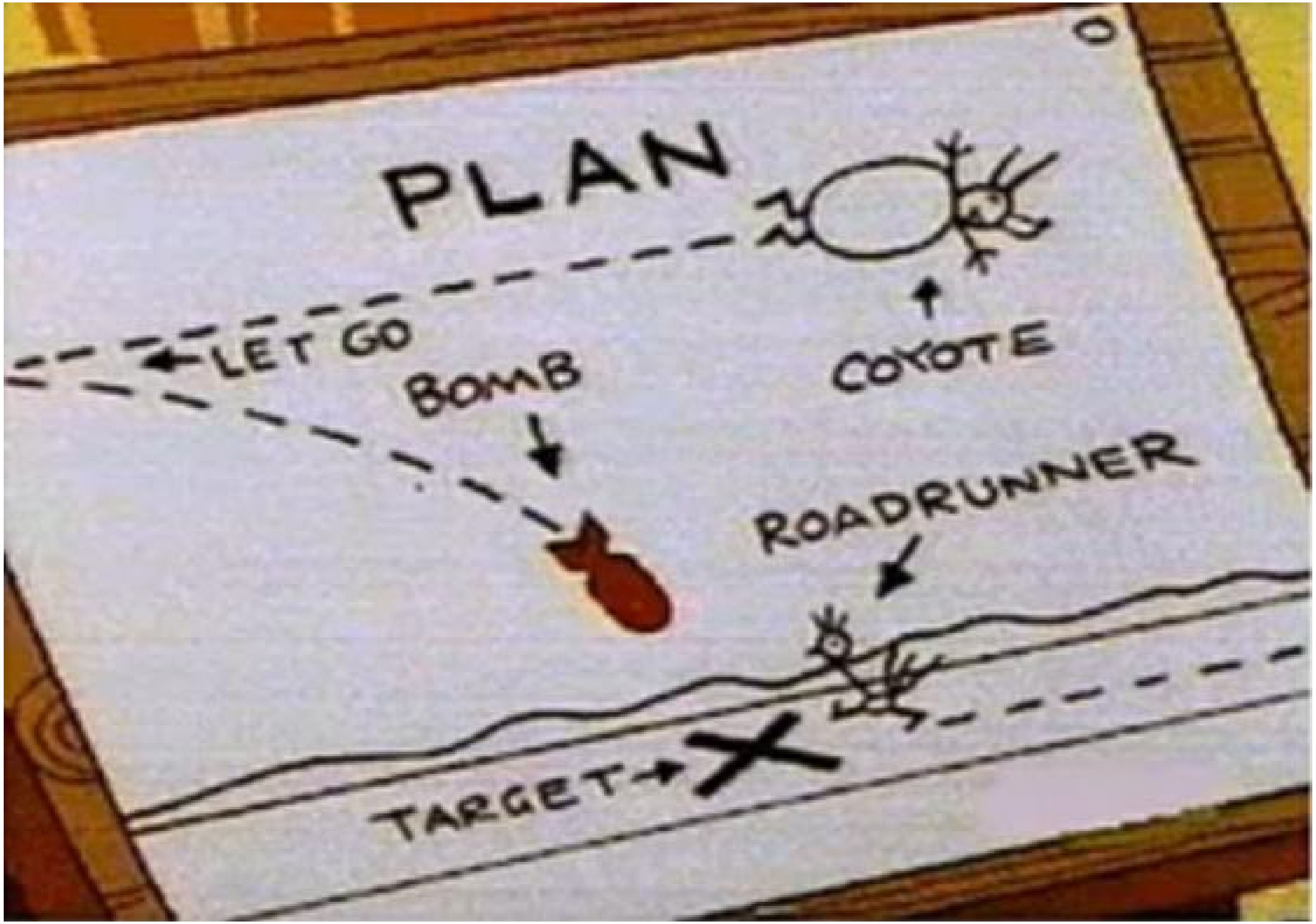
V_D (parallel organs)

D_{mean} (parallel organs)

$D_{2\%}$ (serial organs)



Thank you for your attention!



Questions?

Treatment Planning: Tools and General Principles

Steven Buckney and Michelle Leech

Learning Outcomes

- Following this presentation, you will be able to:
  - Describe the steps in the planning process
  - Outline the differences between fixed FSD and isocentric treatments
  - Appreciate the difference between single, parallel opposed and multi-field techniques
  - Describe when wedges, weighting and bolus are required in treatment planning
  - Appreciate when different beam energies are preferred.

Steps in the 3D Conformal Treatment Planning Process

- Patient Positioning & Immobilisation
- Image acquisition and transfer
- Target Volume and OAR Delineation
- Optimisation
- Normalisation
- Dose calculation
- Plan evaluation and improvement
- Plan implementation and verification

3D Conformal Treatment Planning

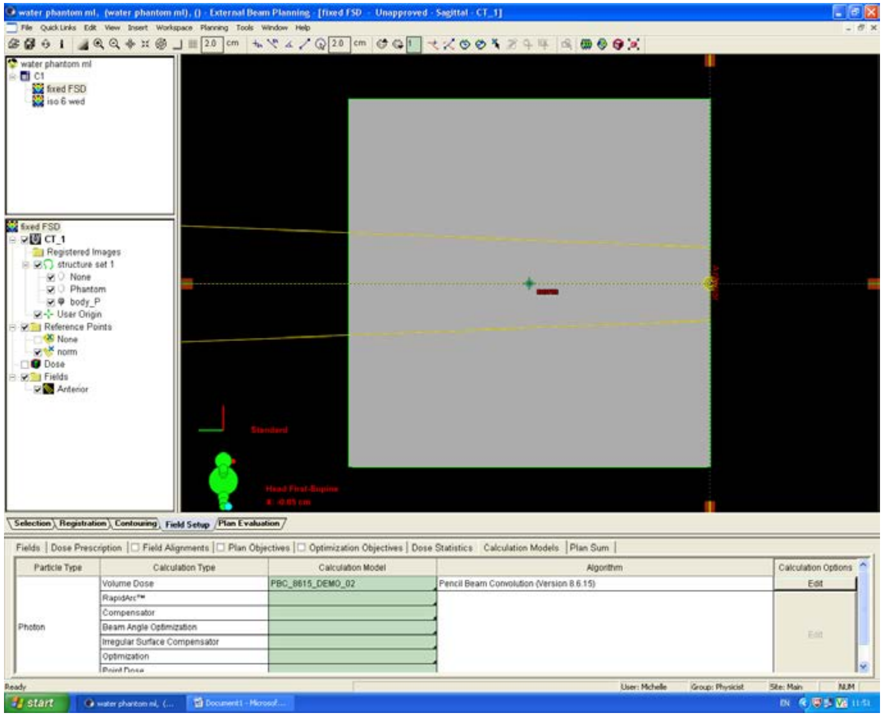
3DCRT is performed using **forward planning.**

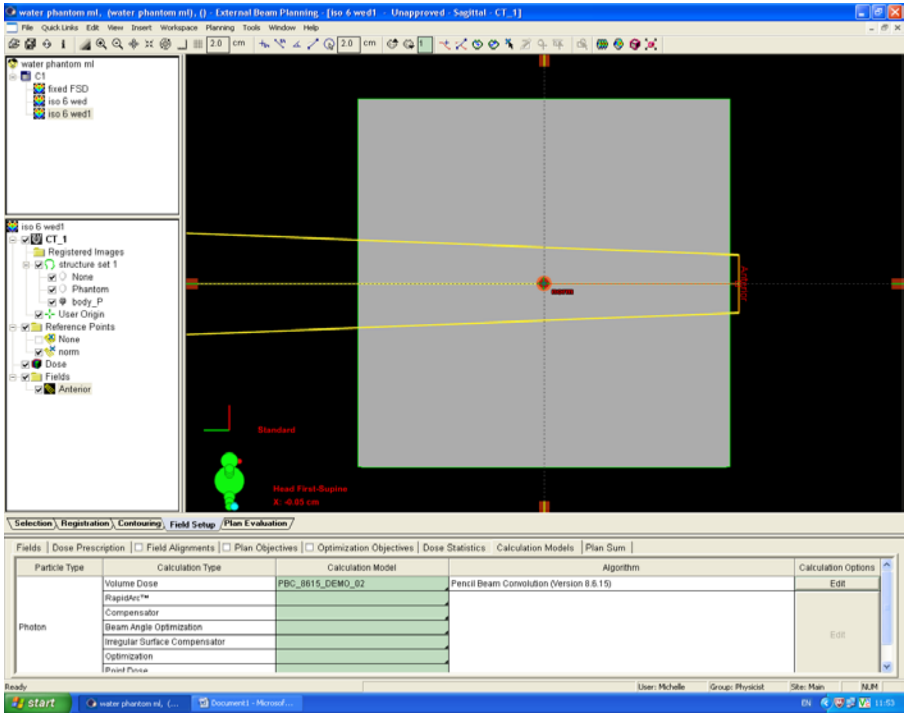
- Relies on planner's experience
- Required number of open/wedged beams selected
- Appropriate beam geometries selected
- TPS calculates the composite dose
- Parameters altered until acceptable distribution is achieved.

Optimisation

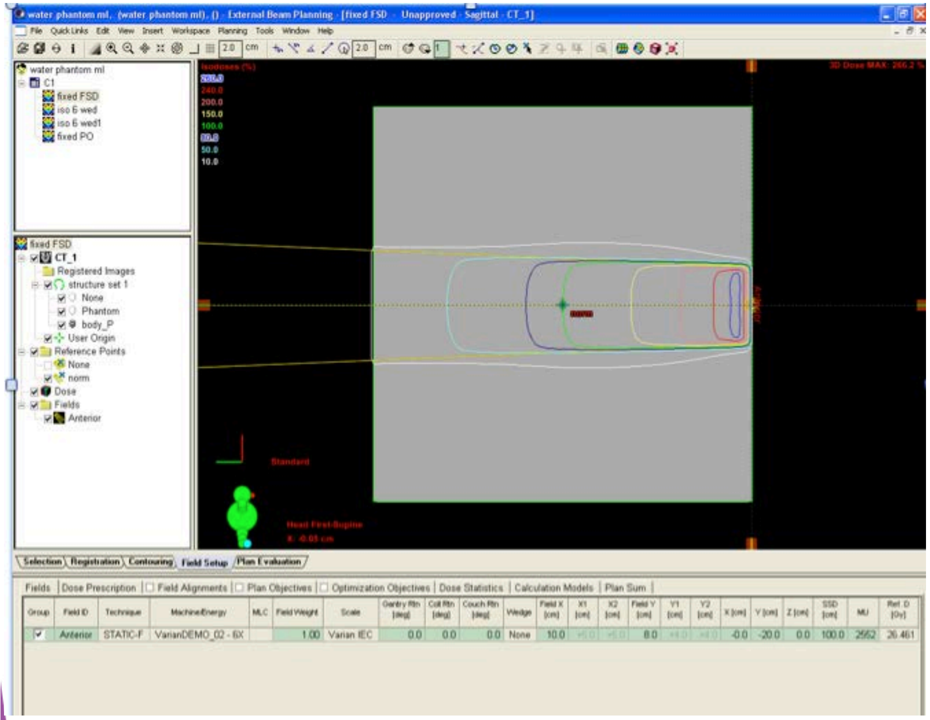
- Includes:
  - Technique selection
  - Beam orientation
  - Isocentre Placement
  - Beam energy
  - Field shaping
  - Wedging
  - Weighting
  - Use of bolus

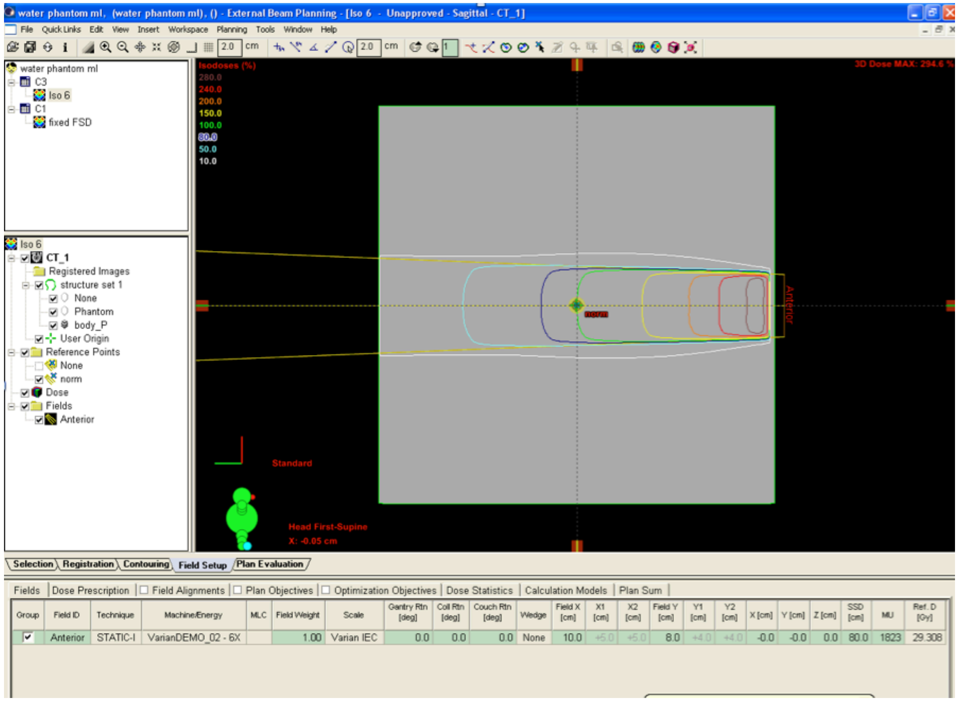
Fixed FSD vs. Isocentric Single Field





Fixed FSD vs. Isocentric Dose Single Field





Fixed Vs. Isocentric Single Field

- Higher monitor units with fixed FSD technique
- Field size will differ:
  - FSD field: Field size is defined at the surface of the phantom
  - Isocentric field: Field size is defined at isocentre

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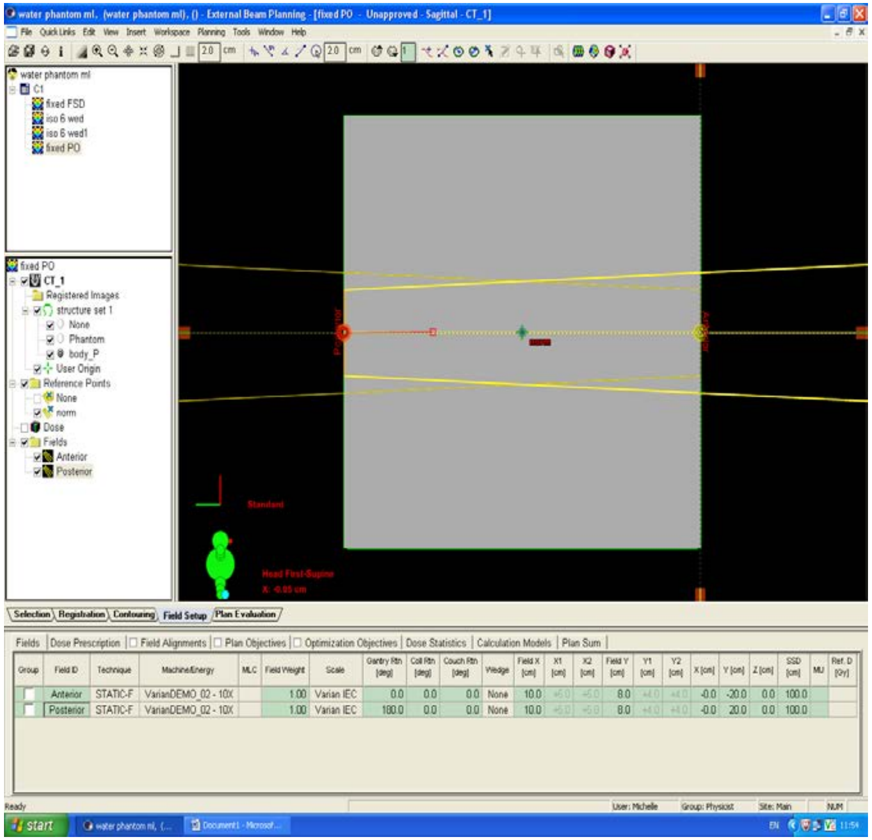
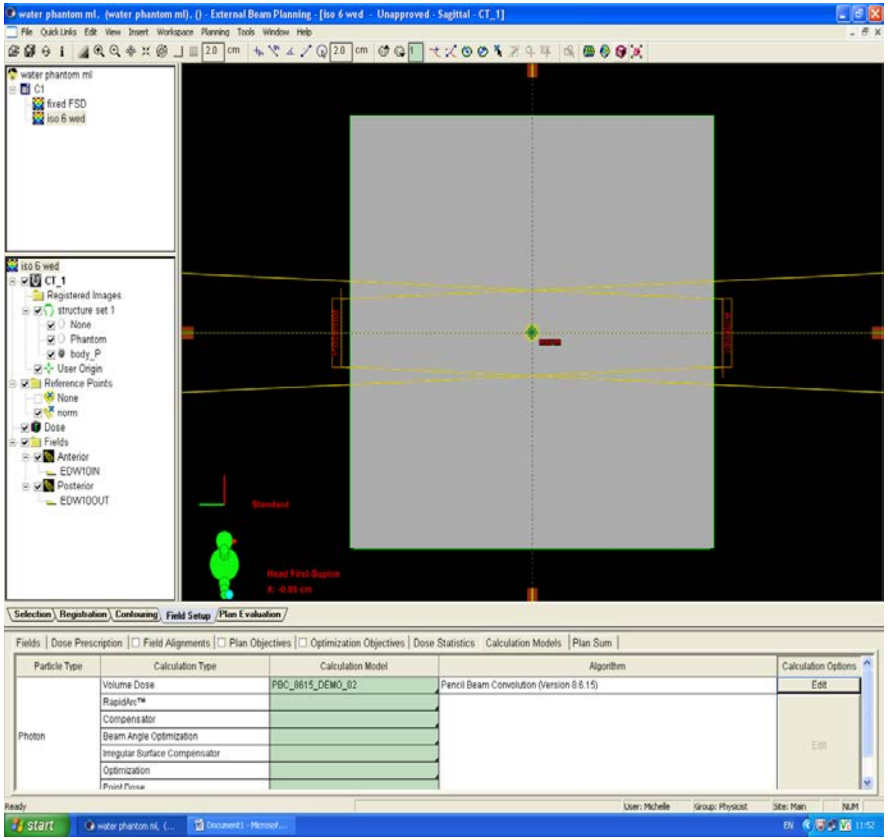
Fixed Vs. Isocentric Parallel Opposed





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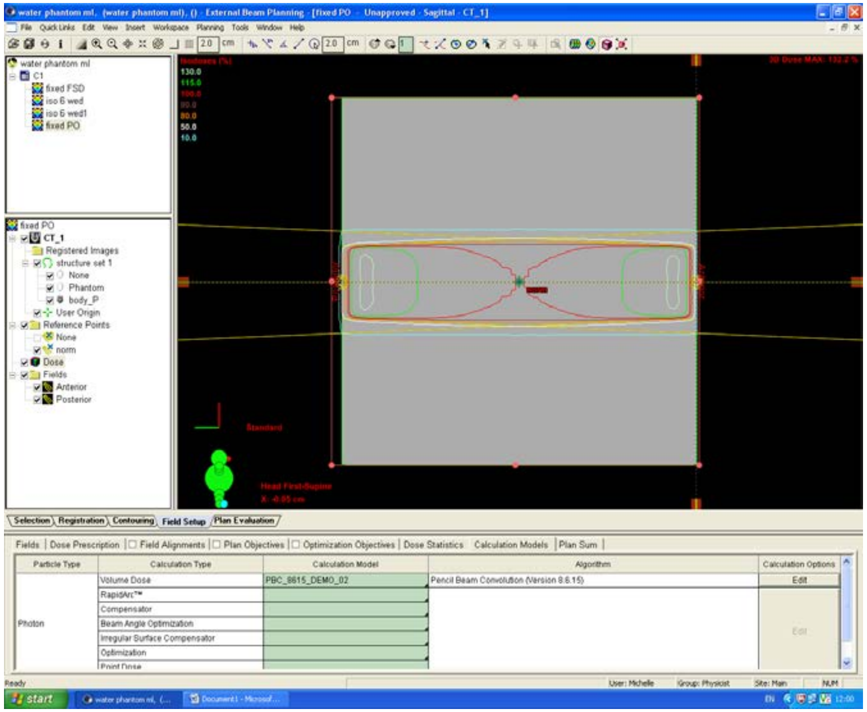
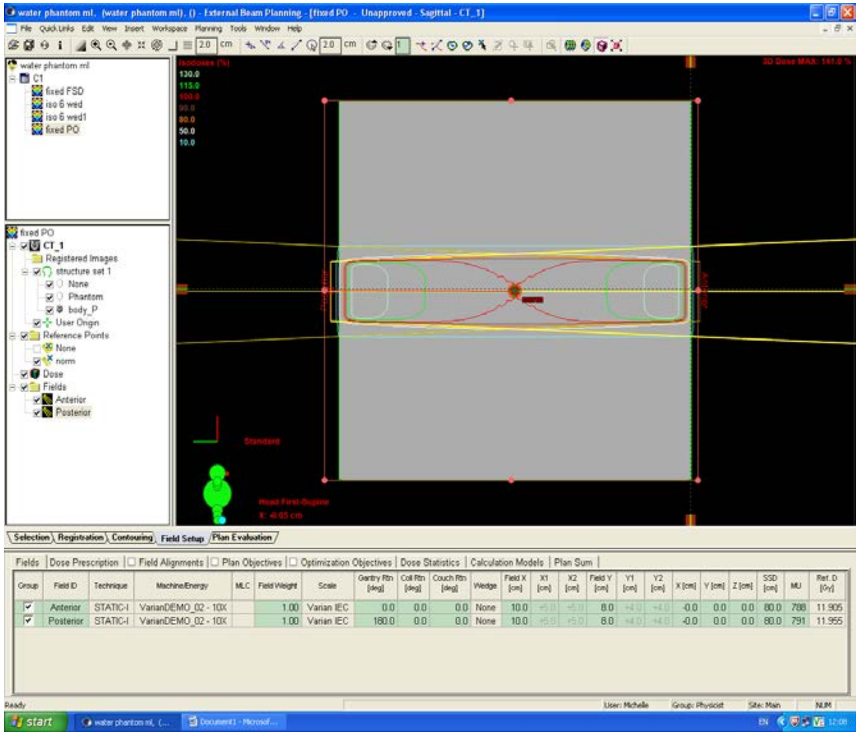
Fixed Vs. Isocentric Parallel Opposed (Dose)

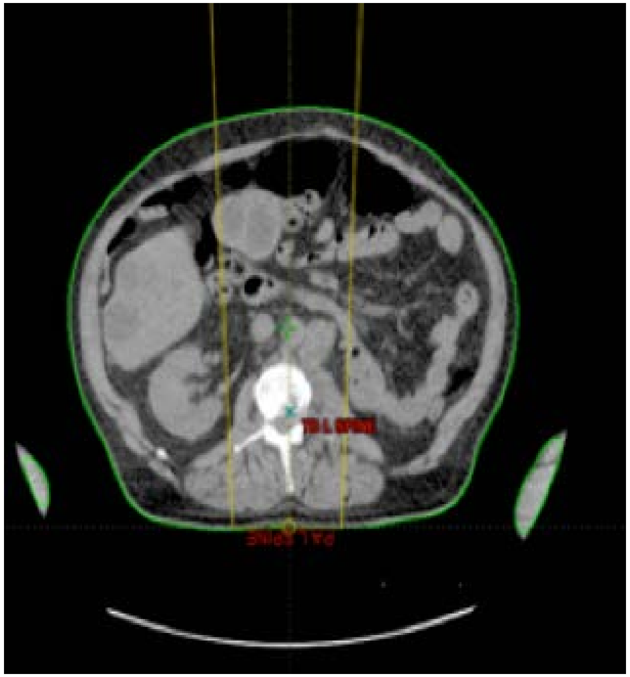


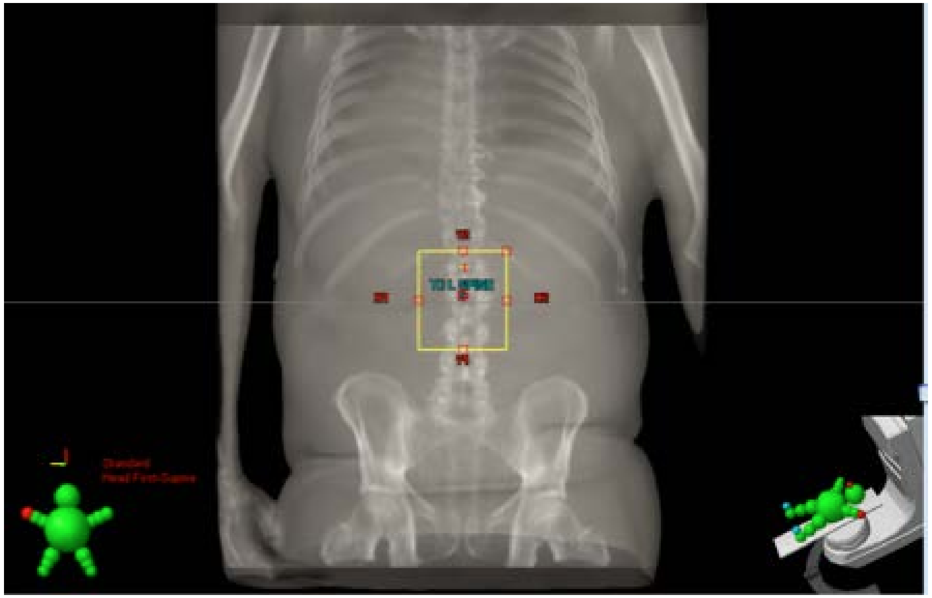


Fixed Vs. Isocentric PO

- Higher monitor units for fixed FSD plan (Time factor)
- Need to move couch between fields to reset FSD (chance of error in this)
- Field sizes will need to be increased for isocentric technique to cover the same volume

Gantry Angle

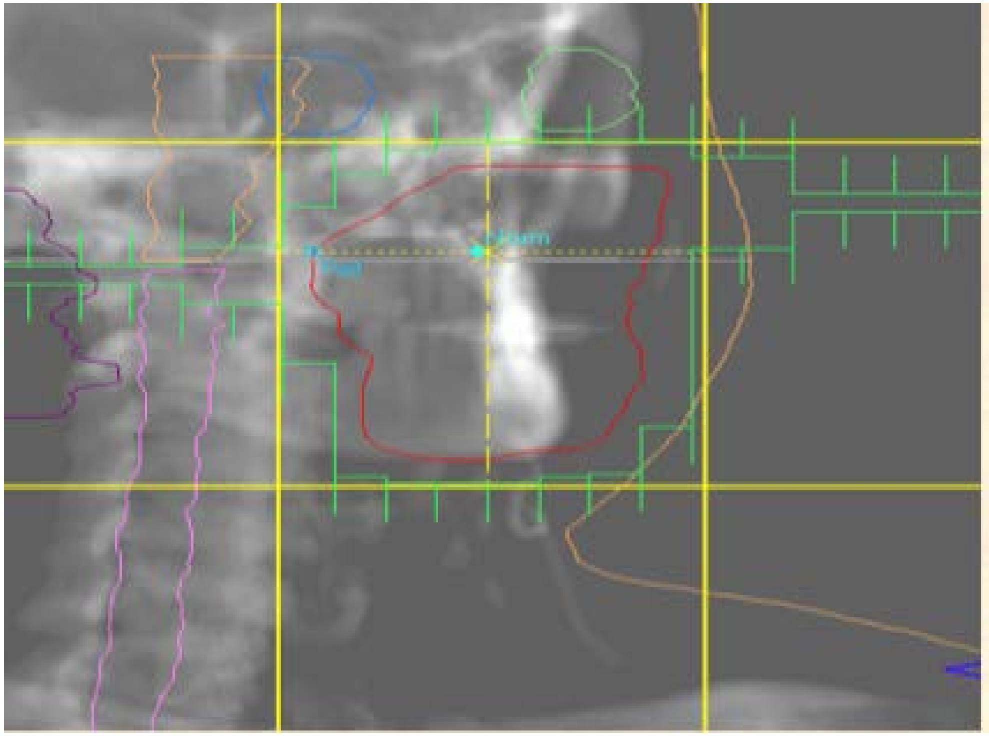




Single direct posterior field is adequate for this spine

Note location of kidney

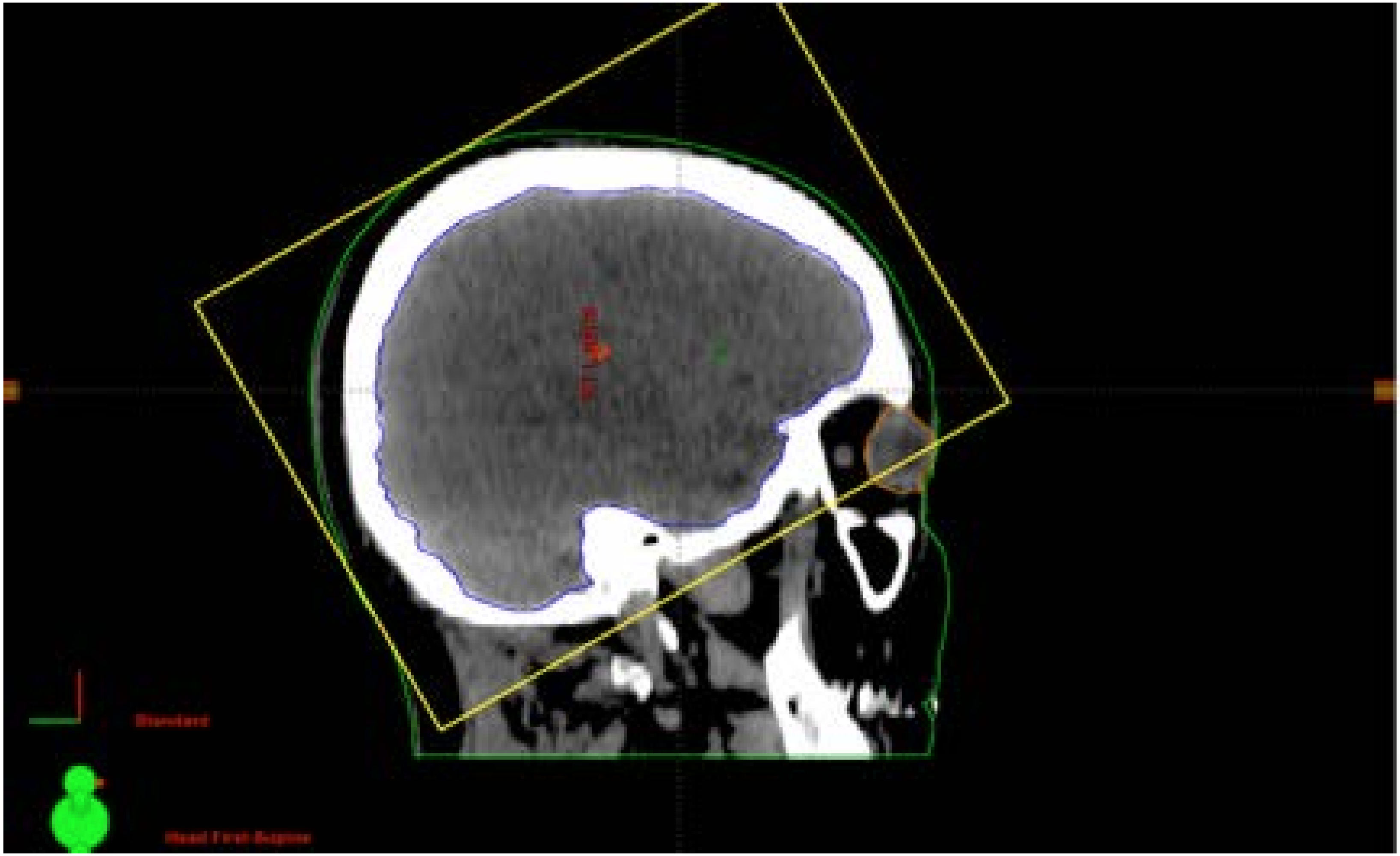
Gantry Angle



Avoid exiting through critical structures.

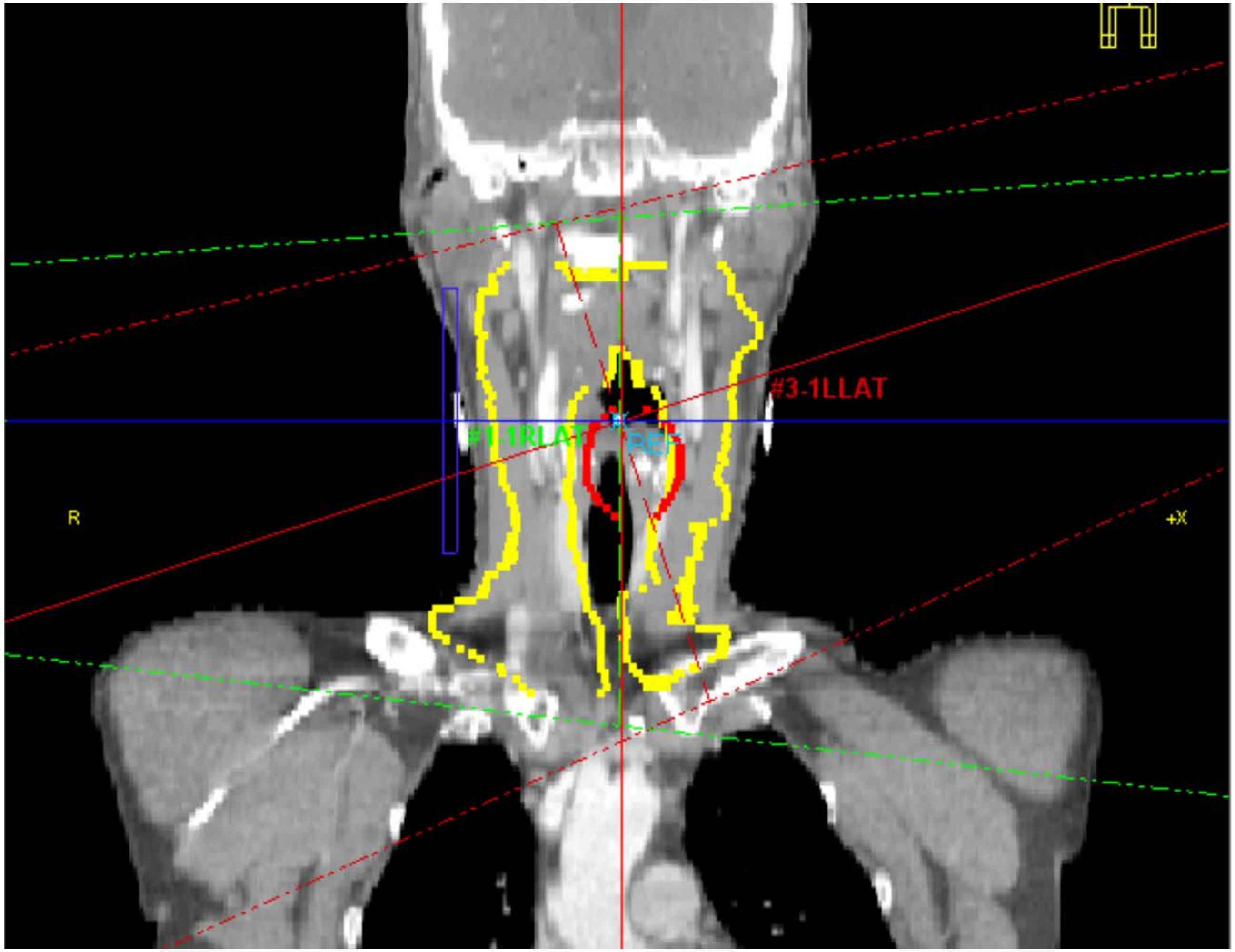
This RPO field exits close to the eyes.

Collimator Angle



Field turned to follow the angle of the base of brain

Floor Angle



Floor turned to avoid the shoulder on the left side

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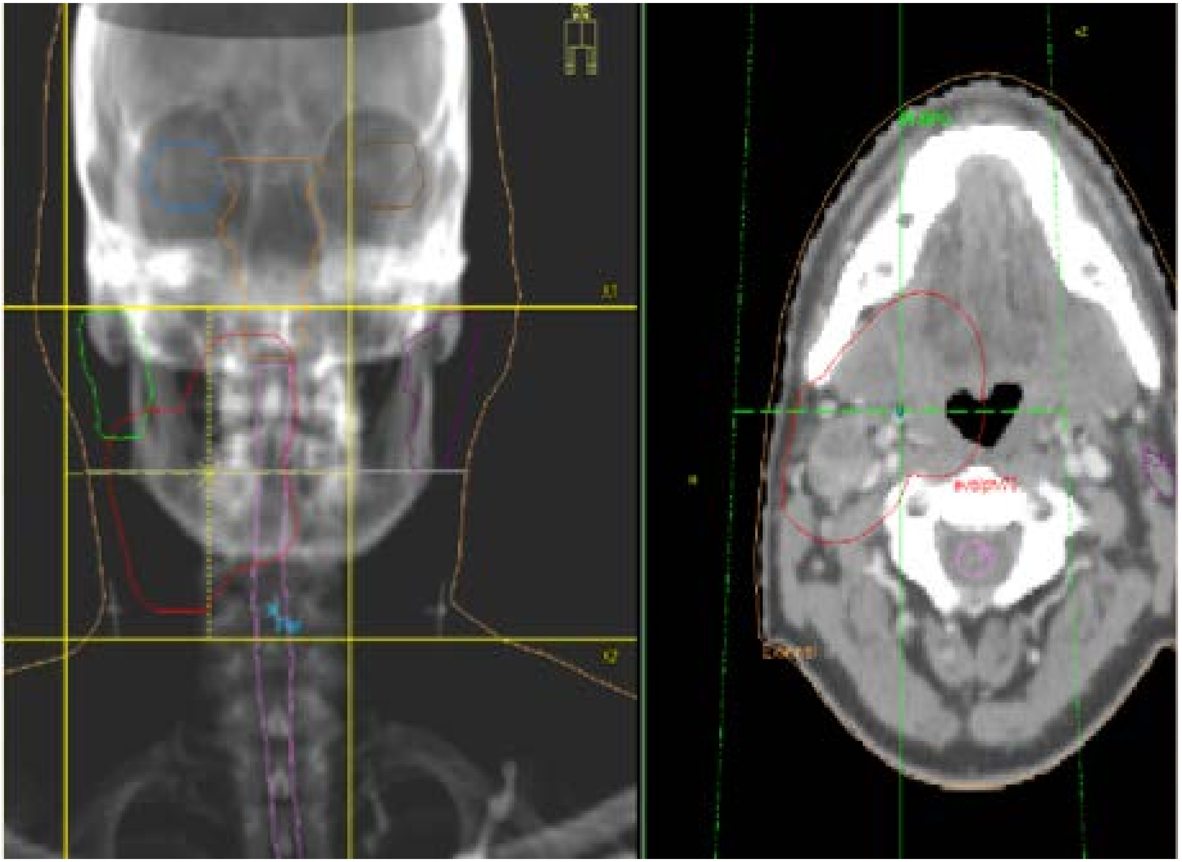
Isocentre Placement



Three Options:

1. At reference point
2. At centre of PTV
3. Elsewhere within the PTV

Isocentre Placement 2

- Ref point
  - ➢ will not need moves/verif
  - ➢ not always suitable for ipsilateral target
- Centre of PTV
  - ➢ will require daily moves in all directions and verif
- Standard moves
  - ➢ will require moves daily and verif but can be made in whole numbers and only in required directions
- For ease of set-up and accuracy no moves from ref point is the ideal (high proportion of errors in RT are in relation to moves) however if needed try to keep them standard

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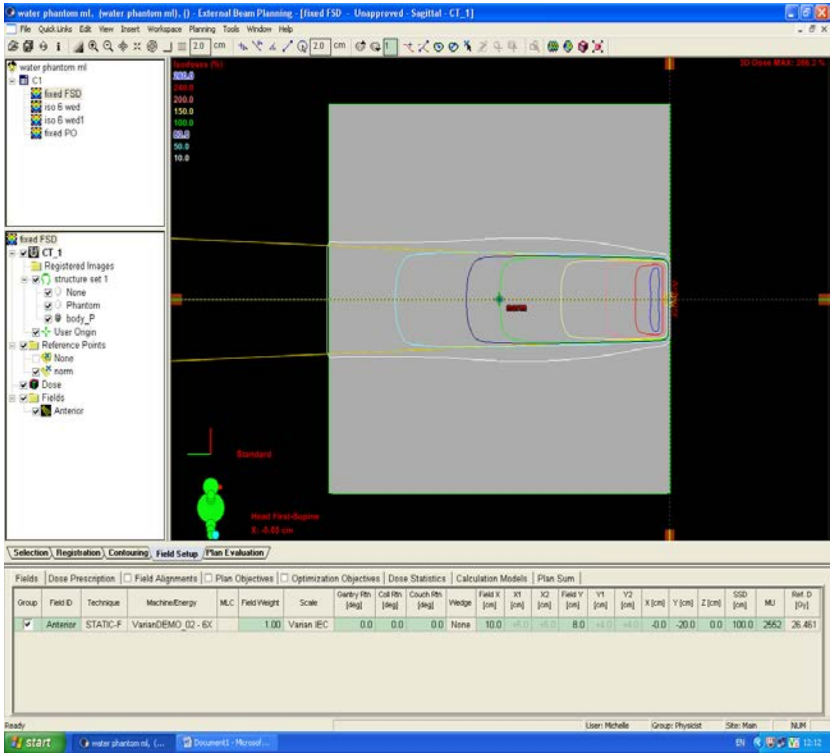
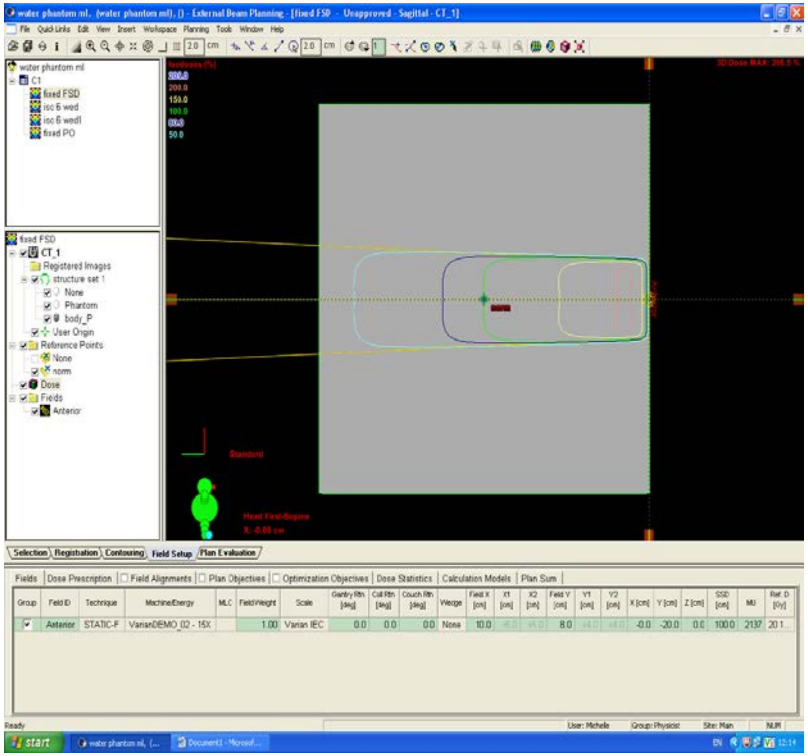
Energy Selection





6MV

15 MV

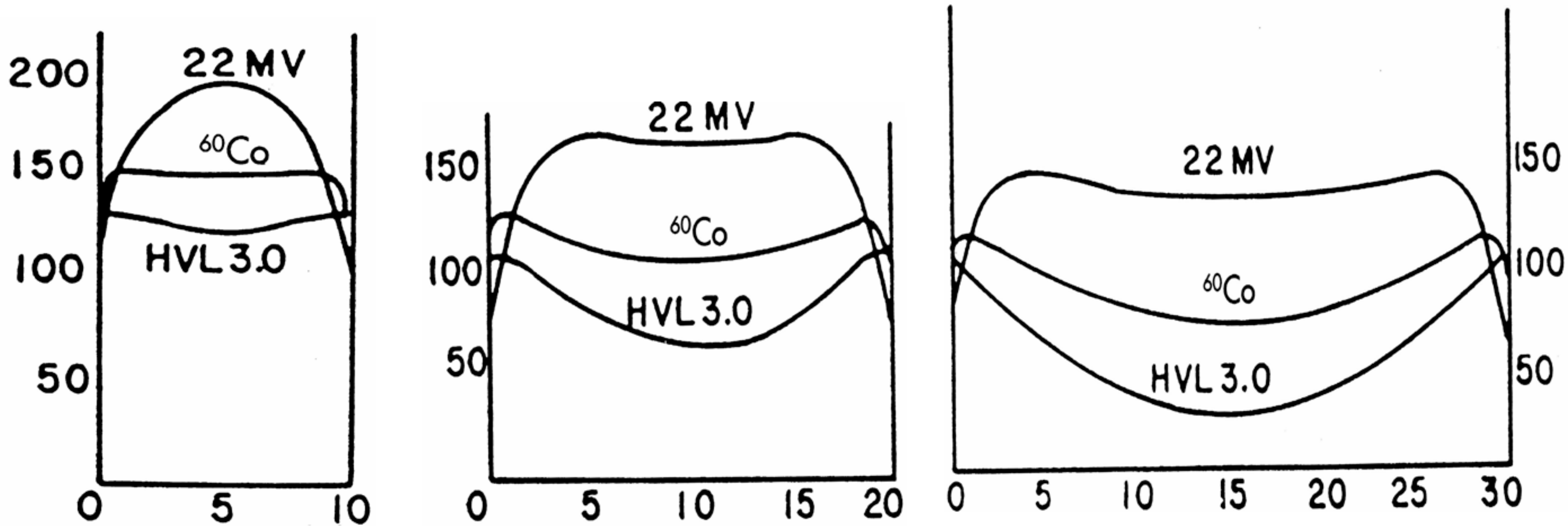
Energy Selection

- Higher maximum dose in plan with lower energy
- Lower isodose lines reach a greater depth with higher energy (See 50% isodose line on previous slide)
- Increased skin sparing with higher energy
  - ➢ 6MV dmax = 1.6 cm
  - ➢ 15MV dmax = 3 cm

*Consider the patient separation

*Consider the need for dose on skin or in the build up region (superficial target)

Effect of Energy and patient separation on Planning



Thin Medium Thick

Question

- Should the field size set be larger than the volume you have to cover?
  - A: The field size should be larger as a margin is needed to compensate for set up inaccuracies
  - B: The field size and target should be exactly the same to spare organs at risk
  - C: The field size should be larger to compensate for the penumbra effect at the beam edge

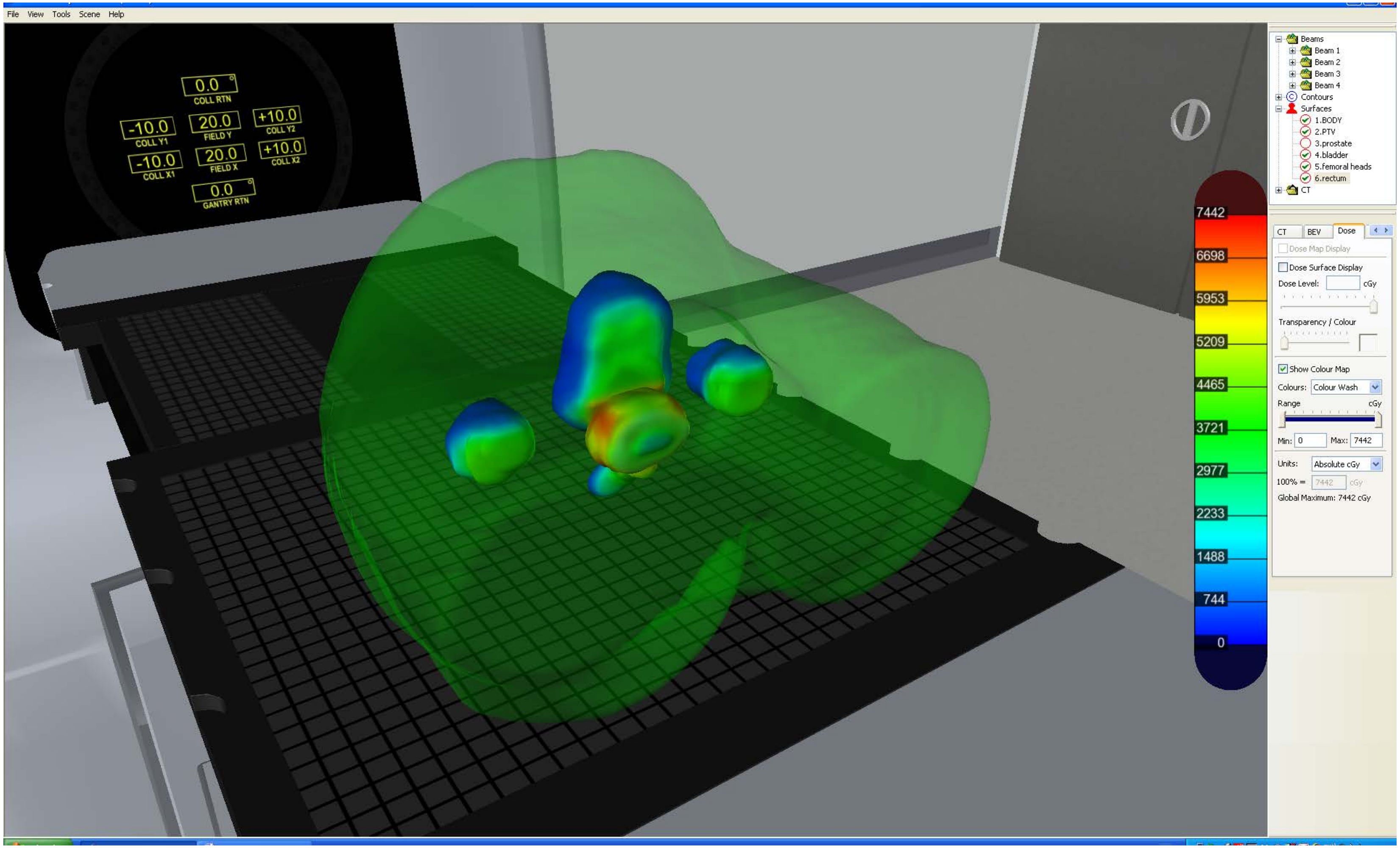
Penumbra

- Penumbra is often defined as the distance between the 20% and the 80% (10% and 90%) isodose lines
- The penumbra is the region near the edge of the field where the dose falls off rapidly
  - Width depends on
    - Size of ‘source’
    - SSD/FSD (Lower SSD, higher penumbra)
    - Energy (Increasing penumbra with increasing energy: increased field size)

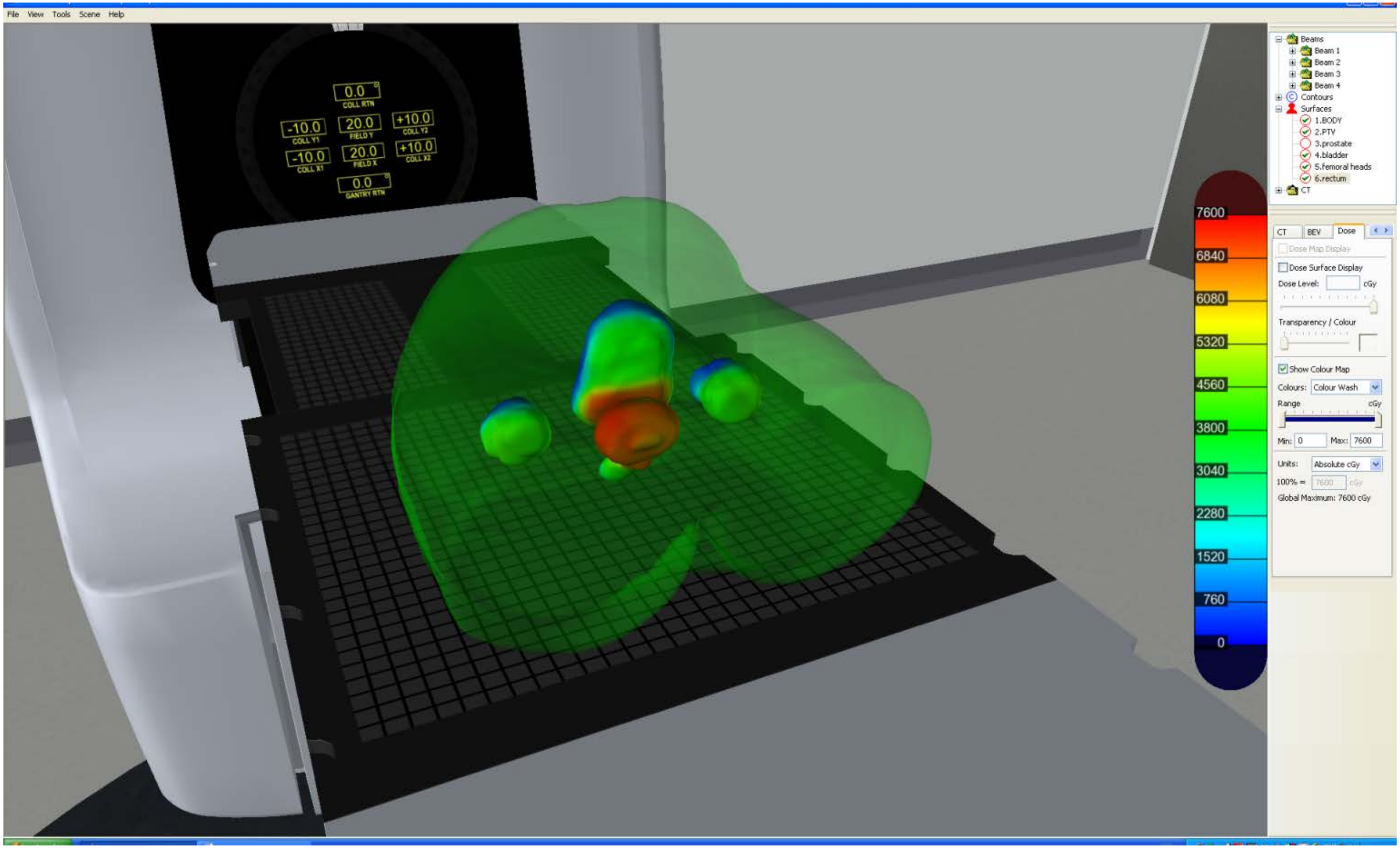
Field Sizes

- The PTV needs to be covered with a margin in order to cover the edges of the target adequately
- If this is not done, the PTV will be underdosed.
- The set field size is greater than the dimensions of the PTV

Shaping fields to PTV only



Shaping fields considering penumbra



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Wedges

- The purpose of a wedge is to shape the isodose distribution.

- Done by reducing the radiation intensity progressively along a beam.

- The wedge angle is the angle through which the isodose curve is tilted relative to their normal position at the central axis of the beam at a specified depth.

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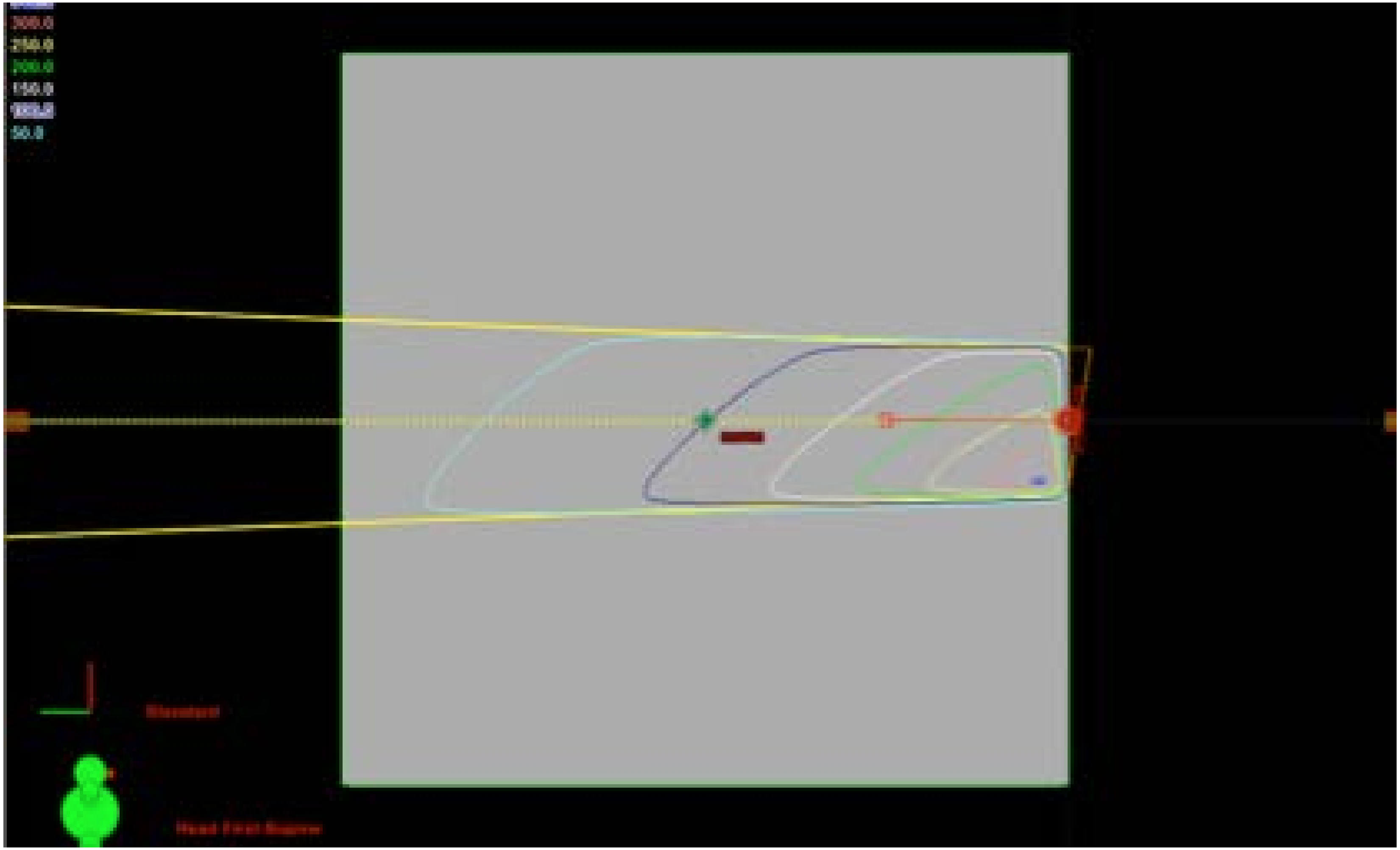
Wedging



Why shape isodoses with wedges?

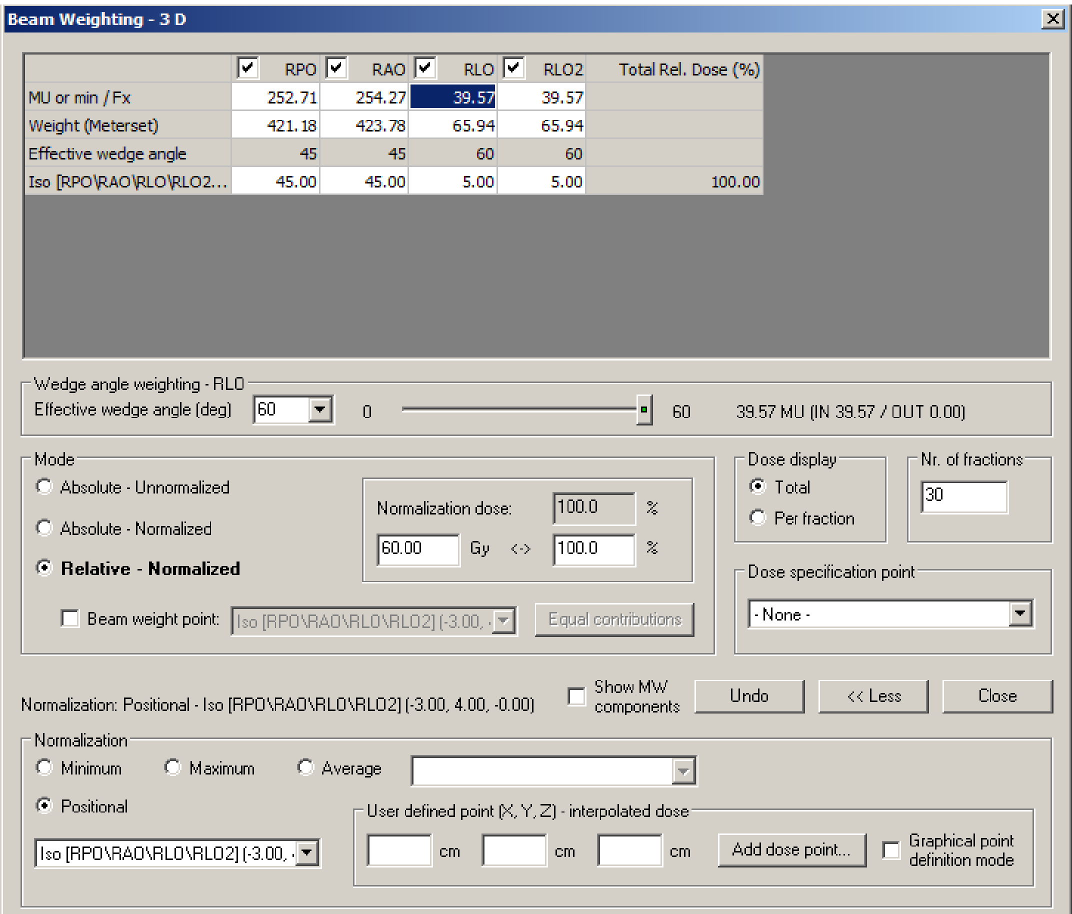
- To create a uniform dose distribution when beams are arranged at angles to one another

- To compensate for surface obliquity.

Beam Weighting

- The **relative** contribution of the beam to the overall plan
- If used appropriately, can improve dose distribution and reduce exit doses to OARs, e.g. parotid, lung.
- Start with conventional weighting and modify based on the patient and situation in hand

Dose Weighting



Working Example:

- For this case, start with 45% to each main field and 5% to each lateral field
- Lateral fields require full or no wedge due to their low MUs

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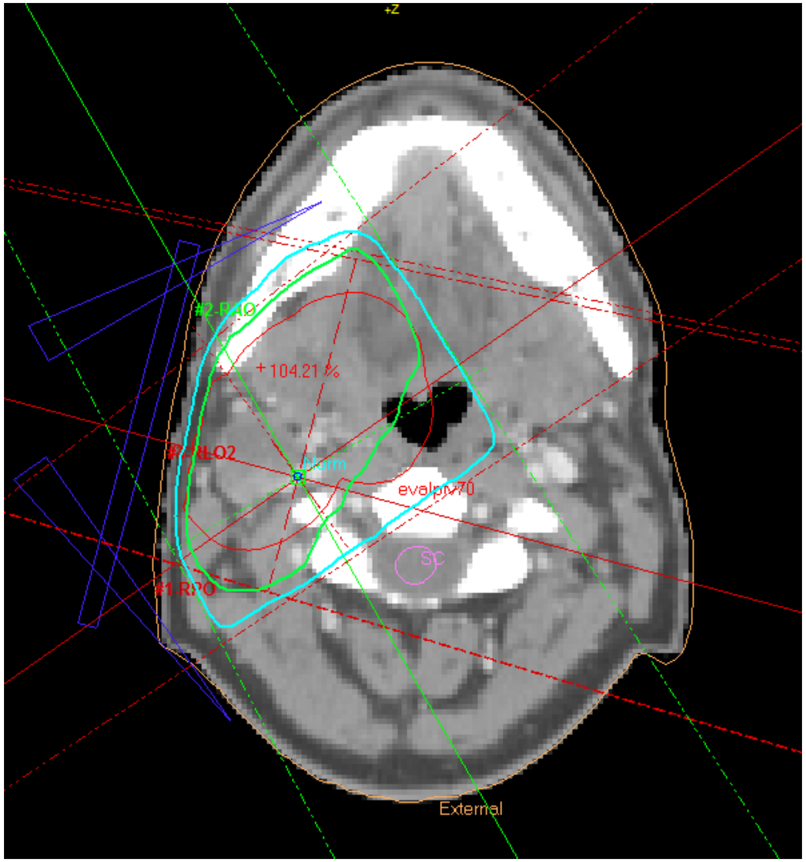
Dose Weighting



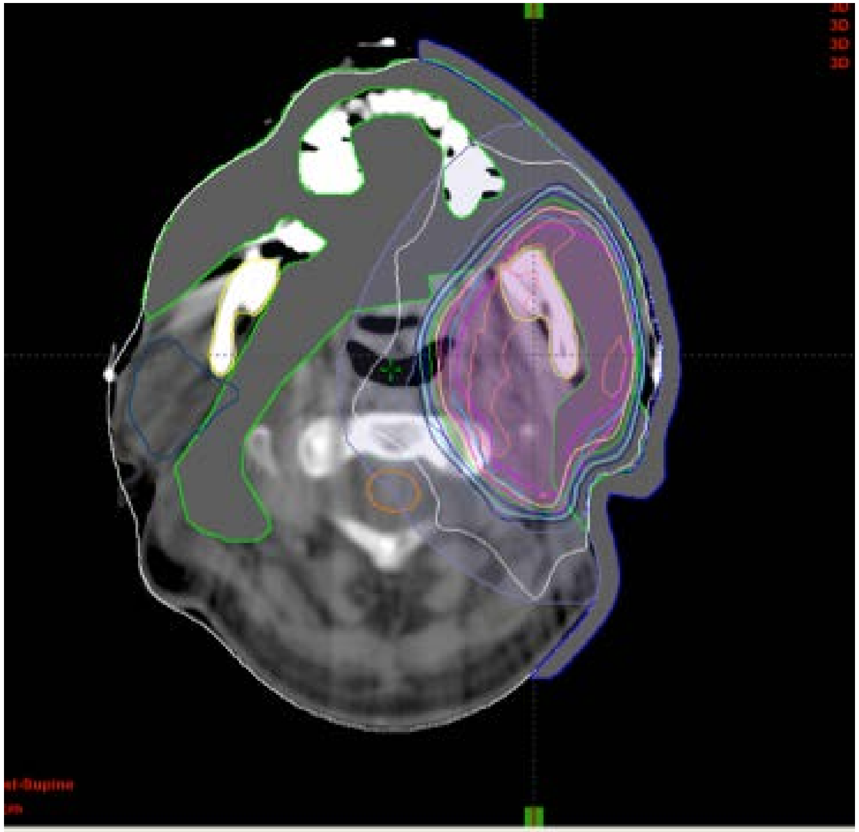
Weight lateral field low to avoid contralateral parotid

Bolus

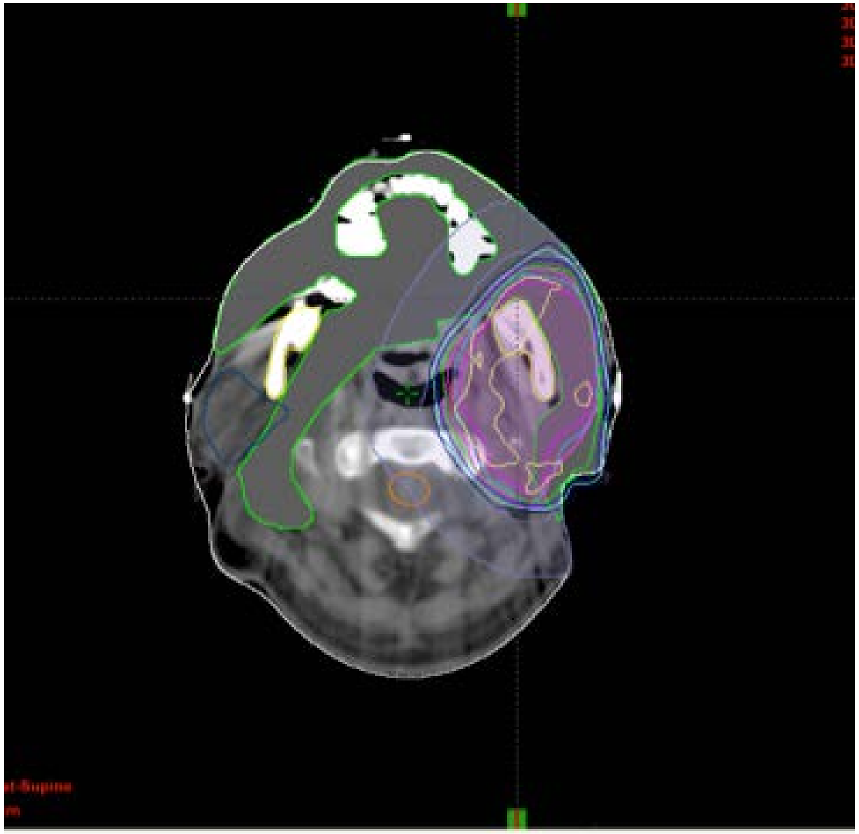
- Bolus is a tissue-equivalent material placed directly on the skin
- Purpose of bolus is to increase the dose on the surface
- If bolus is used across entire field width, all isodose lines are closer to the surface
- Counteracts the skin-sparing effect of megavoltage X-rays, while retaining penetration

Effect of Bolus

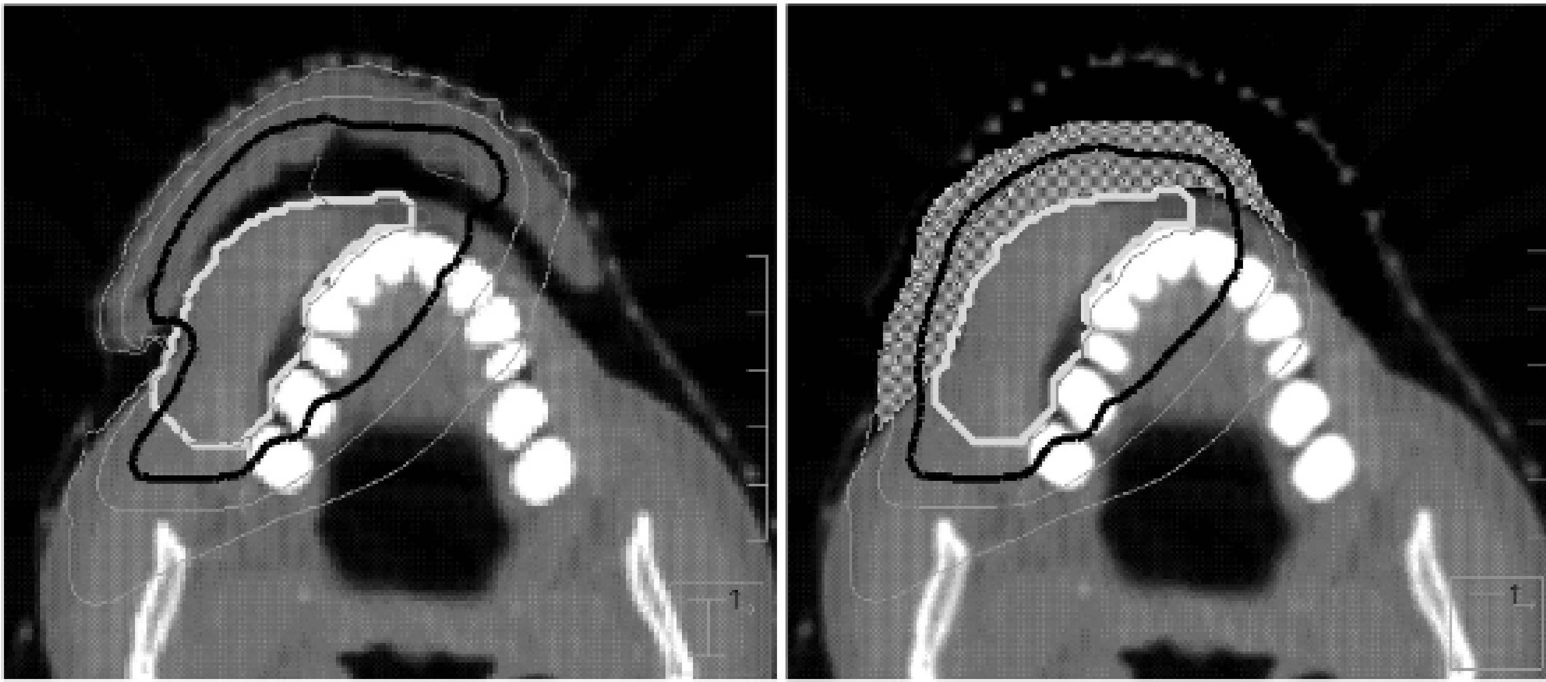
With Bolus



Without Bolus



Scanning with bolus in situ



dose distributions in an axial slice planned with the clinically placed bolus (left frame) and the same plan with the v
is rendered in black and the CTV is outlined in gray.

A. Luu et al./Journal of Medical Imaging and Radiation Sciences ■ (2014) 1-6

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Normalisation

- The normalisation ‘point’ is the ‘point’ where the dose is ‘forced’ to 100% and the dose everywhere else is changed by the same ratio.
- Plans are usually normalised at the geometric centre of PTV (Isocentre)

Normalisation

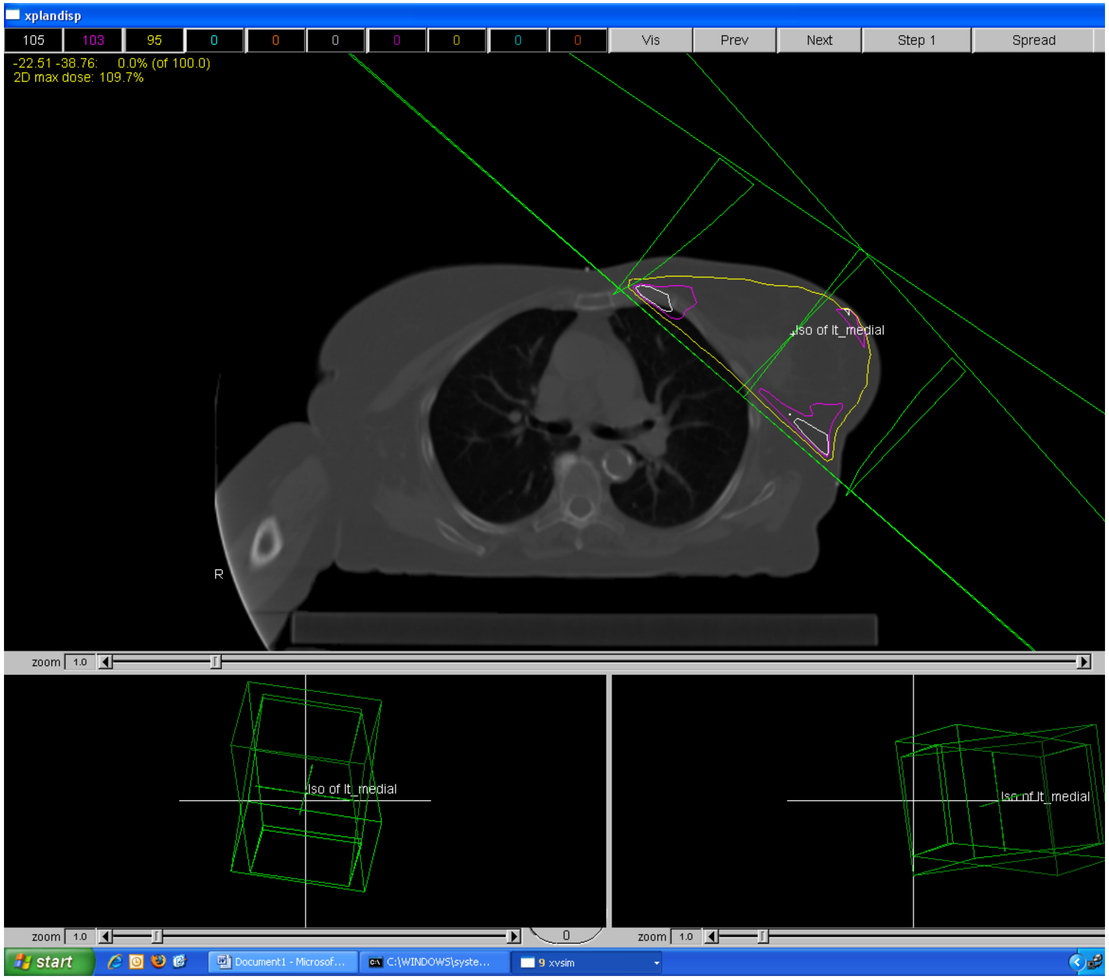
If isocentre is:

- At the posterior edge of a beam
- Located in an inhomogenous tissue
- Located near a field edge or shielding

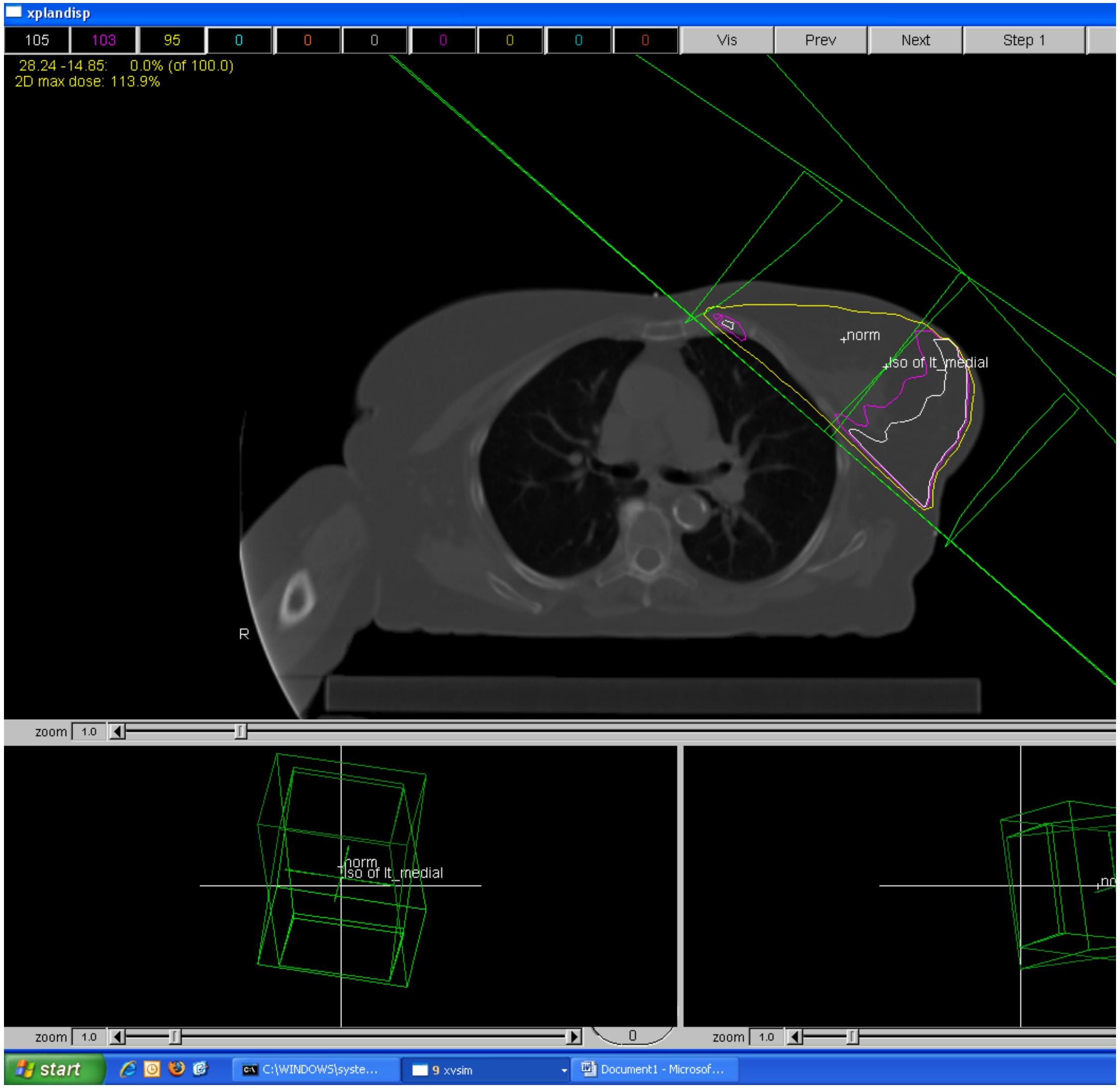
Then need to normalise to a a region that is more representative of the target volume!

Volumetric normalisation: ICRU 83

Normalisation at isocentre



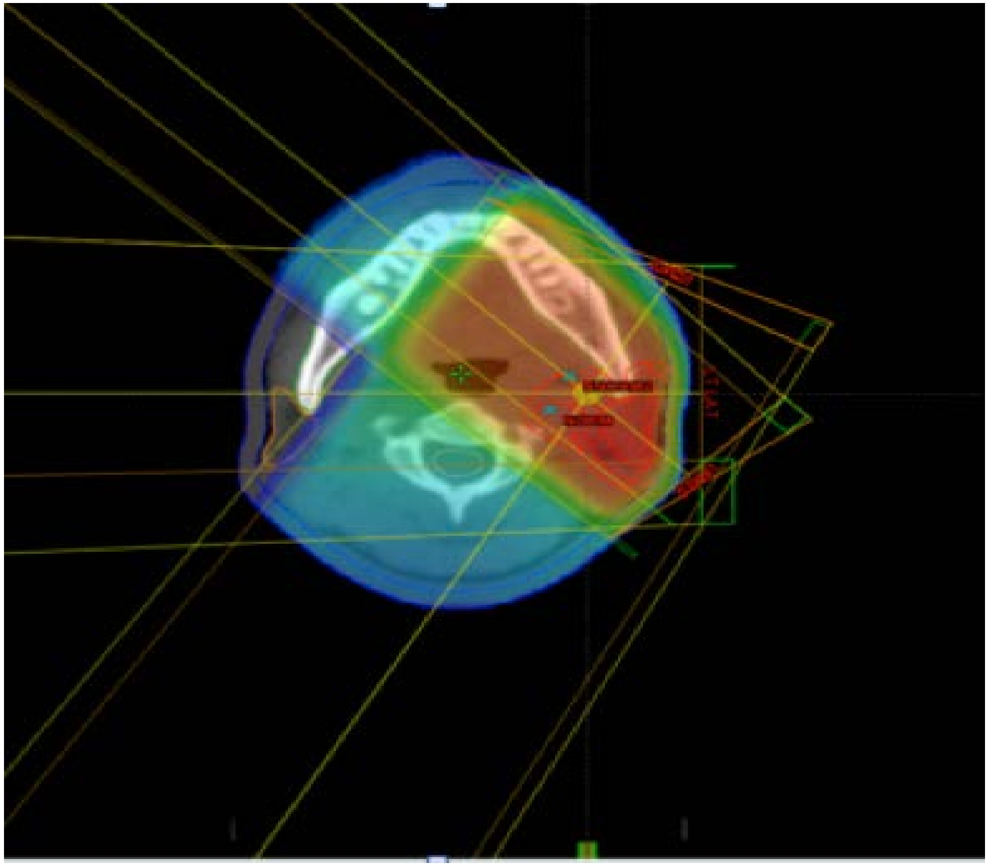
Normalisation to a point



Plan Evaluation: Isodoses

- An isodose curve is one passing through points of equal dose and representing percentage of dose at a reference point

Isodose distribution



Plan evaluation

- Most common method is to visually assess a plan in terms of PTV coverage, dose uniformity and check the tolerance of normal tissue. i.e. analyse your distribution in 3D

- Main plan evaluation tools:
  - ➢ Visual assessment of isodose distribution in 3D (axial, coronal and saggital views)
  - ➢ Cumulative DVH for volumetric analysis
  - ➢ Summary statistics for minimum, maximum and mean doses

Visual Assessment of Plan

- Check in three dimensions
- Work in order of priority:
  - Dose to target volumes
  - Dose to organs at risk (critical and others)
  - Low dose elsewhere

Depending on the clinical situation, the hierarchy of priorities may vary

- Importance of clinical relevance of the plan as well as individual patient factors.
- Remember potential organ motion and its likely impact during daily delivery

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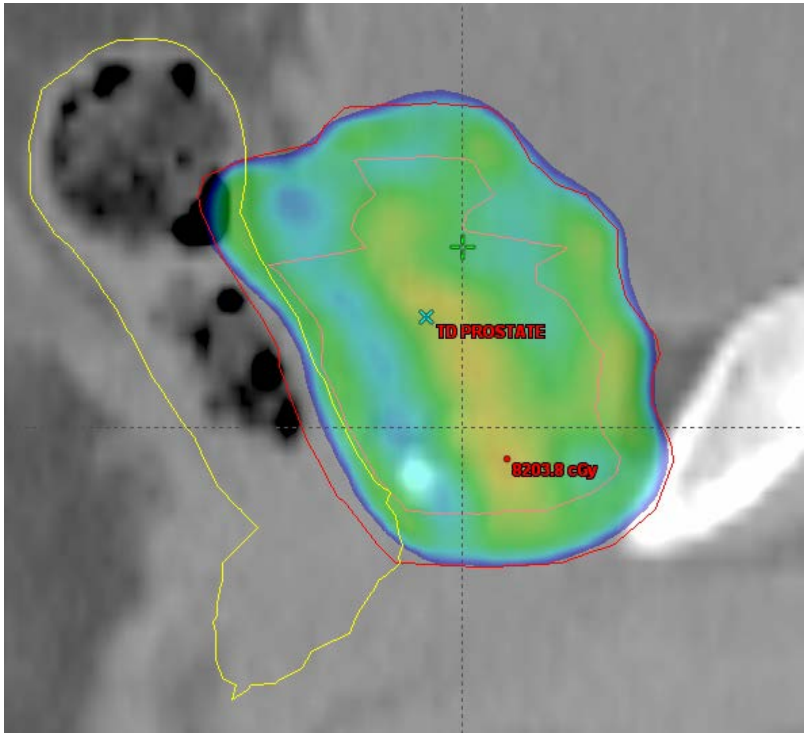
Target coverage inspection

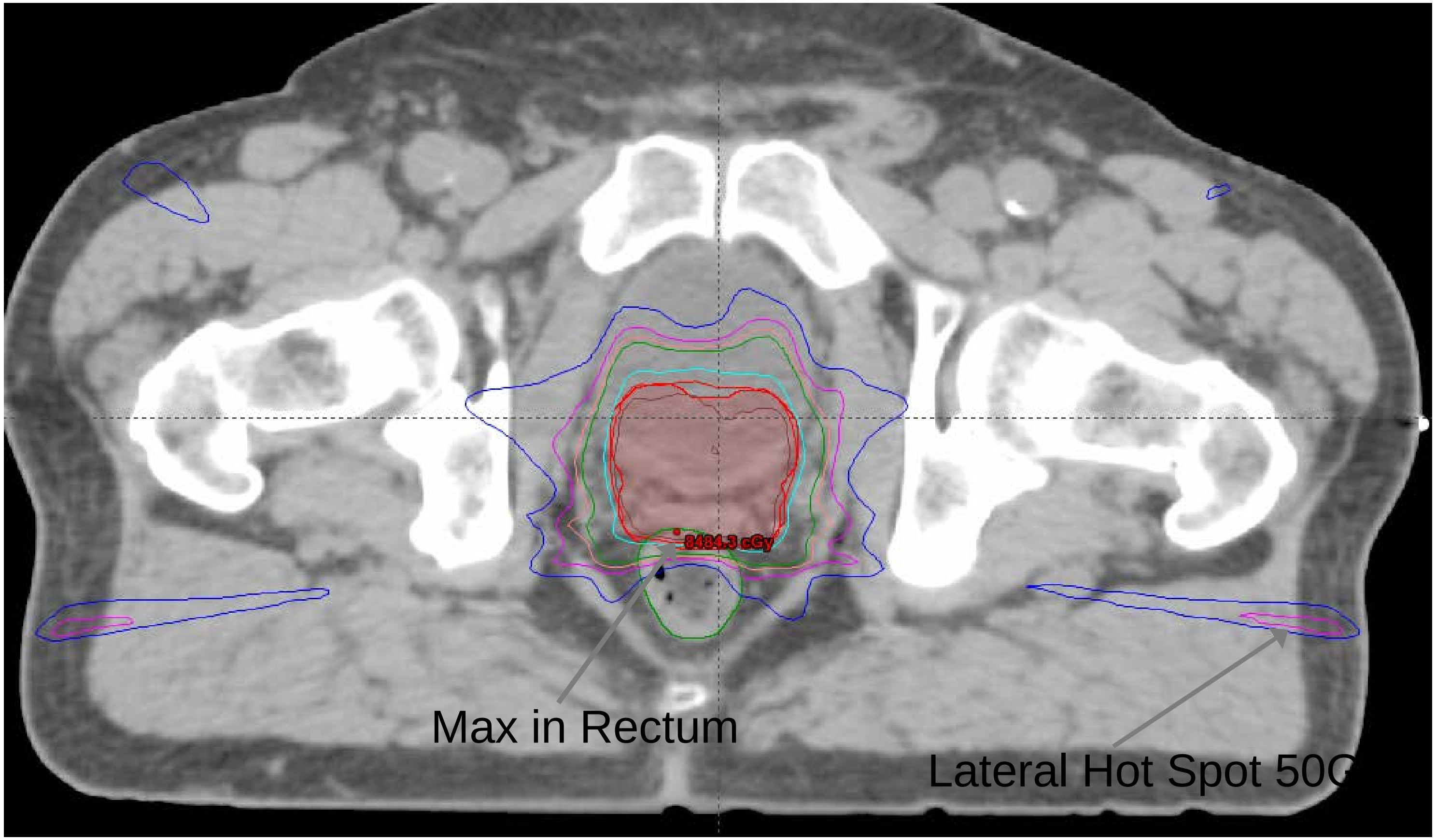
- Check where target coverage is problematic so as to focus your efforts on improving this

Poor target coverage posteriorly in this example

*Use dose colour wash functionality for ease of view



Organ at risk inspection



Plan analysis:
Dose Volume Histograms

- A DVH is a graphical representation of the dose-volume relationship inside a pre-determined volume, such as PTV or OAR
- It is dependant upon
  - ➢ Patient anatomy
  - ➢ Contouring/Delineation method use to define the structure of interest

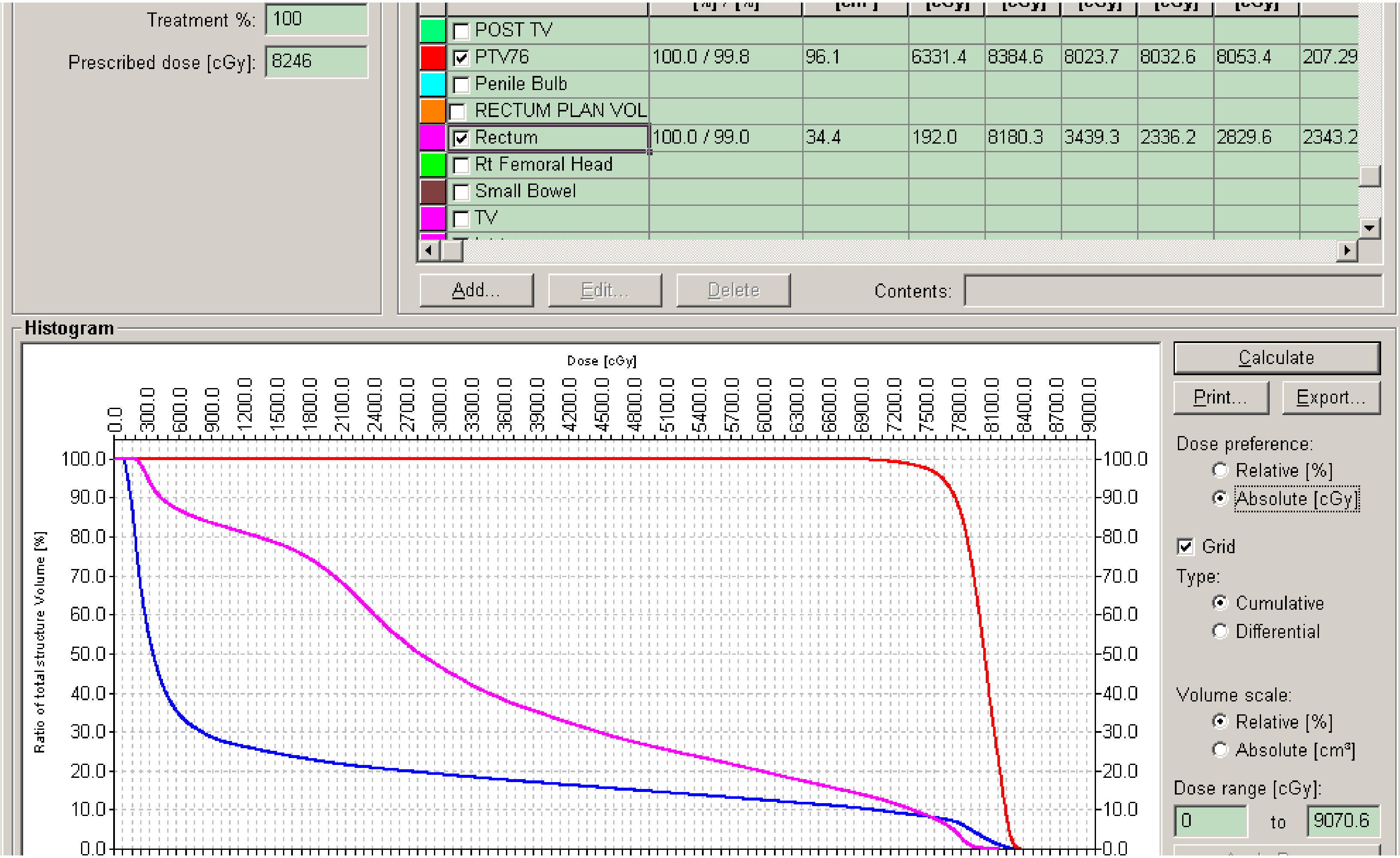
DVH

- It summarises the information contained in the 3D dose distribution and is an extremely powerful tool for **quantitative** evaluation of treatment plans
- For external beam 3DCRT, cumulative DVHs are most commonly used.

Cumulative DVH

- The computer calculates the volume of the target (or organ at risk) that receives **at least** the given dose and plots this volume (or percentage volume) versus dose
- All cumulative DVH plots start at 100% of the volume for 0Gy, since all of the volume receives **at least** no dose.

Cumulative DVH



Cumulative DVH

- From this one can determine for each structure of interest
    - Vyy: Volume receiving a dose equal or higher than yyGy
    - DxxGy: Dose received by xx volume.
    - Mean dose
    - Maximum dose

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What are dose volume constraints (DVCs?)

- Dose Volume constraints(DVCs) are used in 3DCRT to predict the likely manifestation of a side-effect of a particular magnitude when a specified dose is received by an OAR.
- The use of dose volume constraints in a department **must** be related to the manner in which OARs are delineated
  - Consistency in delineation and in dose volume constraints applied in 3DCRT is paramount in ascertaining the manifestation of radiation-induced toxicities.

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How to read a dose volume constraint

OAR	Dmax	Constraint	Constraint	Constraint	Constraint
Rectum		V65<25%	V60<35%	V75<15%	V50<50%
Bladder		V75<25%	V70<35%	V65<50%	
Femoral Heads	<50 Gy				

Example: *V65<25% means that 25% volume of the rectum should not receive a dose of more than 65 Gray*

Cumulative DVH

Analysis using DVHs

- The main drawback of DVHs is the **<u>loss of spatial information</u>** that results from the condensation of data when DVHs are calculated.

- The parameters of volume and dose are useful, but some questions remain unanswered:
  - Is an entire segment across the spinal cord being irradiated or just an elongated segment on one side?
  - In combined lung DVHs, is one lung receiving a very high dose and the other very little dose, or are both receiving equal dose?

Dose volume constraints

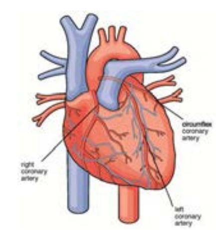
- The **prescribed** goals of radiotherapy treatment planning are often expressed in terms of dose volume constraints
- Seminal work by Emami et al in 1991
- Expanded upon by Milano et al in 2007
- Currently, QUANTEC guidelines (2010) are the most recent evidence-based guidelines though clinicians' experience and judgement are also required

Which constraint is most important for normal tissue?

- Whether a maximum constraint or a volumetric constraint is most important for normal tissue depends on the structure and functionality of that organ
- Organs can be considered to be constructed of Functional Sub-units (FSUs)
- Some FSUs are arranged in series

- Some FSUs are arranged in parallel

- The majority of organs are a combination of both



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Organs with high seriality

- The irradiation of a single FSU to a certain dose level might alter the functionality of the organ and cause complications
- For 3DCRT, the **maximum dose** is important for serial organs

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Int. J. Radiation Oncology Biol. Phys., Vol. 76, No. 3, Supplement, pp. S42–S49, 2010

0360-3016/10/$–see front matter

doi:10.1016/j.ijrobp.2009.04.095

QUANTEC: ORGAN SPECIFIC PAPER **Central Nervous System: Spinal Cord**

RADIATION DOSE–VOLUME EFFECTS IN THE SPINAL CORD

John P. Kirkpatrick, M.D., Ph.D.,* Albert J. van der Kogel, Ph.D.,† and Timothy E. Schultheiss, Ph.D.‡

From the *Department of Radiation Oncology, Duke University Medical Center, Durham, NC; †Department of Radiation Oncology, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands; and ‡Department of Radiation Physics, City of Hope Cancer Center, Duarte, CA

RECOMMENDED DOSE–VOLUME LIMITS

With conventional fractionation of 2 Gy per day including the full cord cross-section, a total dose of 50 Gy, 60 Gy, and ~69 Gy are associated with a 0.2, 6, and 50% rate of myelopathy. For reirradiation of the full cord cross-section at 2 Gy per day after prior conventionally fractionated treatment, cord tolerance appears to increase at least 25% 6 months after the initial course of RT based on animal and human studies. For partial cord irradiation as part of spine radiosurgery, a maximum cord dose of 13 Gy in a single fraction or 20 Gy in three fractions appears associated with a <1% risk of injury.

Organs with architecture arranged in parallel

- Irradiating **a certain proportion** of the total organ volume will be required before the functionality of the organ is impaired and complications arise

Int. J. Radiation Oncology Biol. Phys., Vol. 76, No.3, Supplement, pp. S70–S76, 2010

0360-3016/10/$–see front matter

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doi:10.1016/j.ijrobp.2009.06.091

QUANTEC: ORGAN-SPECIFIC PAPER — Thorax: Lung

RADIATION DOSE–VOLUME EFFECTS IN THE LUNG

Lawrence B. Marks, M.D.,* Soren M. Bentzen, D.Sc.,† Joseph O. Deasy, Ph.D.,‡
Feng-Ming (Spring) Kong, M.D., Ph.D.,§ Jeffrey D. Bradley, M.D.,‡ Ivan S. Vogelius, Ph.D.,†
Issam El Naqa, Ph.D.,‡ Jessica L. Hubbs, M.S.,* Joos V. Lebesque, M.D., Ph.D.,||
Robert D. Timmerman, M.D.,¶ Mary K. Martel, Ph.D.,# and Andrew Jackson, Ph.D.**

8. RECOMMENDED DOSE/VOLUME LIMITS

Recommending dose/volume limits is challenging because there are no clear and consistent ‘‘thresholds’’ for candidate metrics (i.e., the response function is often gradual), and

the ‘‘acceptable’’ risk level varies with the clinic scenario. Radiotherapy fields for lung cancer may be appropriately large for target coverage; physicians and patients often need to accept the significant pulmonary risks. Furthermore, there are marked interpatient variations in pre-RT lung function that may impact symptom development, and tumor-related dysfunction may improve after RT.

Despite these caveats, it is prudent to limit V20 to ≤30–35 % and MLD to ≤20–23 Gy (with conventional fractionation) if one wants to limit the risk of RP to ≤20% in definitively treated patients with non–small-cell lung cancer. Similar guidelines for other parameters can be extracted from the figures. Limiting the dose to the central airways to ≤80 Gy may reduce the risk of bronchial stricture (30). In patients treated after pneumonectomy for mesothelioma, it is prudent to limit the V5 to <60%, the V20 to <4–10%, and the MLD to <8 Gy (see Miles *et al.* [37] for detailed review).

Conclusion

- In this presentation, you have learned to:
  - Describe the steps in the planning process
  - Outline the differences between fixed FSD and isocentric treatments
  - Appreciate the difference between single, parallel opposed and multi-field techniques
  - Describe when wedges, weighting and bolus are required in treatment planning
  - Appreciate when different beam energies are preferred.

Treatment Considerations for Palliative Radiotherapy

Dr Paul Kelly
Cork University Hospital

Outline

- Common indications
- Treatment goals
- Field arrangements
- Cases
  - ➢ Spinal Cord Compression
  - ➢ Whole Brain Radiation
  - ➢ Palliative Lung
  - ➢ Neck node

Common Indications

Emergencies

- Spinal Cord Compression
- Uncontrolled Bleeding eg haemopytsis
- Superior Mediastinal Obstruction

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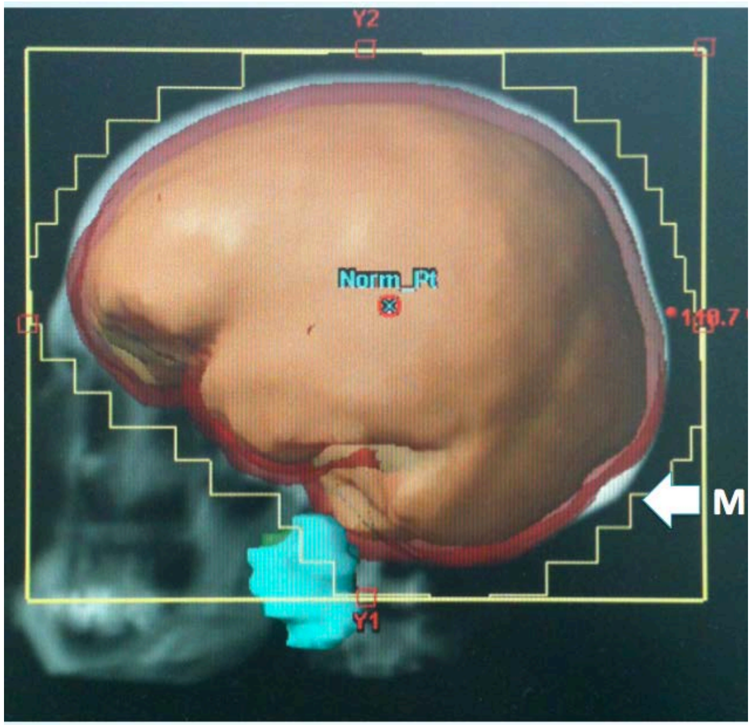
Common Indications

Emergencies

- Spinal Cord Compression
- Uncontrolled Bleeding eg haemopytsis
- Superior Mediastinal Obstruction

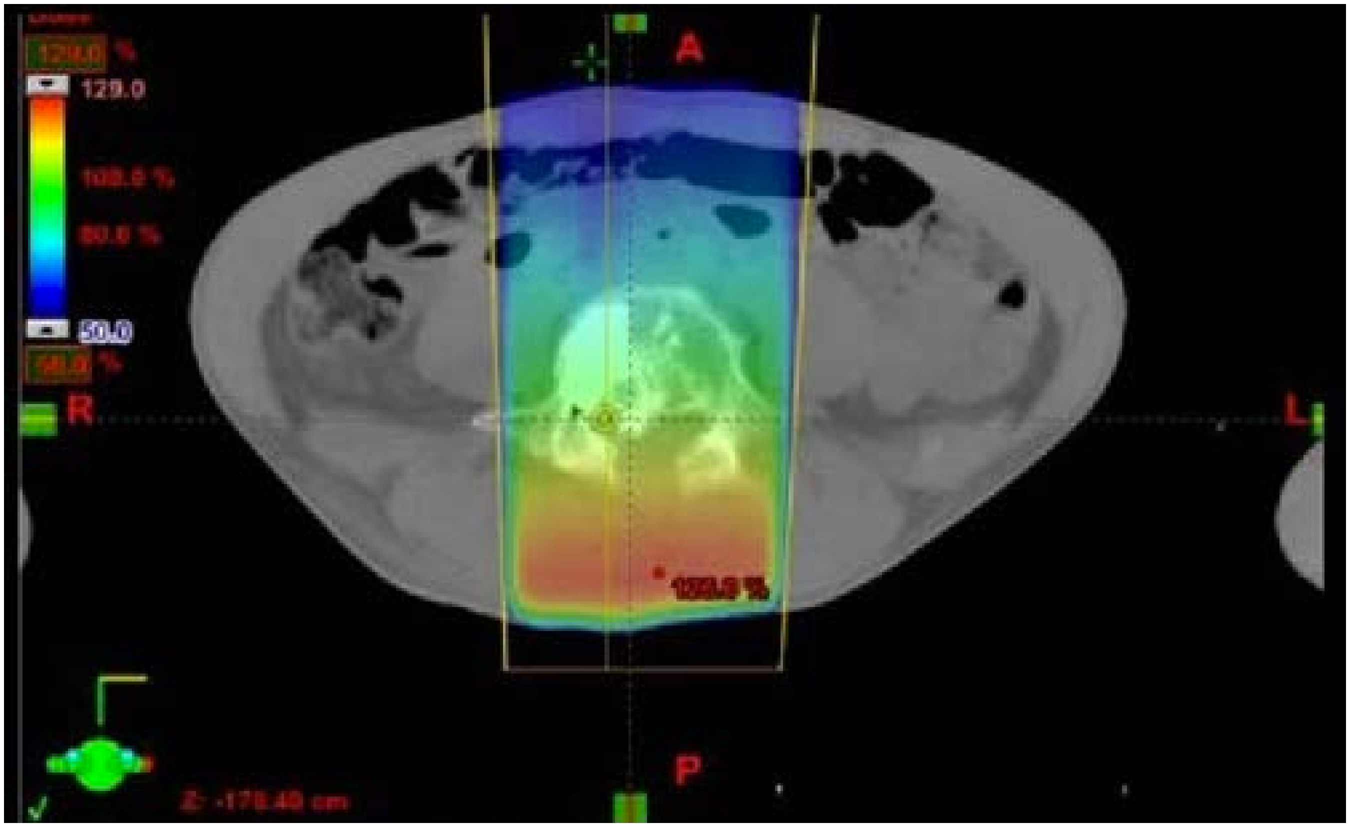
Non-Emergency Treatments

- Bone Pain
- Whole Brain Radiotherapy
- Tumour masses eg lung/pelvis/lymph node



Treatment Goals

- Relief of symptoms
- Not cure!
- Speed of delivery
- Technique dependent on:
  - time and resources available
  - logistics
- Convenient fractionation schedules
- Simple field arrangements
- Simple dose calculations/dose distributions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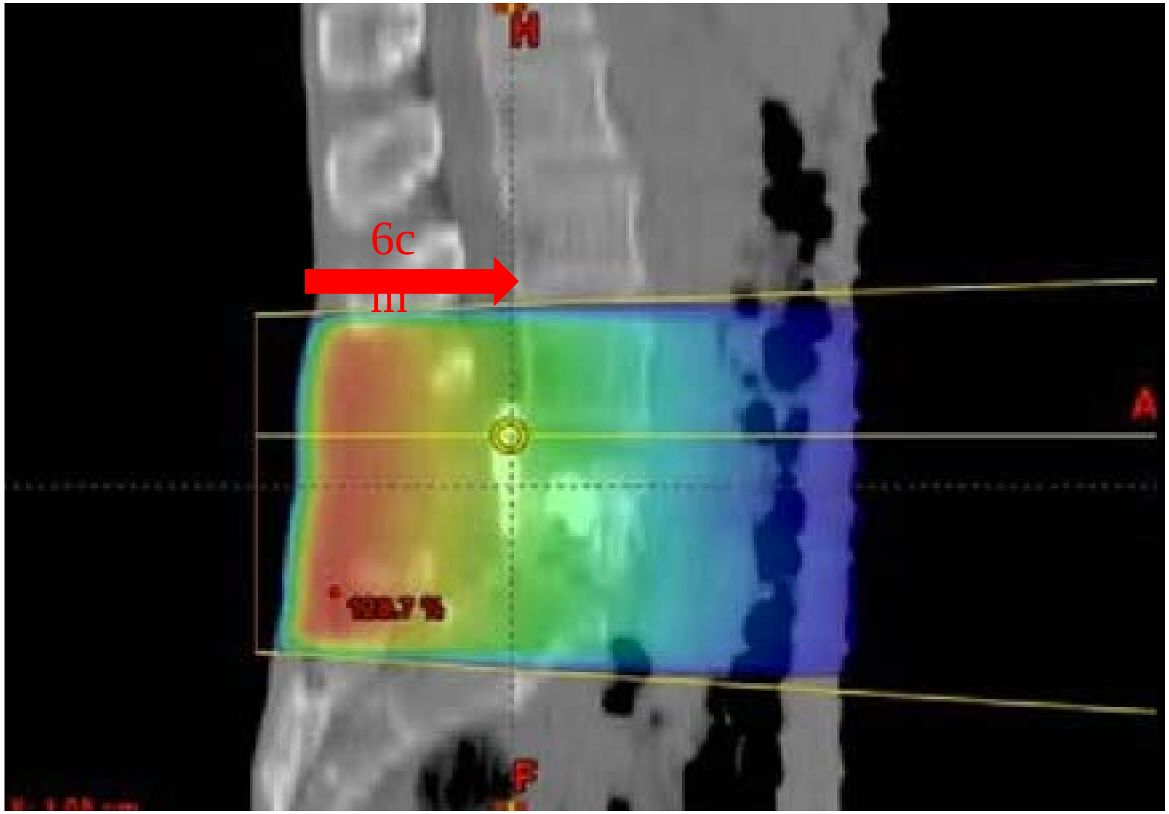
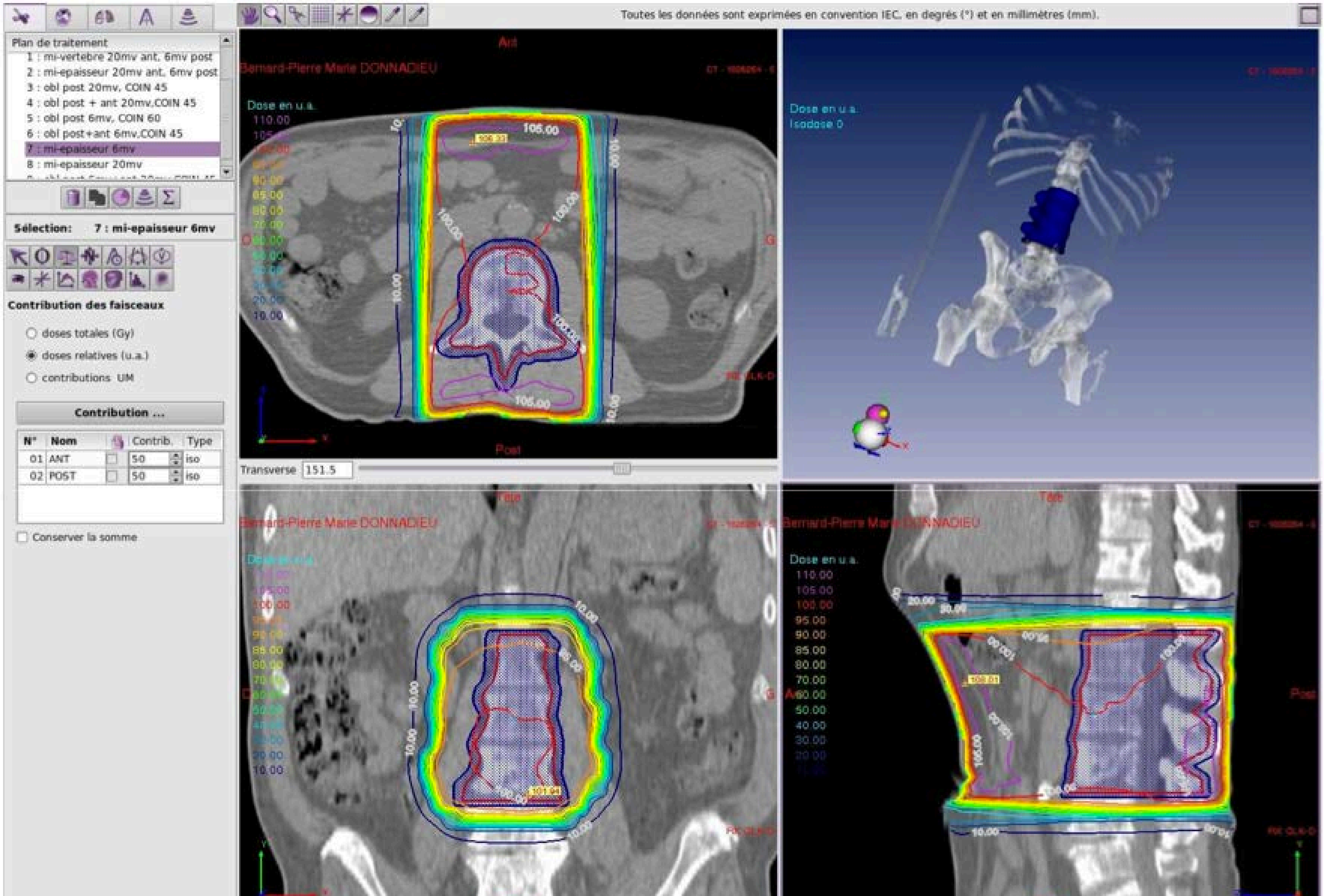
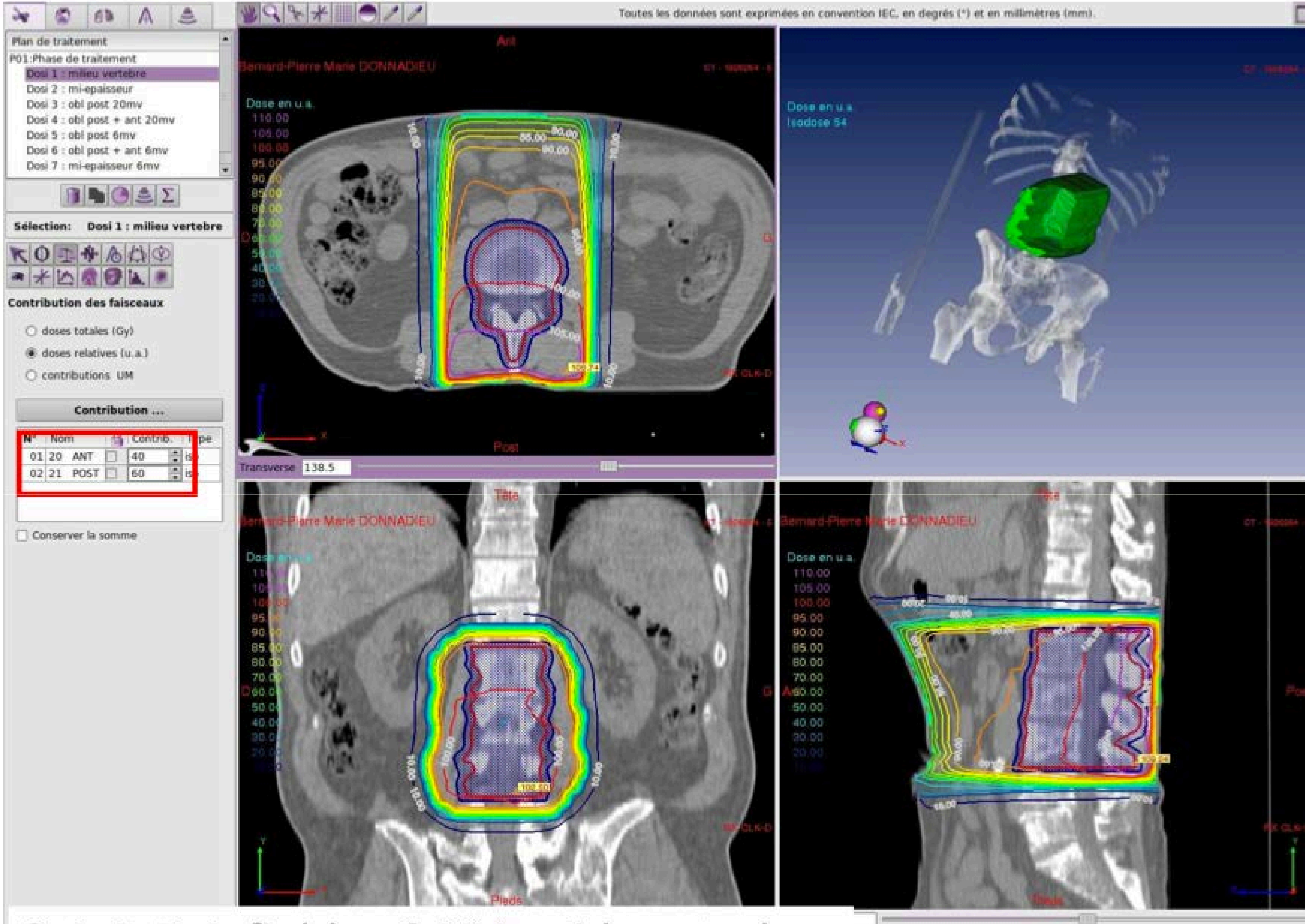


Dmax 6 MV beam @ 1.5cm



2 A-P P-A fields, 6 MV, half body



2 A-P P-A fields, 6 MV, mid vertebra

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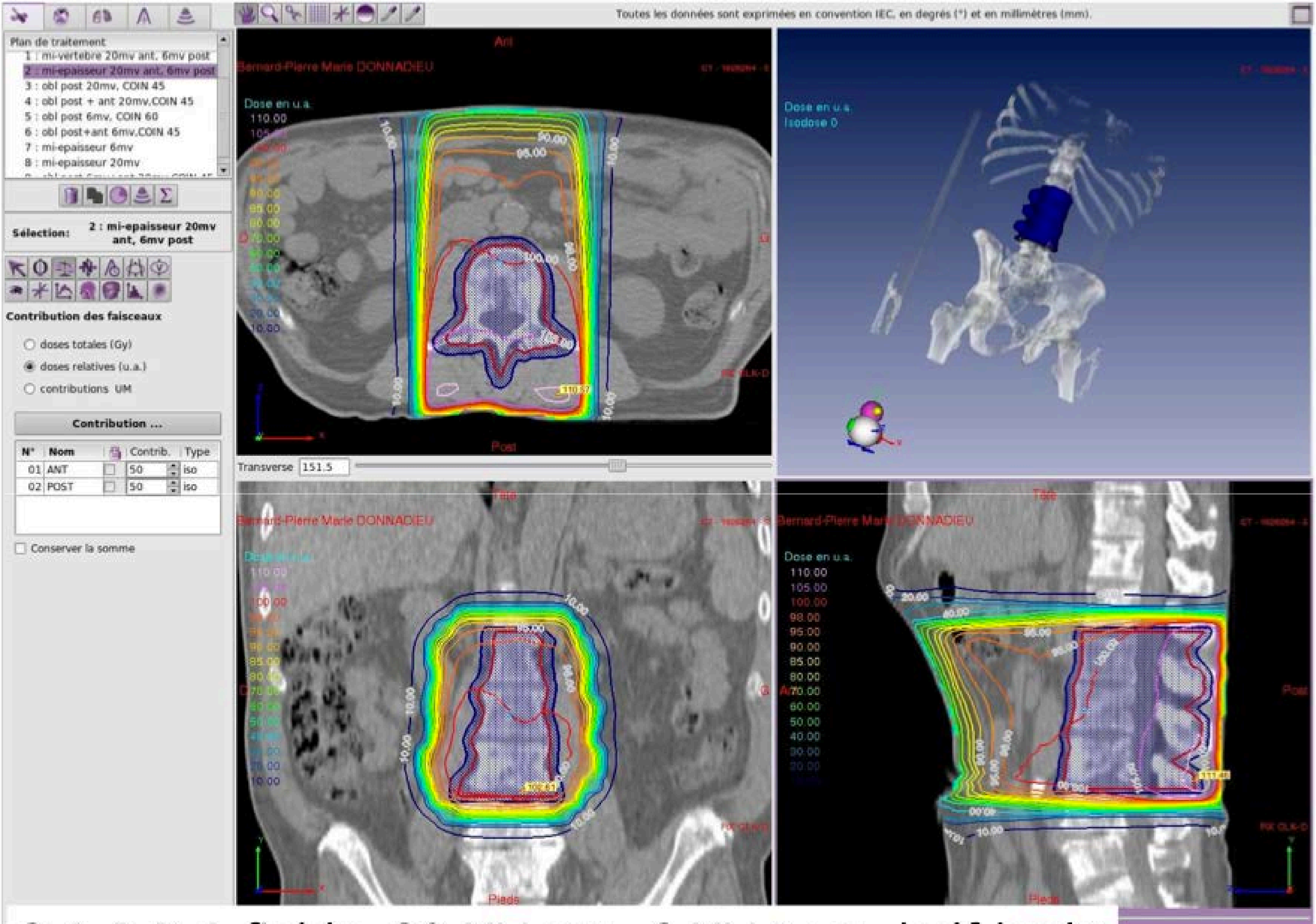
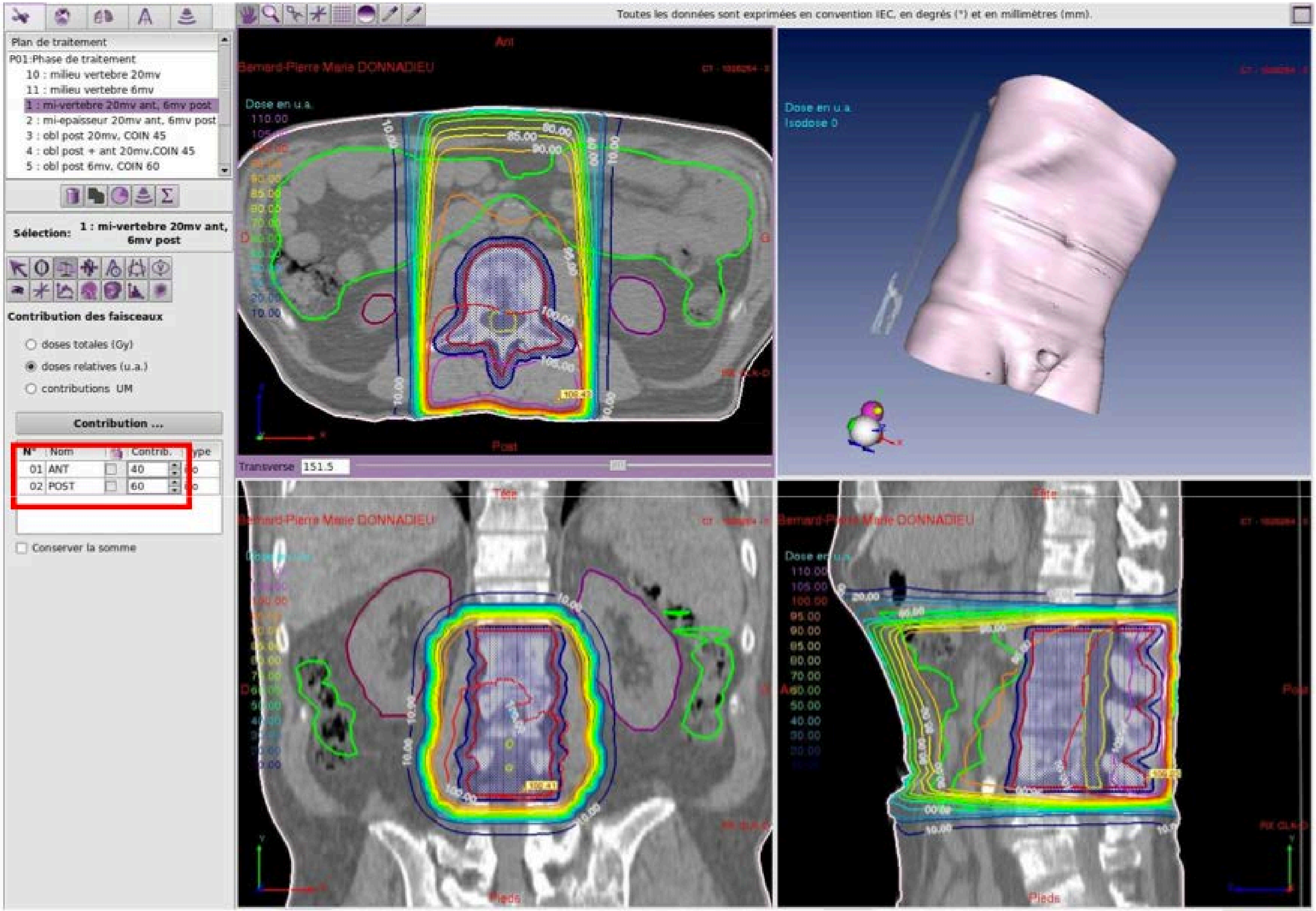


2 A-P P-A fields, 20 MV ant, 6 MV post, half body



2 A-P P-A fields, 20 MV ant, 6 MV post, mid vertebrae

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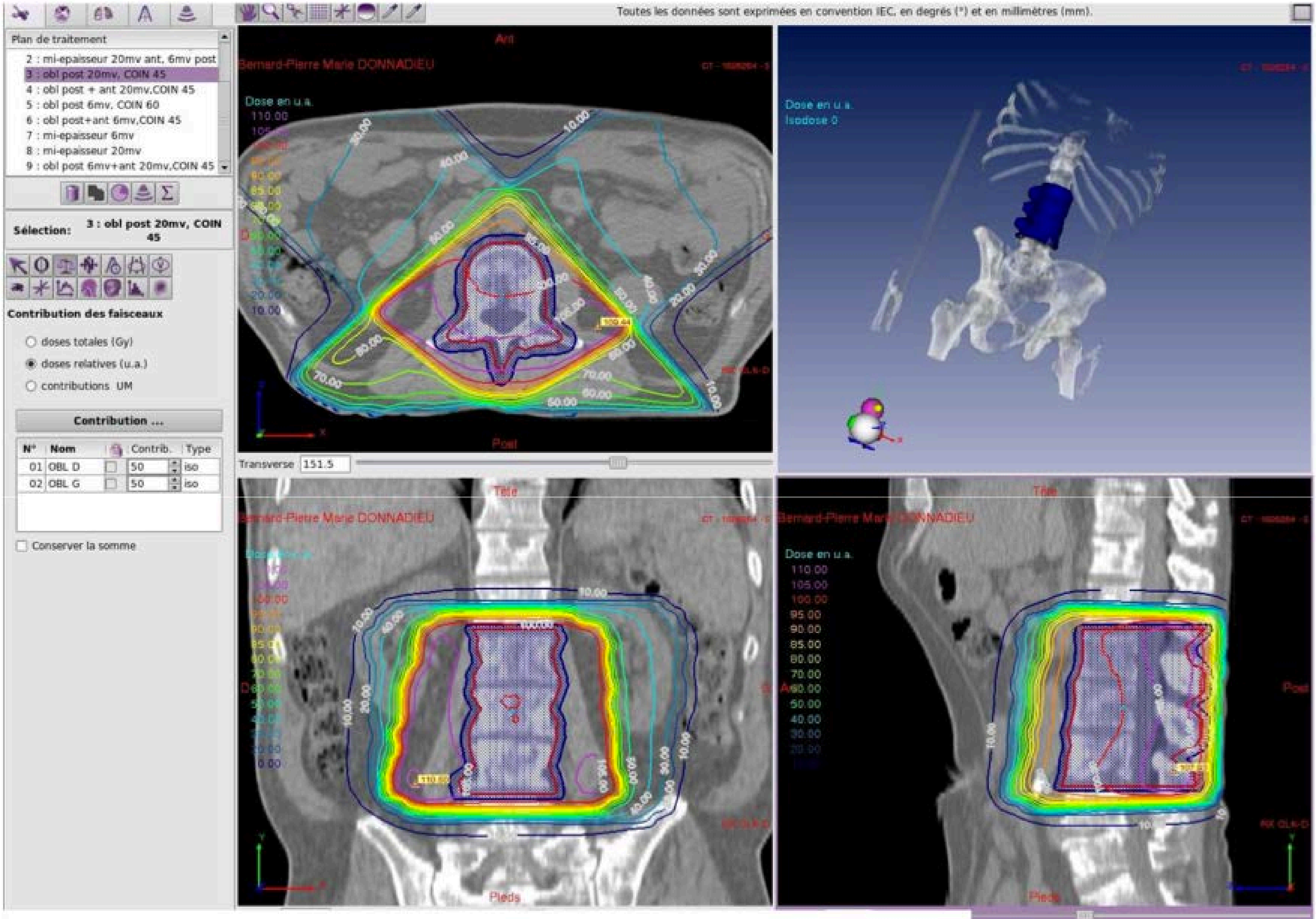

2 oblique post fields, 20 MV + 45° wedges

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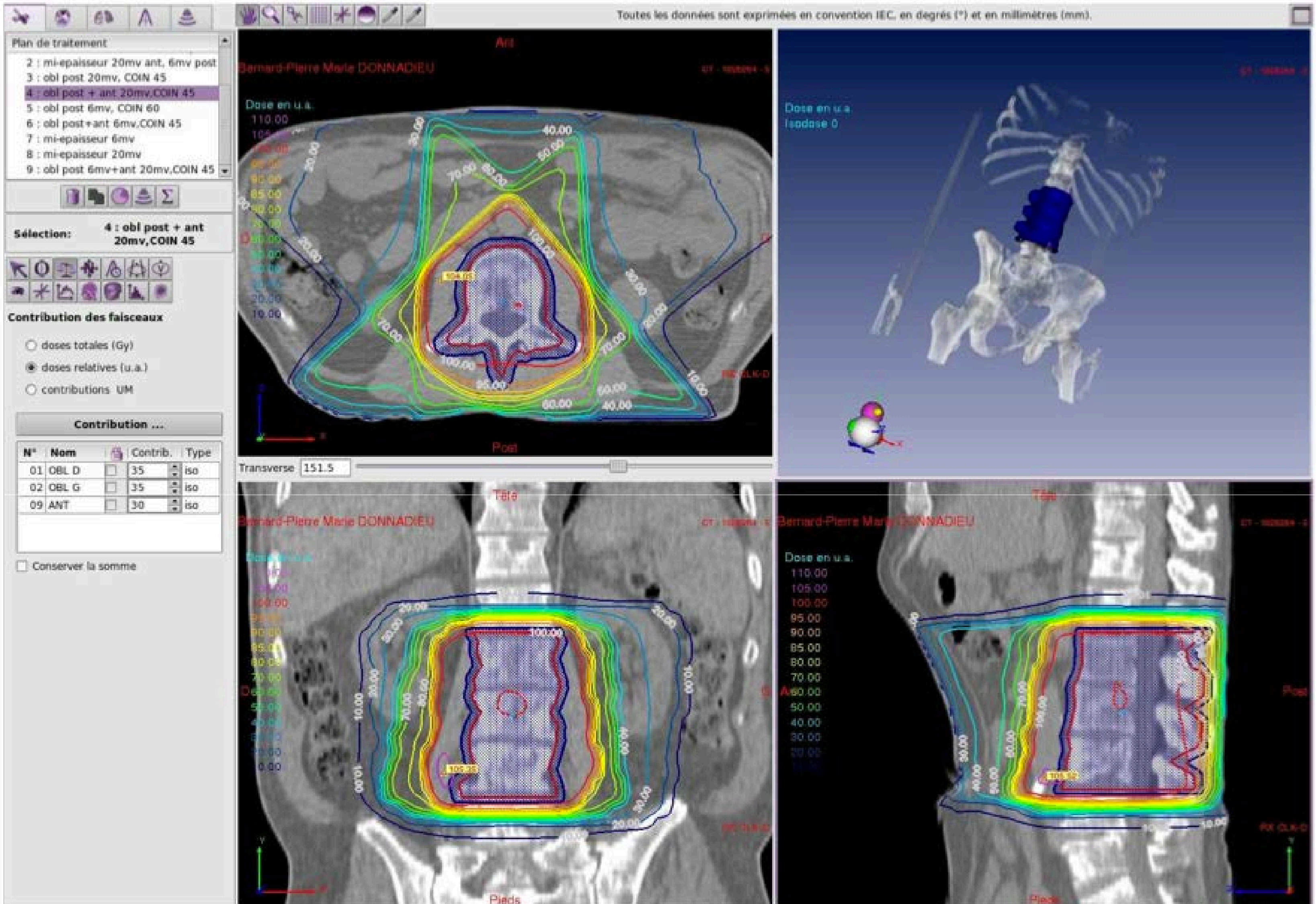
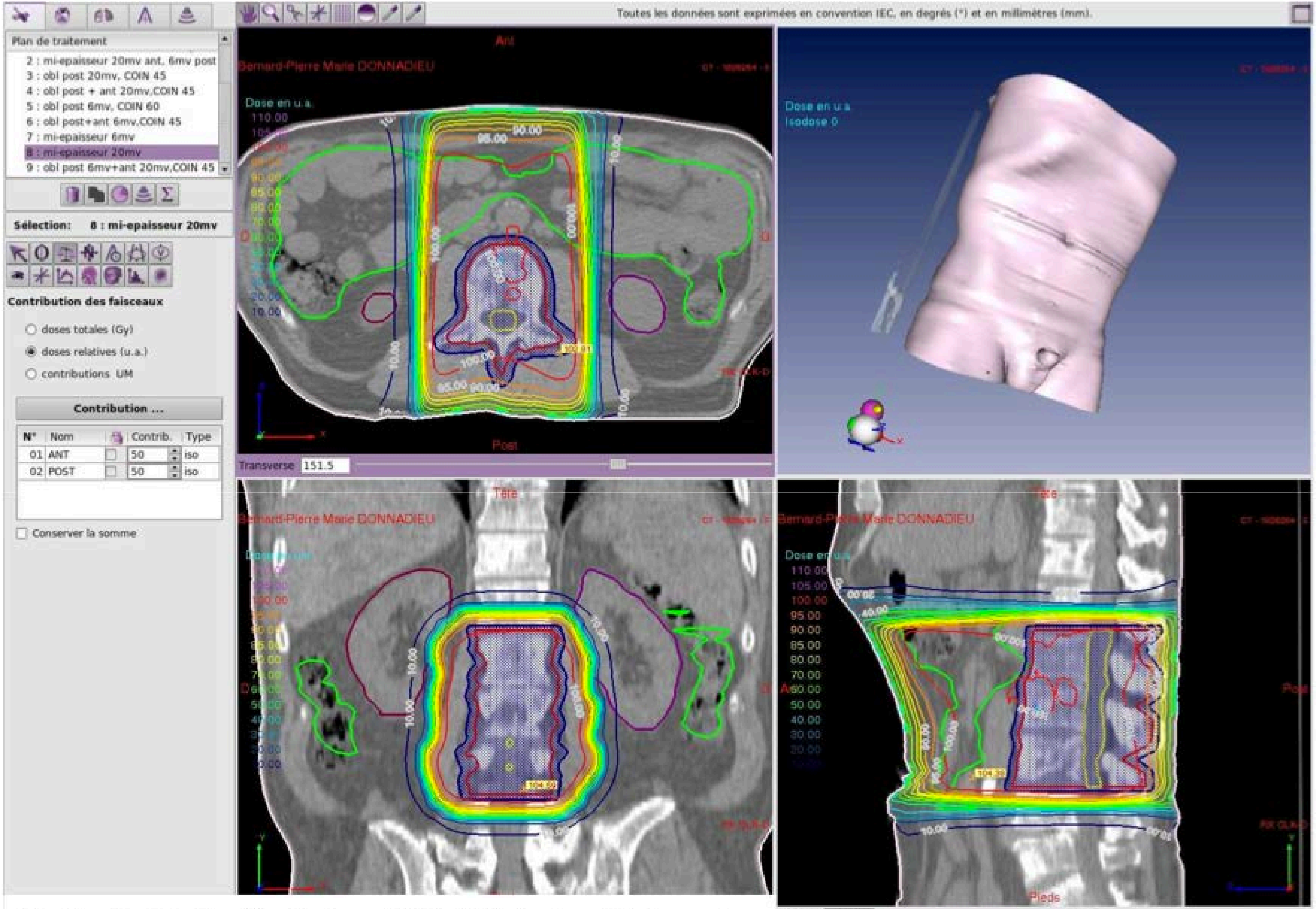
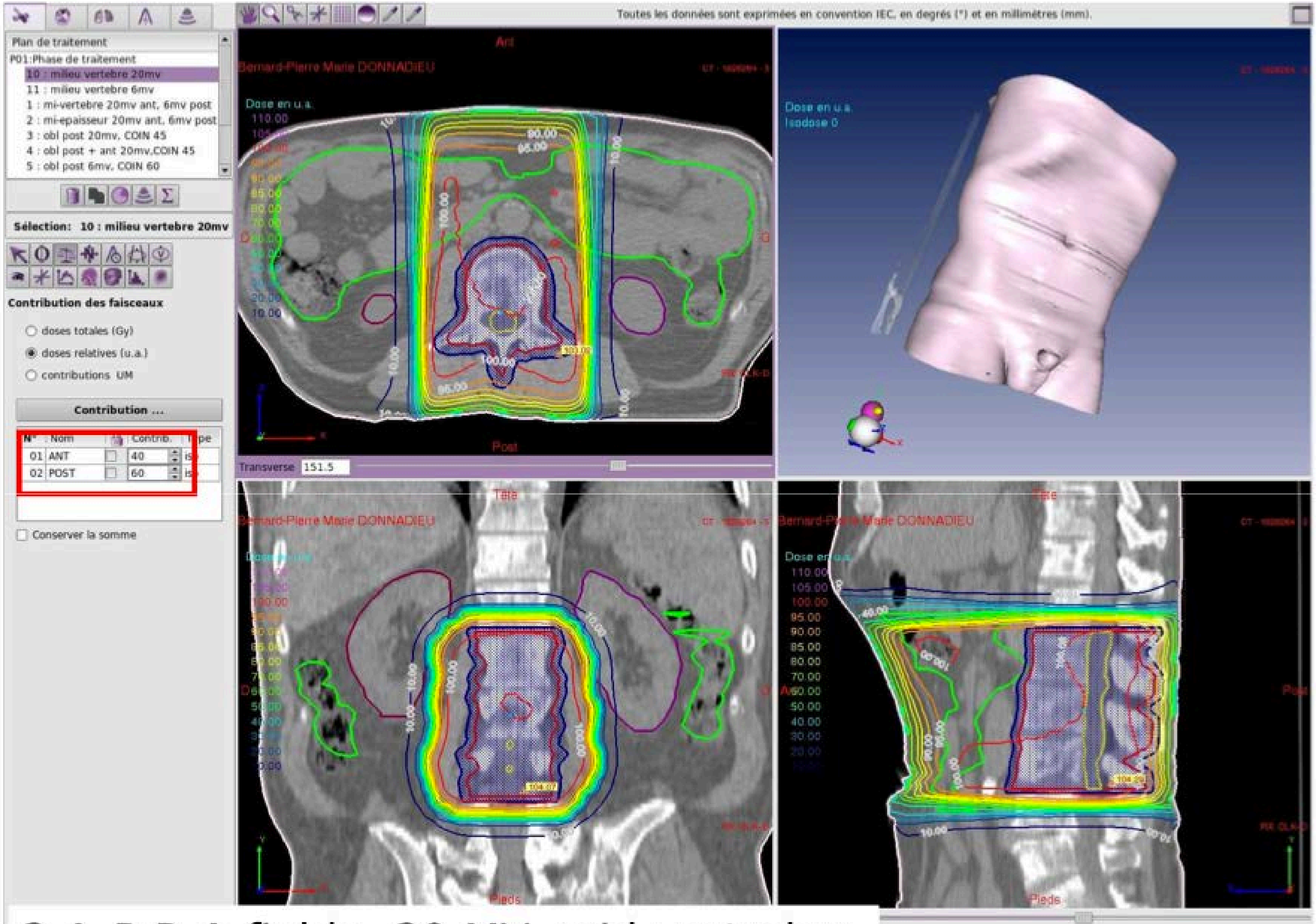


2 oblique post fields, 45° wedges, + A-P field, 20 MV



2 A-P P-A fields, 20 MV, half body



2 A-P P-A fields, 20 MV, mid vertrebra

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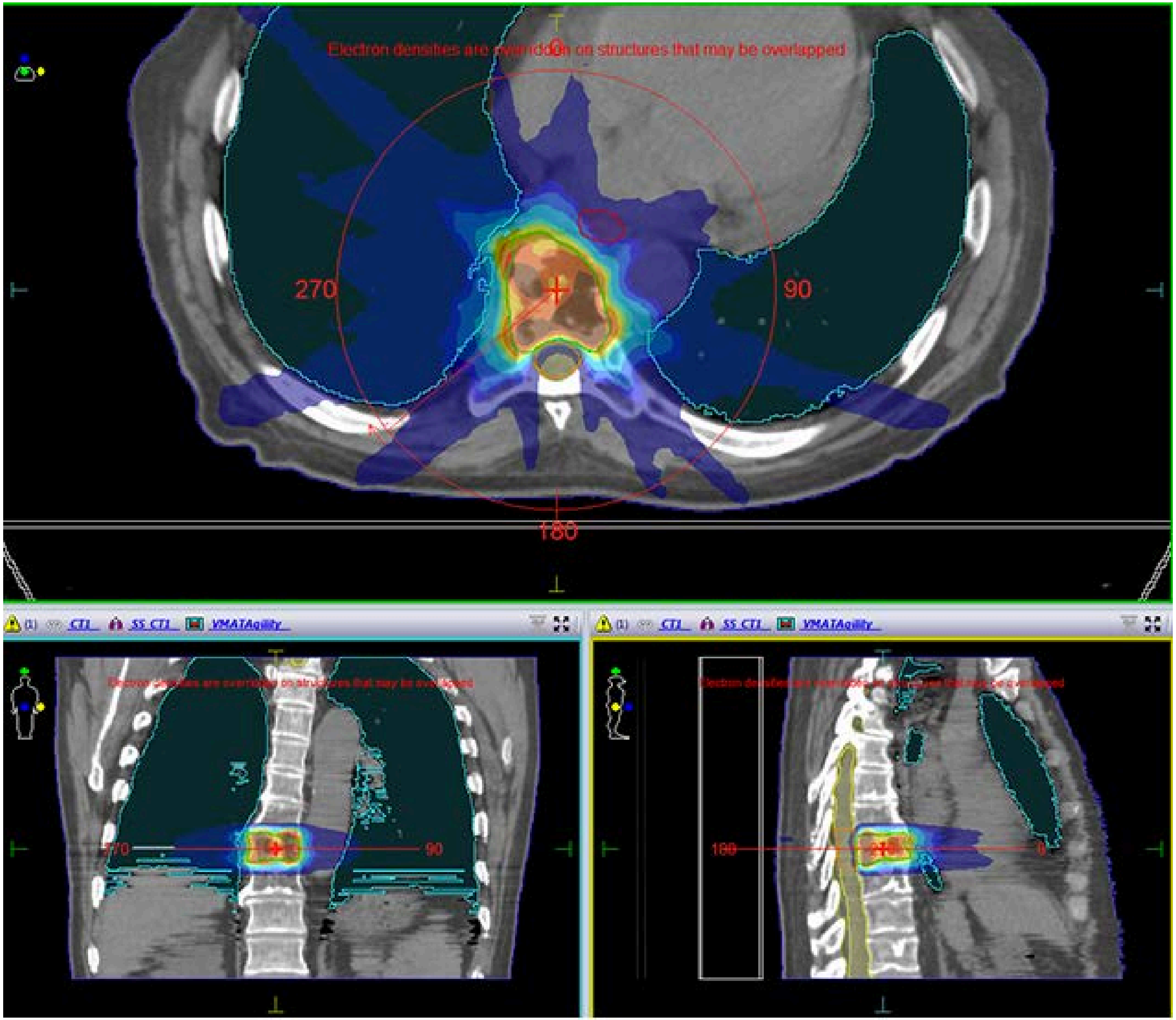

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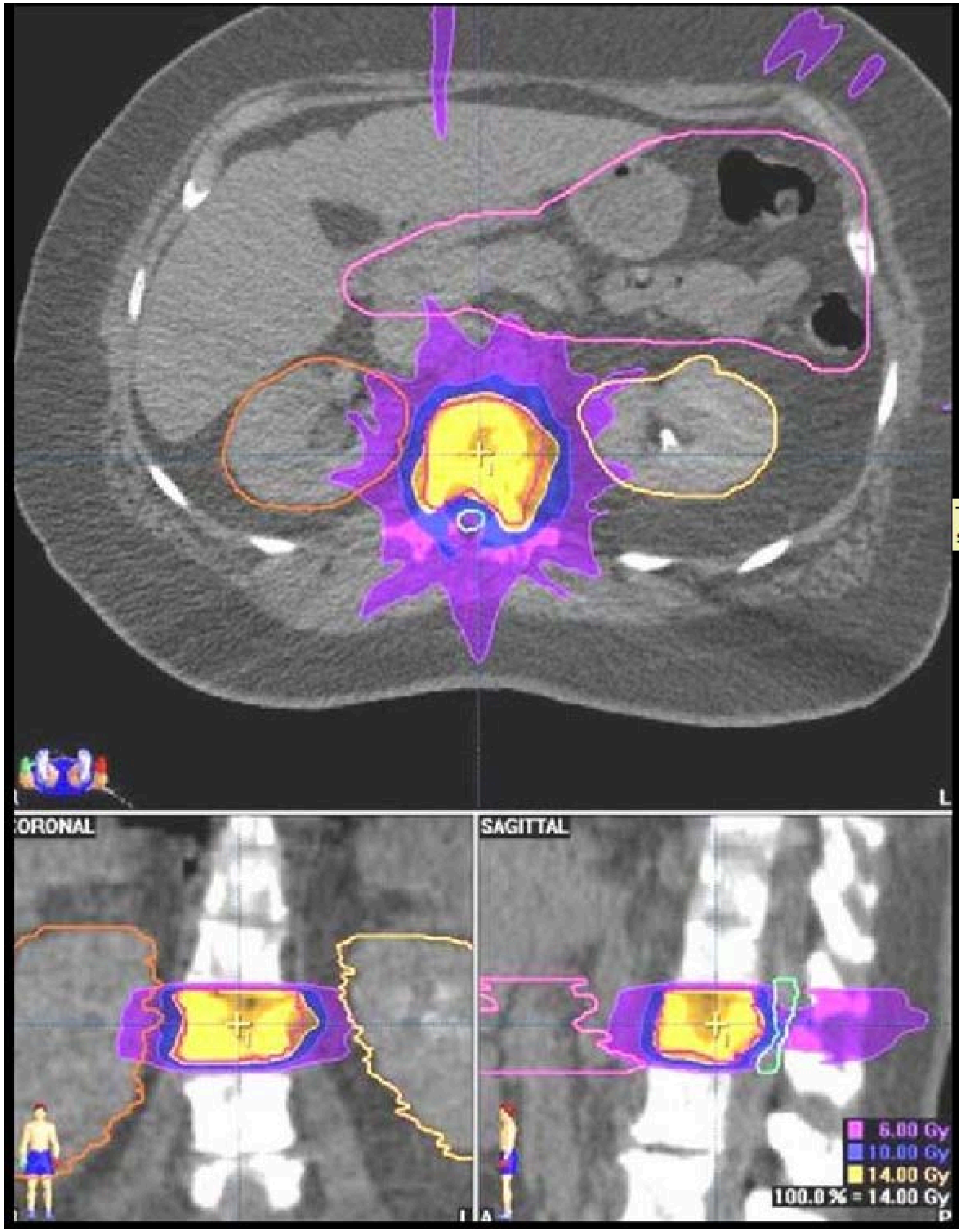

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Palliation of metastatic bone pain: single fraction versus multifraction radiotherapy (Review)

Sze WM, Shelley M, Held I, Mason M

THE COCHRANE COLLABORATION®

This is a reprint of a Cochrane review, prepared and maintained by The Cochrane Collaboration and published in *The Cochrane Library* 2006, Issue 2

http://www.thecochranelibrary.com

WILEY
Publishers Since 1807

a) Fractionation scheme

Meta-analysis on 3500 pts:

- Breast 40%, Prostate 24%, Lung 20%
- spine, 34%, pelvis, 32%
- 1 x 8 Gy *vs.* 4 Gy x 5 / 3 Gy x 10

Results:

- Overall pain response rate, **60 *vs.* 59 %**
- Complete response rate, **34 *vs.* 32 %**
- Re-treatment rate, **21 *vs.* 7 %,** NS
- Pathological fractures, **3 *vs.* 1.5 %,** p=0.03
- Spinal cord compression, **2 *vs.* 1.5**, NS

NO DIFFERENCE in efficacy

HIGHER re-treatment / fracture rate

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Single Fraction vs Multiple Fractions

- No significant differences for Overall and Complete Response
- Significantly higher re-treatment rate for patients treated with SF
- Trend (not statistically significant) toward an increased risk of pathological fracture and spinal cord compression with the SF regimen
- 1 study reported a significantly higher re-mineralization and increase in bone density in the MF group (-> *RT* treatment of patients with a good prognosis)

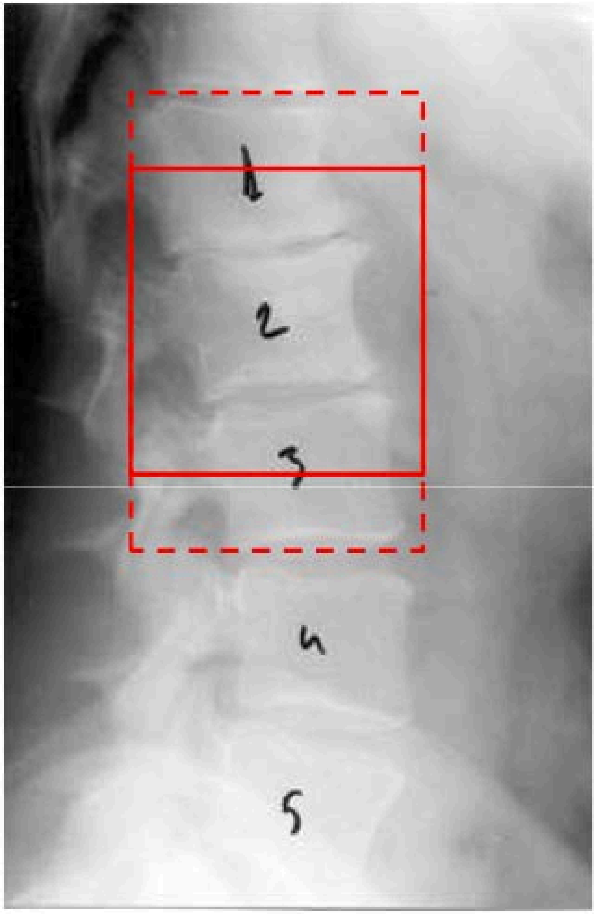
Palliative radiotherapy trials for Bone Metastases: A Systematic Review
E. Chow, K Harris, G. Fan, M. Tsao, WM. Sze
J Clin Onc, 25 (11) 2007

b) Radiation Field

CC ± 1 Vertebra

CC ± ½ Vertebra

3DCRT
CC ± 1 cm
LL ± 2cm



Spinal Cord Compression

- Commonest emergency in Radiation Oncology

- Emergency because consequences disastrous for patients: paralysis/incontinence/loss of independence and dignity

- Treatment goals:
  - Pain relief
  - Maintenance of independence/function

Commonest sites of cord compression

- Thoracic 60%
- Lumbosacral 30%
- Cervical 10%

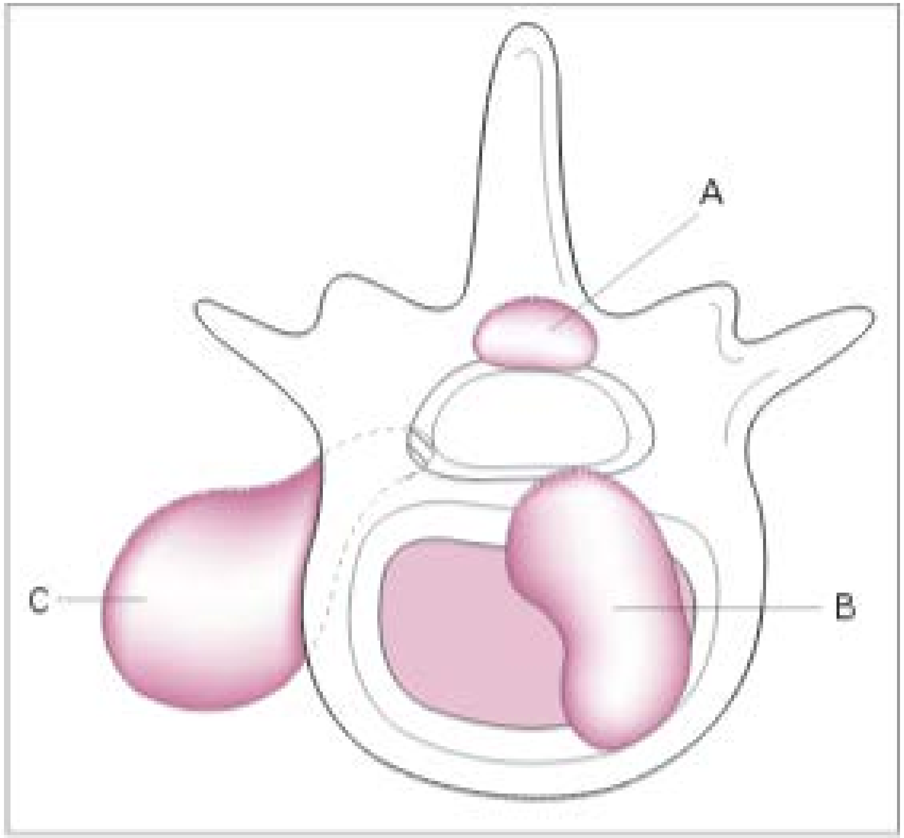


Figure 8.2 Epidural compression of the cord may be caused by metastasis from the vertebral body (A and B) or from paravertebral metastasis penetrating the intervertebral foramen (C). The vertebral body is the commonest site.

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Presentation

- Pain 90%
- Nerve root/Radicular pain

LATE:

- Power/Sensation loss: sensory level
- Paraplegia/quadriplegia
- Loss of anal tone/sensation
- Saddle anaesthesia
- Faecal incontinence/urinary obstruction

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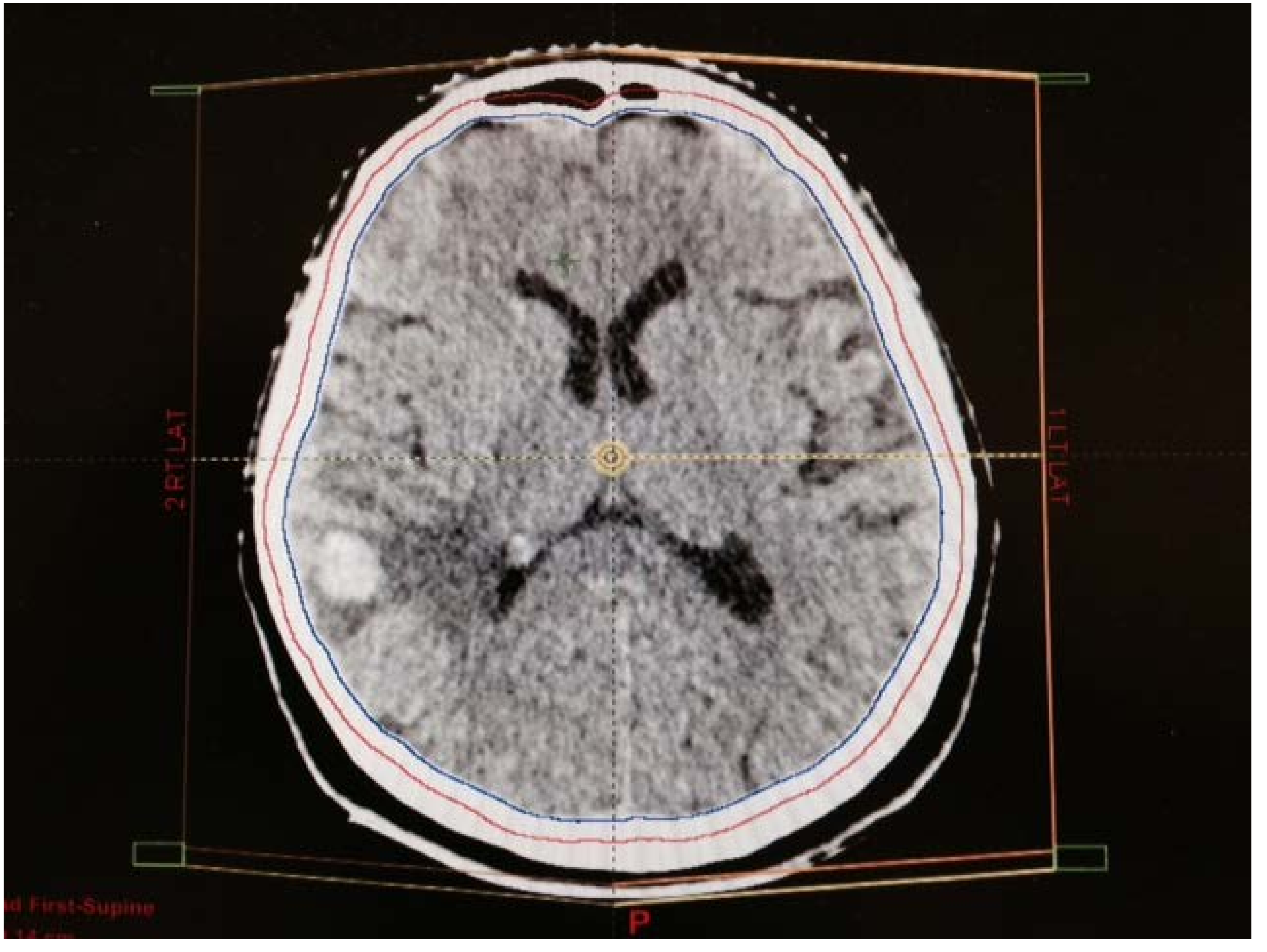
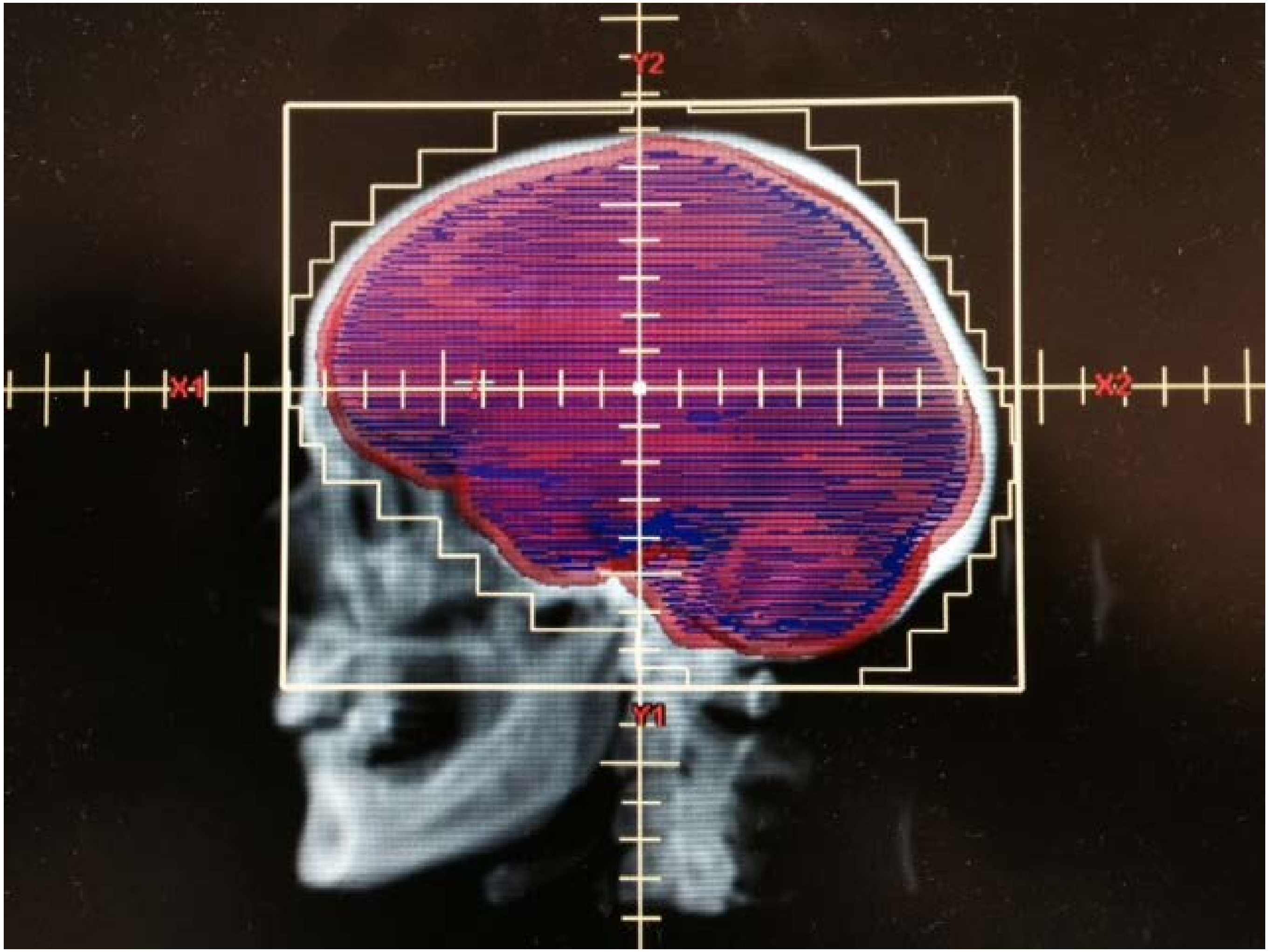
Can be at multiple levels so important to image all of the spine

Whole Brain Radiotherapy

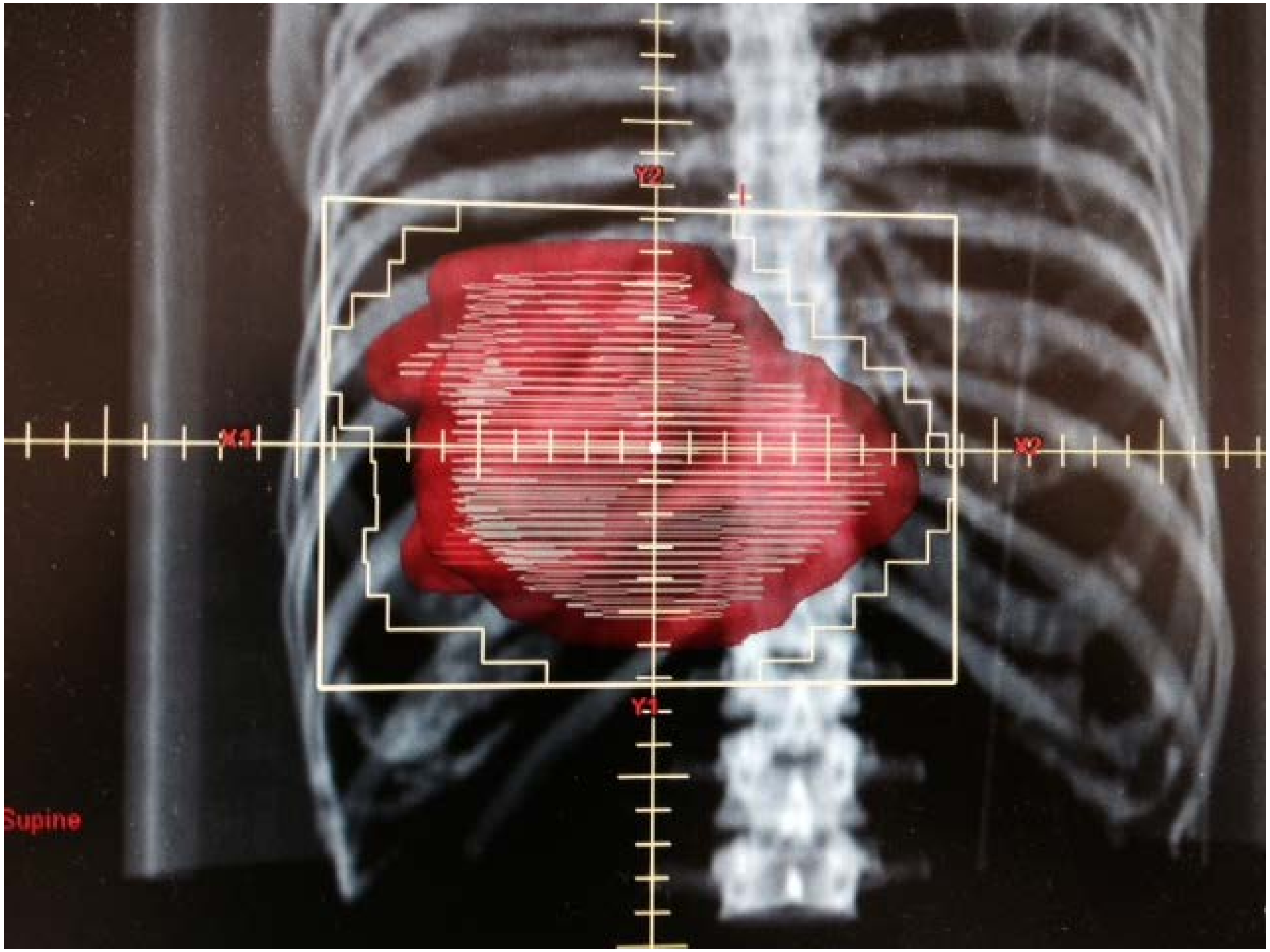


WBRT



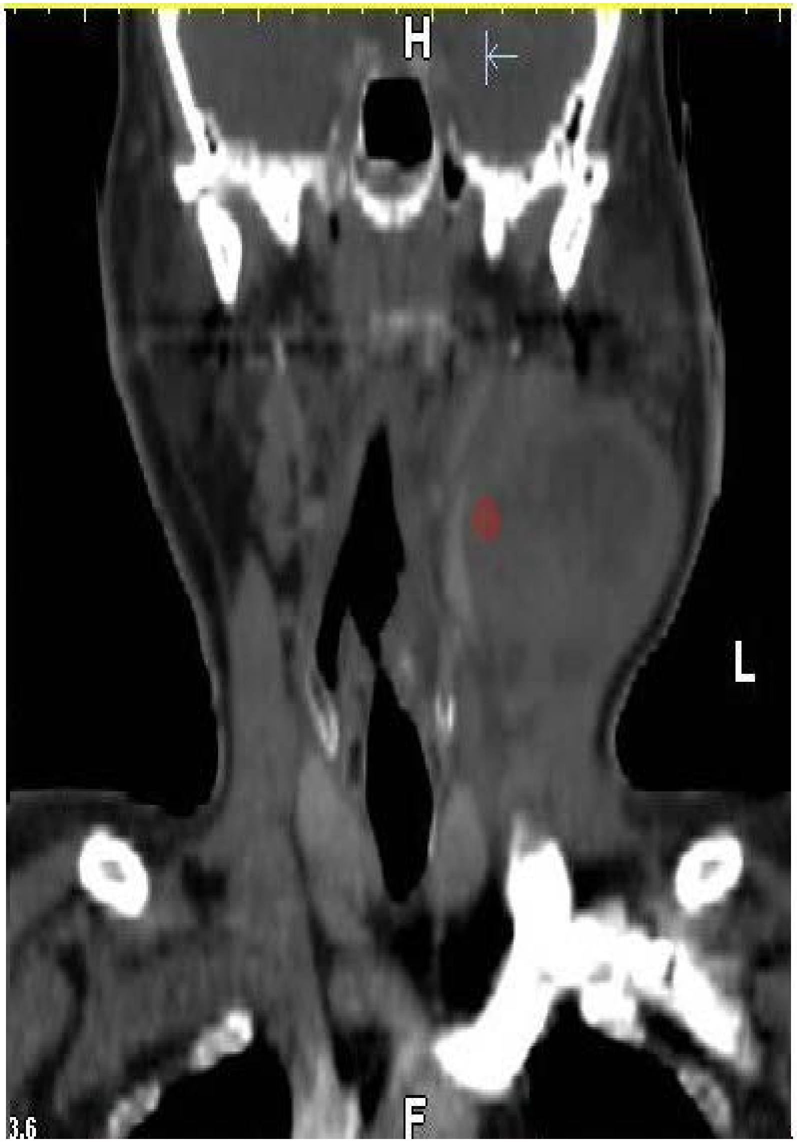
Palliative Lung Case

Palliative Lung Case



Palliative Lung Case

Unfit 75yr old man presented with a rapidly growing lump in the neck for 3 weeks



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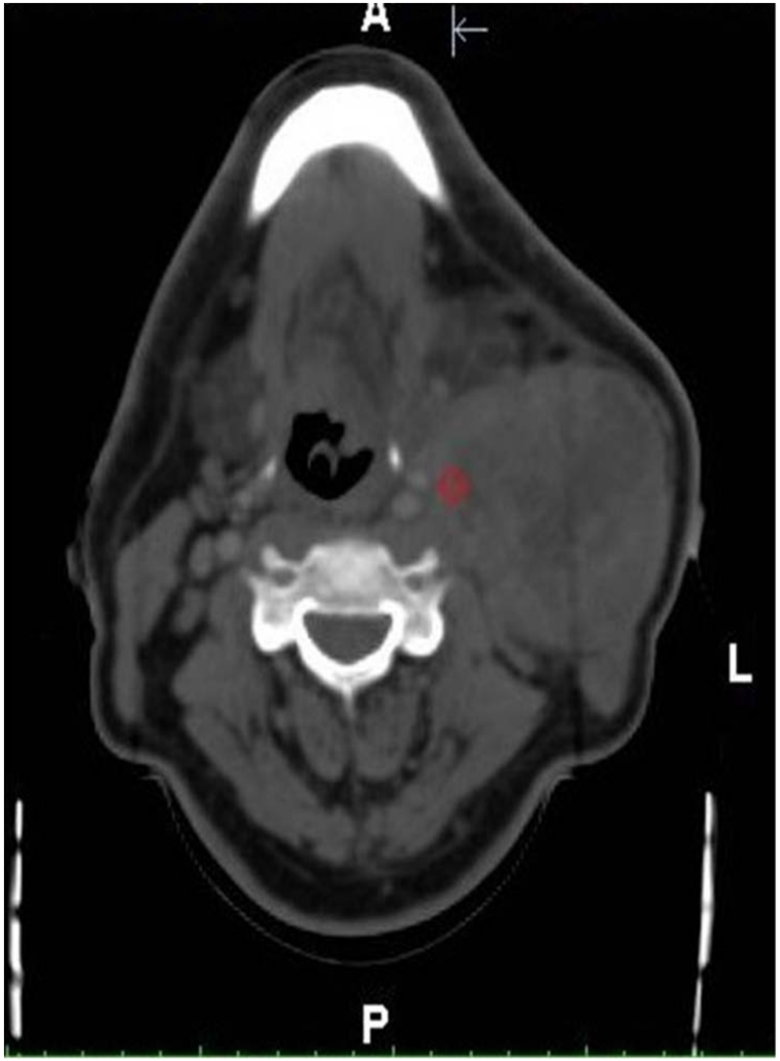
Decide target, margins, field arrangement and dose



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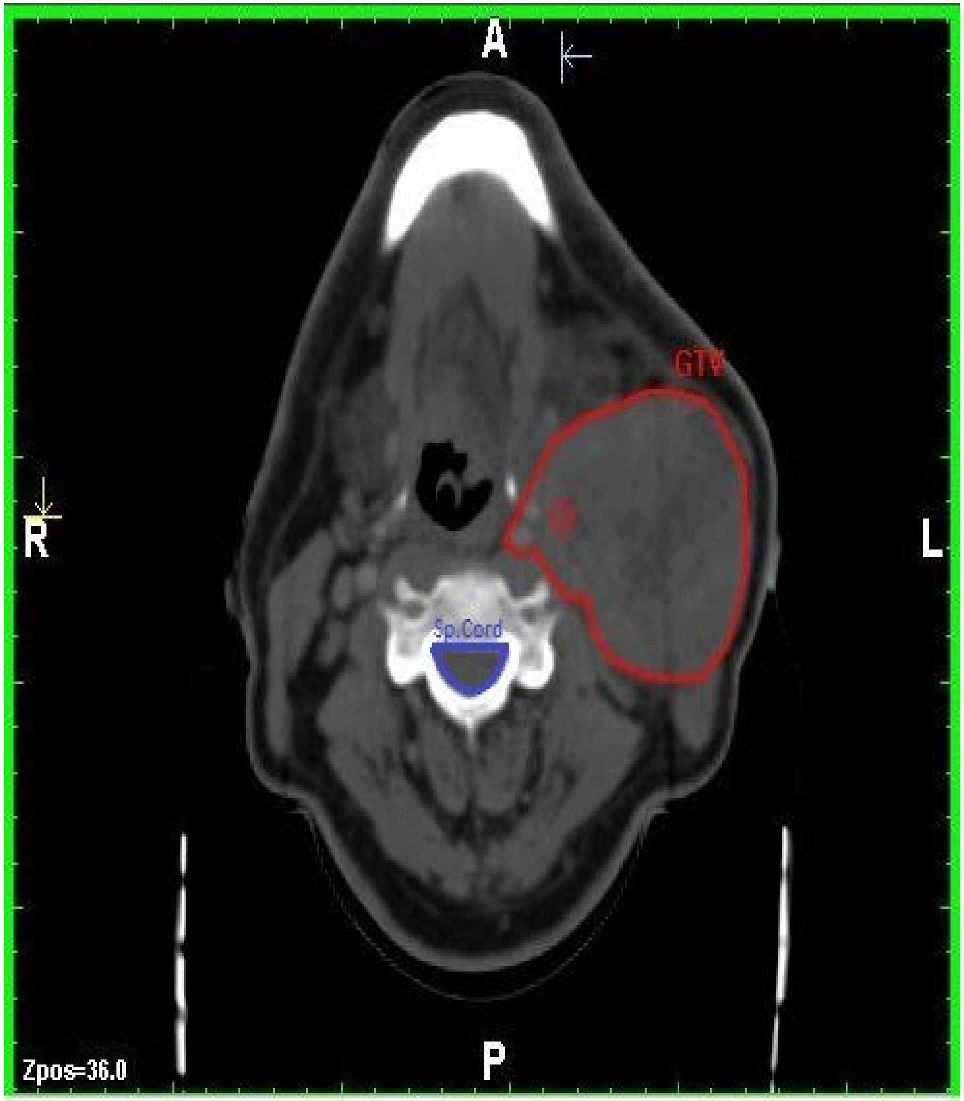

- Target : gross tumour (GTV)
- GTV + 1 cm = PTV
- Field options:
  - ➢ Anterior/Posterior
  - ➢ Oblique fields (wedge pair)
- Main goals:

1. Avoid sore throat
2. Relieve symptoms
3. Local control

- Dose options:
  - ➢ 30 Gy in 10 fractions
  - ➢ 20 Gy in 5 fractions

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Take Home Messages

- Simple field arrangements
- More rapid workflow
- Short treatment schedules

IGRT and margin determination:

General introduction and IGRT in palliative treatment

Martijn Kamphuis MSc, MBA candidate

Radiation Therapist IGRT

Department of Radiotherapy

Amsterdam, the Netherlands

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Content of the presentation

- Overview of IGRT lectures @ the BP course
- IGRT? I'm at a planning course, right?
- IGRT in palliative treatment

OVERVIEW OF IGRT LECTURES @ THE BP COURSE

Overview of IGRT lectures @ the BP course

- Day 2:
  - Why IGRT?
    - IGRT in Palliative treatment

- Day 3:
  - Margin determination
  - Impact of motion management in prostate
  - Strategies dealing with organ motion
  - Added value of multi modality imaging

Overview of IGRT lectures @ the BP course

- Day 4:
  - IGRT for breast
  - How to deal with anatomical changes?
  - Breathing control: DIBH

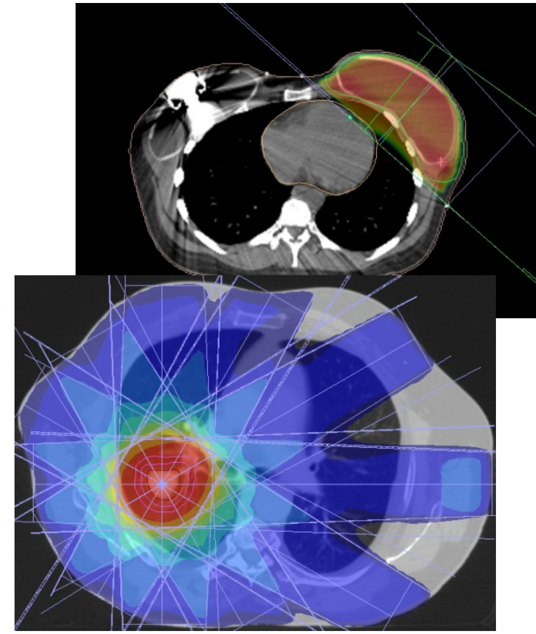
- Day 5:
  - Optimising the treated volume in Lung
    - Multiple approaches, including TP ☺
  - Why IGRT?

IGRT? I'M AT A TREATMENT PLANNING COURSE, RIGHT?

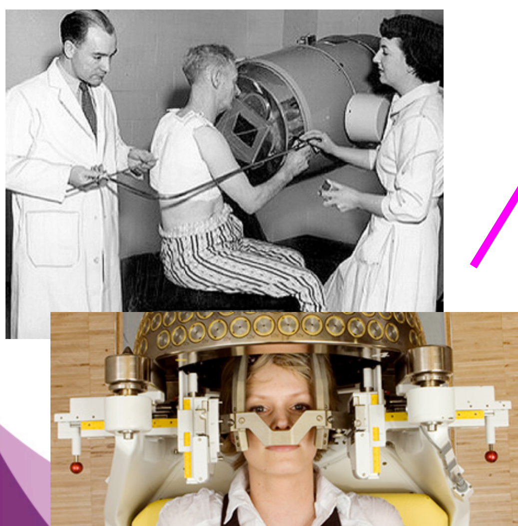
What do people from the Linac want to know about the TP?

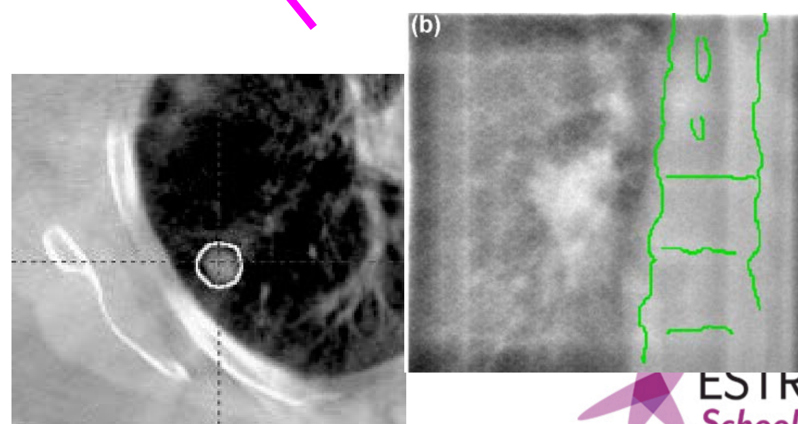
- How accurate should the delivery be?
- Position of critical points in TP

How accurate should the delivery be?



MARGINS





Position of critical points in TP

- Examples:
  - Spinal cord very critical dose
  - Influences
    - size and shape ROI
    - daily or offline imaging
    - the position of the correction reference point

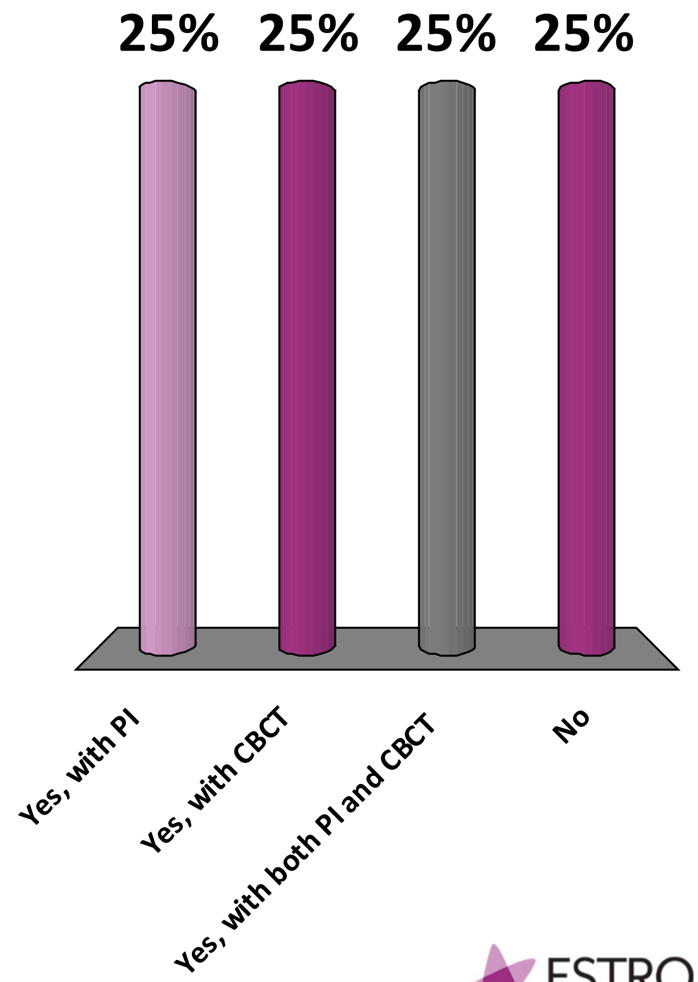
How realistic in my TP?

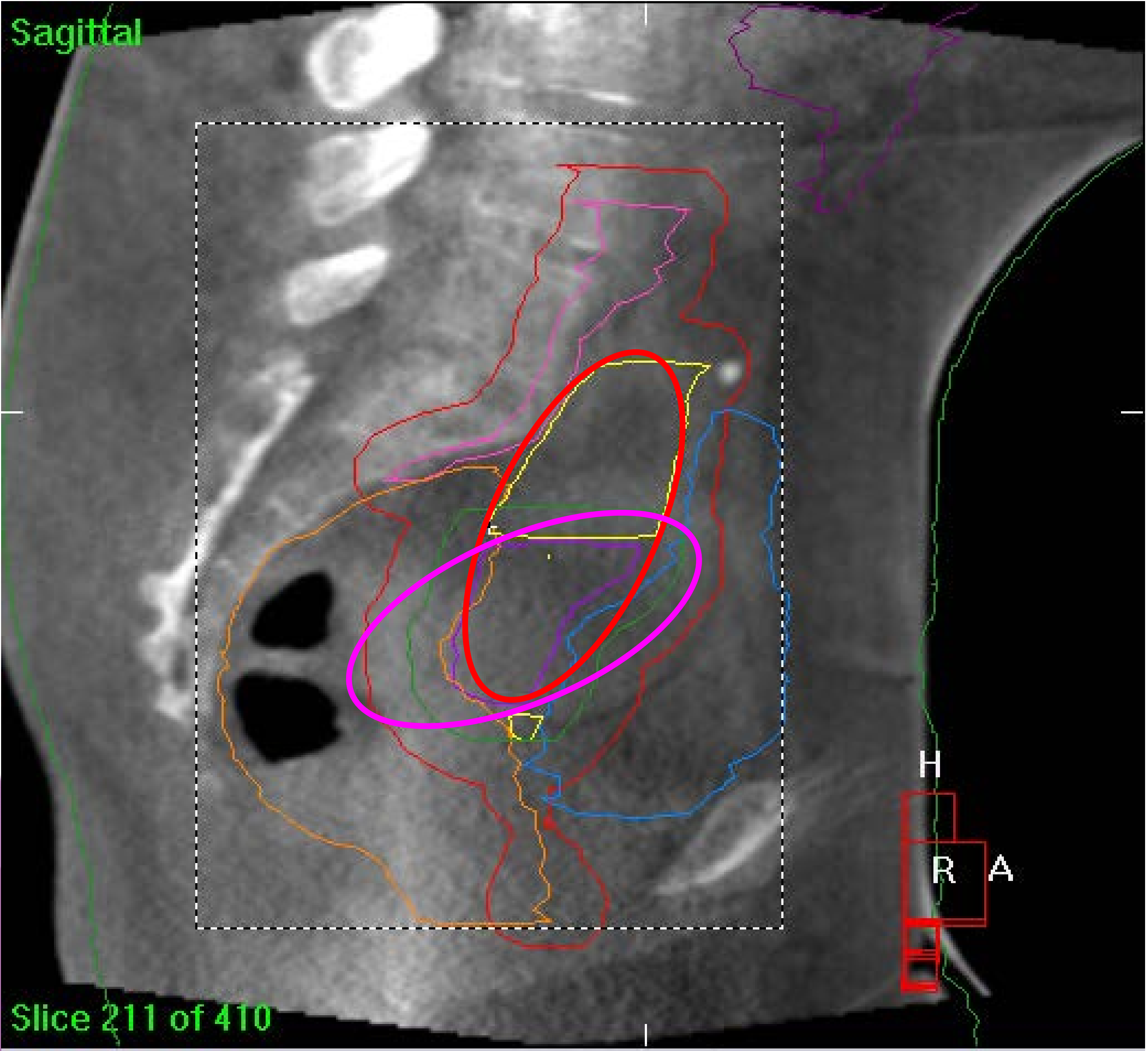
Example cervical cancer

- IMRT, 1 cm CTV-PTV margin
  - ➢ Portal imaging
  - ➢ CBCT

Is this realistic/achievable?

A. Yes, with PI
B. Yes, with CBCT
C. Yes, with both PI and CBCT
D. No





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IGRT IN PALLIATIVE TREATMENT

Imaging modalities

- Ultrasound systems
- Electromagnetic tracking
- Portal Imaging (EPID)
- kV cone beam CT
- 3D CBCT
- MV (CB)CT
- Surface scanning

- MR linac

Imaging modalities

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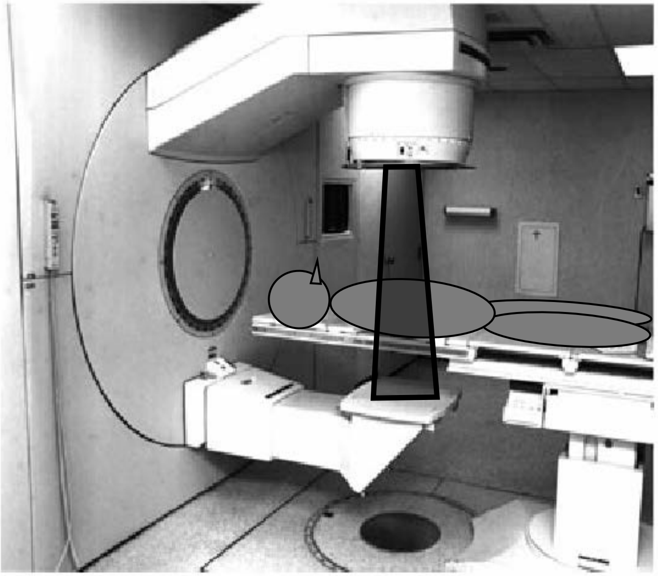
- MV (CB)CT
- Surface scanning

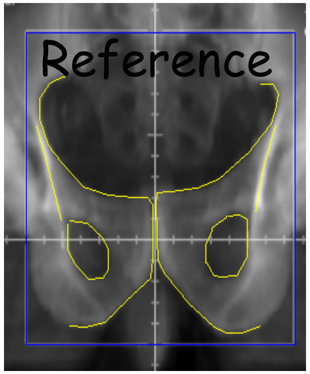
- MR linac

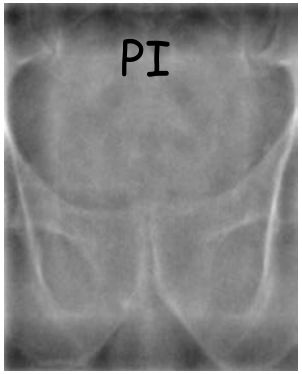
Portal Imaging - *physics*

- An imager used to detects the photons that cross the patient

- The portal image is compared to a reference image







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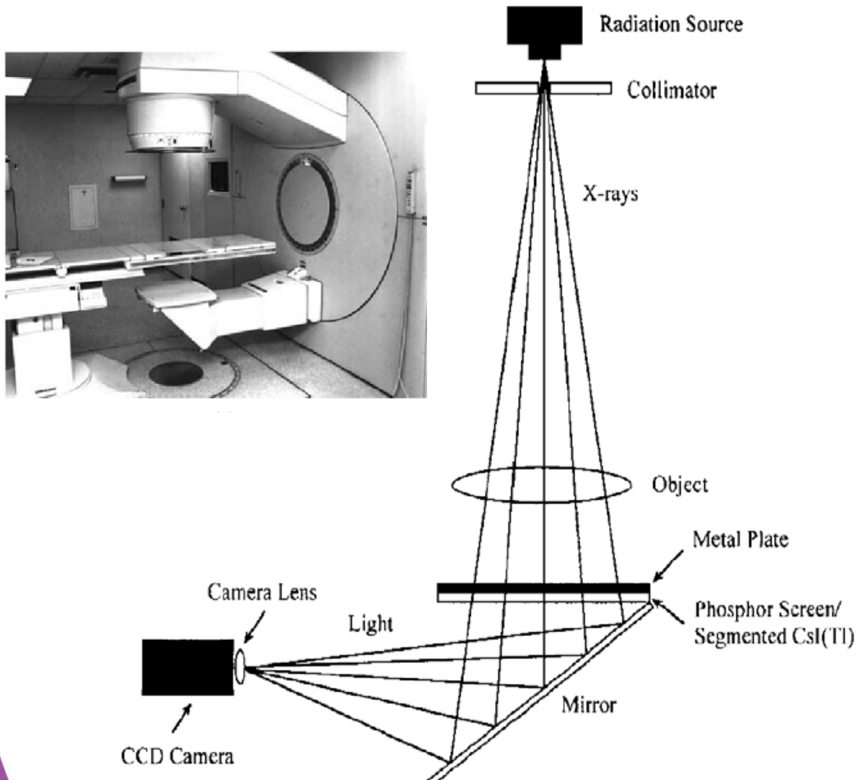
Goals of Portal Imaging

- Position verification

- Documentation of treatment
- Portal dosimetry (in-vivo)
- QA (MLC adjustment)

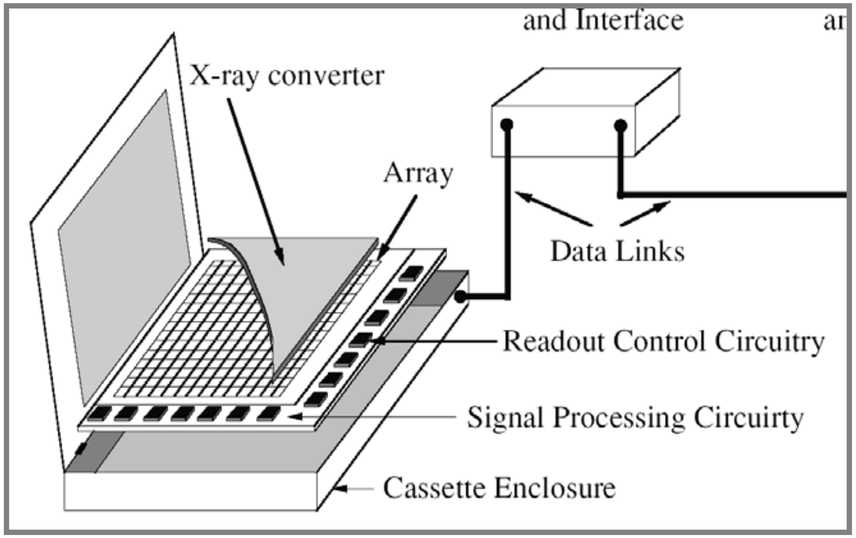
Technical aspects of EPIDs

Camera-mirror based systems

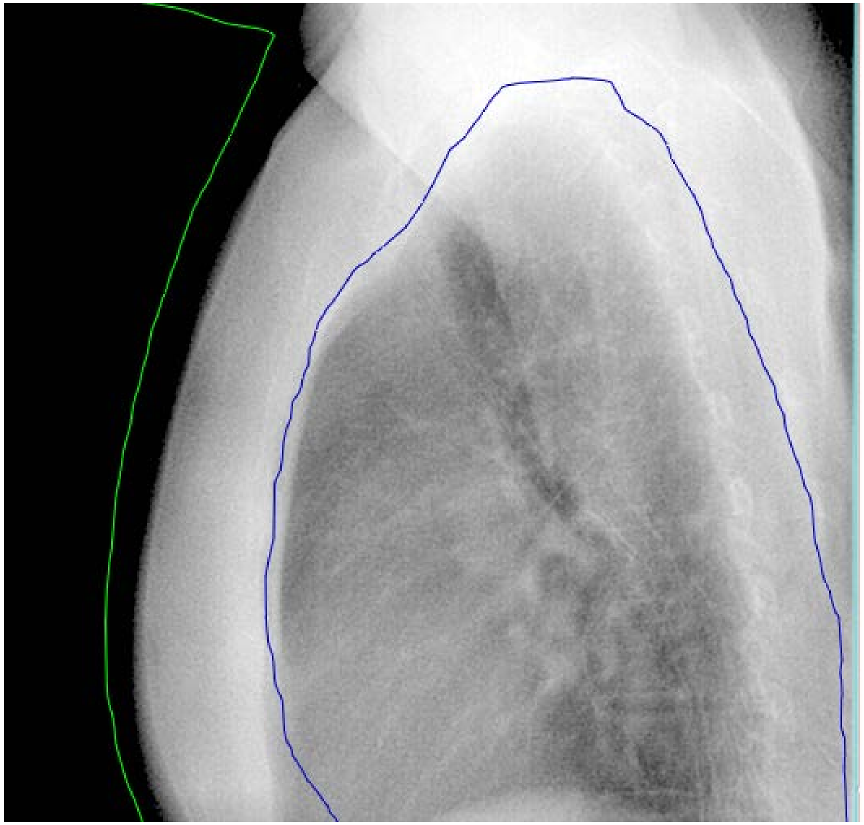


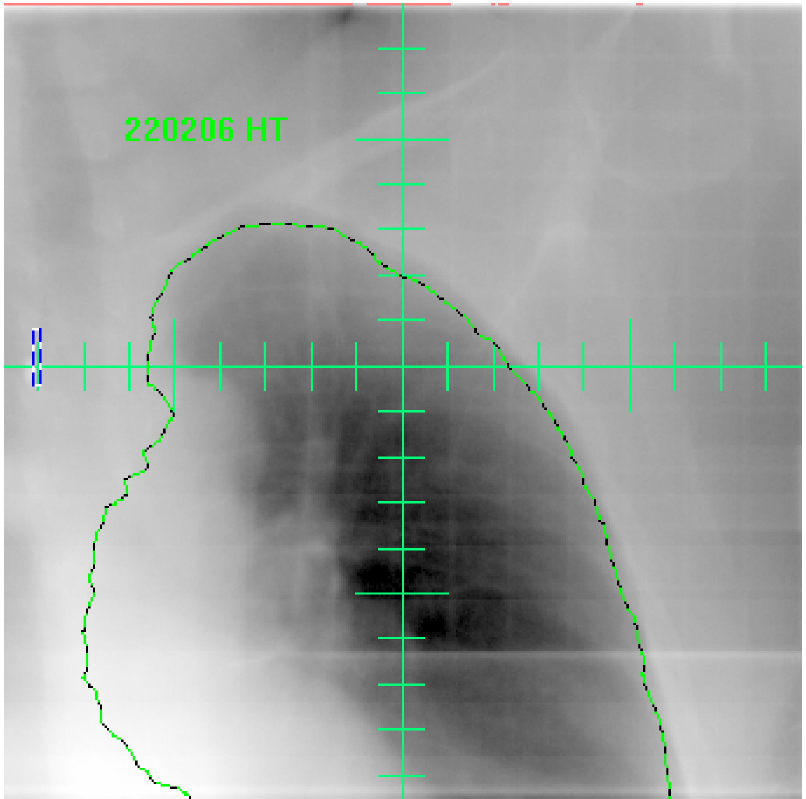
Active matrix flat panel imagers (AMFPI)

- also called amorphous silicon imagers



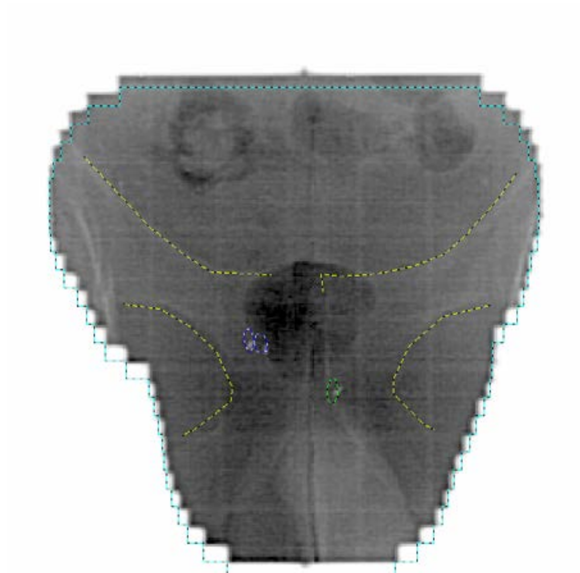
Examples of portal images

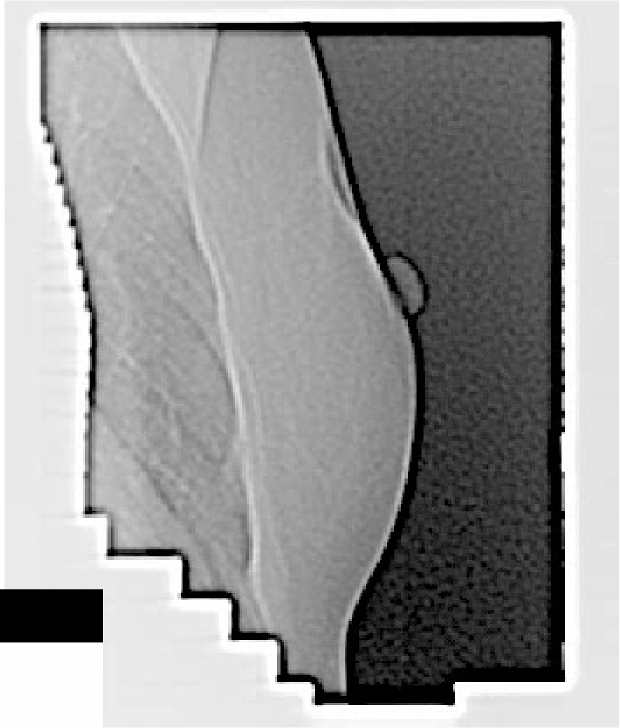


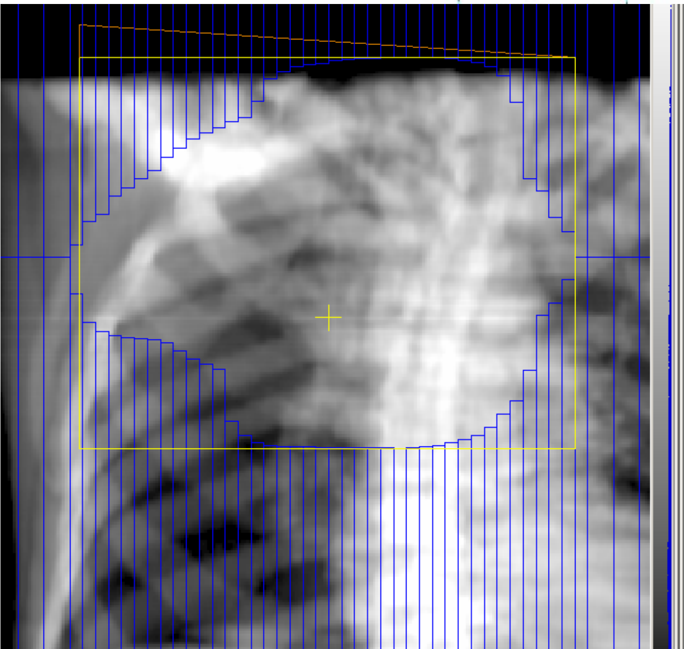


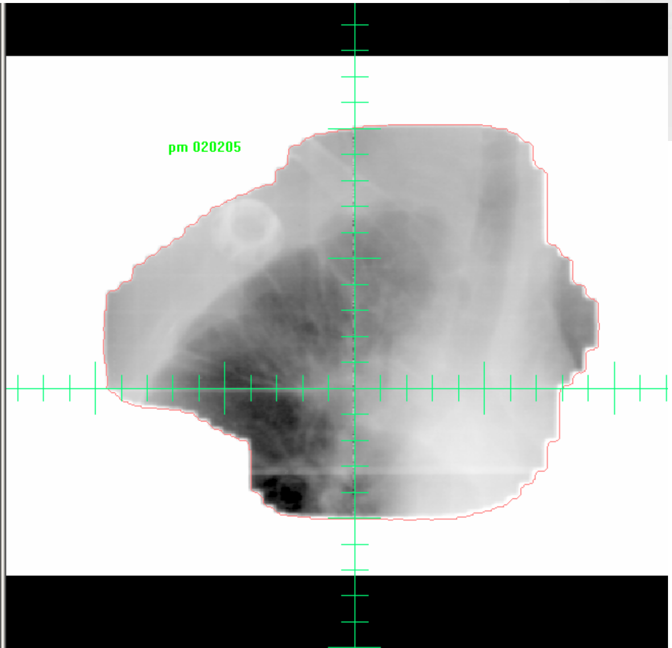
Images: M. Josopovic

EPID – field images









Images: M. Josopovic

Electronic Portal Imaging

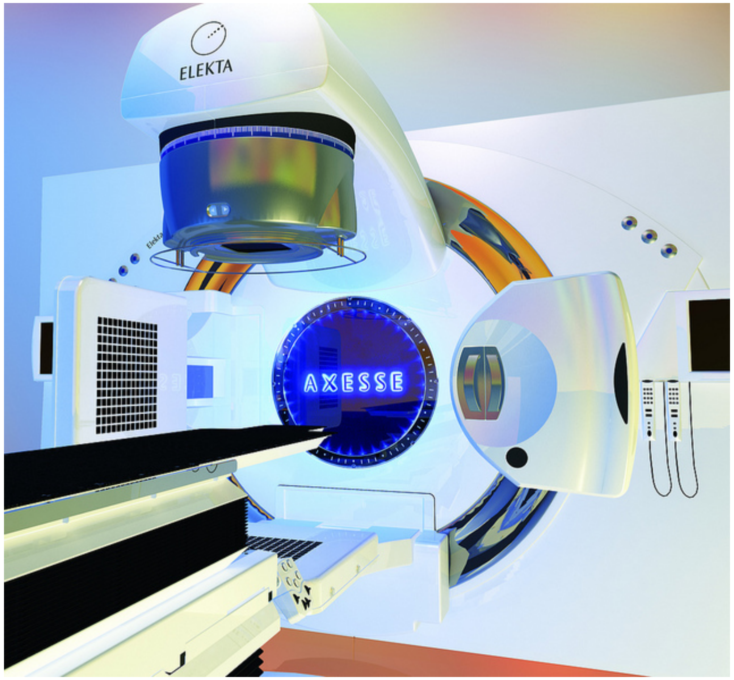
Pros

- Image made with treatment beam
- Imaging during treatment
- Possible to perform dosimetry

Cons

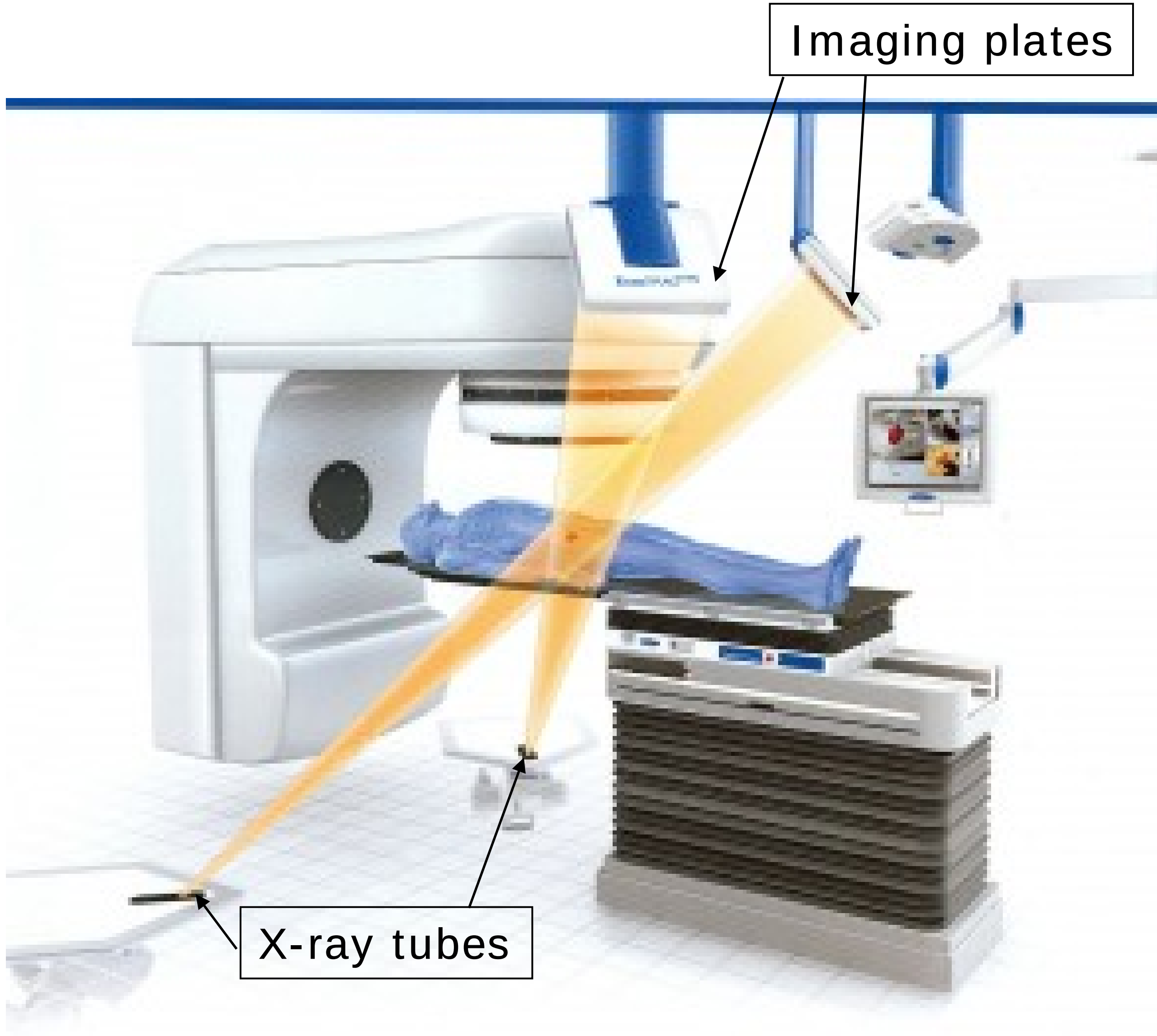
- Surrogate imaging
  - ➢ Additional margins
- Imaging dose
  - ➢ Although it is possible to compensate for
- Imaging quality
  - ➢ Potential mismatch!

kV source moutend on linac

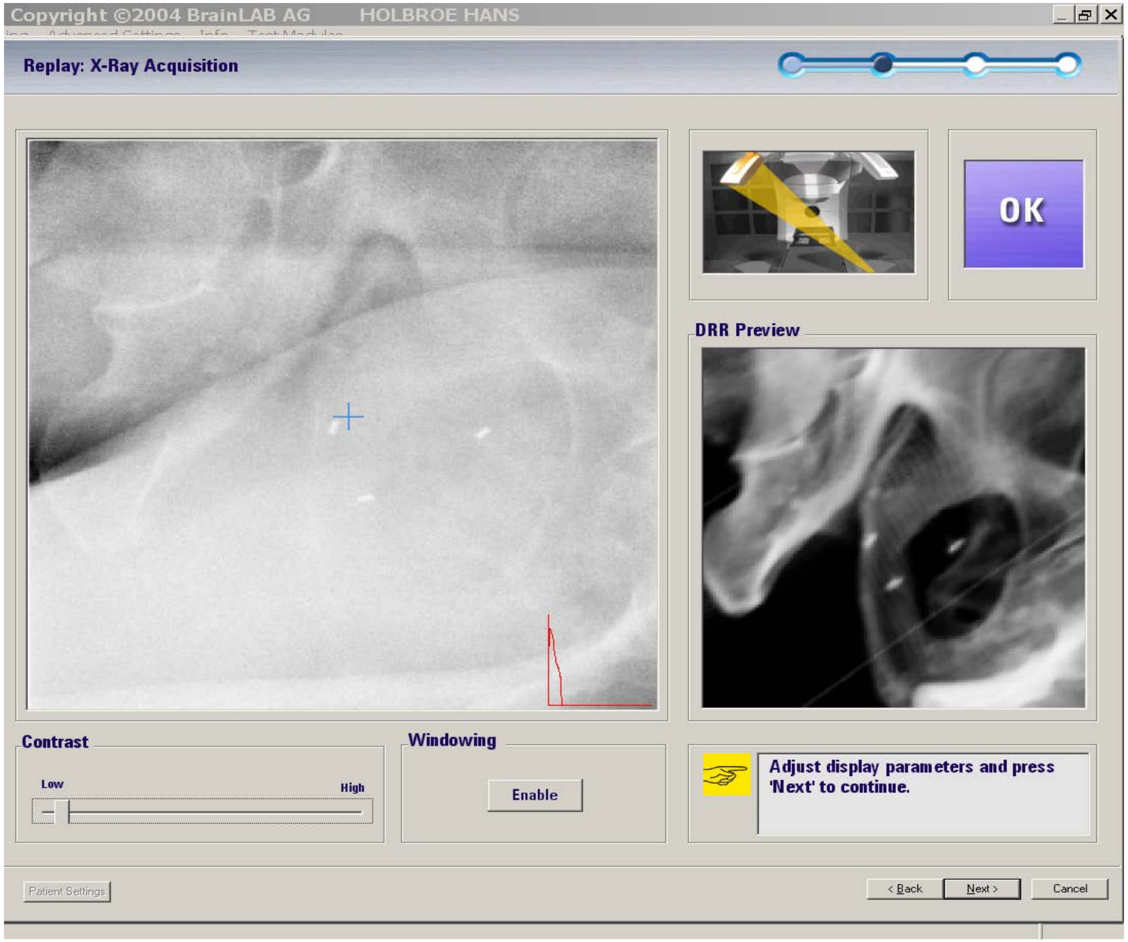


kV imaging: Cyberknife

Exac Trac® IGRT system



Exac Trac® IGRT system



Images: M.Josopovic

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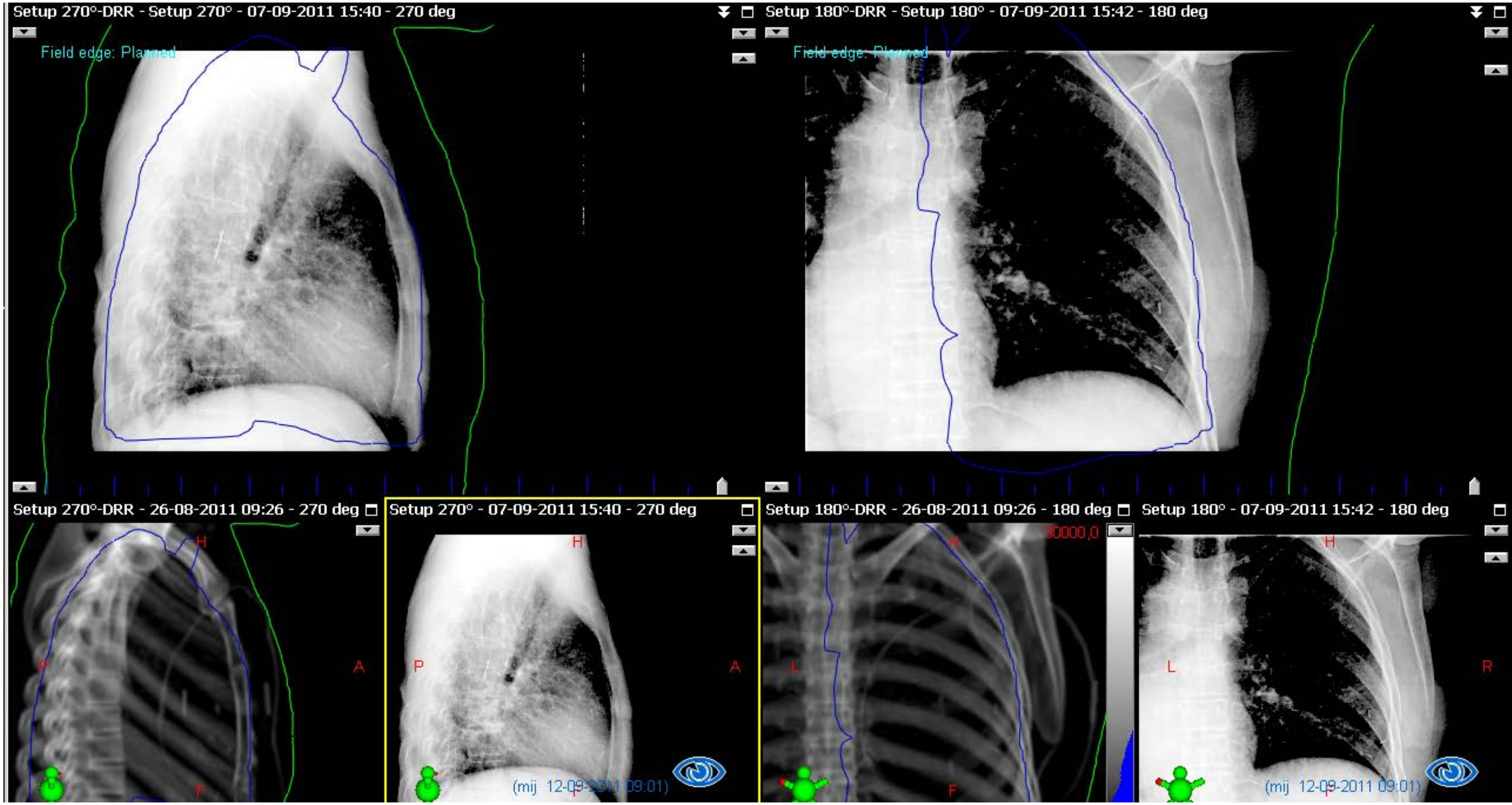
Some images



Images: M.Josopovic

kV imaging

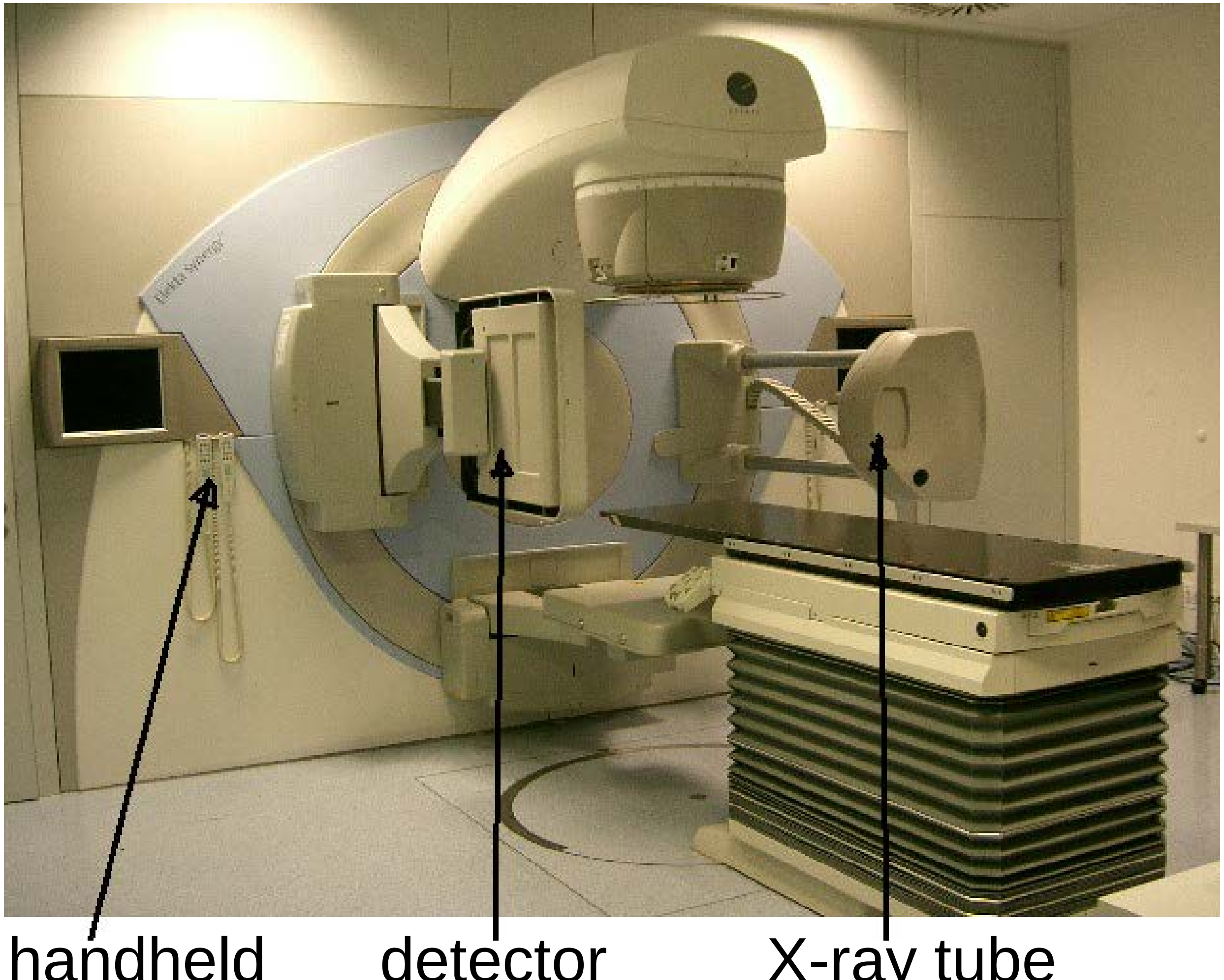
Pros:

- Imaging dose is low
- High 2D imaging quality
- Real time imaging in some systems

Cons

- No anatomical information

Cone beam CT



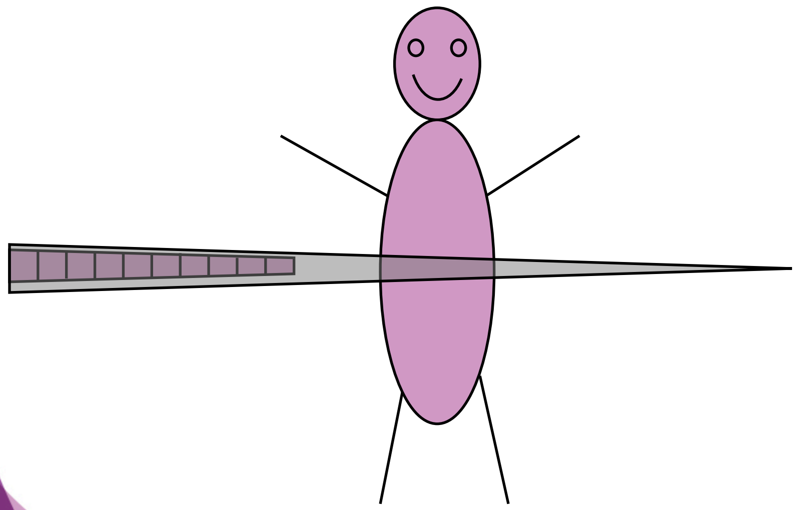
CBCT Acquisition

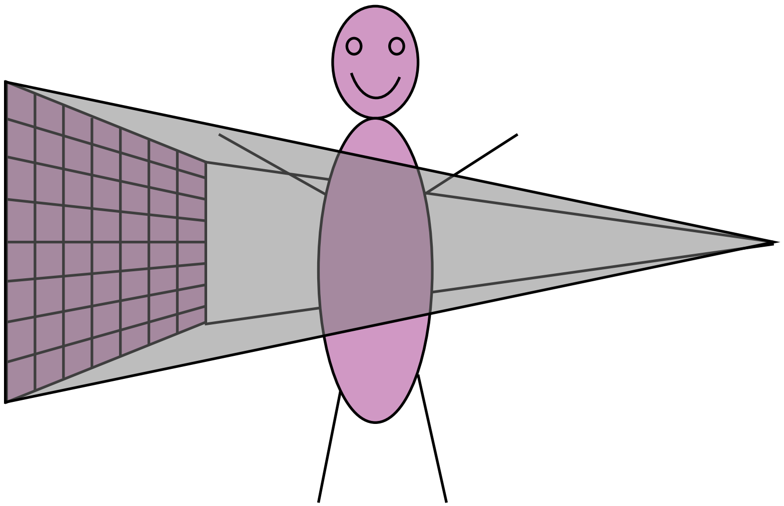
Conventional CT

- 'Fan' beam
- 1D detector
- 1 rotation = 1 slice

Cone-beam CT

- 'Cone' beam
- 2D detector
- 1 rotation = volume (many slices)

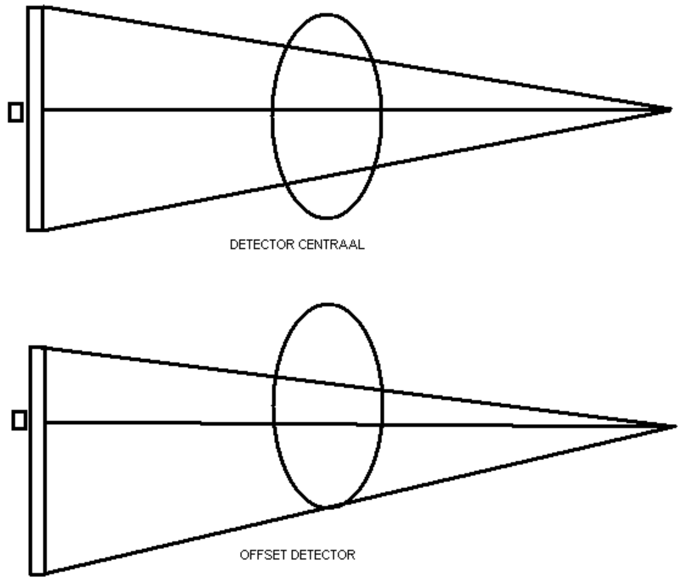




Courtesy: Peter Remeijer

How does it work?

Variable detector position



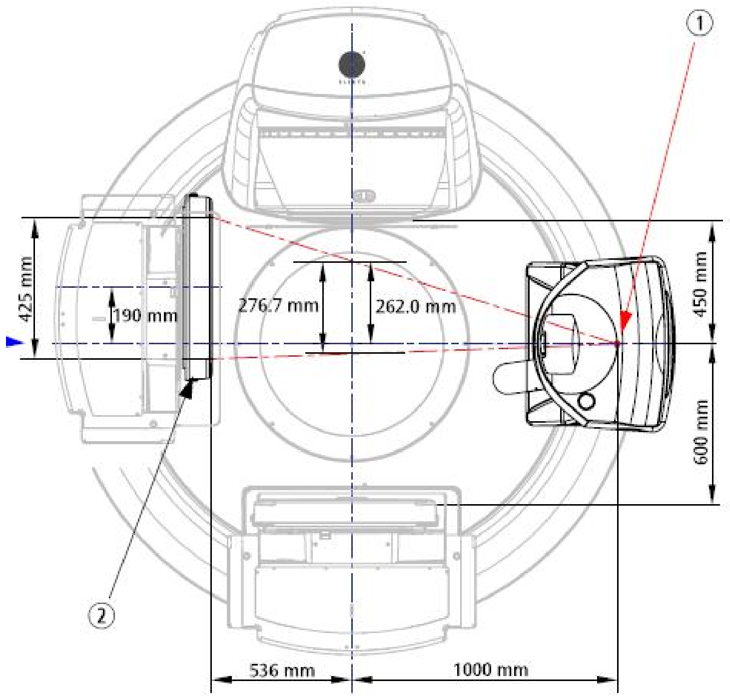
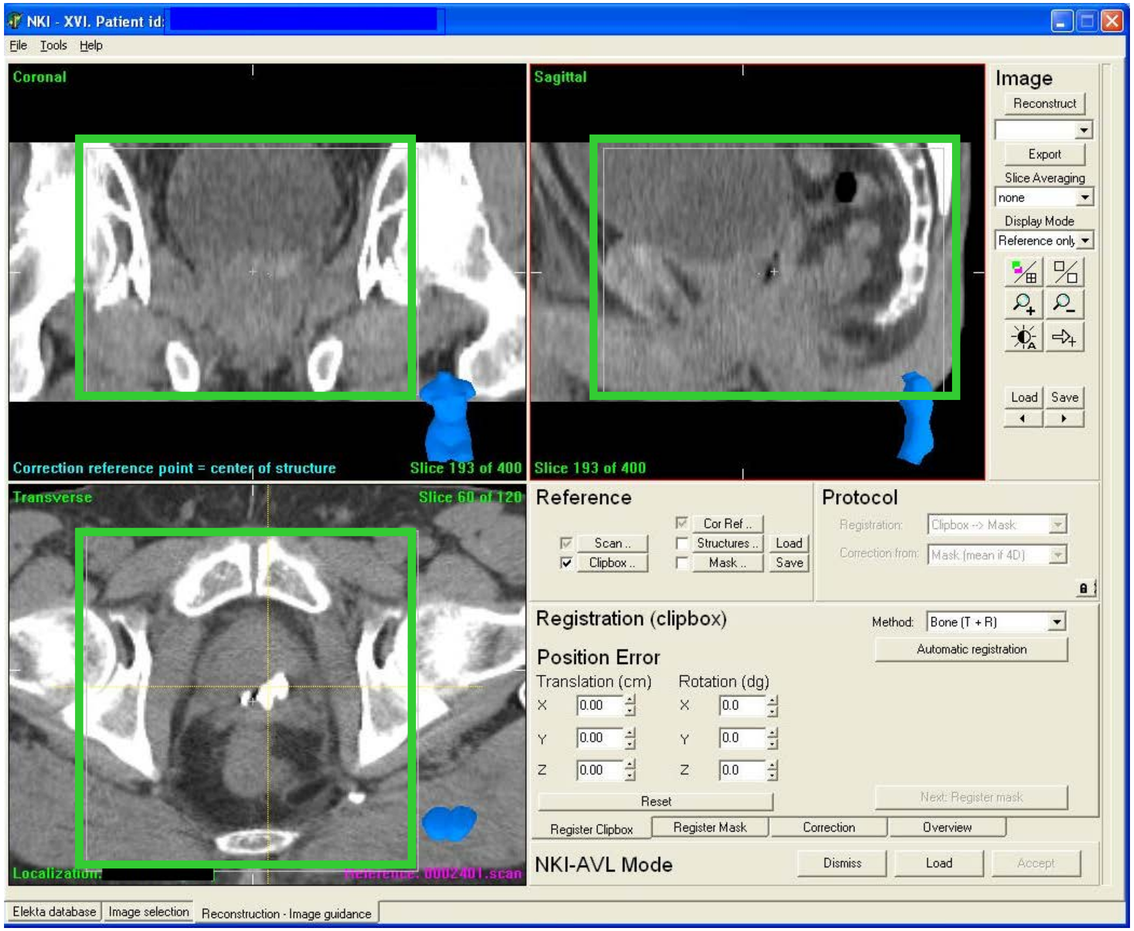


Image registration: Defining the ROI



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CBCT imaging

Pros:

- Imaging dose is moderate
- High 3D imaging quality
  - ➢ Lower chance of mismatch
- Anatomical information
  - ➢ Fractures are visible

Cons:

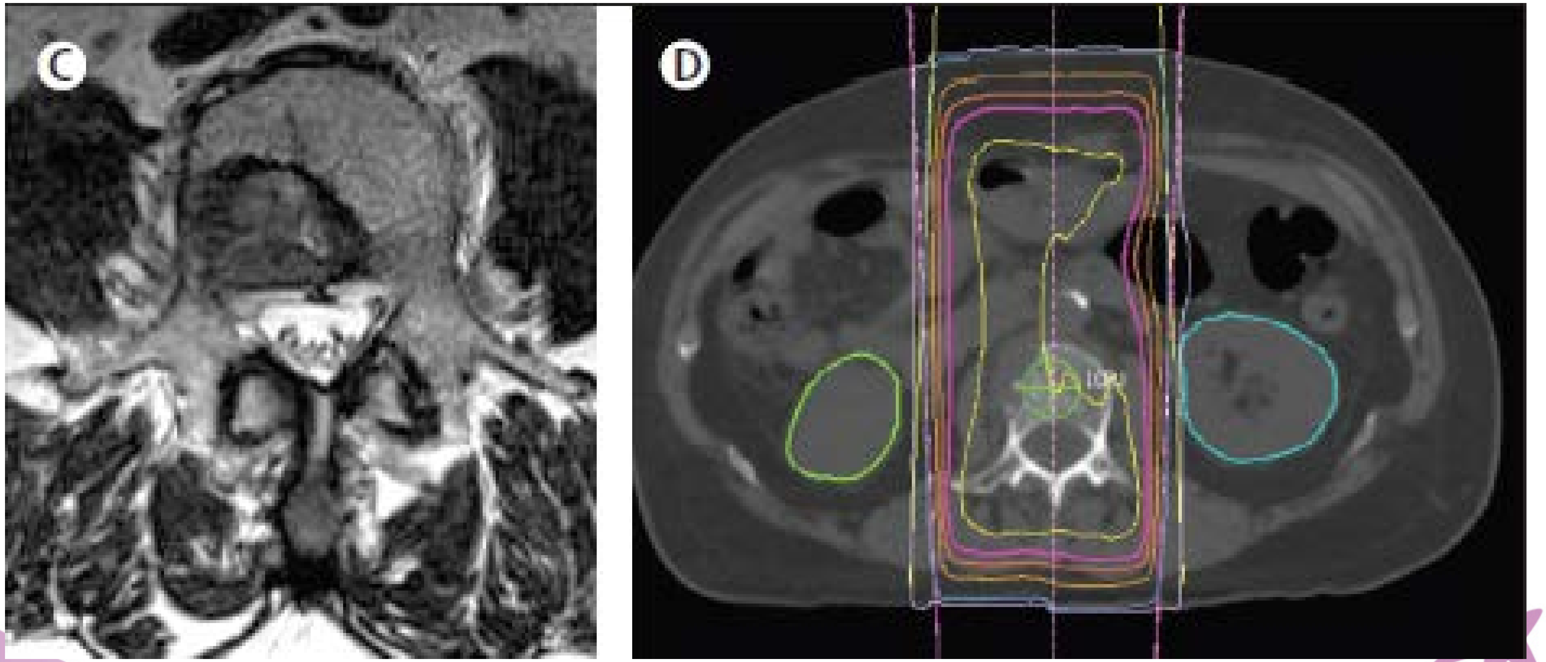
- Limited soft tissue information

TRADITIONAL TP IN PALLIATIVE RADIOTHERAPY

Traditional TP in Palliative RT

Characteristics

- Most of the time 1 or 2 VS
    - PA or APPA
- Whole vertebrae
- Sufficient margins



Traditional TP in Palliative RT

Pros:

- Easily preparable
- Monitor unit calculation only possible
  - “Fast”
- Quick delivery

Cons:

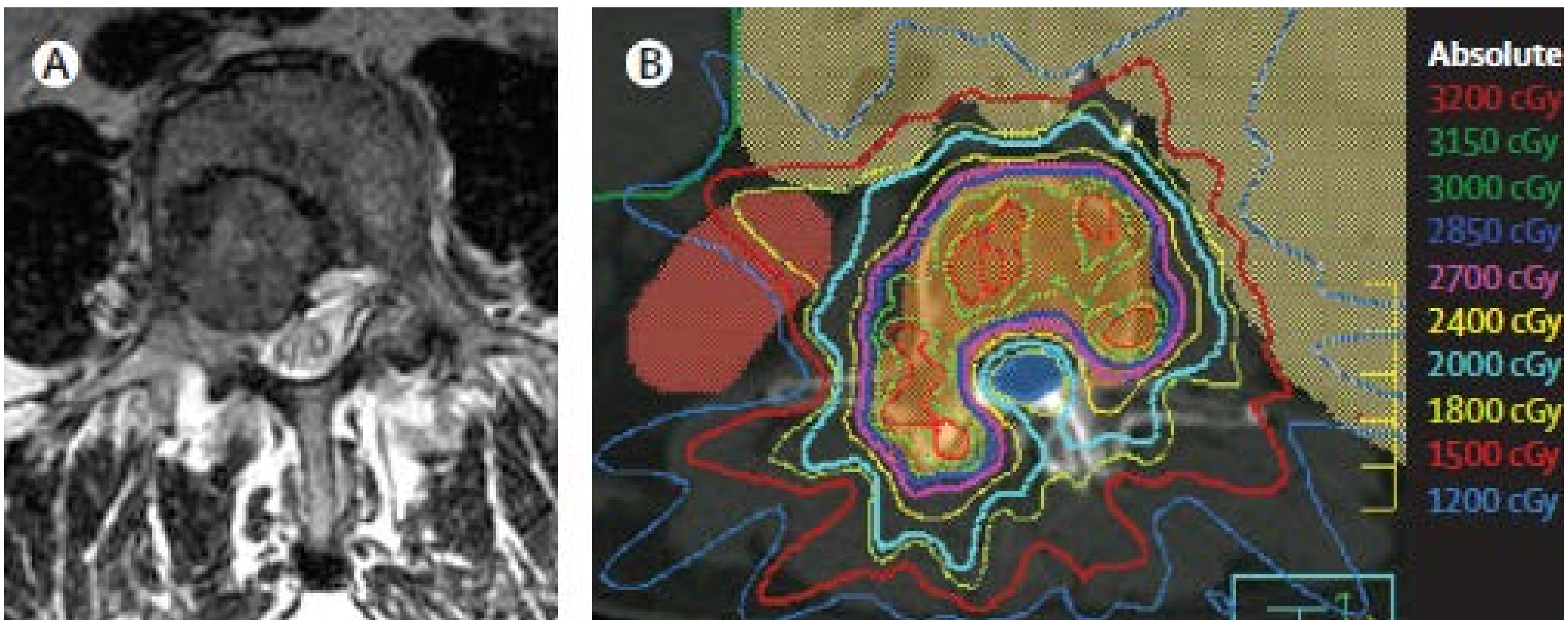
- Unnecessary dose in spinal cord
  - Is not the target most of the time
  - Leading to dose limitations in future
- (Unnecessary) Bowel toxicity
  - N & V
  - Additional medication necessary

SBRT FOR SPINAL CORD COMPRESSION

SBRT for spinal cord compression

Characteristics

- VMAT of multiple beam IMRT
- Partial vertebrae treatment
- Small margins



   - ➢ Motion detection

SBRT for spinal cord compression

Pros:

- High dose
  - Longer benefit?
- Limited dose in spinal cord
- Reirradiation possible

Cons

- Time consuming procedure
- Risk of overdosing spinal cord
- Possible fractures?
- Cost effectiveness?

Take home messages

- TP and IGRT are part of radiotherapy treatment chain
  - ➢ Changes in one subdiscipline will influence the other
- RT treatment chain need to be in balance
  - ➢ Margins
- Palliative (IG)RT:
  - ➢ Traditionally quick and easy
  - ➢ New complex developments

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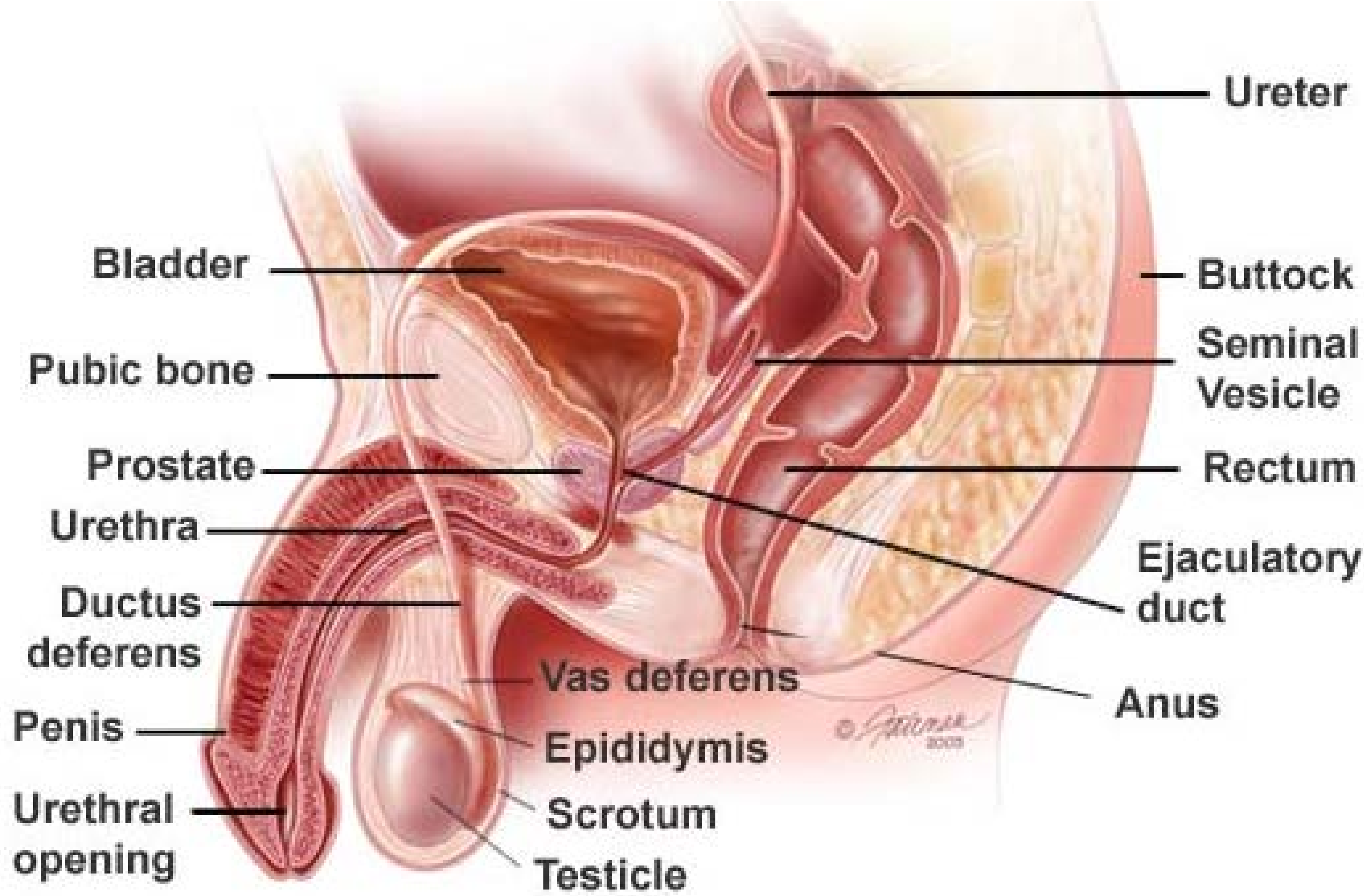
Treatment Planning for Pelvic Cancers

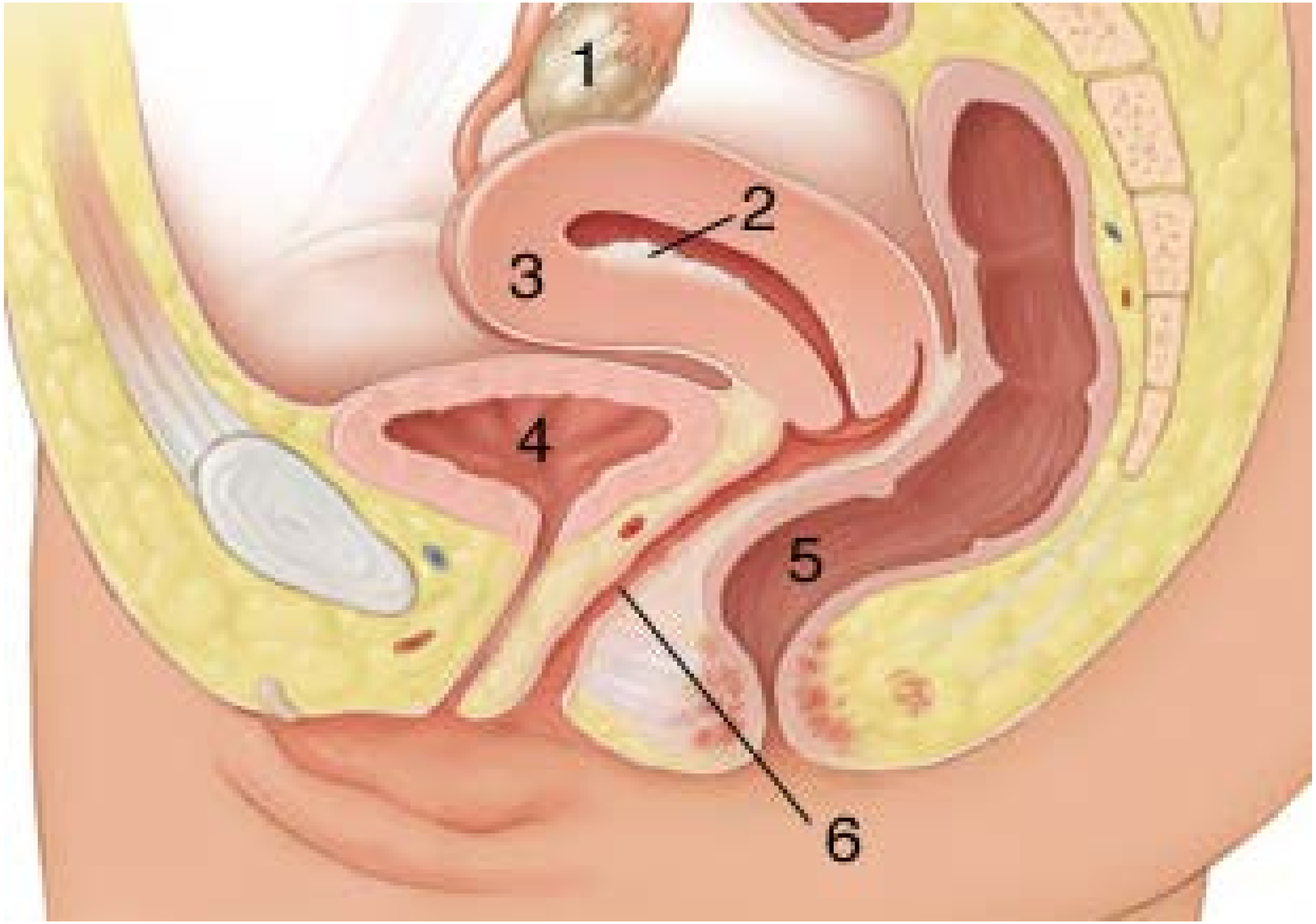
Charles Gillham
Consultant Radiation Oncologist

St Luke's Radiation Oncology Network
Dublin, Ireland

Male Pelvis Anatomy



Female Pelvis Anatomy



1 Ovary
2 Endometrium
3 Myometrium
4 Bladder
5 Rectum
6 Vagina

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Overview

- Epidemiology
- Anatomy and patterns of spread
- Overview of treatment
- Indications for radiotherapy
- Positioning and Immobilisation
- Target volume delineation
- Toxicity

Pelvic Cancers

Male	**Female**
Prostate	Ano-rectal
Ano-rectal	Uterus
Bladder	Ovary
	Cervix
	Bladder
	Vulva/Vagina

Pelvic Cancers

Male	**Female**
Prostate	Ano-rectal
Ano-rectal	Uterus
Bladder	Ovary
	Cervix
	Bladder
	Vulva/Vagina

Diagnostic Work-Up

- Full history/examination
- Blood tests
- Tumour markers (PSA – prostate, CEA – rectum)
- Examination under anaesthetic (cervix/anus)
- Endoscopy (ano-rectum)
- **Biopsy**
- MRI pelvis
- Imaging of thorax/abdomen (CT+/- PET)

Cervical Cancer

Epidemiology

1	Malawi	75.9
2	Mozambique	65.0
3	Comoros	61.3
4	Zambia	58.0
5	Zimbabwe	56.4
6	Tanzania	54.0
7	Swaziland	53.1
8	Burundi	49.3
9	Bolivia	47.7
10	Guyana	46.9
11	Madagascar	44.6
12	Uganda	44.4
13	Mali	44.2
14	Rwanda	41.8
15	Senegal	41.4
16	Kenya	40.1
17	Guinea	38.4
17	Lesotho	38.4
19	Suriname	38.0
20	Fiji	37.8

Cases per 100,000 per year

528,000 diagnosed in 2012

>80% occur in under-developed countries

5th most common cause of cancer death in women

Incidence 16/100,000/yr

Deaths 9/100,000/yr

253,000 deaths per year

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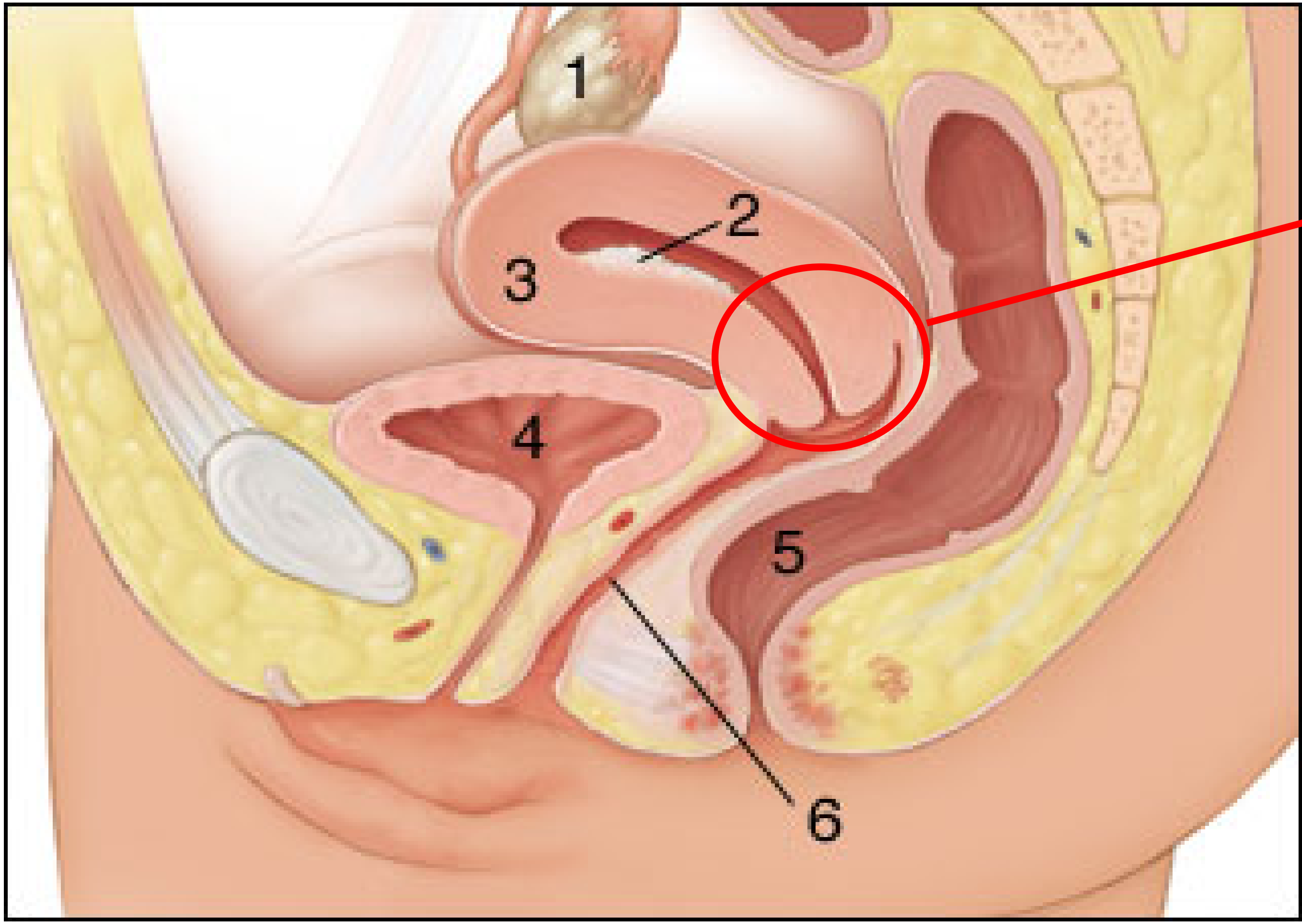


Cervix

Aetiology

Sexual Behaviour

↑ incidence early age at first intercourse

high no. of sexual partners

Viral infections

HPV types 16, 18, 31, 33 implicated

HPV 16 present in 90-100%

HPV 18 associated with adenocarcinoma

Smoking

Immunosuppression increases risk of CIN

Pathology

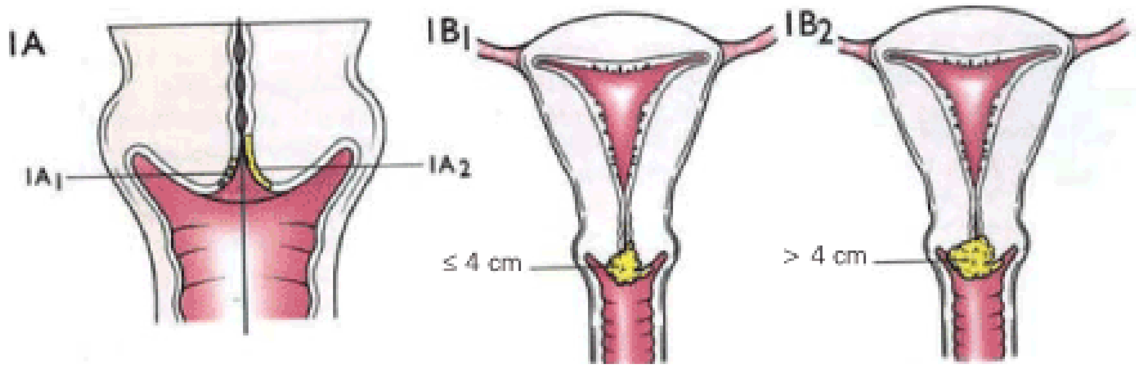
Majority ***squamous cell*** (85-95%)

Others...

Adenocarcinoma	occurs in women ~35yrs
	incidence ↑ – currently 10-20%
Small cell	rare
Lymphomas	usually diffuse large B cell type
Sarcomas	
Melanomas	

Pre-malignant – cervical intraepithelial neoplasia (CIN)

Management



Microinvasive disease
Small volume tumours
Early stage I and IIa

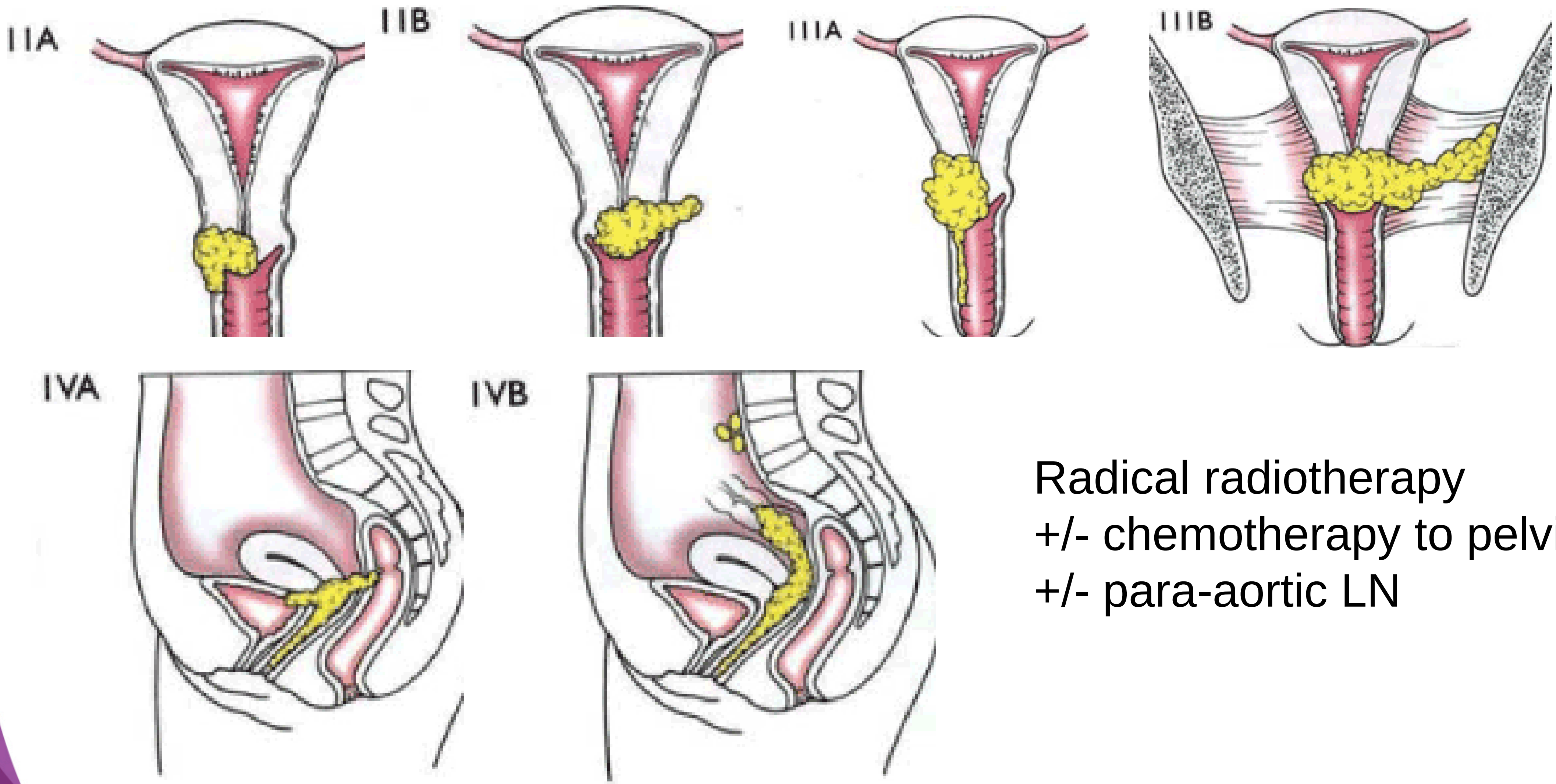
↓

Radical Surgery

(hysterectomy/cuff of vagina/BSO/pelvic + LN dissection)

Try to avoid 1° radical surgery + adjuvant RT+/- chemo because of ↑late toxicity

Cervix Radiotherapy



Radical radiotherapy
+/- chemotherapy to pelvis
+/- para-aortic LN

RT in Cervix Cancer

- Definitive/Primary

  Bulky IB2/IIA – IVB (PAN only)

  - ➢ Pelvic EBRT (45-50Gy/25-28#) +/- weekly cisplatin
  - ➢ Intra-cavitary brachytherapy (21-28Gy/3-4#)

- Adjuvant
  - ➢ High Risk - +ve margins/parametrium/LNs (RT+C)
  - ➢ Intermediate Risk – LVSI, stromal invasion, size (RT alone)
  - ➢ 45-50.4Gy/25-28# +/- cisplatin

- Salvage – recurrence following surgery

- Palliative

Peters (2000) *JCO* Apr; 18(8): 1606-13.
Rotman (2006) *IJROBP May 1; 65(1): 169-76.*

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Cervix Radiotherapy

Supine (consider supine on bellyboard post-op)

Intravenous contrast

Comfortably full bladder

Knee supports/ankle stocks

Anterior and lateral tattoos

Pinkawa et al. *Radioth Oncology* 69 (2003):99-105

Contouring: Key Publications

Lim et al (2011). Consensus Guidelines for delineation of clinical target volume for intensity modulated pelvic radiotherapy for the definitive treatment of cervix cancer. *IJROBP*. Feb 1;79(2):348-55.

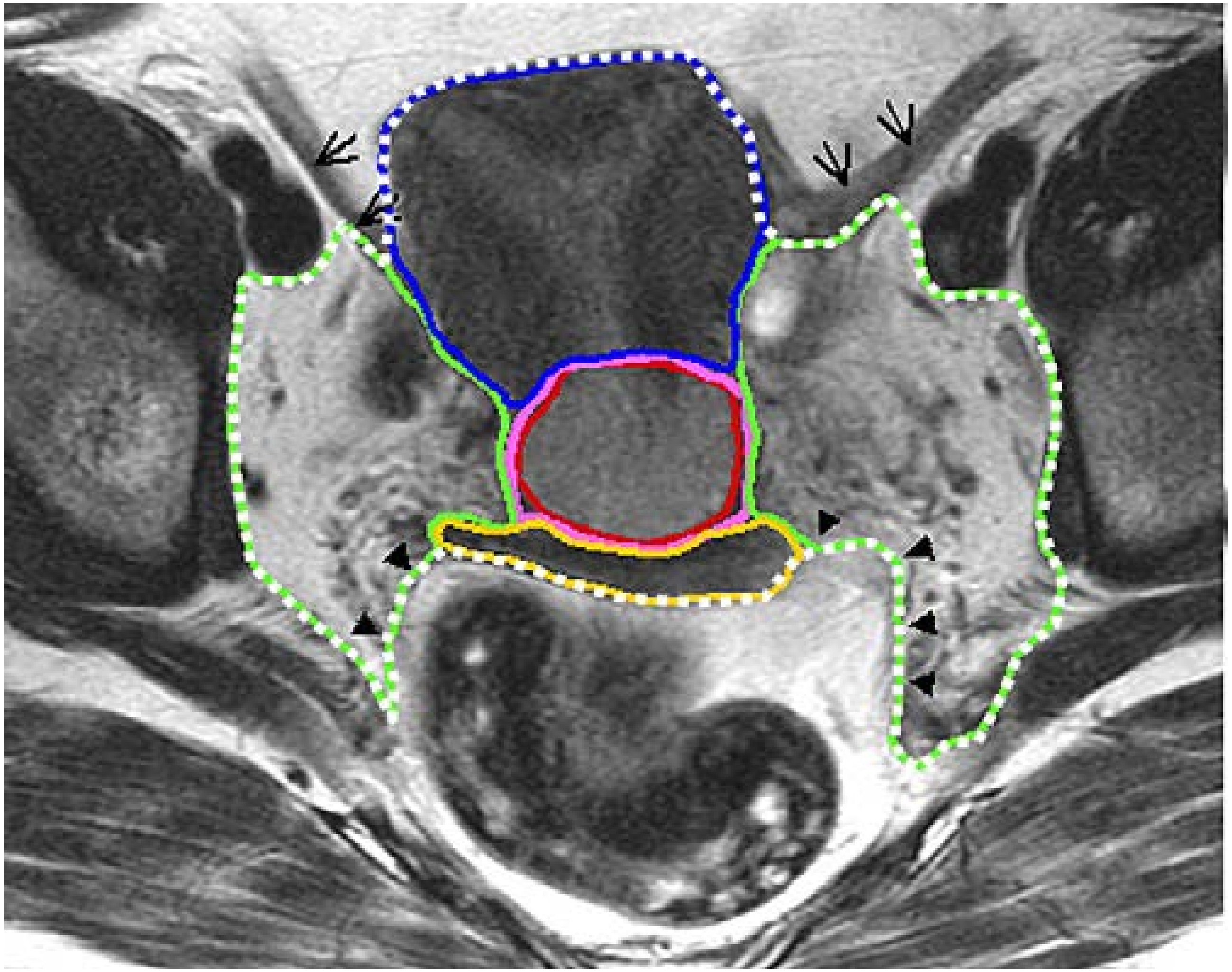
Taylor A et al (2005). Mapping pelvic lymph nodes: guidelines for delineation in intensity-modulated radiotherapy. *IJROBP*. Dec 1;63(5):1604-12.

Components* of CTV-T

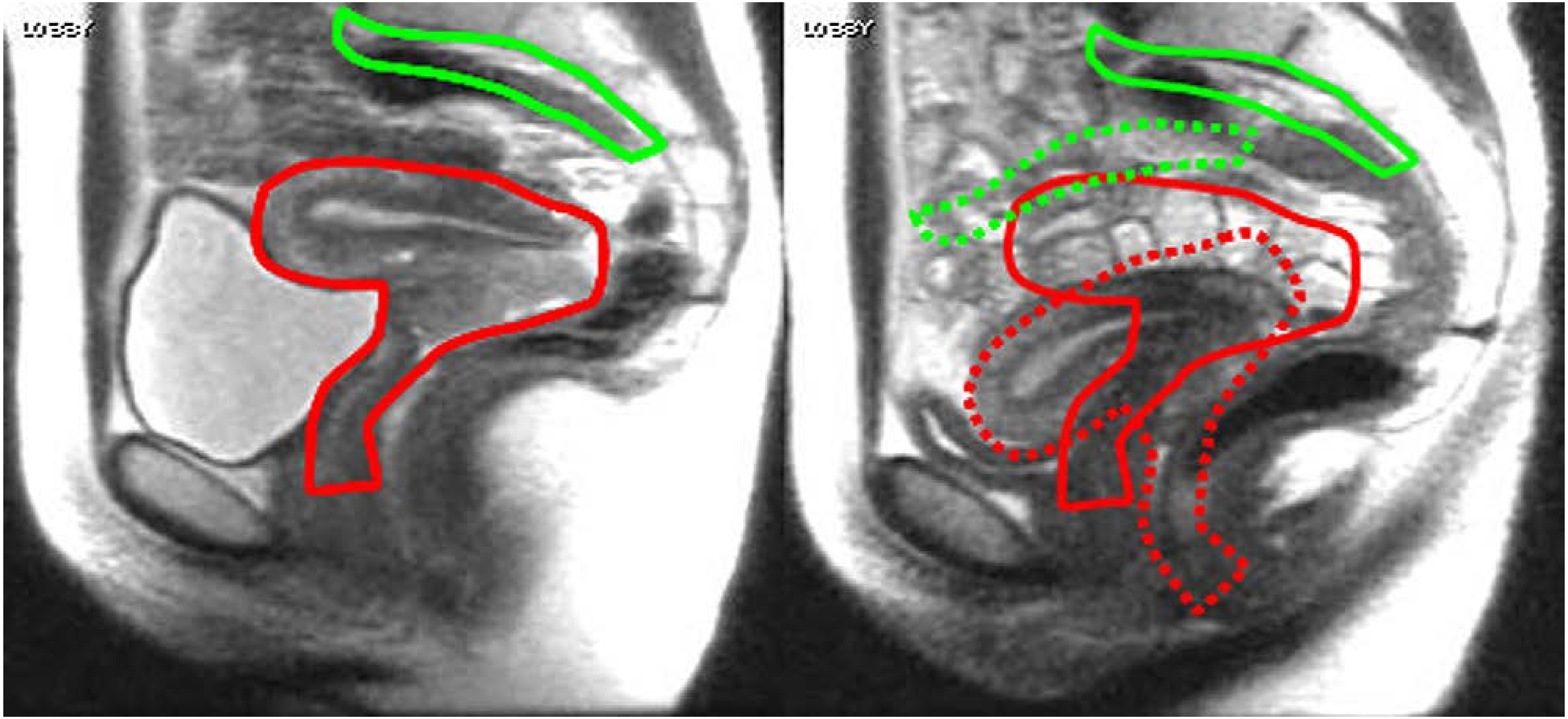
GTV	Intermediate/high signal seen on T2-weighted MR images
Cervix	Entire cervix - if not already included in GTV contour
Uterus	Entire uterus including ovaries
Parametrium	Entire parametrium (+ entire mesorectum if uterosacral ligament involved)
Vagina	Minimal/no vaginal extension - upper 1/2 of vagina Upper vaginal involvement - upper 2/3 of vagina Extensive vaginal involvement - entire vagina

*Extrapolated from surgical approach

Axial



GTV (red), cervix (pink), uterus (blue), vagina (yellow), parametrium (green). Arrow heads refer to uterosacral ligaments and mesorectal fascia. Arrows refer to the broad ligament and top of the fallopian tube. Dashed white lines represent the CTV.



Images obtained 1 week apart from same patient.
Primary tumour CTV (red) and nodal CTV (green) overlaid.
Note difference between uterus and cervix positions, with altered bladder filling.

Target Volume Delineation

Definitive

PTV-T	CTV + 15mm in all directions except inferiorly/laterally where 7mm is sufficient

Adjuvant

PTV-T	CTV +12mm in all directions except inferiorly/laterally where 7mm is sufficient

Chan P et al. Inter- and intra-fractional tumour and organ movement in patients with cervical cancer undergoing radiotherapy.
IJROBP 2008;70: 1507–1515.

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Nodal Margins

GTV-N Includes all gross disease as per imaging

CTV-N GTV + 5 – 10mm margin. Uninvolved nodal areas are contoured according to the printed atlas (Taylor guidelines). Internal iliac, external iliac and obturator nodes are included in all cases.

The common iliac nodes are included in node positive cases.

PTV-N = CTV + 7mm margin.

Taylor A (2005) Mapping pelvic lymph nodes: guidelines for delineation in intensity-modulated radiotherapy. *Int.J.Radiat.Oncol Biol.Phys. 63(5): 1604-1612.*

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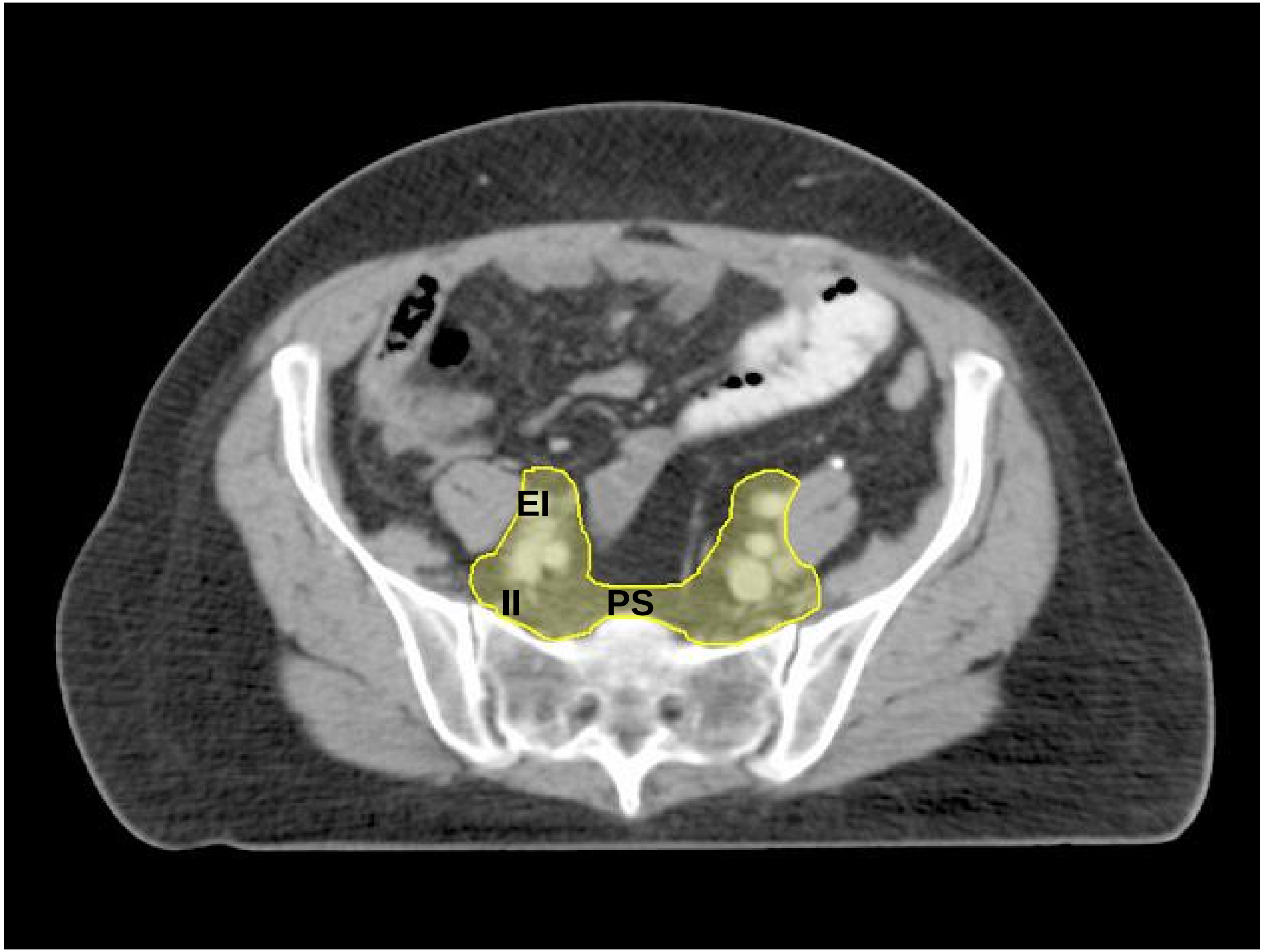
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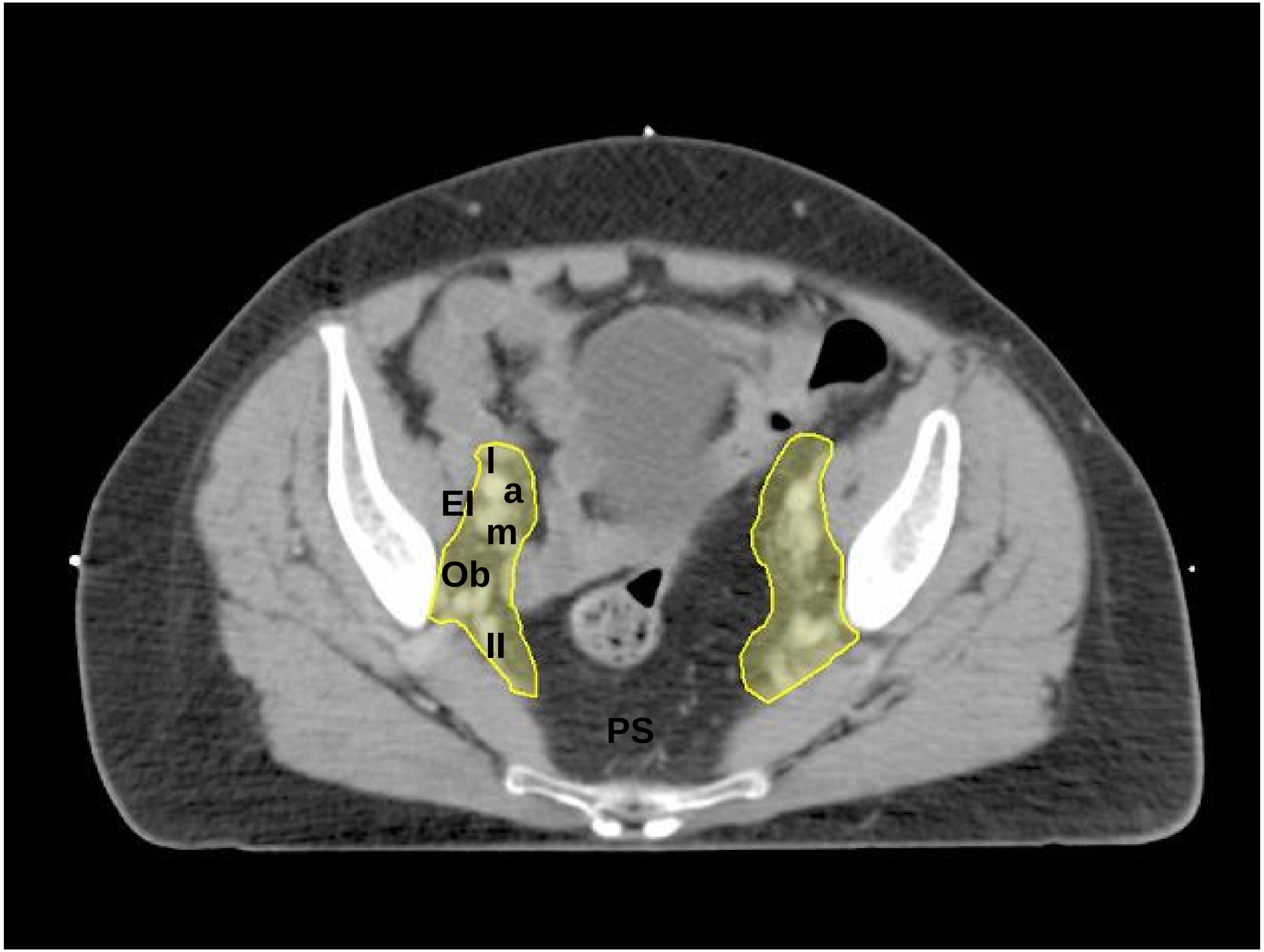
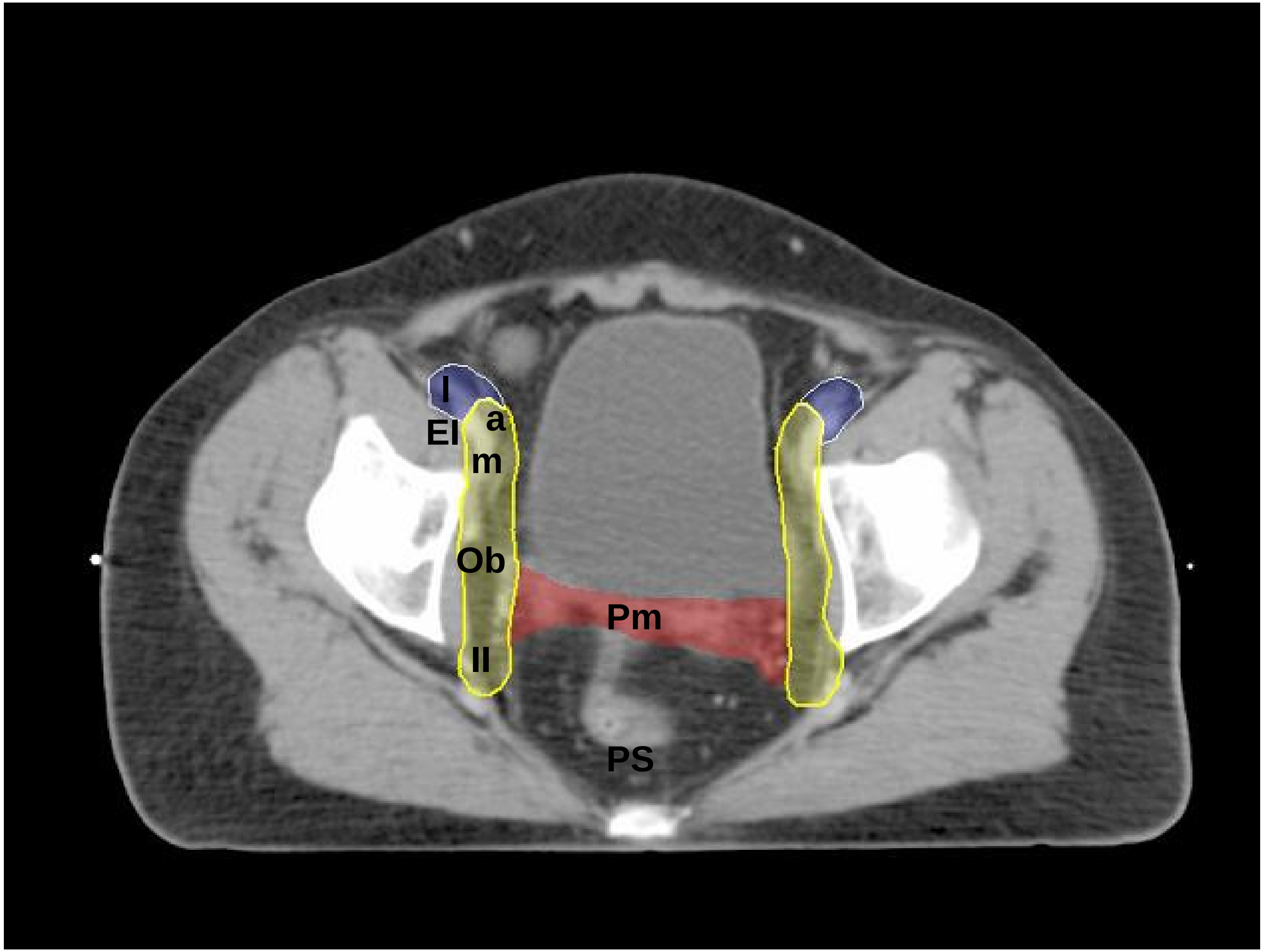


Ob: obturator LN



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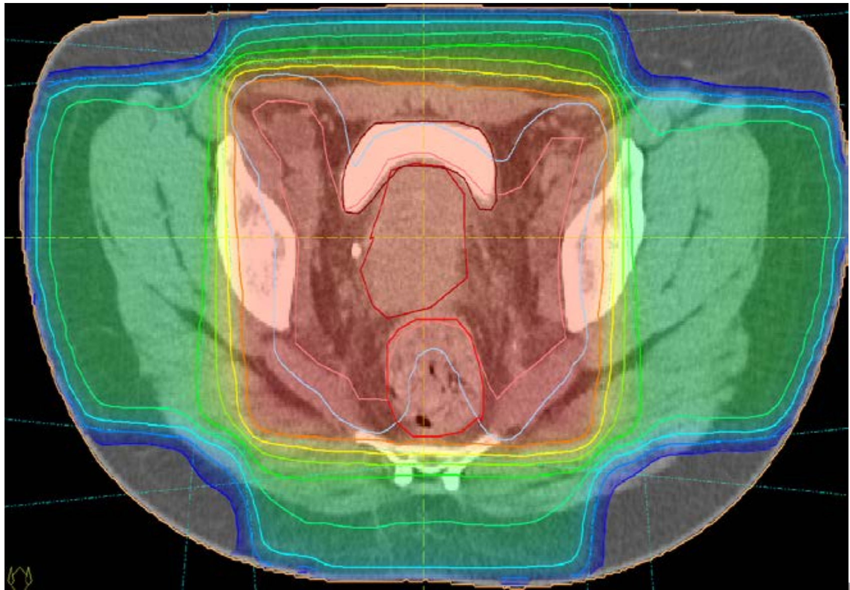
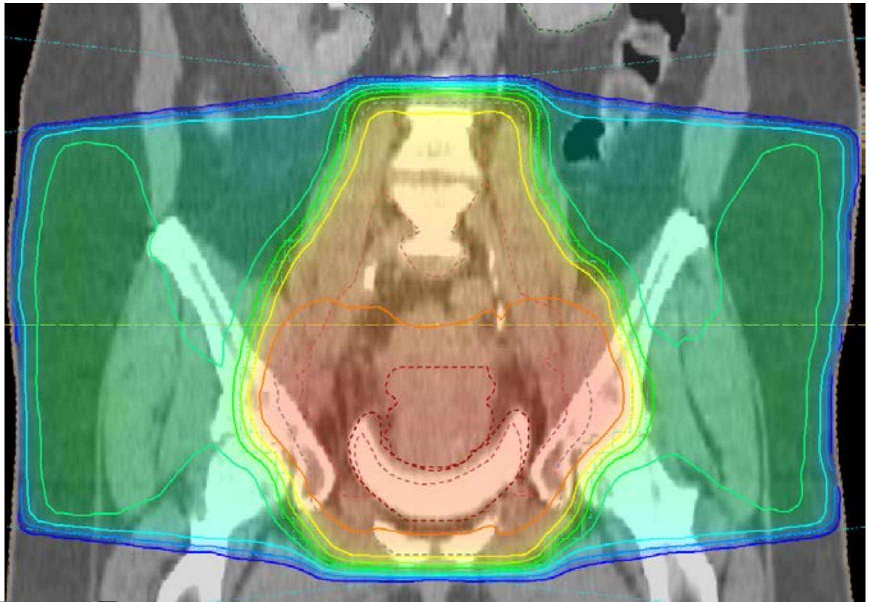
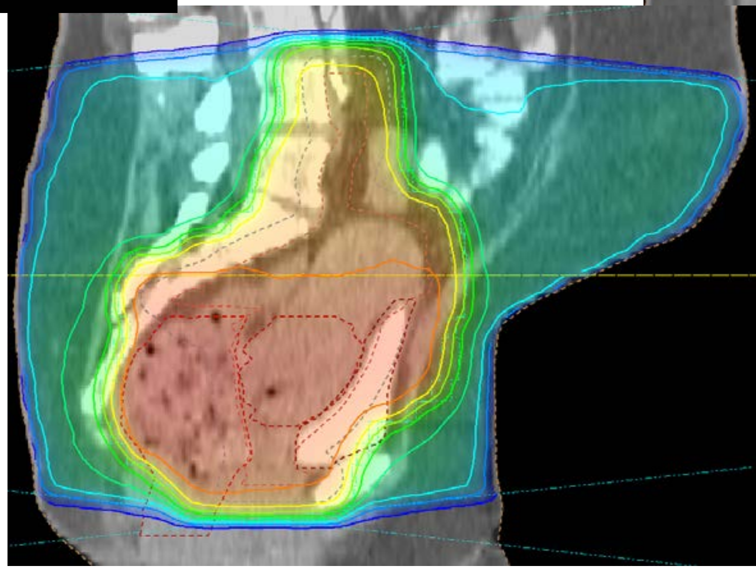
Radical Cervix Radiotherapy







Dose

1° therapy:

45-50.4Gy/25-28#/5-5.5wks

Followed by intra-cavitary brachytherapy

Total Dose (EBRT/brachy) ~80-85Gy EQD_2

Following surgery:

45-50.4Gy/25-28#/5-5.5wks

No vaginal vault brachytherapy (unless +ve vaginal margin)

Uterus

Epidemiology

1	Barbados	34.1
2	FYR Macedonia	29.0
3	Armenia	26.7
4	Luxembourg	24.2
5	Guyana	22.6
6	New Caledonia	22.1
7	United States of America	19.5
8	Slovakia	19.0
9	Czech Republic	18.0
10	Serbia	17.9
11	Bulgaria	17.8
12	Lithuania	17.7
13	Guatemala	17.4
14	Belarus	17.1
15	France, Guadeloupe	17.0
16	Norway	16.9
16	Poland	16.9
18	Latvia	16.7
19	Ukraine	16.6
20	El Salvador	16.3
20	Canada	16.3

Incidence 10-15/100000/yr

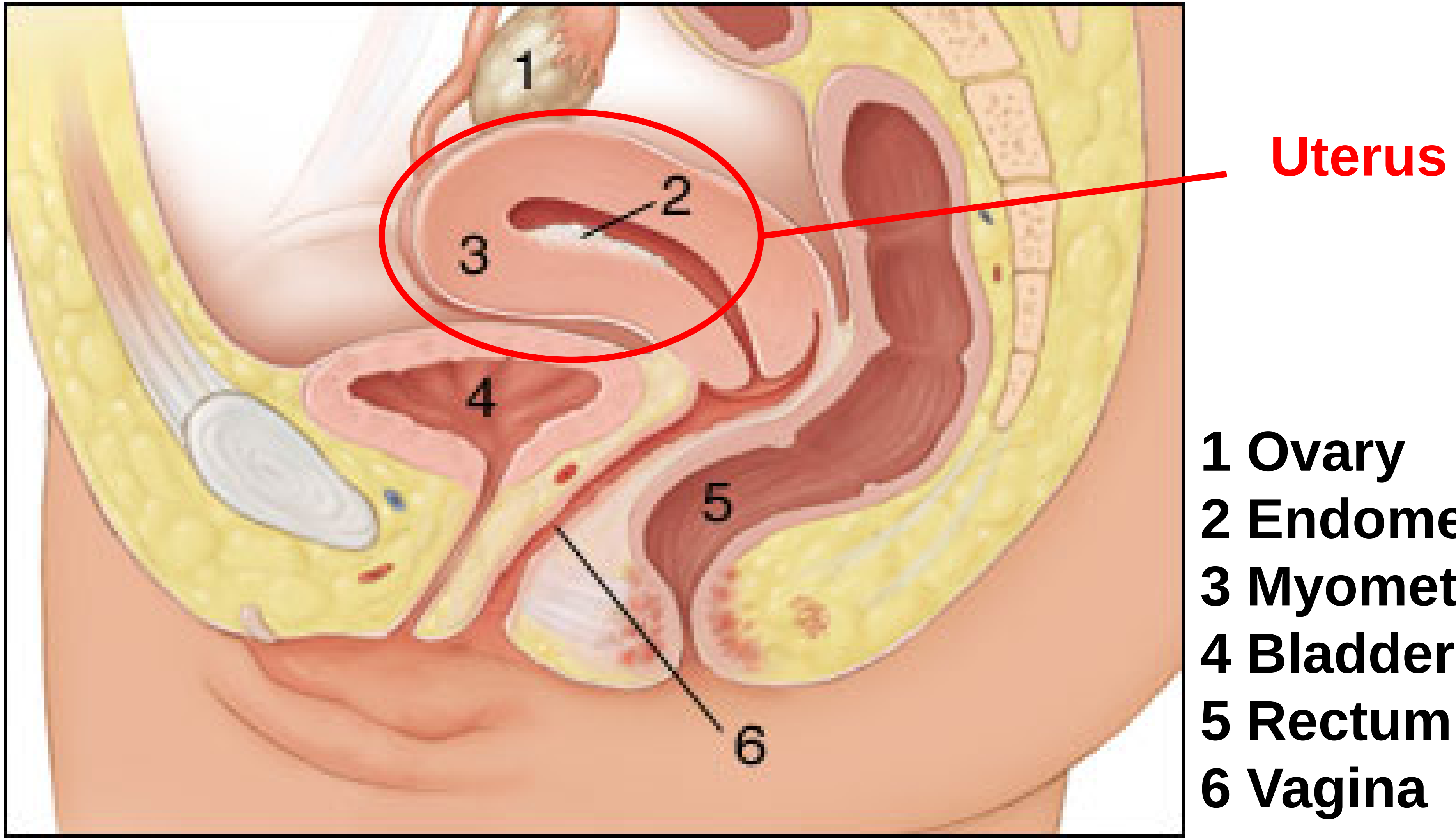
Age median 60yrs

Race High in Caucasians

Low in Asians

Commonest gynaecological cancer in USA

Primarily a disease of post menopausal women (>70%)



1 Ovary
2 Endometrium
3 Myometrium
4 Bladder
5 Rectum
6 Vagina

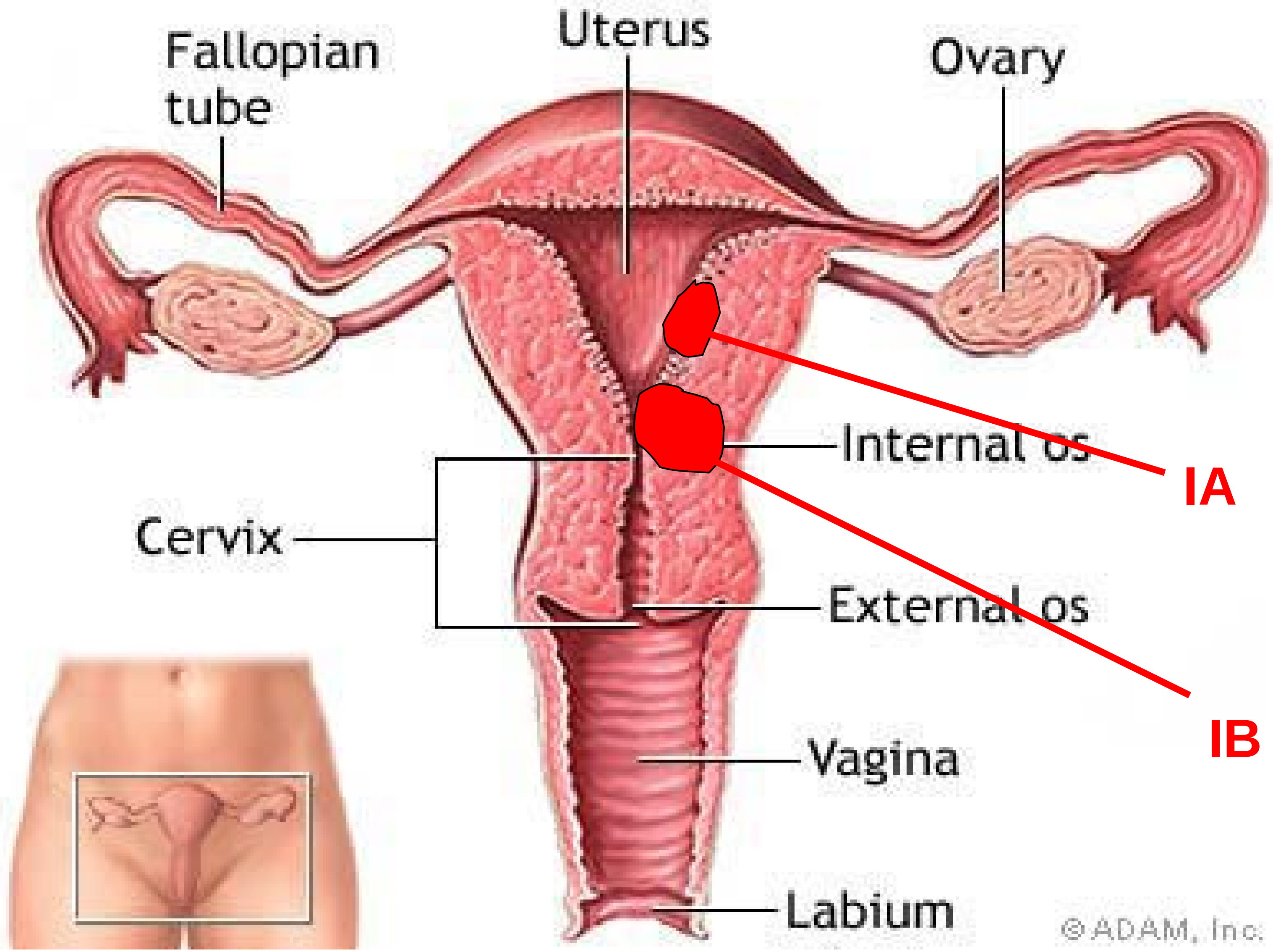
Management: Stage I-III

Standard surgical procedure:

Total Abdominal Hysterectomy* (TAH)
+ bilateral salpingo-oopherectomy (BSO)
+ peritoneal washings
+/-pelvic lymphadenectomy

* but increasingly laparoscopically assisted vaginal hysterectomy

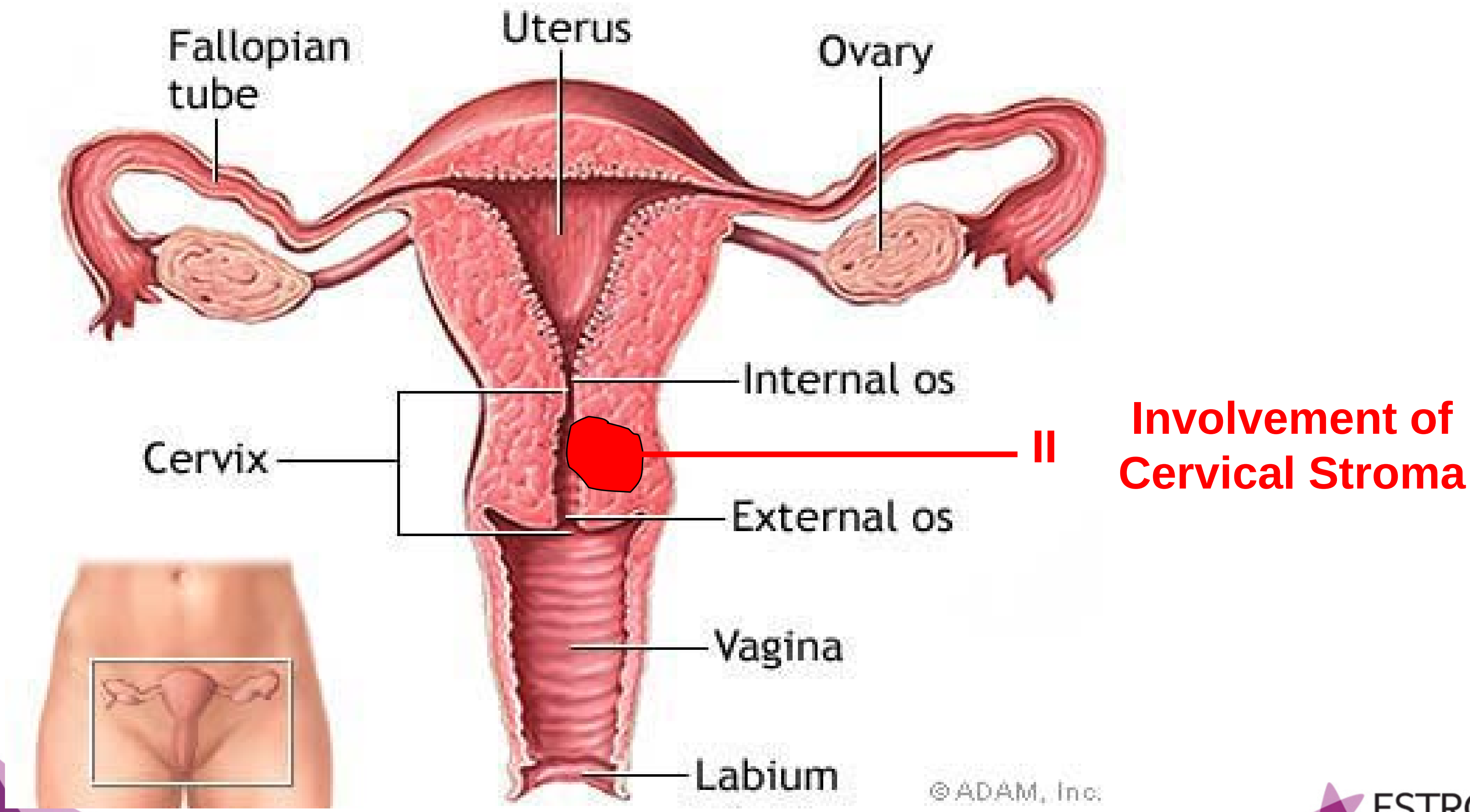
Stage I



≤50% myometrium involvement

>50% myometrium involvement

Stage II



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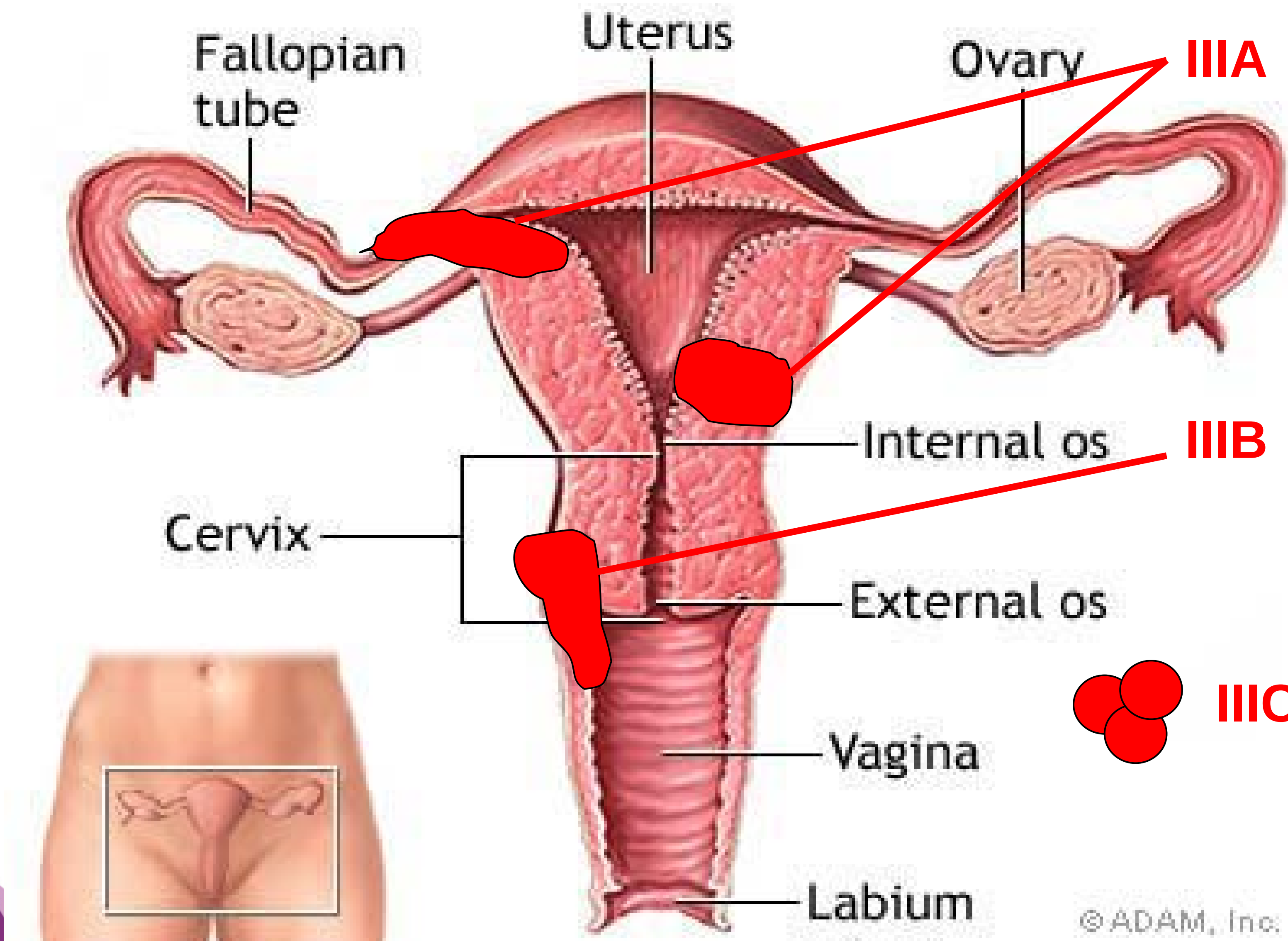
Stage III

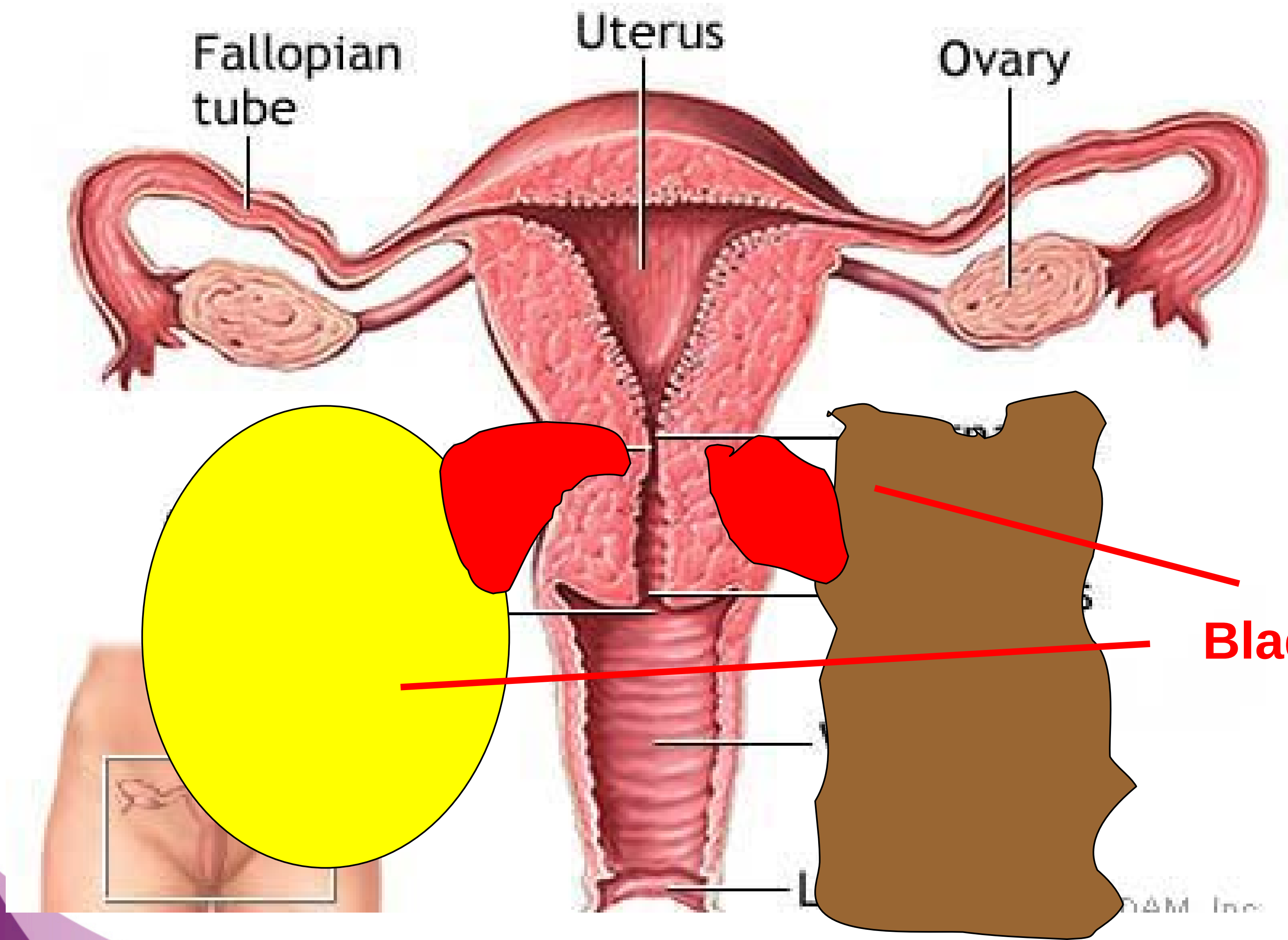


IIIA
Extension to serosa +/or adnexa

IIIB
Extension to Parametrium +/or vagina

IIIC
Involvement of Pelvic +/or Para-aortic LN

Stage IV



IVB

Distant Metastases

IVA

Invasion of Bladder or Rectum

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Adjuvant Radiotherapy

Benefit of pelvic EBRT is ↑local control

No convincing impact on survival

Benefit has to be balanced against risk

Used with less frequency in early stage disease

Stage I: *controversial*
Treatment following surgery for adenocarcinoma

	Grade		
	1	**2**	**3**
IA	Observe	Observe	VBT
IB	VBT	VBT	EBRT + ?VBT

VBT: Vaginal Vault Brachytherapy
EBRT: External Beam Pelvic RT

Some *may* add pelvic RT if risk factors - lymphovascular space invasion, lower uterine segment involvement, age >60yrs, bulky tumour

Adjuvant Therapy: Stage II/III

EBRT +/- brachy following appropriate surgery (if medically fit)

Post-Op Endometrial RT Contouring

- **CTV-T** = Upper 3cm of vaginal vault and parametrium.
- **PTV-T** = CTV + 12mm in all directions except inferiorly and laterally where 7mm is sufficient.
- **CTV-N** = (as per Taylor guidelines) includes obturator nodes, external iliac lymph nodes, internal iliac lymph nodes. The common iliac nodes may be included for node positive patients (Stage IIIC1). The para-aortic nodes may be included for those with Stage IIIC2 tumours.
- **PTV-N** = CTV + 7mm margin.
- **PTV final = PTV-T + PTV-N**

Dose

45-50.4Gy/25-28#/5-5.5wks prescribed to 100% using 6-15MV photons

Role of IMRT in Gynae Cancers

Findings based on review of 4 cohort studies - total of 619 patients.

If main interest is reducing toxicity then IMRT > 3DCRT

If disease-related outcomes - insufficient data to recommend IMRT

Reasons...

IMRT in the treatment of gynaecological cancers. D'Souza et al; Members of the IMRT Indications Expert Panel. Clin Oncol (R Coll Radiol). 2012 Sep;24(7):499-507.

ESTRO School

Rectal Cancer

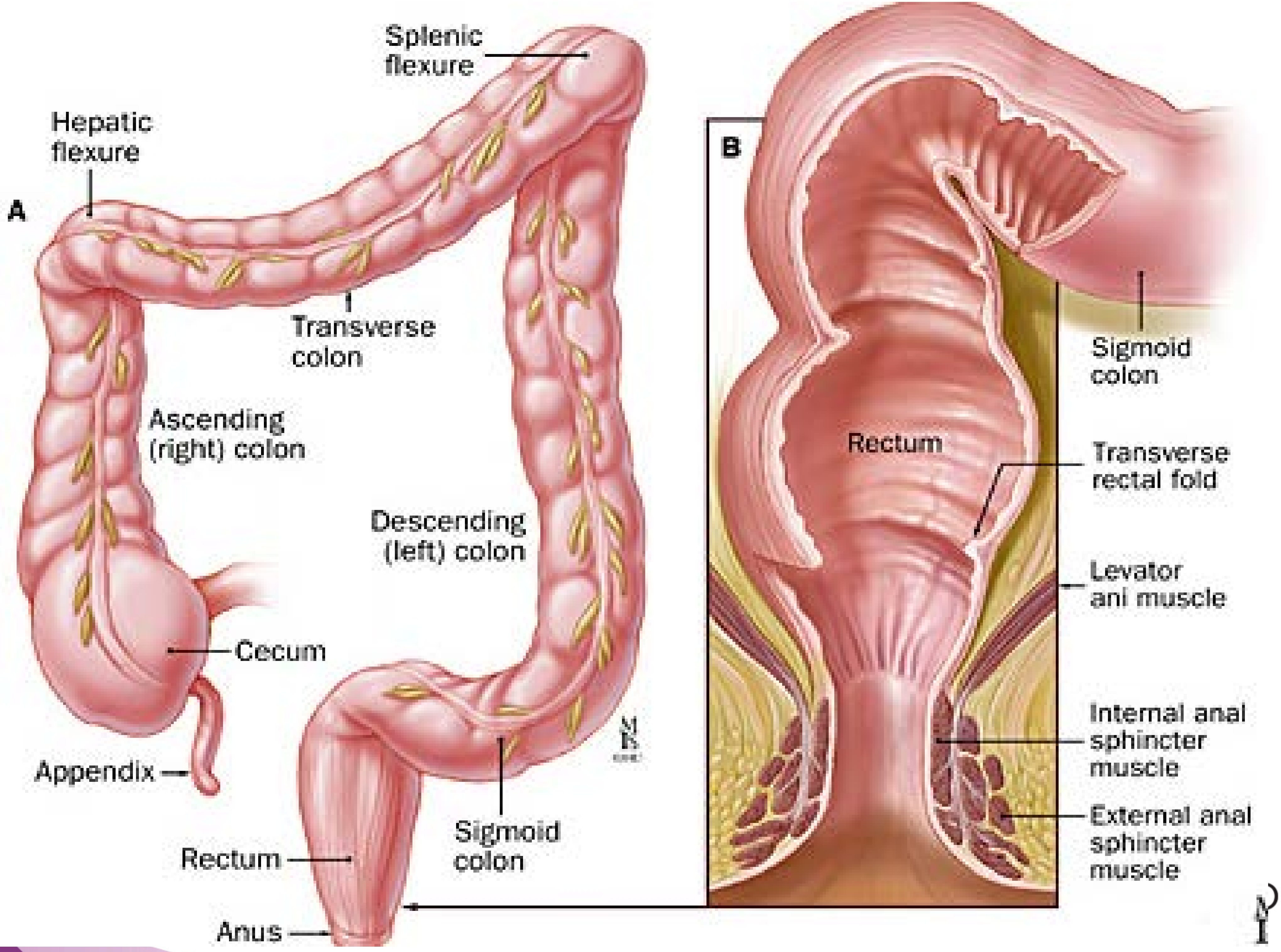
Epidemiology (*colo*rectal cancer)

1	Korea, Republic of	45.0
2	Slovakia	42.7
3	Hungary	42.3
4	Denmark	40.5
5	The Netherlands	40.2
6	Czech Republic	38.9
6	Norway	38.9
8	Australia	38.4
9	New Zealand	37.3
10	Slovenia	37.0
11	Belgium	36.7
12	Israel	35.9
13	Canada	35.2
14	Ireland	34.9
15	Italy	33.9
16	Singapore	33.7
17	Spain	33.1
18	Croatia	32.9
19	Serbia	32.6
20	Japan	32.2

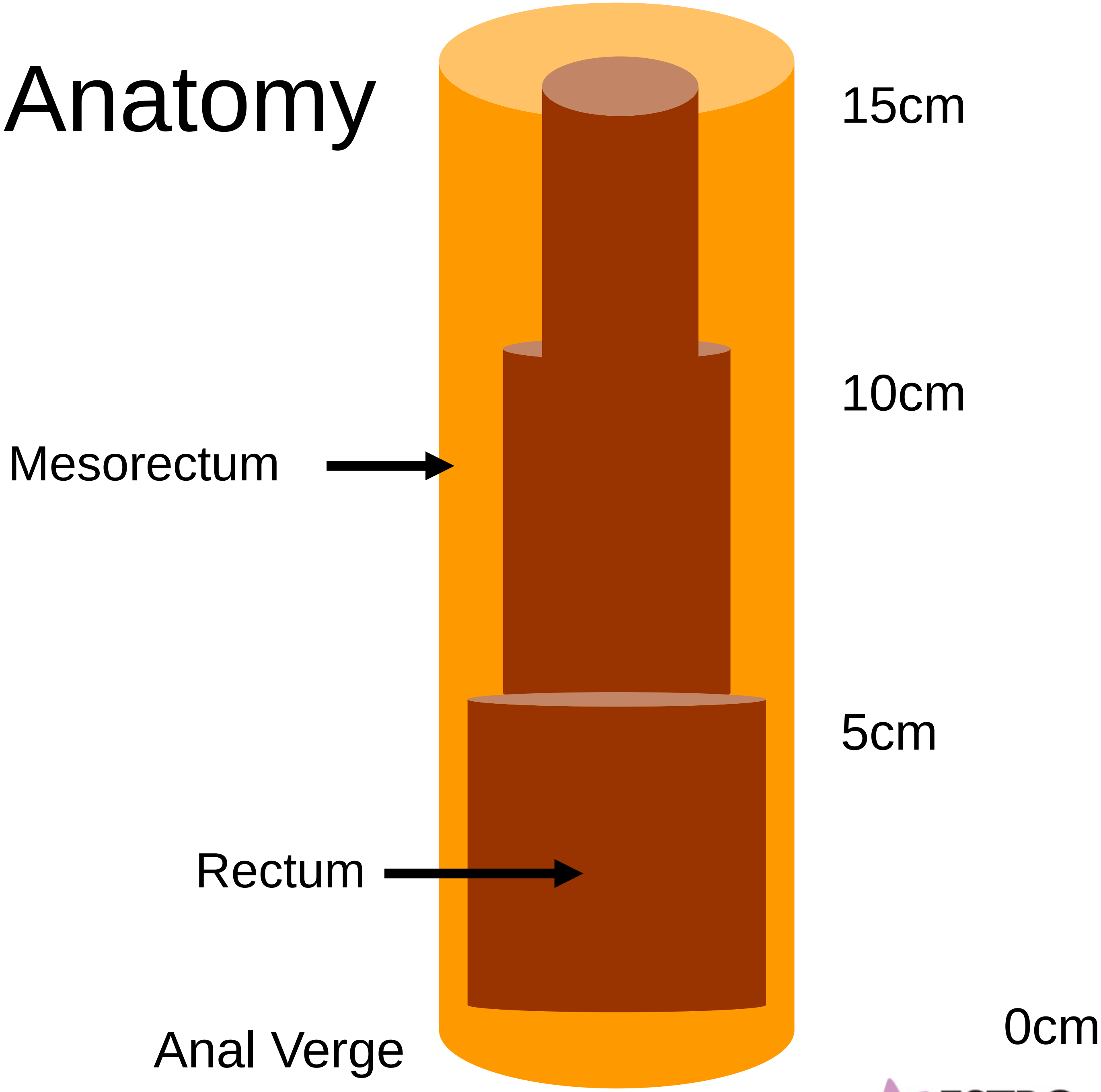
Cases per 100,000 per year
Males and females

1.4 million diagnosed in 2012

More common in developed world


A
Hepatic flexure
Splenic flexure
Transverse colon
Ascending (right) colon
Descending (left) colon
Cecum
Appendix
Sigmoid colon
Rectum
Anus
B
Sigmoid colon
Rectum
Transverse rectal fold
Levator ani muscle
Internal anal sphincter muscle
External anal sphincter muscle

Rectum Anatomy



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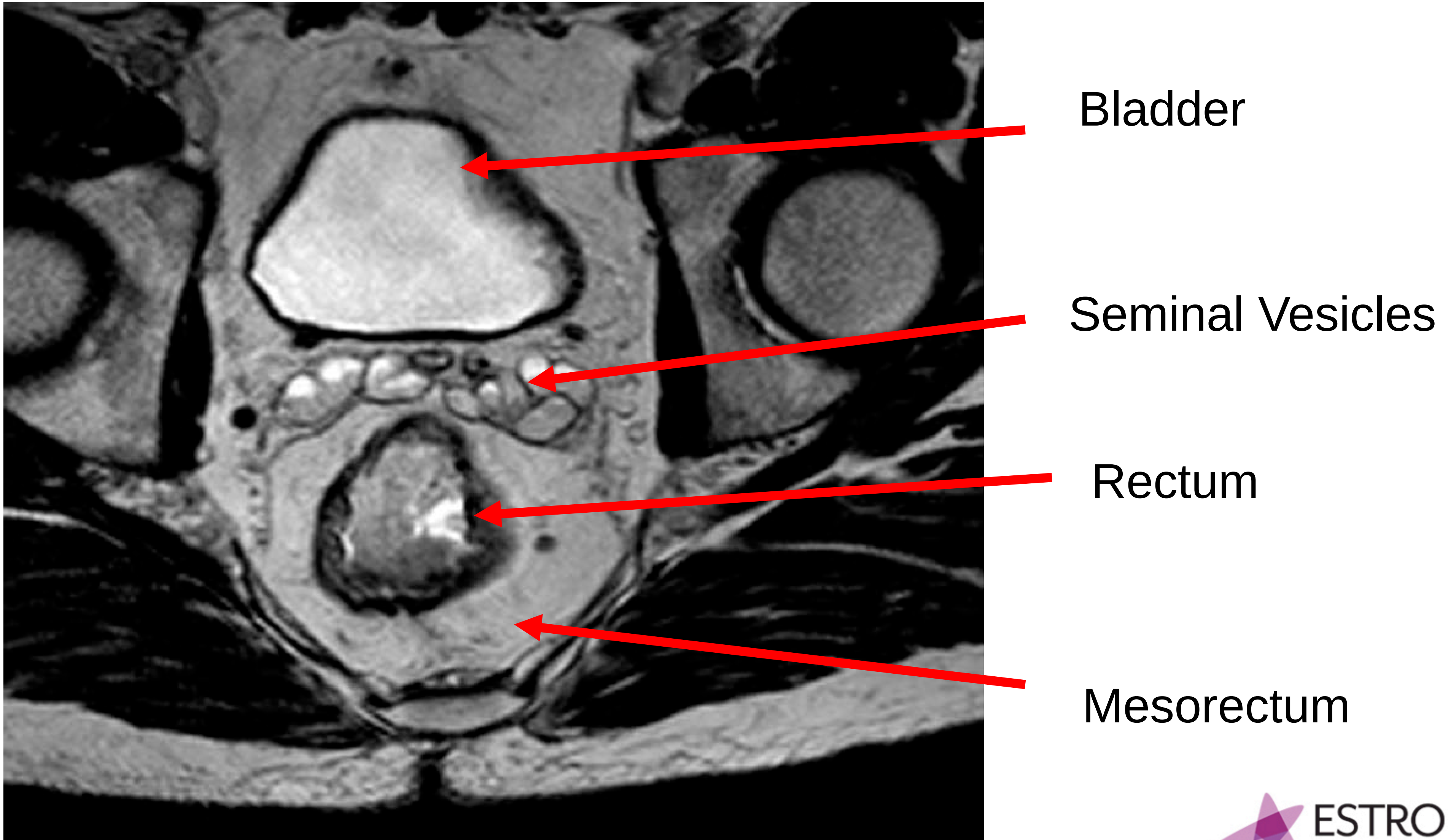
Pathology

- >90% adenocarcinoma
- Others: carcinoid
  melanoma
  sarcoma



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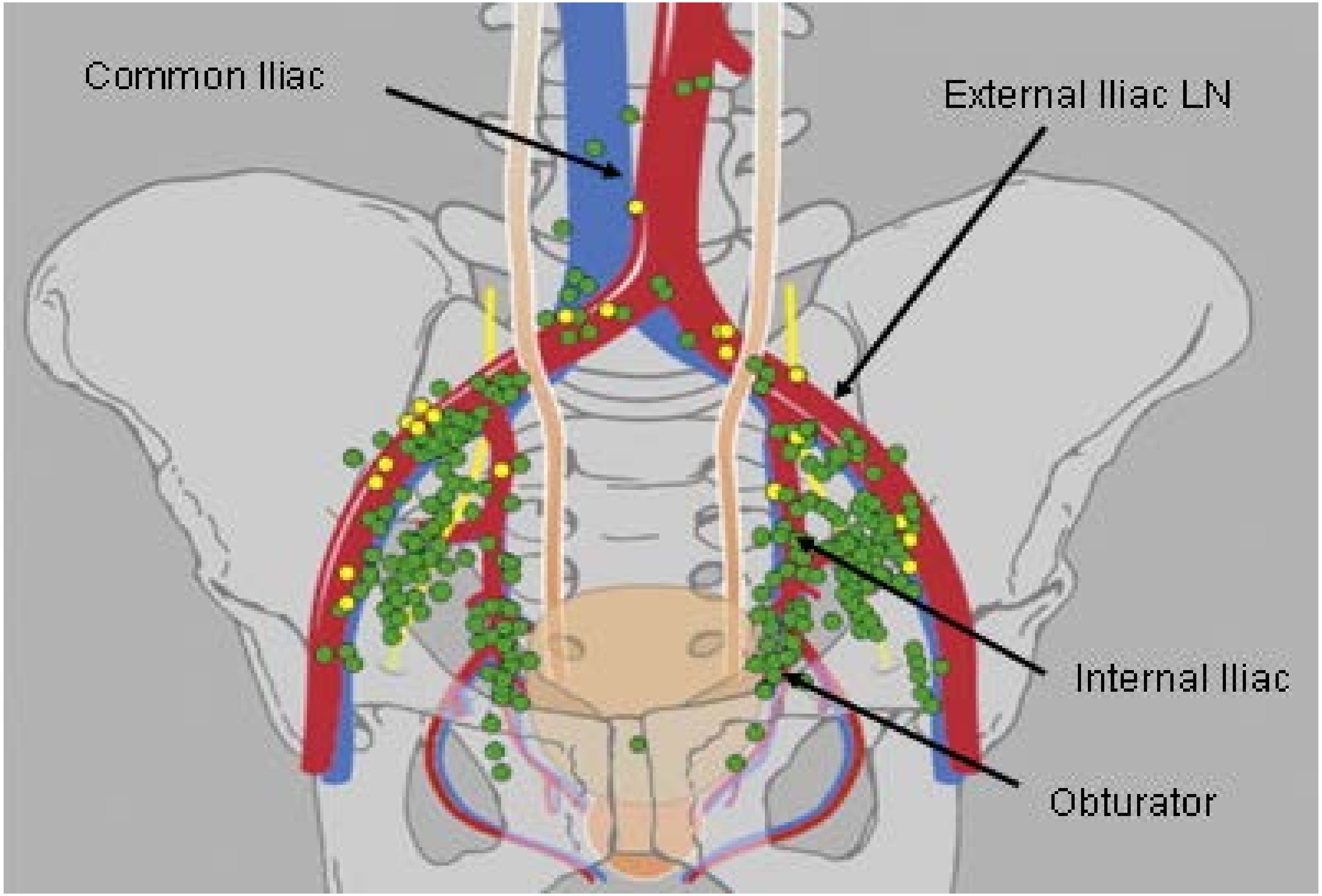
Spread

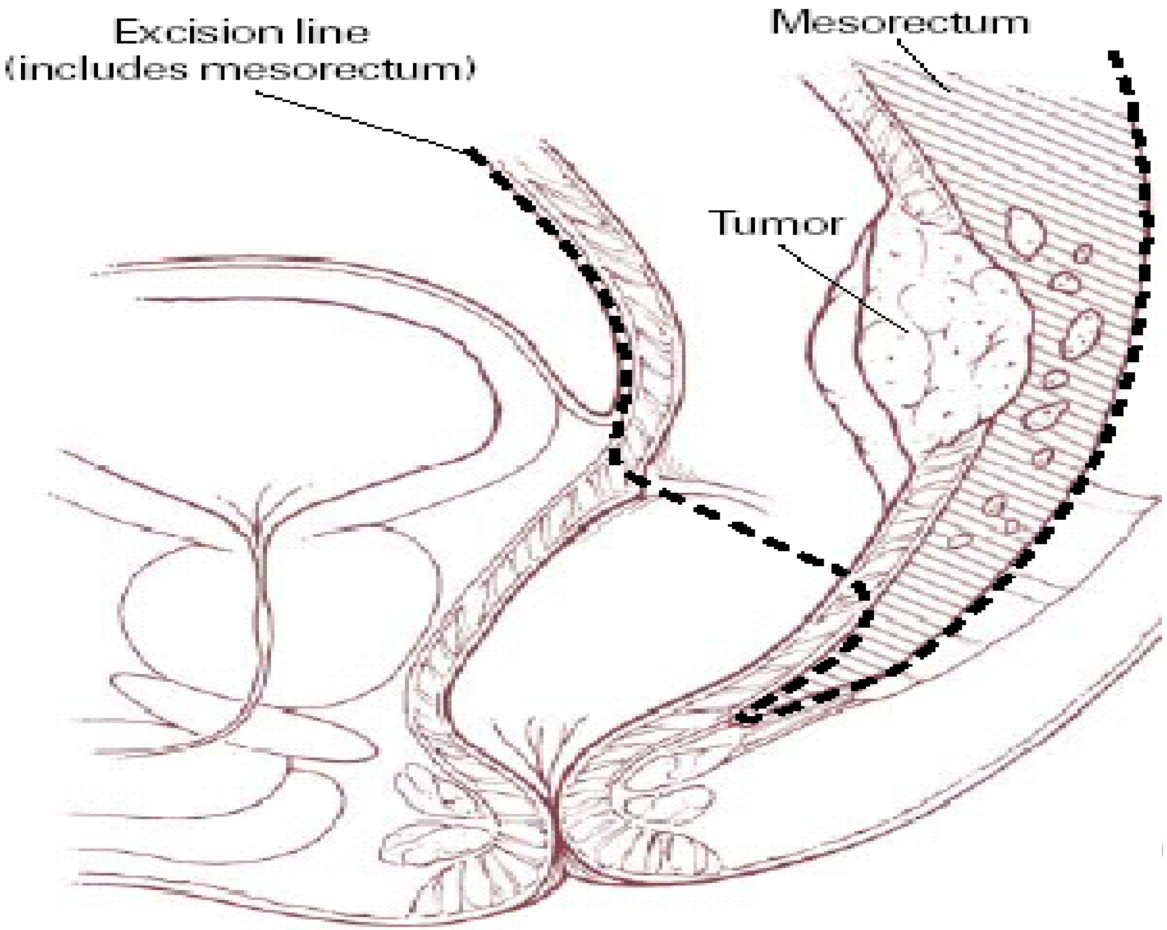
- Local: thru mesorectum into bladder, vagina, sacrum
- Nodal: mesorectum>int/ext iliac>para-aortic
- Blood: liver, lung, bone


Common Iliac
External Iliac LN
Internal Iliac
Obturator

Total Mesorectal Excision (TME)

Plane of dissection is formed by the mesorectal fascia, which encloses the fatty mesorectum

Associated with the lowest reported local recurrence rates



Management – localised

- Surgery

  Tumour within 5cm (lower) from anal verge

  Total mesorectal excision (TME) + abdomino-perineal resection (APR) + permanent colostomy

  Tumour 5-15cm (mid-upper) from anal verge

  TME + anterior resection (no permanent stoma)

- Pre-operative RT+/- chemotherapy if ↑risk of local recurrence

Aims of Additional Therapy

- Minimise local recurrence
  - debilitating + difficult to cure
  - LR >50% prior to adequate surgery

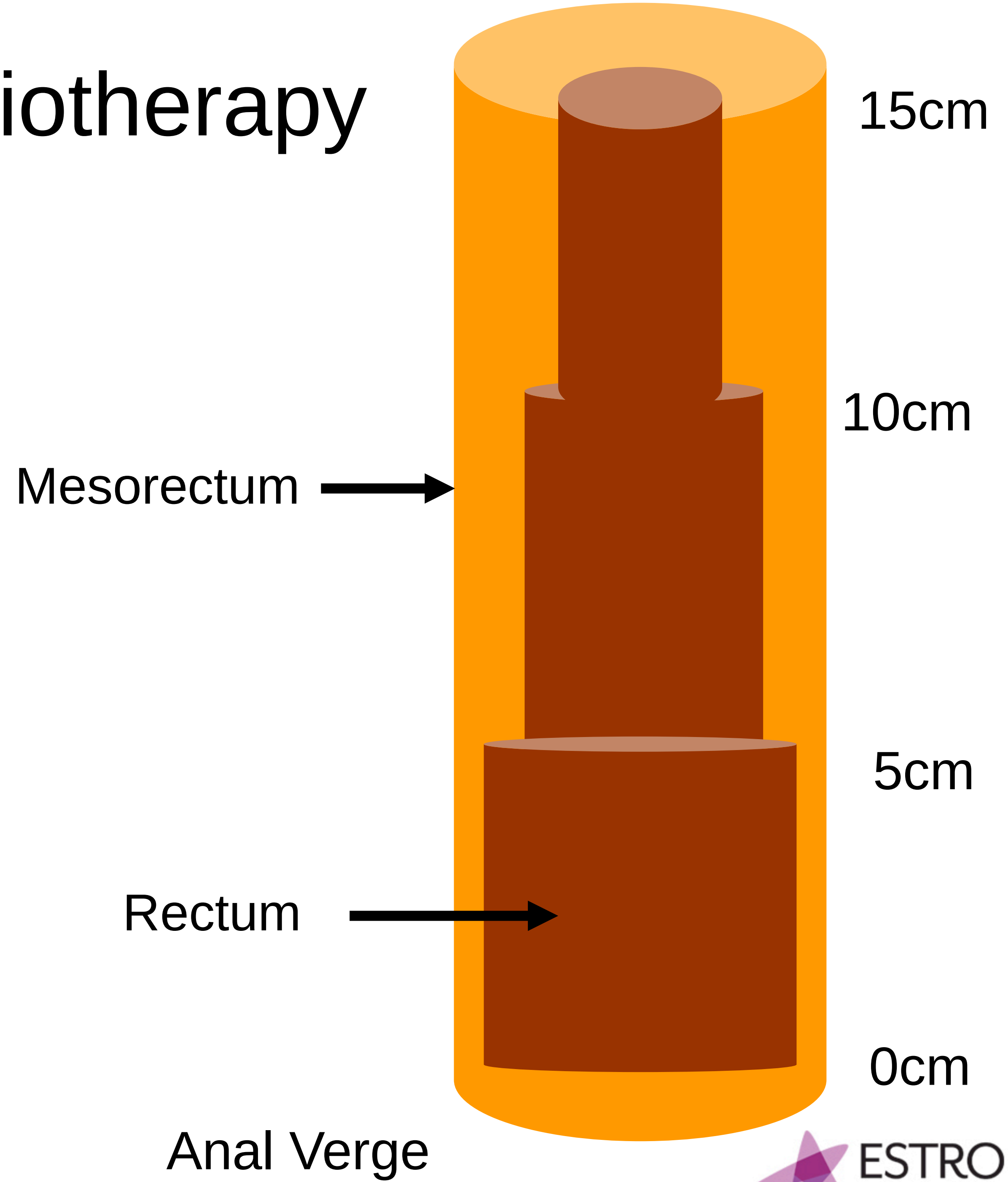
- Maximise chance of sphincter-sparing surgery

- Improve overall survival

Pre-Operative Radiotherapy

Benefit is related to risk of recurrence following surgery

Benefit of pre-operative treatment appears to be greater for those patients with tumours lower in the rectum



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Pre-Operative RT in Rectal Cancer

- Short Course
  - 25Gy/5#/1 week followed by surgery within 10 days
  - Common practice in Northern Europe
  - Appropriate if tumour doesn't need to shrink prior to surgery

- Long Course
  - 45-50.4Gy/25-28#/5-5.5 weeks followed by surgery 6-8 weeks later
  - More frequently used for locally advanced cancers
  - When tumour shrinkage required

Positioning/Immobilisation

- Supine
- Ankle +/- knee supports
- Bladder comfortably full
- Intravenous contrast
- Anterior and lateral tattoos

Rectum Pre-Op Radiotherapy Planning

- GTV: clinical exam, sigmoidoscopy, MRI
- CTV: entire mesorectum from L5/S1 to 2-3cm below GTV
    - ➢ Consider external iliac LN if tumour invades other organs
    - ➢ Consider inguinal LN if tumour very low (ano-rectal)
- PTV: CTV + 8-10mm (institutional)

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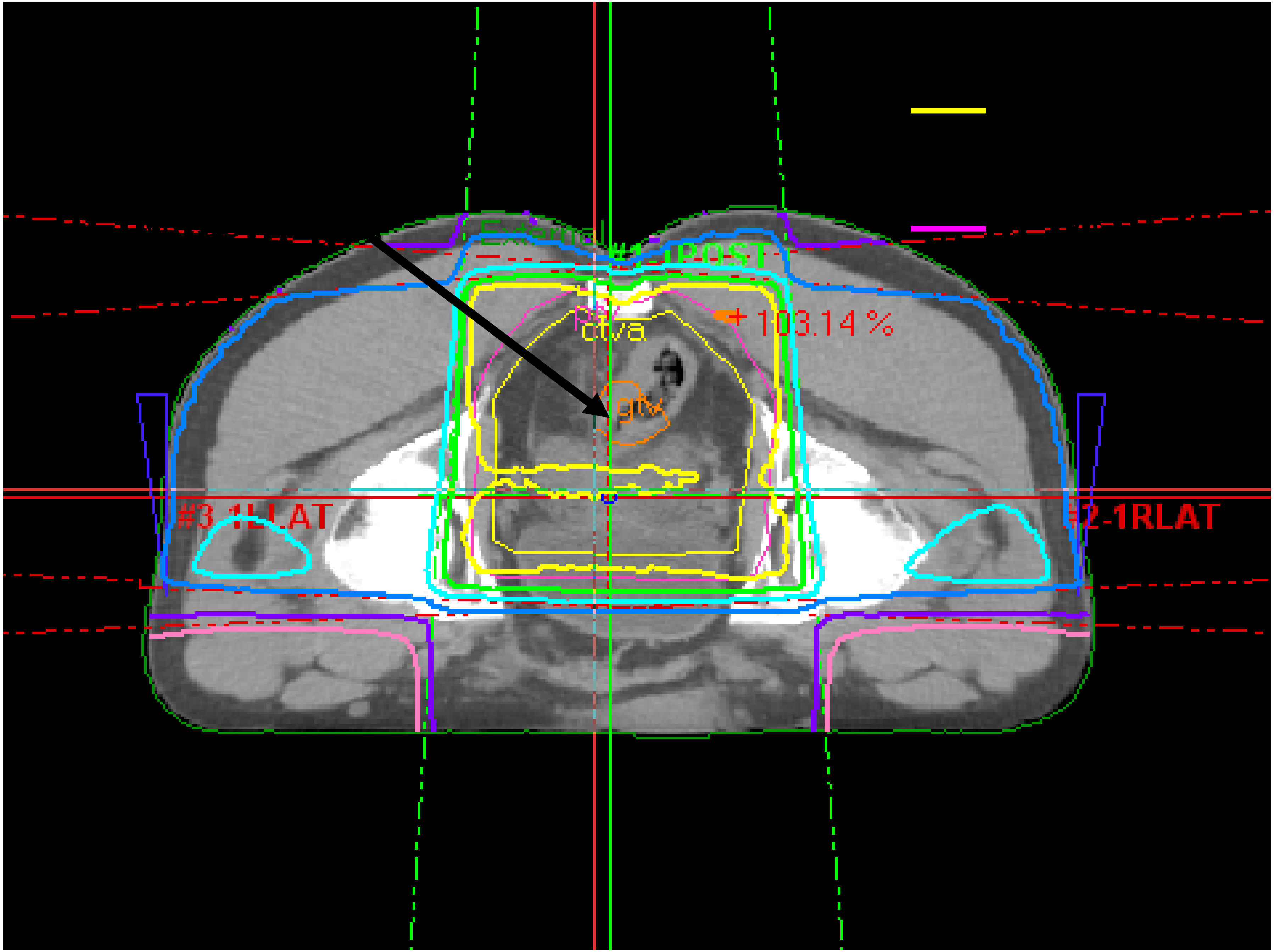
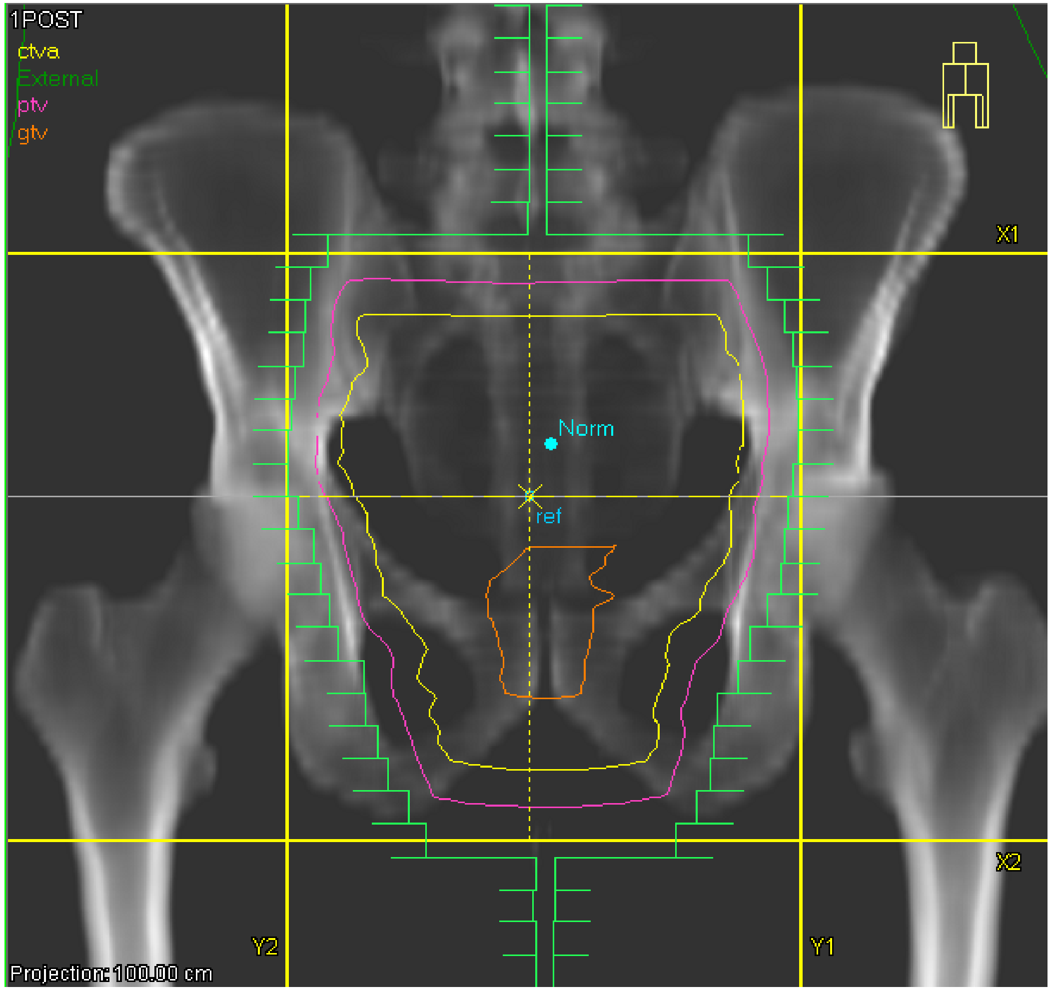
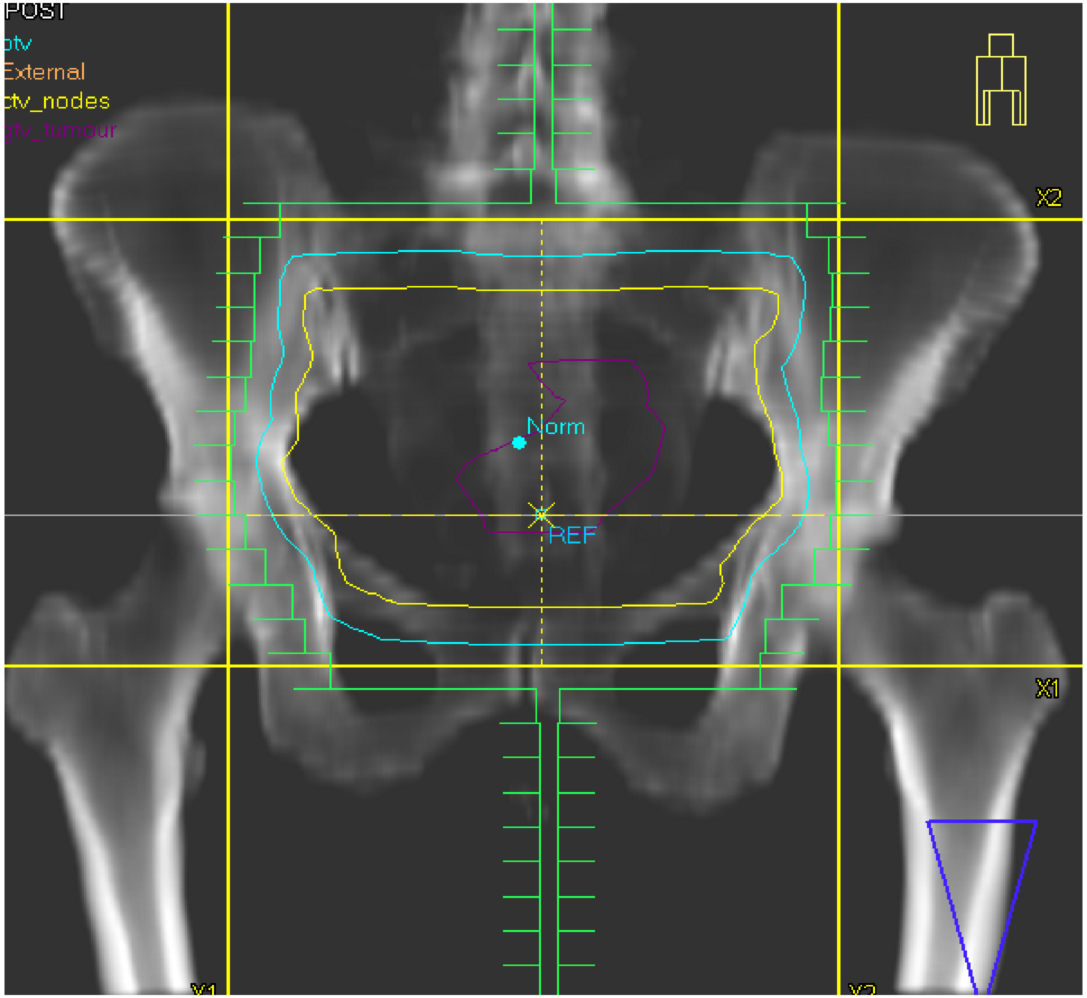


Note patient is prone (less frequent position now)

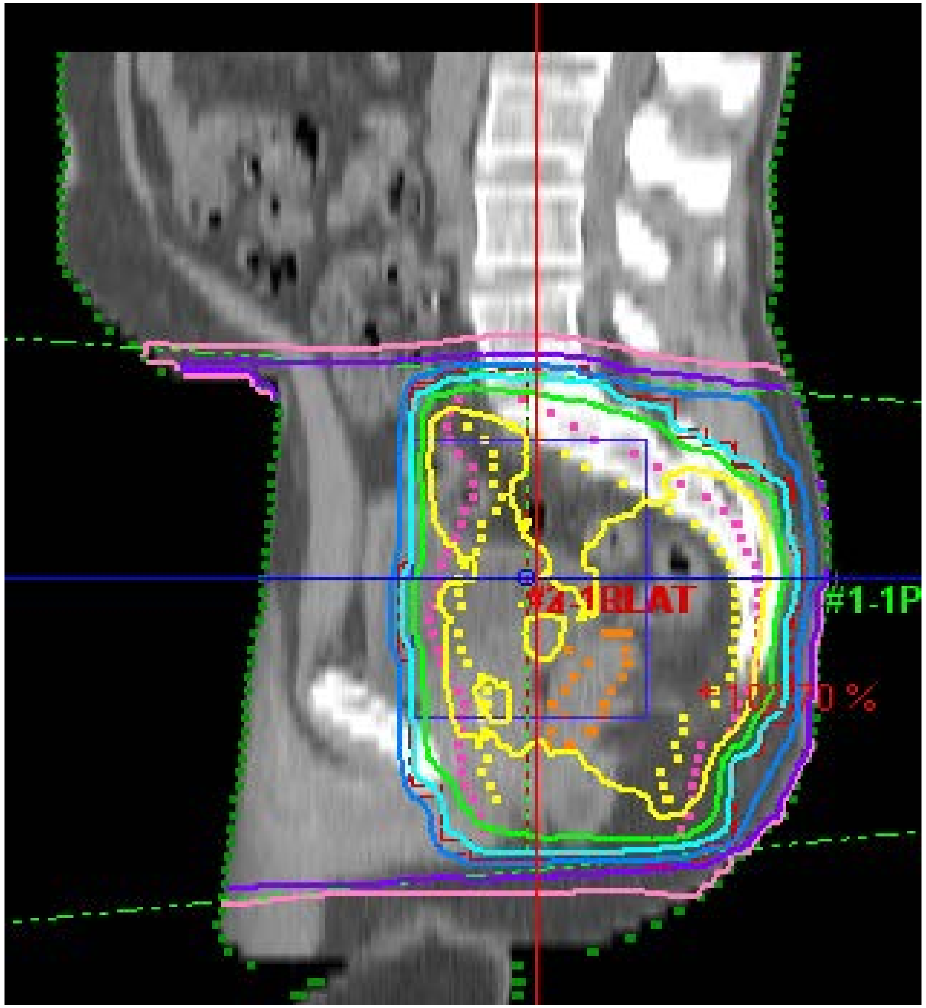


Lower Rectal Tumour

Upper Rectal Tumour



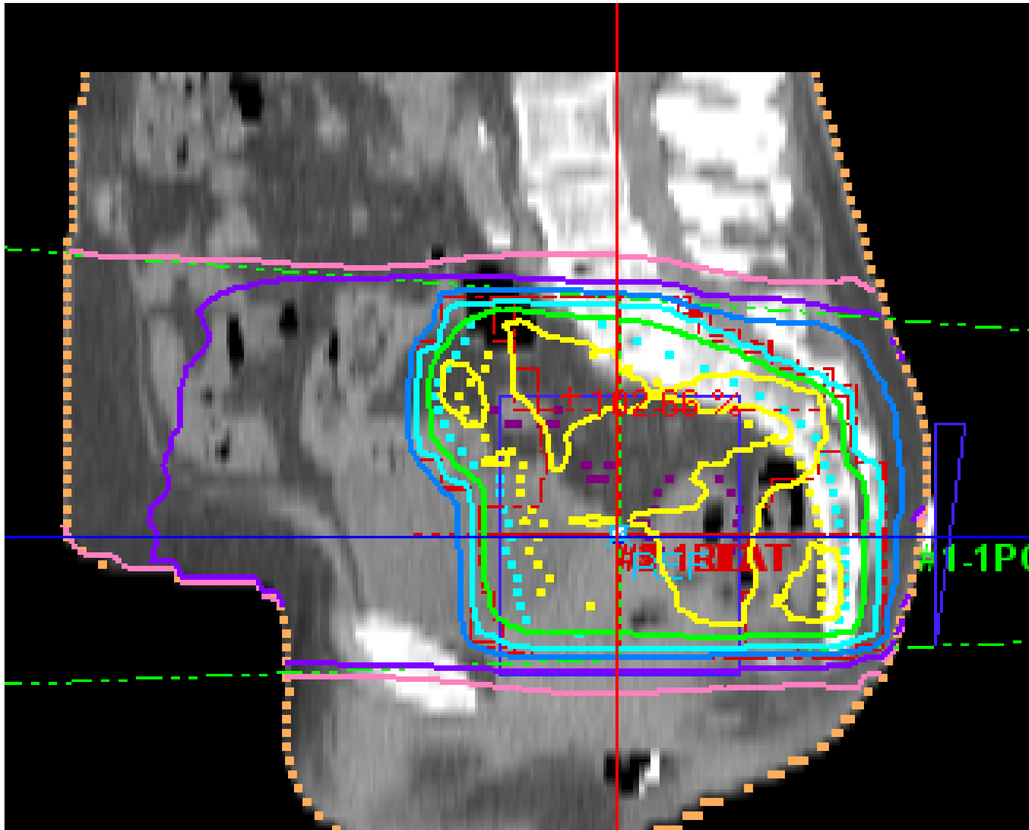
ESTRO School



Lower Rectal Tumour

95% isodose

Upper Rectal Tumour



Anal Cancer

Epidemiology

- 1-2% of large bowel cancers
- Peak age 50-60yrs
- Anal canal commoner in women
- Anal verge commoner in men
- Associated with HPV/HIV infection

Invasive Cancer

- Tumours originate near mucocutaneous junction and grow up into rectum or down into perineal tissue
- Squamous cell > transitional cell > adenocarcinoma
- Melanoma/BCC rare

Spread - lymphatic

- Upper lymphatics of anus communicate with rectum that lead to presacral/int+ext iliac nodes → para-aortics

  Lower lymphatics lead to perineum then superficial inguinal nodes.

  14% LN+ at presentation

  30% LN+ if tumour >5cm

Management

Small (<2cm) low grade N0 tumours of the anal verge: simple excision with 1cm margin (80% cure)

Can be re-excised if recurs

Controversial

Management (≥T2 N0)

Resection of the anorectum – 55% 5 year survival overall (now generally reserved for Salvage ie local relapse/persistence following chemoRT)

or

Chemoradiation achieves comparable figures, but with sphincter preservation

Radiotherapy Technique

Informed Consent

Bladder full

CT simulation

Supine

Lateral and anterior or posterior tattoos

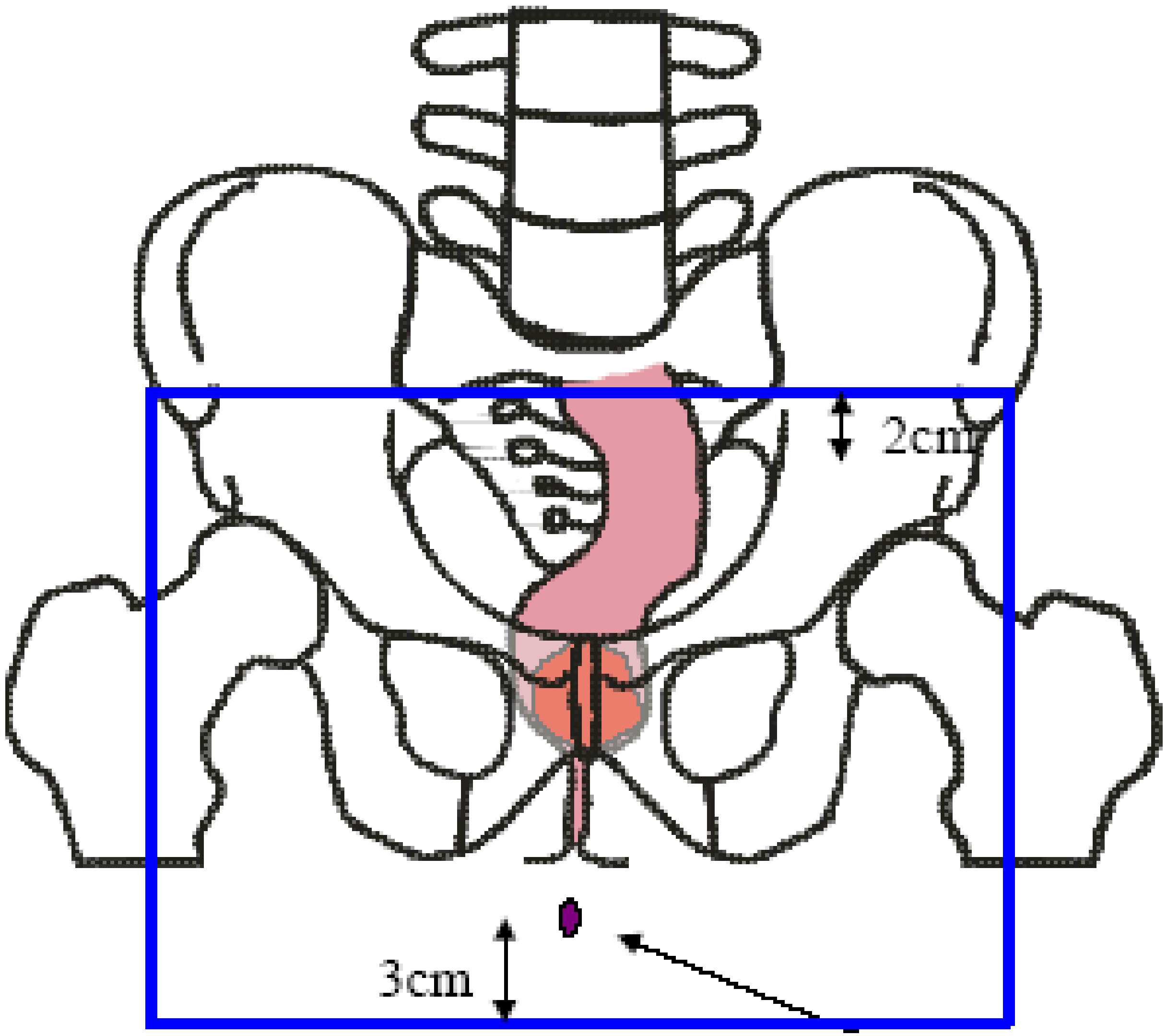
Target Volume Definition

<u>Phase I</u>

GTV	Primary tumour + involved LN
CTV	GTV +2.5-3cm margin + (at risk LN) ext/int/pre-sacral/mesorectal (up to mid SIJ)
PTV	CTV +8-10mm

Dose: 30.6Gy/17#/3.5 weeks. 6-15MV photons

Phase I



Target Volume Definition

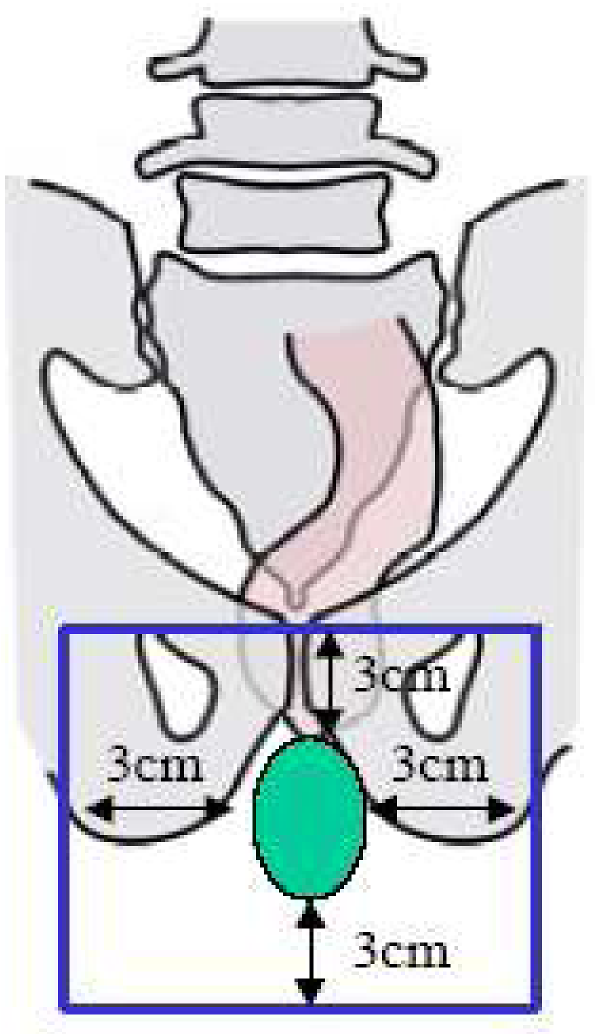
<u>Phase II</u>

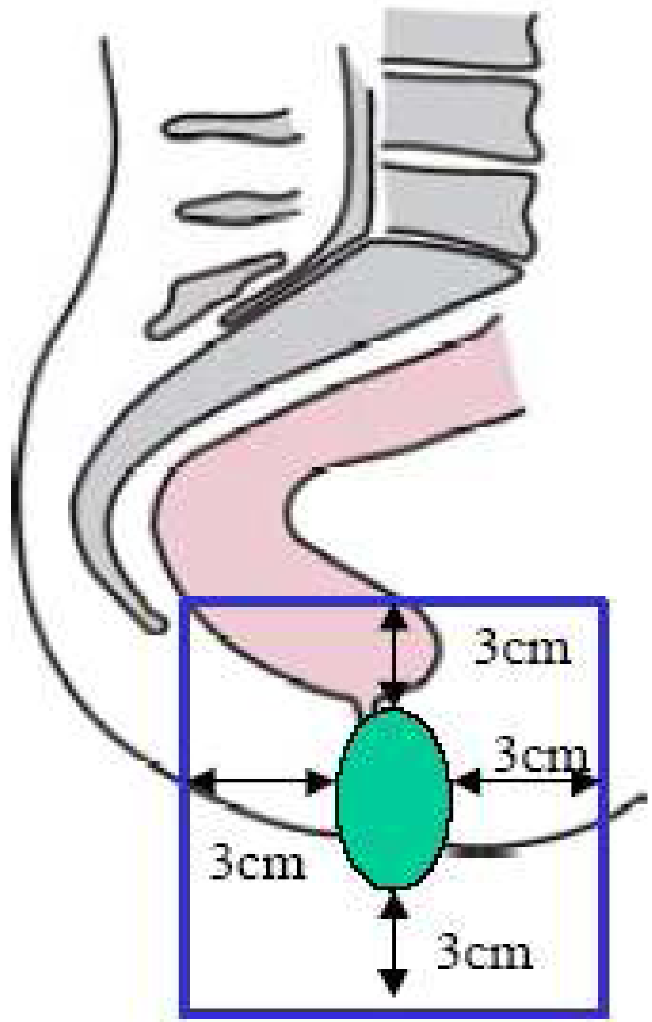
GTV	Primary tumour + involved LN
CTV	GTV +2cm margin
PTV	CTV +8-10mm

Dose: 19.8Gy/11#/2.5 weeks

6-15MV photons +/- electrons (for involved inguinal LN)

Phase II



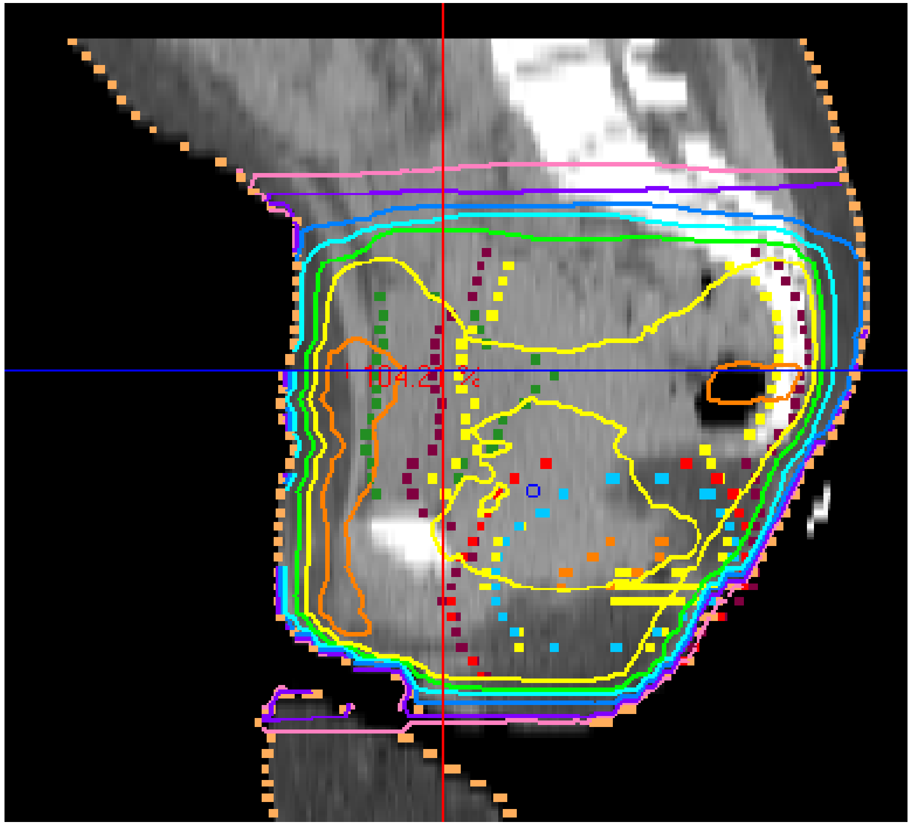


More Advanced Cancers

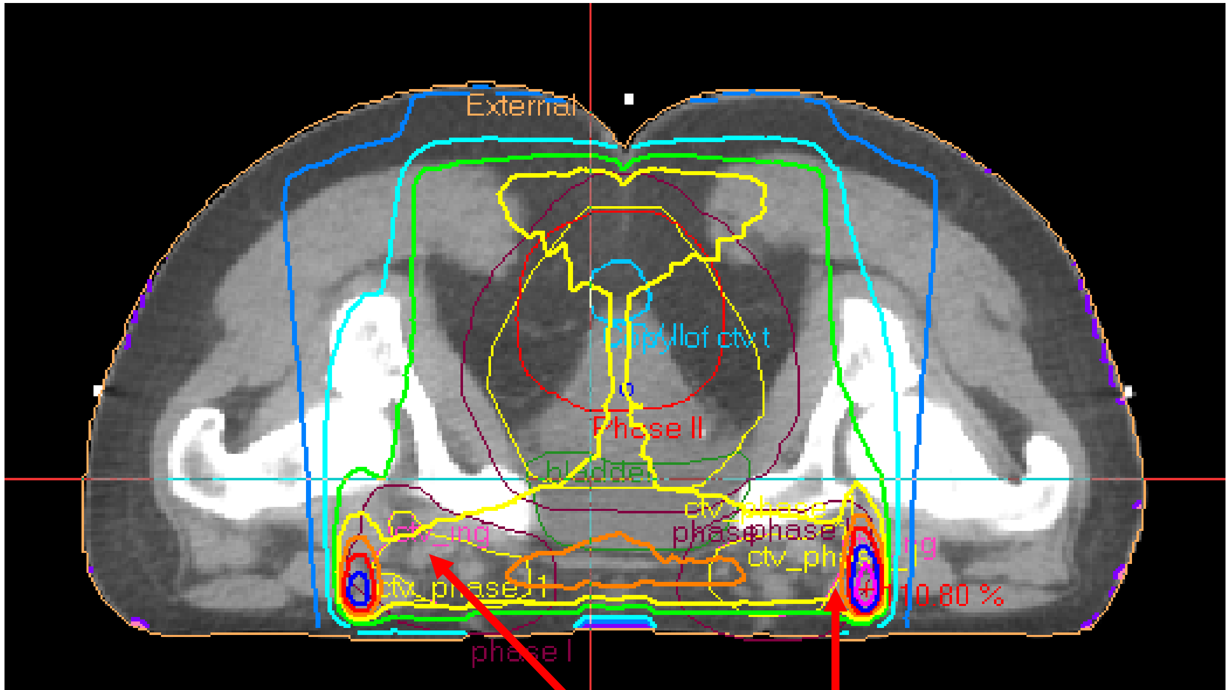
For T3/4 tumours and/or patients with node positive bulky disease, consider alternative fractionation

Phase I: 45Gy/25#/5wks

Phase II: 9Gy/5#/1wks

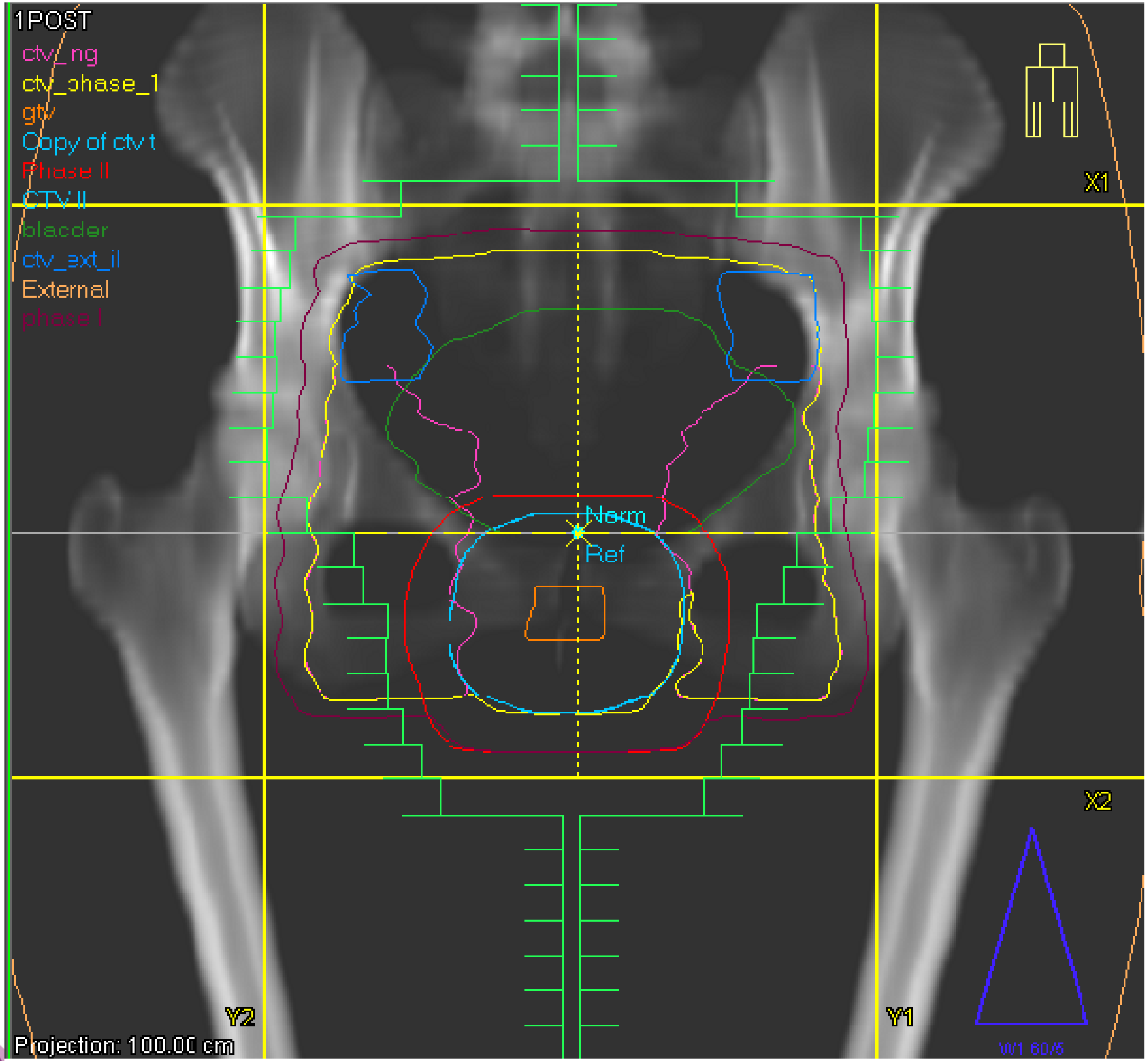


Sagittal Phase I

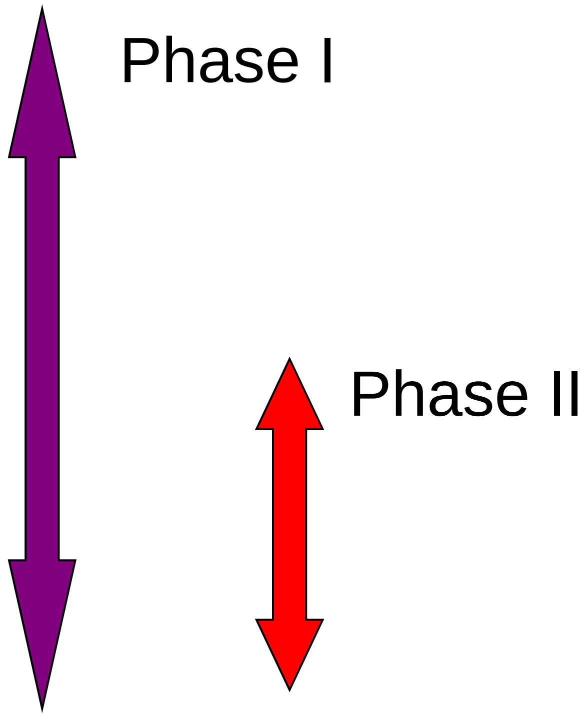


Axial Phase I

Inguinal LN



DRR Posterior Field



Toxicity - Early

Diarrhoea, anaemia, rectal discomfort, fatigue, urinary frequency, dysuria, erythema, dry/moist desquamation, renal impairment, bone marrow suppression

- most of these are self-limiting but may be enhanced by coexisting conditions

  eg inflammatory bowel disease, diabetes

Female Pelvic RT Toxicity - Late

Menopause (within 4 months) in premenopausal

Uterus unable to carry foetus to term

30% vaginal stenosis/dyspareunia

10% proctitis/cystitis

5-10% pelvic insufficiency fractures

2-8% small bowel damage

2-5% femoral neck fractures (↑in elderly)

1-2% fistulae

Ureteric stenosis and lumbosacral plexopathy rare

Male Pelvic RT Toxicity - Late

Infertility (scatter dose to testis)

10% proctitis/cystitis

5-10% pelvic insufficiency fractures

2-8% small bowel damage

2-5% femoral neck fractures (↑in elderly)

1-2% fistulae

Ureteric stenosis and lumbosacral plexopathy rare

Summary

- Radiotherapy part of curative treatment of many pelvic cancers
  - Pre-operative
  - Post-operative
  - Alone/Definitive
  - +/- concurrent chemotherapy

- GTV/CTV dependent on site of primary

- PTV institutional variation
  inter/intra-fraction organ motion

Treatment Planning for Pelvic Cancers

Thank you

Treatment Considerations for Prostate Cancer

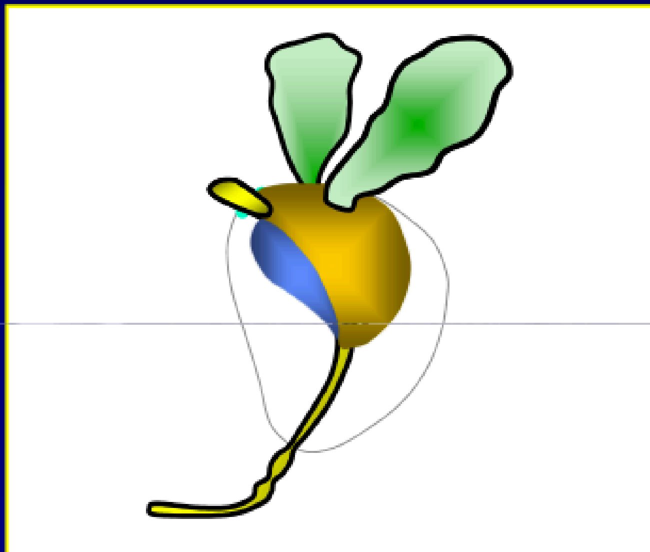
Dr Paul Kelly
Cork University Hospital

Outline

- Prostate Anatomy
- Organs at Risk
- Patient setup
- Delineation uncertainties
- Bowel and bladder motion
- IGRT

Zonal Anatomy

Central Gland

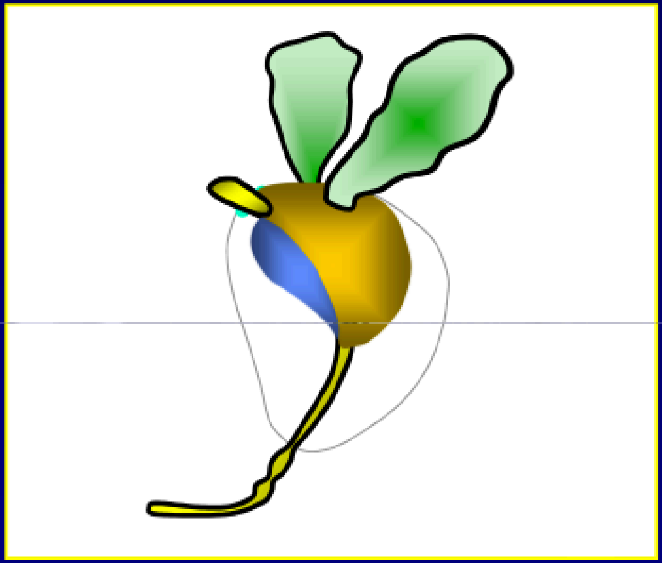


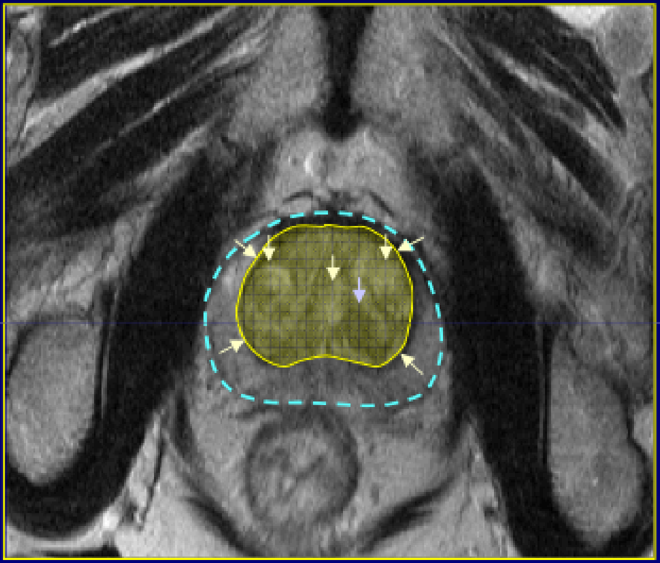
Periurethral Glands +
Transition Zone +
Central Zone =
CENTRAL GLAND

MR

Zonal Anatomy

Central Gland



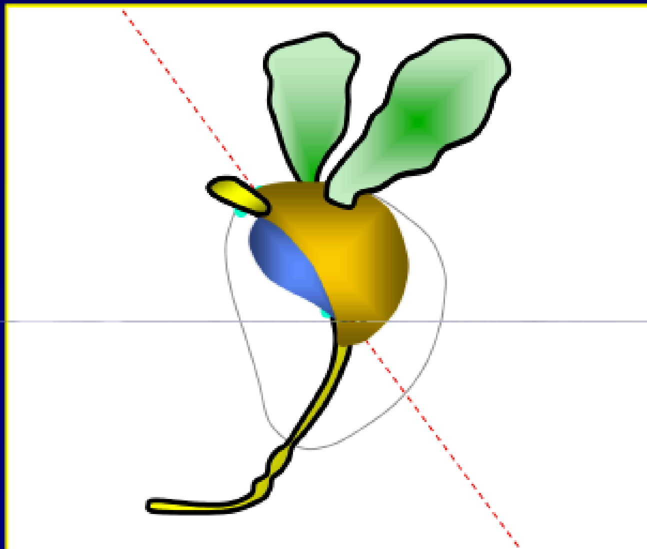


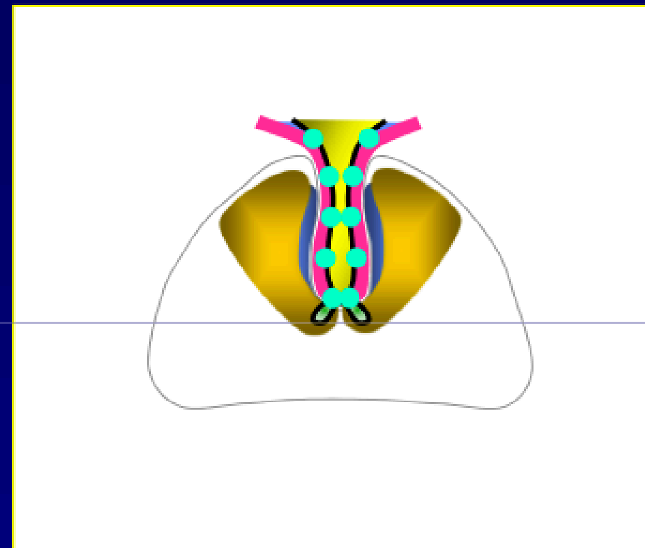
Periurethral Glands +
Transition Zone +
Central Zone =
CENTRAL GLAND

MR

Zonal Anatomy

Central Gland



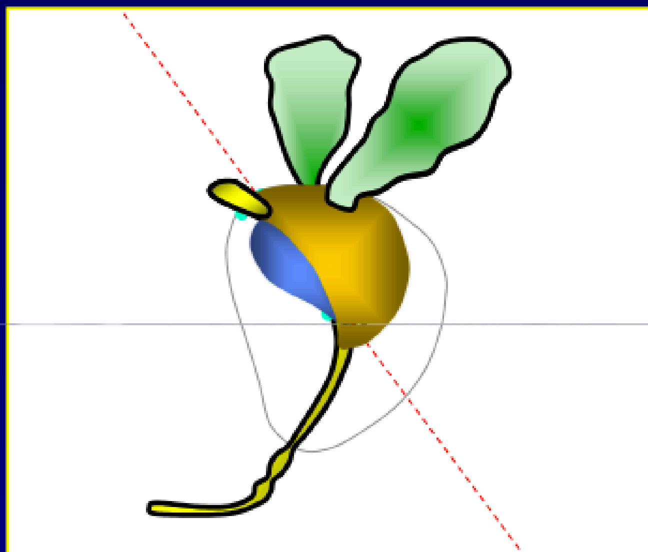


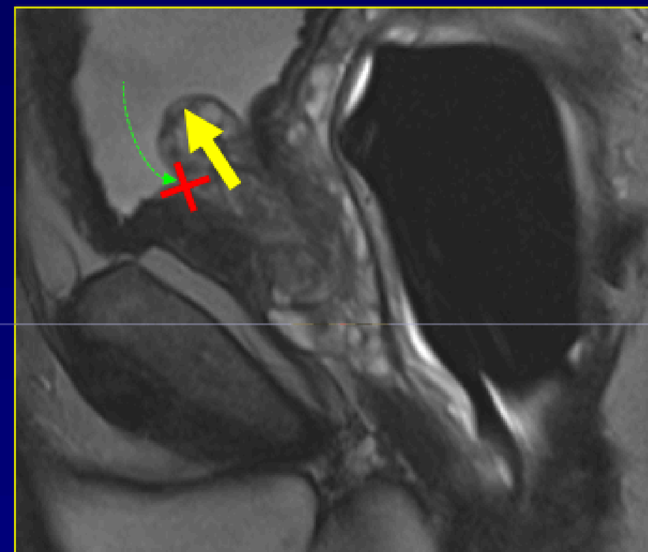
Central Gland

Hypertrophied
Periurethral Glands

Zonal Anatomy

Central Gland



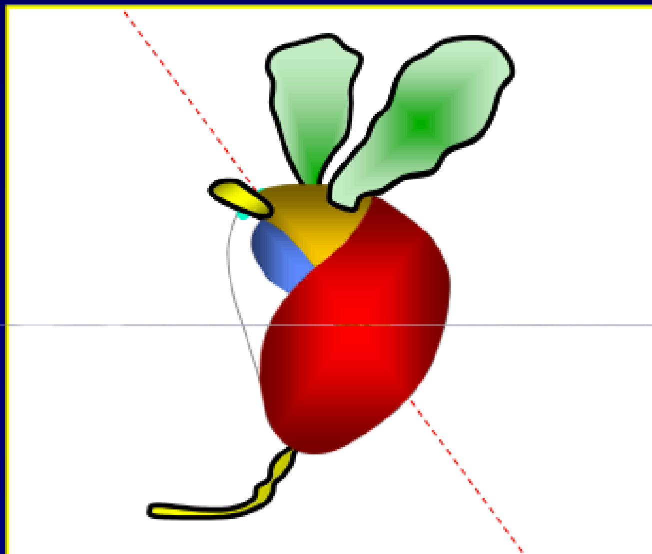


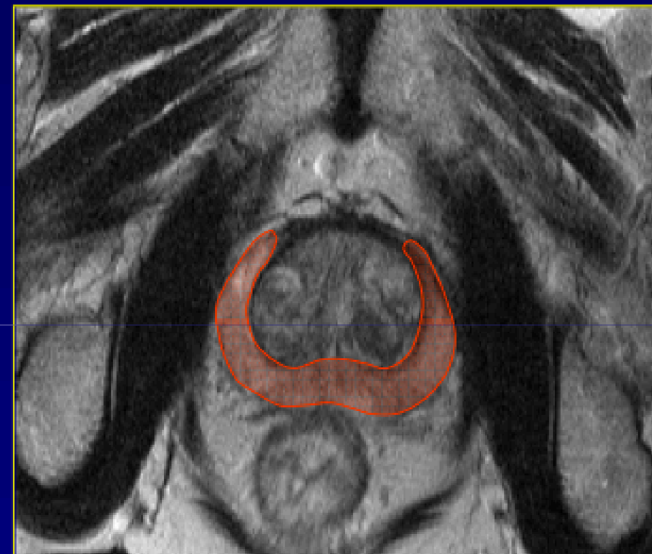
Central Gland

Median Lobe Hyperplasia

Zonal Anatomy

Overview



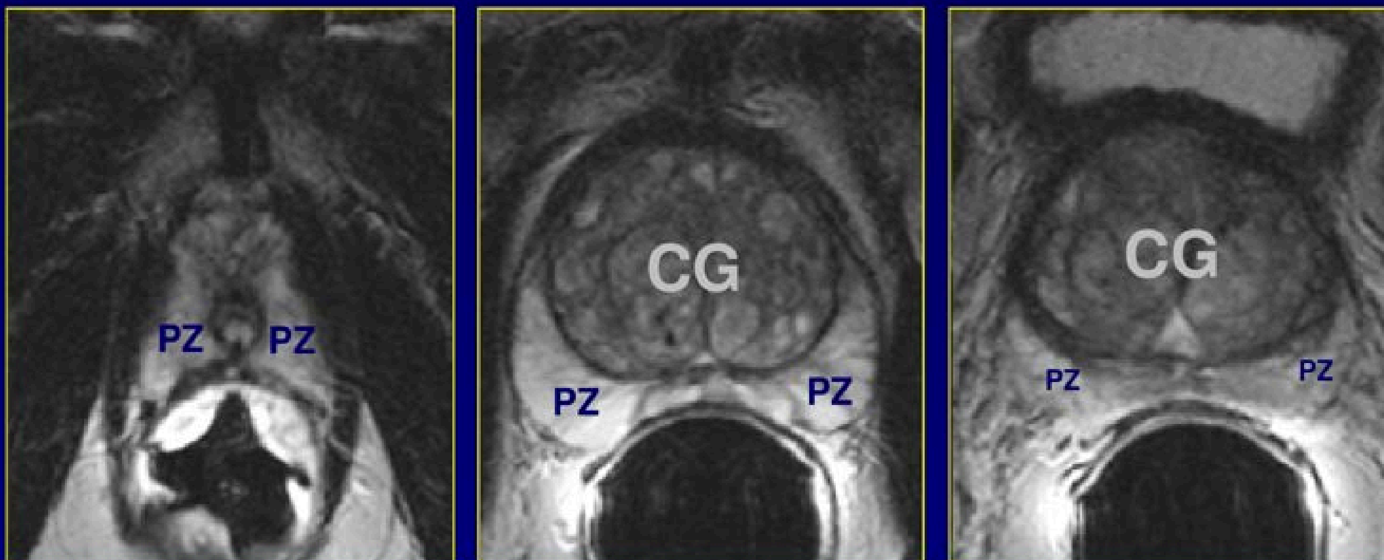


Central Gland

Peripheral Zone

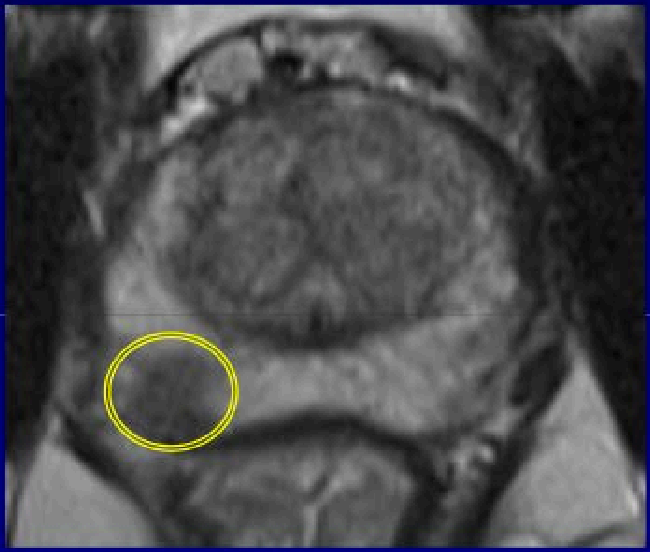
Anatomy

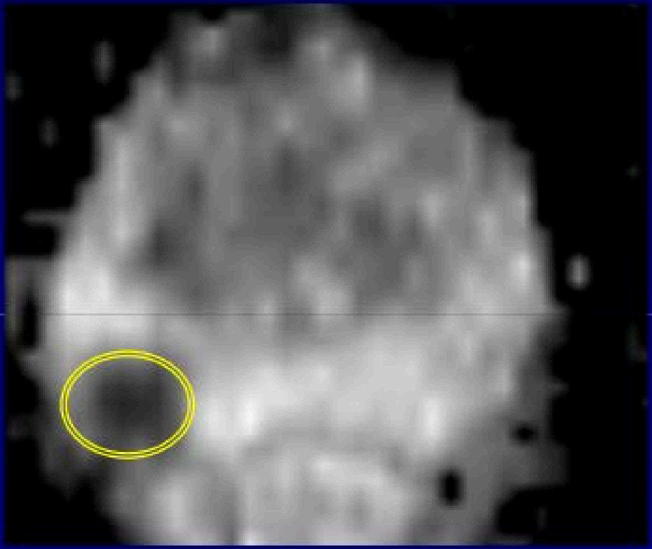
Prostate



Prostatic Apex	Midprostate	Prostatic Base

Diffusion Weighted Imaging





Low T2 signal in PZ

ADC 64

References

- Myers – *Anatomy of radical prostatectomy as defined by MRI* – **J Urol 1998;159:2148**
- McNeal – *Zonal distribution of prostate adenocarcinoma* – **Am J Surg Pathol 1988;12:897**
- Villeirs – *Magnetic resonance anatomy of the prostate and periprostatic area: a guide for radiotherapists* – **Radiother Oncol 2005;76:99**

ESTRO School

Prostatic Function
Summary

- Maximization of fertility
  - Dilution of sperm
  - Energy provision to spermatozoa
  - Maintenance of spermatozoa in a reversibly quiescent state

ESTRO School

Organs at Risk

- Bone – Femoral heads, Pelvis
- Bowel – Rectum, Sigmoid Colon, Small Bowel
- Bladder
- Penile bulb

Computed Tomography

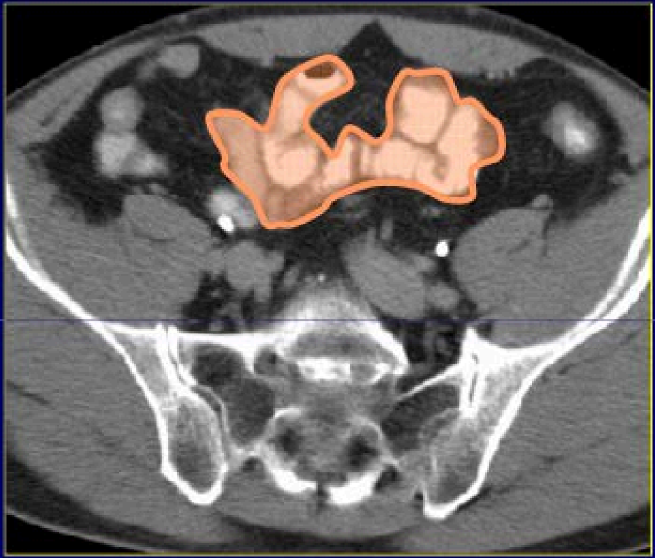
Bony Pelvis

Bony Pelvis (sacrum)

Bony Pelvis (ischium)

Computed Tomography

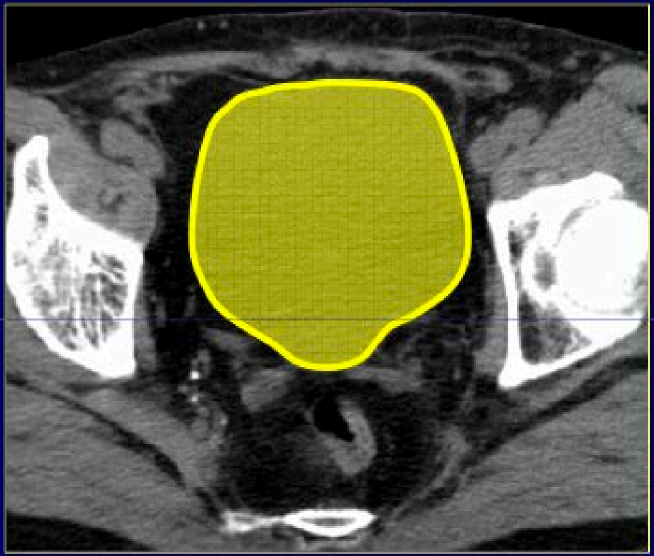
Bowel

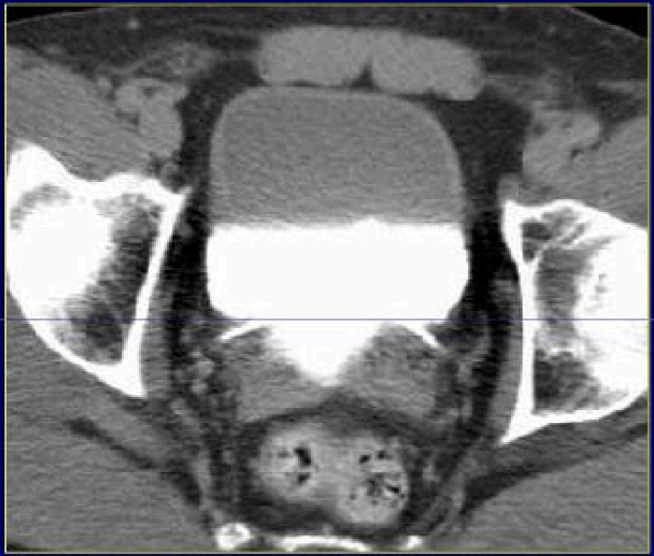


Small bowel loops

Sigmoid colon

Computed Tomography
Bladder and Ureters

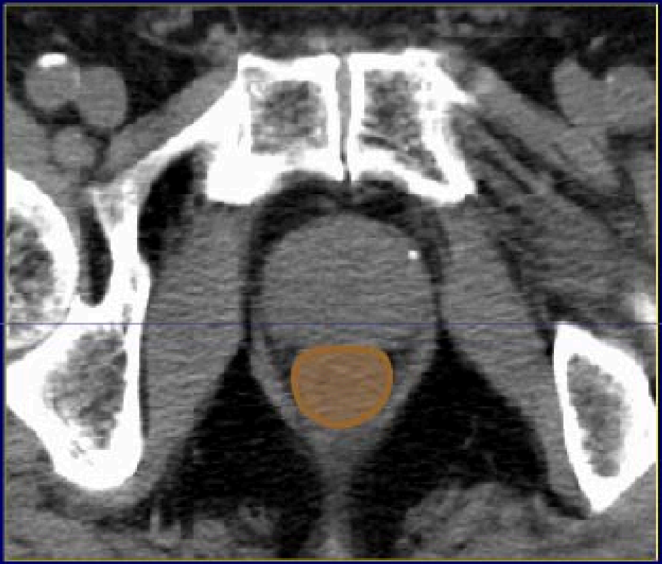


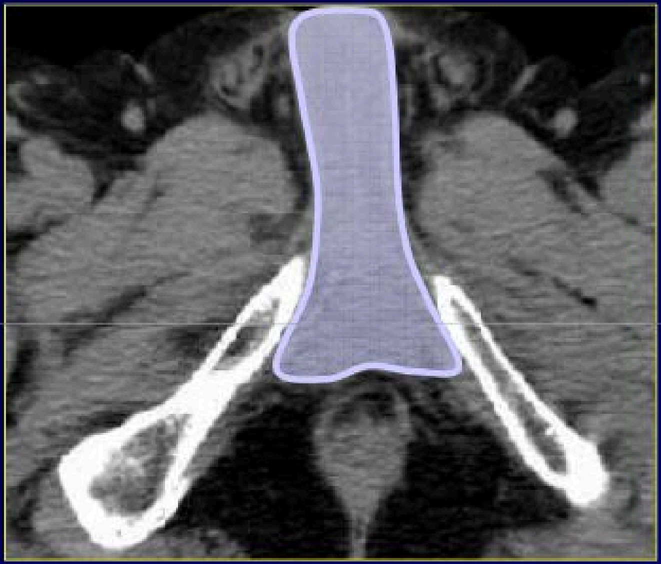


Bladder

Ureters

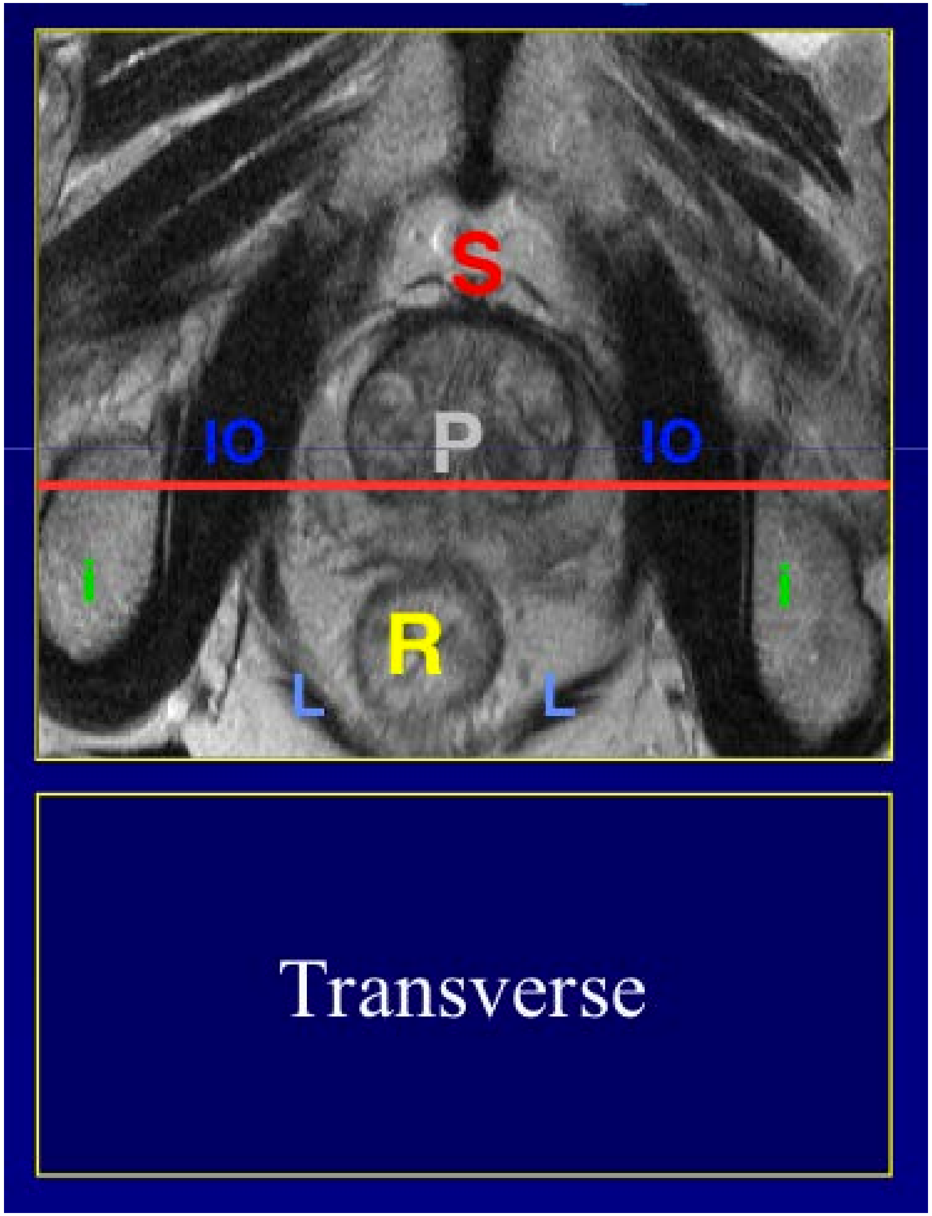
Computed Tomography
Rectum and Penis





Rectum

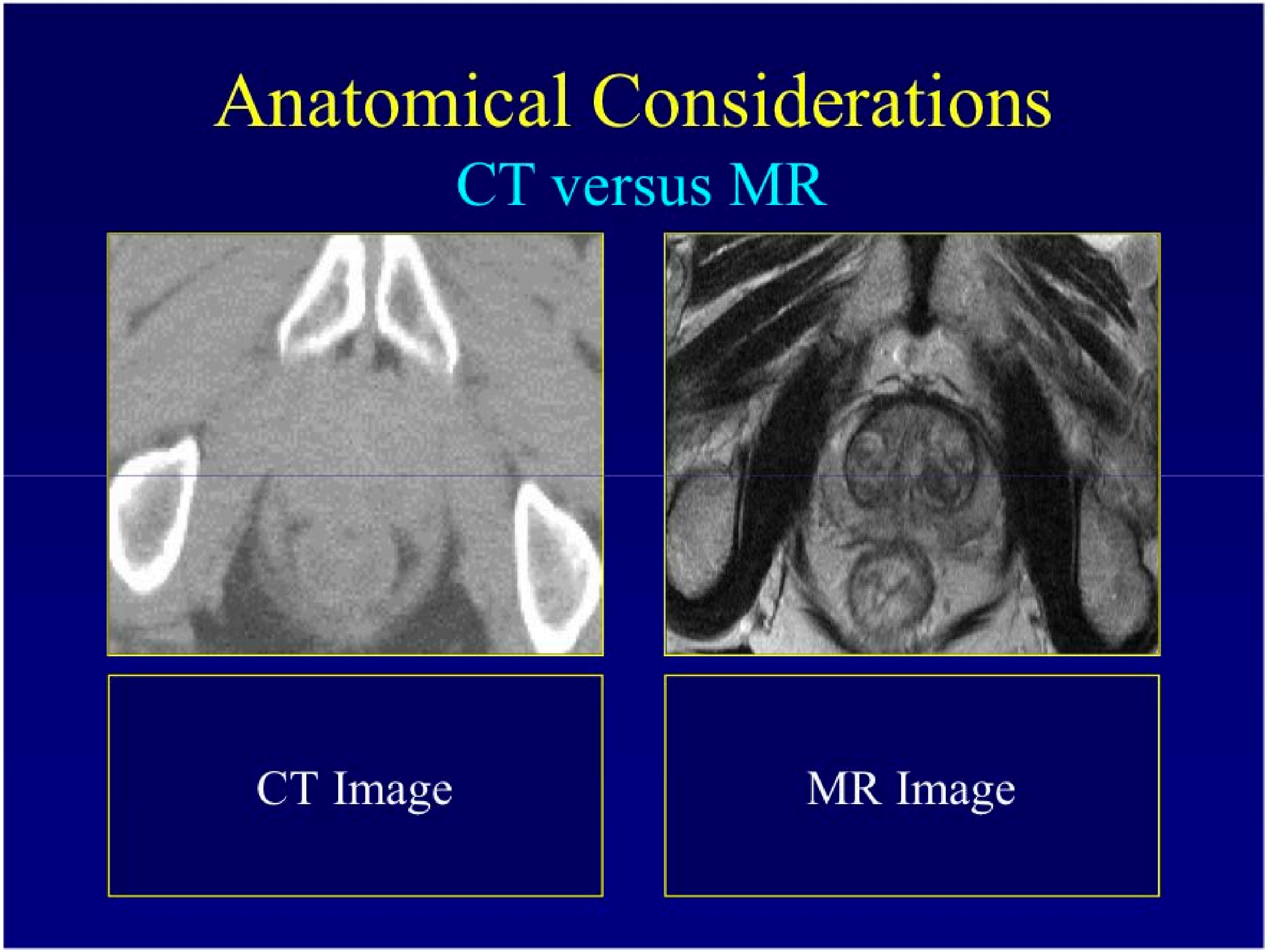
Penis and penile bulb



S	Symphysis
IO	Obturator Internus muscle
P	Prostate
R	Rectum
L	Levator ani muscle
i	Ischium

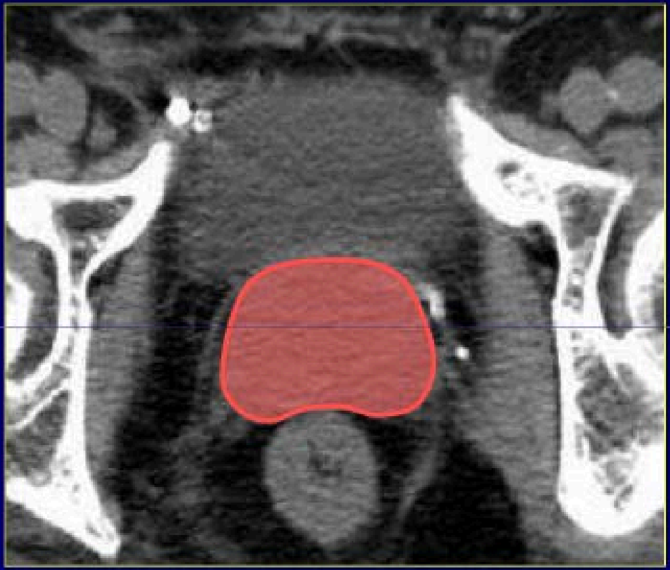
Patient Immobilisation

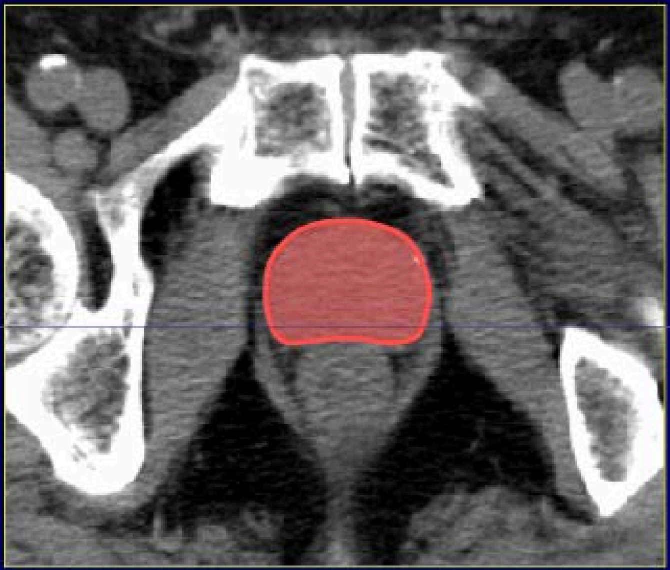
Delineations



Computed Tomography

Prostate



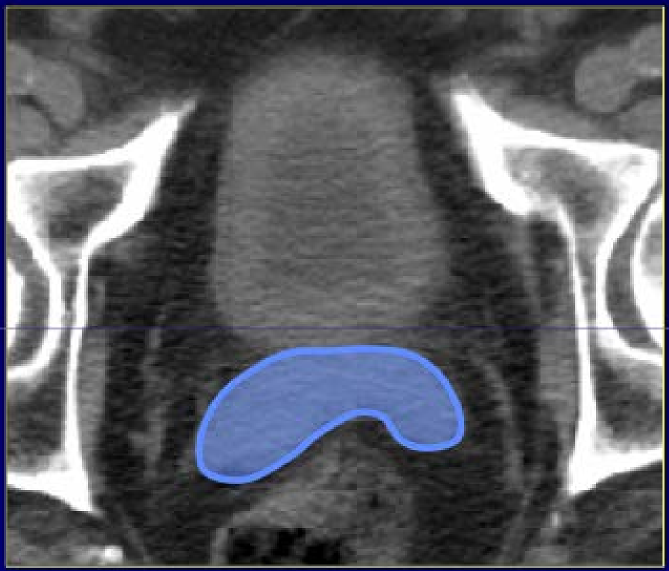


Prostate Gland
(Base)

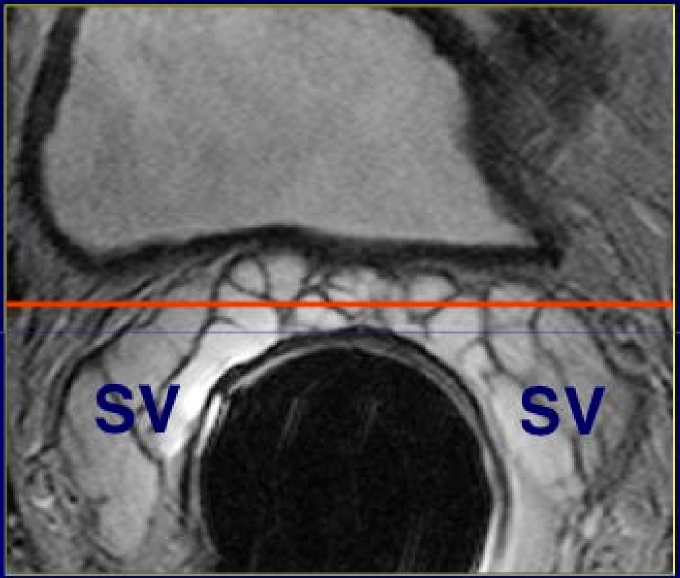
Prostate Gland
(Midprostate)

Variation in Contouring

Delineations



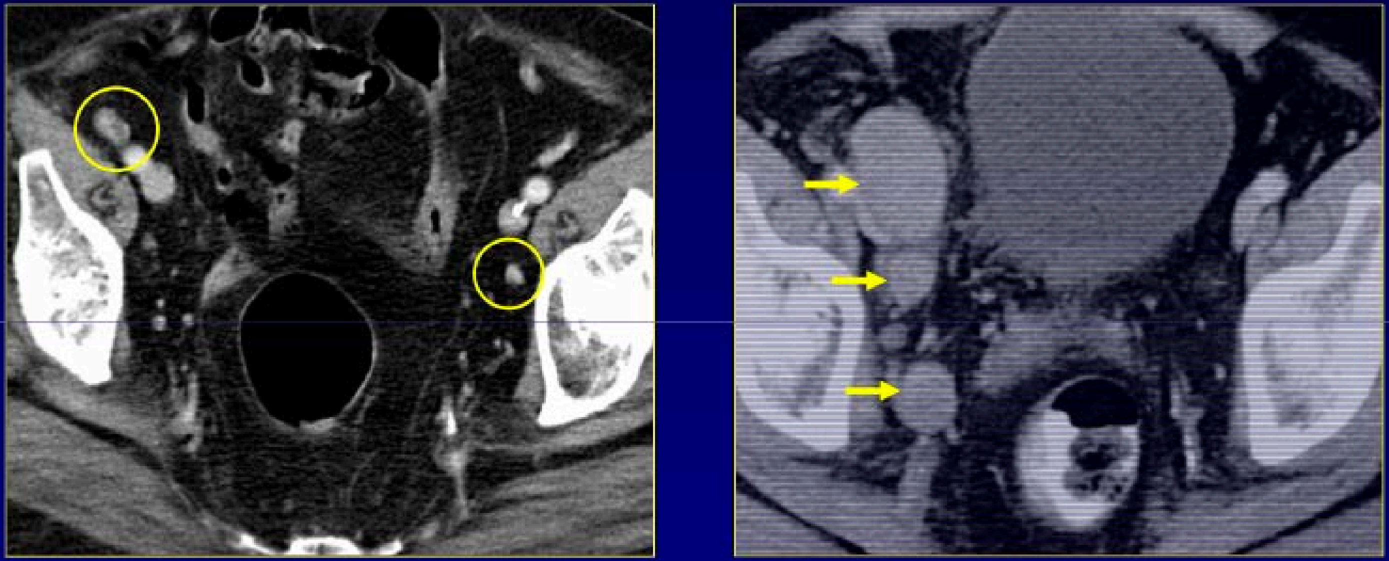
Seminal Vesicles



Transverse

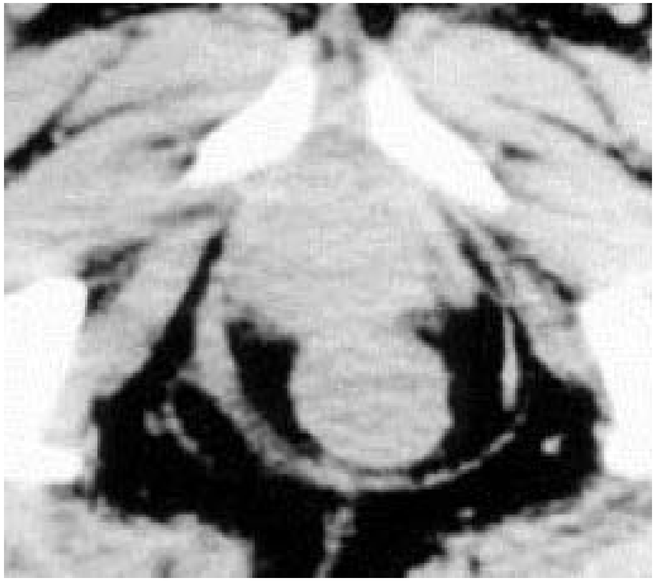
Computed Tomography

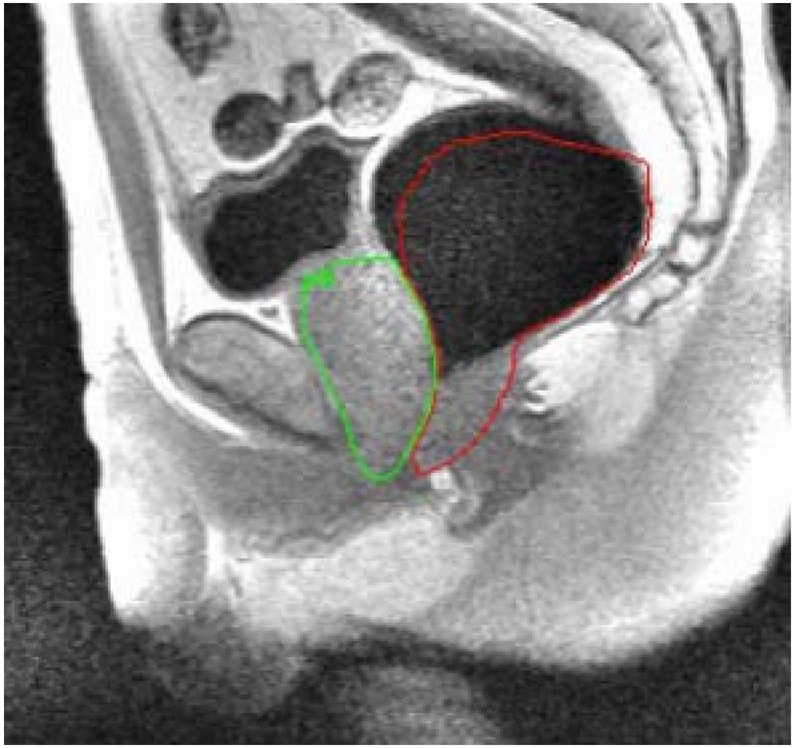
Lymph nodes

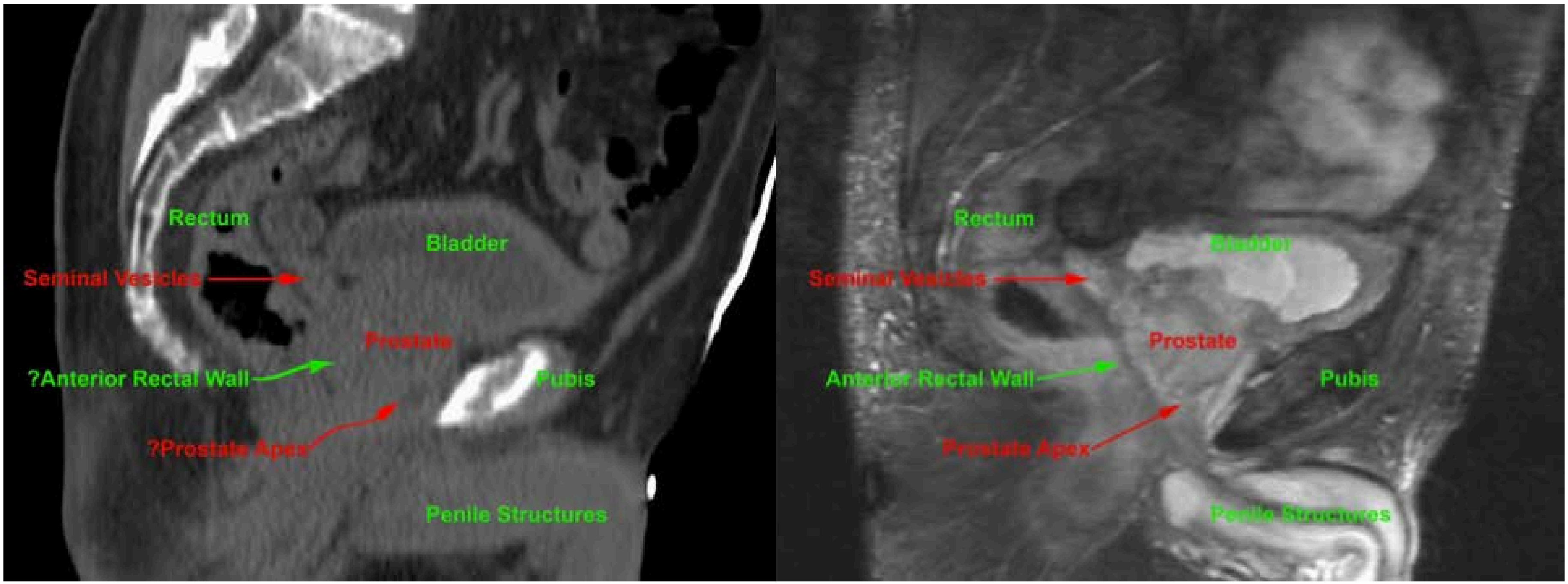


Lymph Node Staging
Oval node > 10 mm
Round node > 8 mm

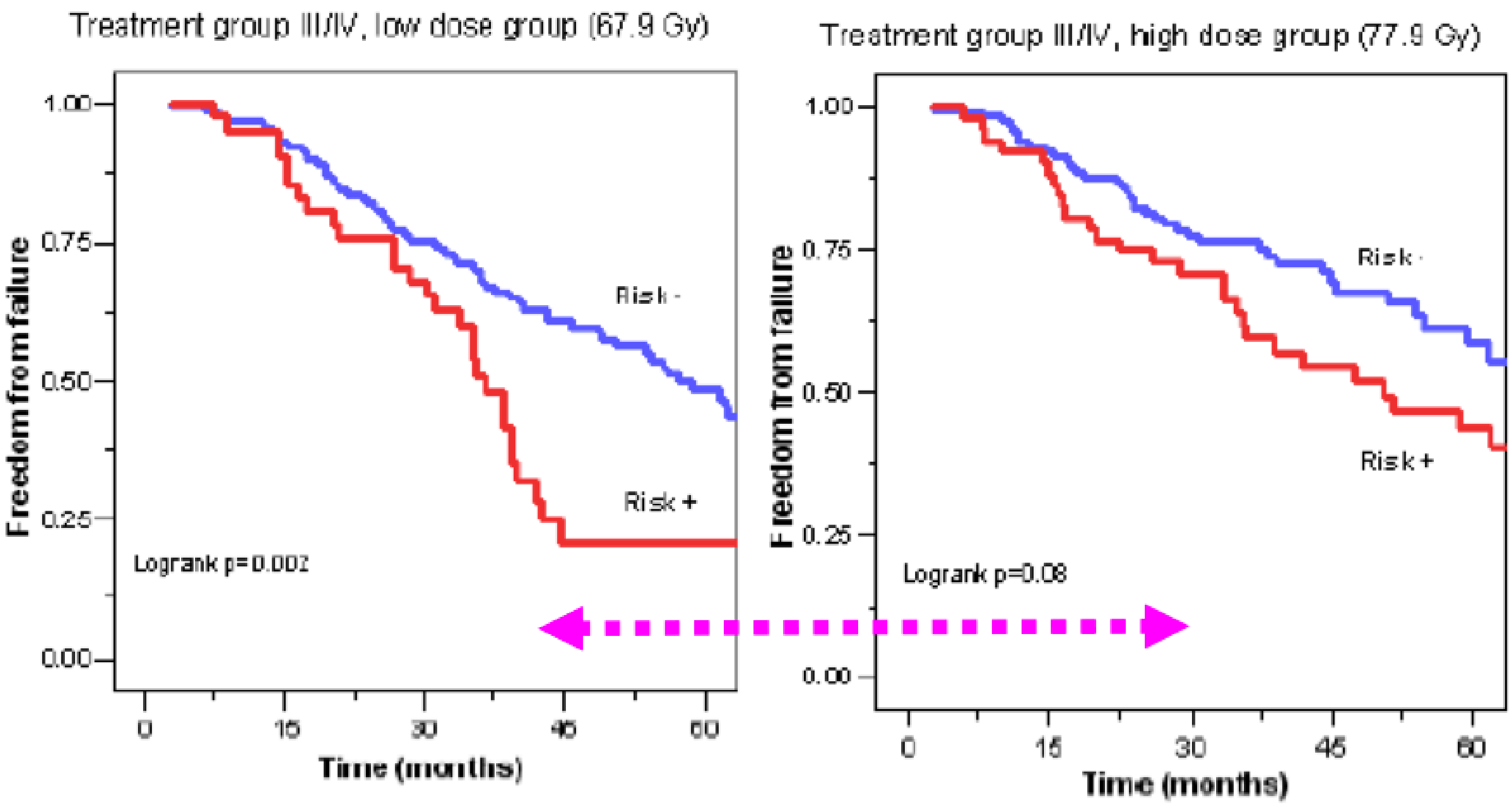
Organ Motion



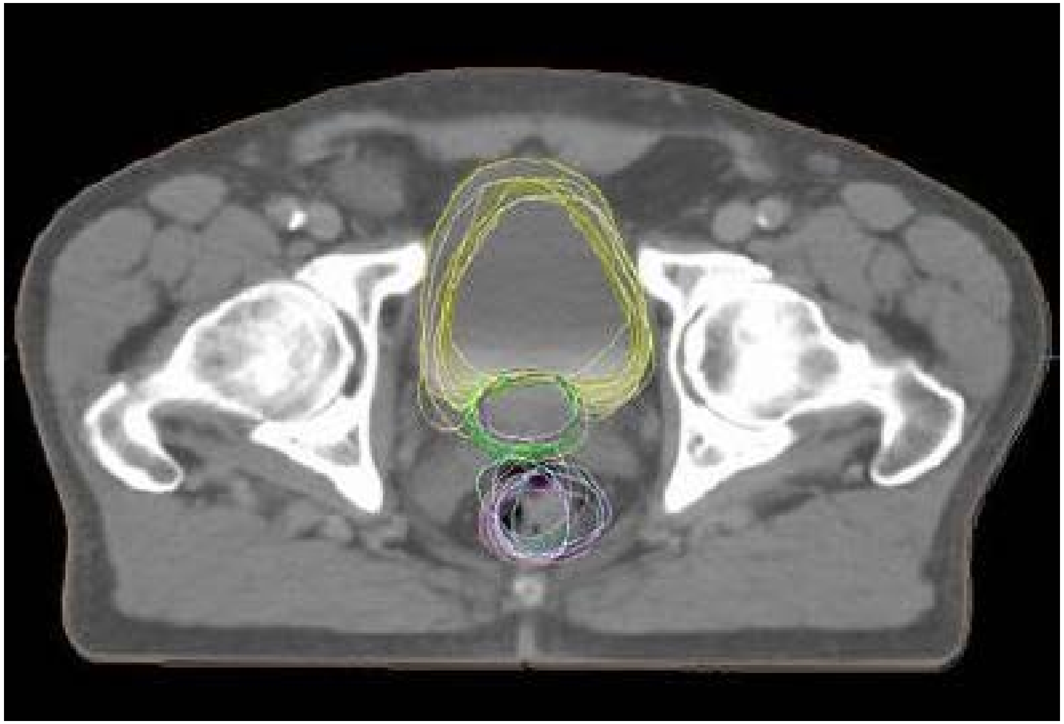



Rectum
Bladder
Seminal Vesicles
Prostate
?Anterior Rectal Wall
Pubis
?Prostate Apex
Penile Structures
Rectum
Bladder
Seminal Vesicles
Prostate
Anterior Rectal Wall
Pubis
Prostate Apex
Penile Structures

Impact of Rectal Distension



Heemsbergen et al IJROBP 2006



Strategies to address with Organ Motion

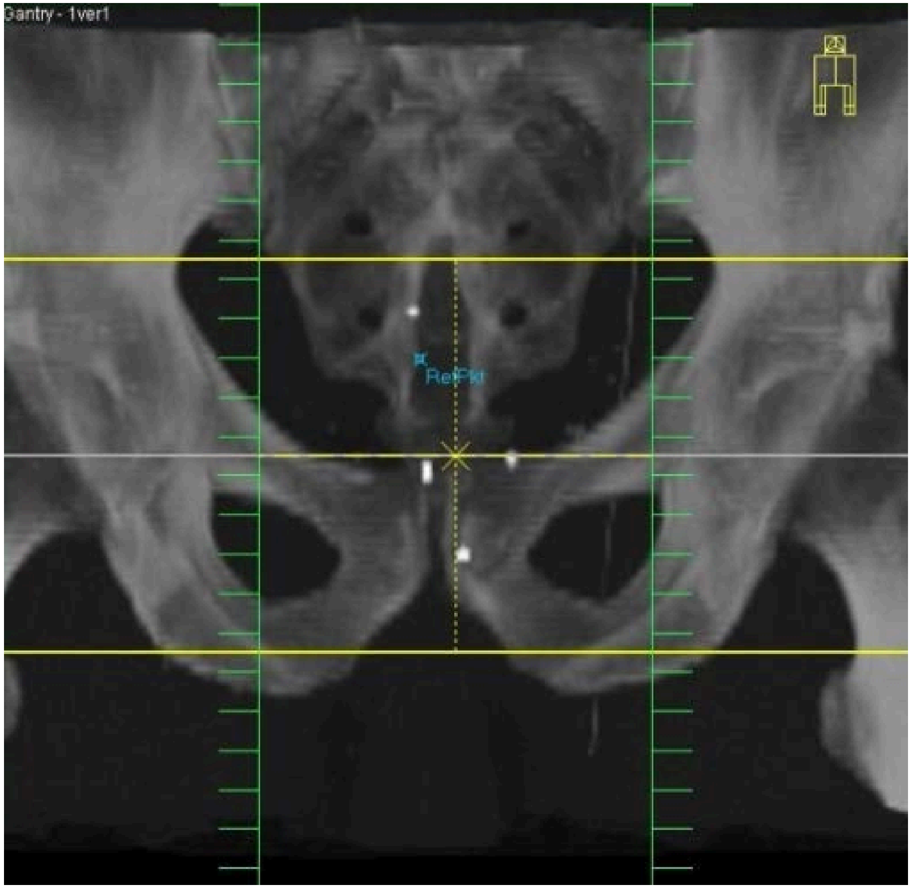
- Patient Preparation:
  - Immobilisation devices
  - Bladder Filling with consistent protocol
  - Rectal Emptying
    - Dietary advice
    - Laxative/Enema use
    - Rectal balloon

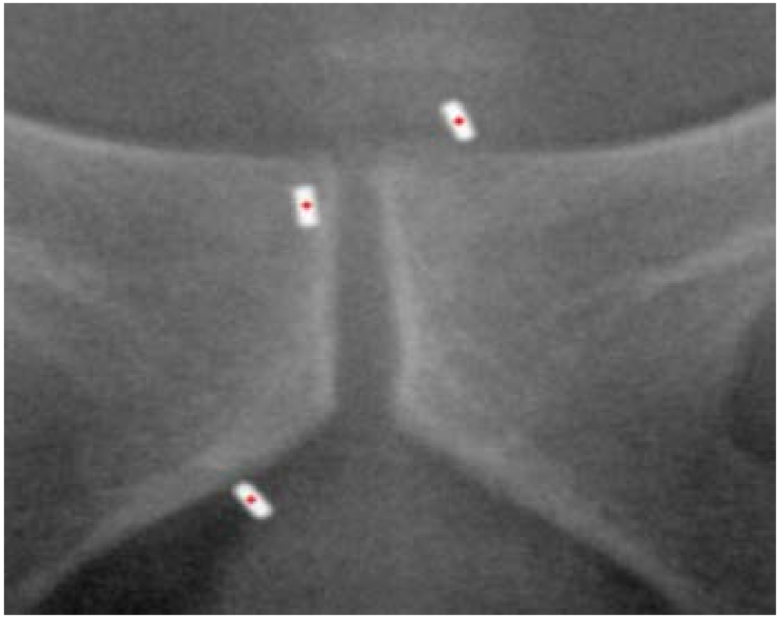
- PTV margins to account for CTV motion

- Image-Guided Radiotherapy:
  - Cone Beam CT
  - Fiducial Markers


200.0 mm
200.0 mm

Fiducial Markers





Take home message

- Planning CT is only a snapshot in time
- The prostate is constantly moving
- The bladder and rectum are distensible organs at various stages of filling

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Contouring Session 1: Pelvis

Danilo Pasini

Charles Gillham

Paul Kelly

Anatomical Definition: Rectum

- Anatomy and relations:
  - Fixed part of the large intestine, 12-15cms in length.
  - Begins anterior to the level of the third sacral vertebra
  - Continues superiorly to the sigmoid colon
  - Follows the curve of the sacrum and coccyx and ends 3-4cms anteroinferior to the tip of the coccyx
  - Inferiorly, rectum lies immediately posterior to the prostate in males and to the vagina in females
  - End of the rectum lies posterior to the apex of the prostate in the male

Anatomical Definition: Bladder

- Empty bladder lies almost entirely in the pelvic minor, superior to the pelvic floor and posterior to the pubic symphysis
- As the bladder fills, it moves into the pelvic major, a very full bladder can ascend to the level of the umbilicus
- The posteroinferior surface is called the fundus and is in close proximity to the anterior wall of the vagina in females and to the rectum in males

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Anatomical Definition: Bladder

- The anterior end is known as the apex of the bladder and points anteriorly towards the superior edge of the symphysis pubis
- The inferior aspect or ‘neck’ rests on the prostate in males

Contouring Guidelines

International Journal of Radiation Oncology biology • physics

www.redjournal.org

Clinical Investigation: Genitourinary Cancer

Pelvic Normal Tissue Contouring Guidelines for Radiation Therapy: A Radiation Therapy Oncology Group Consensus Panel Atlas

Hiram A. Gay, M.D.,[*] H. Joseph Barthold, M.D.,[†,‡] Elizabeth O'Meara, C.M.D.,[§]
Walter R. Bosch, D.Sc.,[*] Issam El Naqa, Ph.D.,[||] Rawan Al-Lozi, B.A.,[*]
Seth A. Rosenthal, M.D.,[¶] Colleen Lawton, M.D.,[**] W. Robert Lee, M.D.,[††]
Howard Sandler, M.D.,[‡‡] Anthony Zietman, M.D.,[§§] Robert Myerson, M.D., Ph.D.,[*]
Laura A. Dawson, M.D.,[||||] Christopher Willett, M.D.,[††] Lisa A. Kachnic, M.D.,[¶¶]
Anuja Jhingran, M.D.,[***] Lorraine Portelance, M.D.,[†††] Janice Ryu, M.D.,[¶]
William Small, Jr., M.D.,[‡‡‡] David Gaffney, M.D., Ph.D.,[§§§]
Akila N. Viswanathan, M.D., M.P.H.,[||||||] and Jeff M. Michalski, M.D.[*]

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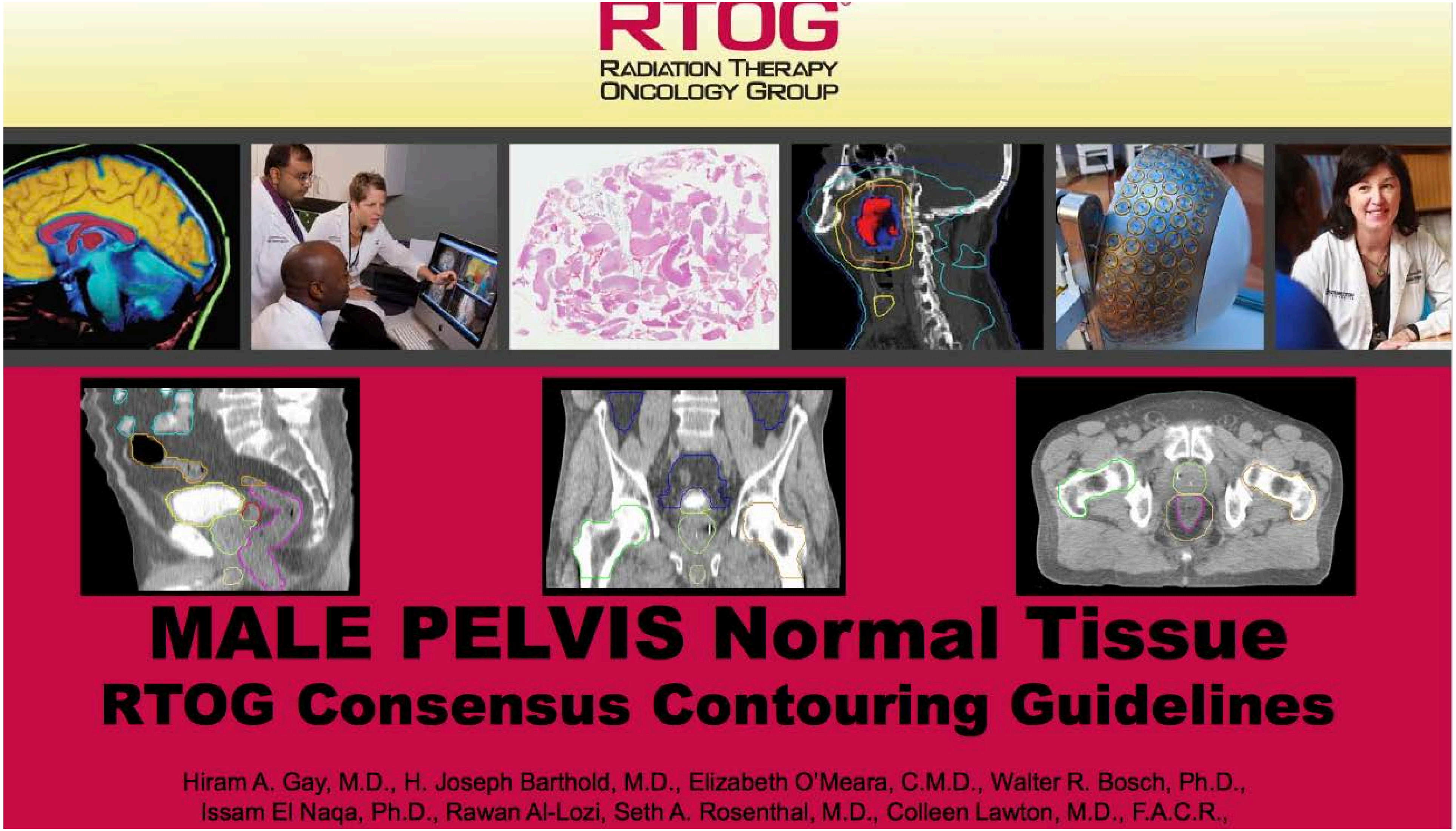
Contouring Guidelines and Atlas



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RTOG Guidelines: Rectum

GU

Organ	Standardized TPS Name	Tumor Category	Consensus Definition
rectum	`Rectum`	GU	Inferiorly from the lowest level of the ischial tuberosities (right or left). Contouring ends superiorly before the rectum loses its round shape in the axial plane and connects anteriorly with the sigmoid. The Rectum is used with the BowelBag.
bowel bag	`BowelBag`	GU	* Inferiorly from the most inferior small or large bowel loop, or above the Rectum (GU) or AnoRectum (GYN), whichever is most inferior. If when following the bowel loop rule the Rectum or AnoRectum is present in that axial slice, it should be included as part of the bag; otherwise it should be excluded. Tips: Contour the abdominal contents excluding muscle and bones. Contour every other slice when the contour is not changing rapidly, and interpolate and edit as necessary. Finally, subtract any overlapping non-GI normal structures. If the TPS does not allow subtraction leave as is.

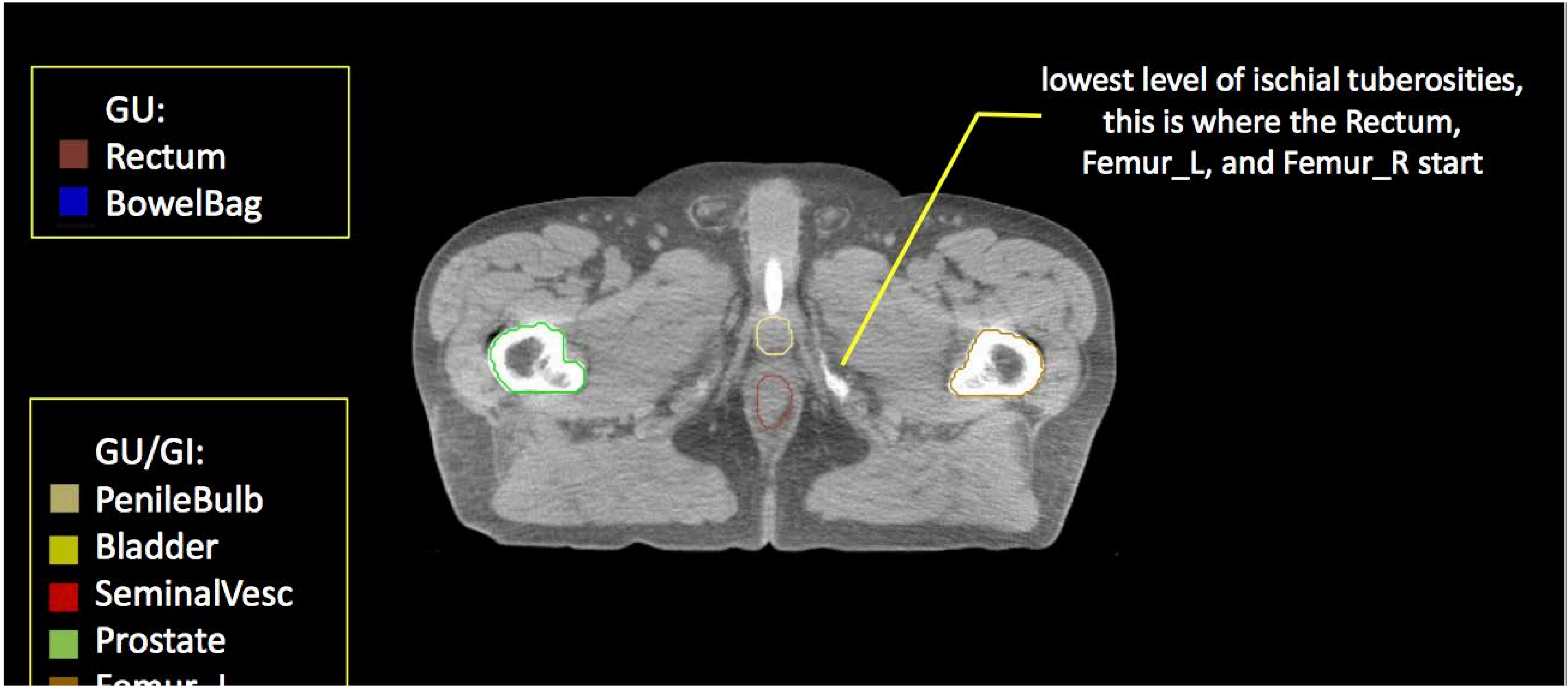
*Stop contouring the BowelBag, SmallBowel, and Colon 1 cm above PTV for most coplanar beam plans, but the choice will depend on the treatment technique. Stop these PTVs at distances much greater than 1 cm for non-coplanar beam plans depending on the beam angle and path. Tomotherapy plans will require stopping from 1 to 5 cm above the PTV, depending on the selected field size, which is often 2.5 cm.

RTOG guidelines: Bladder

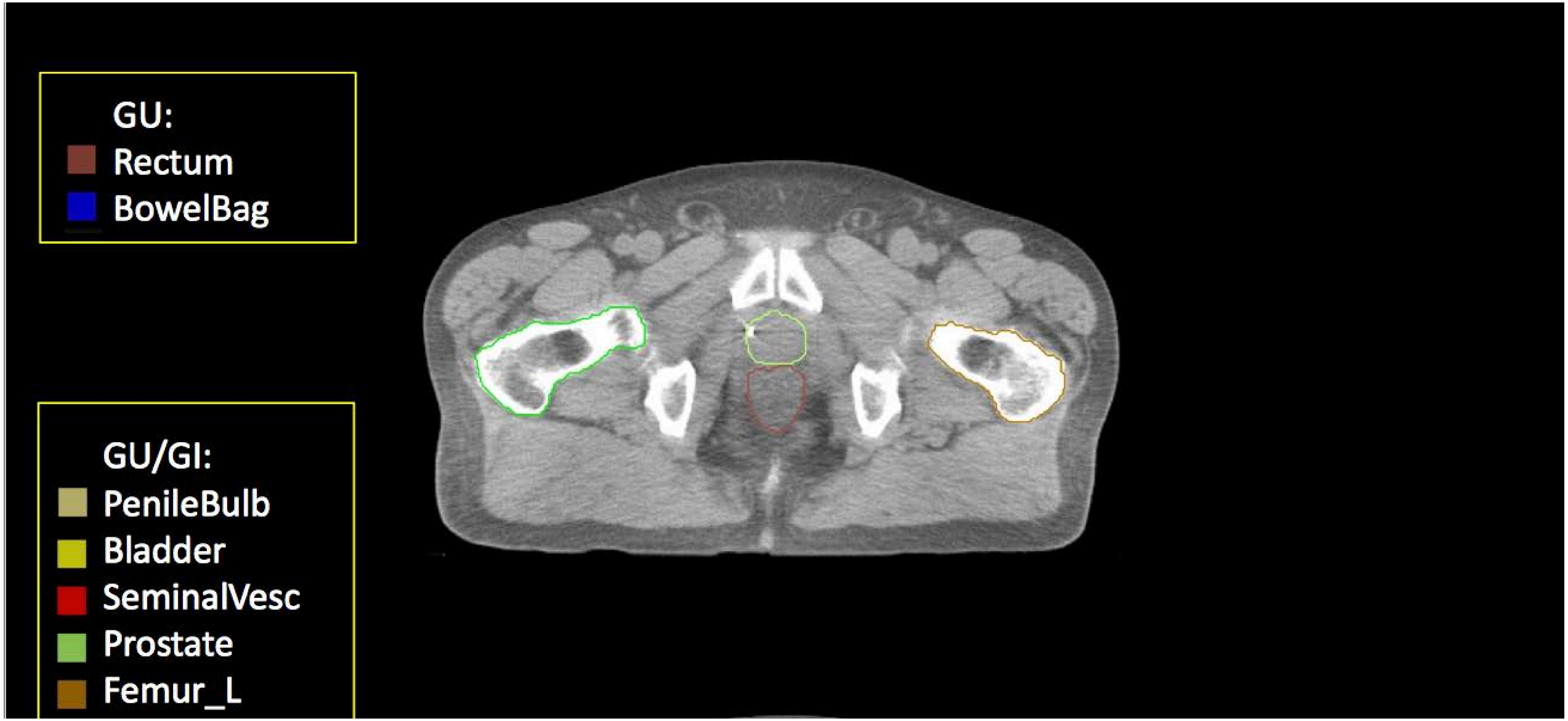
GU / GI

Organ	Standardized TPS Name	Tumor Category	Consensus Definition
bladder	`Bladder`	GU, GI	Inferiorly from its base, and superiorly to the dome

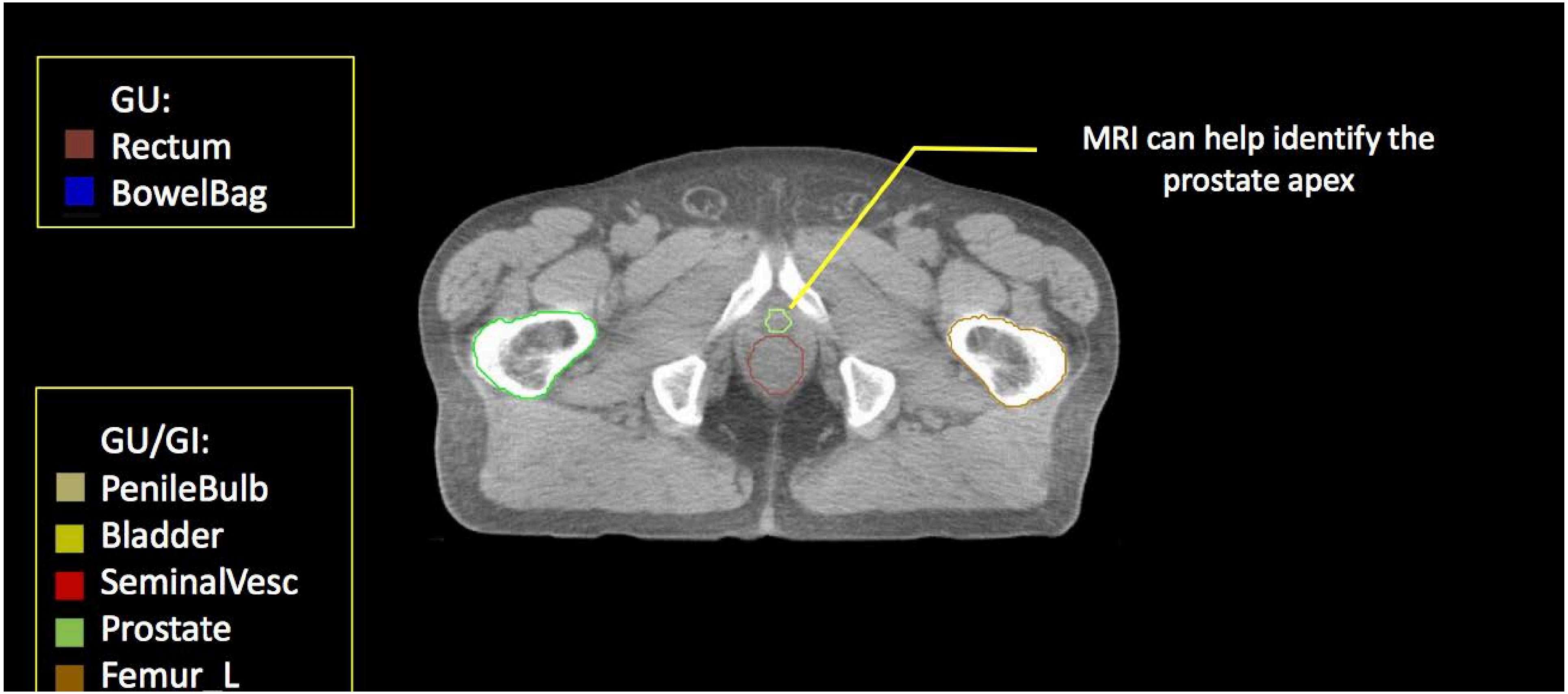
Start of rectum



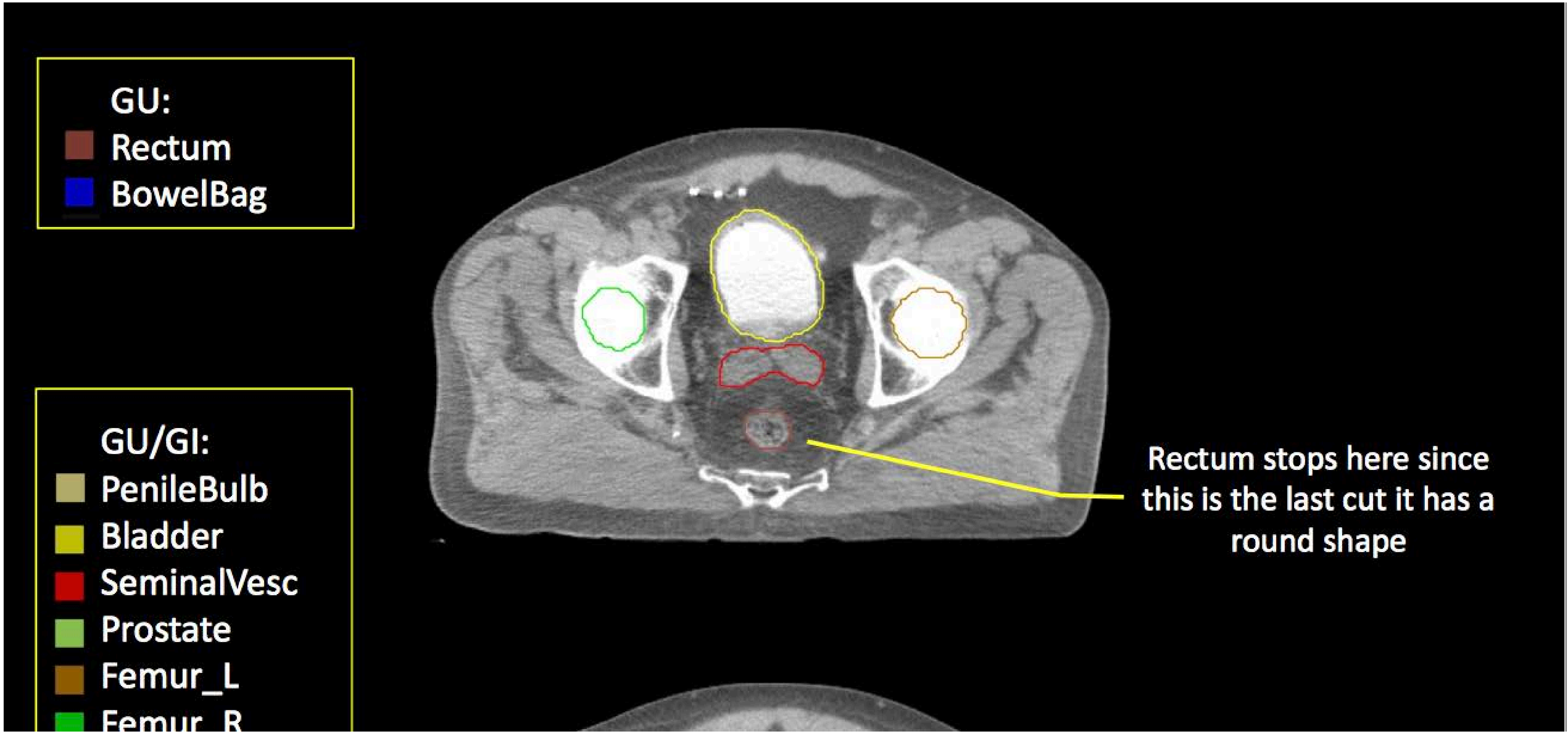
Rectum


GU:
Rectum
BowelBag
GU/GI:
PenileBulb
Bladder
SeminalVesc
Prostate
Femur_L

Prostate Apex

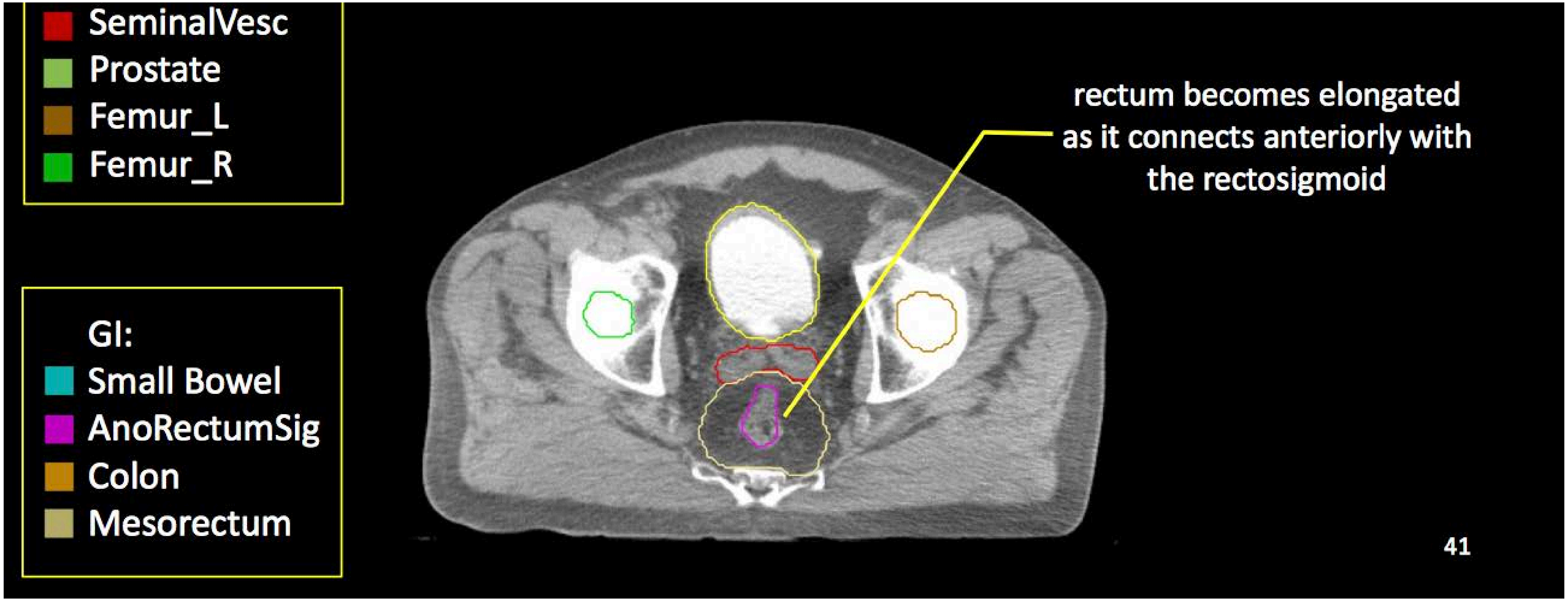


Rectum



GU:
Rectum
BowelBag
GU/GI:
PenileBulb
Bladder
SeminalVesc
Prostate
Femur_L
Femur_R
Rectum stops here since this is the last cut it has a round shape

Rectum



SeminalVesc
Prostate
Femur_L
Femur_R
GI:
Small Bowel
AnoRectumSig
Colon
Mesorectum
rectum becomes elongated as it connects anteriorly with the rectosigmoid
41

QUANTEC Segmentation Rectum

- The rectum should be segmented from above the anal verge to the turn into the sigmoid colon (this anterior inflection is best appreciated on saggital CT). including the rectal contents.
  - Although there can be variation in defining these landmarks, the superior limit is where the bowel moves anteriorly, close to the inferior level of the sacroiliac joints, and the inferior limit is commonly at the bottom of the ischial tuberosities.

QUANTEC Papers

- Michalski JM, Gay H, Jackson A, Tucker SL, Deasy JO. *Radiation dose-volume effects in radiation-induced rectal injury*. IJROBP 2010 76 (Supp3): S123-129
- Viswanathan AN, Yorke ED, Marks LB, Eifel PJ, Shipley WU. Radiation dose-volume effects of the urinary bladder. IJROBP 2010 76 (Supp 3):S116-122

IGRT and margin determination in:

Pelvic treatment

Martijn Kamphuis MSc, MBA candidate

Radiation Therapist IGRT

Department of Radiotherapy

Amsterdam, the Netherlands

ESTRO School

Content of the presentation

- Basic knowledge on margin determination.

- Impact of motion management on the margin used in case of the prostate

- Strategies to deal with organ motion in pelvis, using mainly CBCT (markers/plan of the day).

- Added value of multi modality imaging (MR) in pelvic treatment

Margin determination

Errors in the radiotherapy chain

Physical patiënt →

Patient → 1 time

CT room	Treatment room
– Lasers	– Lasers
– Skin markers	– Skin markers
– Images	– Bone
– Bone	– Tumour
– Tumour	
– Delineation	– Beam
– Margin	– Accelerator
– Planned Beam	– Treatment room

35 x

Beam data →

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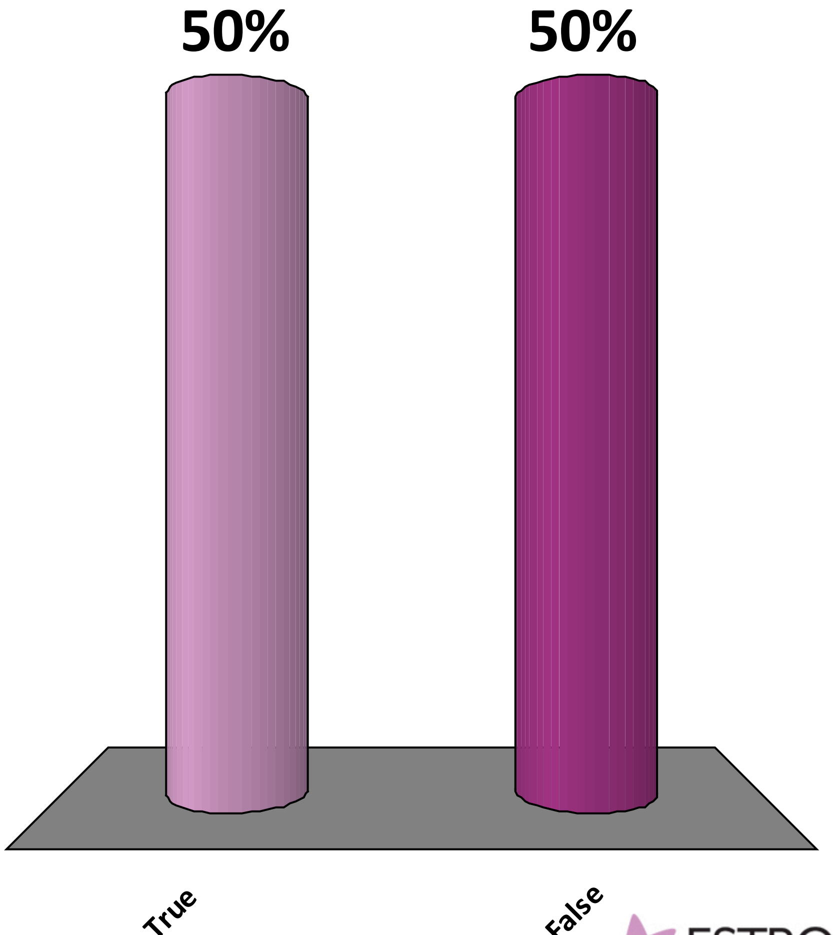
Errors and Margins

- A: Random errors
  - ➢ Treatment execution errors
  - ➢ Errors that vary each fraction

- B: Systematic errors
  - ➢ Treatment preparation errors
  - ➢ Errors that are made once per patient

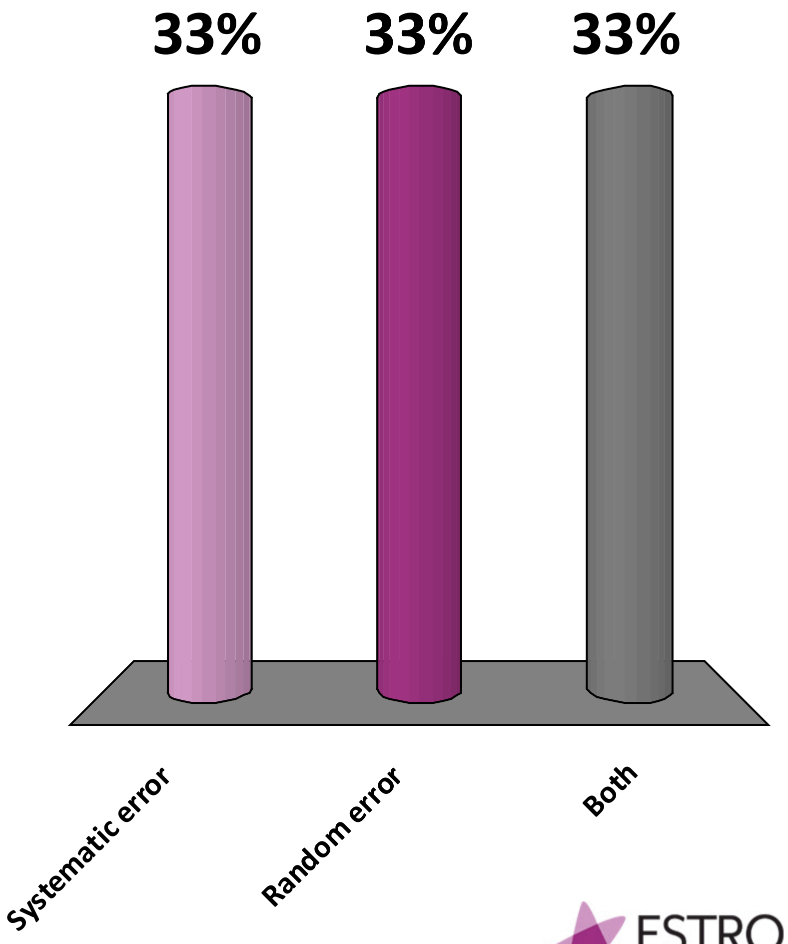
The delineation error is a random error

A. True
B. False



Organ motion is a:

A. Systematic error
B. Random error
C. Both



Errors in the radiotherapy chain

(McKenzie et al., BIR 2003)

- Systematic errors: *treatment preparation errors*
  - Delineation errors
  - Organ position and shape at time of localization
  - Phantom transfer errors
    - Geometric imaging error (e.g. CT alignment laser errors)
    - Treatment planning system error (e.g. shielding blocks)
    - Linear accelerator geometry error (e.g. laser & coll. position)
  - Set-up error at time of localization
  - TPS beam algorithm error
  - Breathing positional error

- Random errors: *treatment execution errors*
  - Organ position and shape
  - Daily set-up error

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How to solve the problem?

CTV-PTV Margins

Example of a margin recipe that is often used in clinical practice:

$$M = 2.5\Sigma + 0.7\sigma'$$

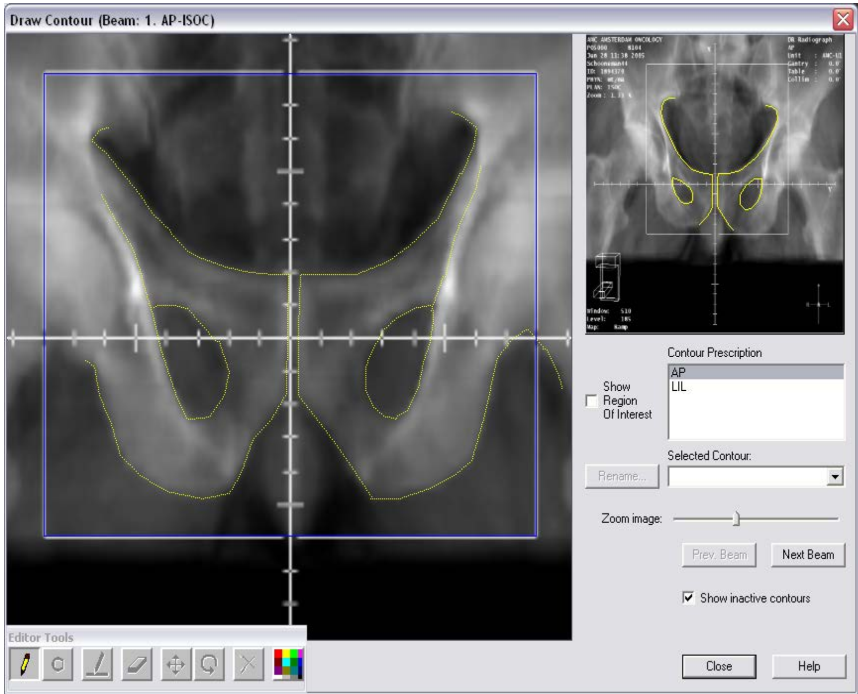
To ensure a minimum dose to the CTV of 95% of the reference dose for 90% of the patients

Margin for prostate RT

- Prostate IGRT in general
  - Offline bony anatomy matching
  - Offline marker registration using fiducial markers and PI
  - Online marker registration using fiducial markers Portal or static kV imaging
  - Online marker registration using Conebeam-CT

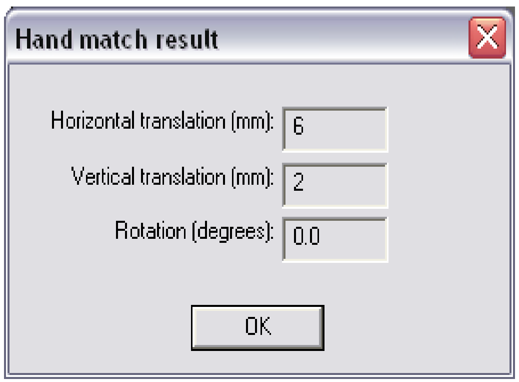
Offline/Online bony anatomy matching

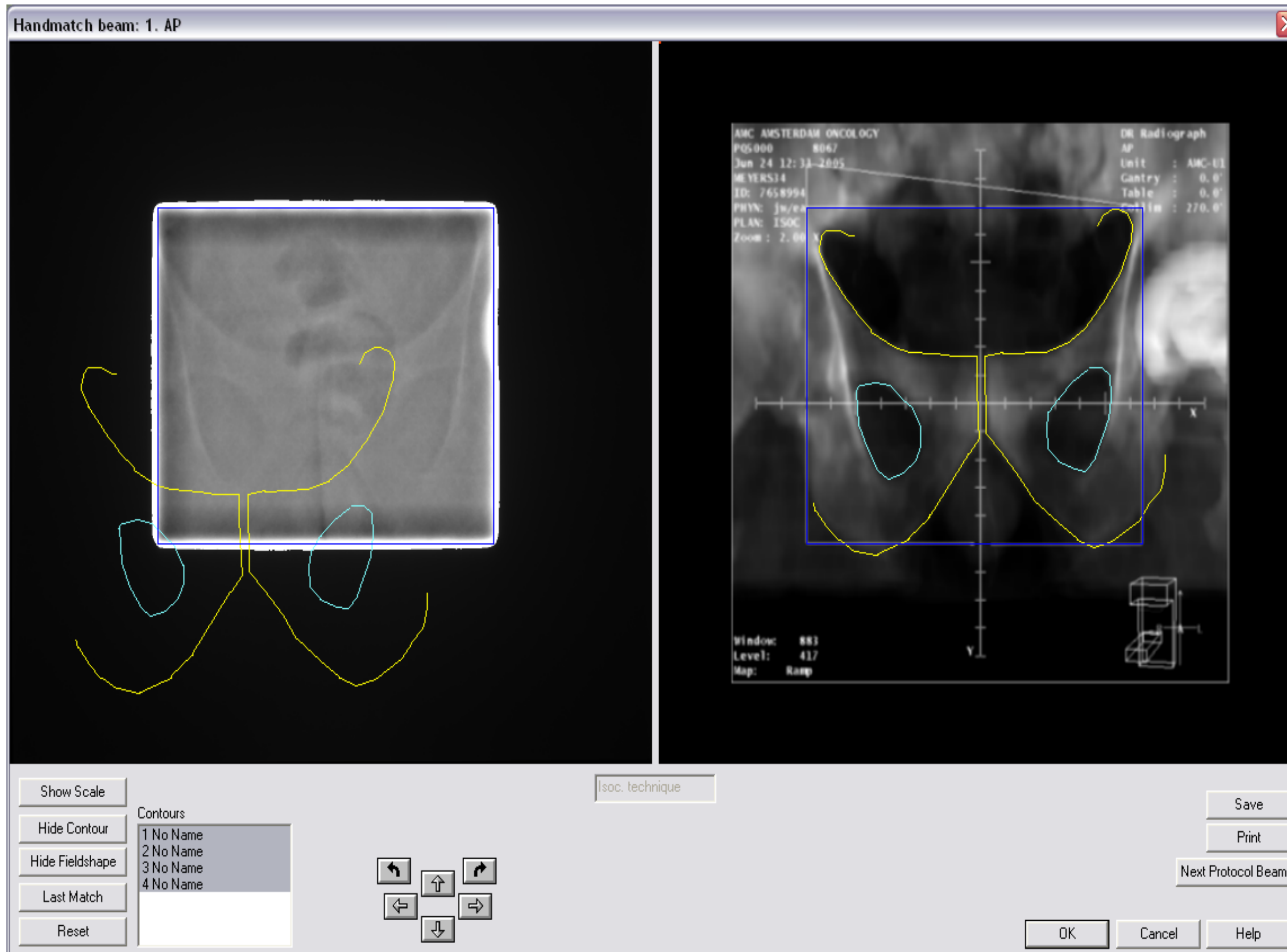
- Create an image with sufficient data
- Draw contours (templates) in reference images
- Contours should have a proper correlation with target
  - ➢ E.g. no trochantor or femur
- Produce guidelines!



Offline/Online bony anatomy matching

- Field edge match
- Match PIs

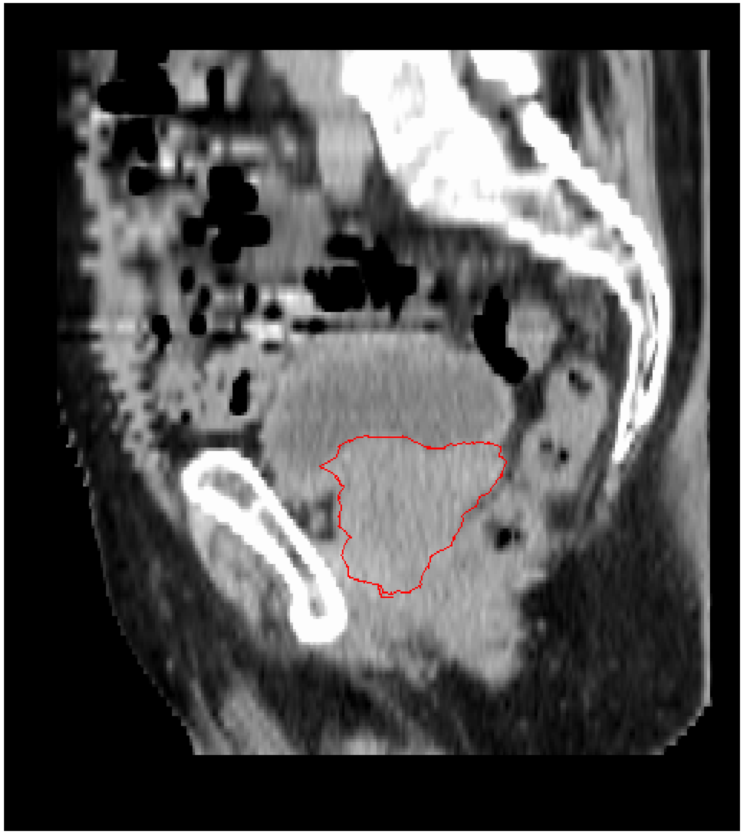




Offline marker registration using fiducial markers

Problem/challenge

- Displacement of bony anatomy does not (always) represent displacement of target



Van Herk et al.

Fiducial markers

- Displacement of bony anatomy does not (always) represent displacement of target
  - Neederveen et al. 2003: prostate cancer

	LR (mm)			AP (mm)			CC (mm)		
	marker	bone	mk. rel. bone	marker	bone	mk. rel. bone	marker	bone	mk. rel. bone
Mean	0.0	0.0	0.0	− 1.0	− 1.0	0.0	1.1	0.1	1.0
Σ	2.4	2.1	1.0	**4.4**	**4.4**	2.3	**3.7**	2.1	**4.1**
σ	2.1	1.8	0.8	**3.4**	**2.2**	2.4	**2.7**	1.7	**2.4**

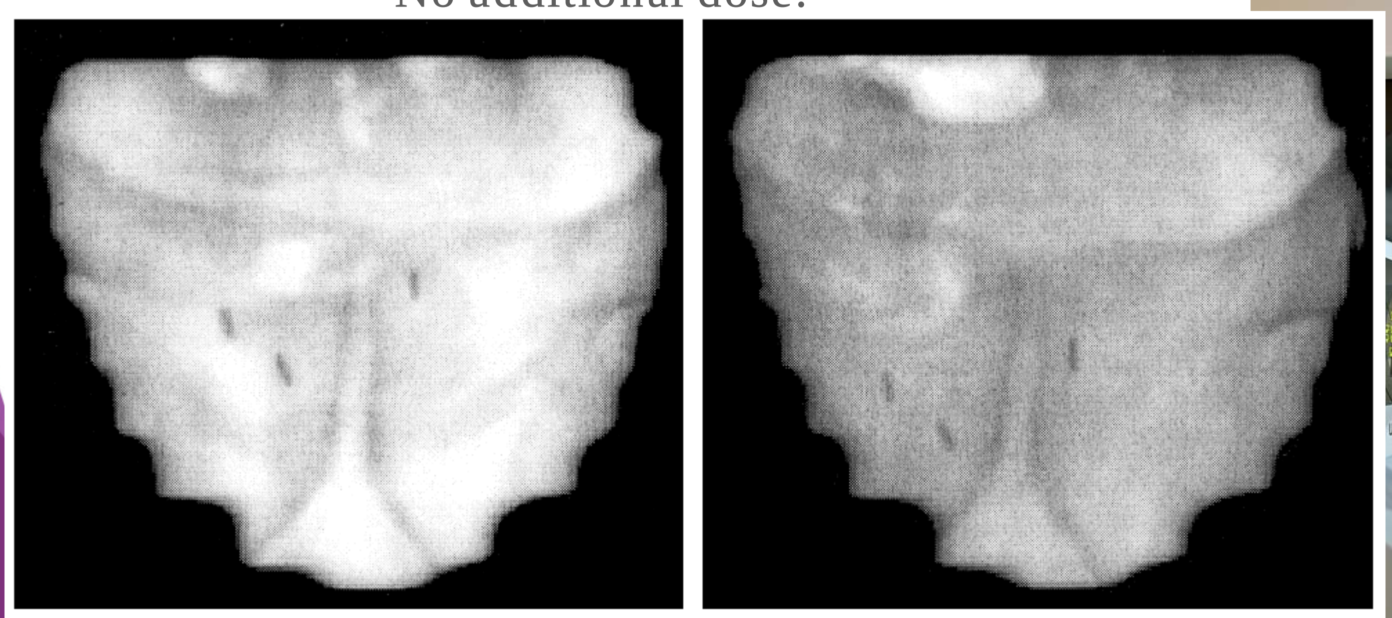
Standard deviations for the systematic and random case that do differ significantly are printed in bold.

  - For 6 out of 23 patients → increase of systematic error after correction based on bony anatomy !!

Fiducial markers: offline

Based on Van der Heide *et al*. 2007:

- 5 field IMRT treatment
- Daily offline imaging:
  - Treatment field: 40, 180 and 320 degrees
  - SAL (α=8, N=4)
  - Threshold SAL= $\alpha/\sqrt{N}$
- Limited (radiation) fields adequate
  - No additional dose!



Fiducial markers: offline

- Succesfull reduction of systematic error!
  - Without applying a correction protocol, the systematic errors (*Σ)* are:
    - 4.8, 2.2 and 2.9 mm in the vertical, lateral and longitudinal directions
  - The SAL protocol
    - 0.7, 0.8 and 0.8 mm, respectively.
  - Random position variations are not reduced in an off-line correction protocol

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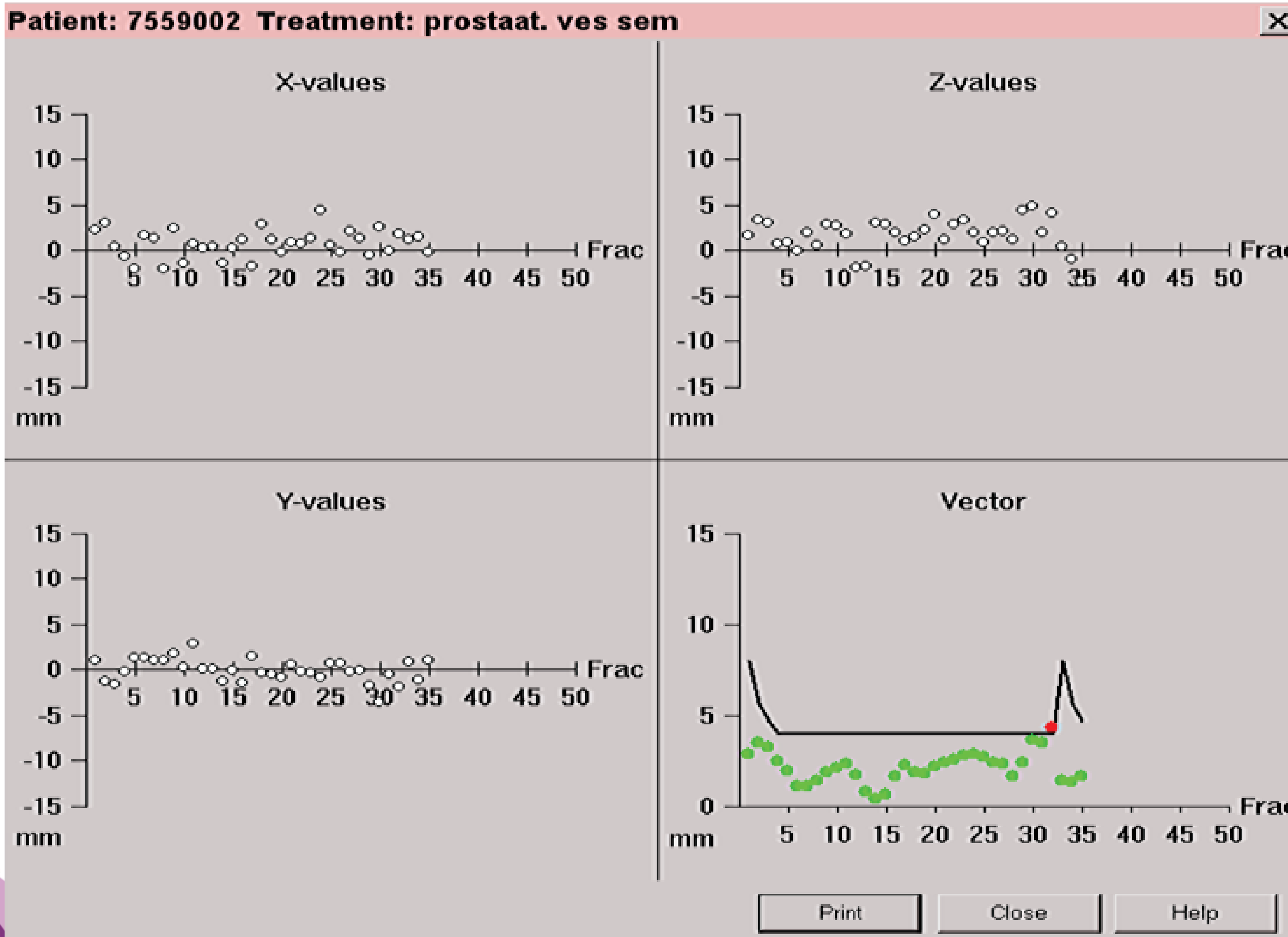
Online fiducial marker registration

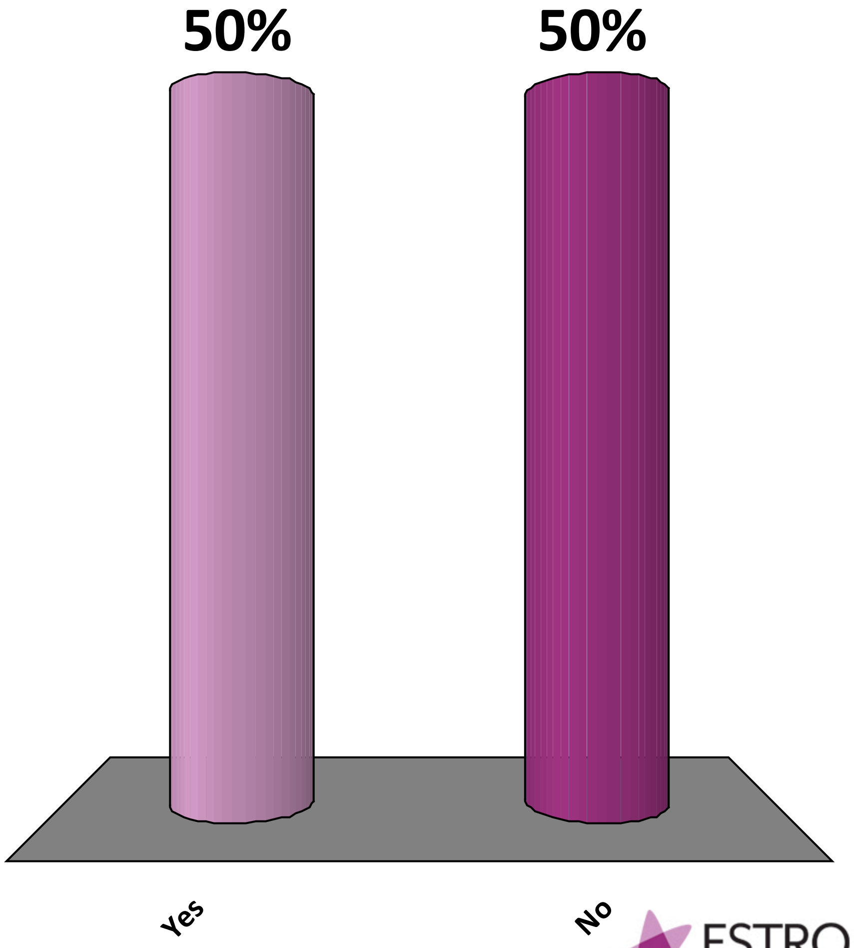
Food for thought!



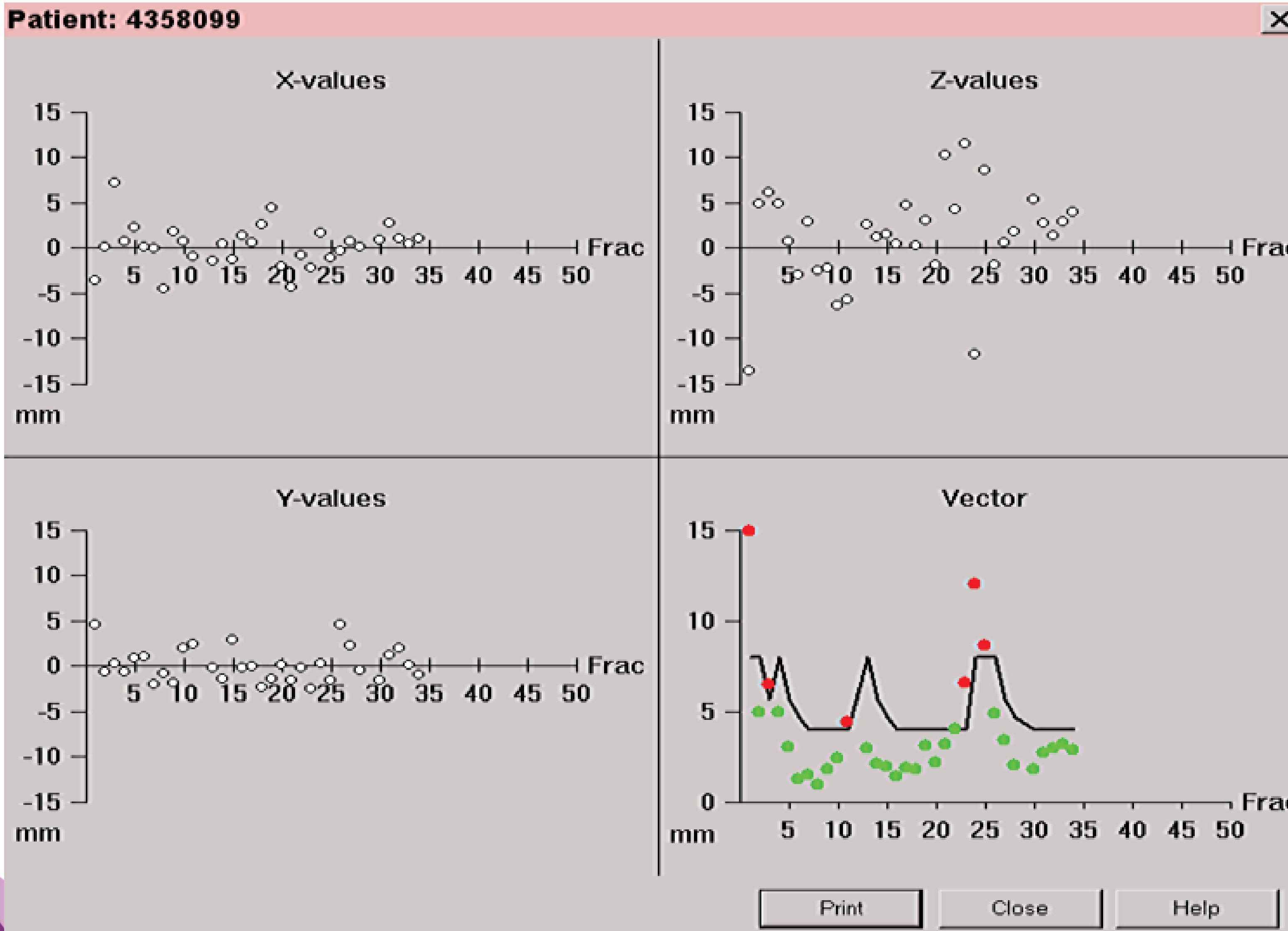
Would you like to treat a patient like this offline?

A. Yes

B. No

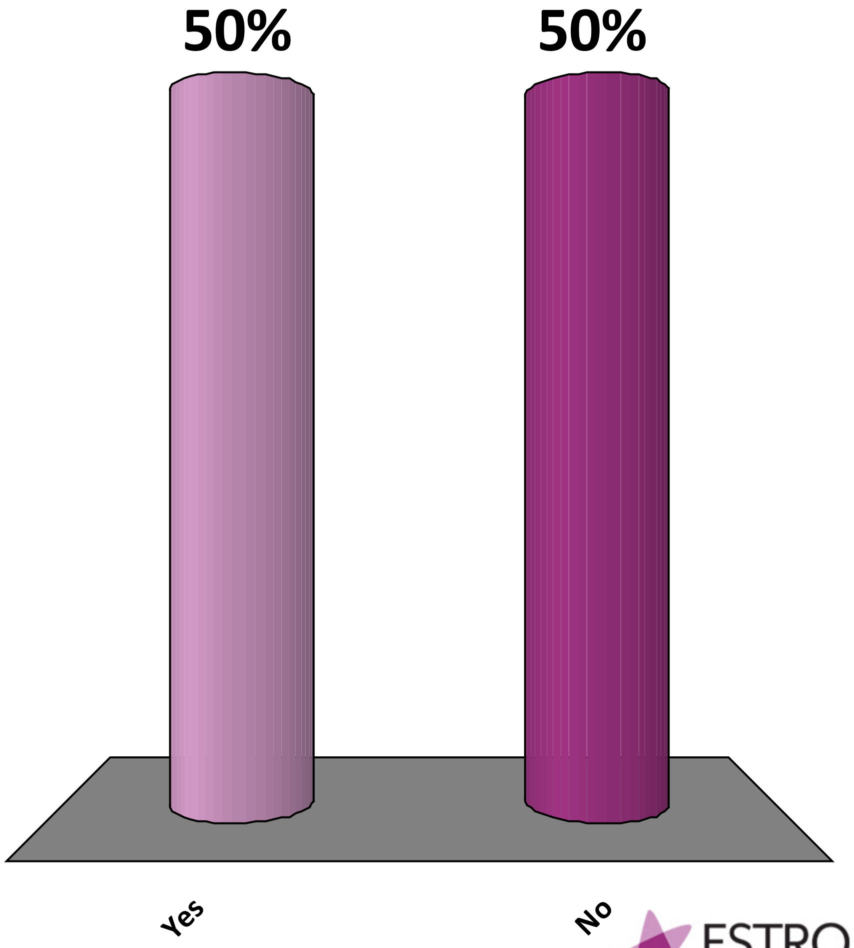


Food for thought!



Would you like to treat a patient like this offline?

A. Yes
B. No



Online Position Verification

- To reduce random error:
  - Online position verification is needed

- Different methods available
  - Two dedicated EPI field, e.g. 40 and 320 degrees
    - Correction for imaging dose necessary
  - Stereo Graphic Targeting
    - MV and kV together
    - Correction for imaging dose necessary
  - Two kV images
    - With CBCT or OBI
    - With ExacTrack system

Offline vs Online

		Results (mm)		
		X	Y	Z
Offline	Sys. error	0.8	0.8	0.7
	Random error	2.3	2.5	4.0
Online	Sys. error	0.8	0.6	0.9
	Random error	1.0	1.0	1.2

Online Position Verification

Online procedure

- Random error minimalized

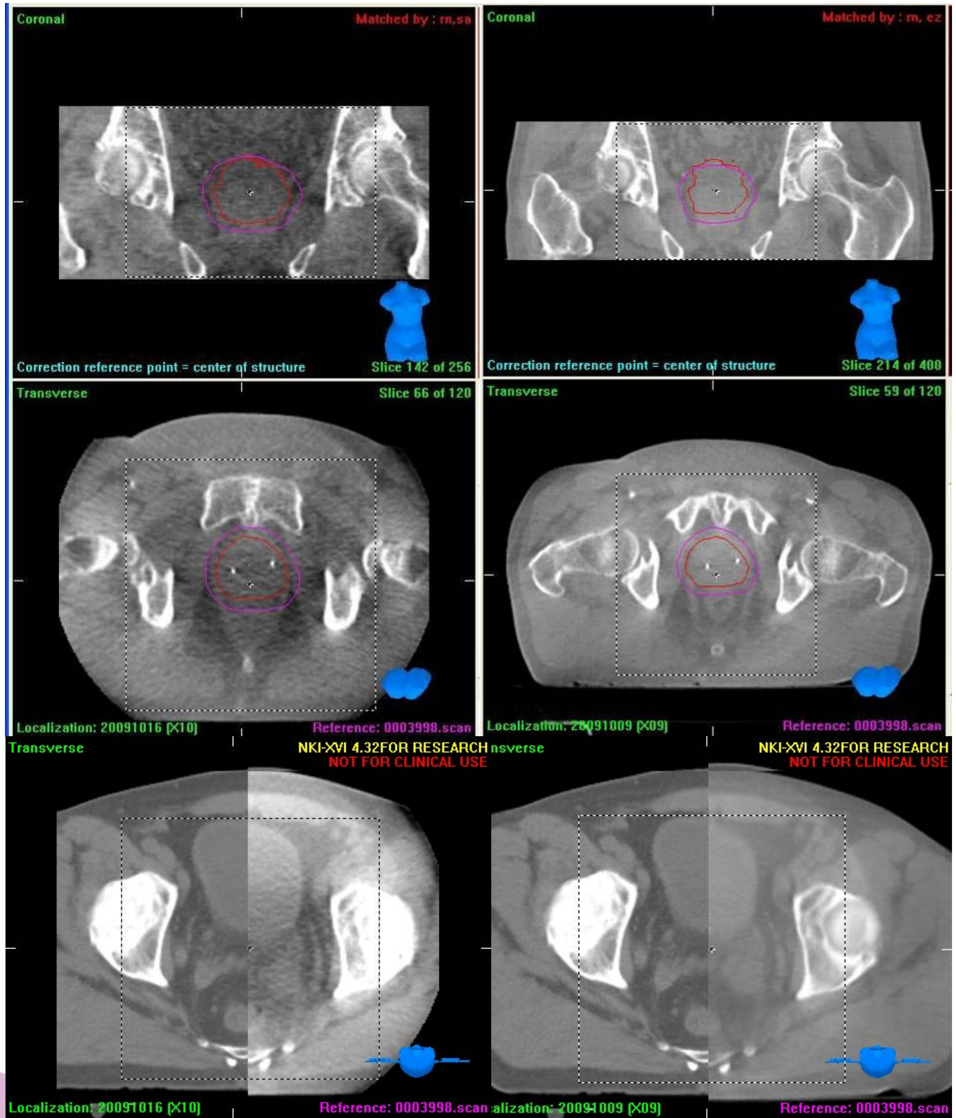
Enables **limited** margin reduction!

treatment execution β * σ	3.3	7.7	3.6
breathing b	0.0	0.0	0.0
scalar a – β * σ_p	-2.7	-6.6	-2.7
CTV-PTV marge (mm)	6.6	7.2	7.1
Eenvoudige formule van Herk: 2.5*SIGMA+0.7*sigma	8.0	7.8	8.7
Formule Stroom: 2.0*SIGMA+0.7*sigma	6.8	6.6	7.5

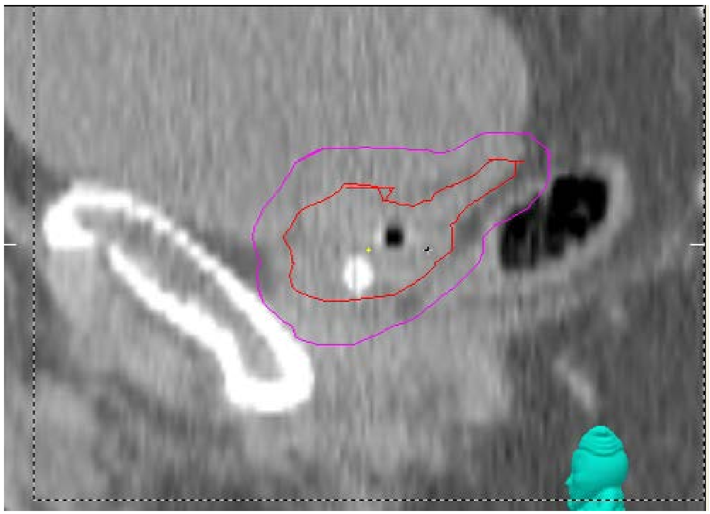
[illegible]	[illegible]	[illegible]	[illegible]
breathing b	0.0	0.0	0.0
scalar a – β * σ_p	-2.7	-6.6	-2.7
CTV-PTV marge (mm)	6.2	6.2	6.1
Eenvoudige formule van Herk: 2.5*SIGMA+0.7*sigma	7.1	6.8	7.0
Formule Stroom: 2.0*SIGMA+0.7*sigma	5.9	5.6	5.8

Online marker registration using CBCT

0.4 cGy 3 cGy

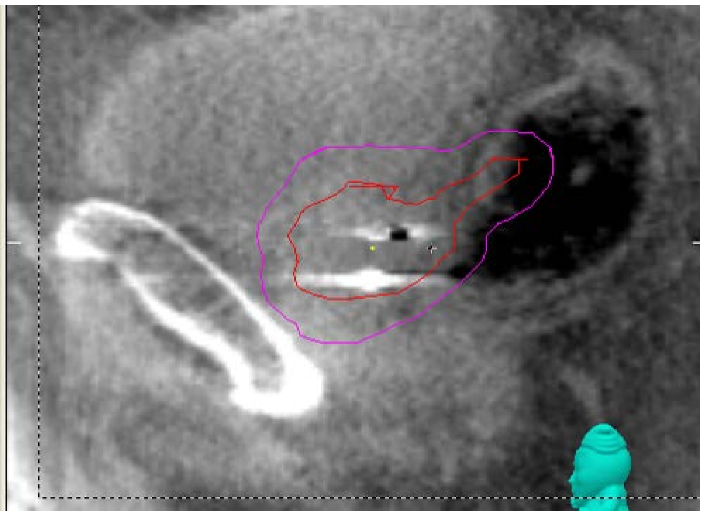


ConeBeam CT: soft tissue information



Red = Prostate + sem.ves.

Purple = PTV



CBCT : sem.ves outside PTV

Acknowledgements NKI/AvL

Many ways to Rome!

Method	Margin (AMC)	Extra treatment time	Imaging dose	Corretable?	Relevant anatomical information
Bone match	10 mm	2-3 minutes	(3cGY*2) High	Possible	-
Offline fiducial PI	8 mm	0 minutes	No	-	+
Online fiducial PI	7 mm	1-3 minutes	Very low (kV) to high (MV)	Correctable in case of PI	+
Online CBCT	7 mm	1-3 minutes	0.4-3.5 cGy/scan	Partly	+++

If there is a balance with the used margin:

1. LC is about the same for the all different procedures
2. Toxicity probably lowest with online IGRT

(Adaptive) strategies

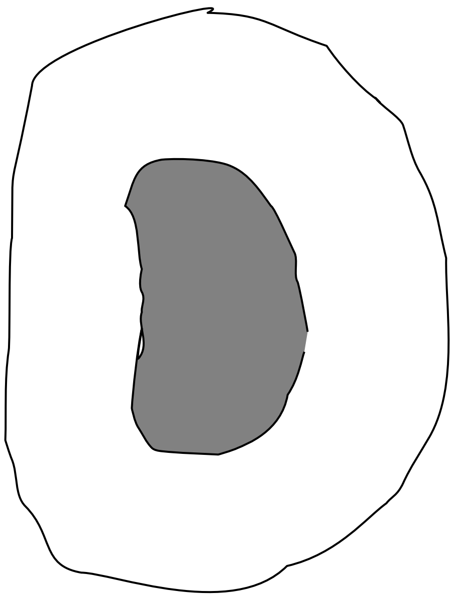
Other physiological motion

- Changes in bladder filling:
  - How to solve shape change problems?

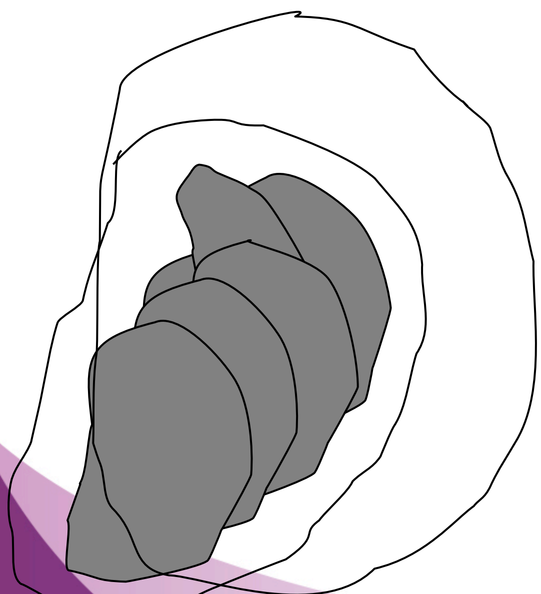
- Adaptive Radiotherapy!
  - Repetitive imaging and replanning
  - Plan of the day

  - Example: *bladder cancer*

Bladder strategy 1



Initial tumor position plus 2 cm margin



Adaptive margin strategy:

5 CT scans during first week of RT

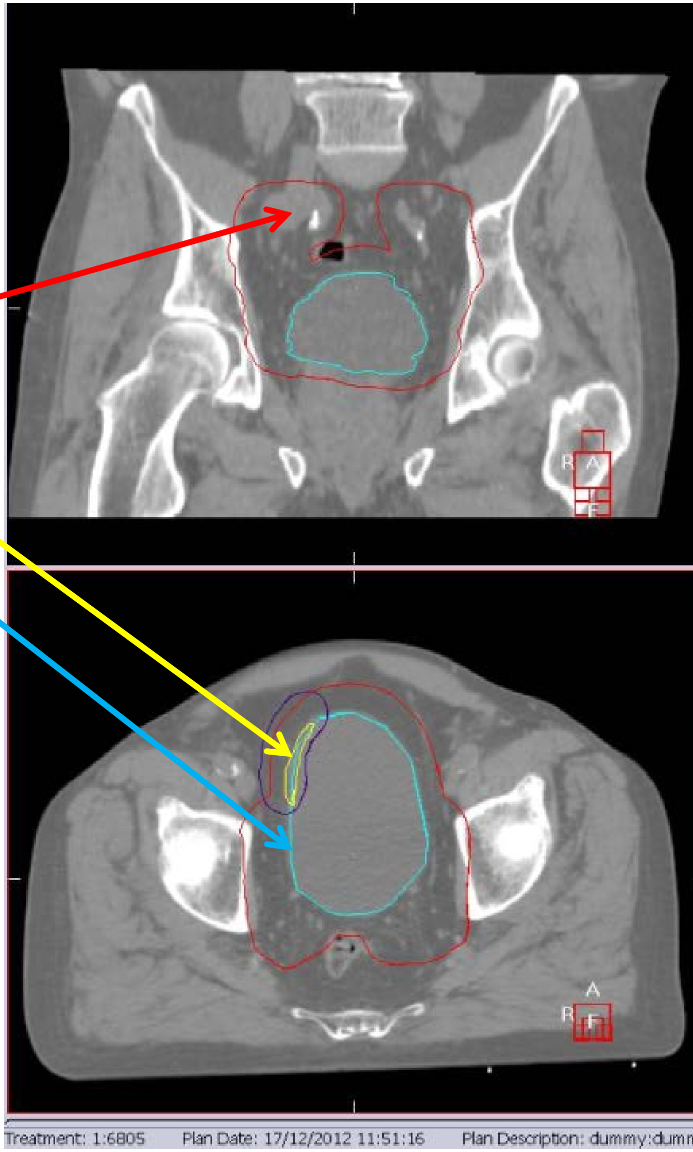
Delineate 6 tumor positions plus 1 cm margin

- 40% boostvolume reduction (*pos et al 06)*

- less geografical missers

Strategy 2: Plan of the day

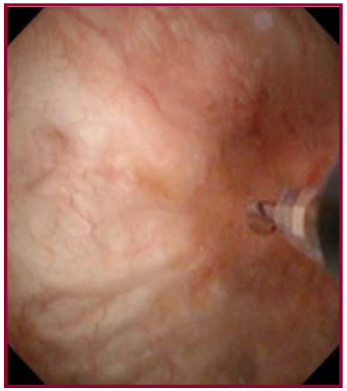
- Clinical problem/challenge: multiple targets
  - Bladder tumor (2,75 Gy)
  - Elective bladder (2 Gy)
  - Elective lymph node irradiation (2 Gy)

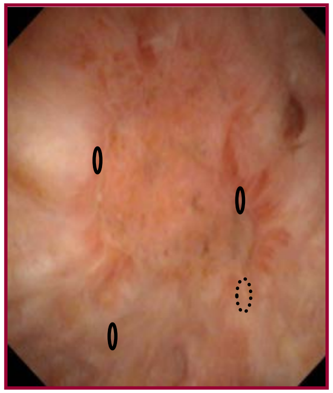


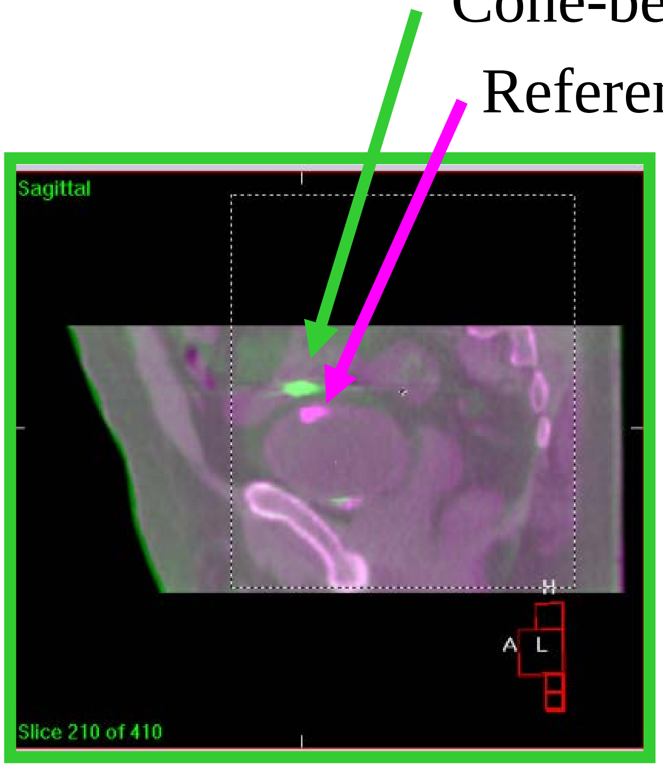
Solving visibility problems

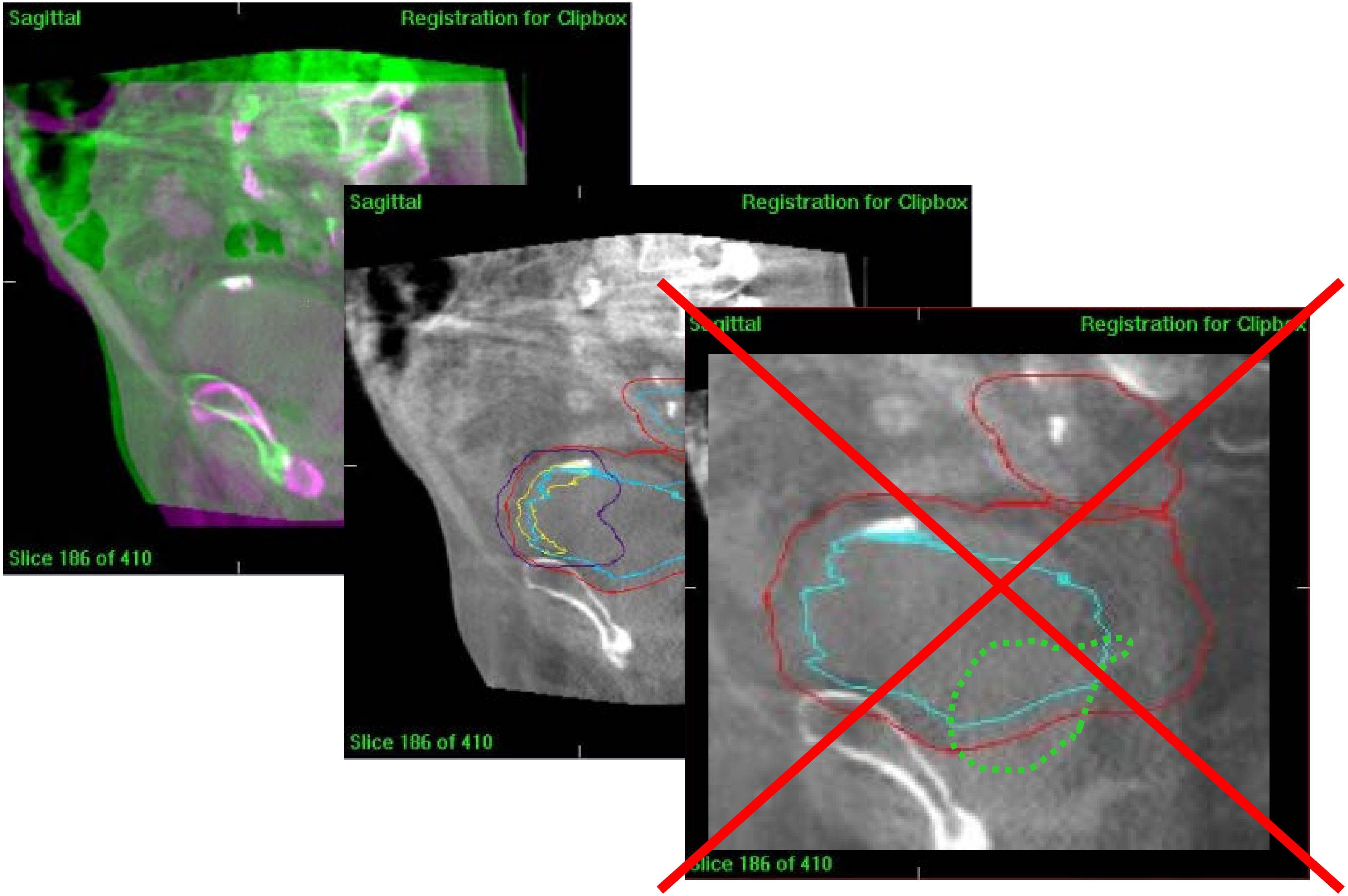
Lipiodol markers

- High contrast liquid, visible on (CB)CT
- Cystoscopically injected around tumor (2-3x)









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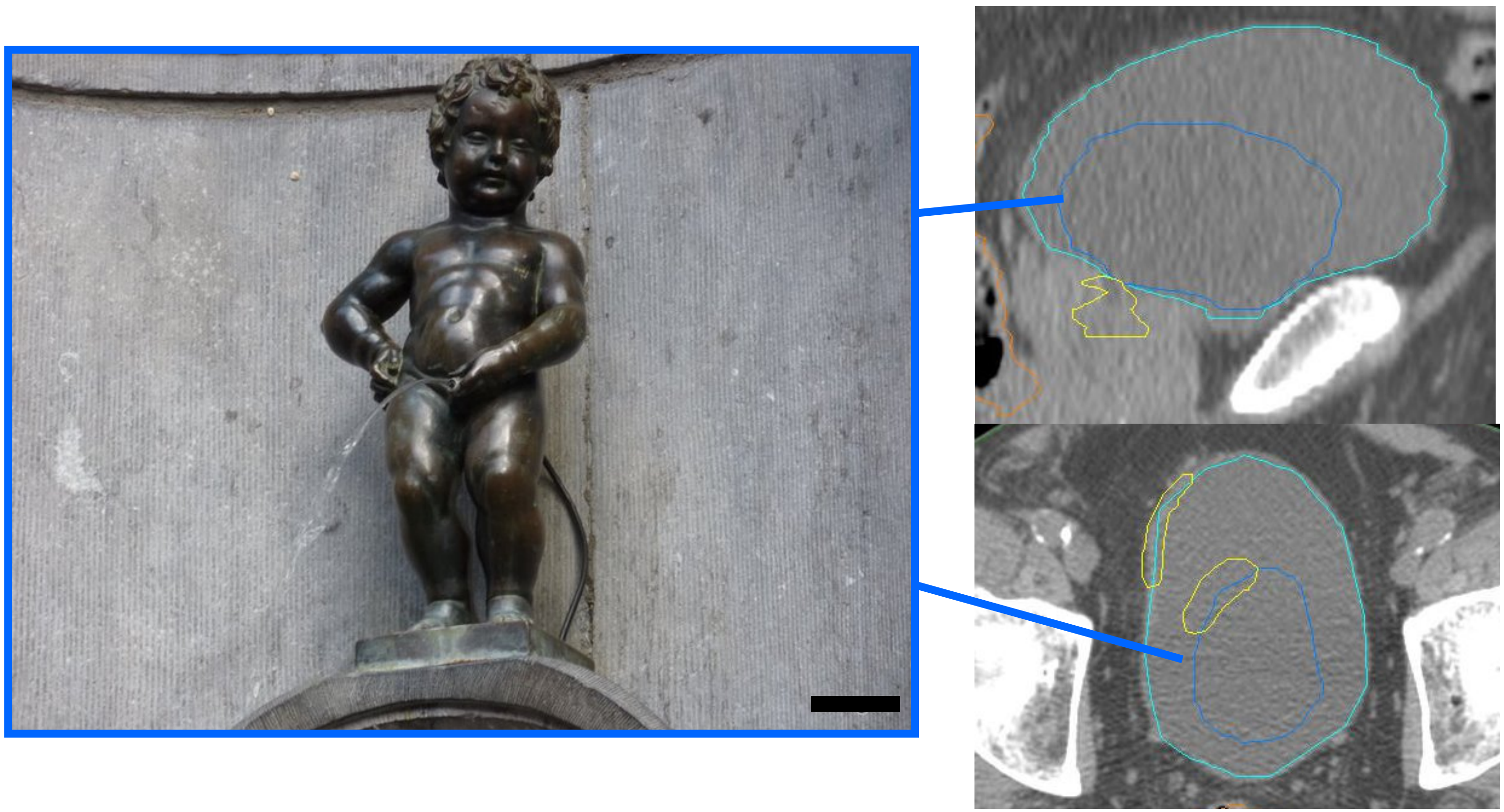
“Predictable” random changes



*G.J.Meijer *et al*, 2012

Plan of the day

Inter- and extrapolation of bladder contours

- Matterhorn: TPS spline
- 5 plans are generated on the TPS (oncentra, Elekta)

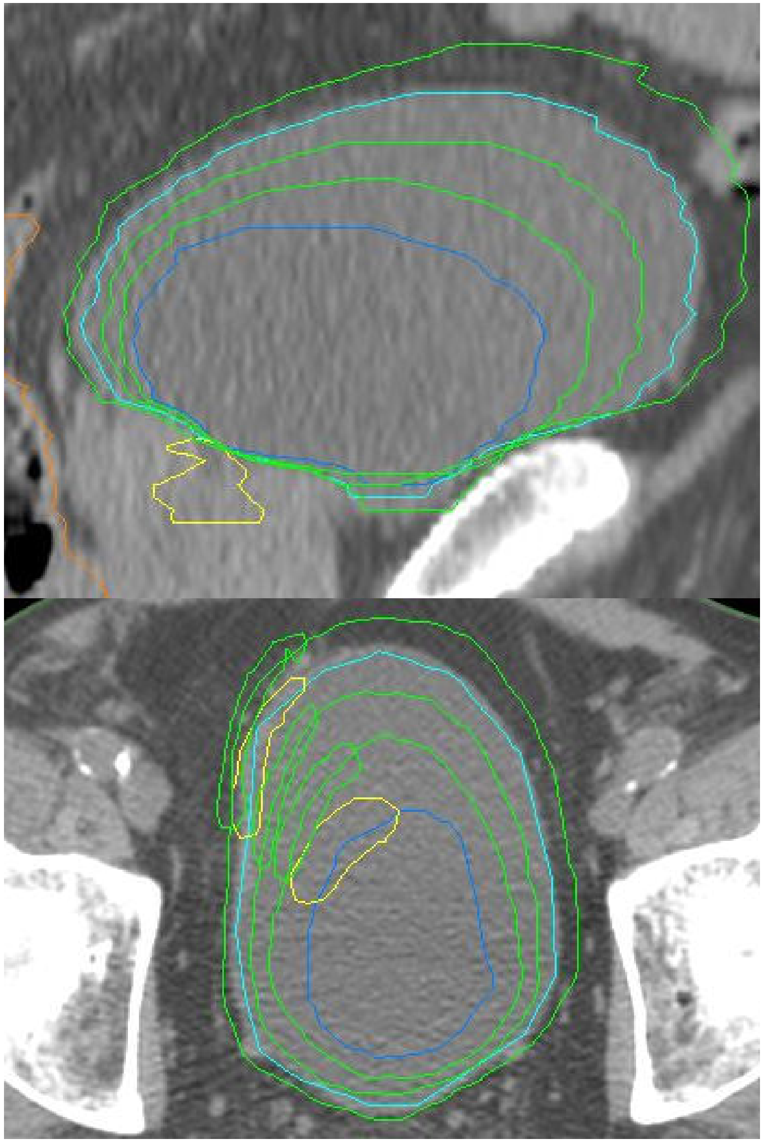
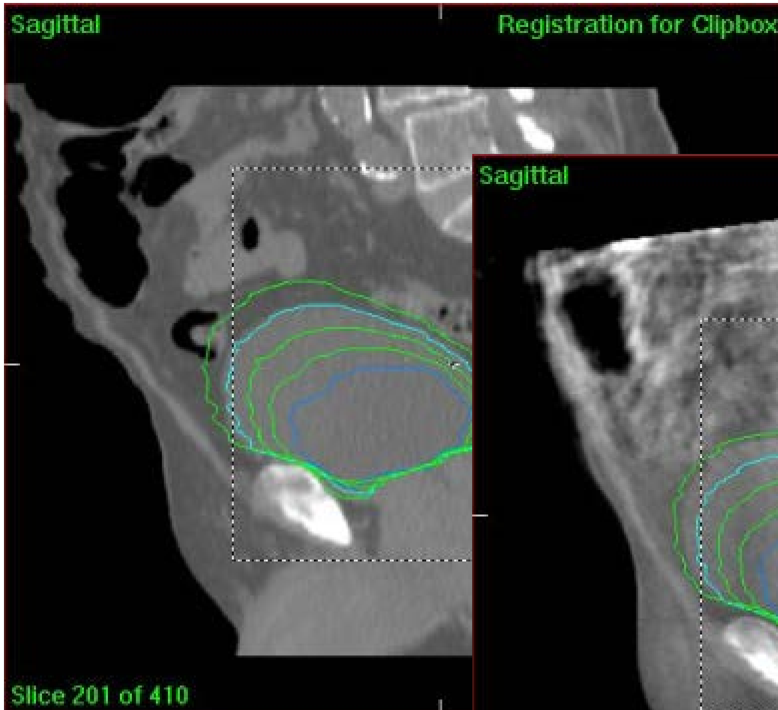
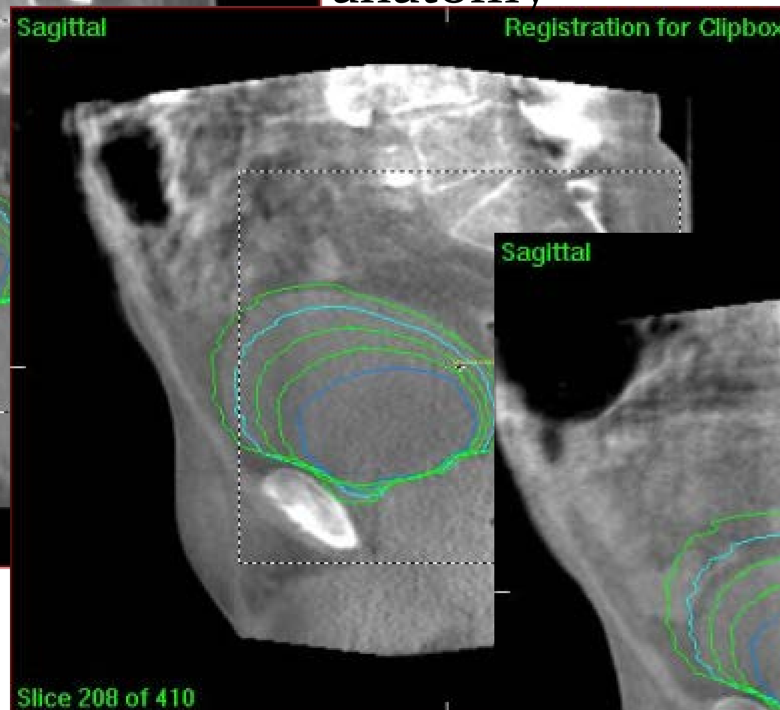
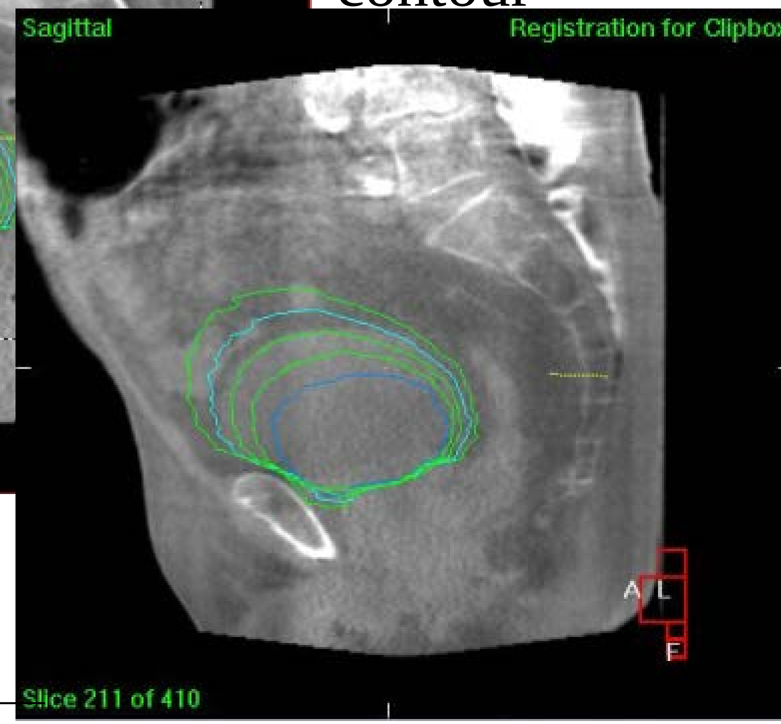


Image registration on bony anatomy



Selection of plan by selecting the contour





Bladder less filled

Treatment Planning: Tools and General Principles Part 2.

Steven Buckney
Michelle Leech
Basic Treatment Planning Course
Lisbon 2015

ESTRO School

Learning Outcomes

At the end of this presentation, you will be able to:

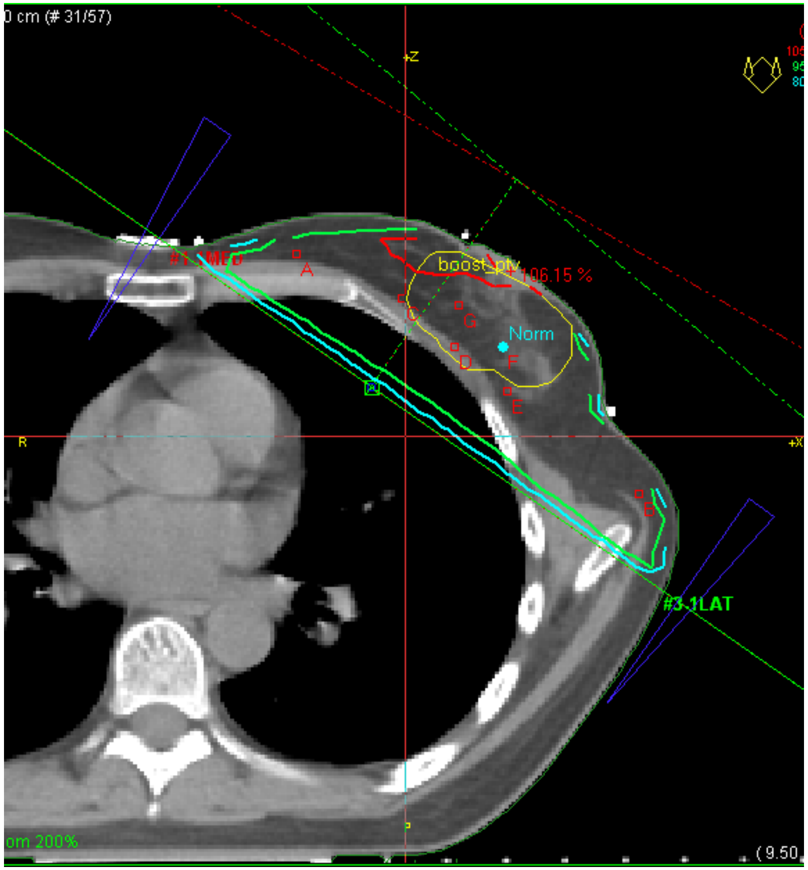
- Describe the effect of inhomogenities on dose distributions
- Differentiate between the effect of pencil beam and collapsed cone algorithms on dose distributions
- Comprehend the use of segmented fields and their applications
- Appreciate the advantages of IMRT planning and treatment over 3DCRT in selected cases

Inhomogeneities

Inhomogeneities

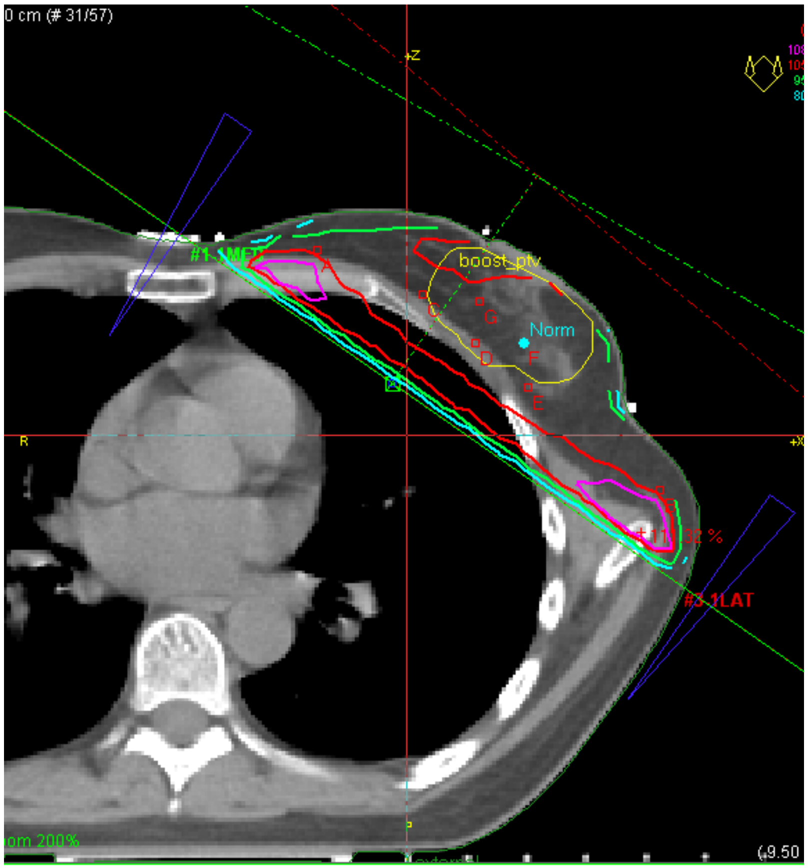
- TPS must be able to compute dose in regions of varying densities
  - Fat
  - Bone
  - Air cavities
  - Lung
  - Prostheses
  - Contrast media
  - Irmmobilisation devices

Effect of Lung (Pencil Beam Algorithm)



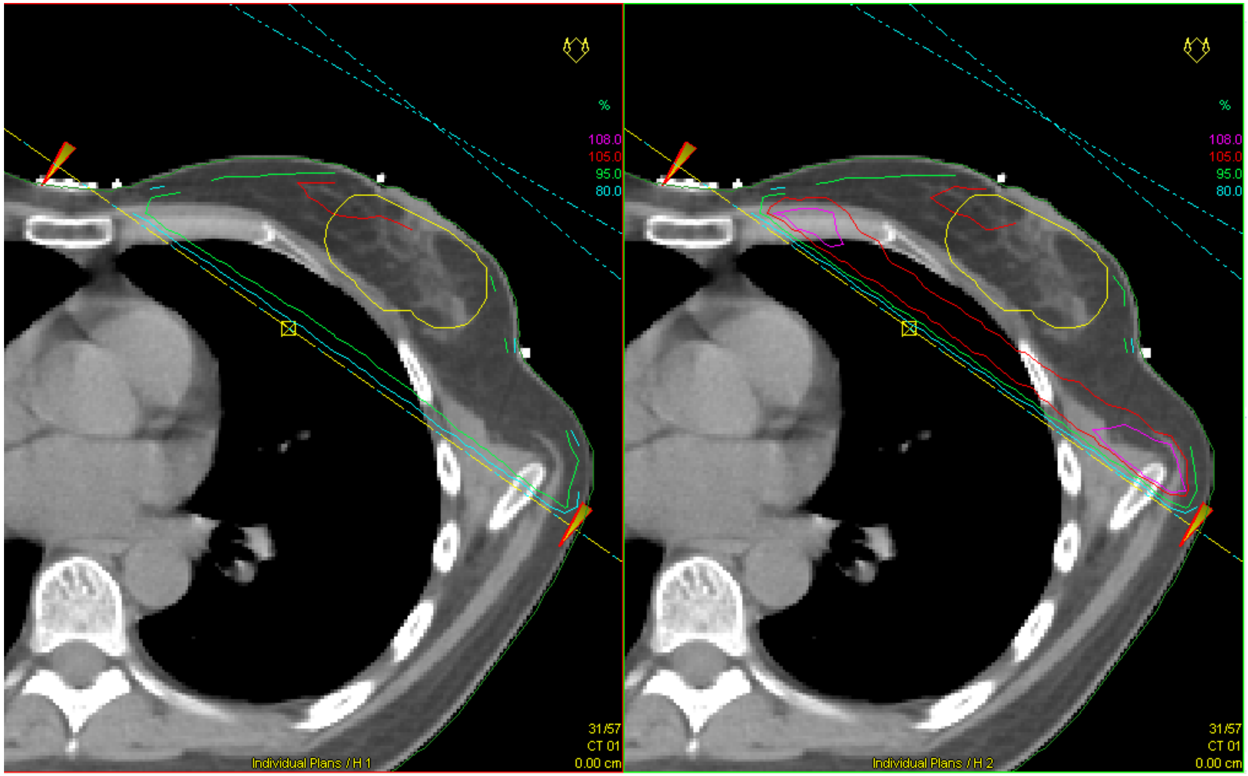
- Distribution done with no correction for lung inhomogeneity
- Result appears better than reality
- 2D plans were often done with no correction for lung

Effect of Lung (Pencil Beam Algorithm)



- Same distribution with lung inhomogeneity included
- Note large hot area through lung
- Avoidance of high dose to lung is an advantage of CT planning

Effect of Lung



- Comparison without and with lung correction (PB)

Inhomogeneities

- Rare to calculate without homogeneity correction today
- Instances where this may happen are:
  - Re-planning on Cone Beam CTs in selected cases (Pelvis)
  - Most TPS would default to use of homogeneity corrections
  - Phantom plans (e.g. gamma indices for IMRT) are often conducted without homogeneity corrections.

How does the TPS compute dose in inhomogeneities?

- TPS uses an **algorithm** to achieve this
- An algorithm is a set of rules which specify how to solve a problem
- Needs to be accurate to correlate dose with predicted clinical outcome
- Must calculate doses in reasonable time

Dose Calculation Algorithm Review

- *Model-based algorithms*

  - Model-based algorithms **model the photon beam** pathway from the head of the treatment unit to its interactions within the patient
  - Always used in TPS today

Dose Calculation Algorithm Review

- The main algorithms currently in use in TPS are:

  - Pencil Beam
  - Collapsed Cone
  - Monte Carlo Simulations
  - Vendors' variations of the above

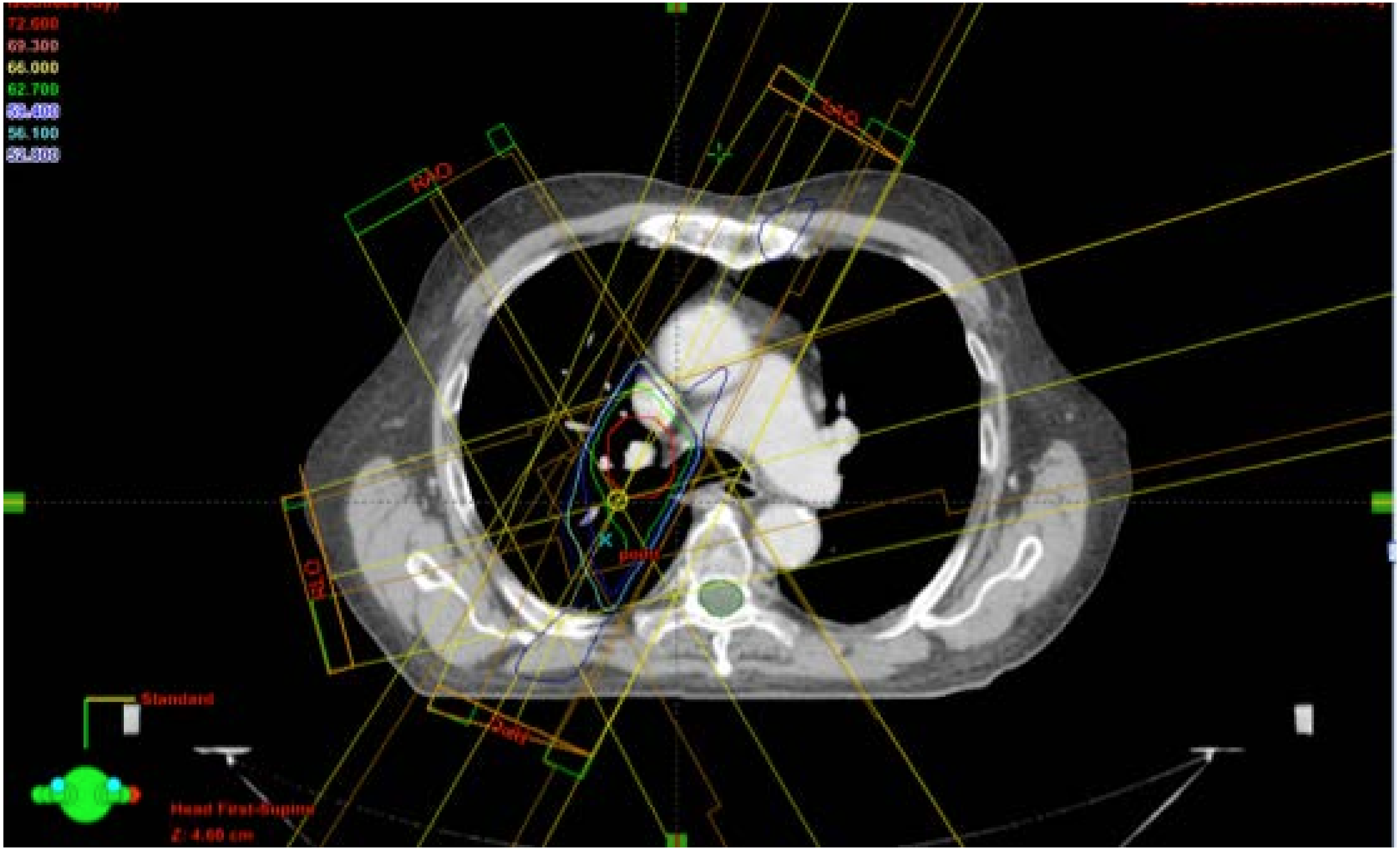
Pencil Beam

- Commonly available in TPS
- Model-based algorithm
- Density correction is in **one dimension** only
- Dose is calculated to a depth along the central axis from the source, to a point
- Less accurate when calculating in areas of inhomogeneity (e.g. lung, head and neck)

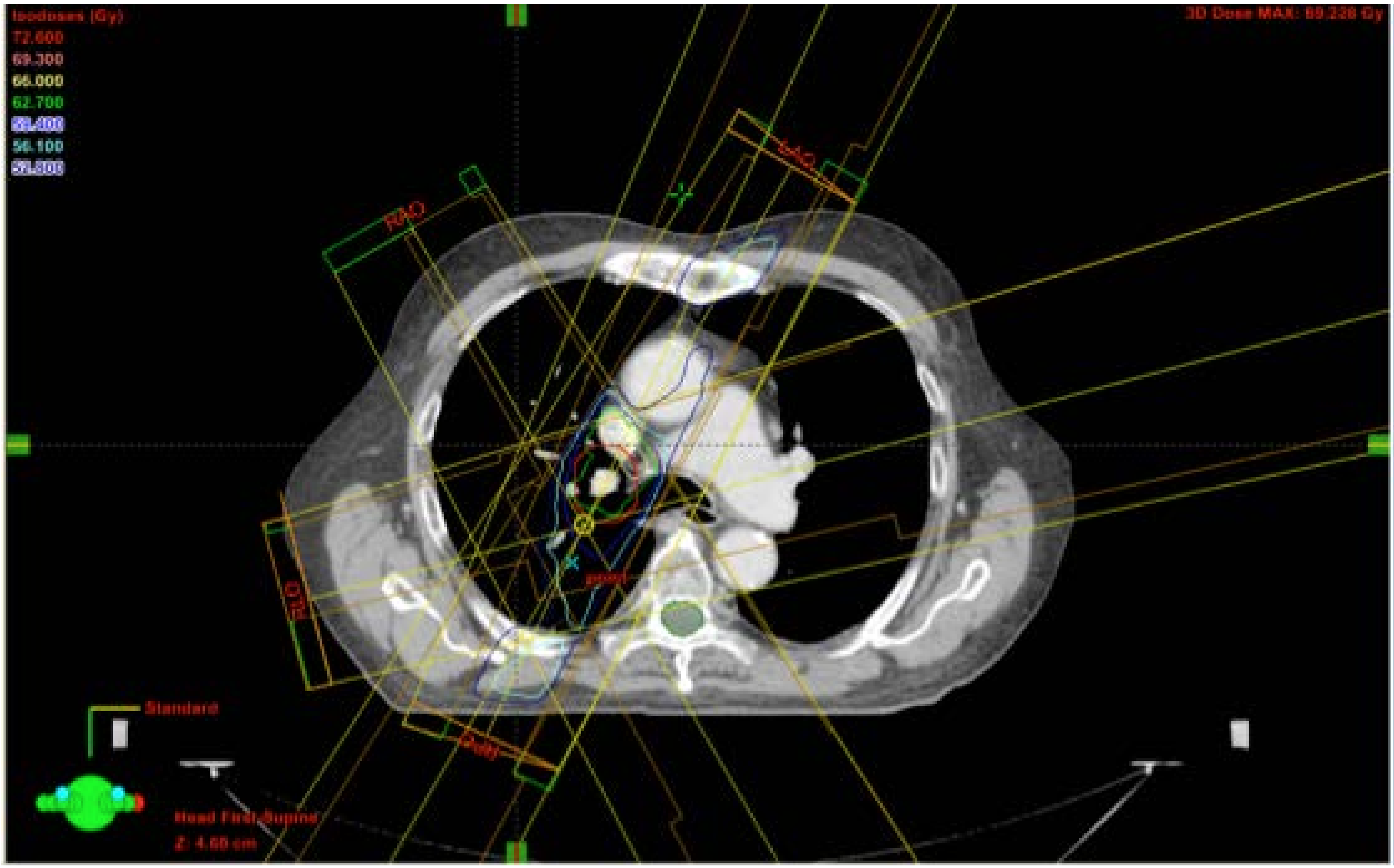
Collapsed Cone

- Commonly available in TPS
- Calculates in 3-D.
- More accurate in calculation of dose in areas with inhomogeneities than Pencil Beam
- Accuracy is greater than Pencil Beam both within the inhomogenous area itself and also in areas beyond it (e.g. paranasal sinus, oesophagus)

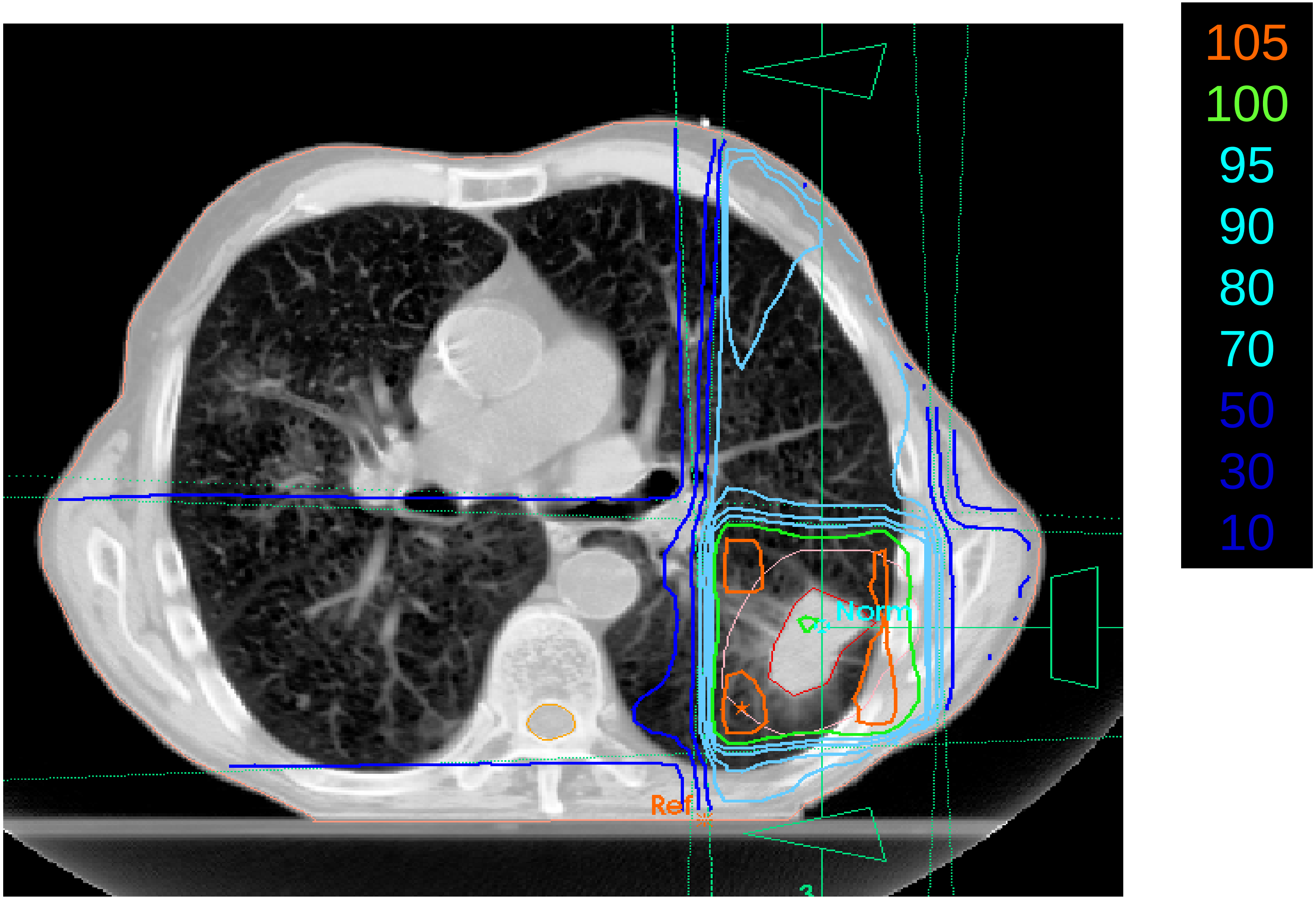
Pencil Beam Algorithm



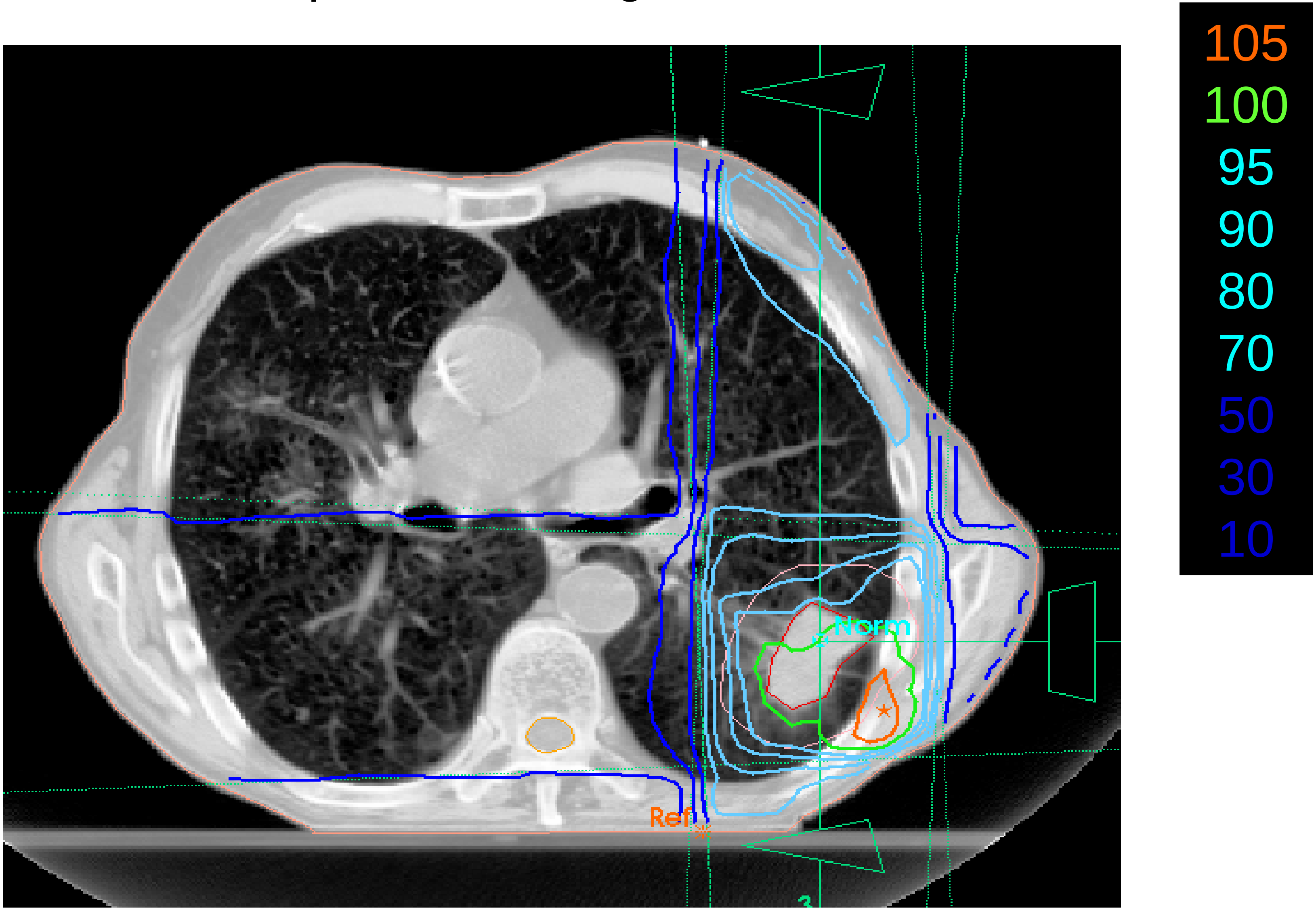
Collapsed Cone Algorithm



Pencil Beam Algorithm



Collapsed Cone Algorithm



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Comparison of Pencil Beam and Collapsed Cone

Pencil Beam

- 95% coverage appears greater
- Overall coverage is increased
- Hotspots appear in areas affected by the lower density of the lung
- Calculates the effect of the inhomogenous areas in 1 dimension

Collapsed Cone

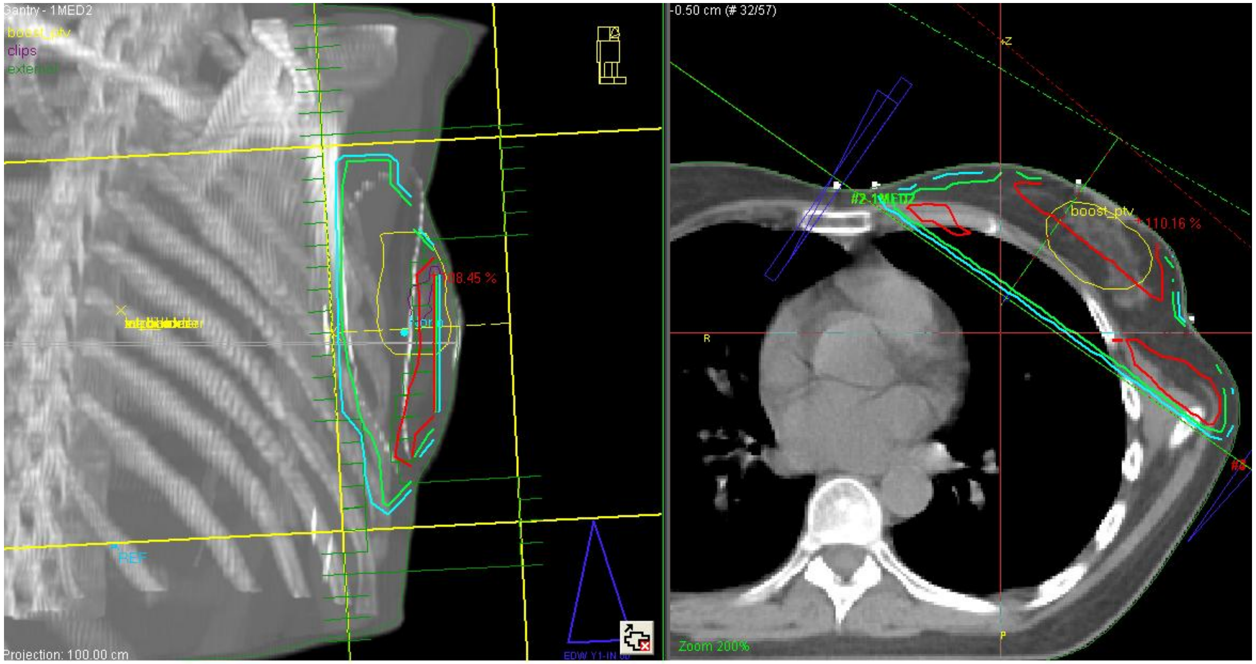
- 95% coverage is compromised in areas of the lung
- Overall coverage is decreased. This can be most noticeable at the superior and inferior ends of the volume
- Hotspots appear minimal
- Calculates the effect of the inhomogenous areas in 3 dimensions

Segmented Fields

Use of segmented fields

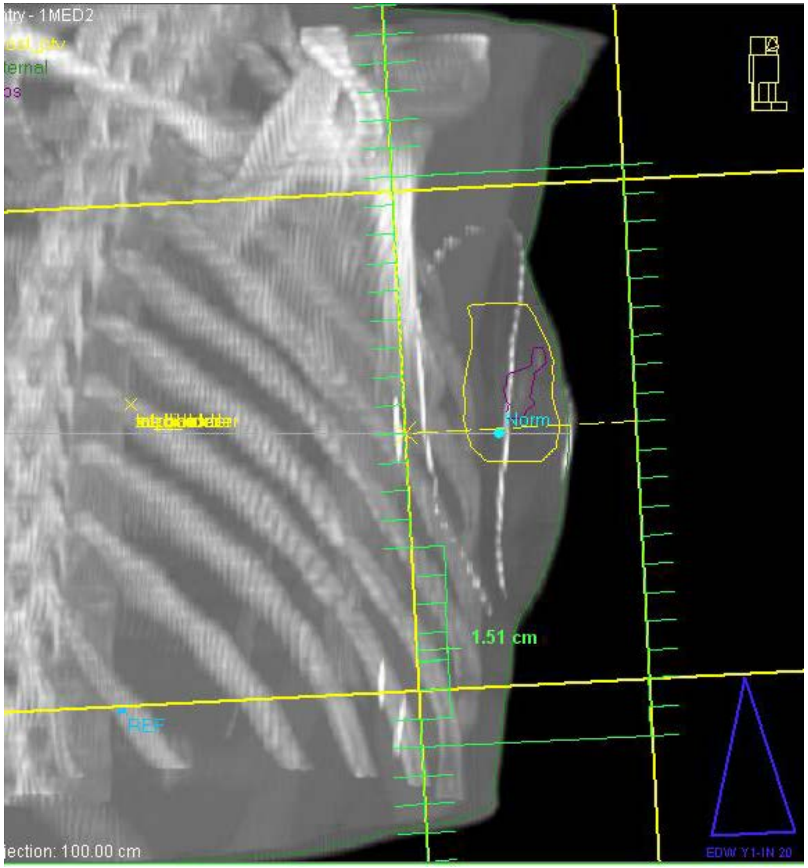
- Can be used to increase dose in areas that are ‘cold’
- More frequently used to reduce/minimise hot spots in a plan.
- Routinely used in many centres and used in almost all sites.

Breast Plan before segments (Note hot areas)



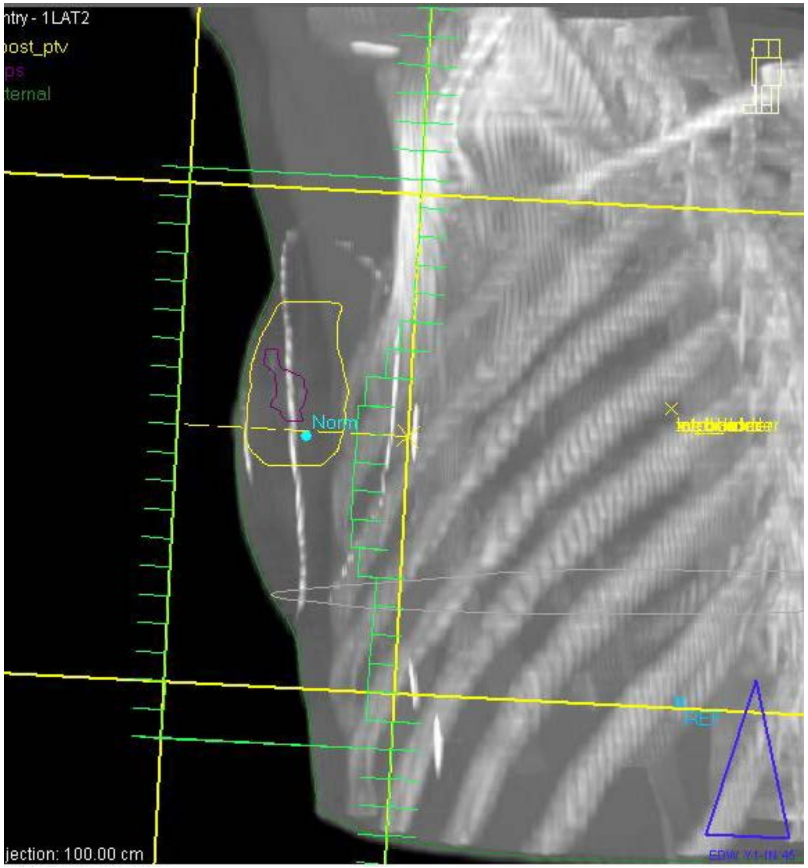
- Can use segmented field MLCs to shield hot areas
- Check sagittal and transverse views to do this

How to create segmented fields in a chest wall case



- Copy the field and turn collimator 90 degrees to allow optimal fit of MLCs
- Reproduce MLCs if any
- Wedge can be used to increase dose at sup or inf end
- Low weighting, therefore needs high wedge angle

Lateral Segment indicating location of MLCs



- Shield post hot areas
- Use extent of lung as guide
- Second segment avoids opposing MLCs coming too close together
- Wedge added to enhance dose at superior end in this case

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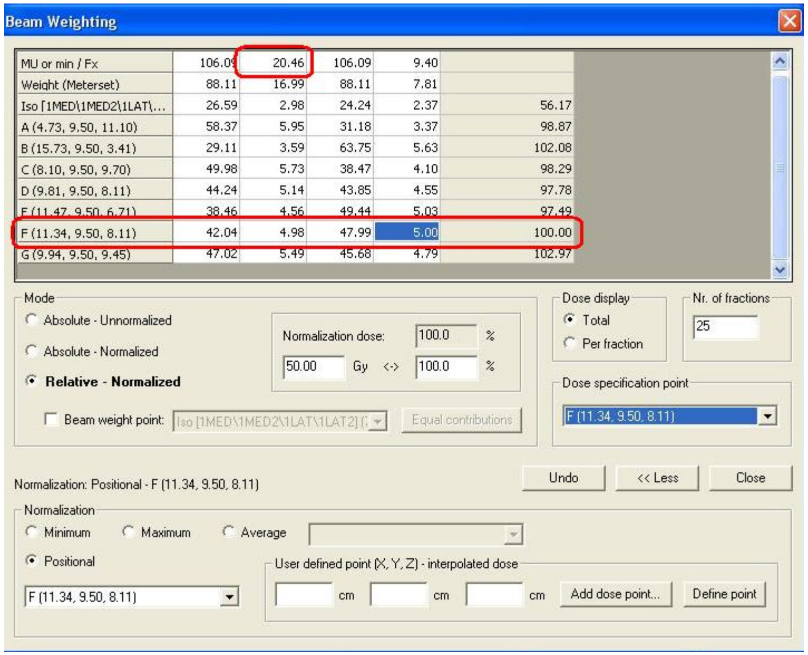
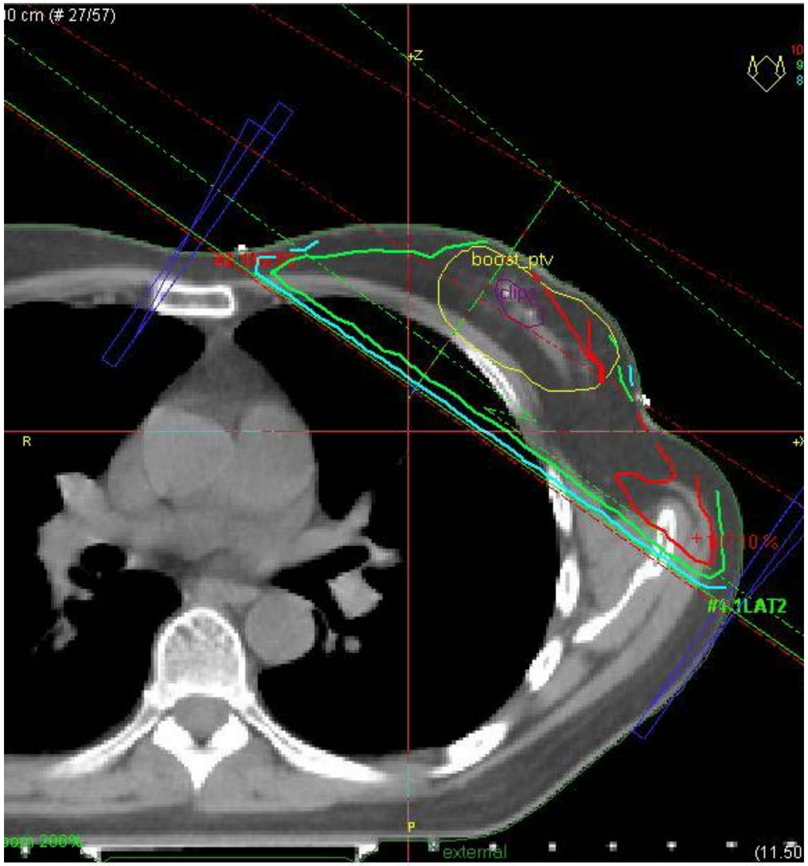
Result - Settings



- Calculate, weight 5% to segmented field
- Remove 5% weighting from main tangential field
- Note 20 MUs minimum required for wedged fields on Varian treatment machine, for example

New Distribution



- Better, still hot in places
- Off balance medially to laterally requires re-weighting of main fields
- In this case 20 MU requirement gives 8% of dose from lat seg field. Note dose reduction medially as a result of this

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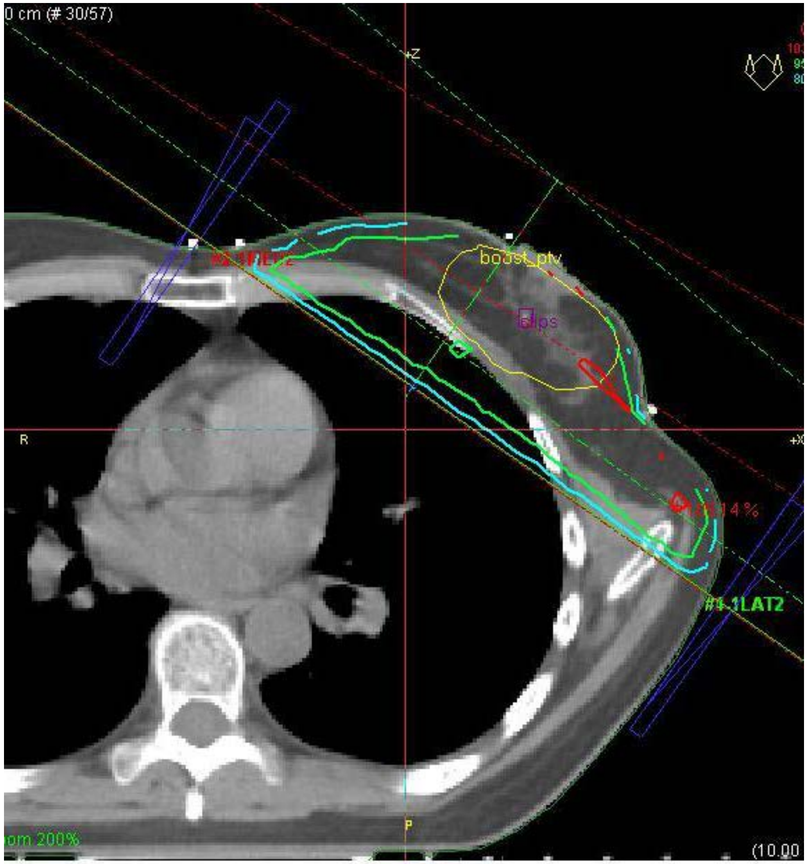
Balanced Weights

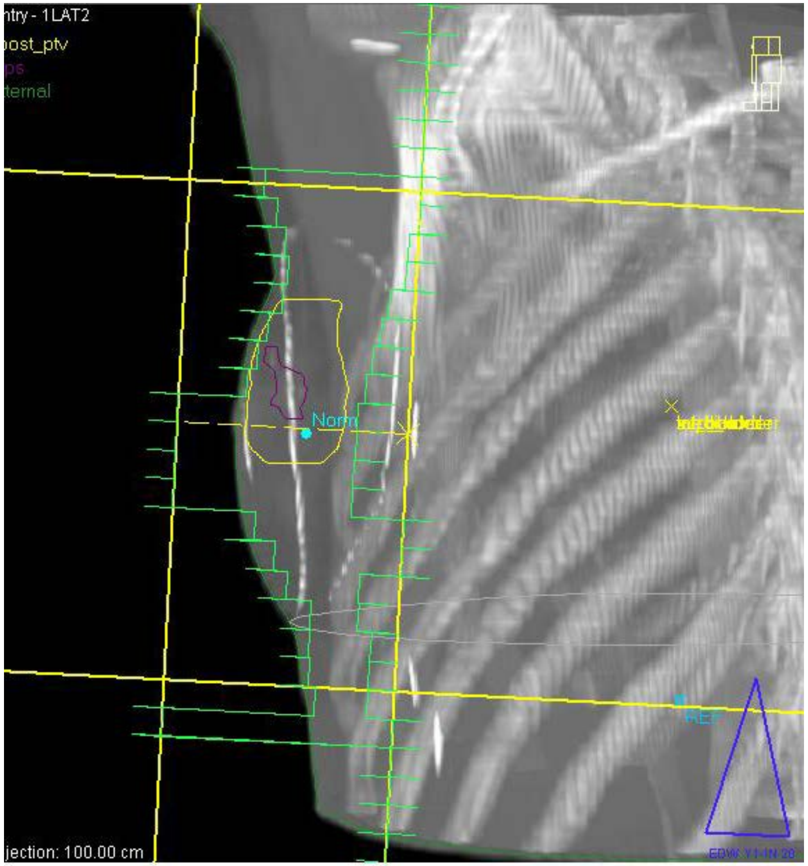
- Superior slice after more weight given to medial field
- Hot areas more balanced
- Still warm, need to reduce amount of sup/inf wedge in this case

Hole in Dose



- Excessive use of MLCs to reduce hot spots has over compensated
- See hole in 95% dose on nearby slice
- Need to pull back the MLCs

Modified MLC



- MLCs modified
- Shields hot areas anteriorly at inferior end
- Already shielded from medial segment
- MLCs backed off around holes in dose
- Angle of wedge reduced

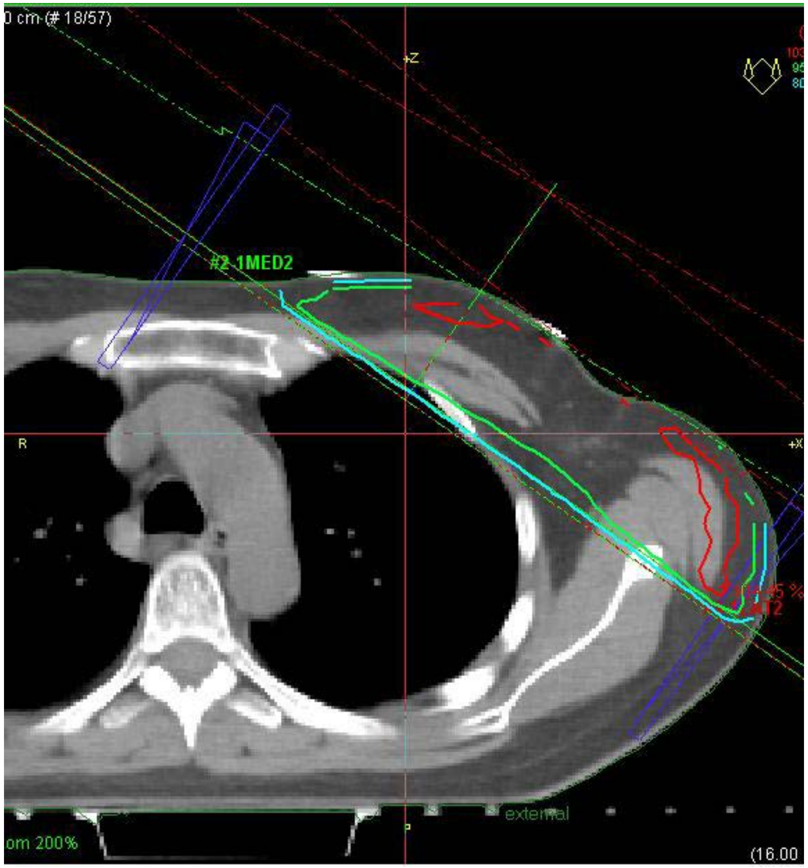
Result

- Nearly there
- Over ambitious shielding created cold spot

Final Dose at Central Axis

- Good coverage
- Minimal hot spots
- No holes in dose

Final Dose at Superior End



- Still some 103%
- But ok

Final Dose at Inferior End

- Good cover
- Hot spots gone

Inverse Planning

Why use IMRT?

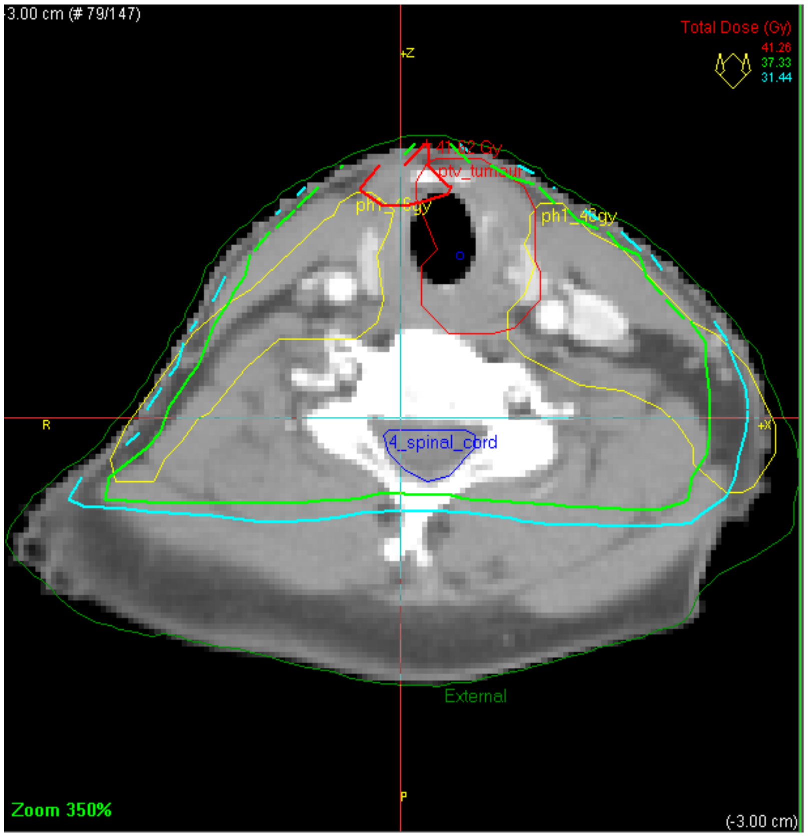
- Improve conformity with target dose, e.g. prostate cases with hip prosthesis
- Reduce irradiation of normal tissues e.g. parotid glands and spinal cord in head and neck cases
- Facilitate dose escalation e.g. prostate and head and neck cases
- Treat concave structures to a high dose, for example, nasopharyngeal cases

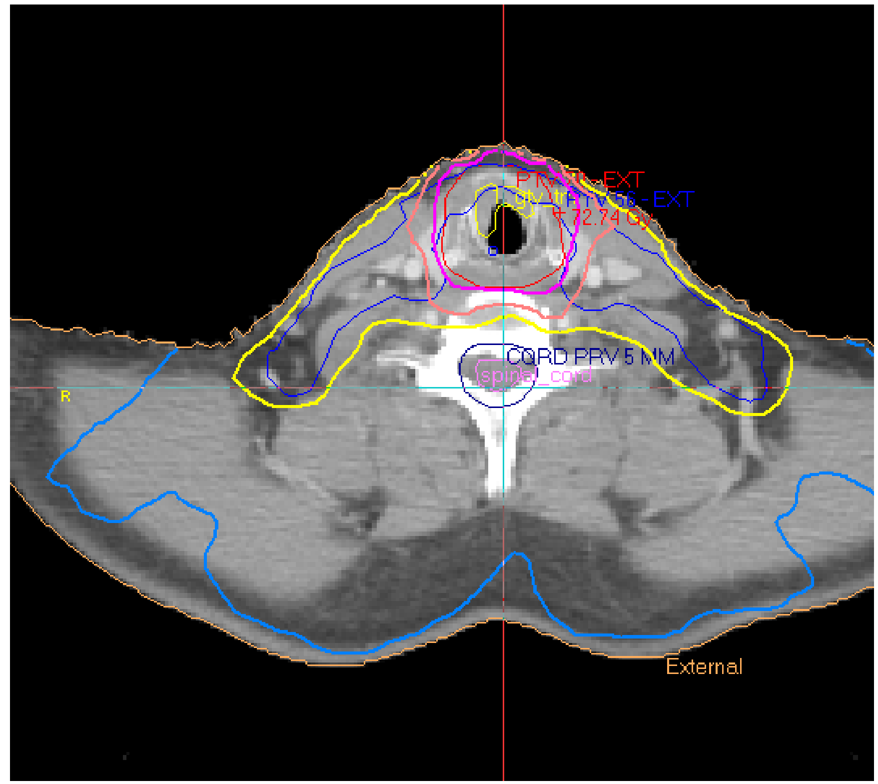
Dosimetric merits of IMRT

- IMRT provides dosimetric advantages over conventional 3DCRT treatments by using non-uniform beam intensity patterns.

- Whether this leads to a biological and therefore clinical benefit for the patient is not clearly understood as yet in all sites

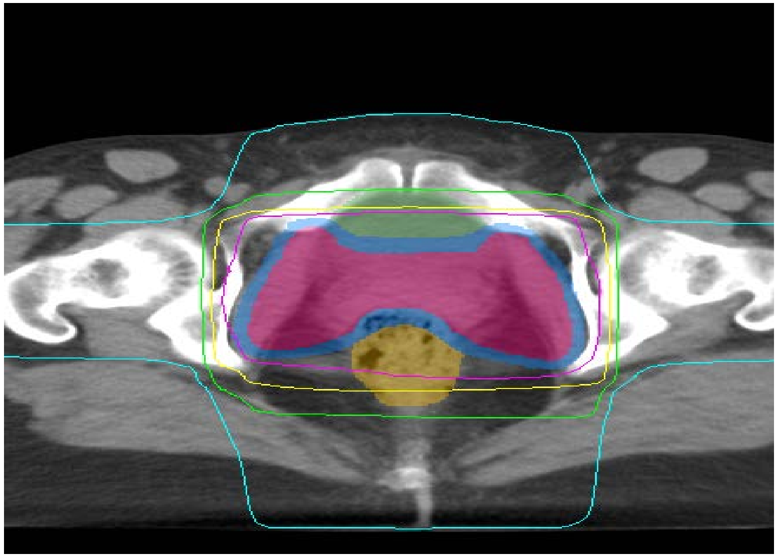
Straight Lats and IMRT Plan

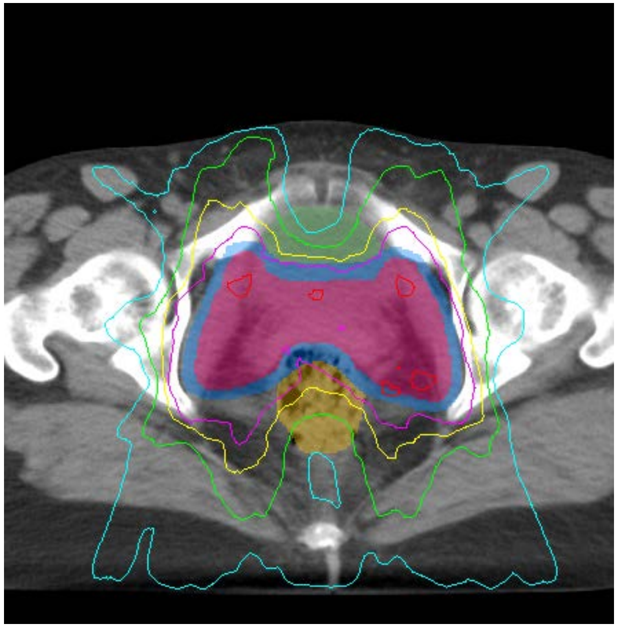




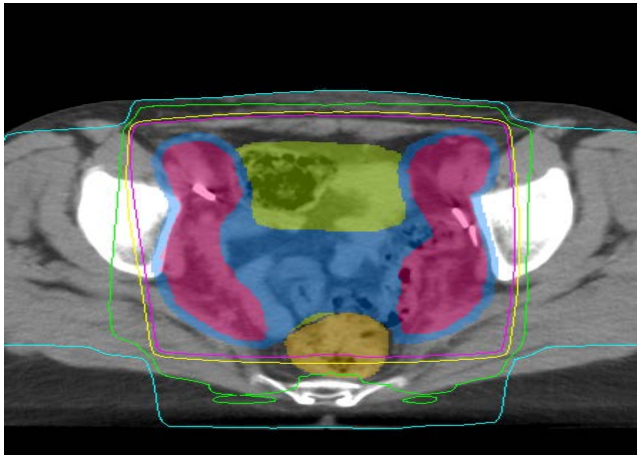
ℨO

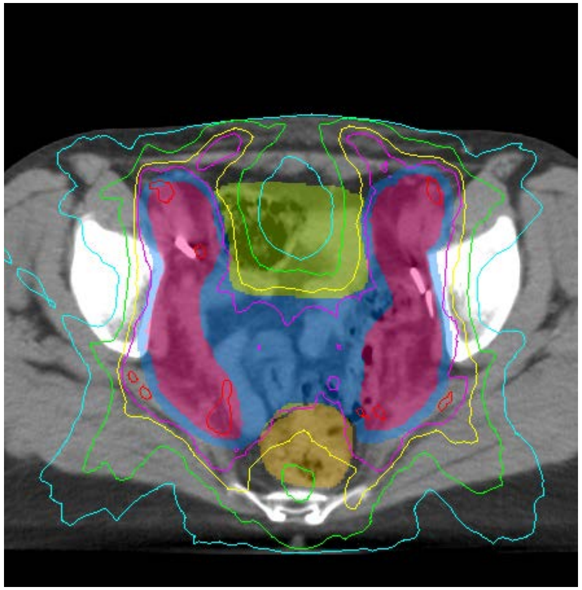
3DCRT vs. IMRT





3DCRT vs. IMRT





Inverse Planning

Some steps in the planning process remain the same:

- CT data required for electron density map
- Image Registration
- Target Delineation (Increased complexity)
- OAR delineation (Increased complexity)
- Refers to ICRU Report No. 83 for target homogeneity
- Dose Volume Constraints for OARs that are non-uniformly irradiated need some consideration

Inverse Planning

- For each planning target volume (PTV) the planner enters the desired criteria for the plan, such as:
  - ➢ Maximum dose
  - ➢ Minimum dose
  - ➢ Dose-volume histogram/Constraint table: 'hard' or 'soft'/cost functions

- For each OAR the planner enters the following criteria:
  - ➢ Desired limiting dose
  - ➢ Dose-volume histogram.

Inverse Planning

- For each IMRT plan the planner may also be expected to stipulate:
  - Beam Energy (Usually 6 MV is standard)
  - Fixed Field or Rotational
  - Number of beams (Usually 7 or 9 if fixed,)
  - Number of iterations (attempts)

- TPS then calculates the pattern of beam intensity or fluence map of the treatment beams through weight optimisation

- Several modifications of parameters may be needed to achieve an optimal or best case plan

Advantages: Inverse Planning

- Inverse planning for IMRT has several advantages over traditional forward planning:
  - Improved dose homogeneity inside the target volume and better potential for limited irradiation of surrounding OARs
  - Increased speed and less complexity in finding an optimised dose distribution.
  - Allows treatment of areas that may otherwise be impossible to treat (e.g. head and neck close to critical structures, re-treatments)

Advantages of Inverse Planning

- Can integrate boosts into a single plan (e.g. Simultaneous Integrated Boost (SIB) H&N)
- More efficient method of planning, less prone to error than multiple plans (e.g. different phases of treatment)
- Can integrate multiple targets
- ‘Dose painting’, different doses/fraction to different targets

Conclusion

In this presentation, you have learned to:

- Describe the effect of inhomogenities on dose distributions
- Differentiate between the effect of pencil beam and collapsed cone algorithms on dose distributions
- Comprehend the use of segmented fields and their applications
- Appreciate the advantages of IMRT planning and treatment over 3DCRT in selected cases

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Treatment Planning for Breast Cancer

Charles Gillham
Consultant Radiation Oncologist

St Luke's Radiation Oncology Network
Dublin, Ireland

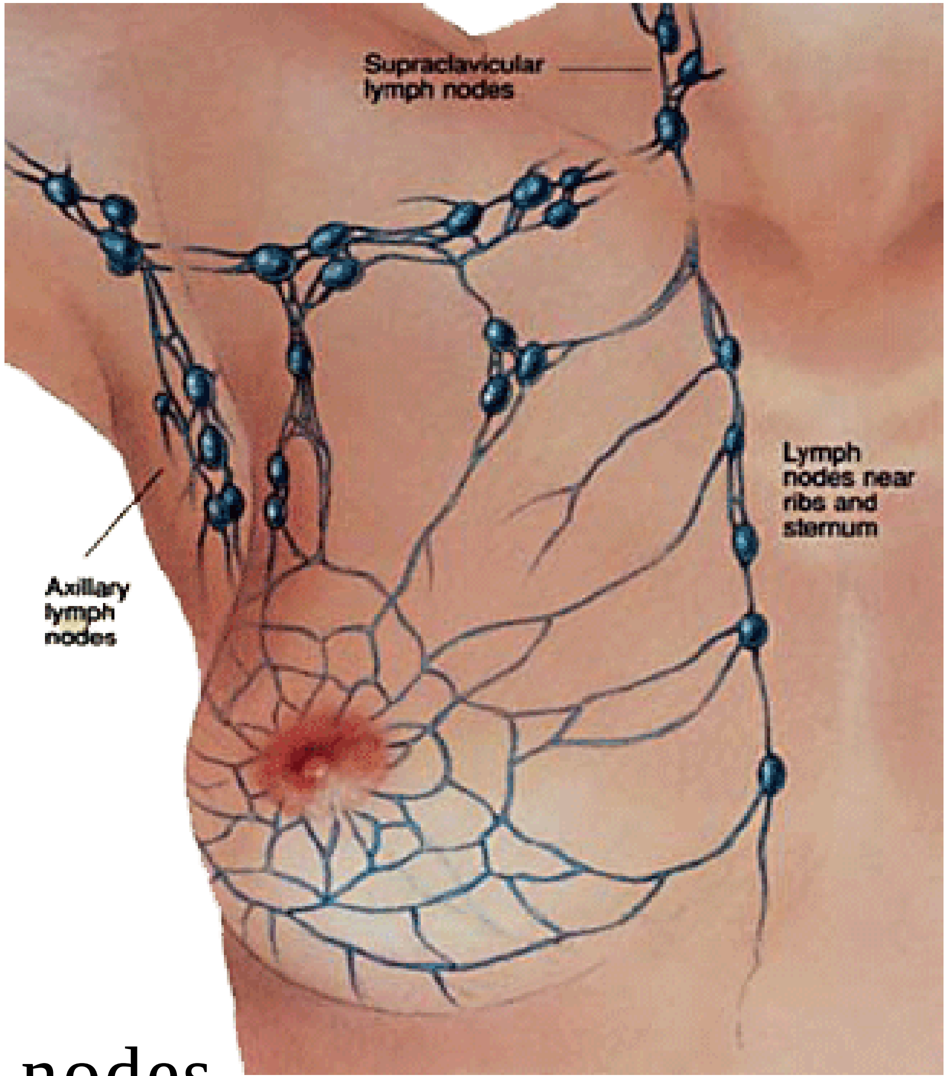
Overview

- Epidemiology
- Anatomy and patterns of spread
- Overview of treatment
- Indications for radiotherapy
- Positioning and Immobilisation
- Target volume delineation
- Toxicity

Diagnostic Work-Up

- Full history/examination
- Blood tests
- Imaging – tumour/stage dependent
- **Biopsy**

Pattern of Spread



Local
- Breast
- Chest wall
- Skin

Regional
- Axillary lymph nodes
- Internal mammary lymph nodes

Distant
- Bone.. Liver.. Lung.. Brain

Local Management

- Methods:
  - Surgery
  - Radiotherapy
- Aims:
  - Complete tumour clearance
  - Determine Prognostic Factors
  - Good cosmetic results
  - ?↑survival

Breast Conserving Surgery (BCS)

Data from 6 randomised controlled trials

Breast Conserving Surgery + Radiotherapy		Modified Radical Mastectomy	
Local Control	DFS	Local Control	DFS
80-97%	37-72%	82-98%	36-69%

→ whole breast RT following BCS accepted as standard

Consider mastectomy…

- High Tumour / Breast ratio
- Extensive DCIS
- Tumour close to nipple
- Large Breast
  - RT dose heterogeneity
- Prior breast augmentation / immediate reconstruction
  - risk of prosthesis encapsulation & fibrosis

BCS and WBI

But…

- Economics
- Convenience
- Toxicity[1]
- Cosmesis

so…can acceptable results be achieved by delivering RT to tumour bed only – partial breast irradiation (PBI)?

….and in shorter period - accelerated

Early Breast Cancer Trialists' Collabarative Group. *Lancet* 2000 355:1757-70

Rationale for Partial Breast Irradiation

Local recurrences

44-86% close to original 1˚

Smith et al. *IJROBP* 2000. 30:11-16

Kurtz et al. *IJROBP* 1990. 18:87-93

Veronesi et al. *Ann Oncol* 2001. 12:997-1003

Fisher et al. *Cancer* 91(s8):1679-87

3-4% in ipsilateral breast outside tumour bed

Accelerated PBI Methods

Interstitial brachytherapy

Intracavitary brachytherapy (Mammosite®)

Intra-operative radiotherapy

External beam radiotherapy

2-Dimensional Whole Breast Irradiation

2-D Whole Breast Irradiation

Field description:

- 2 tangential photon beams: medial entering at midline and lateral entering at the mid-axillary line.
- Exposure of >2-3 cm of the lung should be avoided
- Maximum Heart distance <1cm

Dose schedules

- 50Gy / 25 fractions
- 42Gy / 16 fractions (Canadian Trial)
- 40Gy / 15 fractions (UK START Trial)

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IMRT in breast cancer: data accumulating

Phase III Randomised Trial

WBI vs IMRT

1145 pts

End-point: late toxicity

Results

- IMRT – less telangiectasia
- No impact on breast shape

Not standard

Barnett et al. *IJROBP* 2012

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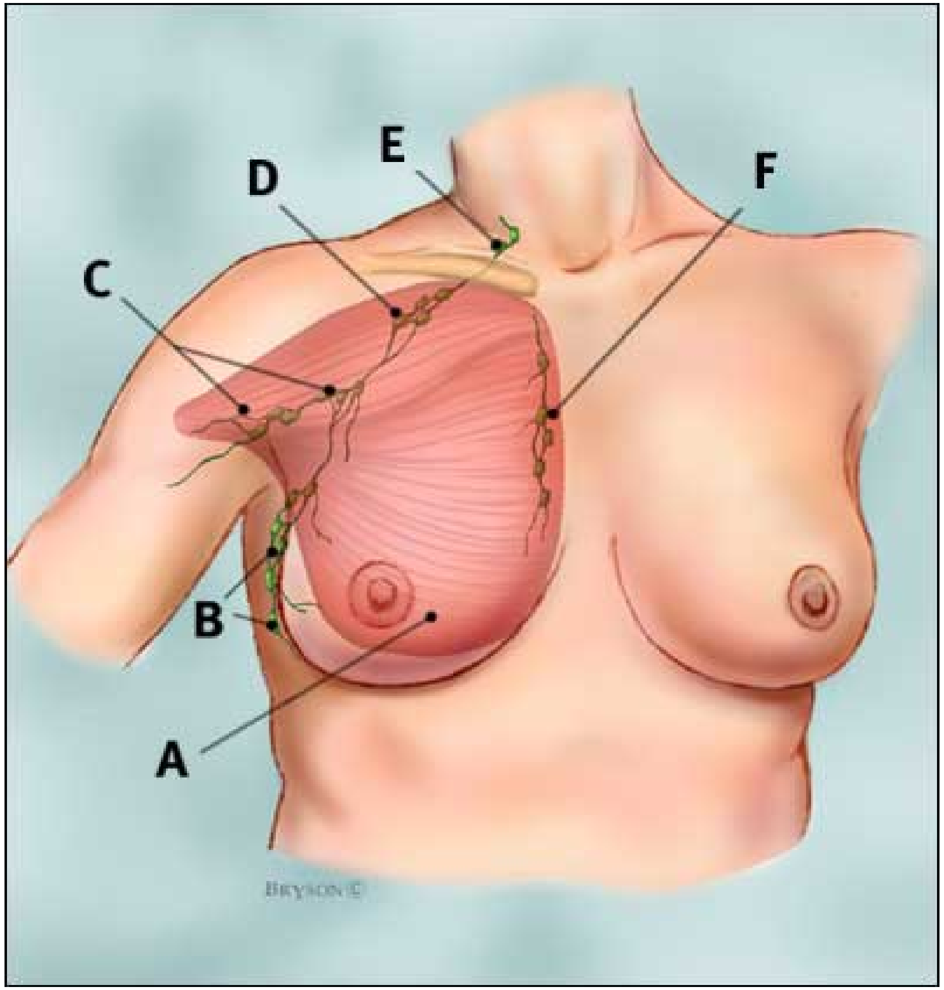
Loco-regional Nodes

Axillary (B, C, D)

Supra-clavicular regions (E)

Internal Mammary regions (F)



Kunkler IH. Breast. 2009 Oct;18 Suppl 3:S112-20.

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Supra-Clavicular RT

Rationale:

- Risk of level III or supra-clavicular involvement is ↑ if axillary LN involved

Clinical series:

- With RT, LR < 5%
- Usually offered $\geq$3 axillary LN+

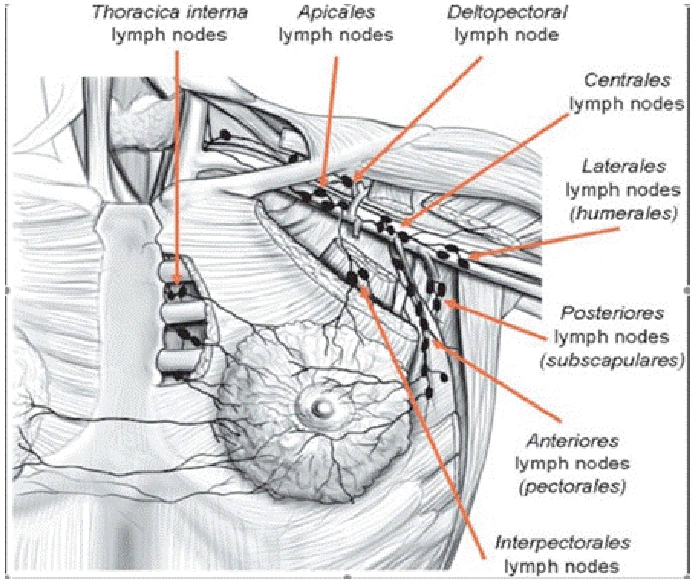
Dose schedule:

- 50Gy/25
- 40Gy/15

Technique:

- Direct anterior field, prescribed at 3cm depth (though ideally individualised)

Axillary RT



Considered if:

- Low-axillary dissection only
- No axillary dissection
- And ?alternative to surgery if SLN+ (Aramos, ASCO 2013)
- Rarely following full nodal dissection

Clinical series:

- With RT, LR < 5% but ↑toxicity

Dose schedule: < 60Gy

- 50Gy/25

Technique:

- Direct anterior field + posterior boost

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Internal Mammary RT

Rationale:

- Risk of IM involvement related to axillary involvement
- Correlated with tumour location (central / medial)

Clinical series:

- Controversial / EORTC trial results awaited

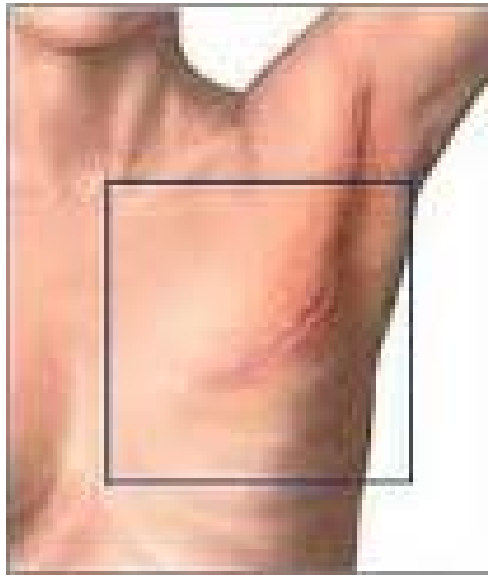
Dose schedule:

- 50Gy/25

Technique:

- Direct anterior field (but varies) – mixed photons/electrons ?IMRT

Post-Mastectomy RT



Rationale:

- ↑Risk of local recurrence for **high**-risk localised breast carcinoma

Clinical trials:

- 3 Randomised trials → survival benefit

Indications (high risk):

- pT3 (>5cm), pectoralis/skin involvement, pN+ (?no. involved – subject of Supremo trial)

Cardiac Toxicity

Retrospective review of cardiac doses with all techniques.
1997-2001 Denmark & Sweden

Mean heart dose: Denmark1.6-14.9, Sweden 1.2-22.1

Mean heart dose **L** side 6.6Gy, **R** side2.9Gy

5-14Gy increases risk cardiac toxicity by 15%; >15Gy increases risk by 108%

3 different manifestations of toxicity

1. **Pericarditis**. If >30% received 50Gy. Latency 1yr
2. **Myocardial damage** - lower mean dose. Latency 5yrs
3. **IHD**. Risk continues to increase 10yrs after RT

Chargari et al. Cardiac Toxicity in Breast Cancer Patients *Cancer Treat Rev.* **2011** Jun;37(4):321-330.
Feng et al. Development and validation of a heart atlas to study cardiac exposure to radiation following treatment for breast cacer. *Int J Radiat Oncol Biol Phys.* **2011**

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Compensating for Respiratory Motion

Deep Inspiration Breath Hold

- May lessen cardiac/lung exposure
- Under investigation
  - ➢ Who benefits most?
  - ➢ Standard for all?
  - ➢ Reproducible?

Hayden et al. *J Med Imaging Rad Oncol.* 2012
Nemoto et al. *Jpn J Radiology*. 2009

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Conclusions

Radiotherapy for breast cancer well defined.

Simple and practical 2D technical solutions

The remaining challenges are:

- The role of APBI
- IM LN irradiation
- The boost: dose & technique
- The role of conformal RT Techniques
- Motion management
- Minimising late toxicity

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Summary

- Radiotherapy part of curative treatment of many thoracic cancers
  - ➢ Pre-operative
  - ➢ Post-operative
  - ➢ Alone/Definitive
  - ➢ +/- concurrent chemotherapy

- GTV/CTV dependent on site of primary

- PTV institutional variation
  inter/intra-fraction organ motion

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Treatment Planning for Breast Cancer

Thank you

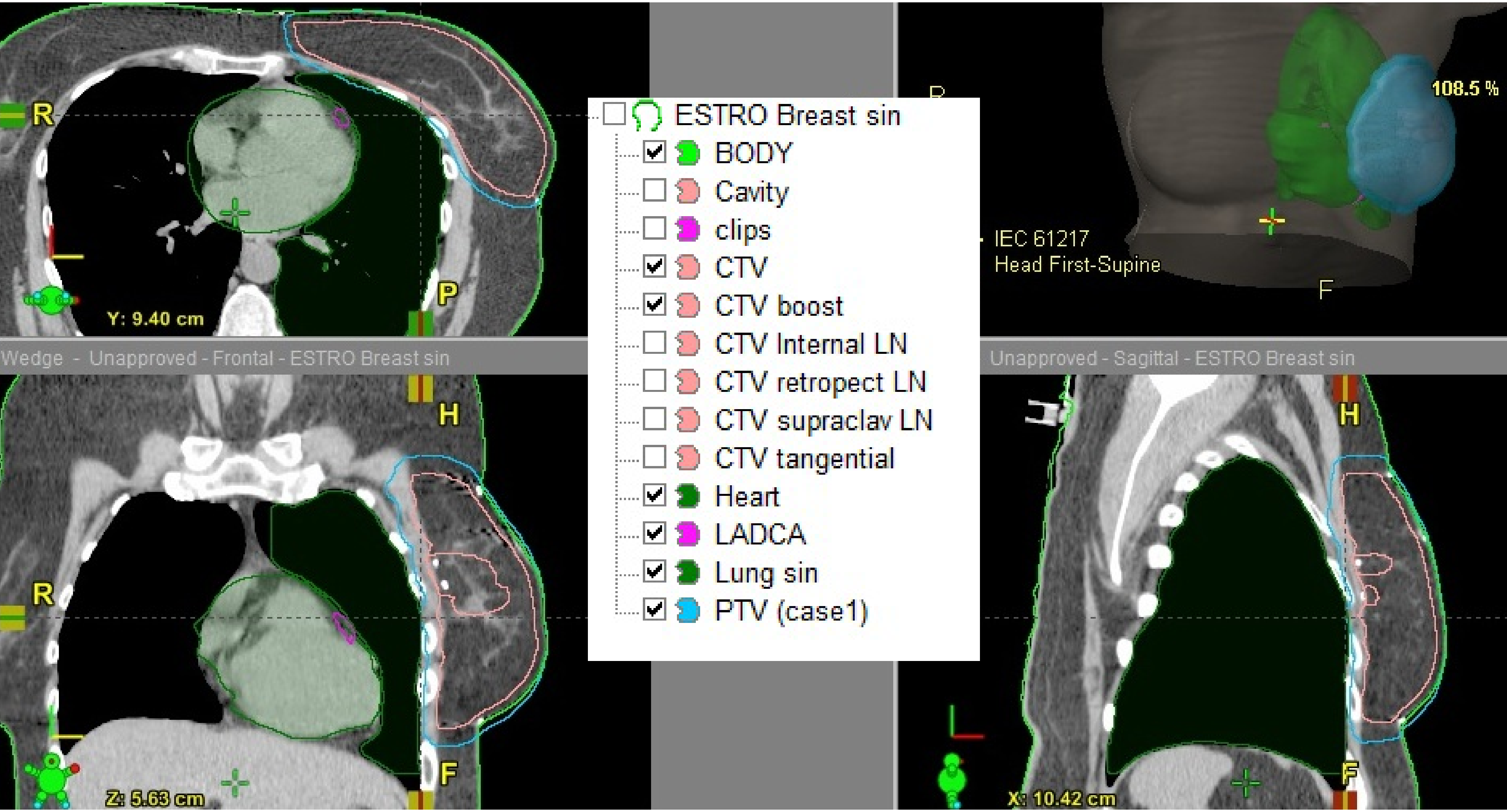
Introduction to the practical treatment planning workshop on Breast

Cases

Breast 1. Tangential breast plan with wedges

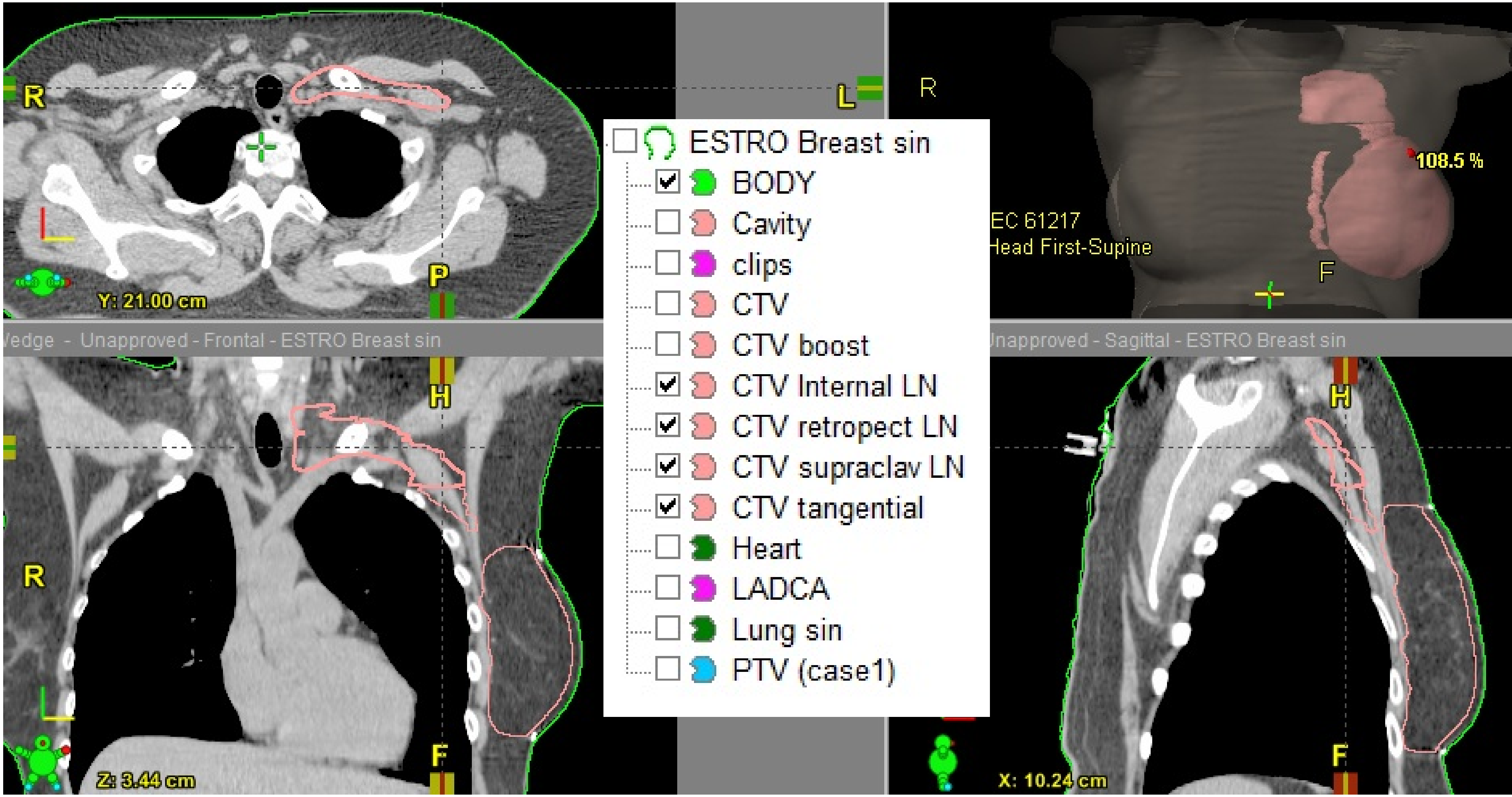
Breast 2. Including lymph nodes

Breast 1



R
Y: 9.40 cm
P
Wedge - Unapproved - Frontal - ESTRO Breast sin
H
R
F
Z: 5.63 cm
ESTRO Breast sin
BODY
Cavity
clips
CTV
CTV boost
CTV Internal LN
CTV retropect LN
CTV supraclav LN
CTV tangential
Heart
LADCA
Lung sin
PTV (case1)
108.5 %
IEC 61217
Head First-Supine
F
Unapproved - Sagittal - ESTRO Breast sin
H
F
X: 10.42 cm

Breast 2



R
L
P
Y: 21.00 cm
ESTRO Breast sin
BODY
Cavity
clips
CTV
CTV boost
CTV Internal LN
CTV retropect LN
CTV supraclav LN
CTV tangential
Heart
LADCA
Lung sin
PTV (case1)
R
108.5 %
EC 61217
Head First-Supine
F
Vedge - Unapproved - Frontal - ESTRO Breast sin
Unapproved - Sagittal - ESTRO Breast sin
H
R
F
Z: 3.44 cm
H
F
X: 10.24 cm

Overall aim

To familiarise participants with the main planning concepts for breast cancer, including:

- Where to put the isocenter
- How to find optimal beam angles
- How to find appropriate wedges and beam weighting
- Where to put the isocenter and appropriate beam angles for cases where lymph nodes are included.
- Compromises between target and OAR.
- How to further improve the treatment plan

Dose Volume Constraints

CTV coverage

Anatomical structure	Dmin	Dmax Vol 98%	Dmax Vol 100%	
CTV breast	95%	107%	110%	2 cm^3 ≤ 110%*
CTV lymph nodes	90%	107%	110%	2 cm^3 ≤ 110%

* 2 cm^3 of the structure may receive above 110% of the dose

Organ at Risk

DVH limits	V40 Gy	V35 Gy	V20 Gy
Heart	5%		10%
LADCA			0%
Ipsilateral lung Breast including lymph nodes			35%
Ipsilateral lung Breast irradiation			25%
Spinal cord	Dmax 48 Gy		
Dmax outside CTV	Dmax 108 %		

DVC from the Danish Breast Cancer Group (DBCG)
Prescribed dose: 2Gy x 25 fractions

Expectations

- Don’t try to create the “perfect plan”
  - That most of you come up with a solution on Breast case 1
  - That most of you start on Breast case 2
- Many of the questions asked can be answered later, so do not let the questions prevent you from moving forward with the practical treatment planning.
- Ask the teachers (principles) and/or vendor (technical) if you need help.
- We do not expect you to be able to give answers to all questions (e.g. DVC in your institution).

Follow the Guidelines

Breast 1: Tangential breast plan with wedges

We will plan this patient with tangential photon beam… …ymph nodes are not part of the target for this first case (Q1-Q3). The targe… …breast called CTV

5. Create a new plan. Name the plan 'Breas… …r initials'.

6. If necessary, choose CTV as you… …volum…

7. Place isocenter with pred… …cm la… …and the longitudinal shift defined at level of mammilla (Fi… …op left)… …predefined shifts (lat and lng) the only shift from the refe… …point th… …o be considered is the vertical shift. Find an appropriate v… …Figure 1)… …1217 coordinate system the relative shift from the refere… …nt is X(Lat) = 7, … (lng) = 9.5, Z(vrt) = 5.6. (**Q4**-Q6)

8. F… …appropriate beam angle e.g. by using BEV (Figure 3, left) or by using r… …measure the angle between the lateral and medial marker of the breast (Figure 3, right).

SAVE YOUR PLANS REGULARLY AS COMPUTER CRASHES CAN HAPPEN!

AND COPY!

Questions

Breast 1: Tangential breast plan with wedges

We will plan this patient with tangential photon beams and lymph nodes are not part of the target for this first case (Q1-Q3). The target is the breast called CTV

5. Create a new plan. Name the plan 'Breast 1_your initials'.

6. If necessary, choose CTV as your target volume.

7. Place isocenter with predefined 7 cm lateral shift and the longitudinal shift defined at level of mammilla (Figure 1 top left). With this predefined shifts (lat and lng) the only shift from the reference point that needs to be considered is the vertical shift. Find an appropriate vrt shift (Figure 1). In IEC1217 coordinate system the relative shift from the reference point is X(Lat) = 7, Y(lng) = 9.5, Z(vrt) = 5.6 (**Q4**-Q6)

8. Find an appropriate beam angle e.g. by using BEV (Figure 3, left) or by using ruler/measure the angle between the lateral and medial marker of the breast (Figure 3, right).

Questions

QUESTIONS FOR BREAST PRACTICAL

Breast 1: Tangential breast plan with wedges

Q1	What technique are you using for similar cases in your centre?	
Q2	Do you delineate OAR and CTV? Do you use PTV? What OAR are you using?	
Q3	What DVC are you using at your centre?	
Q4	**Why do we choose the vrt shift to be around 5.5 cm (consider the bottom images (Figure 1) illustrating different vrt shifts)?**	
Q5	How do you place the isocenter at your centre?	
Q6	An alternative is to place the isocenter at the center of mass (COM) of the CTV (Figure 2). Consider the pros and cons of using 1. COM and 2. predefined lateral (and lng) shifts.	
Q7	Are you using wedges for breast treatment at your centre?	
Q8	**Why are these margins used? What is included in the suggested margins?**	

DVC - Check points

12. Make an opposing field and refit the MLC

13. Calculate the dose with the two open fields only. Normalize to 100% to CTV (target) mean. Try to optimize the plan by modifying the field weights.

14. Evaluate the DVH. What DVCs are fulfilled? Put down your DVC values in the table (Table1) at the end of this document. (**Q11**)

15. Copy the treatment plan and improve the dose to the target by adding wedges. Choose an appropriate wedge angle by evaluating the dose distributions in Figure 4. (**Q12**)

16. Calculate the dose and modify the field weights and optimize your plan with the chosen wedge angle.

17. Evaluate the treatment plan in terms of DVH and isodoses. Put down your DVC values in Table1. (**Q13-Q14**)

TABLE 1

	"Expert" Open fields (14)	Student Open fields (14)	"Expert" Wedged beams (17)	Student Wedged beams (17)
CTV Dmin	84.8		87.9/89.8*	
CTV Dmax			106.6/108.5*	
CTV D2%			104.5/106.4*	
CTV Dmean	100		100/101.7*	
CTV D50%			100/101.7*	
Heart V40Gy			0/0*	
Heart V20Gy			1.1/1.1*	
LADCA V20Gy			23.4/23.4*	
Lung V20Gy			7.3/7.3*	
Global (body) Dmax	108.8		106.6/108.5*	
Comments: e.g location of under/ over dosage and the volume of the under dosage				

Table 1: *The 2 numbers corresponds to two different normalizations. The first number is when plan is normalized to 100% to target (CTV) mean.

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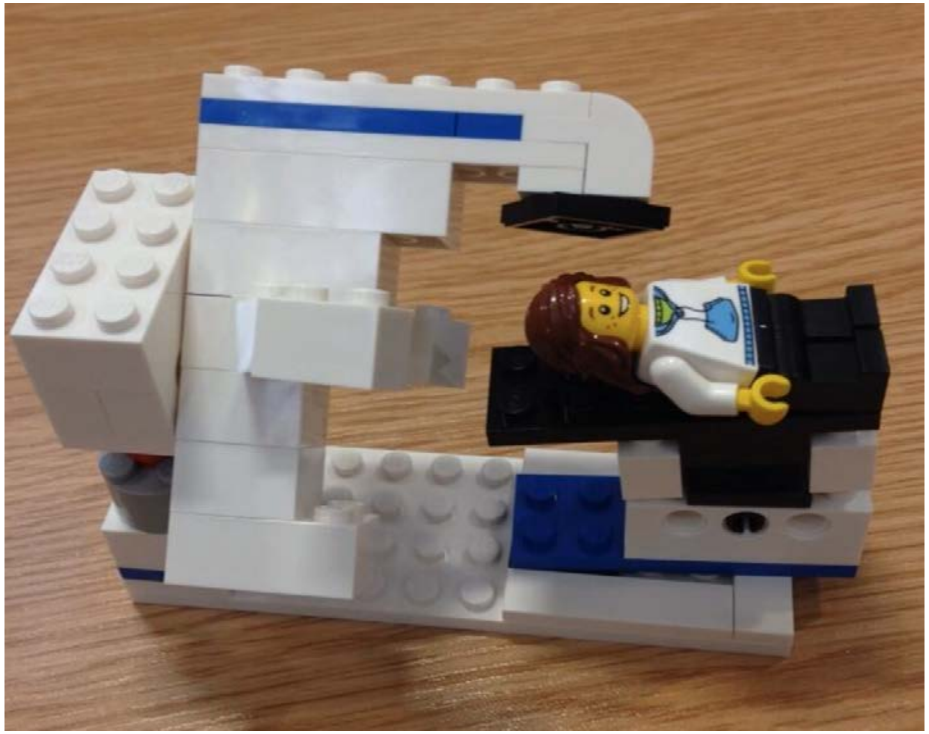
IGRT for breast cancer

Martijn Kamphuis
Department of Radiotherapy
AMC, Amsterdam

Slides mainly by:
Peter Remeijer
Department of Radiation Oncology
The Netherlands Cancer Institute

Content of the presentation

- IGRT for breast cancer:
  - Delineation
  - Margins
  - Treatment planning
  - Epi vs CBCT
  - Anatomical changes
  - Breathhold techniques



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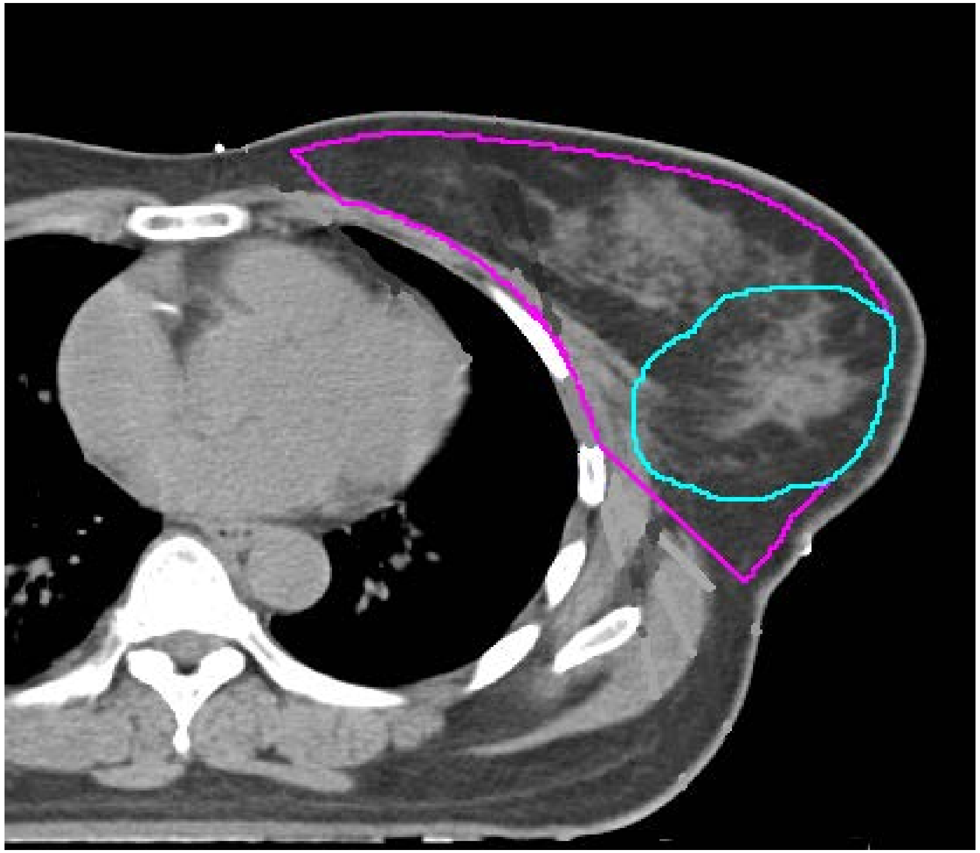
Delineation

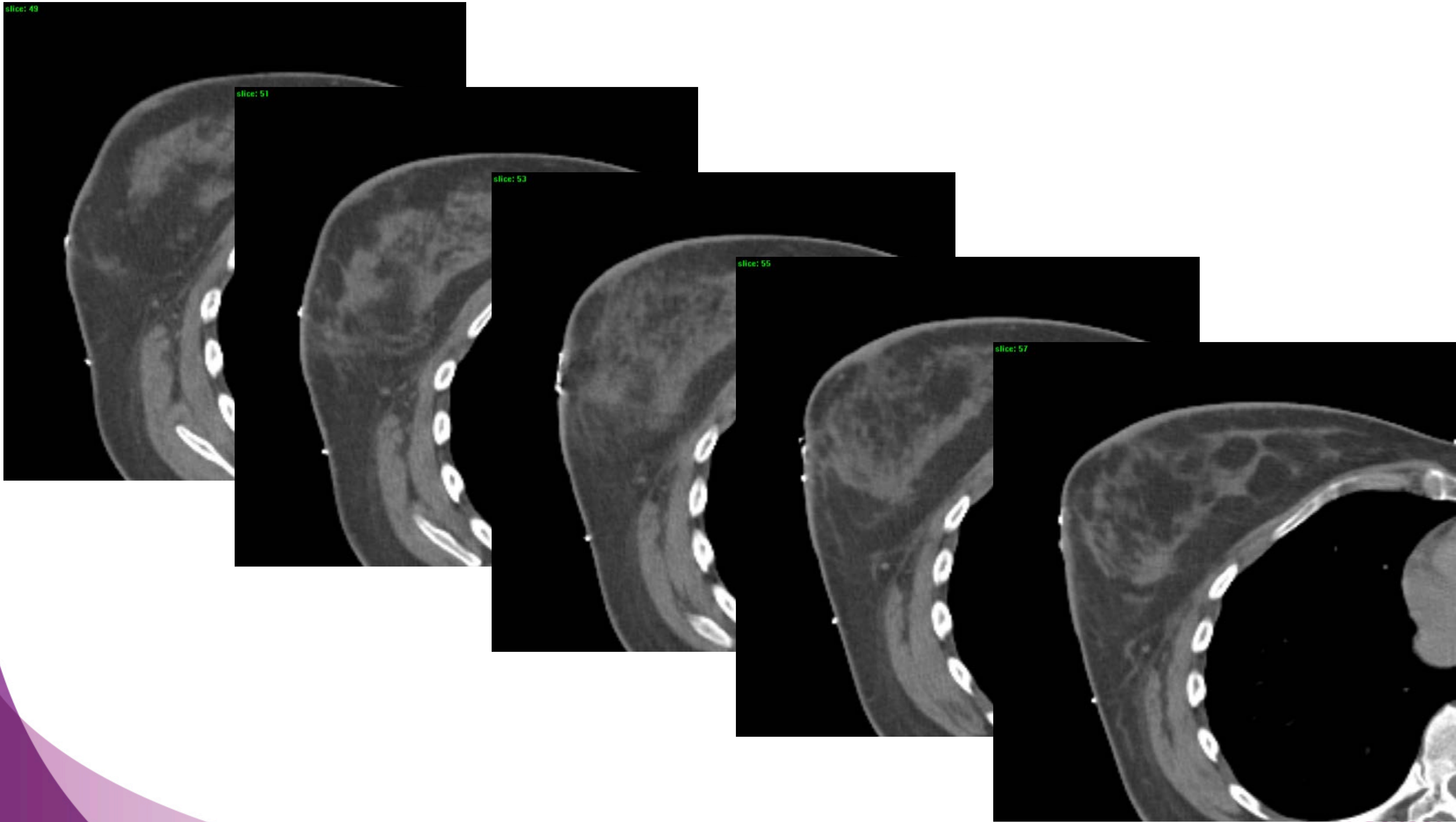
Common target volumes



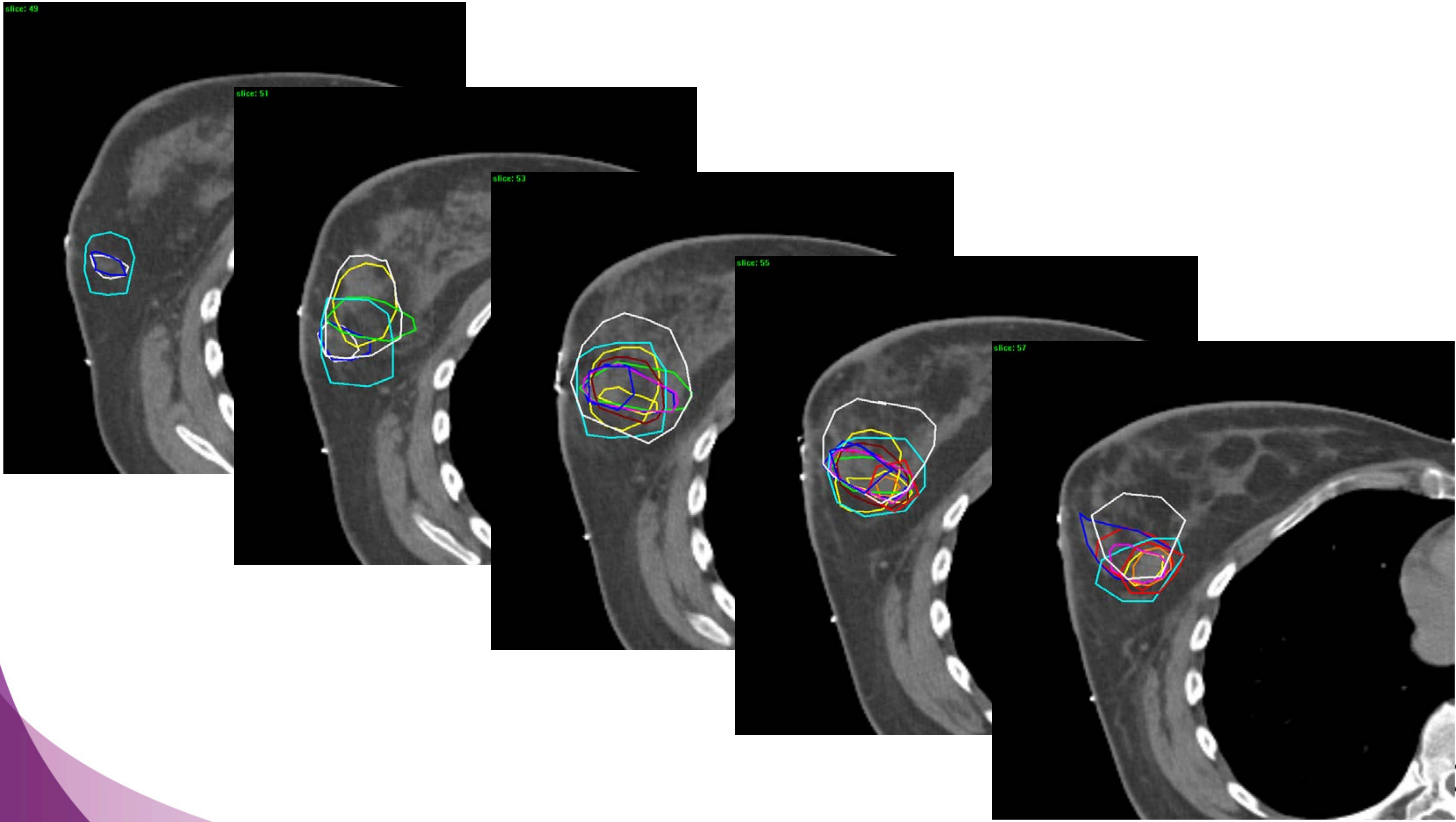
Whole breast (50 Gy)

Excision cavity (16 Gy)

Target volume delineation - variability



Target volume delineation - variability



Target volume delineation - variability

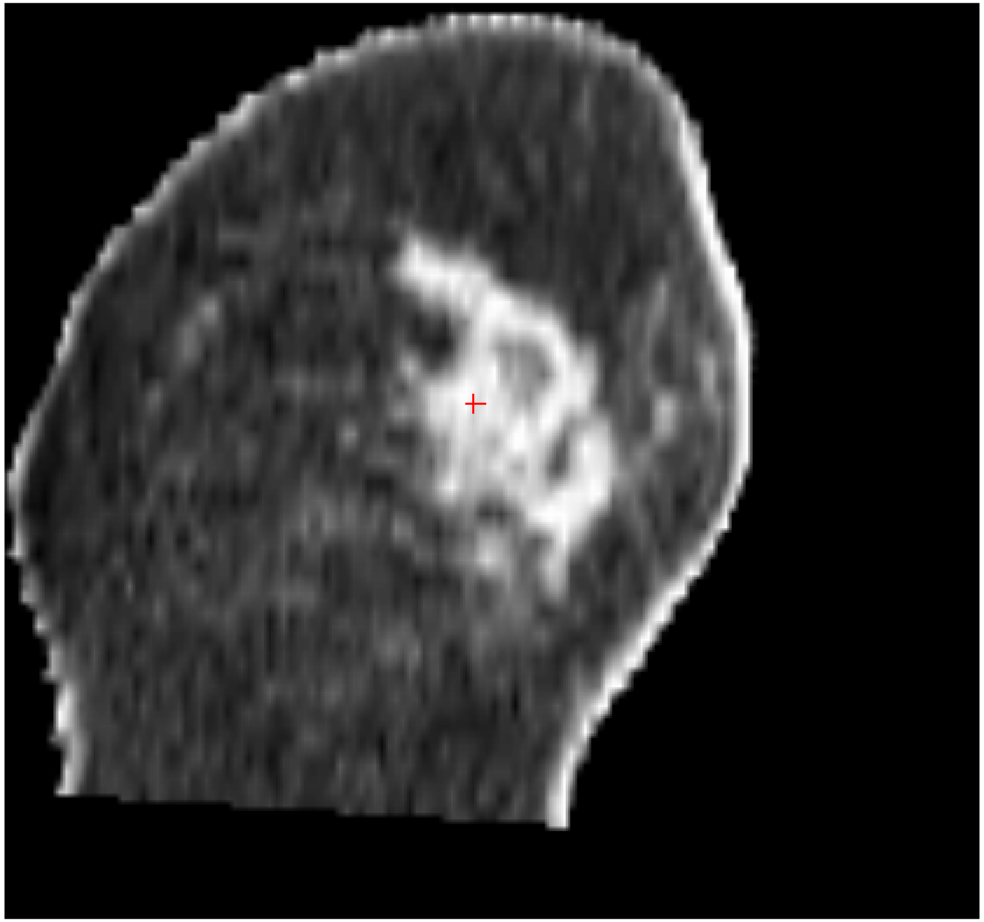
Possible causes

- Different opinion of the clinicians
- Image quality

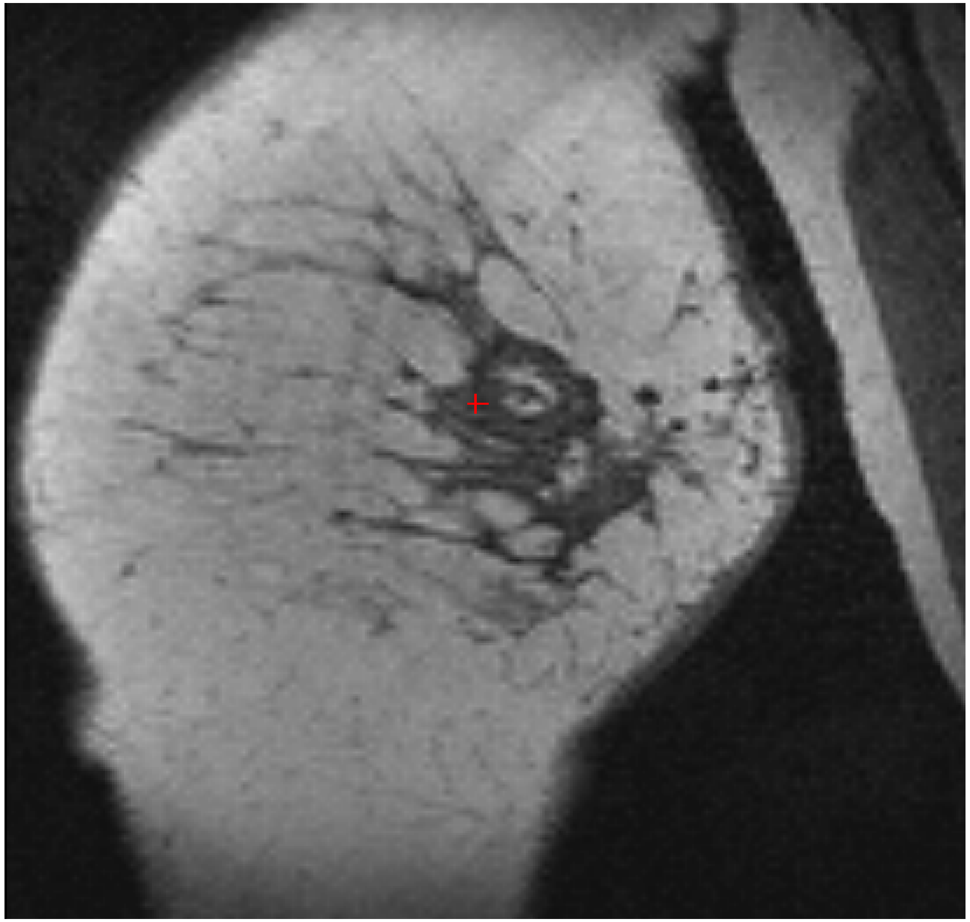
Possible solutions

- Clear protocols, good collaboration between OR, Pathology, RT
- Markers
- Fusion of pre-and post-op imaging (difficult!)
- Multiple modalities

Multiple modalities

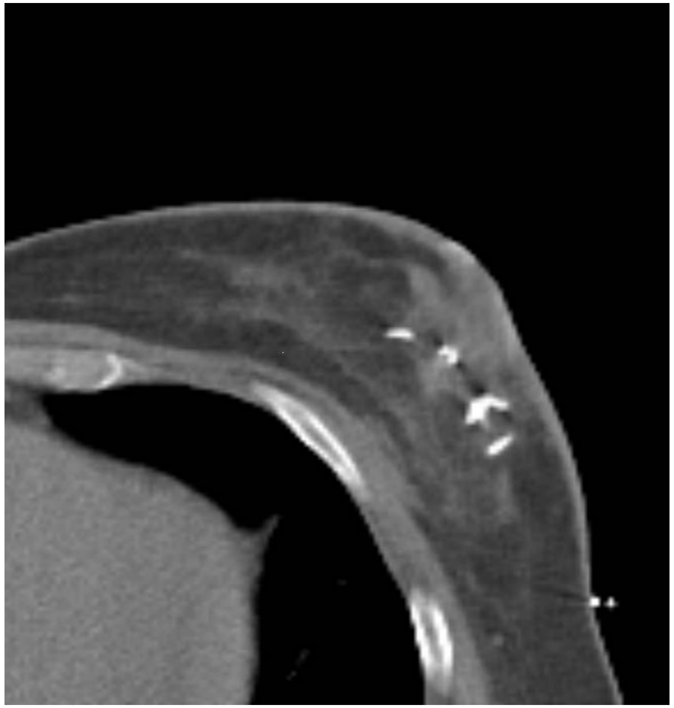


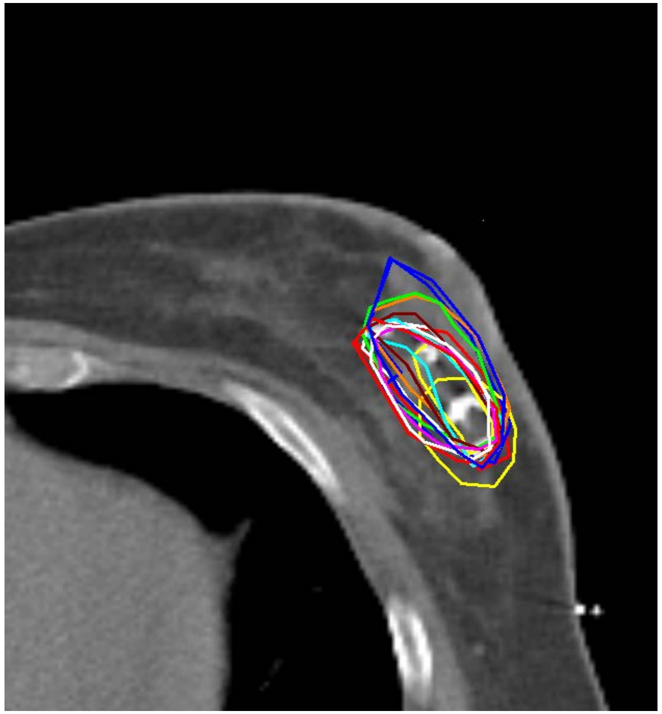
CT scan

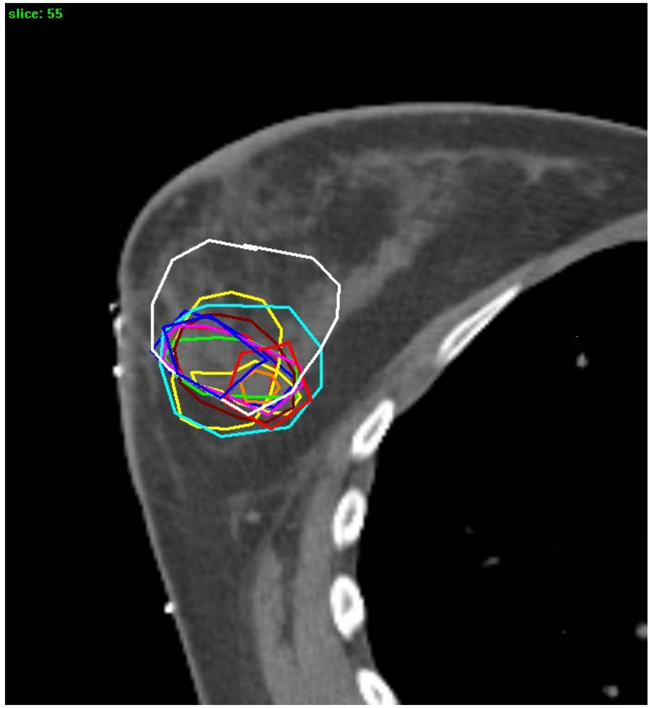


MRI scan

Use of fiducials







Target volume demarcated by markers
→ reduced delineation variability?

How good is the excision cavity – marker correlation?

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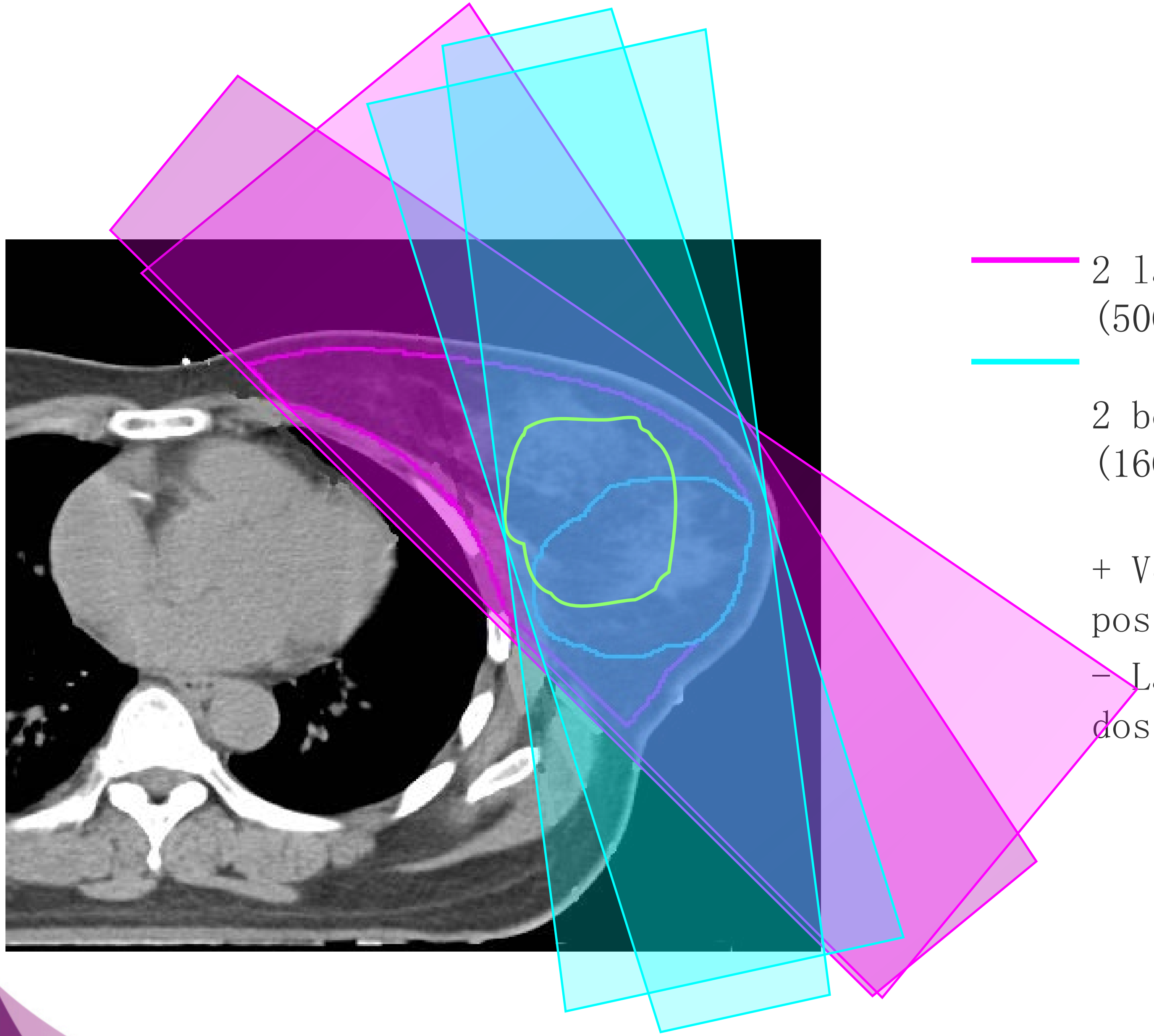
Treatment planning

Treatment planning – Typical beam set-up



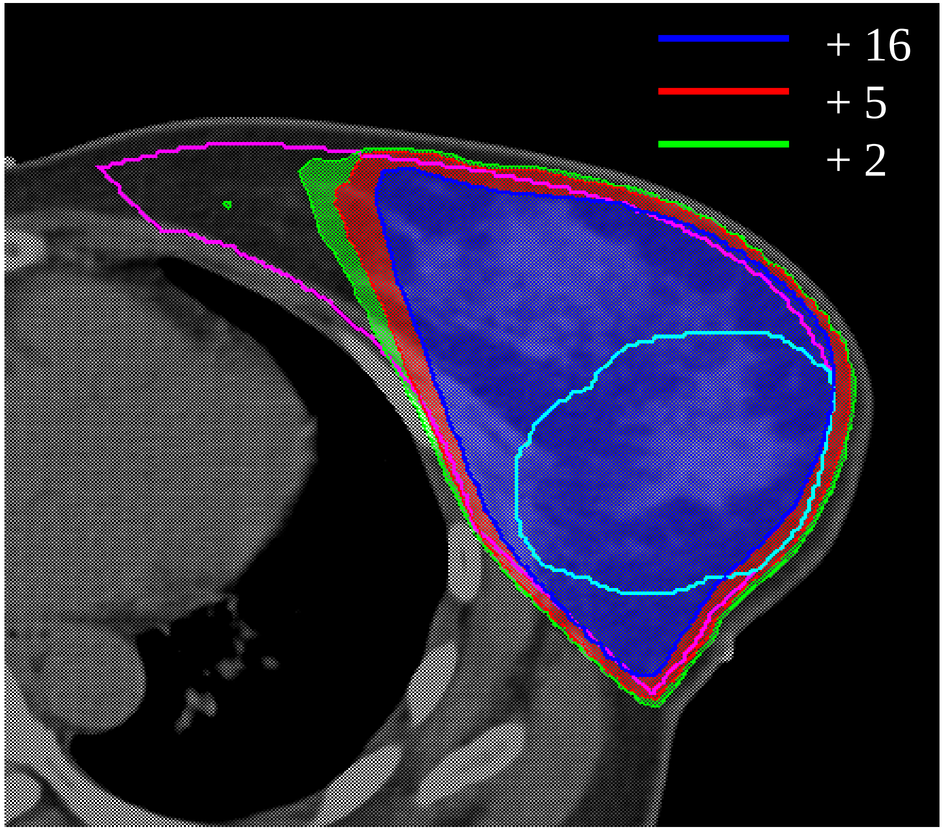
2 large fields for whole breast (50Gy)

2 boost fields for additional dose (16Gy)

+ Very insensitive to exact position of target volume

– Large volume irradiated to boost dose

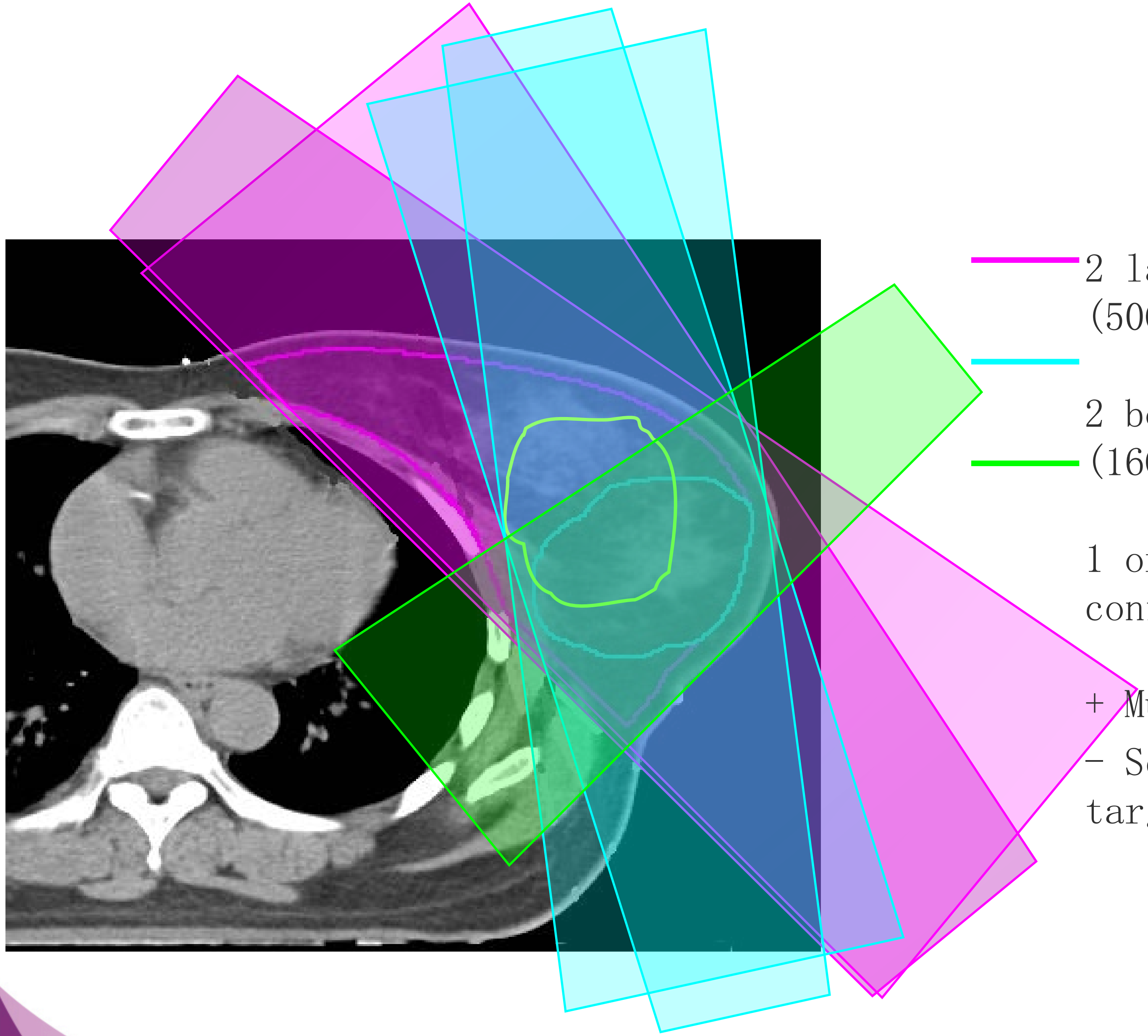
Treatment planning – Typical beam set-up



+ Very insensitive to exact position of target volume

– Large volume irradiated to boost dose

Treatment planning – Typical beam set-up



2 large fields for whole breast (50Gy)

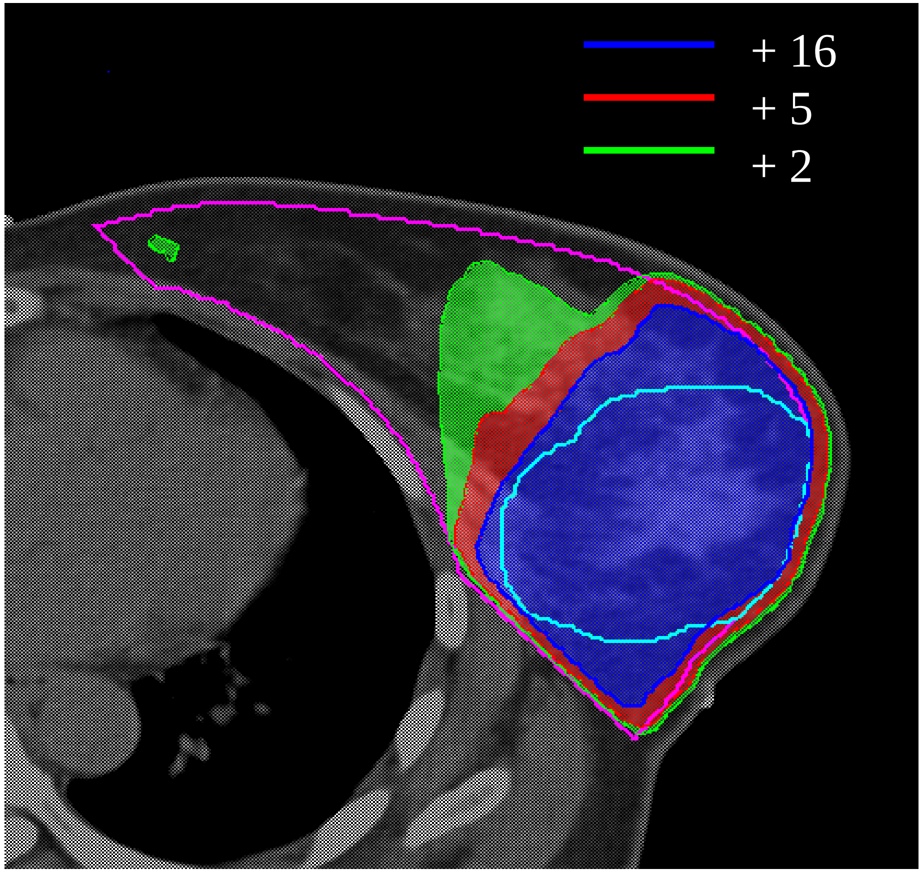
2 boost fields for additional dose (16Gy)

1 orthogonal beam to improve conformance

+ Much smaller high dose volume

- Sensitive to exact position of target volume

Treatment planning – Typical beam set-up



+ Much smaller high dose volume
- Sensitive to exact position of target volume

→ Image guidance / position verification

Margins

Margins

- Clinically used margin for breast: **0 mm!**
  - Adapted from sim-technique - it's just beam setup
  - Clearly not enough according to conventional margin ideas

- Clinically used margin for boost: 5 mm
  - Let's see if that's enough

	Systematic	Random
Delineation	2.0 mm	-
Setup	1.5 mm	2.5 mm
Shape changes	2.0 mm	2.0 mm
Total	3.2 mm	3.2 mm

  - Margin: 2.5 * 3.2 + 0.3 * 3.2 = **9 mm**

Because of background dose

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Unsufficient margins?

- So why is this not leading to lots of local recurrences?

Margins

- For the whole breast
  - It’s a CTV. Small underdosage leads to an even smaller risk of recurrence
  - Ongoing debate whether it’s even necessary to treat the whole breast

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Margins

- For the boost
  - ➢ It's a boost with a 50 Gy background dose, so severe underdosage will not occur
  - ➢ Conformity is not very good with current planning techniques → effectively the margin is bigger
  - ➢ Excision cavity / CTV margin is usually large → compensates for small PTV margin

Epi vs CBCT

Treatment – EPID versus CBCT verification

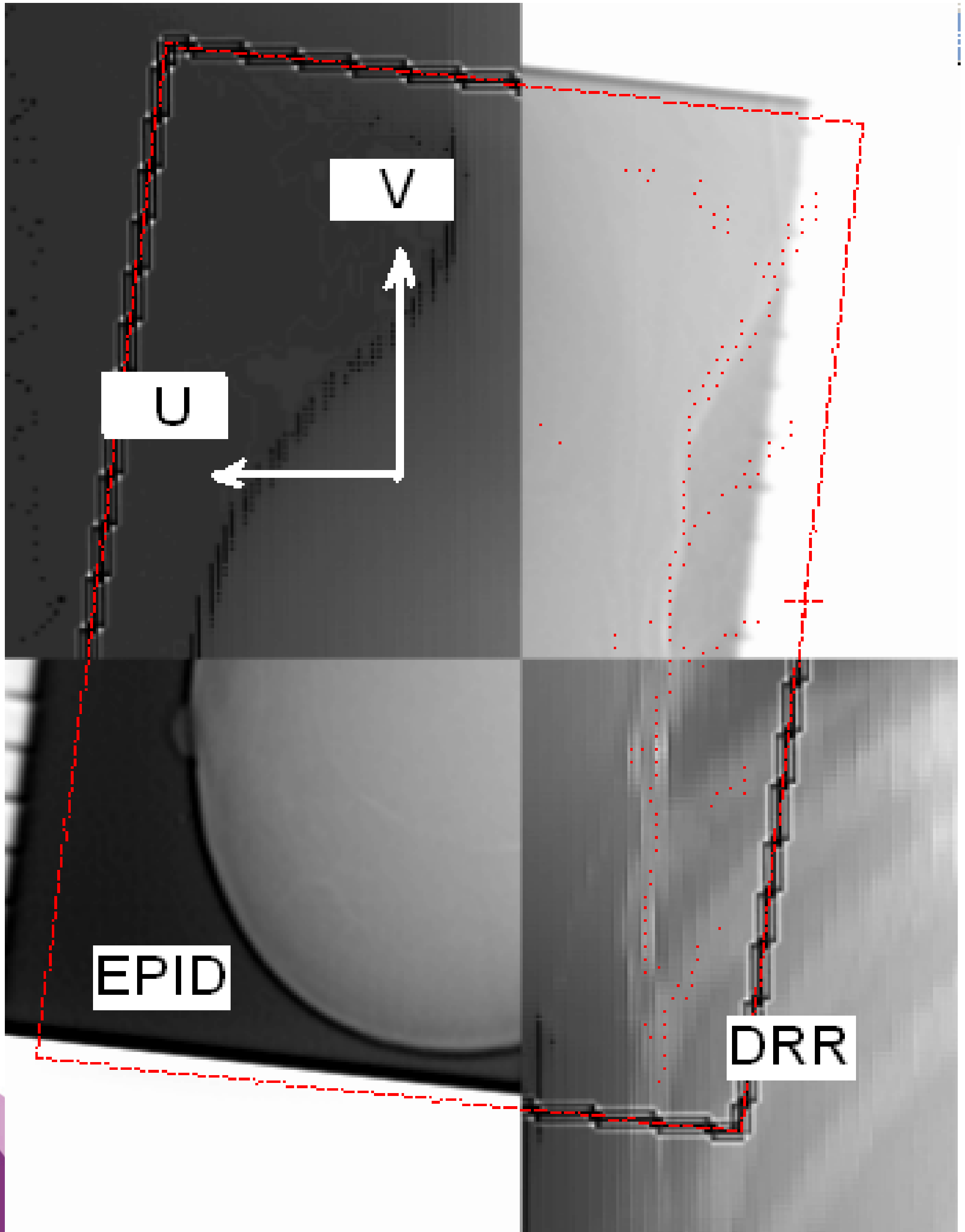
Acquire simultaneous data

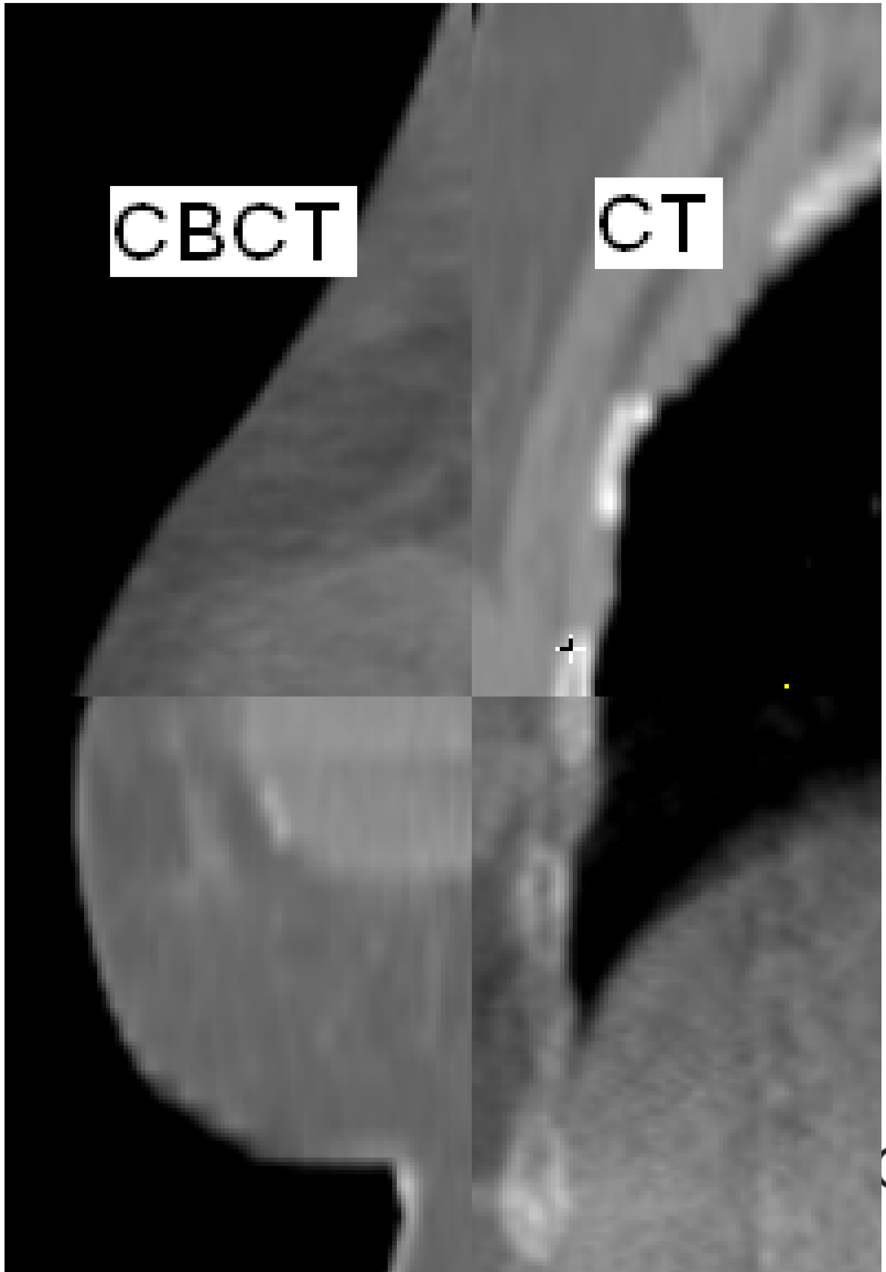
Analyze differences

Correction protocol

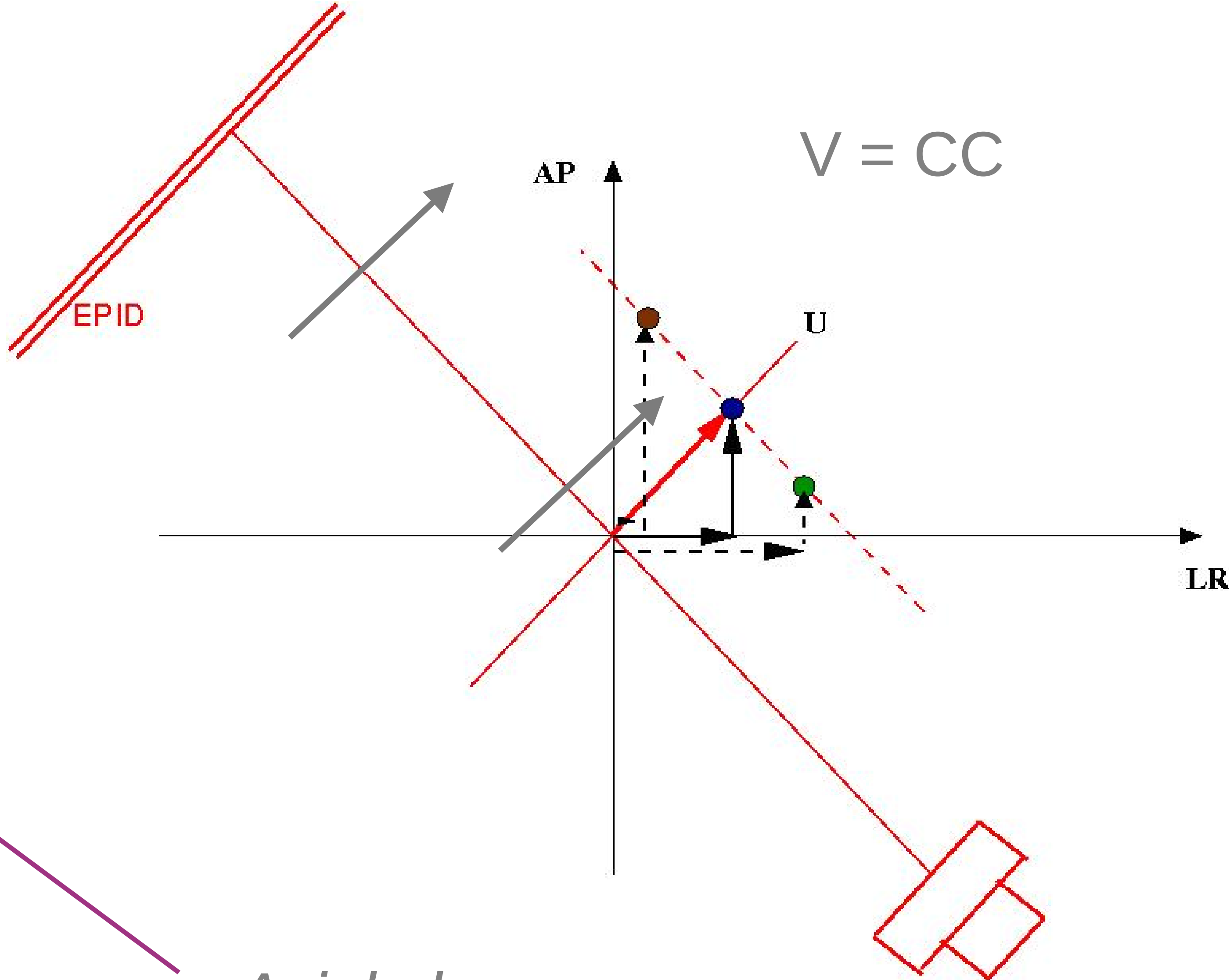
What margin do we need

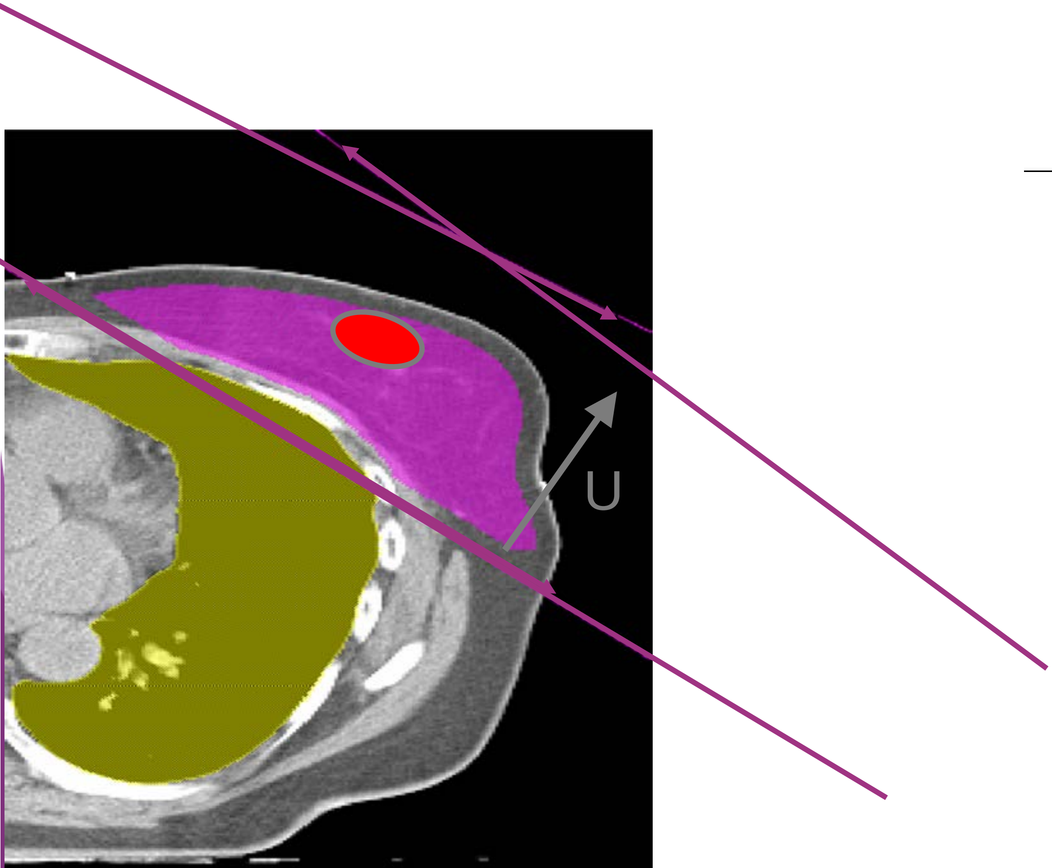
Image quality EPID & CBCT





Coordinates (LR, AP, CC versus U, V)





Axial plane

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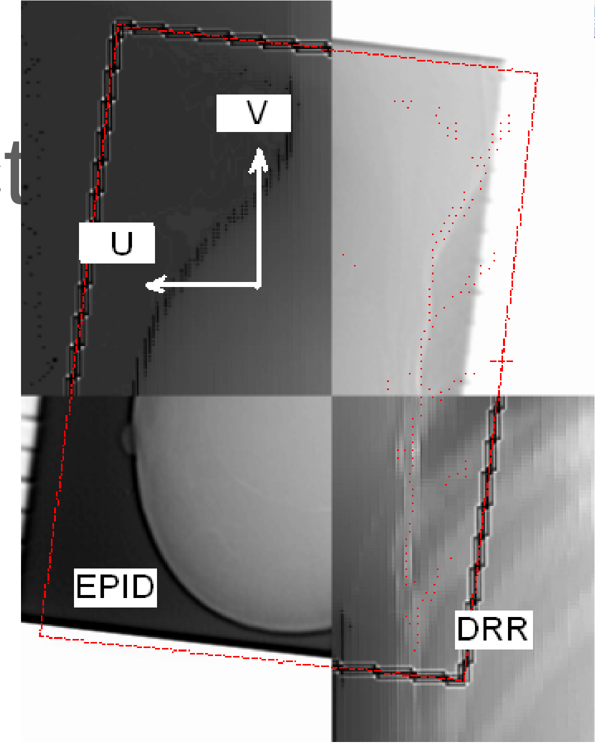
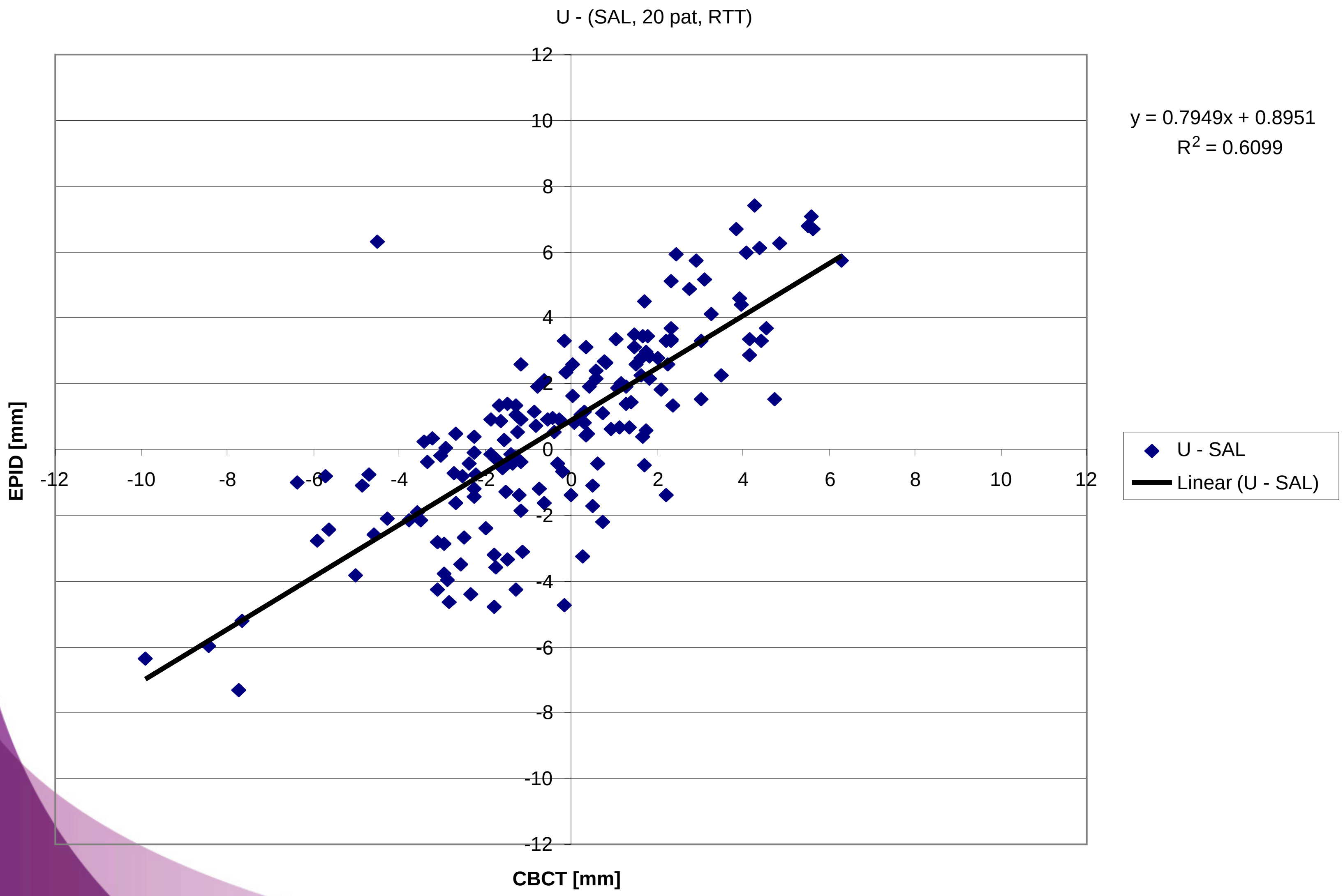
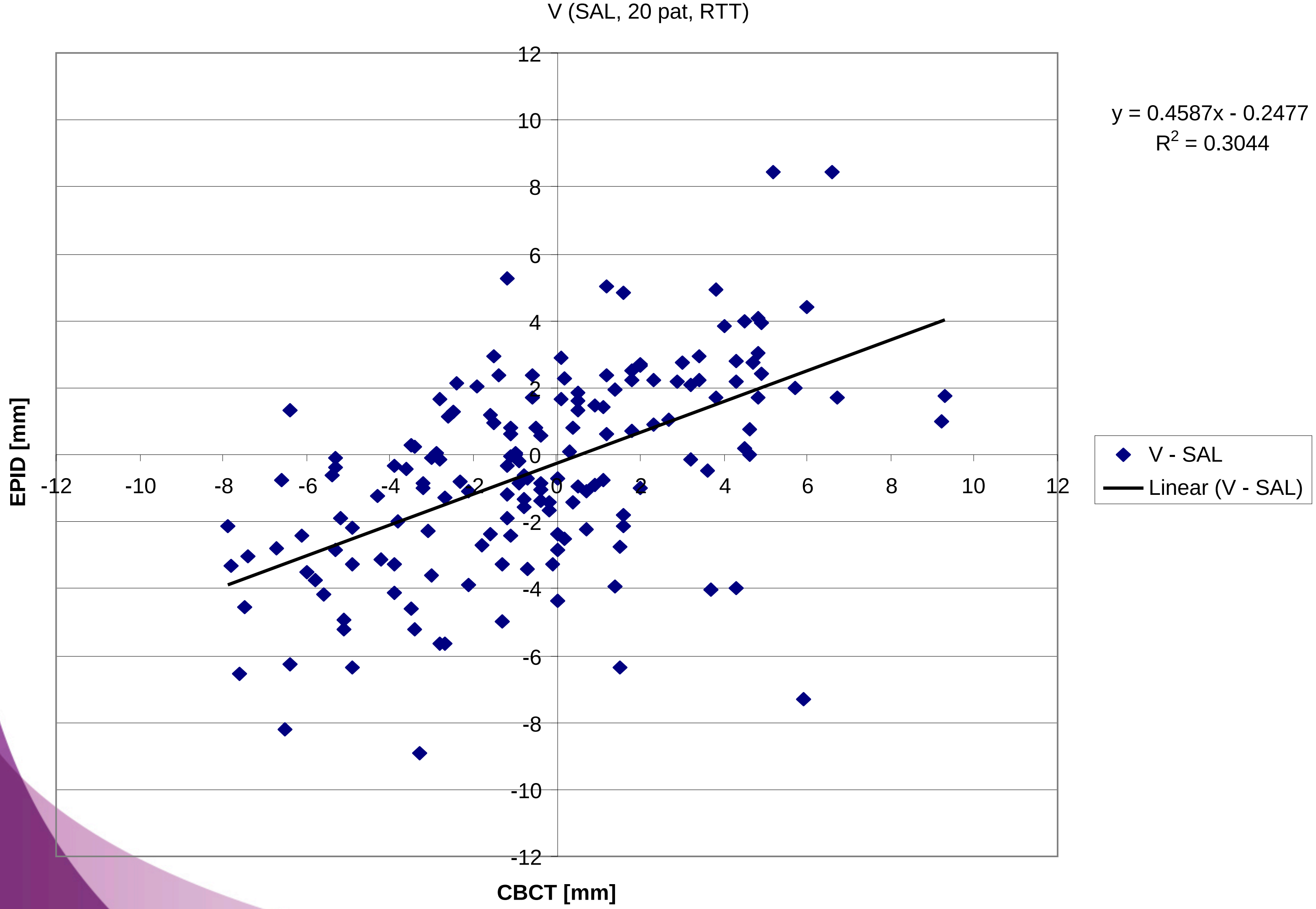
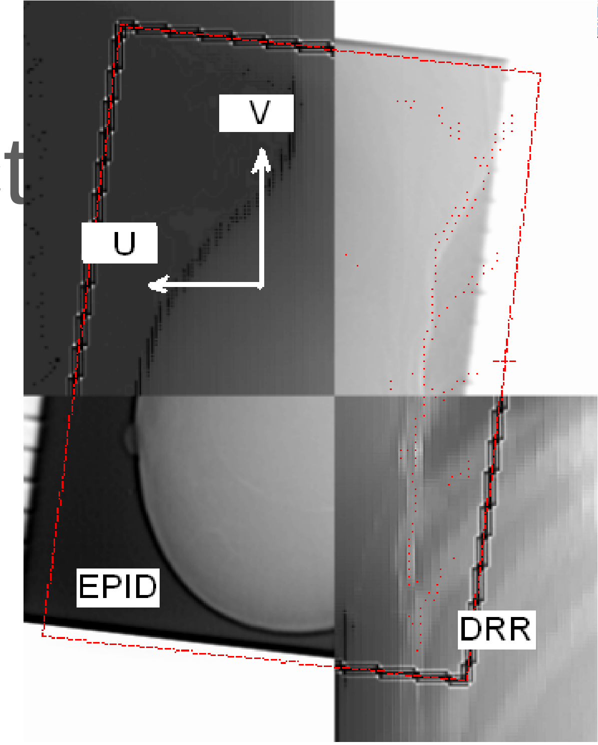
Correlation in the U – direct





Correlation in the V – direct



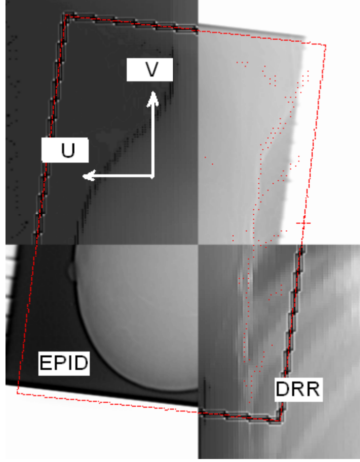


Results

- The slopes of linear regression:
  - U → 0.82
  - V → 0.43

– EPID underestimates setup errors in the V direction more than in the U direction.

Summary



- EPID registration underestimates bony anatomy setup error in breast cancer patients.
- Using EPID instead of CBCT therefore requires larger margins

Anatomical changes

Seroma changes

- Possibly occurs after breast sparing surgery
- Fluid in excision cavity

- Boost is generally based on this seroma volume

T. Alderliesten, S. den Hollander[1], J. Yang[2], P. Elkhuizen[1], A. van Mourik[1], C. Hurkmans C v. Vliet

Seroma changes

- Seroma shrinkage

Planning CT

Repeat CT (during treatment)

Seroma changes

- Comparison of three techniques
  - SEQ: Sequential boost
  - SIB: Simultaneously integrated boost
  - SIB-ART: SIB + replanning (Adaptive RT)

Planning CT

Repeat CT (during treatment)

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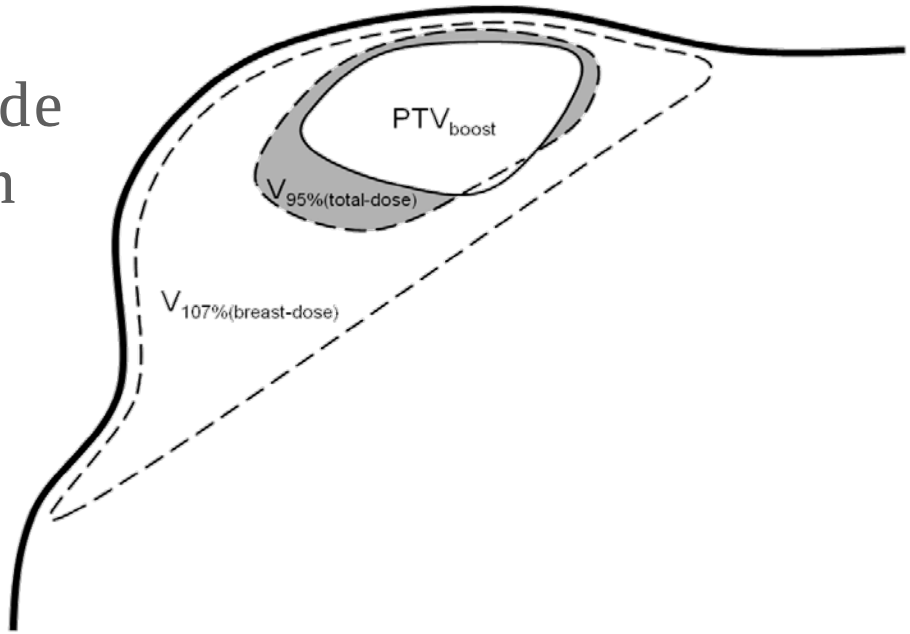
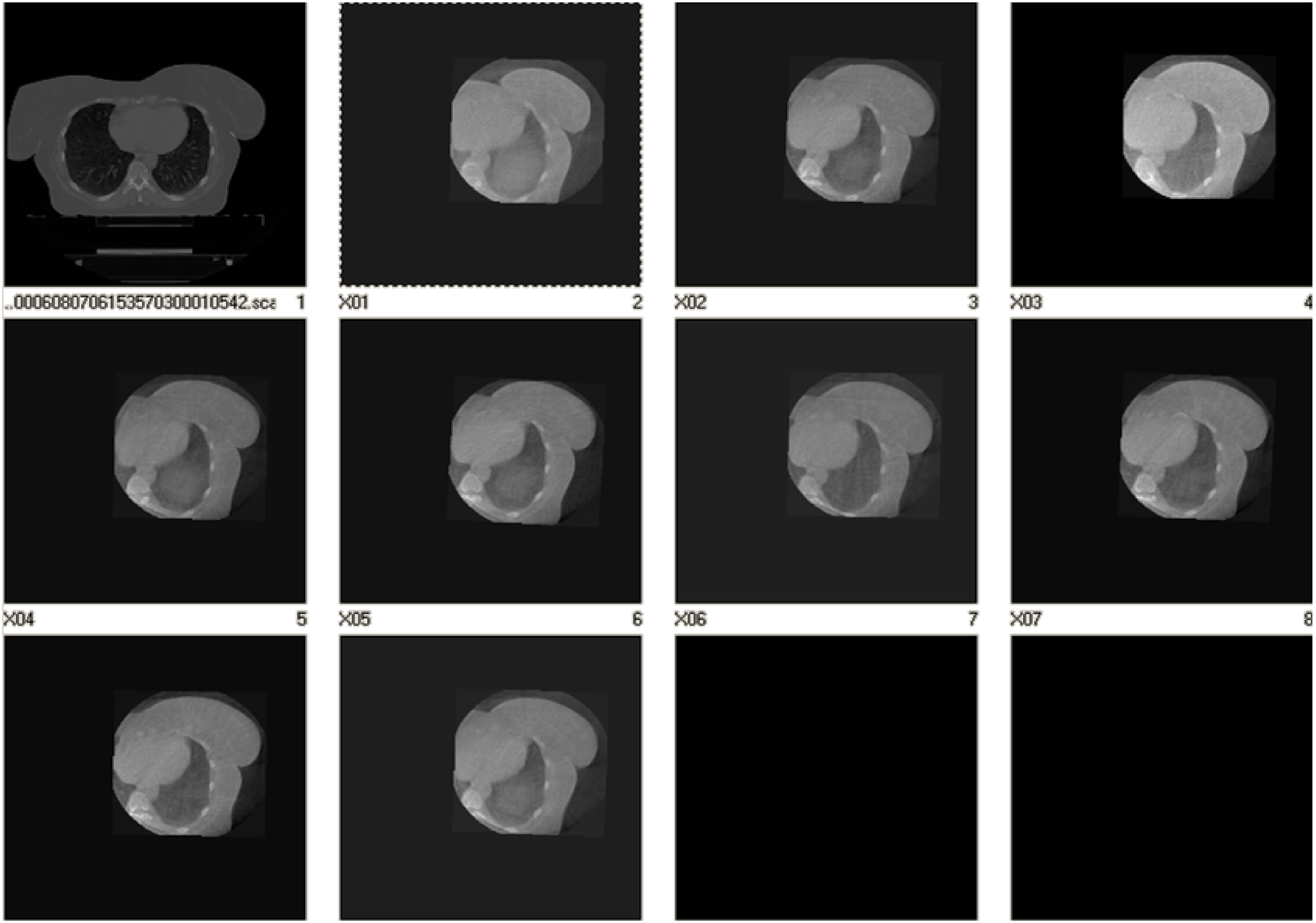
Seroma changes

- Excess volume, i.e. volume outside the boost volume that gets a high boost dose



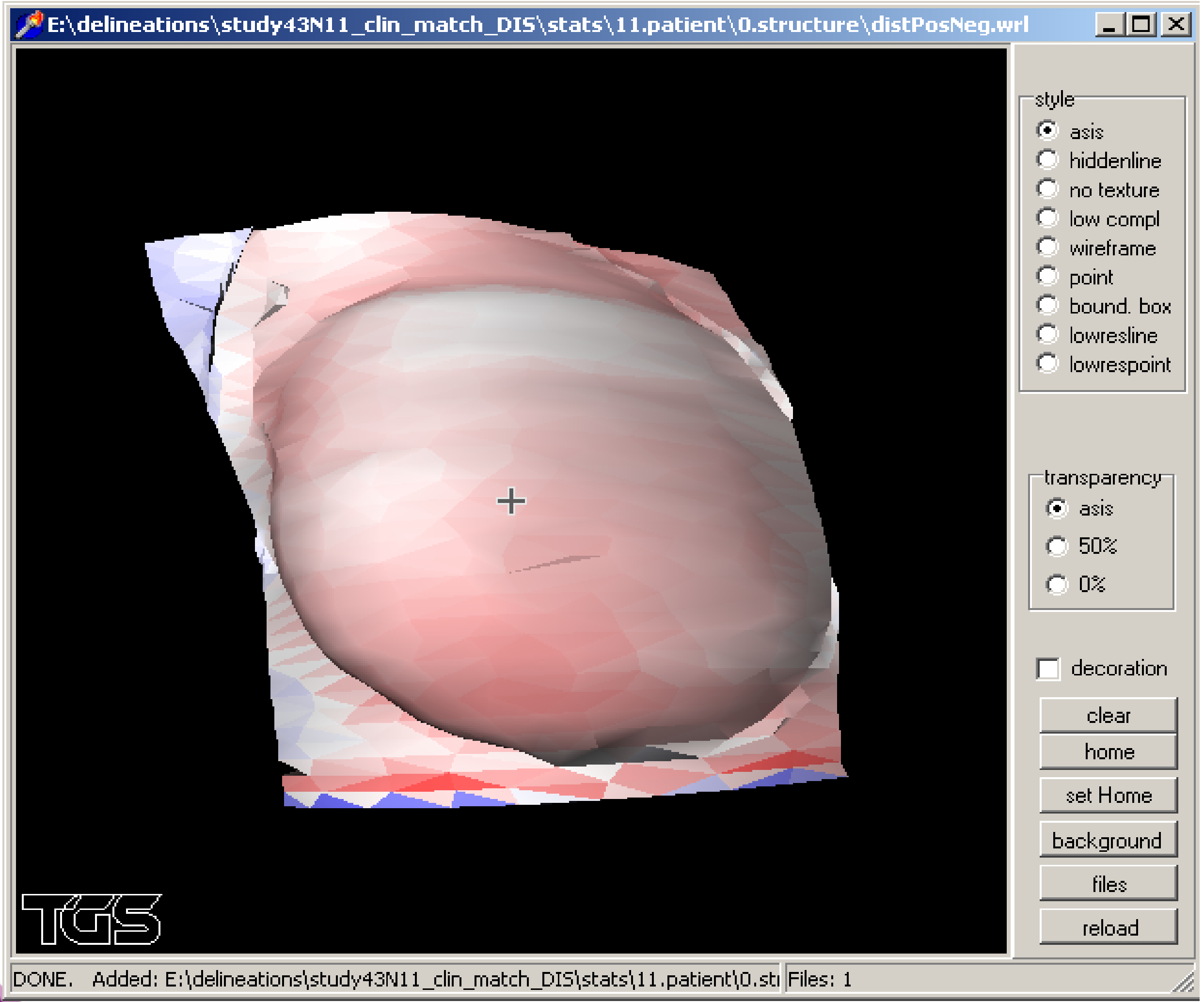
Variabele	Gemiddelde			Friedman	Wilcoxon
	SEQ	SIB	SIB-ART	*p*	
$V_{excess\text{-}dose}$ (cm^3) Planning	134.4	58.3	36.1	<0.001	SIB-ART<SIB<SEQ
$V_{excess\text{-}dose}$ (cm^3) CT5	134.4	150.1	95.0	<0.001	SIB-ART<SEQ<SIB

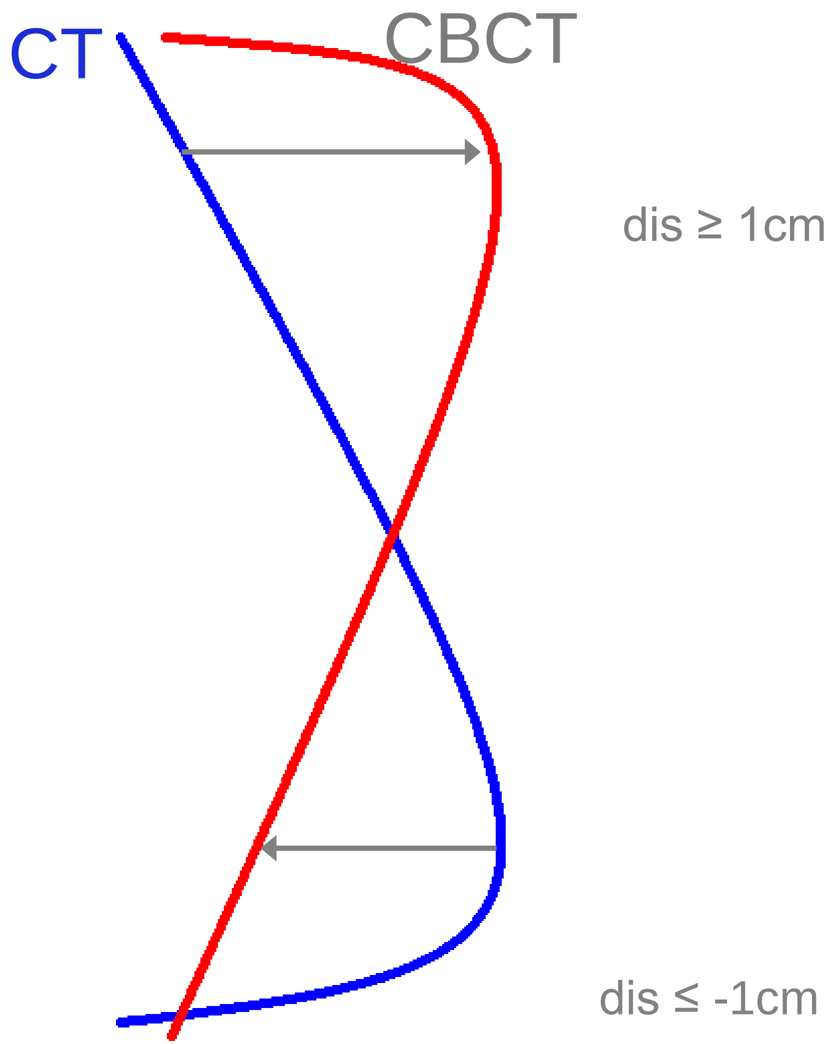
Changes in breast shape

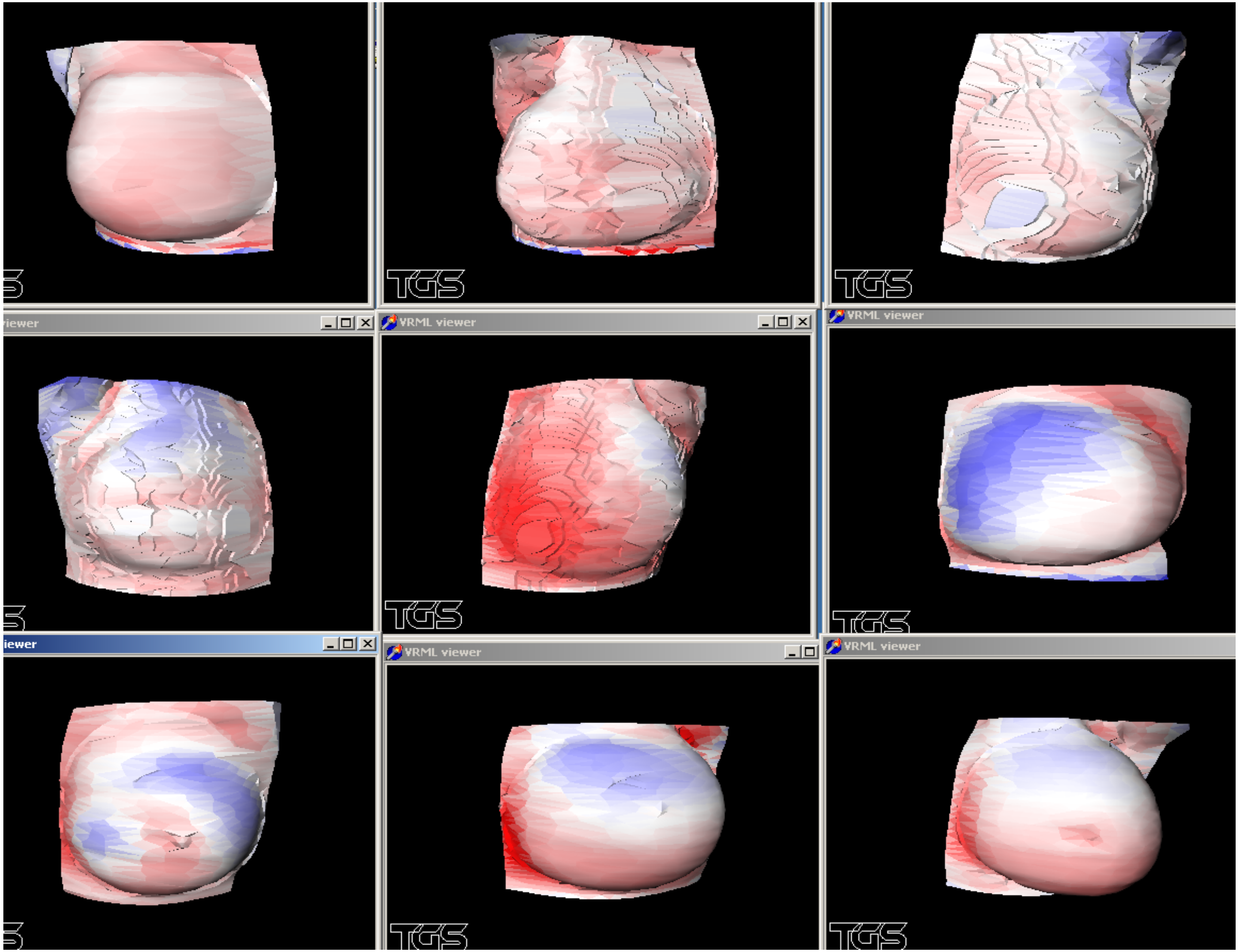


R. Topolnjak et al

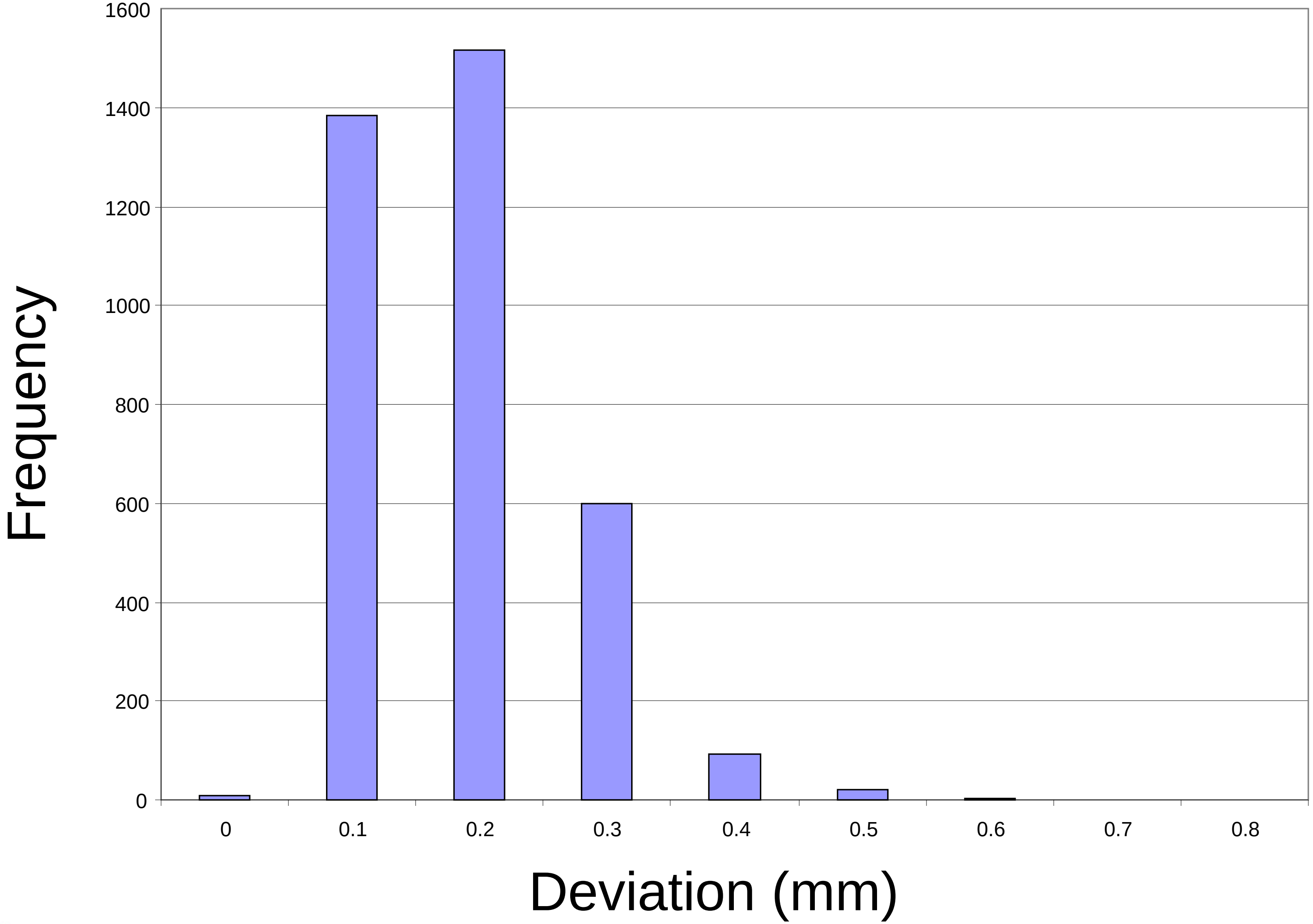
Average difference (treatment → planning)






iewer
VRML viewer
VRML viewer
iewer
VRML viewer
VRML viewer
TGS

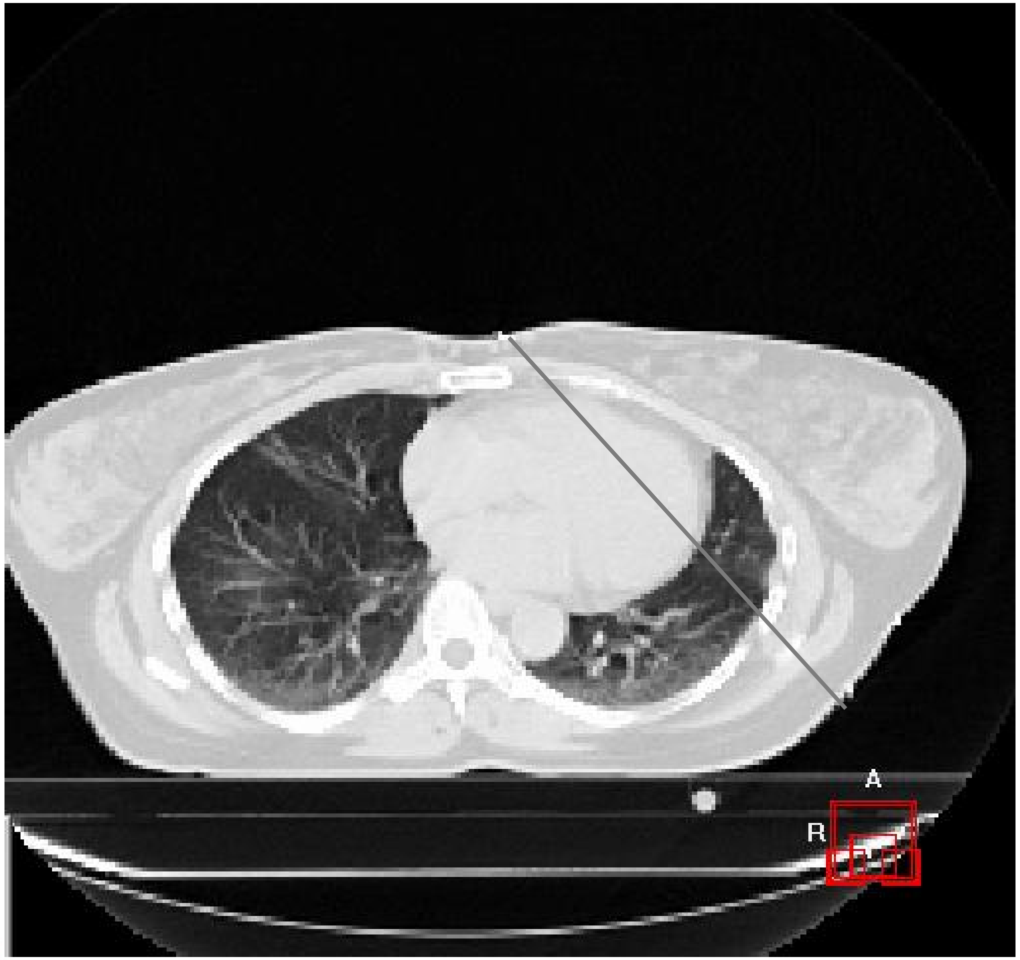
Average difference (treatment → planning)
SD of average distances (all)



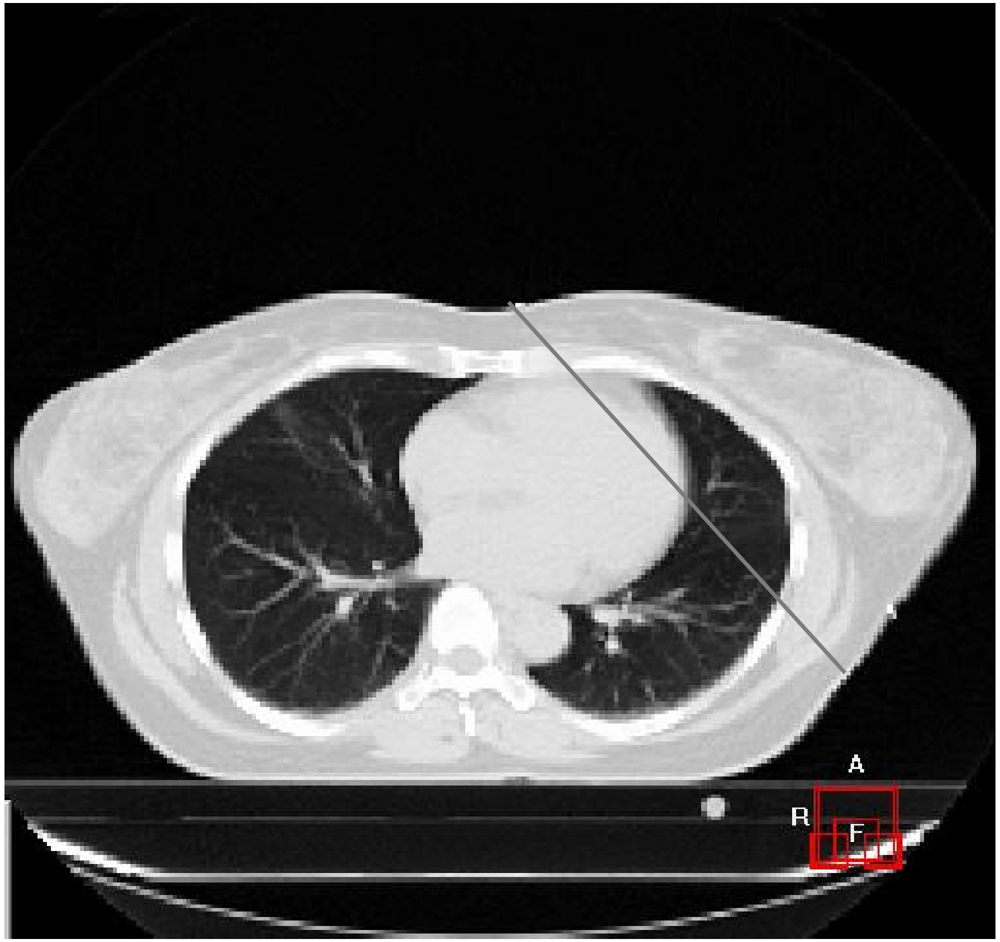
Breathhold technique

Breath hold for breast patients

Normal inspiration

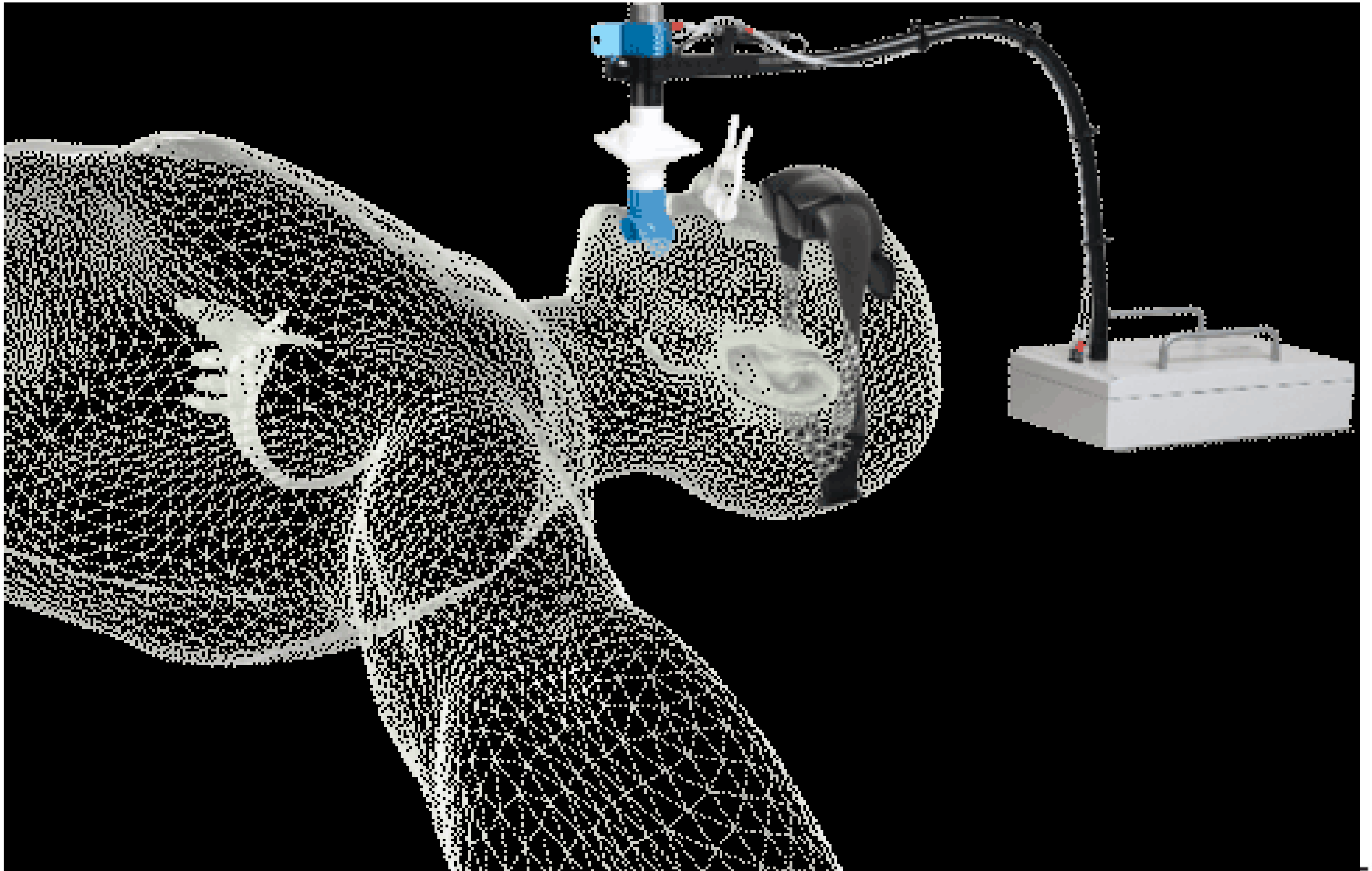


Deep inspiration



J. Sonke

Essential: education & compliance



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Take home messages

Conventional treatment techniques are not very critical with respect to geometrical uncertainties

Partial breast treatments will be more critical because of lack of background dose and more advanced treatment techniques (e.g. VMAT)

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Treatment Planning for Thoracic Cancers

Charles Gillham
Consultant Radiation Oncologist

St Luke's Radiation Oncology Network
Dublin, Ireland

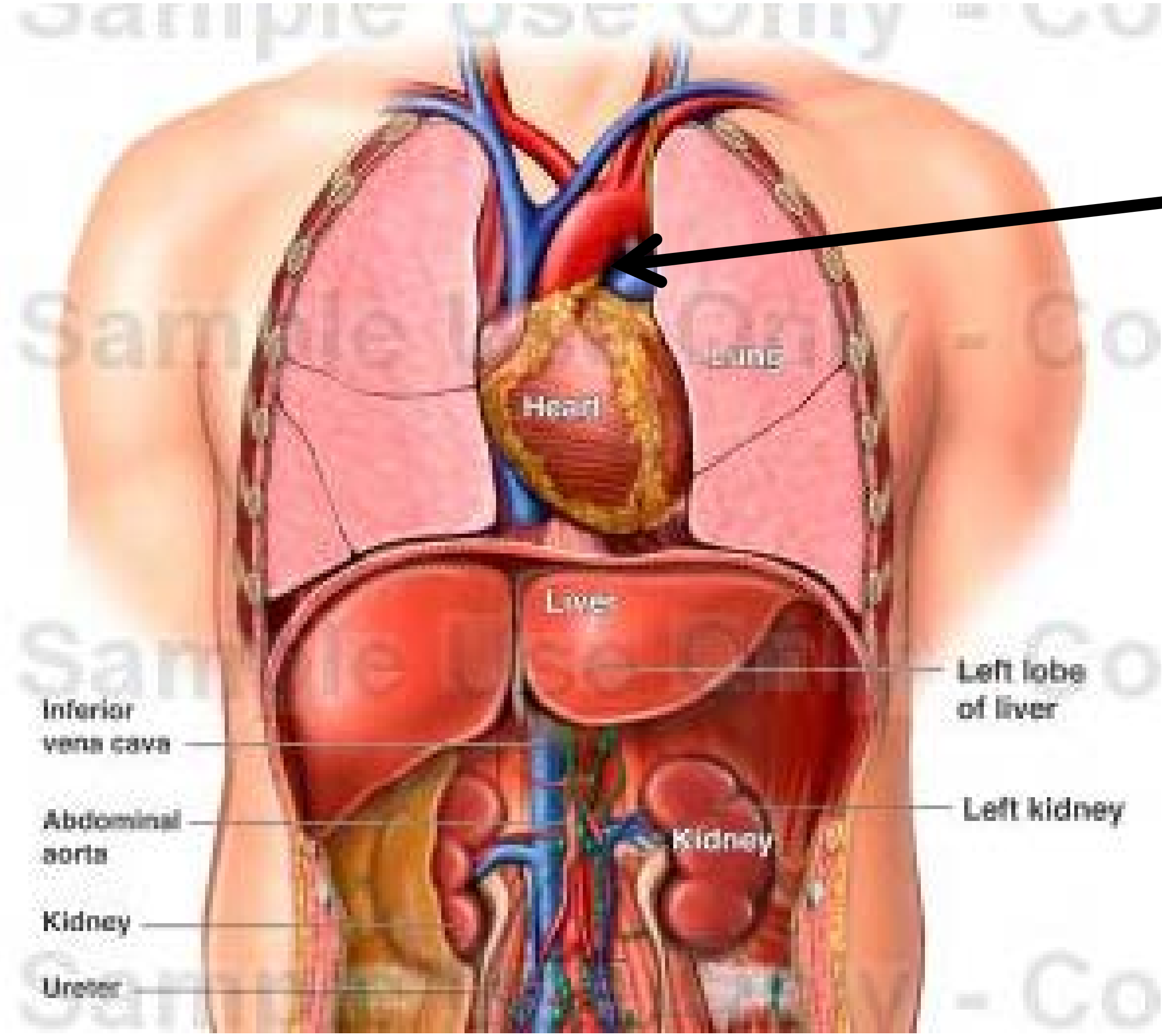
Overview

- Epidemiology
- Anatomy and patterns of spread
- Overview of treatment
- Indications for radiotherapy
- Positioning and Immobilisation
- Target volume delineation
- Toxicity

Thoracic Cancers

Focus on...

- Lung
- Oesophagus


Heart
Lung
Liver
Left lobe of liver
Inferior vena cava
Abdominal aorta
Left kidney
Kidney
Kidney
Ureter
Sample Use Only - Co

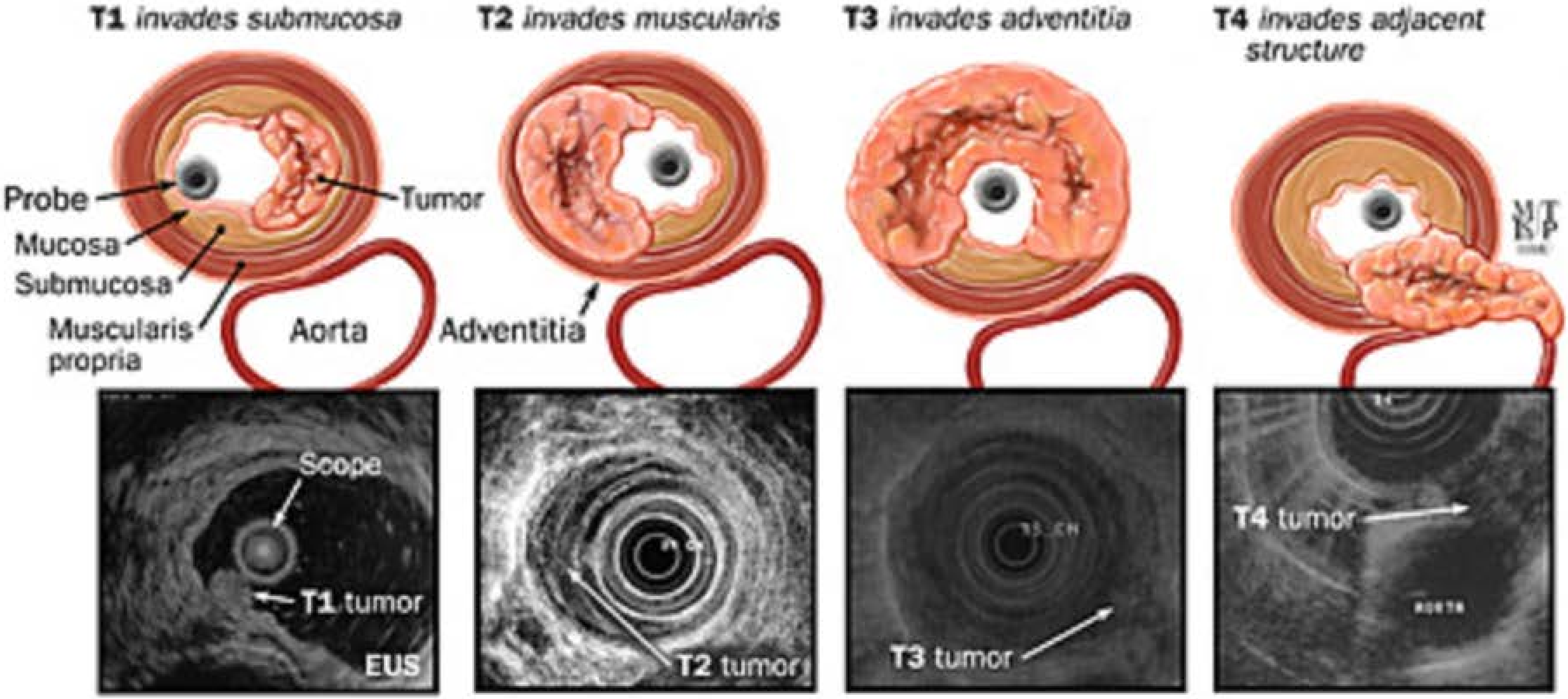
oesophagus

Diagnostic Work-Up

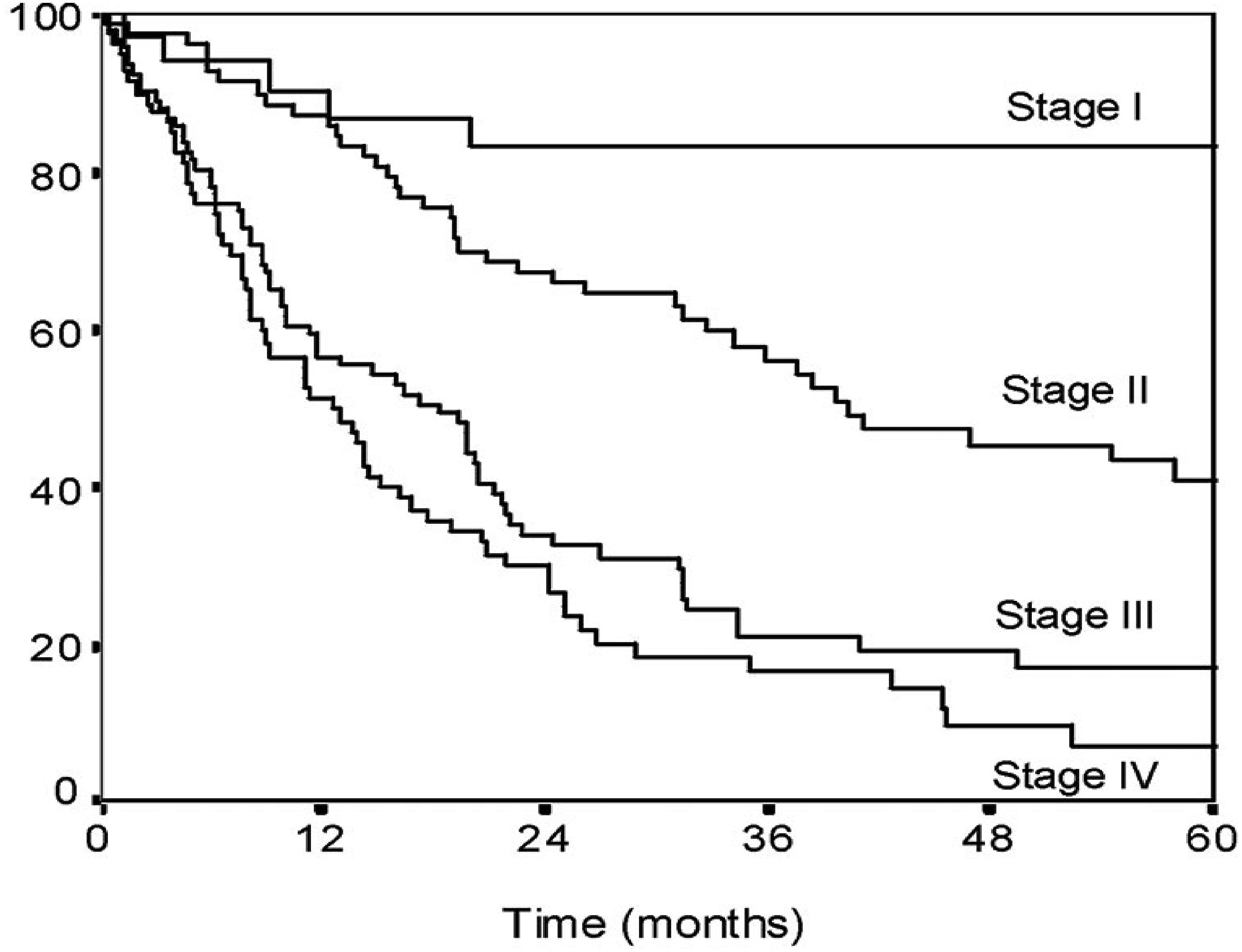
- Full history/examination
- Blood tests
- Bronchoscopy (lung), OGD (oesophagus)
- Mediastinoscopy (lung)
- Imaging – tumour dependent
- **Biopsy**

Oesophagus and OG Junction

Staging


T1 *invades submucosa*
T2 *invades muscularis*
T3 *invades adventitia*
T4 *invades adjacent structure*
Probe
Tumor
Mucosa
Submucosa
Muscularis propria
Aorta
Adventitia
Scope
T1 tumor
EUS
T2 tumor
T3 tumor
T4 tumor

Surgical outcome by stage



Wijnhoven Ann Surgery Volume 245(5) May 2007

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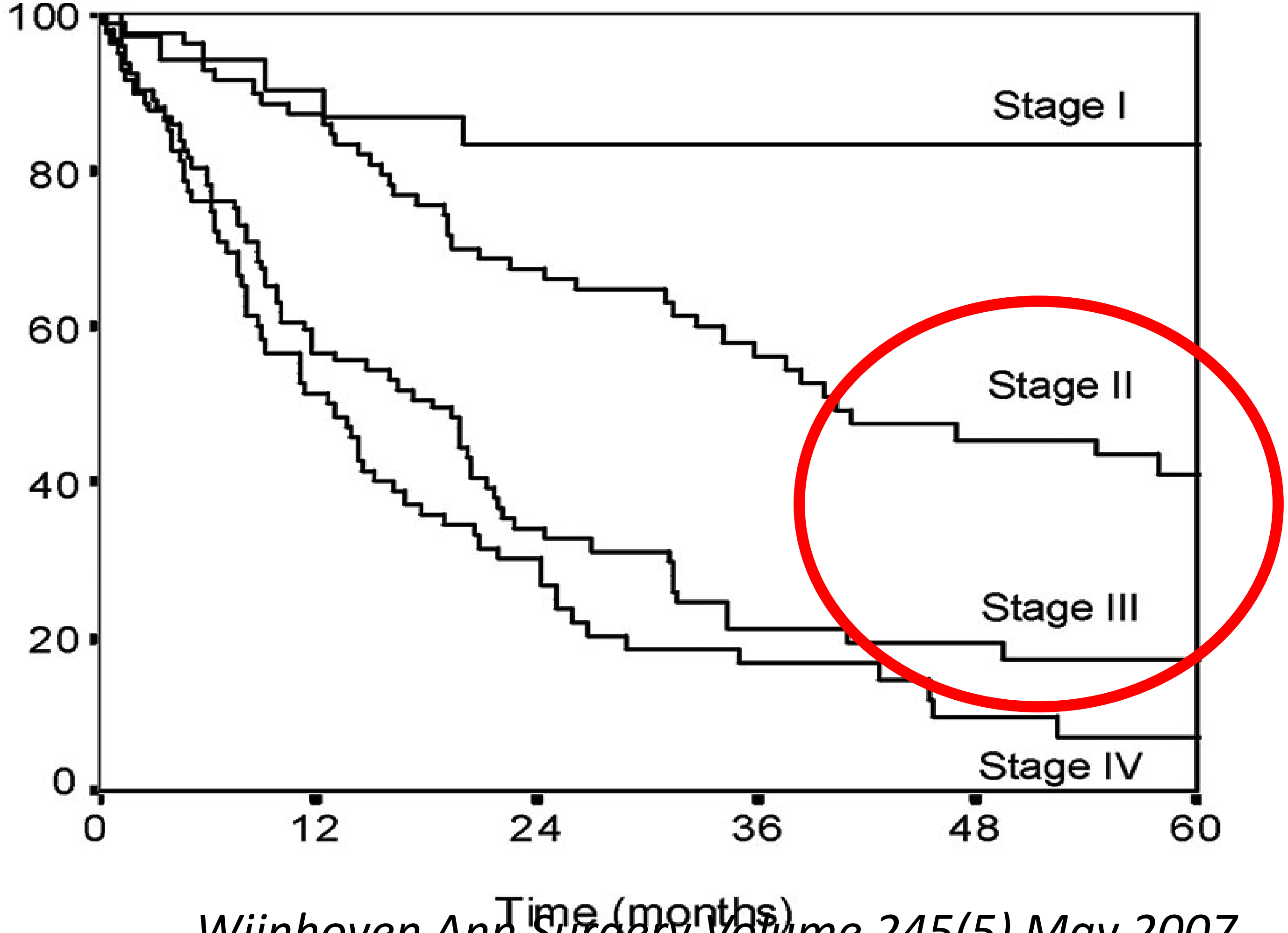
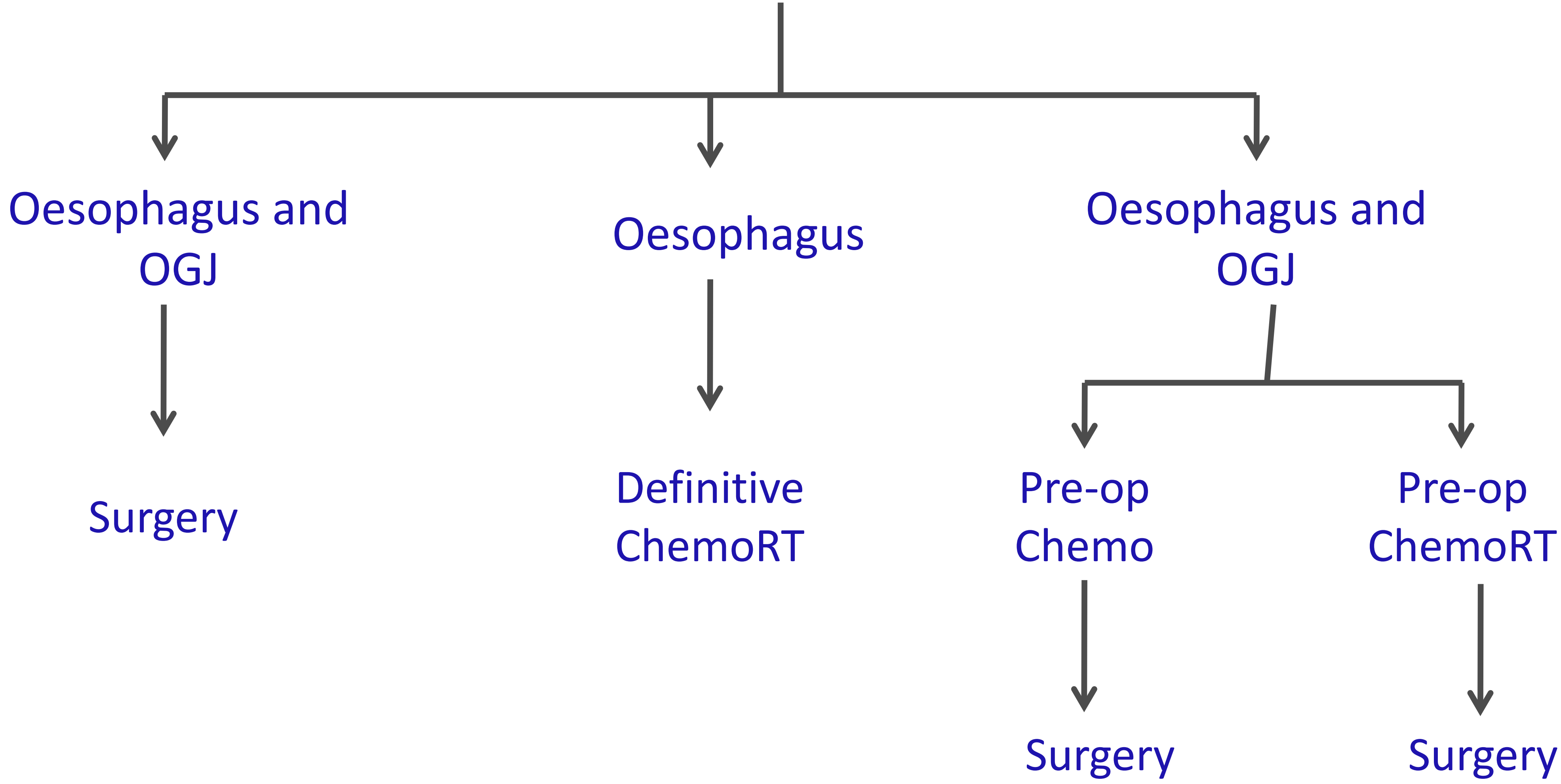
Surgical outcome by stage



Wijnhoven Ann Surgery Volume 245(5) May 2007

Multimodality treatment for localised disease



Definitive Chemoradiation

Consider in those

- Inoperable for medical reasons
- Complete R0 unlikely (T4b)
- Decline surgery
- Upper 1/3 Tumours
- 50-60Gy

If disease can be encompassed in a radical radiotherapy volume

Herskovic NEJM, 326:1393.1992
Cooper JAMA, 281:1623-1627, 1999

CROSS Pre-Op CRT study

Oesophageal
OGJ,
SCC or
Adenoca
cT1N1,
T2-3NX M0

RANDOMISATION

ChemoRT
41.4 Gy/ 23#
Paclitaxel 50mg/m2
Carbo AUC 2 weekly x 5

SURGERY

Surgery < 6 weeks after Chemo RT

Hagen, NEJM 366;22,2012

CROSS Pre-Op CRT study

N=363
86 SCC
273 Adenoca

	Median Survival	3 yr Survival
Surgery	26 months	48%
ChemoRT + Surgery	49 months	59%

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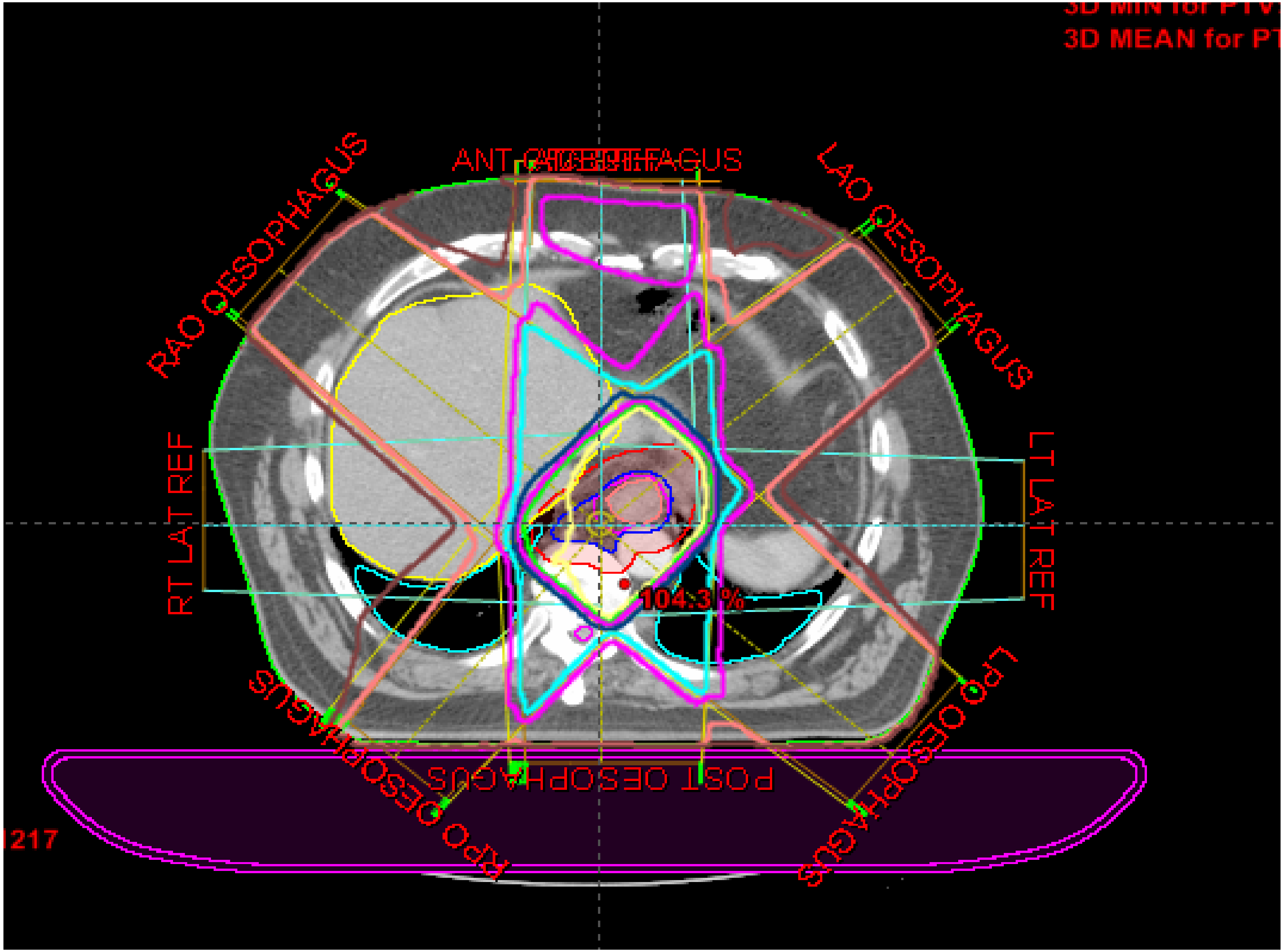
Post operative radiotherapy

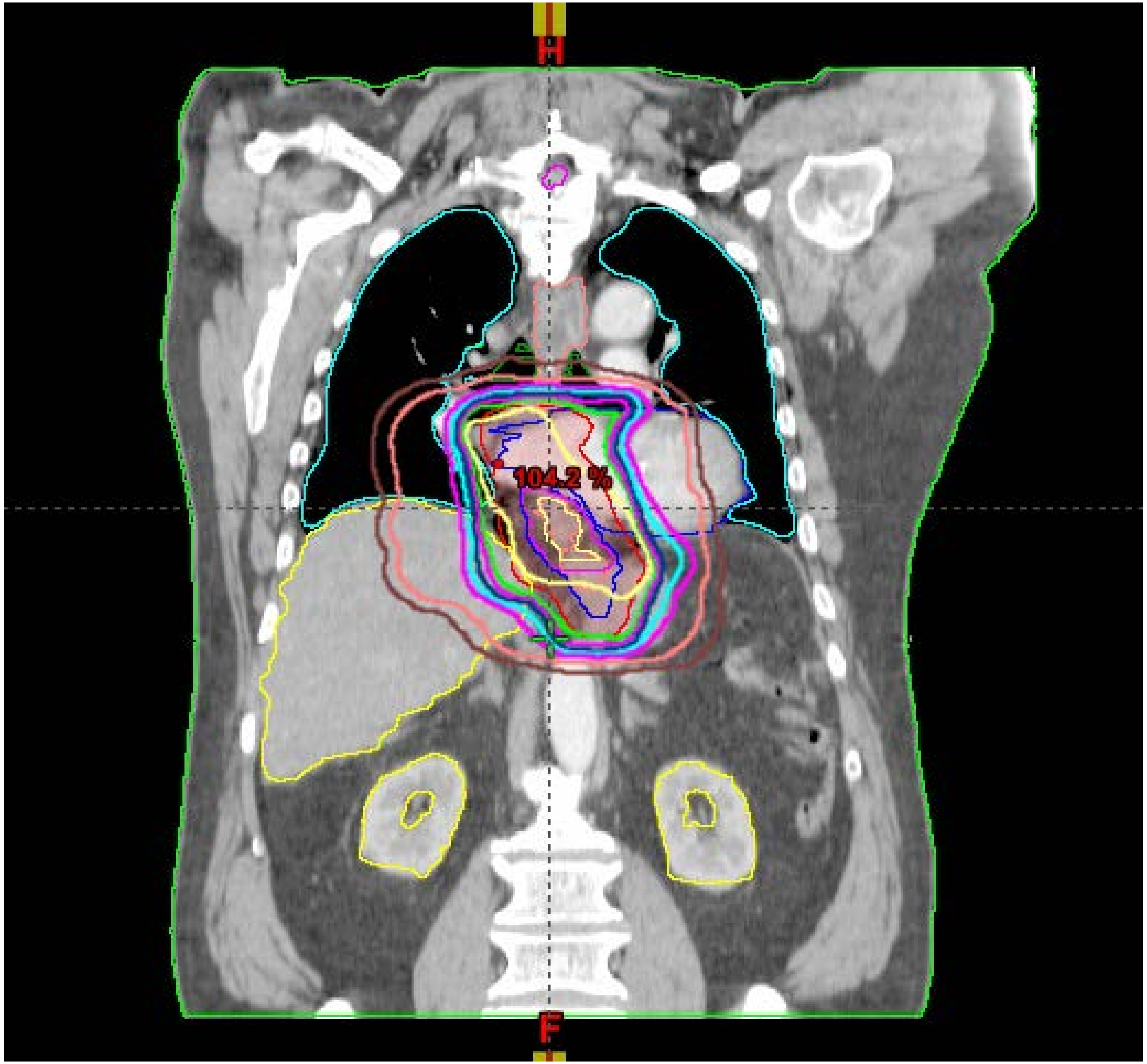
- 2 RCTs – no significant benefit in overall survival for postoperative radiation therapy over surgery alone

- May be considered where a proximal or distal margin is positive or < 2mm

Positioning and Immobilisation

- Supine
- Arms raised
- IVC


3D MEAN for PT
RAO OESOPHAGUS
LAO OESOPHAGUS
RT LAT REF
LT LAT REF
104.3 %
RPO OESOPHAGUS
POST OESOPHAGUS
LPO OESOPHAGUS

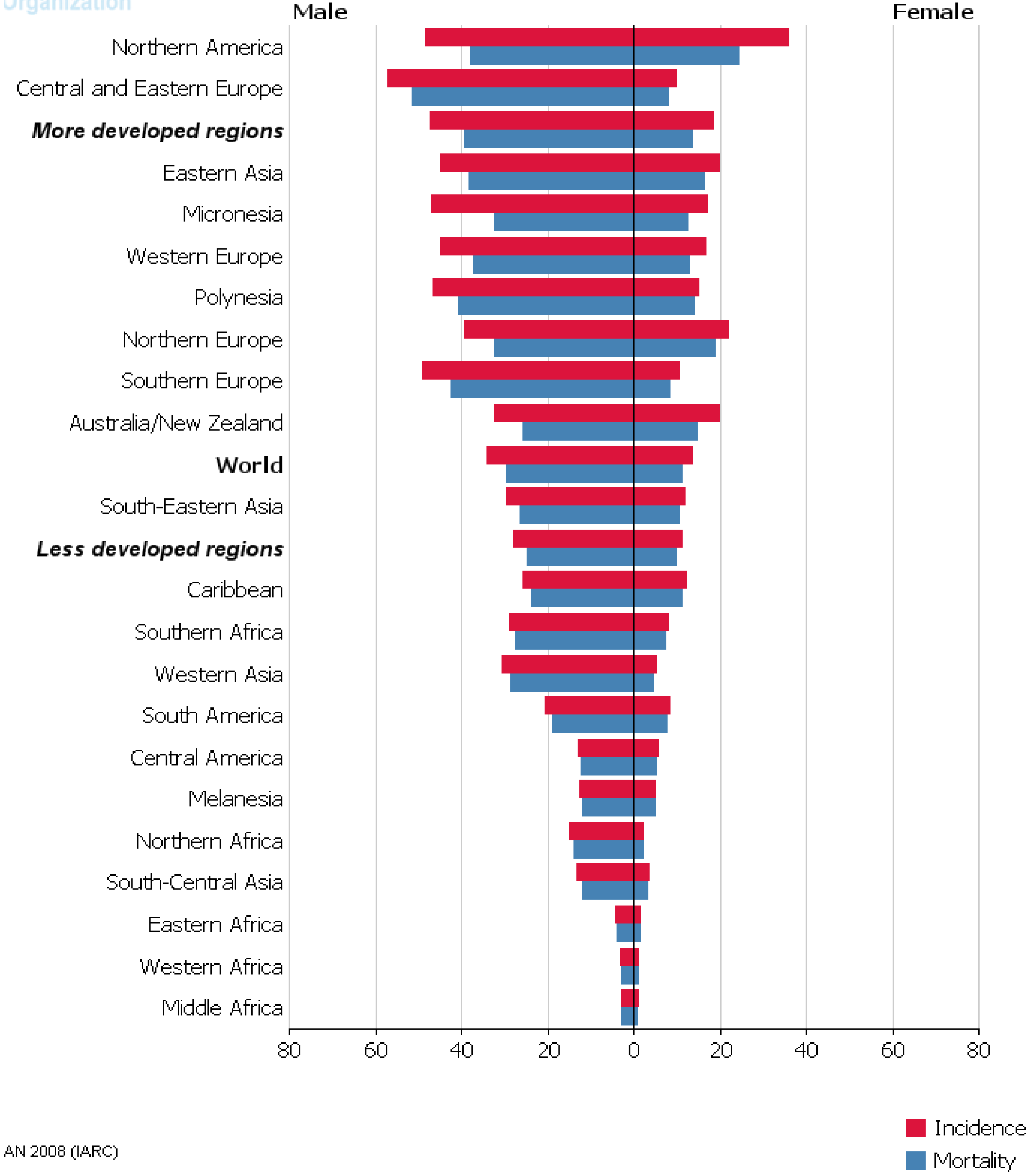

H
104.2 %
F

Toxicity

Acute	Late
Mucositis	Benign stricture
Skin erythema	Myelopathy/ myelitis
Lethargy	Lung fibrosis
Oesophageal perforation	Pericarditis
Pneumonitis	Ischaemic heart disease
Myelosuppression	Tracheo-oesophageal fistula
Gastritis	
Enteritis	
Weight loss	

Lung

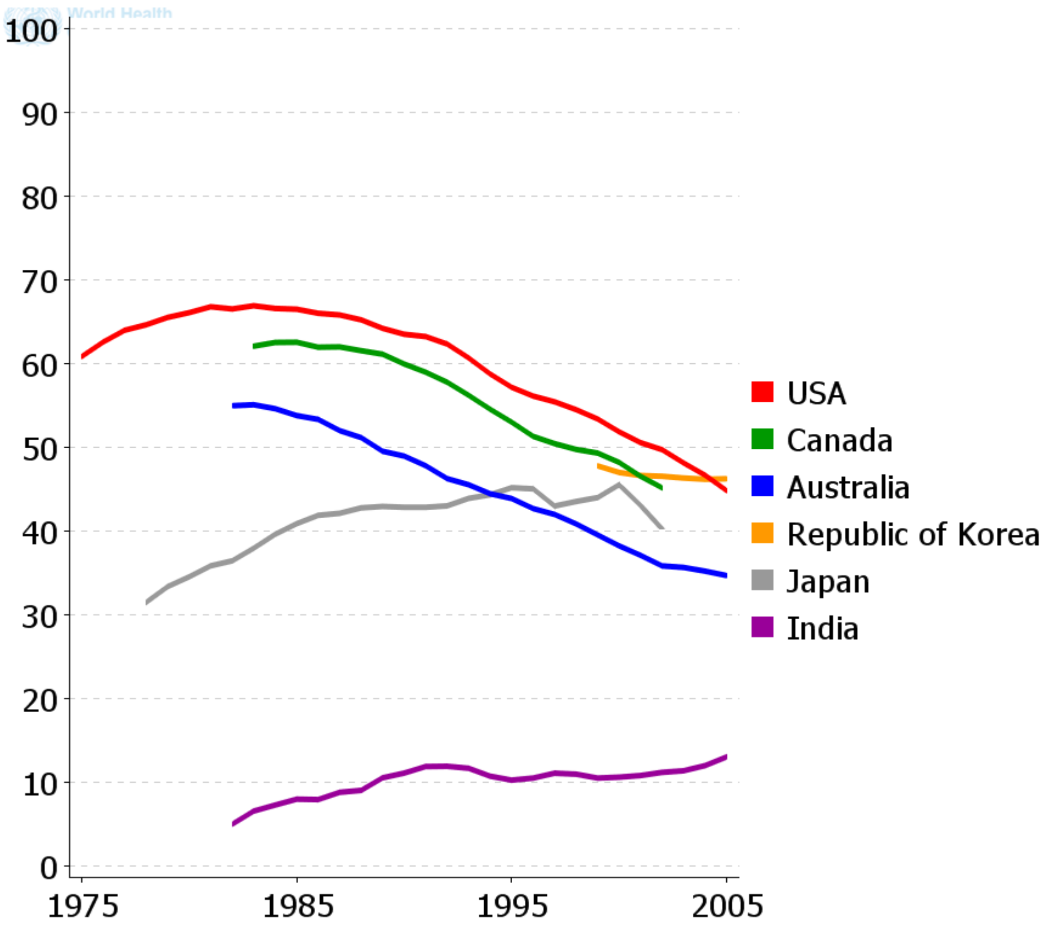
World Health Organization



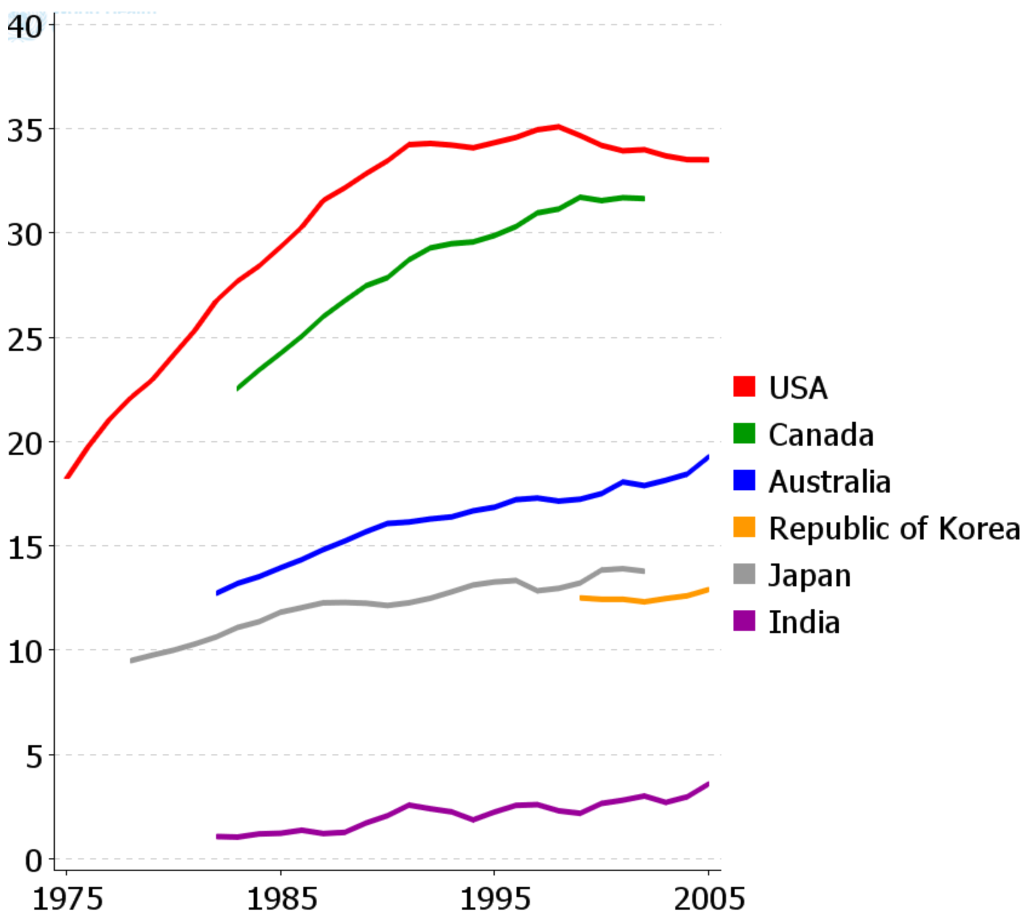
AN 2008 (IARC)

Incidence

Men



Women



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NSCLC: Pattern of Spread

- Local
  - ➢ Surrounding parenchyma and/or bronchial wall, then mediastinum and/or chest wall
- Nodal
  - ➢ Early
  - ➢ Specific pattern
- Distant
  - ➢ Bone, liver, brain

Radical EBRT-NSCLC

- Indications
  - Medically inoperable stage I (SABR)
  - Standard: Non-resectable stage II-III a/b,

- Technique
  - 3D-CRT > 2D standard

- Immobilisation
  - Lung Board
  - CT with contrast

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Radical EBRT- NSCLC

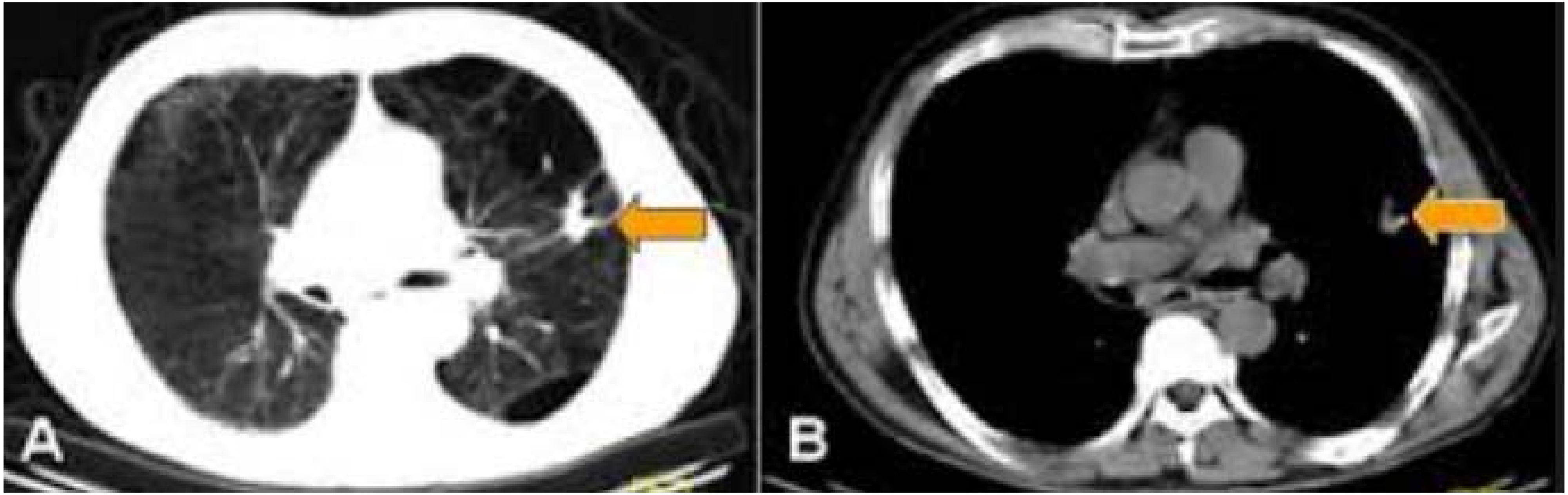
Volume Definition

Volume Definition / Delineation

GTV Primary Tumour

- Primary tumour:
  - ➢ CT scan and bronchoscopy description
- Issues:
  - ➢ Impact of image acquisition technique
  - ➢ Impact of window used for delineation [EORTC]
  - ➢ Associated atelectasis / obstructive pneumonitis?
  - ➢ Inter-observer variation
  - ➢ PET (CT)scan information?

CT Window Settings



Lung

Mediastinum

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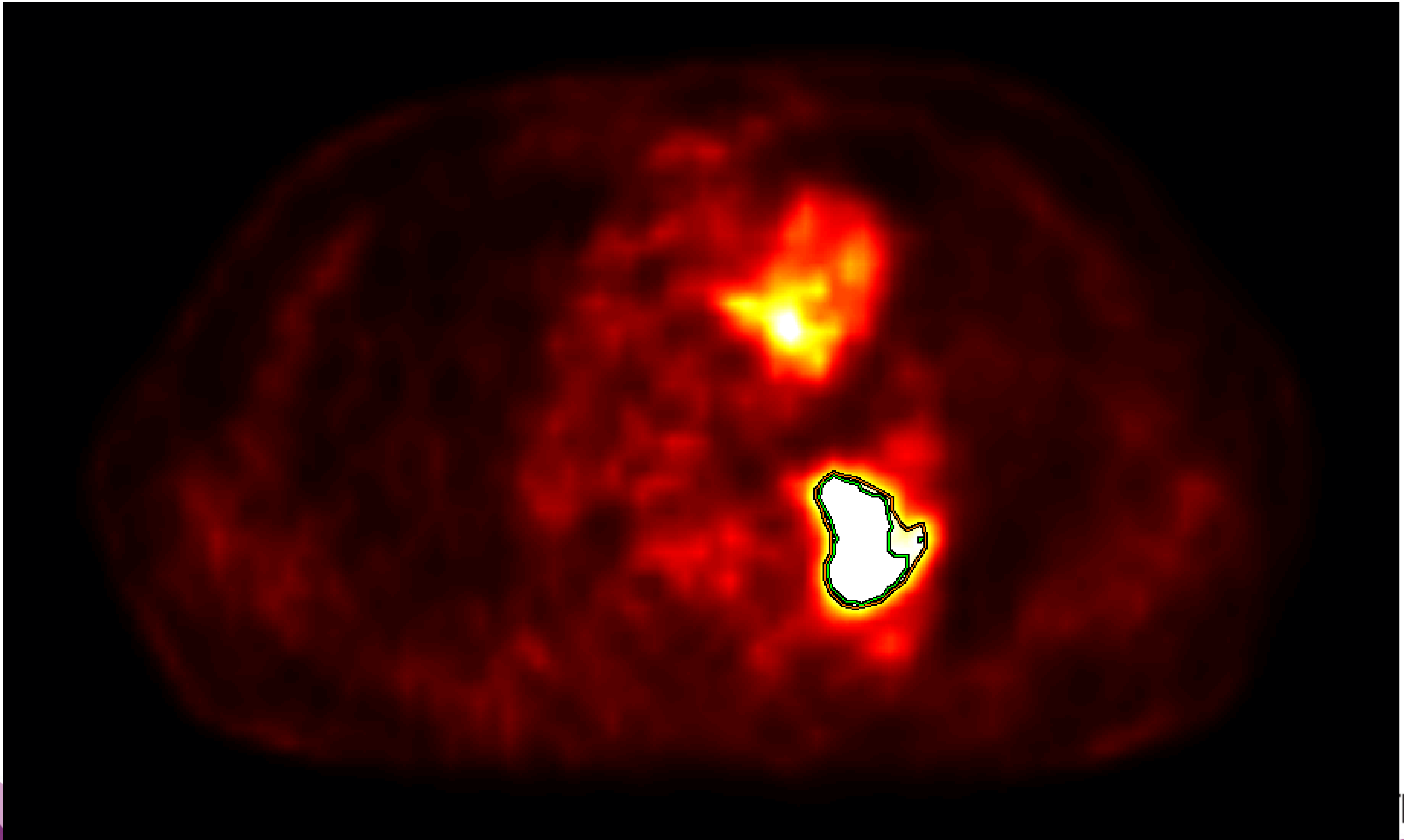
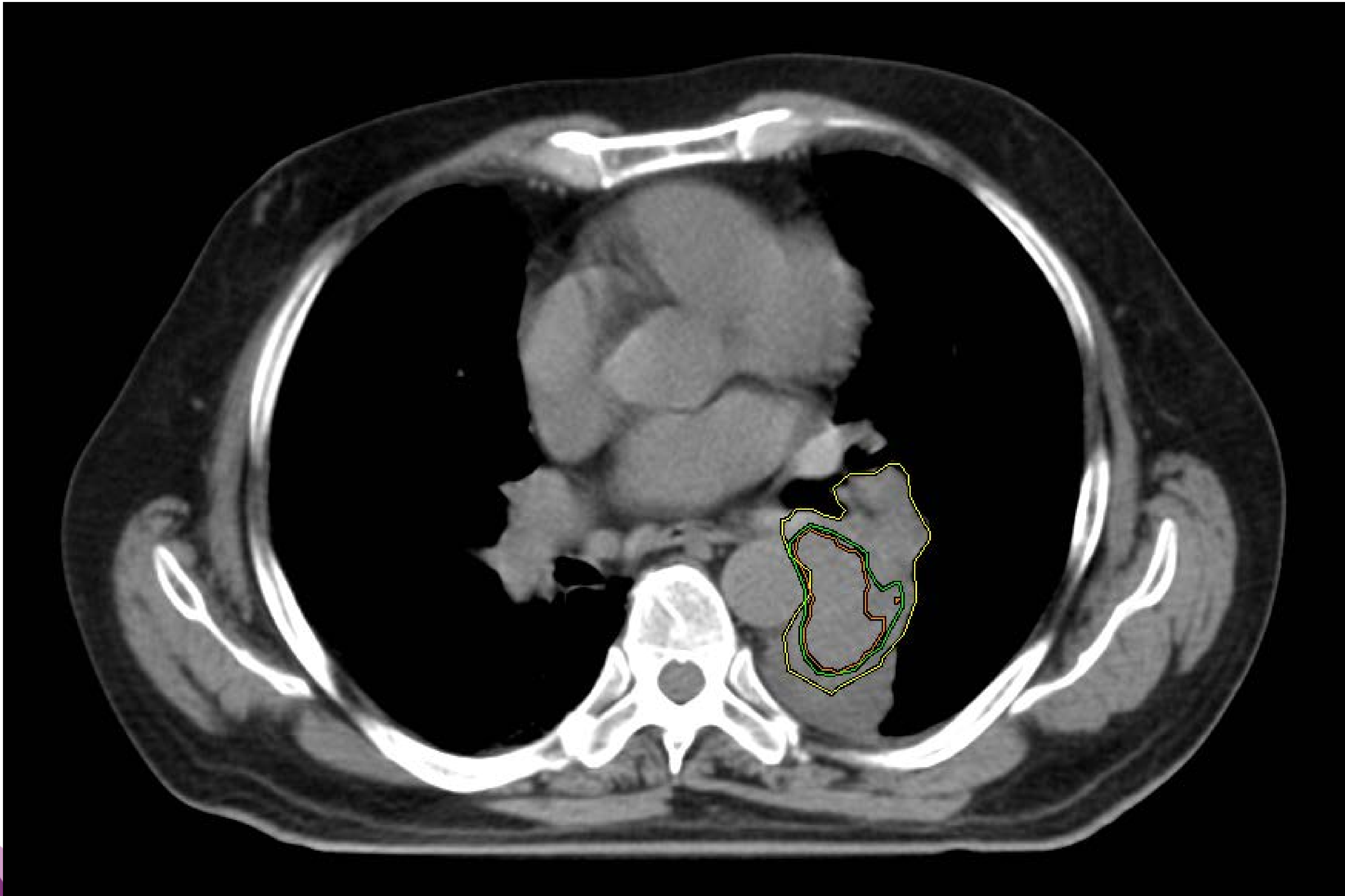
Volume Definition / Delineation

GTV Involved nodes

- Involved nodes:
  - ➢ Based on CT scan / mediastinoscopy / +/- others
- Issues
  - ➢ CT scan definition (1 or 1.5 cm): specificity / sensitivity?
  - ➢ Histologically-proven on mediastinoscopy
  - ➢ PET (CT) information?





Radical EBRT

CTV

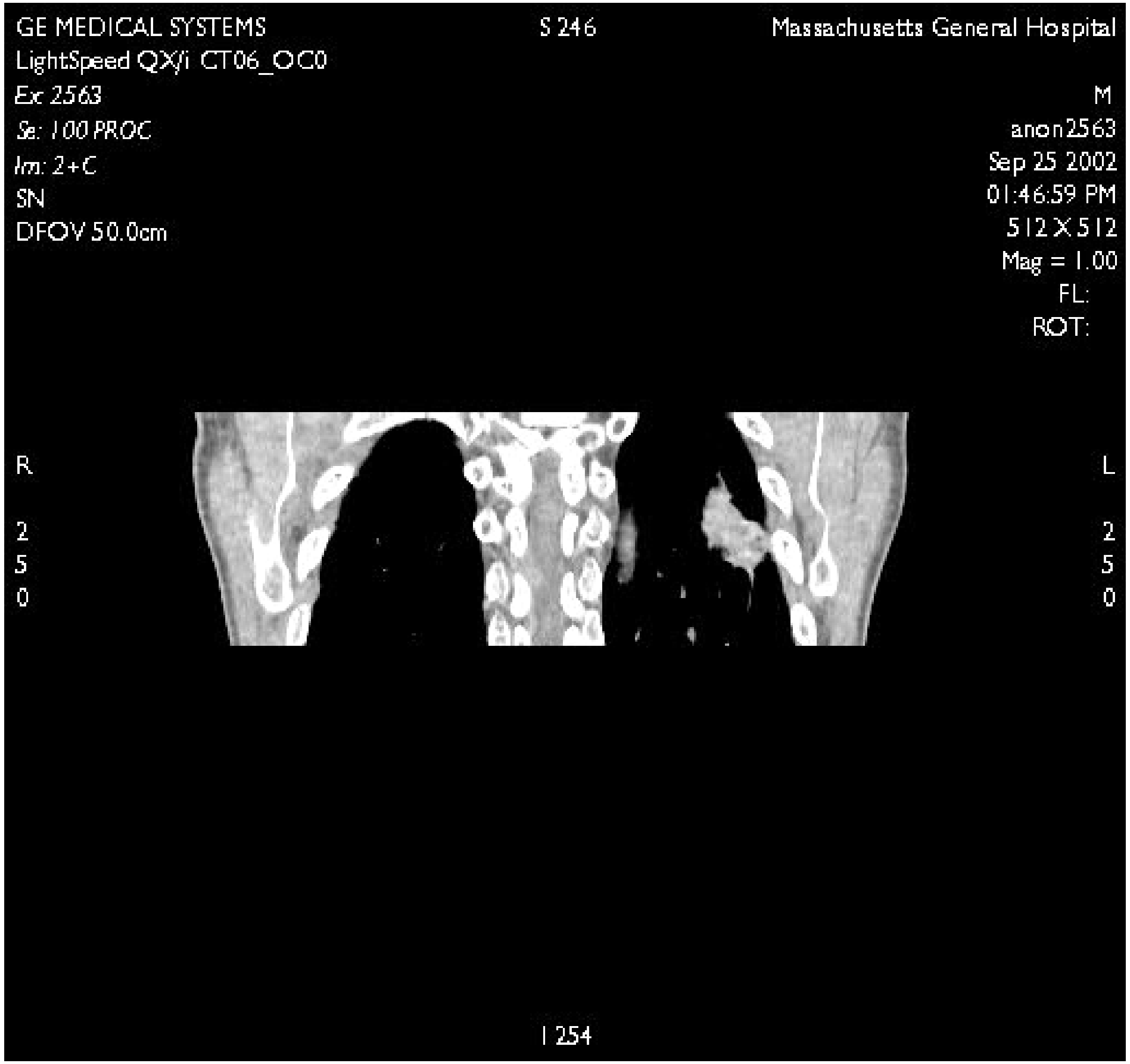
- Microscopic extension around primary tumour
  - ➢ 5 mm margin will cover 80% of microscopic extension for adenocarcinoma and 91% for SCC [Giraud et al]
- Elective nodal irradiation
  - ➢ Can be safely avoided (< 10% isolated relapse)
  - ➢ But incidental irradiation

Radical EBRT

PTV

- IM
  - Internal organ motion (heart / respiration)
- SM
  - Institutional evaluation
  - Impact of immobilisation device on set-up errors [O Shea, 2010]

Respiratory Motion



Lung Tumour Motion (cm)

	Right-Left	CC	AP
Lower lobe / non fixed	2 (0.5-2.5)	12 (5.4-25)	2 (0.9-2.6)
Upper Lobe / fixed	1 (0.2-2.8)	2 (0.2-8.7)	2 (0.2-8.2)

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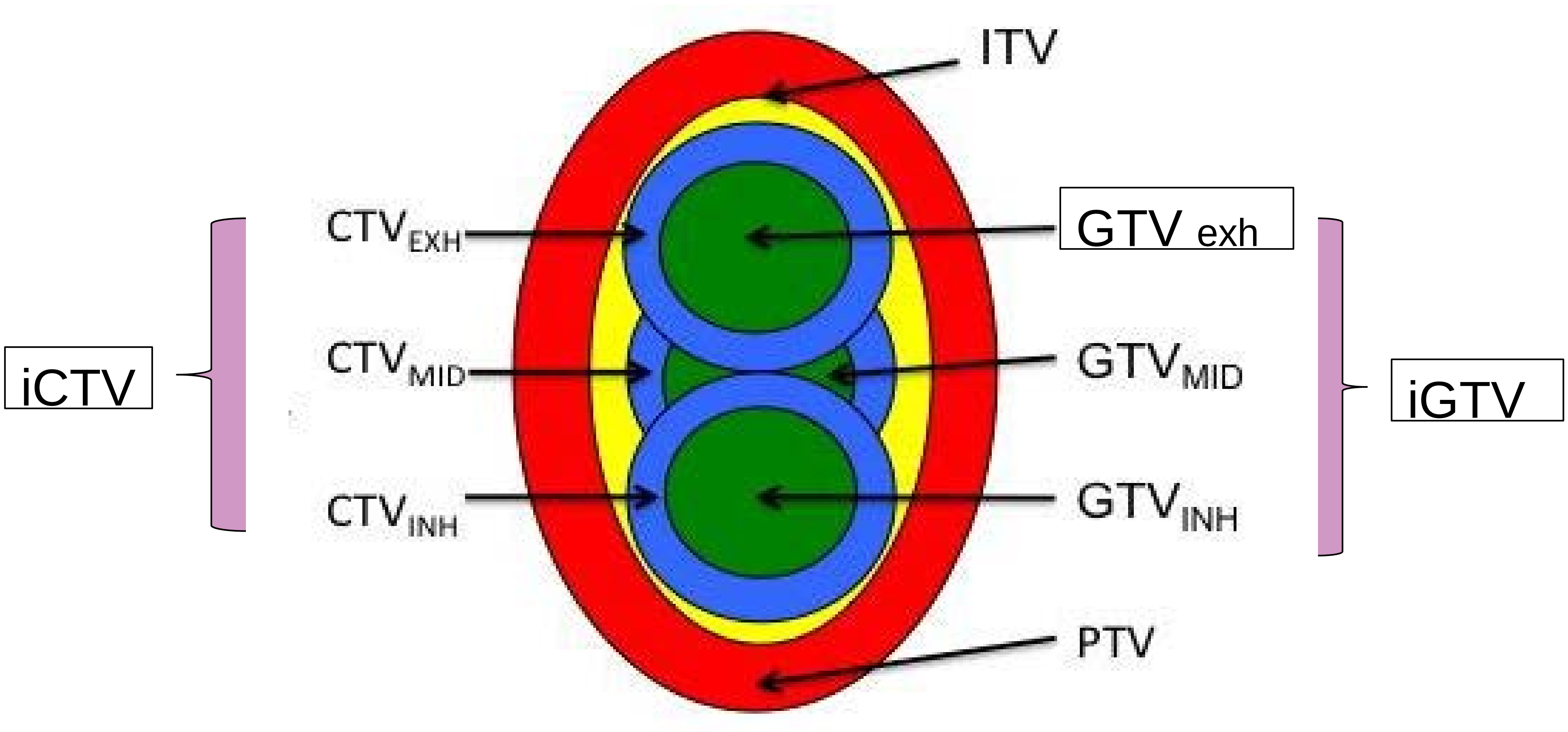
ICRU 83: 4D Volume delineation Process



Organ motion

- IM Reduction strategies:
  - Immobilisation device [Giraud, 2001]
  - ABC
  - Gated delivery
- Organ motion volume integration
  - ITV concept

Radical EBRT- NSCLC

Planning Technique

Radical EBRT: Planning Technique

2 D *vs.* 3DCRT ?

- Rational
  - ➢ Planning studies favour 3DCRT
- Clinical Evidence
  - ➢ Retrospective analyses show better outcome with 3DCRT [ASTRO 2006]
  - ➢ Extensive worldwide experience

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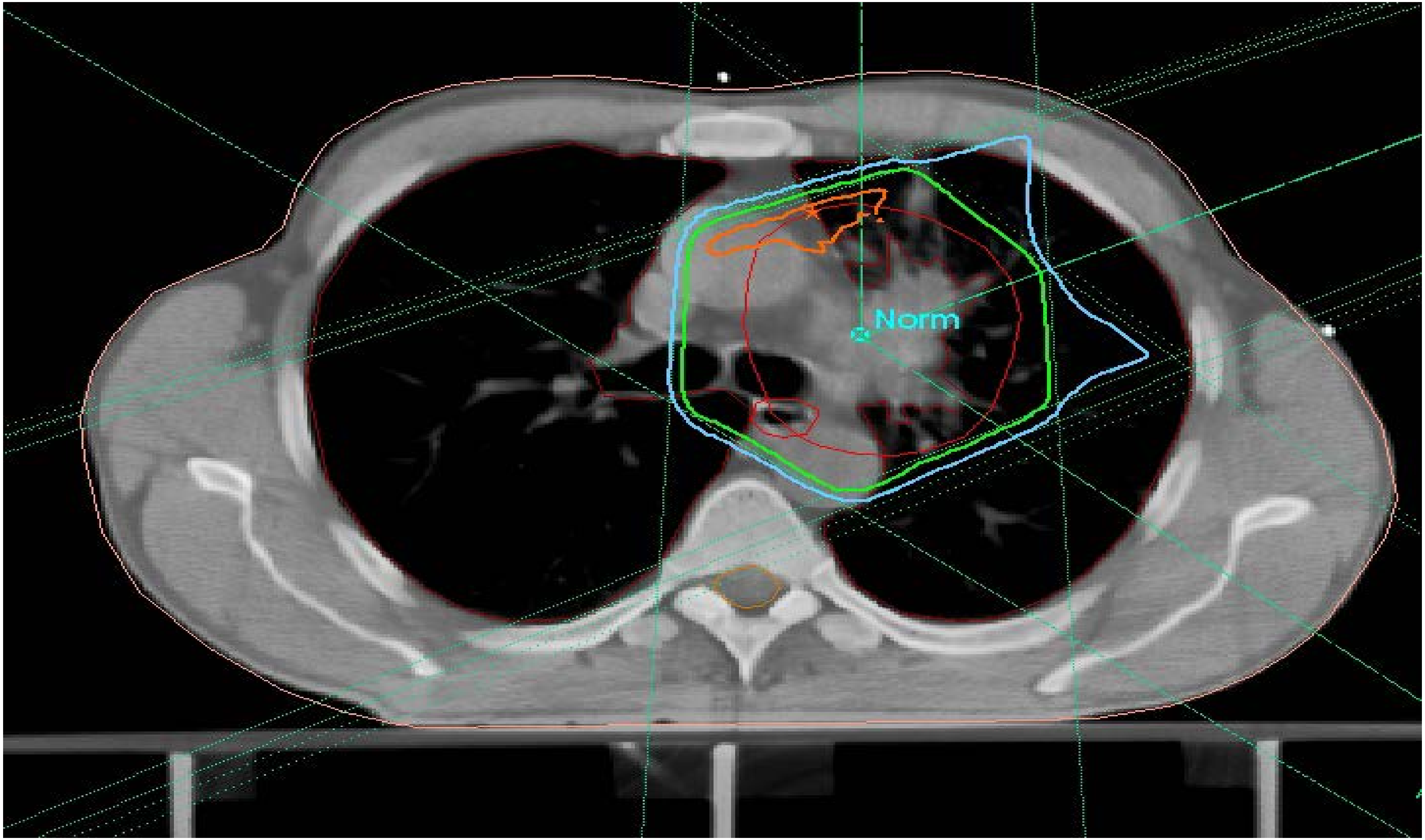
Norm

3DCRT *vs.* IMRT

- Retrospective study: MD Anderson
  - 1996-2006
  - N= 496 NSCLC pts
    - CT/3DCRT: 318 pts, Fup mean Time: 2.1 y
    - 4DCT/IMRT: 91 pts, Fup mean time: 1.3 y
    - Median dose of 63 Gy.
  - HR OS > 1 in favour of 4DCT/IMRT (trend for LRC and DM)
  - Significantly lower toxicity with IMRT/4DCT
  - V20 was significantly higher in the 3DCRT group and was a significant factor in determining toxicity.
  - Freedom from DM was nearly identical in both groups.

Potential Role of IMRT

- IMRT allows
  - Reduction of dose to oesophagus and spinal cord in 100% and 66% of cases respectively
  - Dose escalation to 81 Gy/27 in 11 cases (vs. 8 cases 3D),
  - Dose escalation to 90/30 in 9 cases (vs. 6 cases 3D)

ESTRO, 2004

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Radical Conventional Radiotherapy

RTOG 73-01: 60 Gy> 50 Gy > 40 GY

- 1-year OS: same 40%
- 2 & 3-y OS: 20% vs 15% vs 10% (LC benefit)

Present Standard: > 60 Gy/ 30 fr, over 6 weeks

Local control: 16-60 % *[Arigada, 1992; Perez, 1982]*

Radical Surgery : local control rate 80-95%

Summary

- Radiotherapy part of curative treatment of many thoracic cancers
  - ➢ Pre-operative
  - ➢ Post-operative
  - ➢ Alone/Definitive
  - ➢ +/- concurrent chemotherapy

- GTV/CTV dependent on site of primary

- PTV institutional variation
  inter/intra-fraction organ motion

Treatment Planning for Thoracic Cancers

Thank you

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WWW.ESTRO.ORG/SCHOOL

Contouring Case 2 Thorax

Danilo Pasini
Charles Gillham
Paul Kelly

Anatomical Definition: Heart

- Heart has four chambers: The atria are receiving areas that pump blood into discharging chambers called the ventricles
- Heart and the roots of the great vessels lie in the pericardium, which is located in the middle mediastinum.
- Heart has a base (posterior aspect), apex (inferolateral end), three surfaces (sternocostal, diaphragmatic and pulmonary) and four borders (right, inferior, left and superior)

Heart Delineation Issues

- **Problem 1:** Contour individual structures within the heart: No DVCs available due to limited data
- **Problem 2:** Contour whole organ: No subvolumes for further optimisation

Be consistent in delineation!

Contouring Guidelines

Int. J. Radiation Oncology Biol. Phys., Vol. 79, No. 1, pp. 10–18, 2011

0360-3016/$–see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2009.10.058

CLINICAL INVESTIGATION **Breast**

DEVELOPMENT AND VALIDATION OF A HEART ATLAS TO STUDY CARDIAC EXPOSURE TO RADIATION FOLLOWING TREATMENT FOR BREAST CANCER

Mary Feng, M.D.,* Jean M. Moran, Ph.D.,* Todd Koelling, M.D.,† Aamer Chughtai, M.D.,‡
June L. Chan, M.D.,* Laura Freedman, M.D.,* James A. Hayman, M.D.,*
Reshma Jagsi, M.D., D. Phil.,* Shruti Jolly, M.D.,* Janice Larouere, M.D.,*
Julie Soriano, M.D.,* Robin Marsh, C.M.D.,* and Lori J. Pierce, M.D.*

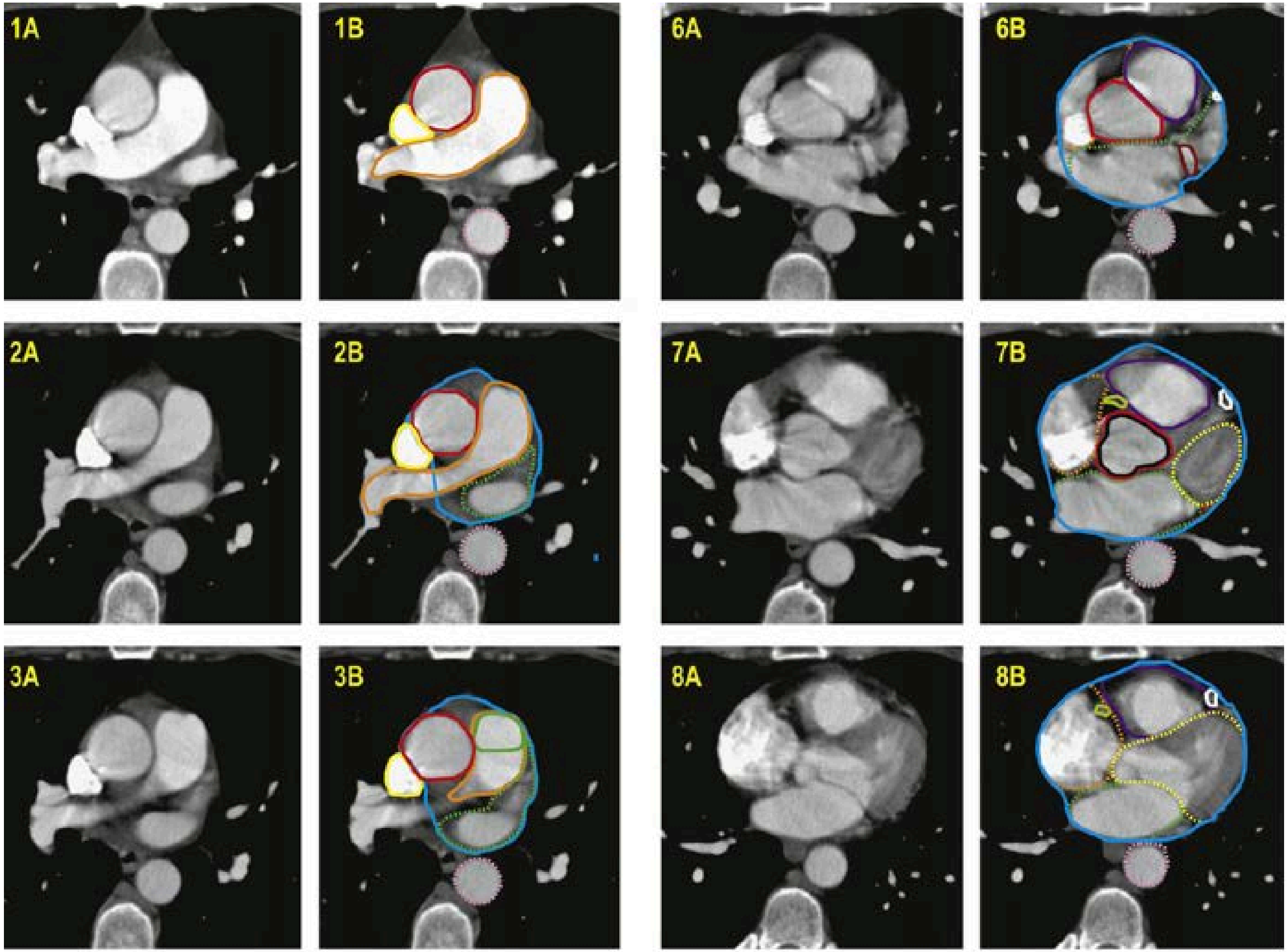
Department of *Radiation Oncology; Internal Medicine, Division of †Cardiology and; ‡Radiology, University of Michigan Medical Center, Ann Arbor, Michigan

Purpose: Cardiac toxicity is an important sequela of breast radiotherapy. However, the relationship between dose

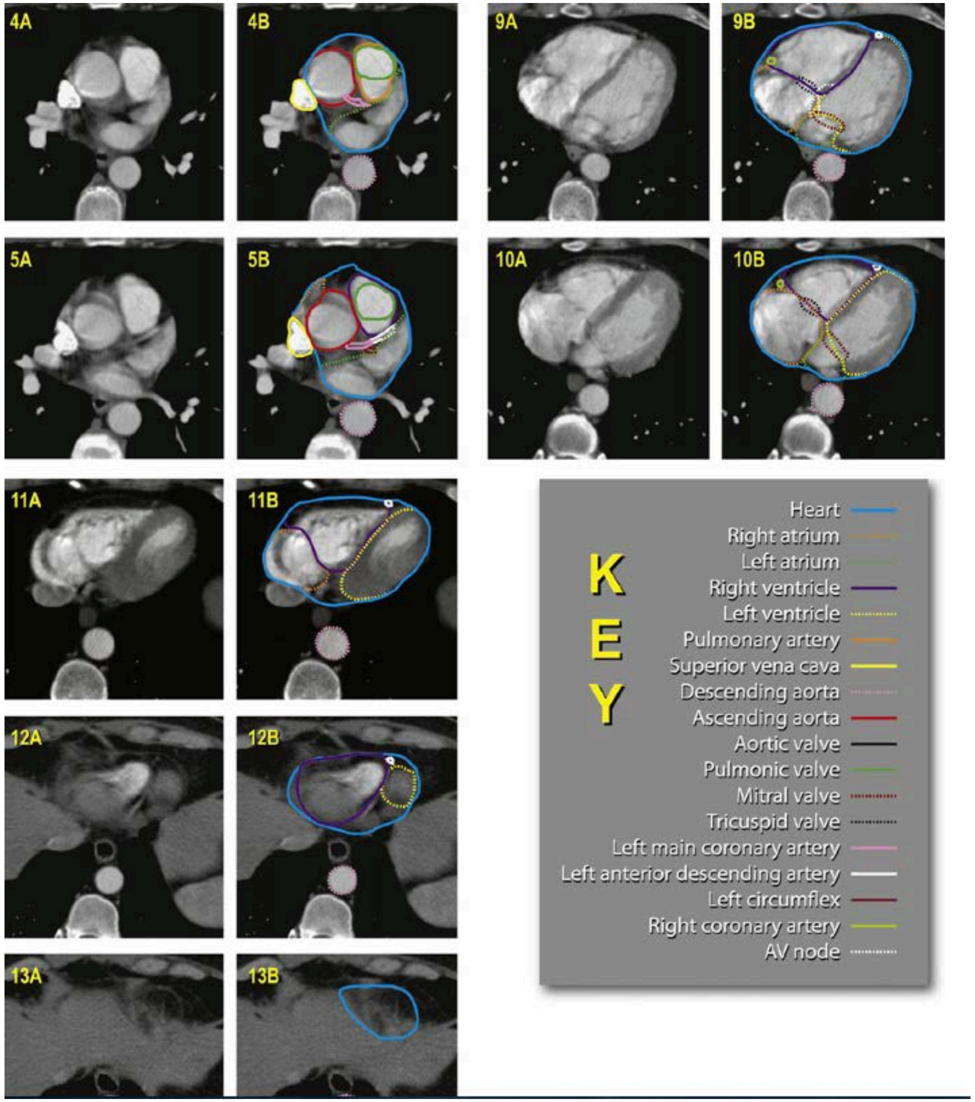
Whole heart and pericardium

- **Feng et al:**
  - ➢ Superiorly: Start just inferior to the left pulmonary artery, include the great vessels in a rounded contour
  - ➢ Inferiorly: Heart blends with the diaphragm. Cardiac vessels are in the fatty tissue within the pericardium, so should be included in the contours, even if there is no heart muscle visible.
  - ➢ If contrast is present, the SVC can be contoured separately from the whole heart. If not possible, include in whole heart contour

Feng: Cardiac Atlas



Feng: Cardiac Atlas

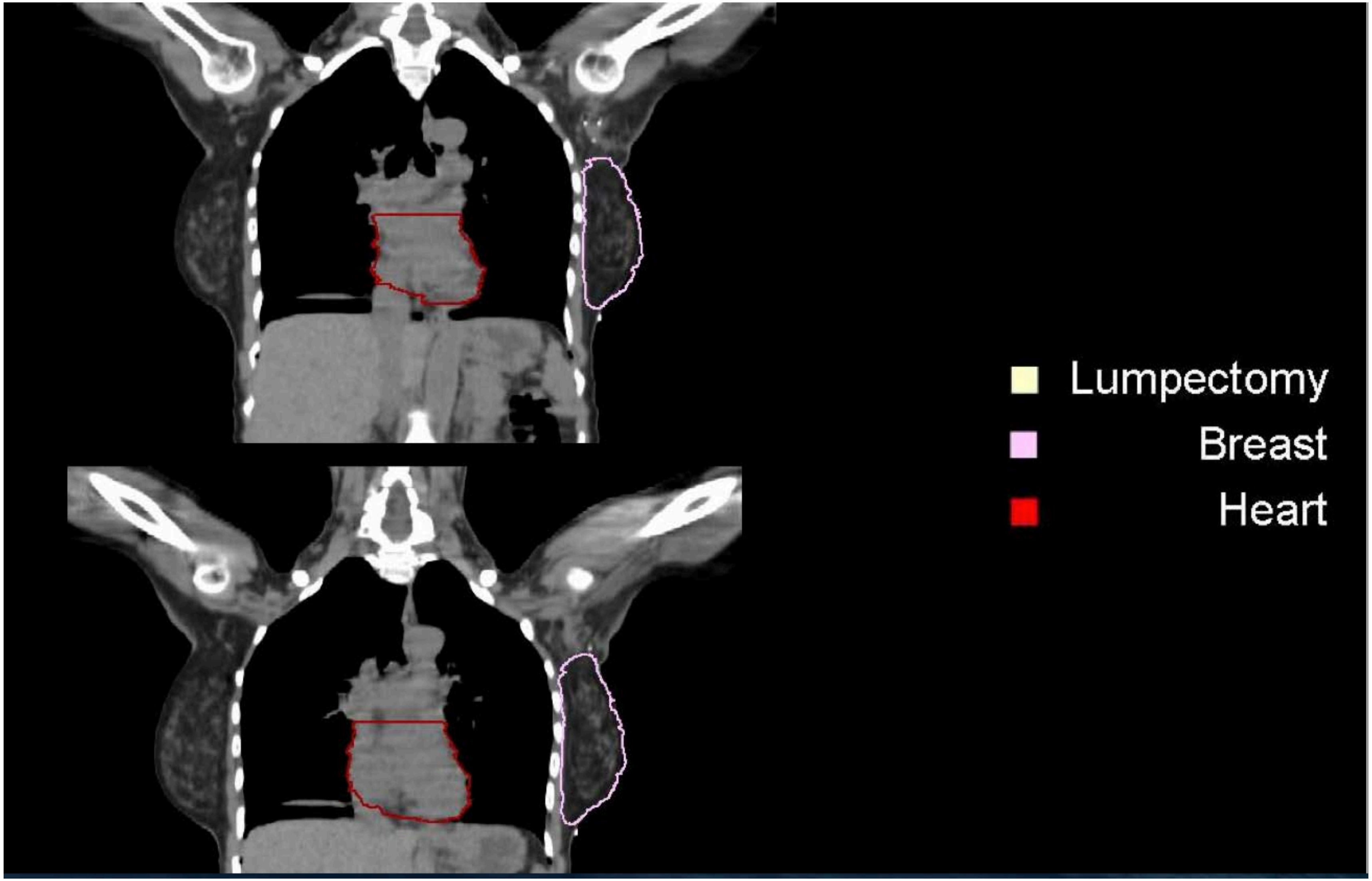


RTOG: Atlas for breast cancer

Breast Cancer Atlas for Radiation Therapy Planning:
Consensus Definitions

RTOG
RADIATION THERAPY ONCOLOGY GROUP

RTOG atlas for breast cancer



Quantec: Heart

Int. J. Radiation Oncology Biol. Phys., Vol. 76, No. 3, Supplement, pp. S77–S85, 2010

0360-3016/10/$–see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2009.04.093

QUANTEC: ORGAN SPECIFIC PAPER **Thorax: Heart**

RADIATION DOSE–VOLUME EFFECTS IN THE HEART

Giovanna Gagliardi, Ph.D.,* Louis S. Constine, M.D.,† Vitali Moiseenko, Ph.D.,‡
Candace Correa, M.D.,§ Lori J. Pierce, M.D.,§ Aaron M. Allen, M.D.,||
and Lawrence B. Marks, M.D.¶

* Department of Medical Physics, Karolinska University Hospital and Karolinska Institute, Stockholm, Sweden; † Department of Radiation Oncology, University of Rochester Cancer Center, Rochester, NY; ‡ Vancouver Cancer Centre, British Columbia Cancer Agency, Vancouver, BC, Canada; § Department of Radiation Oncology, University of Michigan, Ann Arbor, MI; || Department of Radiation Oncology, Dana- Farber Cancer Institute, Boston, MA; Rabin Medical Center Petach Tikvah, Israel ; and ¶ Department of Radiation Oncology, University of North Carolina, Chapel Hill, NC

QUANTEC Heart Segmentation

- The heart border may be difficult to differentiate from liver and diaphragm, but the segmenting of the superior border with the large vessels can be more challenging.
- Three main clinical endpoints have been considered in the study of specific dose–
  - ➢ volume response relationships
  - ➢ mortality from ischemic heart disease, pericarditis
  - ➢ decreased myocardial perfusion

  For these analyses, the volumes considered were the entire heart, pericardium or the left ventricle alone

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QUANTEC Heart segmentation

- Because coronary/ischemic events are a major concern, several investigators have calculated doses to potentially relevant substructures such as coronary arteries or the left ventricle

Anatomical Definition: Thoracic Oesophagus

- Enters the superior mediastinum between the trachea and vertebral column
- Lies anterior to T1 to T4 vertebrae
- Initially it inclines to the left but is moved by the aortic arch to the median plane, opposite the roots of the lungs
- Inferior to the aortic arch, it again inclines to the left as it passes through the diaphragm

Contouring Guidelines: Oesophagus

Int. J. Radiation Oncology Biol. Phys., Vol. 76, No. 3, Supplement, pp. S86–S93, 2010

ELSEVIER

doi:10.1016/j.ijrobp.2009.05.070

QUANTEC: ORGAN-SPECIFIC PAPER **Thorax: Esophagus**

RADIATION DOSE-VOLUME EFFECTS IN THE ESOPHAGUS

Maria Werner-Wasik, M.D.,* Ellen Yorke, Ph.D.,[†] Joseph Deasy, Ph.D.,[‡] Jiho Nam, M.D.,[§] and Lawrence B. Marks, M.D.[§]

*Department of Radiation Oncology, Thomas Jefferson University Hospital, Philadelphia, PA; [†]Department of Radiation Oncology, Memorial Sloan-Kettering Cancer Center, New York, NY; [‡]Department of Radiation Oncology, Washington University School of Medicine, St. Louis, MO; [§]Department of Radiation Oncology, University of North Carolina, Chapel Hill, NC

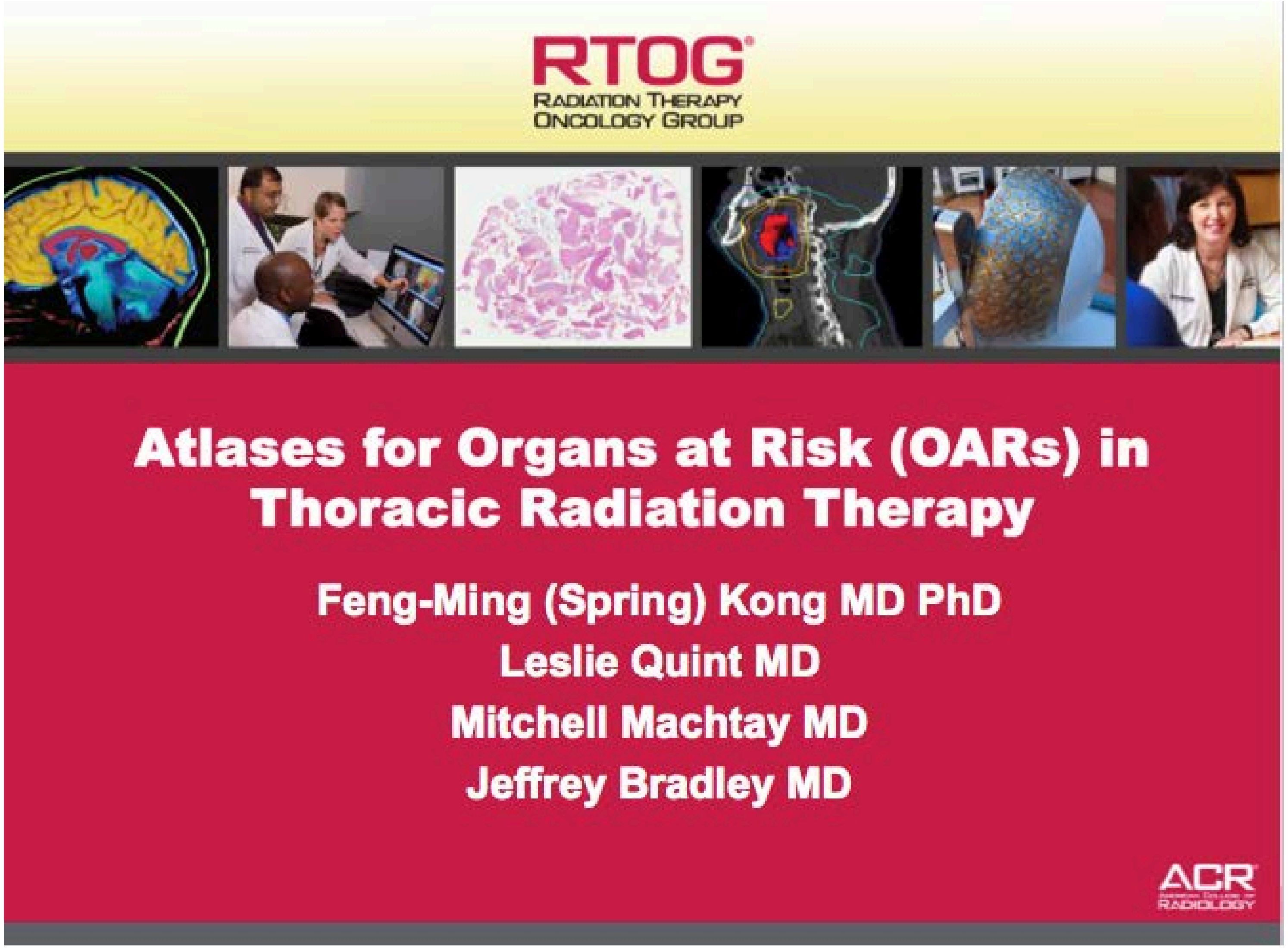
Publications relating esophageal radiation toxicity to clinical variables and to quantitative dose and dose–volume measures derived from three-dimensional conformal radiotherapy for non–small-cell lung cancer are reviewed. A variety of clinical and dosimetric parameters have been associated with acute and late toxicity. Suggestions for future studies are presented. © 2010 Elsevier Inc.

Esophagitis, Lung cancer, Radiotherapy, Esophagus, Toxicity.

QUANTEC Oesophagus Segmentation

- The oesophagus remains closed when not involved in swallowing, and its lumen is often not easily identifiable throughout its entire length, particularly in the middle and caudal levels
- Variable filling...search for air on CT... not always so easy!

Contouring Guidelines



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Contouring Guidelines: Oesophagus RT1106

RTOG 1106 Required OARs

Structure	Description	Structure definition and contouring instructions
Lung	Lungs – PreGTV (composite of CT1GTV and PETMTV)	Both lungs should be contoured using pulmonary windows. The right and left lungs can be contoured separately, but they should be considered as one structure for lung dosimetry. All inflated and collapsed, fibrotic and emphysematic lungs should be contoured, small vessels extending beyond the hilar regions should be included; however, pre GTV, hilars and trachea/main bronchus should not be included in this structure.
Heart	Heart & Pericardium	The heart will be contoured along with the pericardial sac. The superior aspect (or base) will begin at the level of the inferior aspect of the pulmonary artery passing the midline and extend inferiorly to the apex of the heart.
Esophagus	Esophagus	The esophagus should be contoured from the beginning at the level just below the cricoid to its entrance to the stomach at GE junction. The esophagus will be contoured using mediastinal window/level on CT to correspond to the mucosal, submucosa, and all muscular layers out to the fatty adventitia.
Spinalcord	Spinal Canal	The spinal cord will be contoured based on the bony limits of the spinal canal. The spinal cord should be contoured starting at the level just below cricoid (base of skull for apex tumors) and continuing on every CT slice to the bottom of L2. Neuroformanines should not be included.
		This is only required for patients with tumors of upper lobes. Only the ipsilateral brachialplex is required. This will include the spinal nerves exiting the neuroforamina

Contouring Atlas: Oesophagus

Atlas of lung, esophagus, and spinal cord

CLINICAL INVESTIGATION

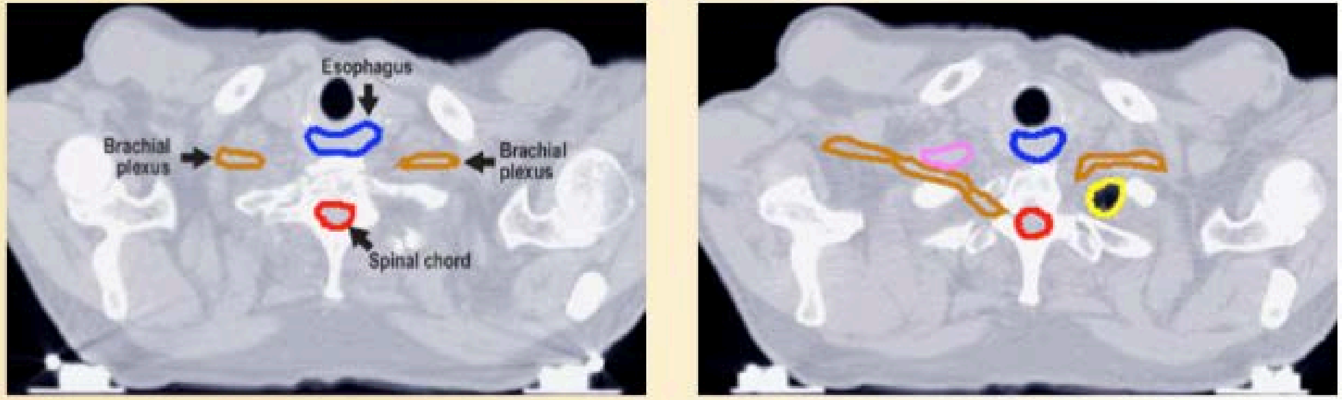
CONSIDERATION OF DOSE LIMITS FOR ORGANS AT RISK OF THORACIC RADIOTHERAPY: ATLAS FOR LUNG, PROXIMAL BRONCHIAL TREE, ESOPHAGUS, SPINAL CORD, RIBS, AND BRACHIAL PLEXUS

Feng-Ming (Spring) Kong, M.D., Ph.D.,[*] Timothy Ritter, Ph.D.,[*] Douglas J. Quint, M.D.,[†] Suresh Senan, M.D.,[‡] Laurie E. Gaspar, M.D.,[§] Ritsuko U. Komaki, M.D.,[¶] Coen W. Hurkmans, Ph.D.,[||] Robert Timmerman, M.D.,[#] Andrea Bezjak, M.D.,[**] Jeffrey D. Bradley, M.D.,[††] Benjamin Movsas, M.D.,[‡‡] Lon Marsh, C.M.D.,[*] Paul Okunieff, M.D.,[§§] Hak Choy, M.D.,[#] and Walter J. Curran, Jr., M.D.[¶¶]

Int J Radiat Oncol Biol Phys. 2011 81(5):1442-57

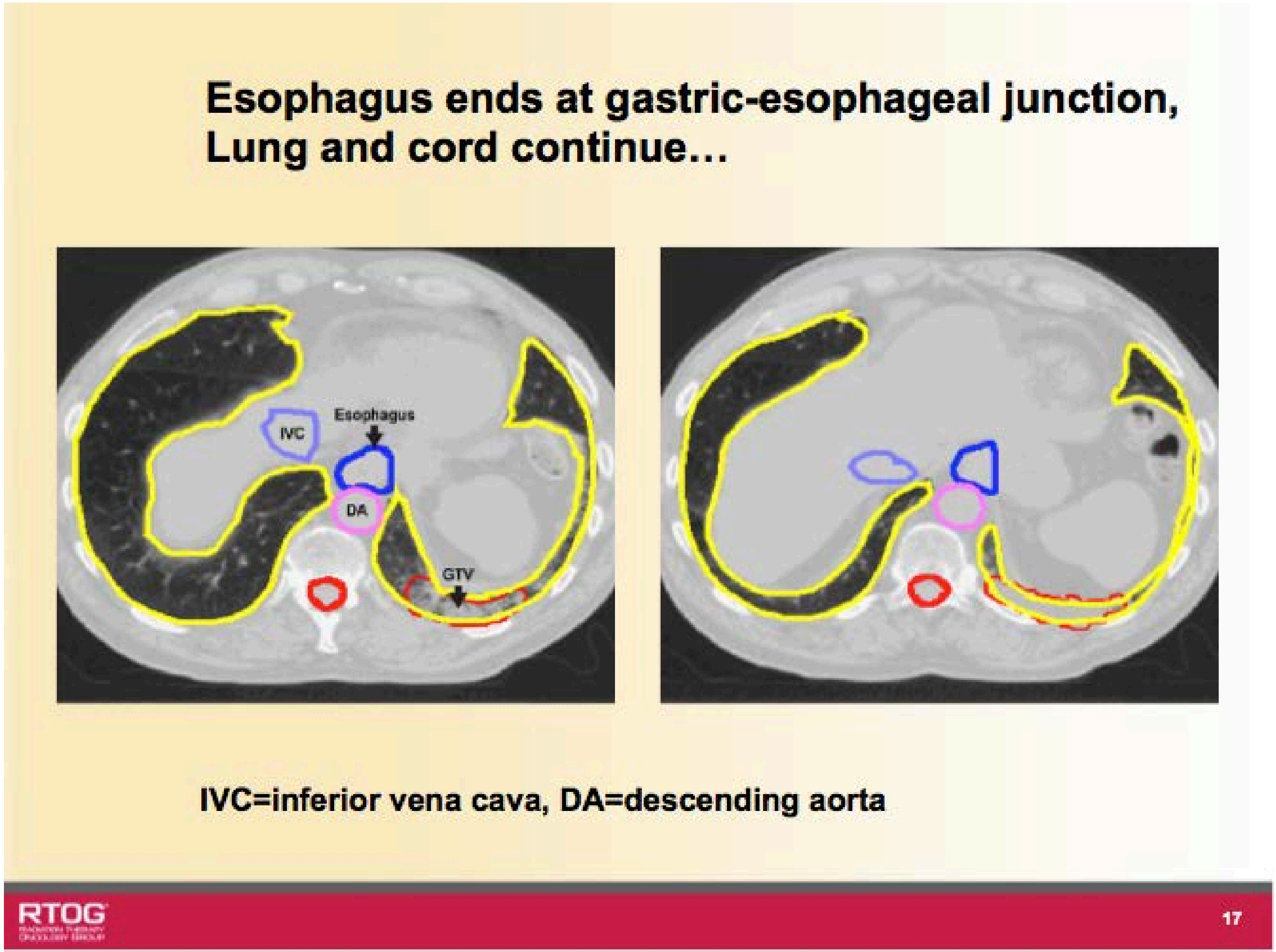
Start of Oesophagus

Esophagus starts at the level of cricoid
Lung is visible now of the left apex



Spinal cord should also start at this level just below the cricord or from the base of skull C1 if scan is available, particularly when the tumors involve neck or apex.

End of Oesophagus



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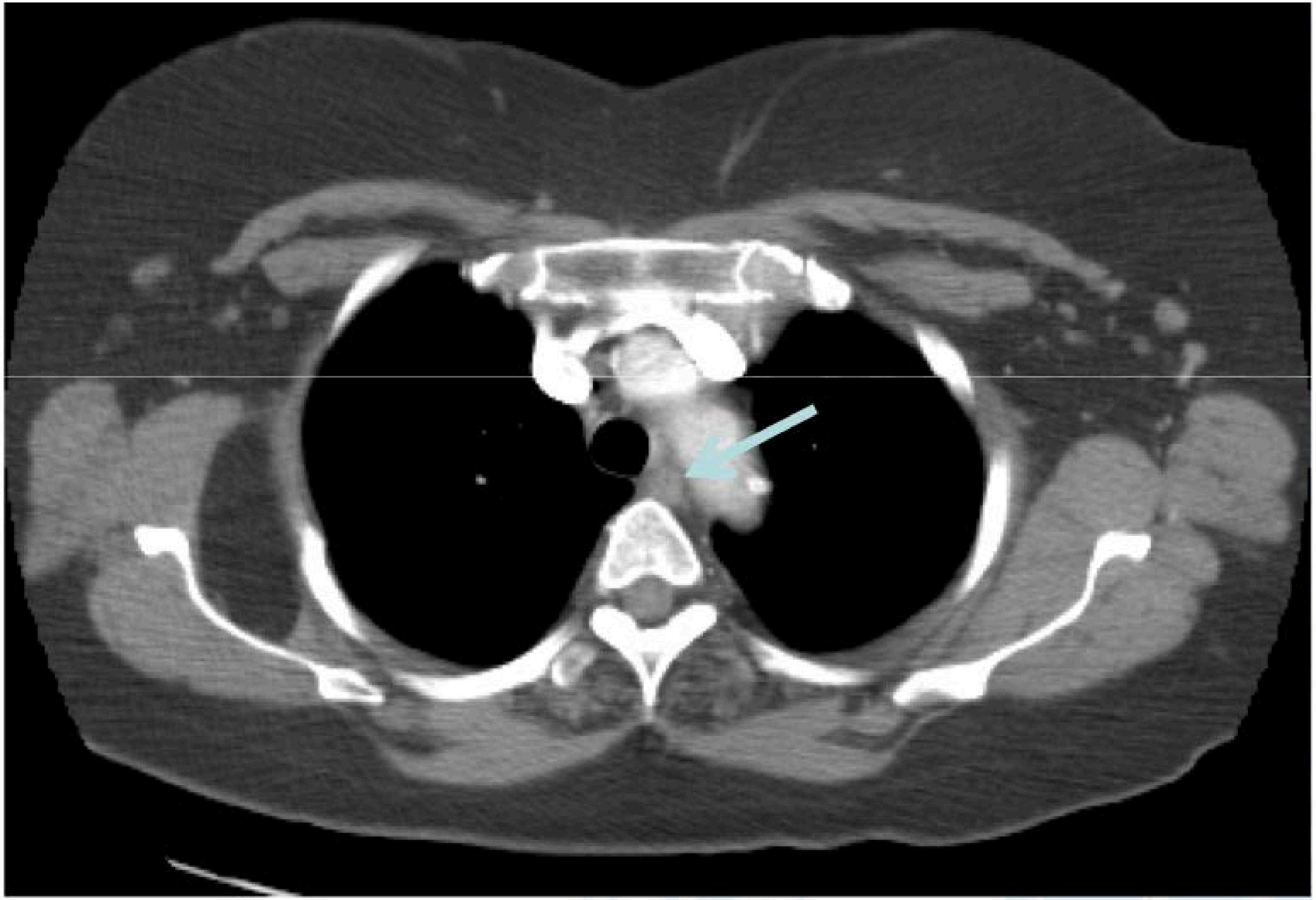
Oesophagus



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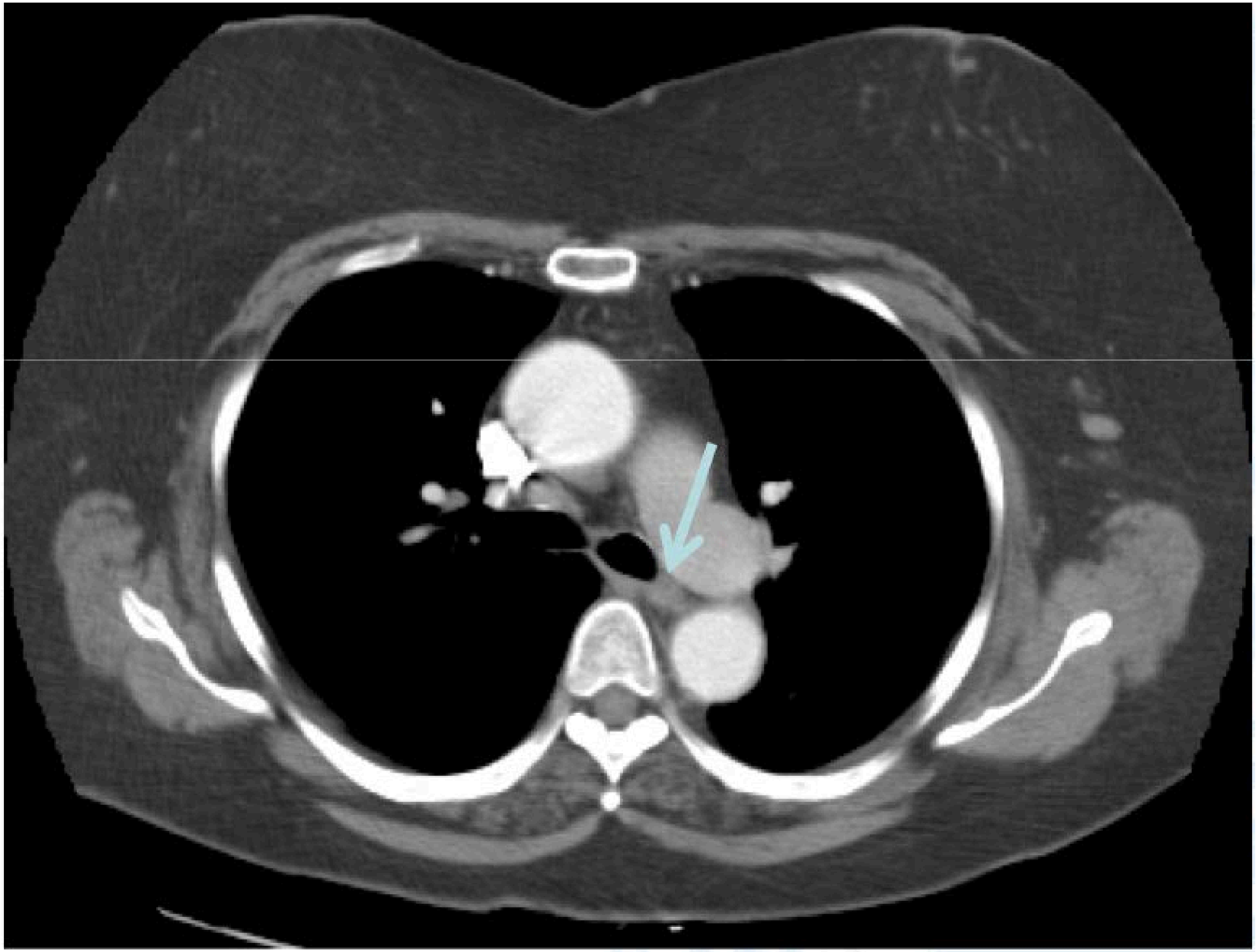
http://radiology.med.sc.edu/Mike%20CT%20Chest.ppt?bcsi_scan_E872BC5C0E0115D2=1

Oesophagus



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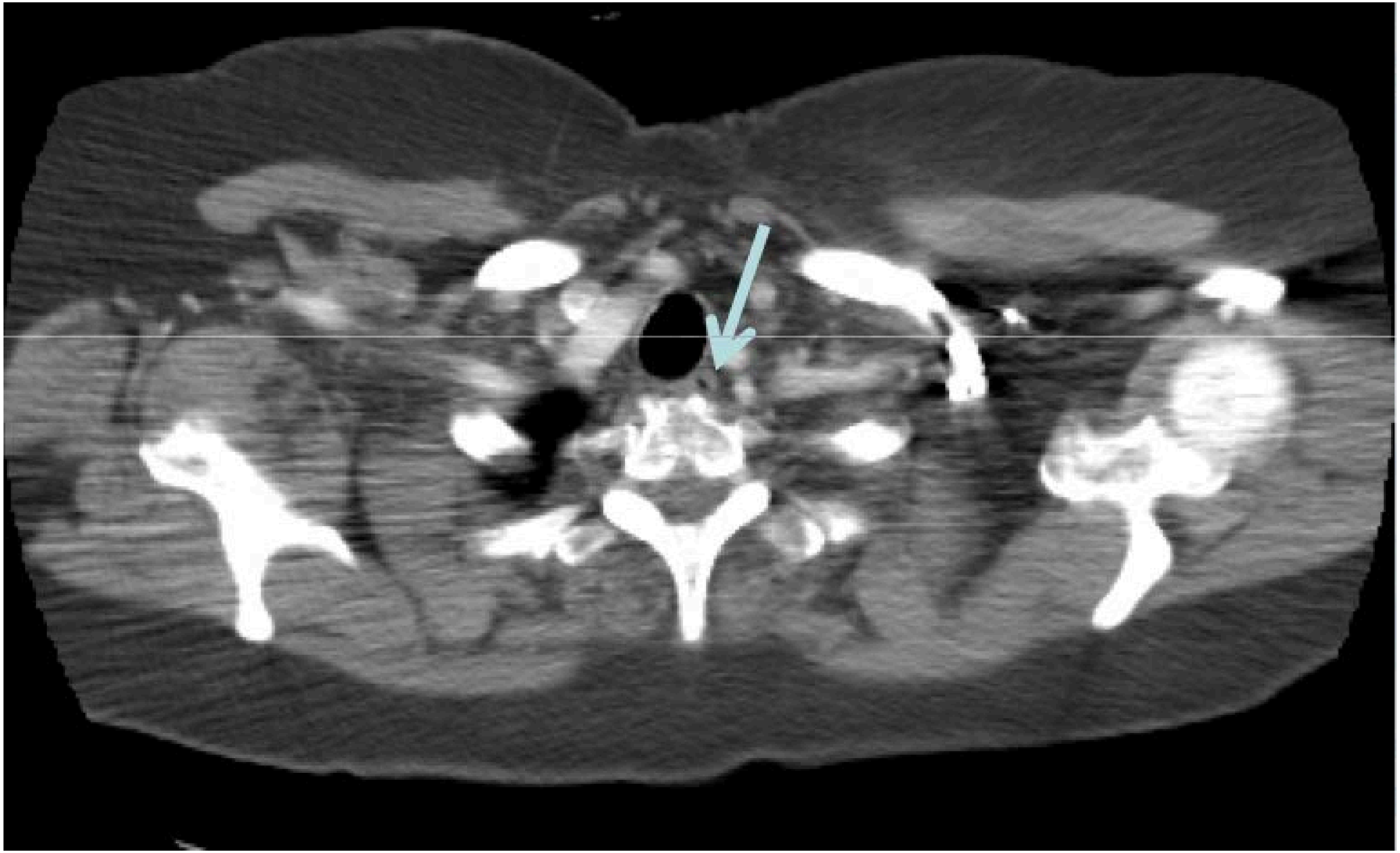
Oesophagus



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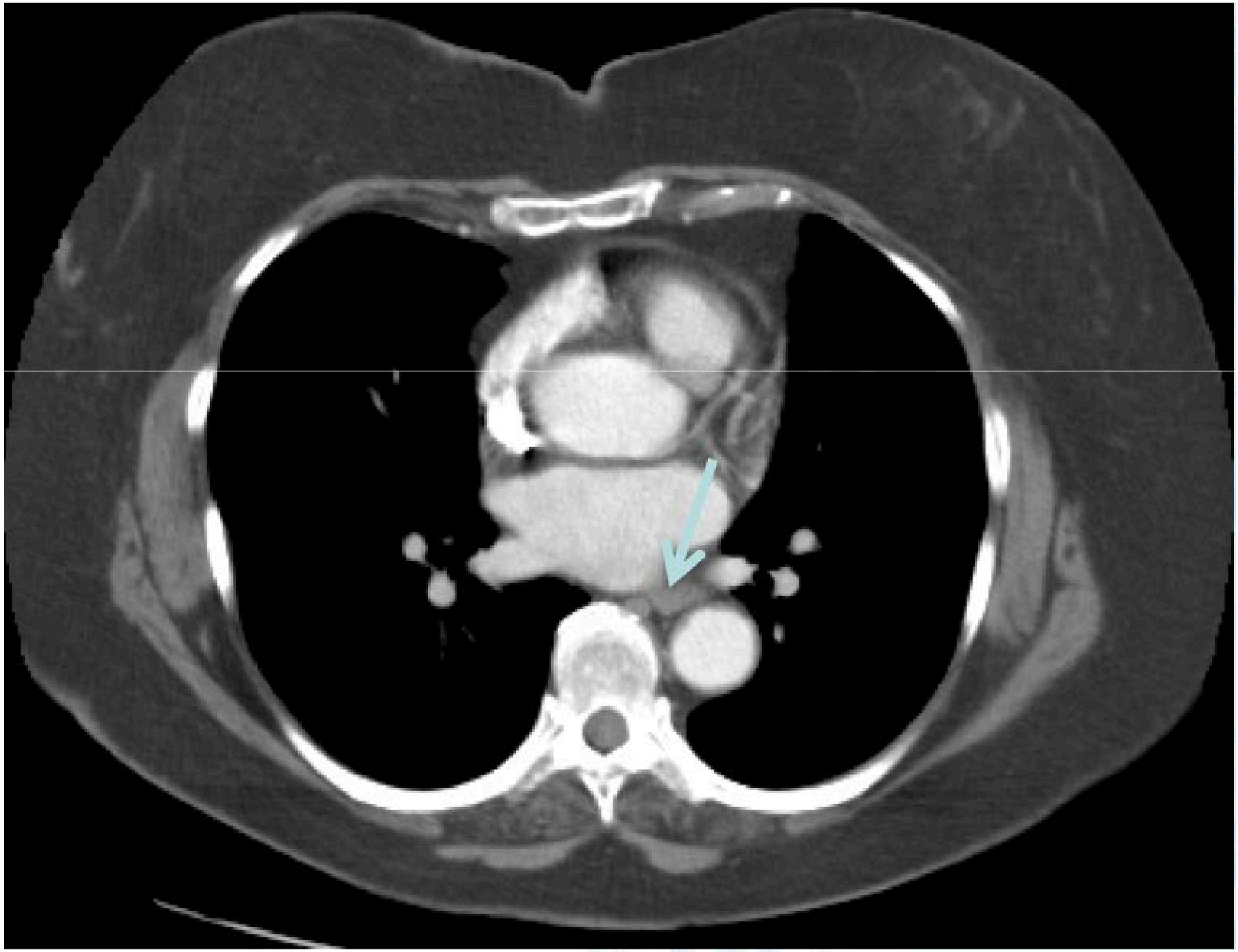
Oesophagus



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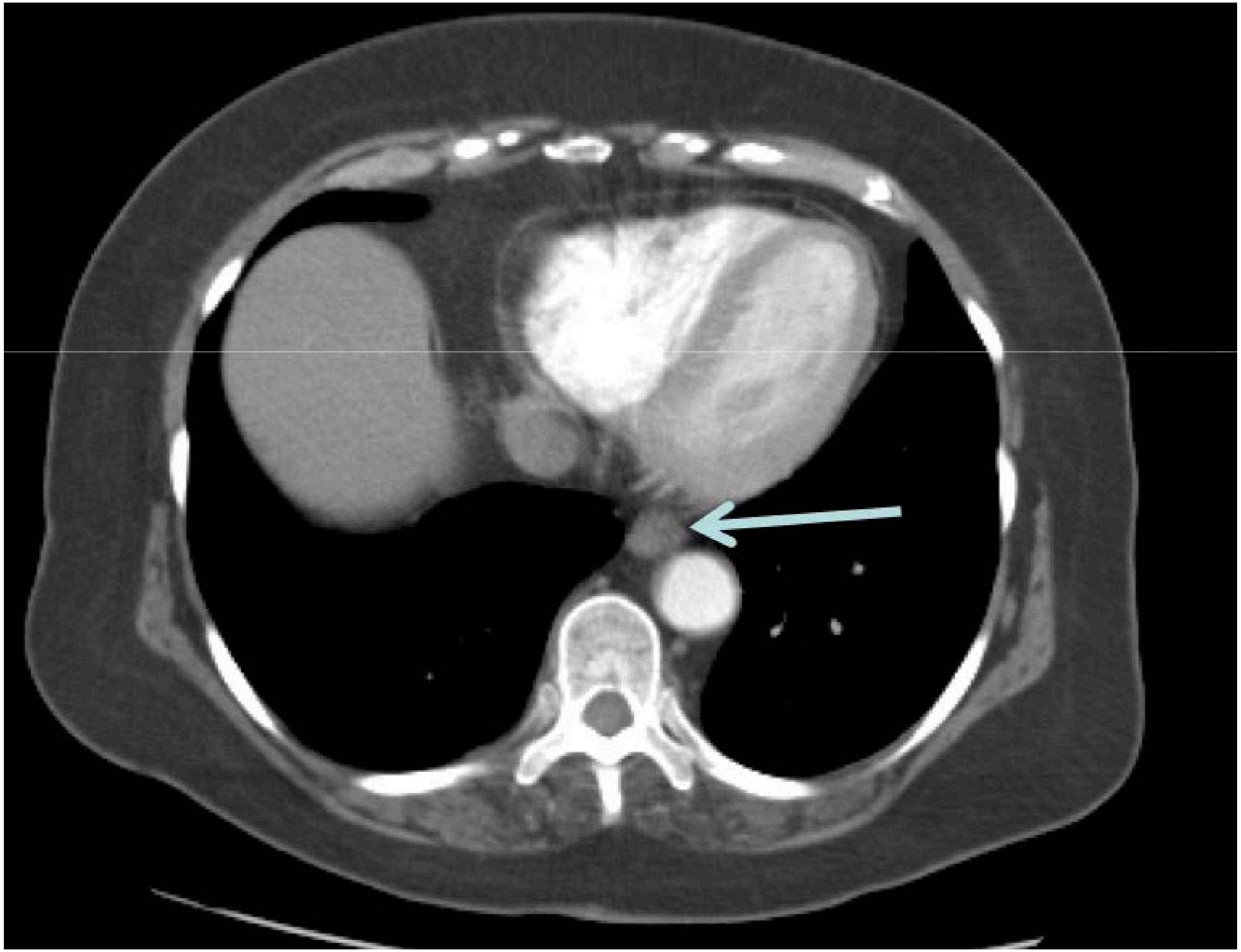
Oesophagus



Available from:
http://radiology.med.sc.edu/Mike%20CT%20Chest.ppt?bcsi_scan_E872BC5C0E0115D2=1

Optimizing the treatment volume in lung

Martijn Kamphuis MSc, MBA Candidate

Radiation Therapist IGRT

Department of Radiotherapy

Amsterdam, the Netherlands

Content of the presentation

- Multimodality imaging in general: e.g. PET-CT in case of the lung
- Dealing with organ motion: e.g. breathing motion compensation
- Dealing with anatomical changes: e.g. atelactesis/baselineshift
- Improving registration techniques: e.g. softissue match in SBRT
- Improving the CI: e.g.how different technique will affect the CI (3D vs IMRT/VMAT)
- Repeating the main question: Why do we need the learn about IGRT in the BPcourse?

Radiotherapy is an effective but toxic treatment

Optimizing:

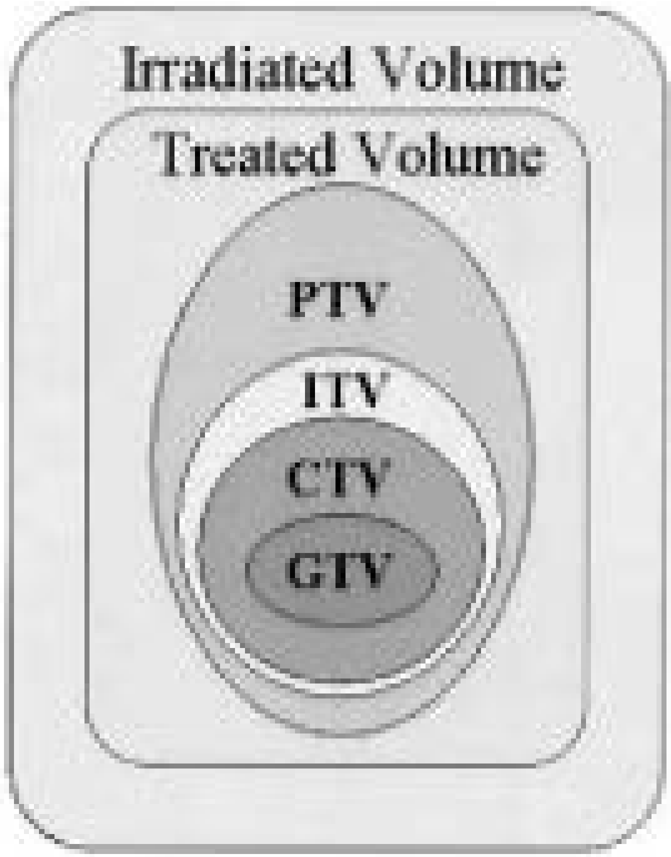
- Trying to reduce side effects
  - ➢ Less dose in OAR= less side effects

Maintain or improve LC/OS rates

- ➢ Volume reduction without dropping rates
- ➢ Room for increasing dose to the target

Systematic approach

- What volumina are defined and how can we reduce them?



(C) ICRU 62

GTV/CTV definition

- The GTV is the gross demonstrable extent and location of the **tumor**
- The CTV is the volume of tissue that contains a demonstrable GTV and/or **subclinical malignant disease** with a certain probability of occurrence considered relevant for therapy
- How to optimize GTV/CTV volumina?

GTV/CTV

- Improve target definition
  - ➢ Not necessarily means smaller volumes

- Guidelines

- Additional imaging modalities (PET or MR)
  - ➢ Improve target definition,
  - ➢ Or at least decrease interobserver variation
  - ➢ Mostly coincides with volume reduction

Positron Emission Tomography

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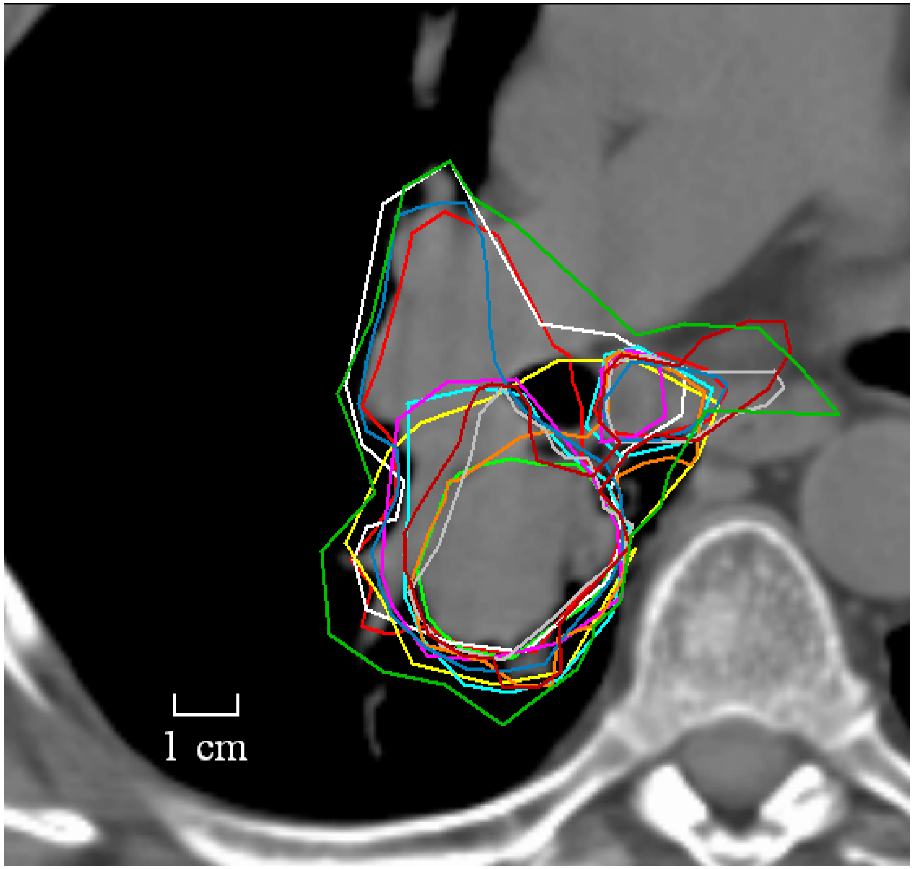
Delineation variation: CT versus CT + PET



CT (T_2N_2)

SD 7.5 mm

R. Steenbakkers *et al (2006).* R&O vol. 65

ITV= IM + CTV

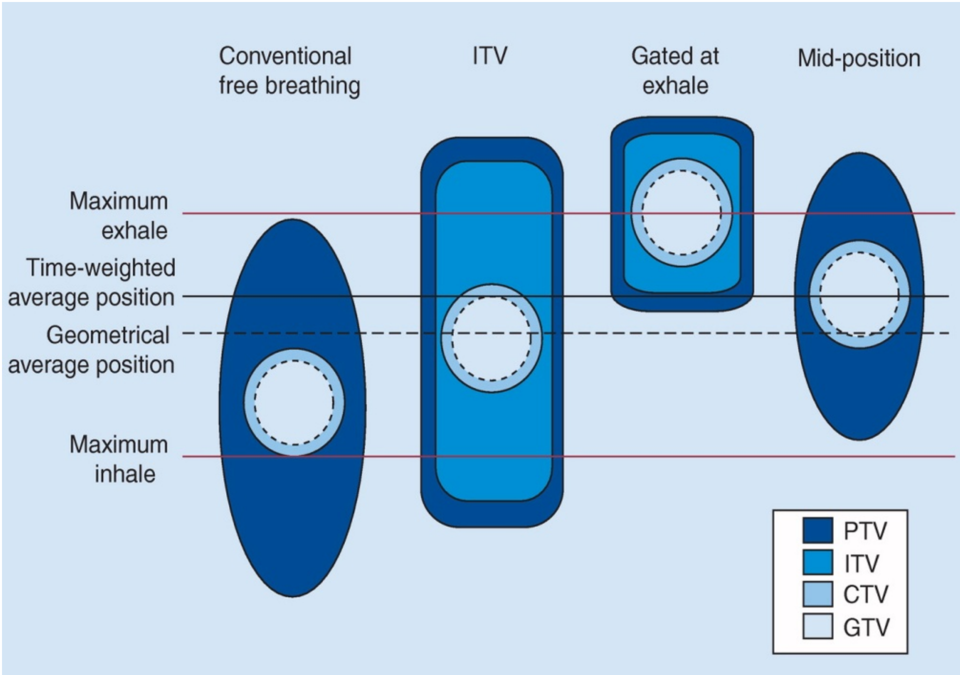
- IM: Internal margin
  - Margin for expected physiological movements and variations in size, shape and position of the CTV

- EG:
  - Respiration
  - Changes in bladder fillings
  - Bowel movement
  - Heart beat etc.etc.

- ITV: Internal Target Volume

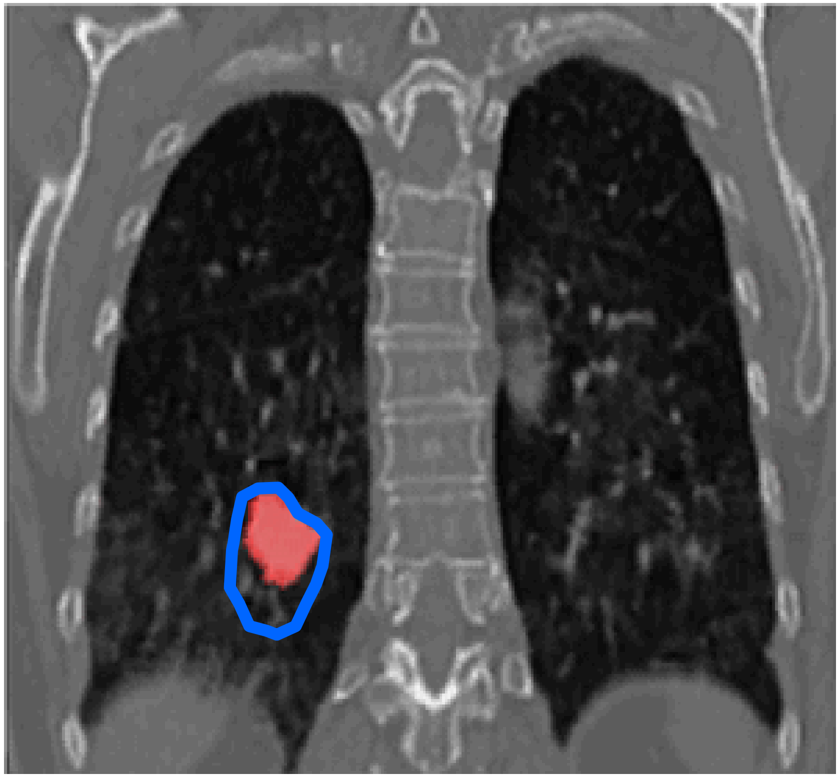
Minimizing the impact of respiration

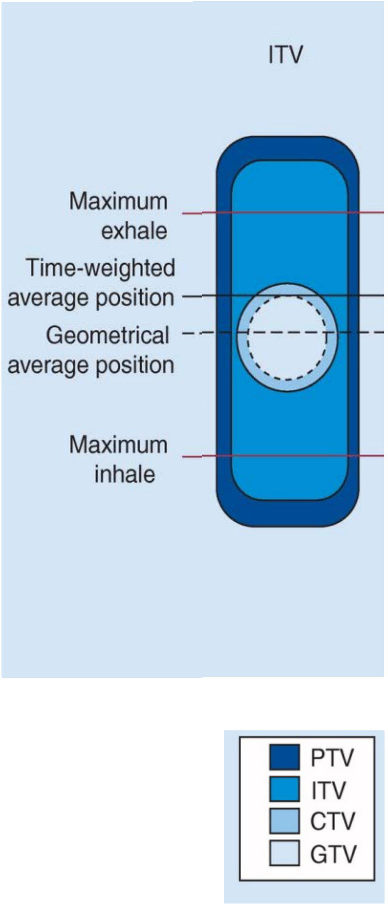
- Motion management strategies
  - Motion encompassing ITV
  - Gating
  - Mid ventilation



J.J.Sonke *et al (Oct 2009), Expert Rev. Anticancer Ther.*

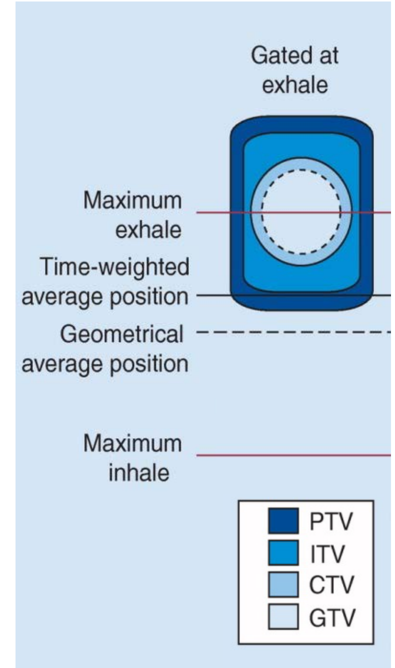
Motion encompassing ITV

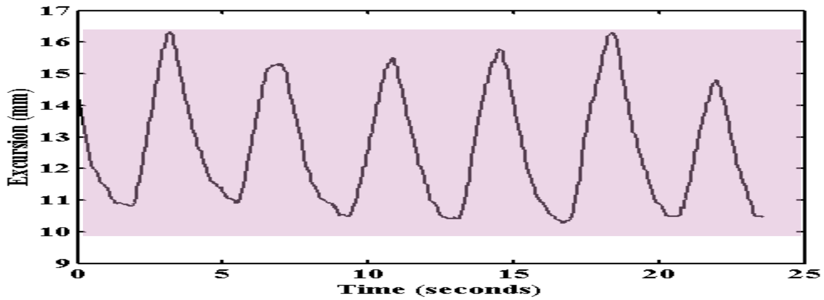




https://www.imi.uni-luebeck.de

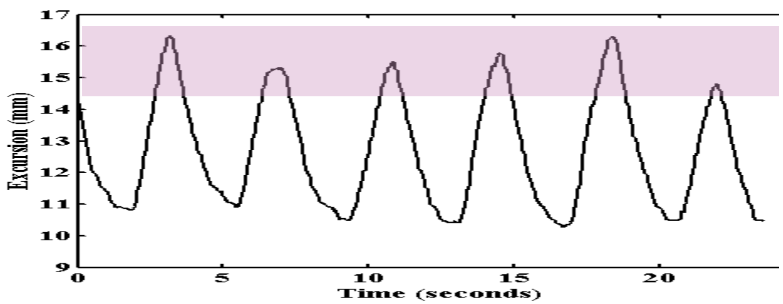
Gating



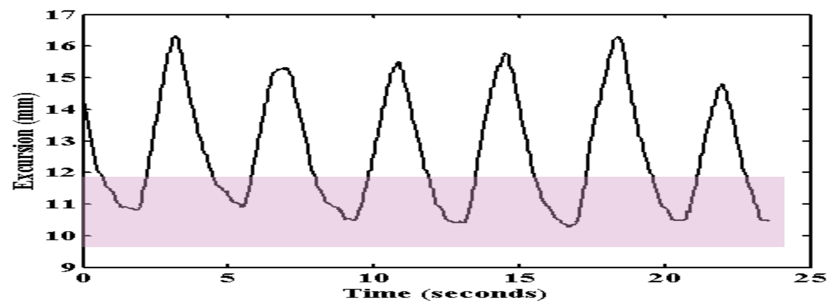


Free Breathing

NO GATING



Free Breathing INSPIRATION gating



Free Breathing EXPIRATION gating

Image courtesy M.Josopovic

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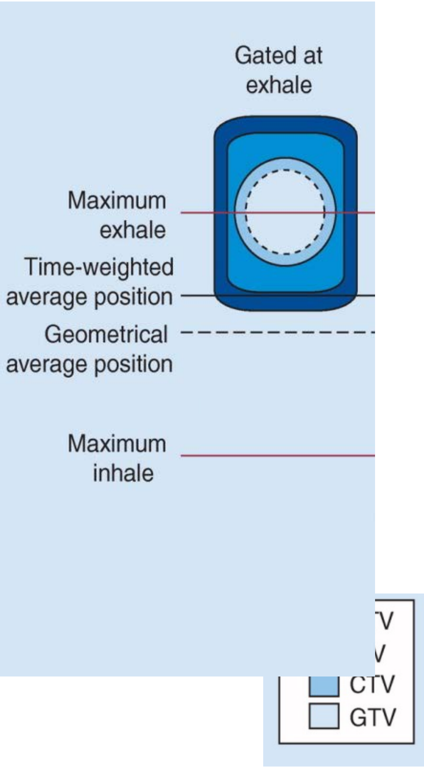
Gating



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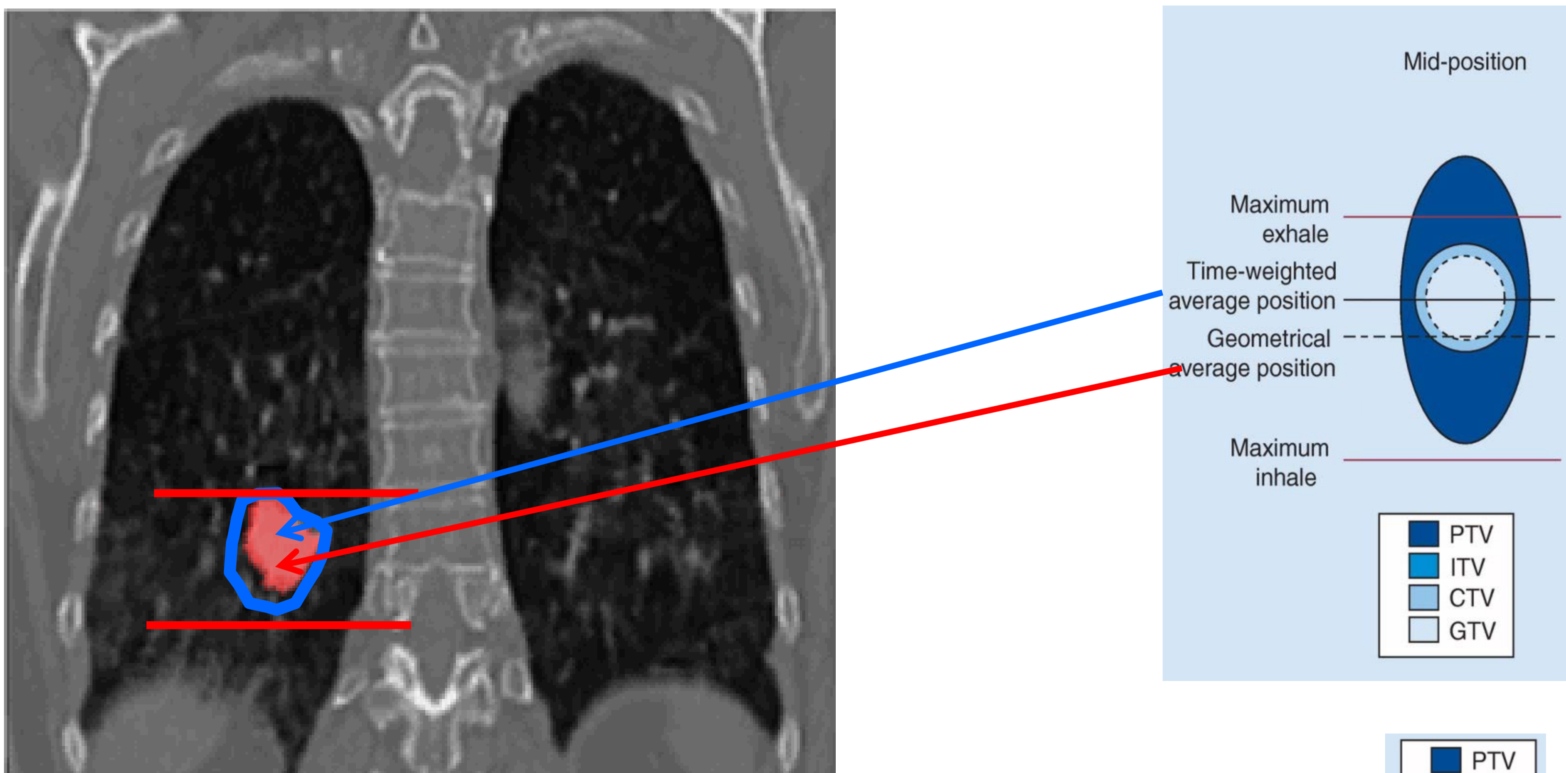
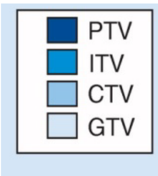
Mid ventilation



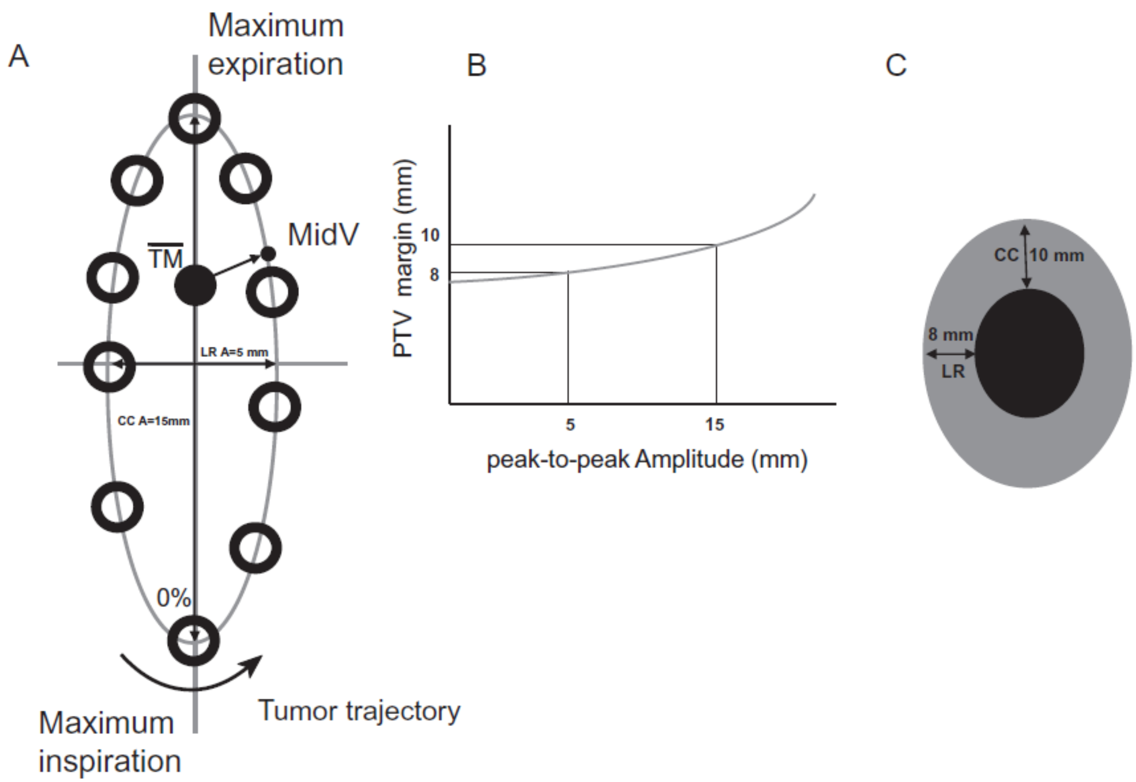


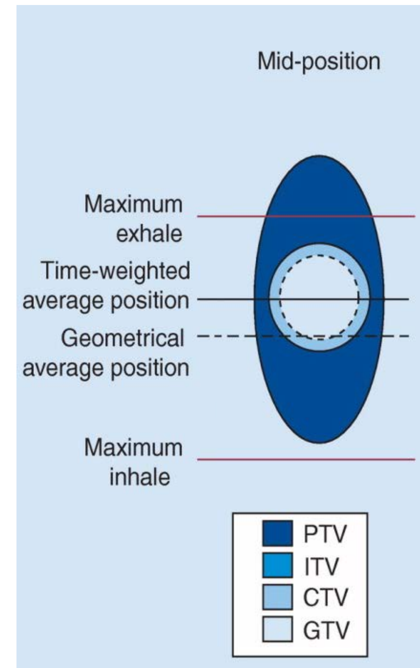
https://www.imi.uni-luebeck.de

Mid ventilation

H. Peulen et al. / Radiotherapy and Oncology 110 (2014) 511–516

Schematic overview of mid-ventilation based PTV margins of an example patient





PTV=ITV+SM (Set-up margin)

- Def: margin to account for uncertainties (*inaccuries and lack of reproducibility*) in patient positioning and alignment

  - Variations in patient positioning
  - Mechanical uncertainties in equipment
  - Dosimetric uncertainties
  - Transfer errors between CT and linac
  - Human factors (skills)

Set-up margin

- Varies from center to center
- Varies from machine to machine
- Optimal QA by technicians

- More impressionable: Imaging strategies
  - What do you image?
  - How do you register?
  - When do you image?

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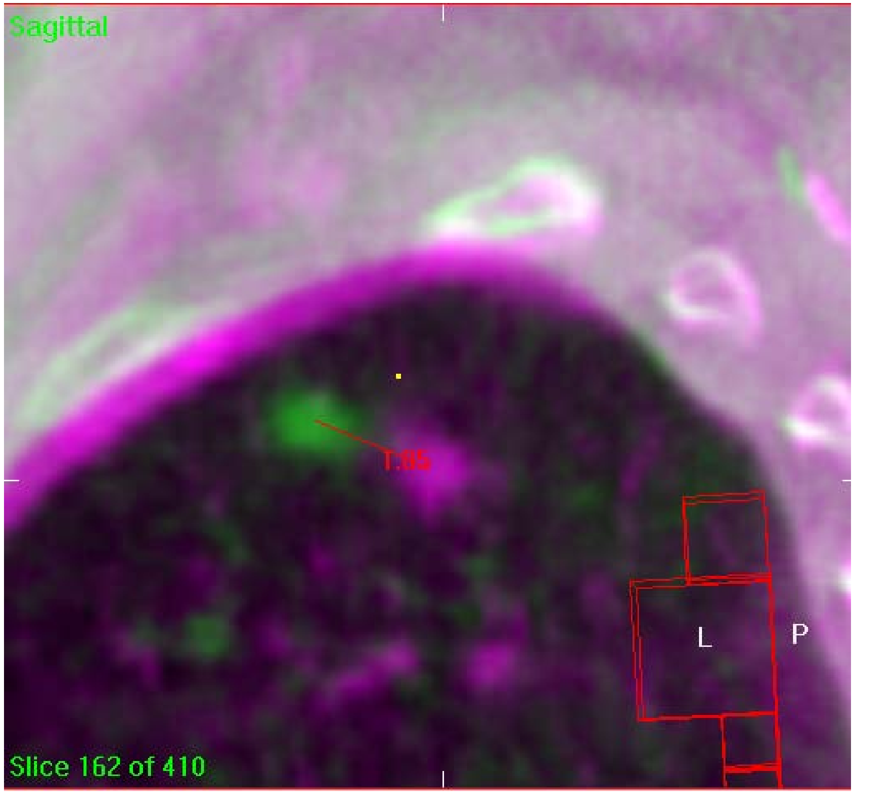
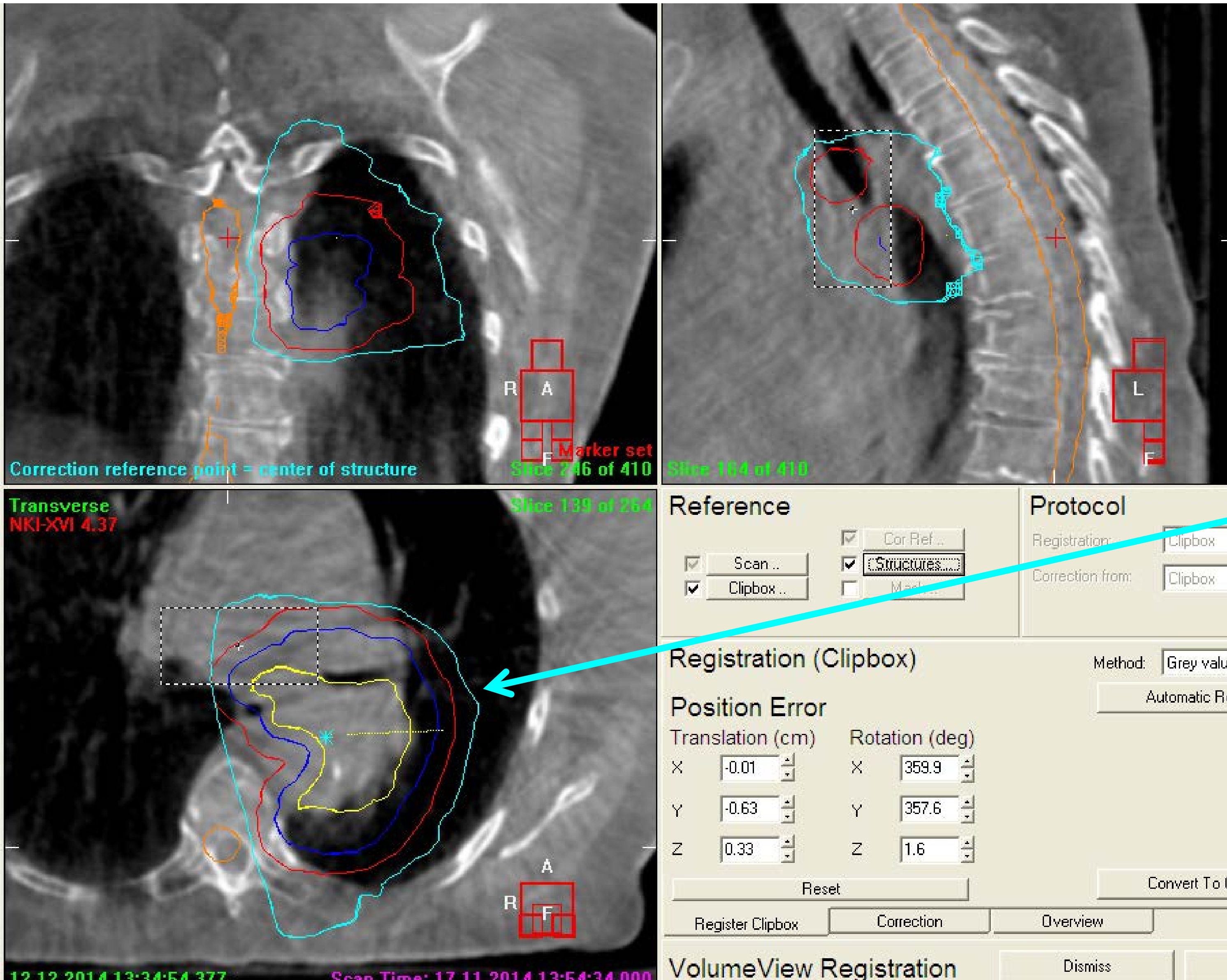
Where to register on?

- Ideally:
  - Tumor registration
- Surrogate:
  - Fiducial markers
  - Carina match
- Least optimal:
  - Bony anatomy

Larger margin if a surrogate is used



Be aware of the OAR: Critical isodose



51 Gy isodose

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How do you register?

- Manual procedure
  - ➢ Individual skills

- Algorithms
  - ➢ Bony anatomy
  - ➢ Grey value

- How to account for multiple targets?
  - ➢ Different margins needed for SIB techniques
  - ➢ In the lung case: LNN & GTV

When do you image?

- What is the frequency?
  - Once @start
  - Offline decision protocols
    - SAL/NAL
    - eNAL
  - Online
  - Intra fractional imaging

Tighter margins

Example: *prostate*

- *No protocol* vs *Online* vs *offline*

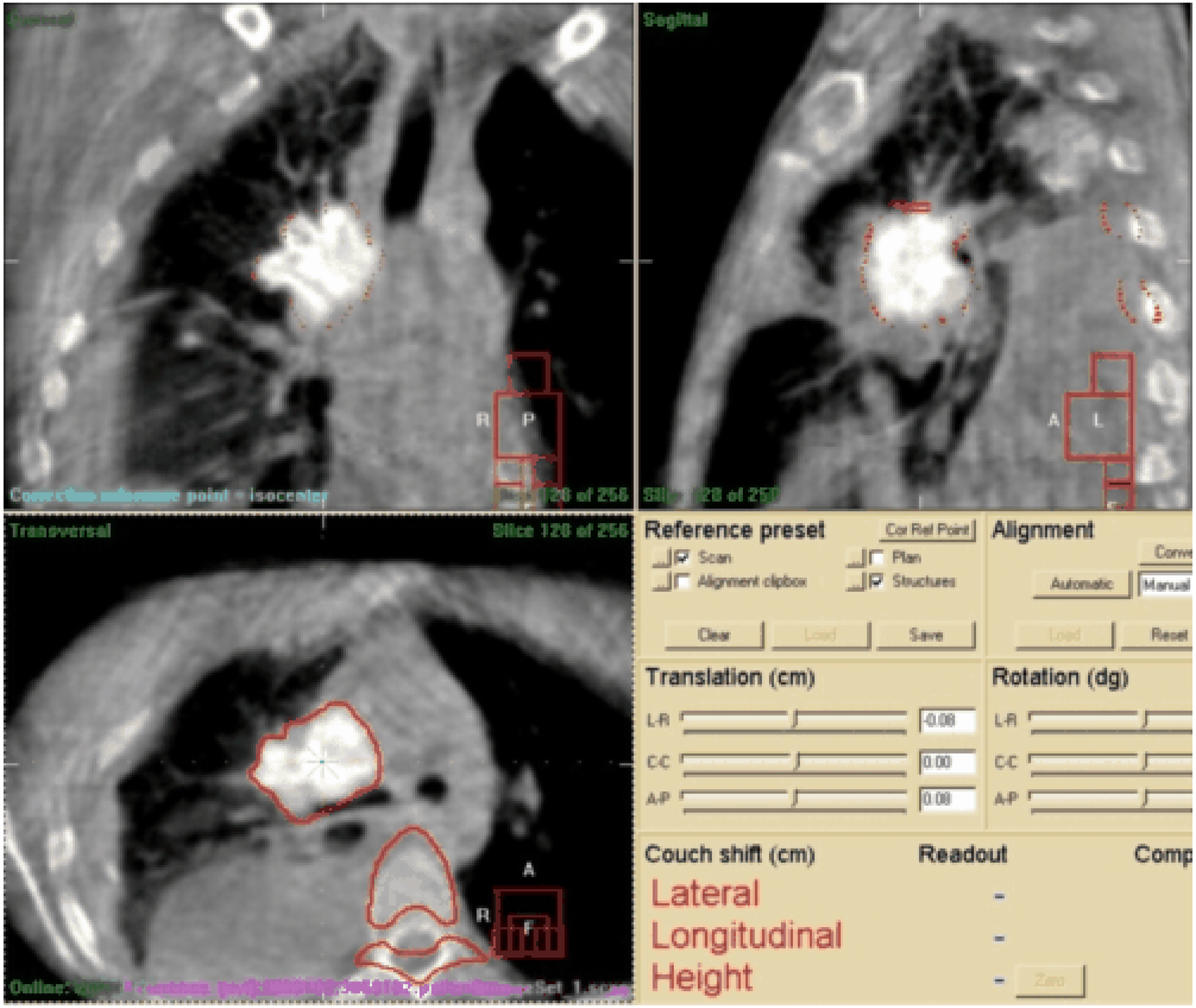
- Margin calculation (X,Y&Z)
  - ➢ No correction: 9, 10 ,15mm
  - ➢ Offline: 8, 8 & 9 mm
  - ➢ Online: 7, 7 & 7 mm

Tighter margins

treatment execution β * σ	3.3	7.7	3.6
breathing b	0.0	0.0	0.0
scalar a – β * σ_p	-2.7	-6.6	-2.7
CTV-PTV marge (mm)	6.6	7.2	7.1
Eenvoudige formule van Herk: 2.5*SIGMA+0.7*sigma	8.0	7.8	8.7
Formule Stroom: 2.0*SIGMA+0.7*sigma	6.8	6.6	7.5

breathing b	0.0	0.0	0.0
scalar a – β * σ_p	-2.7	-6.6	-2.7
CTV-PTV marge (mm)	6.2	6.2	6.1
Eenvoudige formule van Herk: 2.5*SIGMA+0.7*sigma	7.1	6.8	7.0
Formule Stroom: 2.0*SIGMA+0.7*sigma	5.9	5.6	5.8

Special attention to: anatomical changes



If corrected online on CBCT

Courtesy to Alvaro Martinez

Weekly 3D imaging is mandatory!

Data NKI

- 12% of lung patients require ad hoc replanning
- 45% show alternations

And what about TP?

Treated volume:

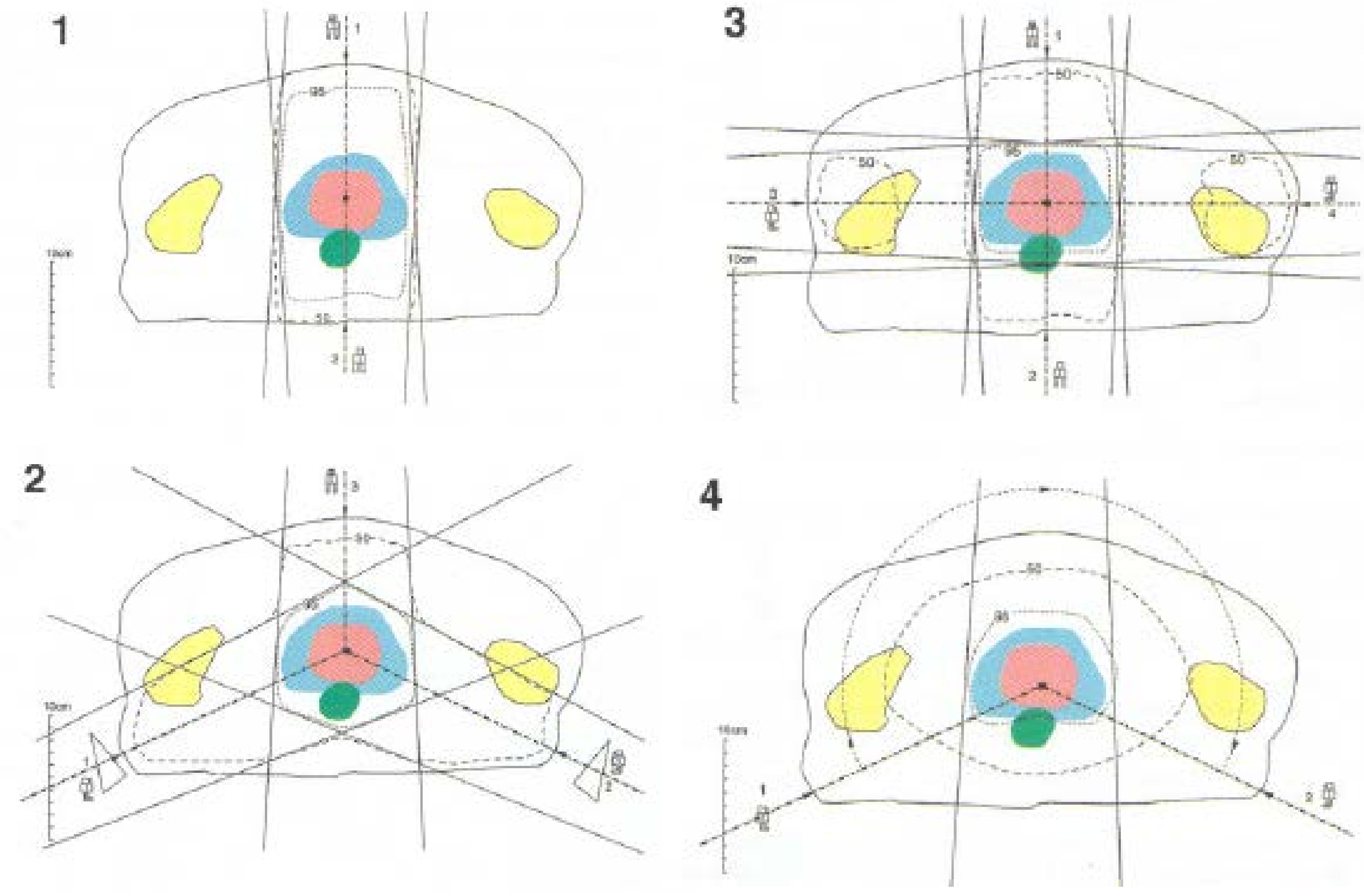
- Def: TV is the tissue volume that is planned to receive a dose specified as being appropriate to achieve the purpose of the treatment.

- Most of the times the TV>PTV
    - ➢ Conformity index (CI)

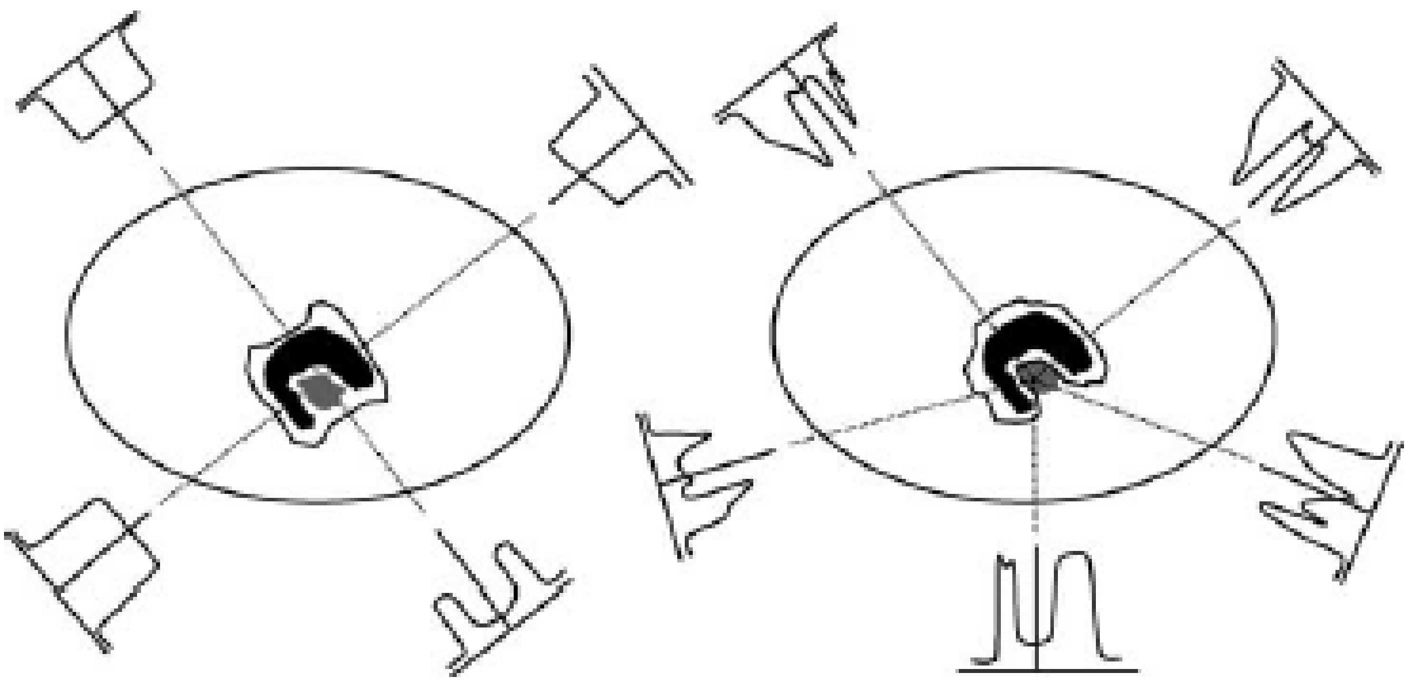
Conformity index (CI)

$$C\,I_{(ref)} = \frac{\text{Volume of PTV covered by the reference dose}}{\text{Volume of PTV}}$$

From low to high conformity



CRT vs IMRT or VMAT



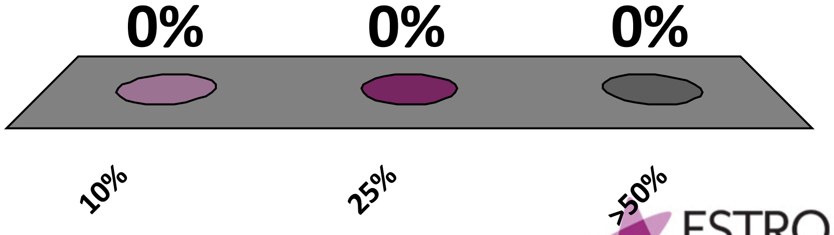
Small reductions in CTV-PTV margin

- *Many ways possible..*
- *Cost a lot effort*

- *Is it really worth it?*

PTV 5 cm diameter
5mm CTV-PTV margin reduction
What will be the % volume reduction?

A. 10%
B. 25%
C. >50%



Is it worth the effort? YES!

Volume:

- Third power
- $4/3\pi r^3$

Dirk Verellen *et al.*(2007), Nature Reviews

Where to start?

- Margins are calculated with recipes:
  - E.g: $M=2.5*\Sigma+0.7*\sigma$
    - Σ= sum of systematic errors
    - σ= sum of random errors
  - Systematic errors: errors occuring in the treatment preparation phase:
    - E.g. delineation, breathing error on CT
  - Random errors: errors occuring in the execution phase:
    - E.g. interfraction motion

$M=2.5*\Sigma+0.7*\sigma$

- Systematic errors have a the largest influence on the margin:
  - 2.5/0.7=3.57 times bigger

➢ First target systematic errors!

➢ Eg. Delineation: introduce guidelines

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Errors summed in quadratic

- Eg treatment with 2 systematic errors
  - Error A: 2mm
  - Error B: 1mm
  - Sum of squares: $2^2+1^2= \sqrt{5}=2.23$mm
  - Margin = 2.5*2.23mm= 5.6mm

- Two scenarios
  - Elimination of error A
  - Elimination of error B

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What happens?

- Elimination of error A:
  - Sum of squares: $0^2+1^2= \sqrt{1}=1$ mm
  - Margin = 2.5*1mm= 2.5 mm
  - Margin reduction: 5.6-2.5= 3.1mm!
- Elimination of error B:
  - Sum of squares: $2^2+0^2= \sqrt{4}=2$ mm
  - Margin = 2.5*2mm= 5 mm
  - Margin reduction: 5.6-5= 0.6 mm!

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Conclusions

- There are many ways to minimize the treated volume
- Efforts can be made throughout the treatment process
- Impact of the effort depends on type of error and its relative size

Treatment Planning Considerations in Head and Neck Cancer

Dr Paul Kelly

Consultant Radiation Oncologist
Cork University Hospital

with thanks to Dr Sinead Brennan for slide sharing

General Overview

- Introduction
- Aetiology
- Presentation
- Investigations
- Staging
- Principles of Treatment
- Side-effects of treatment

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General Overview

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Introduction

- 6 th most common cancer in men worldwide
- More common in men (M:F = 3:1)
- 90% are squamous cell carcinoma

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Aetiology

Alcohol and tobacco are synergistic

– the two together worse than effect of either alone

Genetic susceptibility

Poor oral hygiene

Malnutrition

Mechanical irritation

Occupational exposure

Chronic viral infection

Nasopharyngeal cancer and Epstein-Barr virus

- Endemic in regions of Northern Africa and Asia
- Etiology distinct from other head and neck cancers
- Epstein-Barr viral proteins detectable in majority of nasopharyngeal tumors

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Oropharyngeal Cancer and Human Papilloma Virus

- HPV-DNA detected in 15-62% HNSCC, higher in oropharynx

- Patients with HPV +ve oropharyngeal canrcinoma
  - Typically younger
  - Non-smokers and Non-drinkers
  - LN mets have a firm rather than hard consistency
  - Tumour shows basaloid features
  - +ve for p16 on immunohistochemical staining
  - Outcome is **better** than non-HPV related carcinomas

Rischin D, Young RJ et al. J Clin Oncol. 2010 Sep 20;28(27):4142-8.

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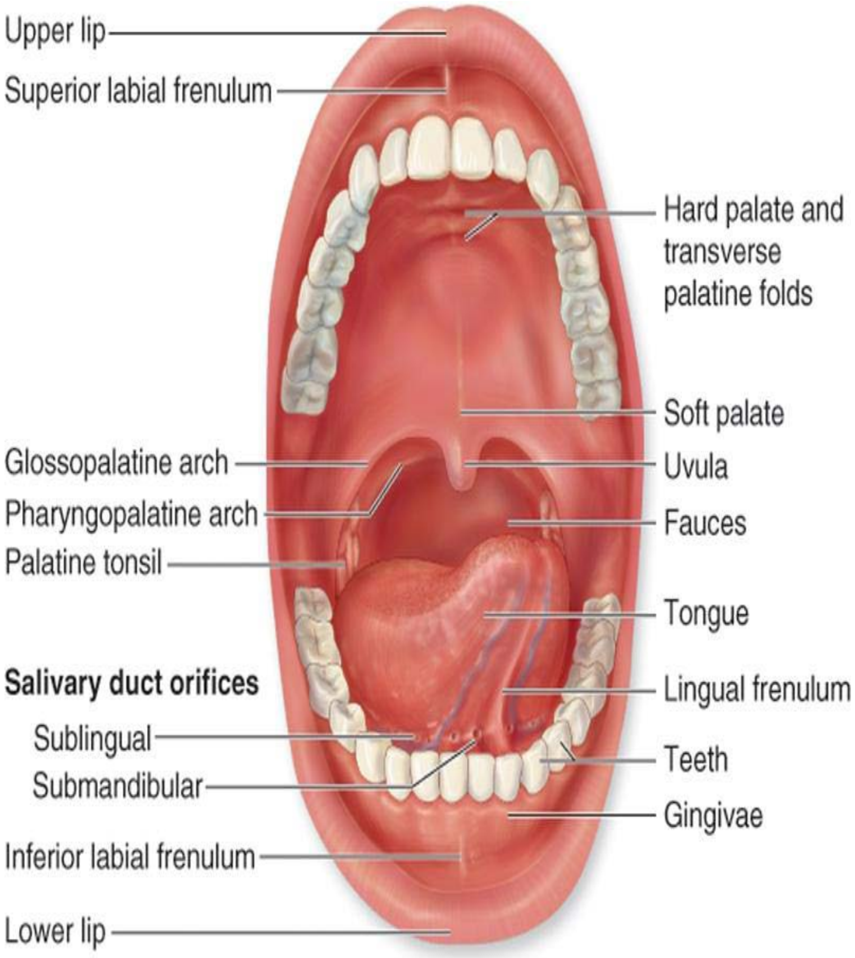
Oral Cavity



Subsites

- Anterior 2/3rds of Tongue
- Buccal Mucosa
- Upper and Lower Alveolar Ridge
- Retromolar Trigone
- Hard Palate
- Floor of Mouth

Oral Tongue Tumour

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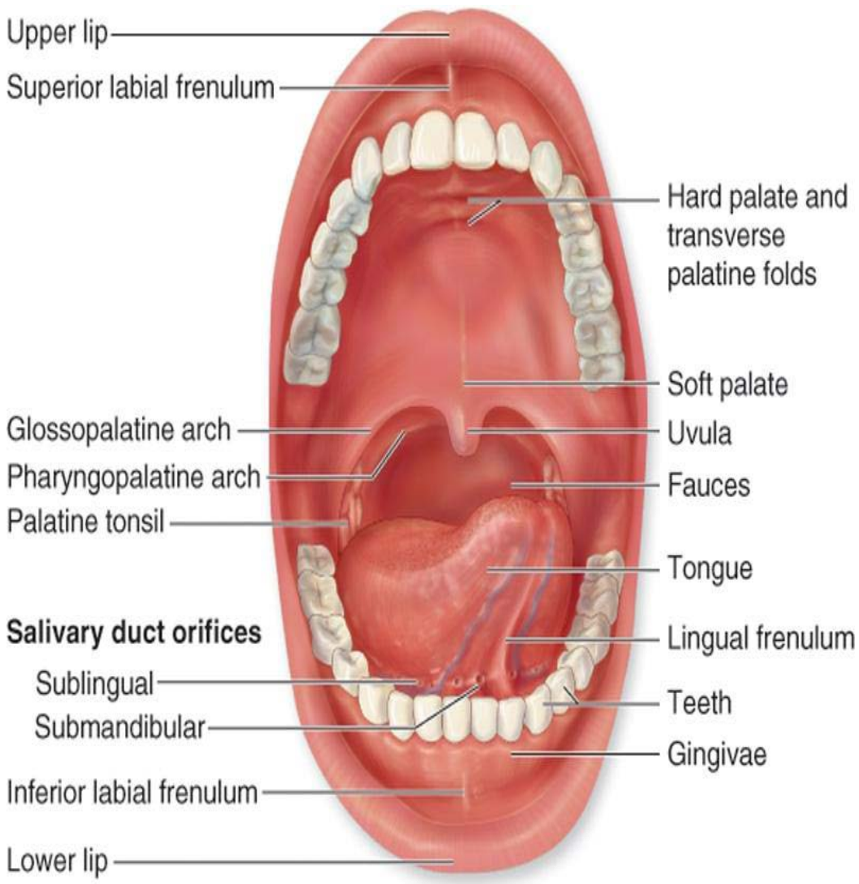
Oral Cavity Tumours

Alveolar SCC Mandible

SCC Floor of Mouth

Cancer Retromolar Trigone

Oropharynx Subsites



Soft Palate

Tonsils

Base of Tongue

Vallecula

Posterior Pharyngeal Wall

Uvula

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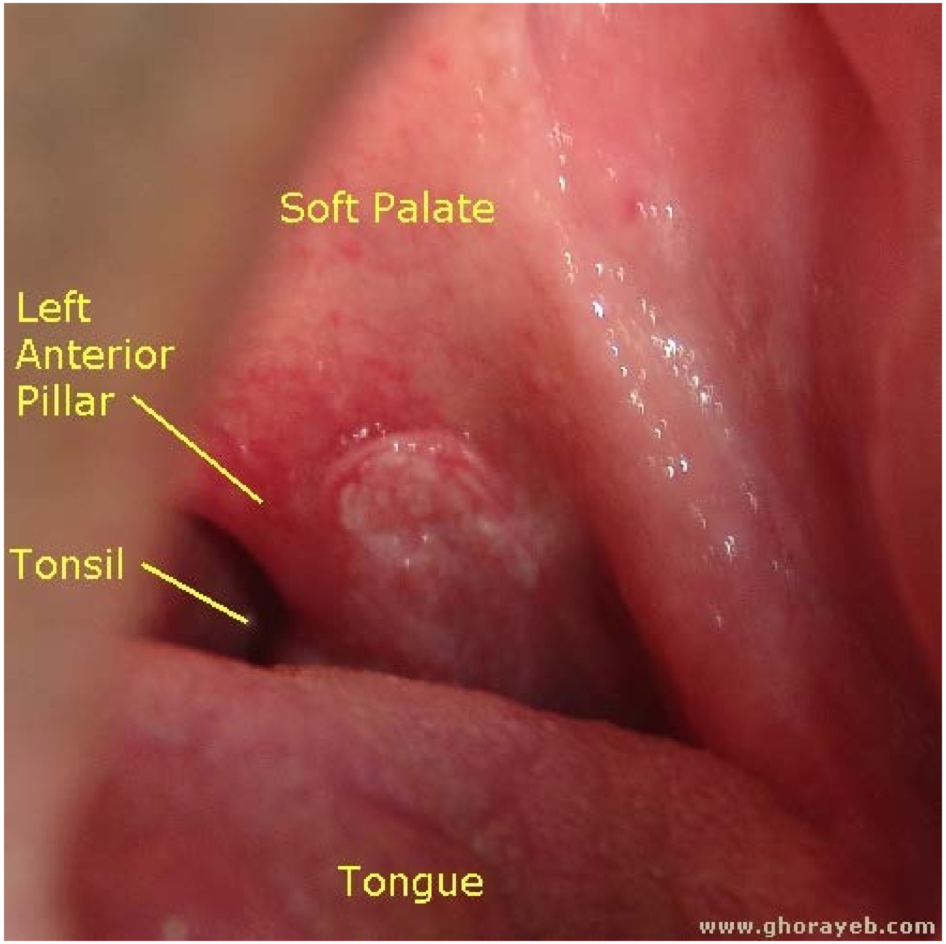
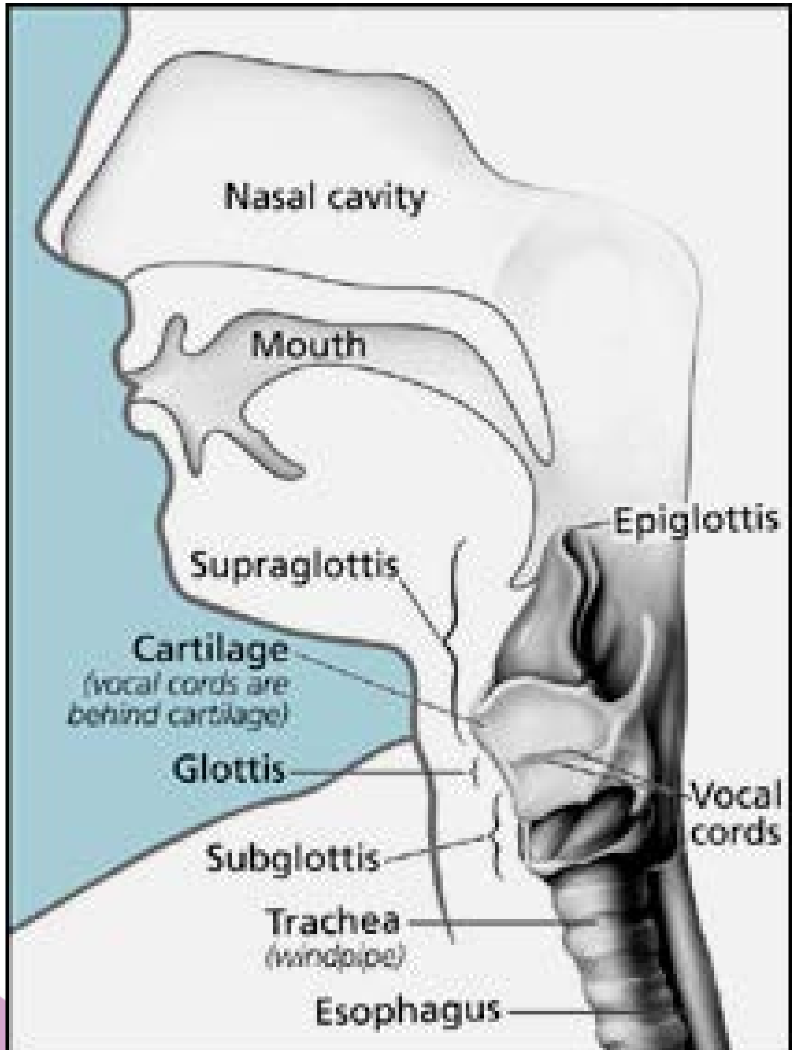
Tonsillar Cancer

Soft Palate Cancer



Larynx Subsites



Supraglottis

- epiglottis
- aryepiglottic folds
- arytenoids
- ventricles
- false cords

Glottis – Vocal Cords (Most Common)

Subglottis – extends from 1 cm below the vocal cords to the lower border of the cricoid cartilage

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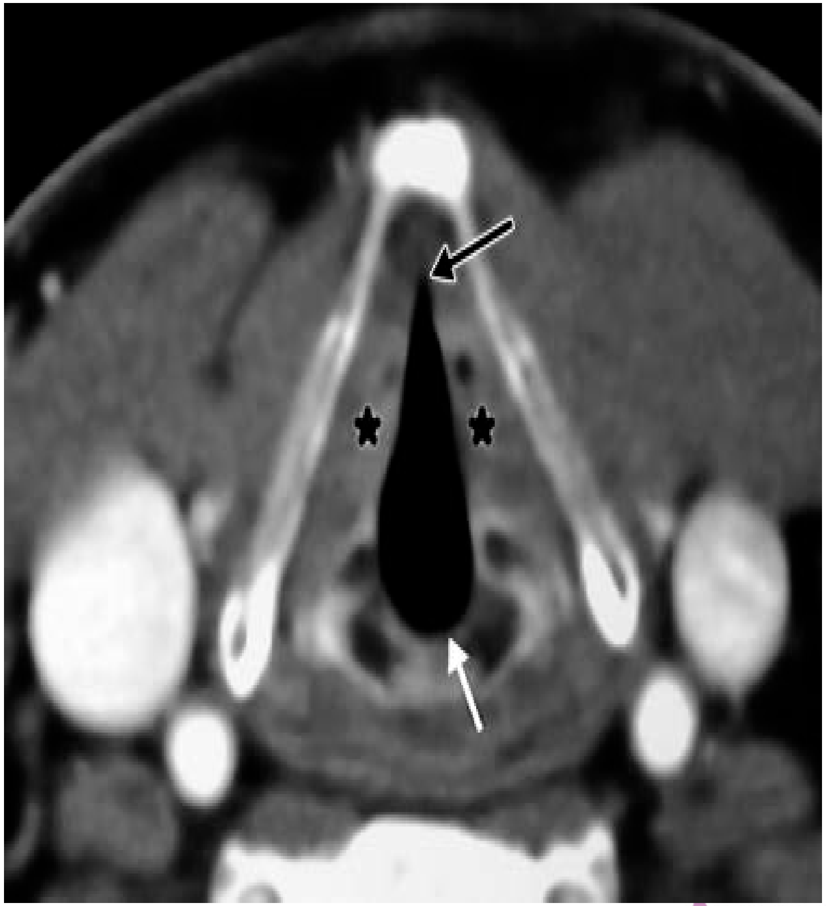
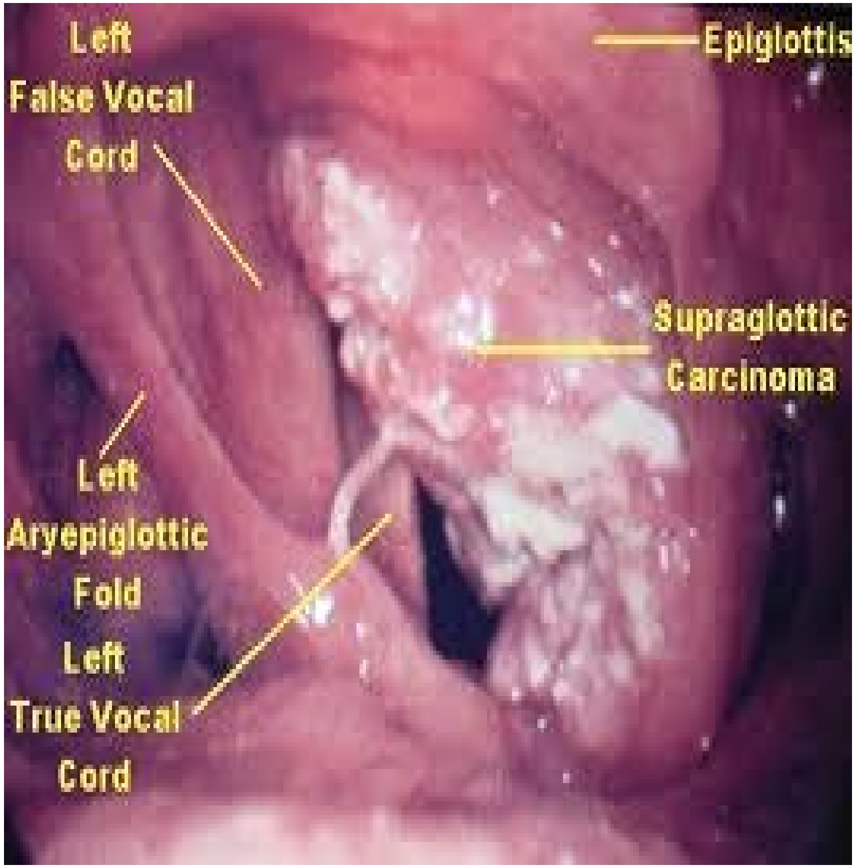
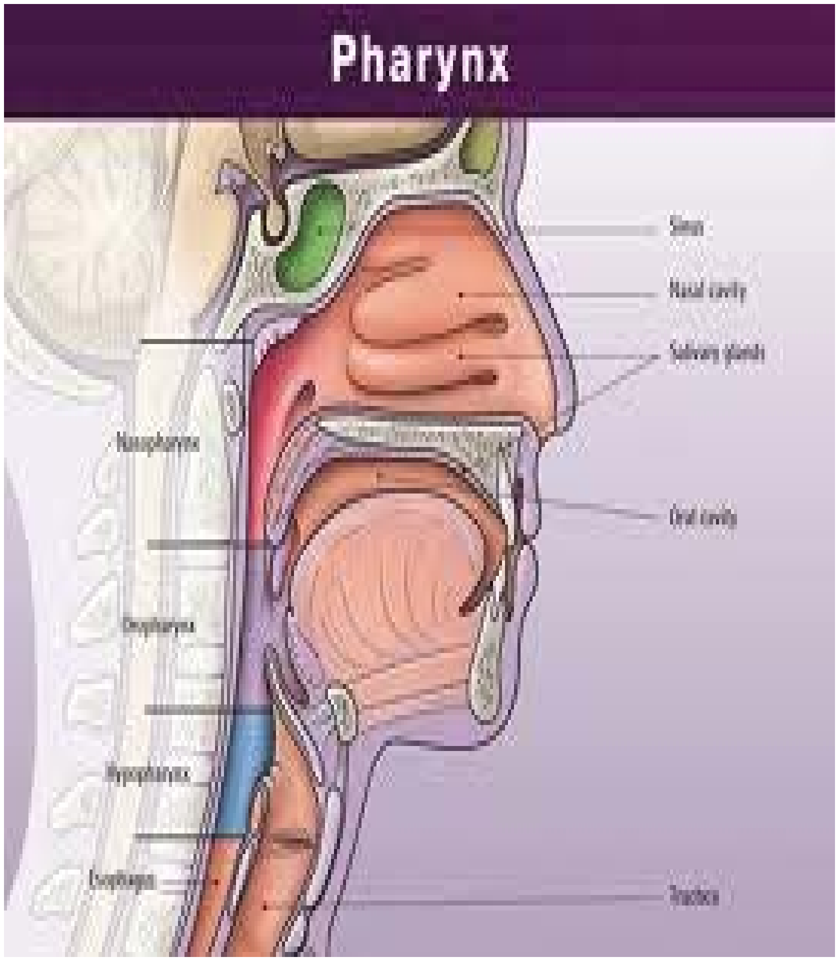
Vocal Cord Anatomy



Vocal Cord Tumour



Hypopharynx Subsites

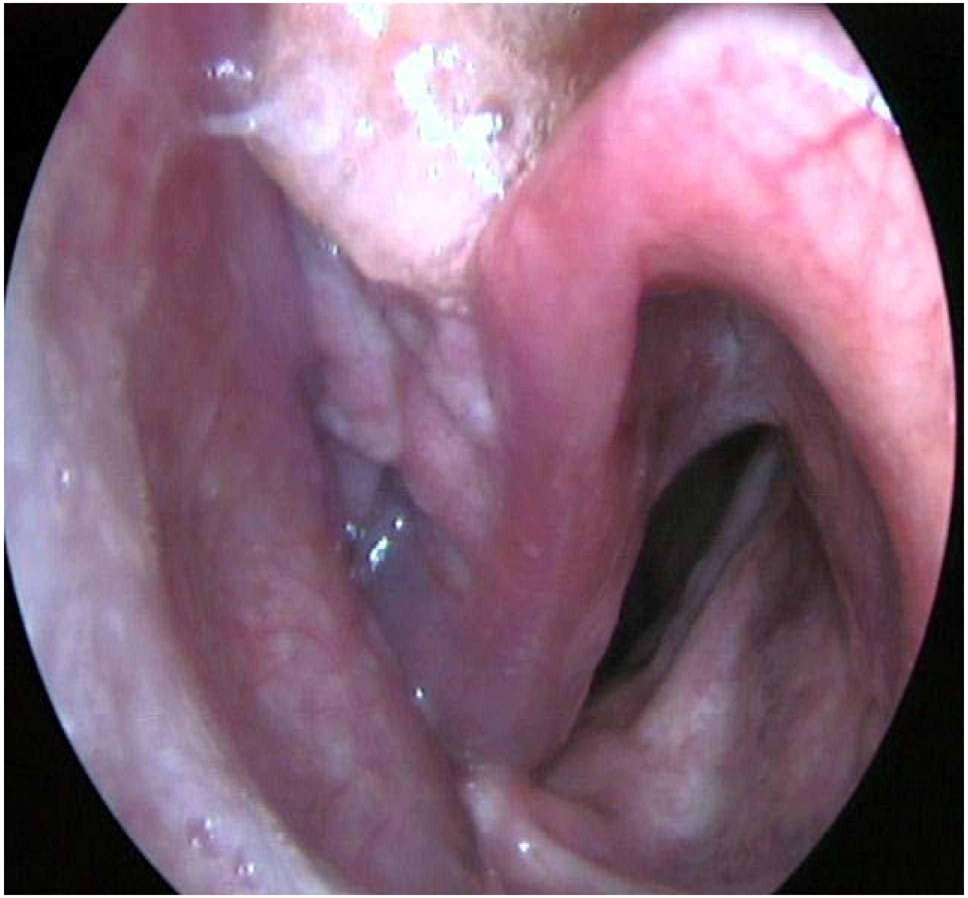


Pyriform Sinus

Postcricoid

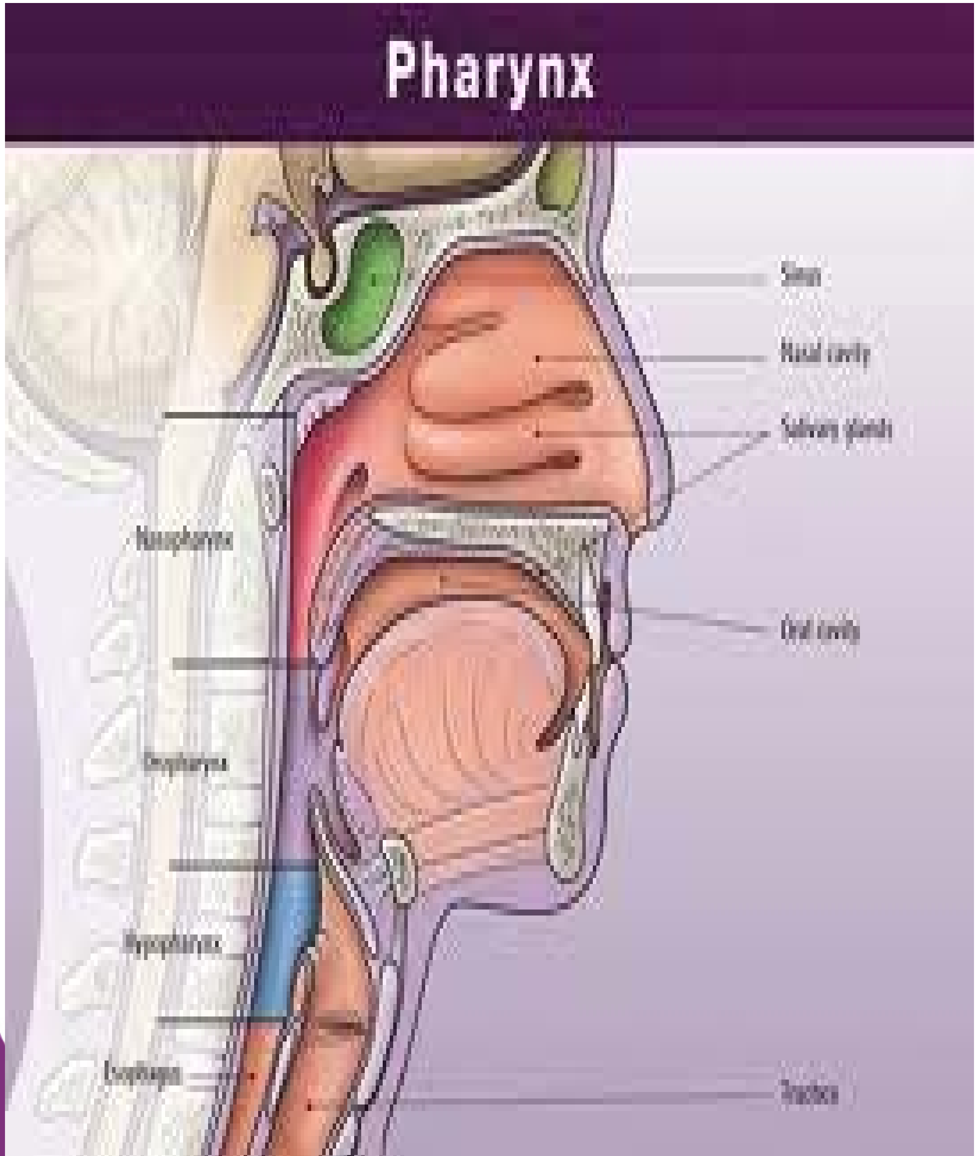
Lateral and posterior hypopharyngeal walls

Pyriform Sinus Cancer



Typically present late and often have bilateral nodal metastases at diagnosis

Nasopharynx



Subsites

- posterosuperior wall
- the lateral walls
- posterosuperior surface of the soft palate

Signs & Symptoms

Neck Mass	- Lymph Node mass
Persistent ulcer	- Oral cavity, oropharynx
Hoarseness	- larynx, hypopharynx
Stridor	- larynx, hypopharynx
Difficulty/pain on swallowing	- larynx, hypopharynx
Ear pain / referred pain	- pharyngeal tumour / LNs
Epistaxis , nasal obstruction	- nasopharynx, paranasal sinuses
Cranial nerve palsies	- VII with parotid gland tumours
Weight Loss , Anorexia	

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- Follow Up

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Work Up

- History (Past Medical History, Medications, Allergies, Social History)
- Assess performance status (suitability for Tx)
- Bloods (FBC, Biochemistry)
- Examination (oral cavity, neck , nasoendoscopy)



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Work Up

History (Past Medical History, Medications, Allergies, Social History)

Assess performance status (suitability for Tx)

Bloods (FBC, Biochemistry)

Examination (oral cavity, neck , nasoendoscopy)

Imaging (CT / MRI / PET)

Imaging: CT / MRI / PET

Assess primary

- size, site, local extension, extent of cartilage involvement (define operability)

Assess cervical nodes

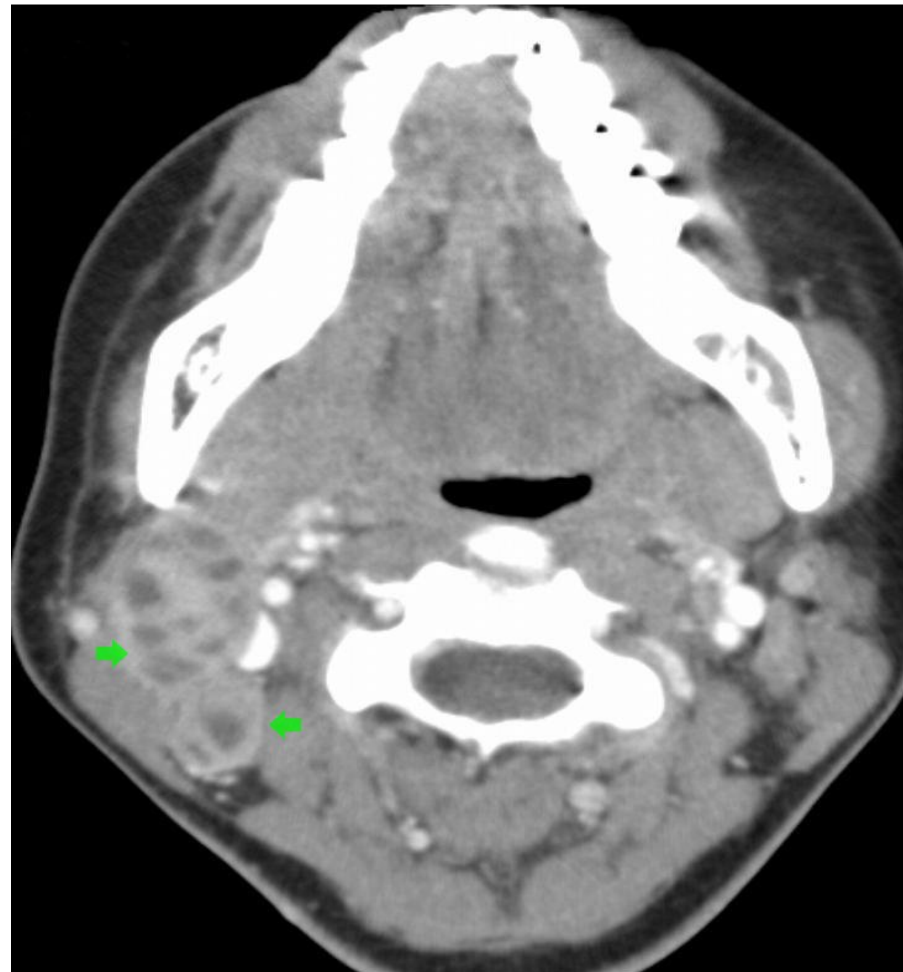
- size, level, number, whether neck dissection required

Assess for distant metastases

- whether radical or palliative

Rule out synchronous primaries

CT Neck - Lymphadenopathy

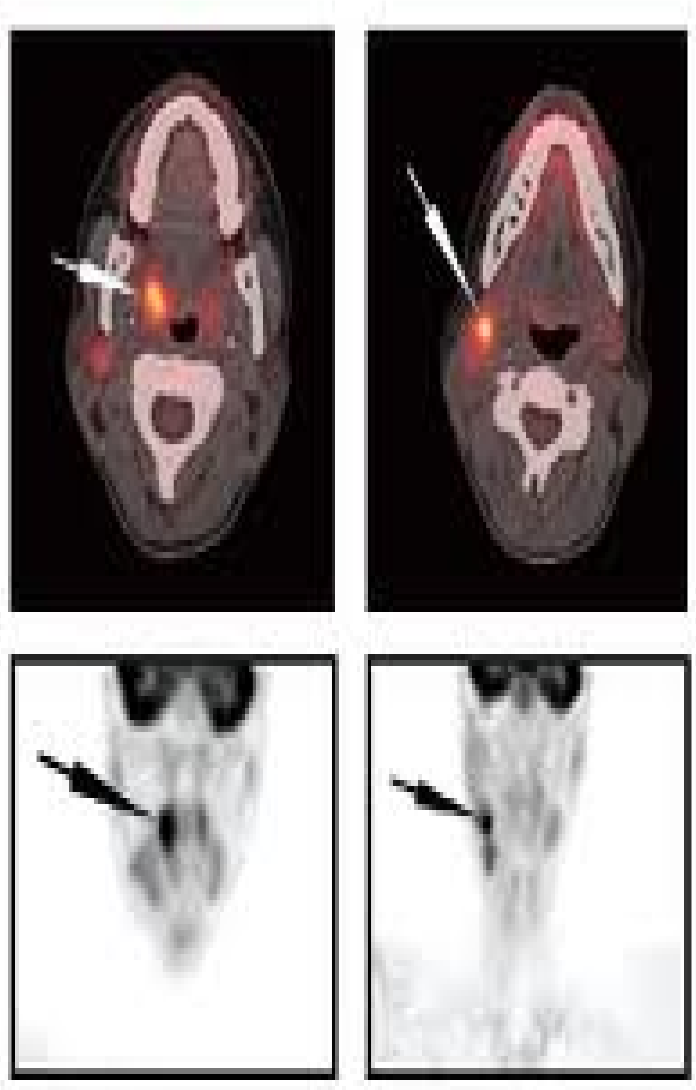


MRI – Primary Tumour

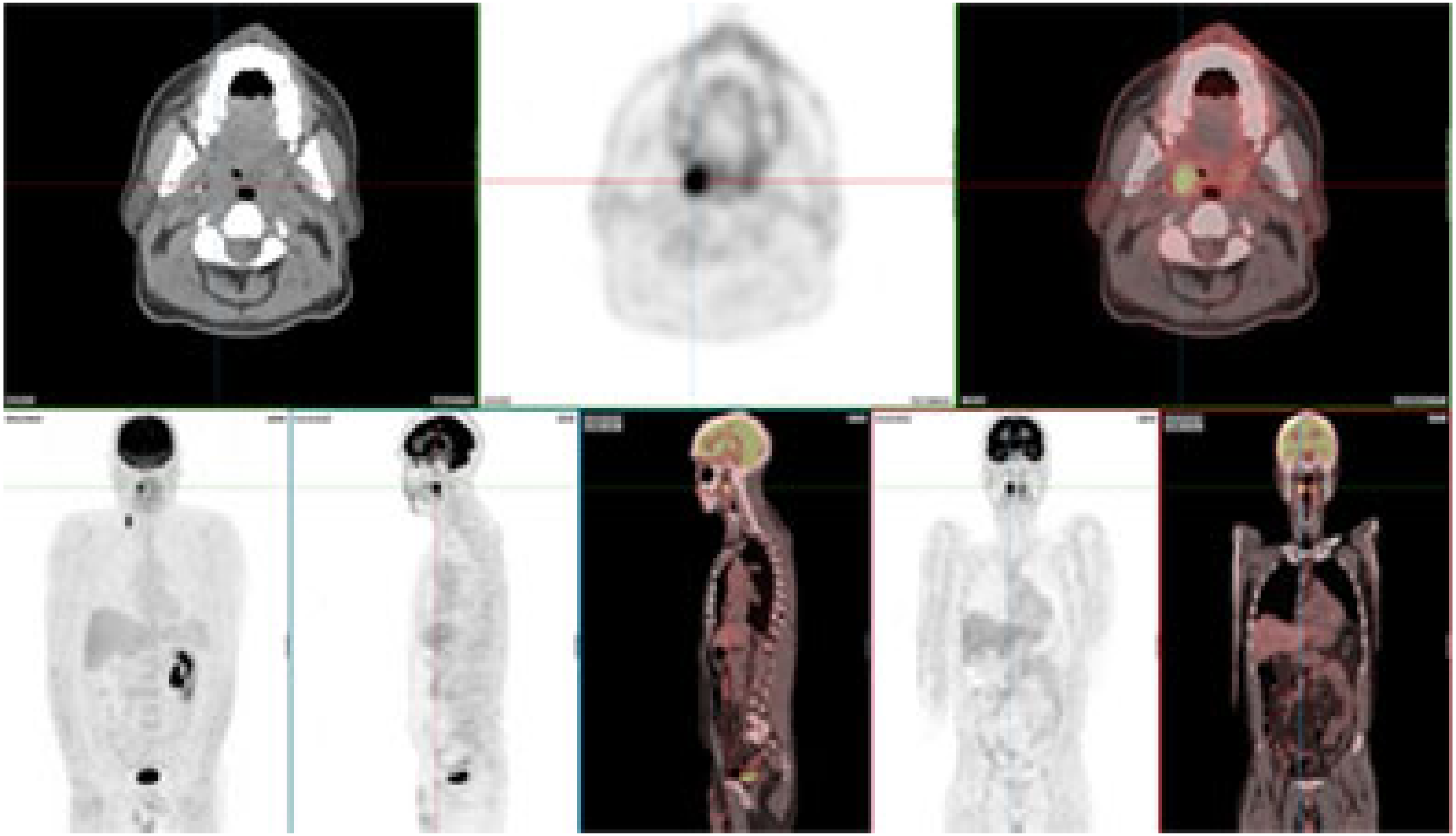
School

PET/CT

Tumour in oropharynx
+ Level 2 Lymph node



PET/CT: Sagittal,Coronal + Axial Views



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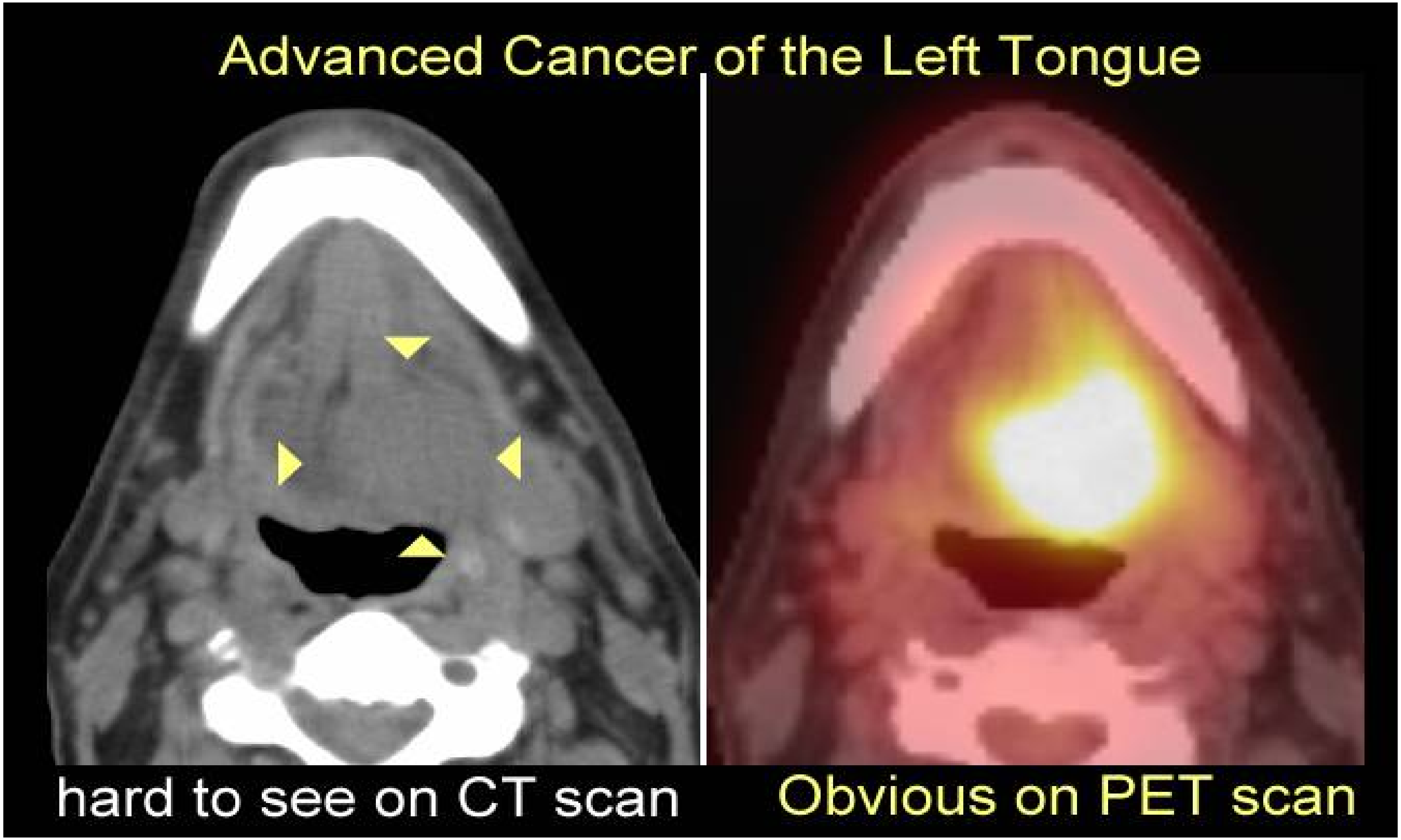
PET/CT : Axial Views



Patterns of Spread

- Local (tonsil to base of tongue, larynx through thyroid cartillage)
- Lymphatic (LN metastases)
- Haematological (Lung metastases)

Work Up

History (Past Medical History, Medications, Allergies, Social History)

Assess performance status (suitability for Tx)

Bloods (FBC, Biochemistry)

Examination (oral cavity, neck , nasoendoscopy)

Imaging (CT/MRI/PET)

Histology

Histology

Biopsy + Examination Under Anaesthesia (EUA)

- Panendoscopy, microlaryngoscopy, direct laryngoscopy, oesophagoscopy, bronchoscopy

US Neck + FNA

- Fine needle aspiration cytology of suspicious LNs

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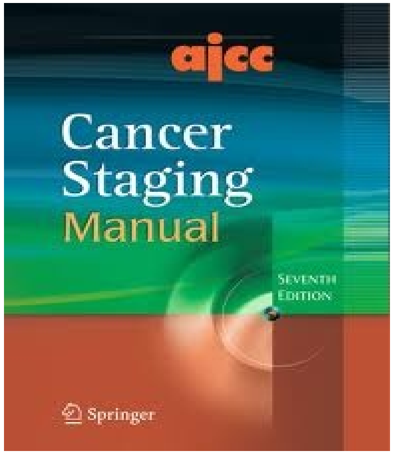
T stage
generally......



TX/0	primary tumour not seen / identified
T1	tumour ≤2cm in diameter
T2	tumour >2cm and ≤4cm
T3	tumour >4cm
T4	tumour invades adjacent structures

T stage
.....but the exceptions

- Larynx – vocal cord mobility
  - T2 - impaired
  - T3 - fixed

- Supraglottis – Number of subsites + vocal cord mobility

- Nasopharynx
  - T1 – confined to the Nasopharynx
  - T2 – extends to the oropharynx or parapharyngeal space
  - T3 - bony invasion
  - T4 - intracranial extension

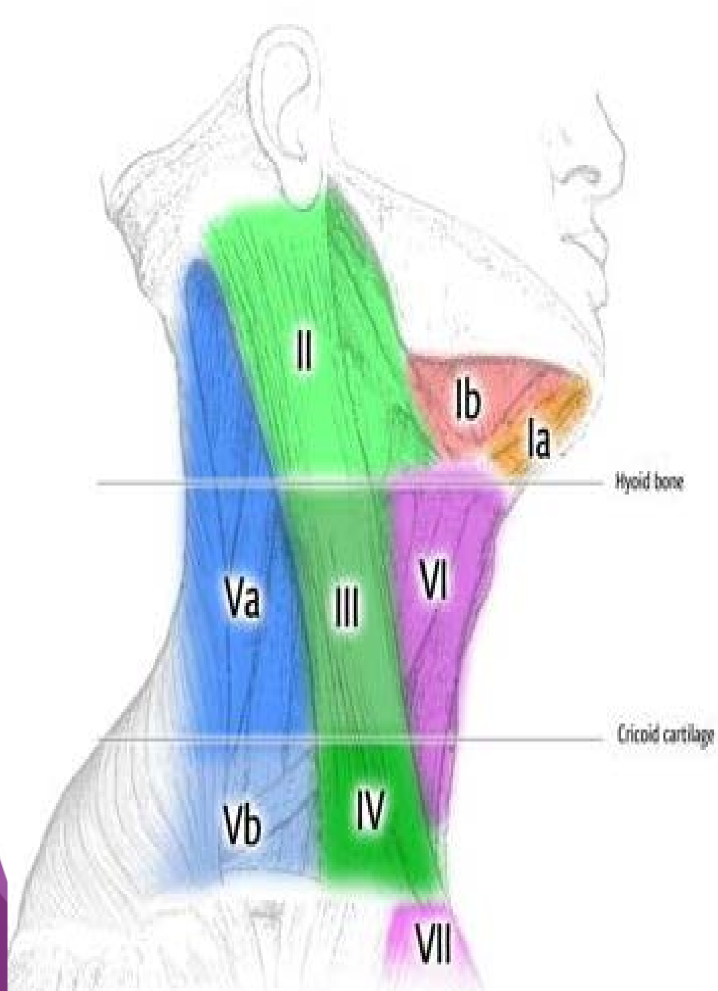
N Stage
(apart from nasopharynx)

Nx	**nodes not evaluable**
N0	**nodes not clinically involved**
N1	**single ipsilateral node ≤ 3cm**
N2a	**single ipsilateral node ≤ 6cm**
N2b	**multiple ipsilateral nodes ≤ 6cm**
N2c	**bilateral or contralateral node(s) ≤ 6cm**
N3	**any node >6cm**

- Nasopharynx

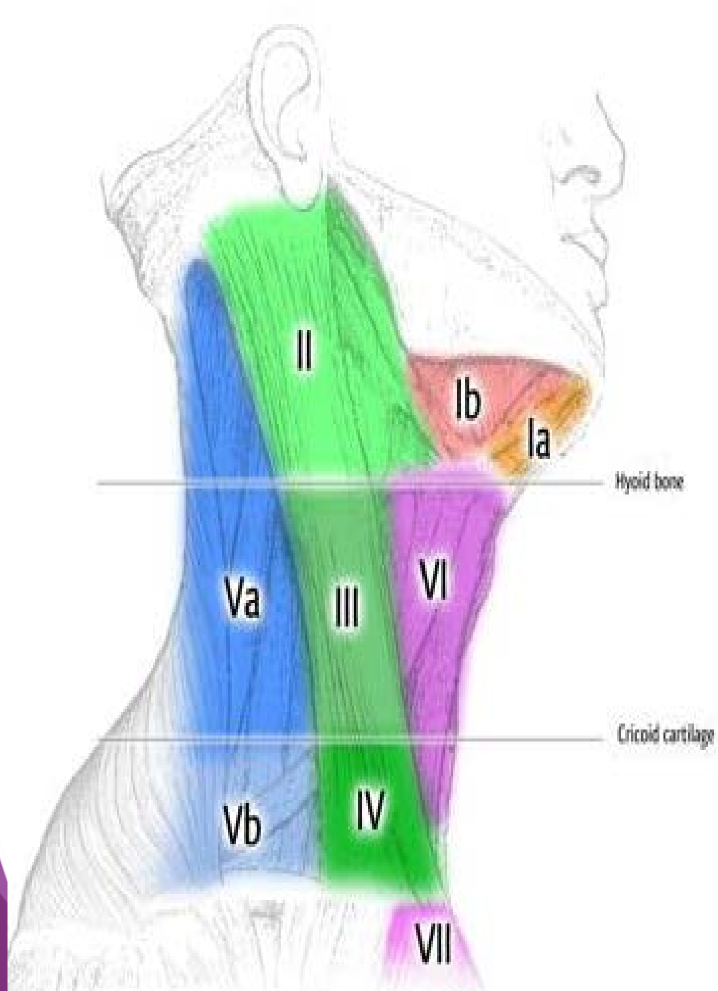
N1	**single LN < 6cm above SCF**
N2	**bilateral nodes**
N3	**>6 cm or SCF**

Lymph Node Levels



I -	Sup	Body of mandible
	Inf	Hyoid Bone
	Ant and Post bellies of digastric	
II -	Sup	Base of skull
	Inf	Hyoid Bone
III -	Sup	Hyoid Bone
	Inf	Lower border Cricoid Cartilage
IV -	Sup	Lower border Cricoid Cartilage
	Inf	Clavicle
V -	Ant	Post border SCM Muscle
	Post	Ant border Trapezius
	Inf	Clavicle
VI -	Sup	Hyoid bone
	Inf	Suprasternal notch

Lymph Node Levels



I - Submental + Submandibular nodes
(Oral cavity)

II - Upper cervical nodes
(Oral cavity, Orophx, Larynx)

III - Middle cervical nodes
(naso- and oropharynx, oral cavity, hypopharynx, larynx)

IV - Lower cervical nodes
(hypopharynx, subglottic larynx, thyroid, esophagus)

V - Posterior triangle nodes
(Nasopharynx)

VI - Anterior compartment nodes
(thyroid, subglottic larynx, oesophageal extension)

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Management: MDM

<u>All</u> patients require MDM discussion

- Pathologist
- Radiologist
- ENT and Maxillo-Facial Surgeons
- Radiation and Medical Oncologists
- Nurse Coordinators

Type of treatment dependent on :

- Site of disease
- Size of tumour
- Cosmesis and functional outcome
- Patient preference
- +/- nodal involvement

General Principles of Treatment

Small lesions: RT or Surgery alone

Advanced disease: **Multimodality** treatment

> Patients may be treated with primary RT+CT and surgery used as salvage or with a combination of primary surgery and postoperative RT +/- CT

Organ preservation – chemo-radiation

What LN Levels to treat in the neck?

Site	N 0-1	N2
Oral Cavity	I ,II,III	I - V
Oropharynx	II- IV	I – V + RP
Hypopharynx	II- IV	I – V + RP
Larynx	II- IV	II- V
nasopharynx	II- IV +RP	II- V + RP

V. Gregoire, P. Scalliet, K.K. Ang. Clinical Target Volumes in Conformal and Intensity Modulated Radiation Therapy. A Clinical Guide to Cancer Treatment. Springer.

Pre Radiotherapy Process
Dental Review Extractions + Oral Hygiene

All Pts require dental examination if irradiating salivary glands / mandible

Complex oral-dental programme including:

- Clinical evaluation of the mucosa, gingiva, + teeth
- X-ray alveolar bony structure+teeth (Orthopantogram)

Dental care or extraction prior to start of RT

Fluoride prophylaxis against dental caries to reduce risk of osteoradionecrosis

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Pre Radiotherapy Process
Oral Stents

- Oral cavity, maxillary sinus , lateralised tongue tumours

- Customised Oral Stent - used to move tongue

  - out of high-dose area when treating non-tongue tumours floor of mouth, alveolar ridge or buccal mucosa

  - into high-dose area in order to limit field size in tongue tumours

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Pre Radiotherapy Process
Dietician + SALT Review

- Assess Nutritional Status (+/-PEG tube)
- Ideally all patients should see Dietician
- Should be seen prior to treatment and weekly during treatment
- Patient weighed at each visit
- Food diary kept to ensure adequate nutritional and calorific intake
- ↓ risk of treatment modifications ie re-plan

- SALT Review (Assess risk of aspiration)

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Pre Radiotherapy Process
Percutaneous Endoscopic Gastrostomy

- Consider Elective PEG placement:
  - Significant weight loss at Dx (>10% in 6 mts)
  - Baseline Swallowing Difficulty due to tumour
  - Extensive resection resulting in impaired tongue mobility or swallowing function or
  - Large Radiotherapy Fields ie bilateral RT
  - Chemotherapy
  - **No role for elective PEG tubes for all H+N patients** due to the 2% mortality rate and up to 8% major complication rate associated with PEG tubes

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Pre-Radiotherapy Process
Medical Oncology Consult

- Review re: chemotherapy
- Bloods (FBC, Biochem)
- Audiogram
- Creatinine Clearance

- Cisplatin 100 mg/m^2 Day 1,22,43 or 40 mg/m^2 weekly

RT Treatment Planning
Patient Positioning

1. Comfortable + reproducible

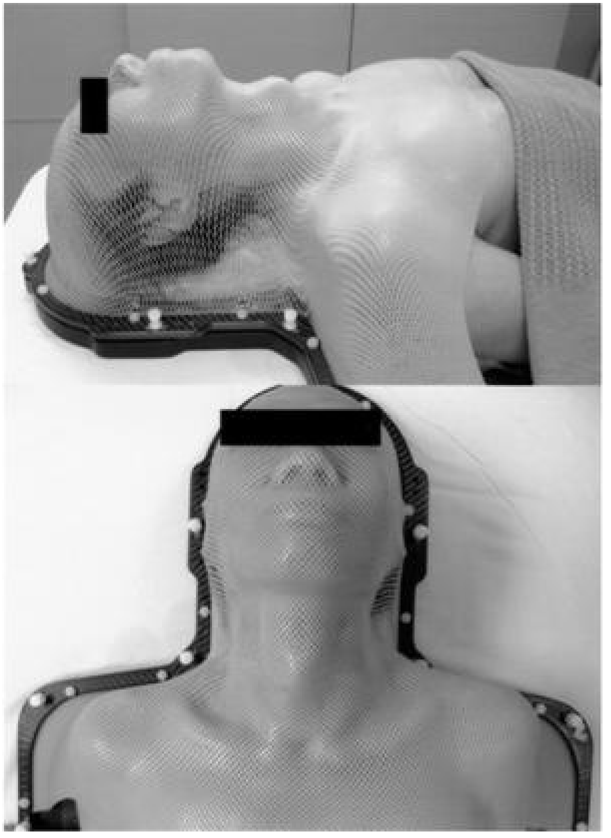
2. Extended position – nasopharynx and parotid

3. Neutral position – larynx , oral cavity, oropharynx and paranasal sinuses

4. Mark any surgical scars , nodes , tracheostomy with wire

RT Treatment Planning
Orfit

- A customized thermoplastic mask covering the head to shoulder region is made to immobilize the patient



RT Treatment Planning Techniques

- **2D** – opposed lateral Fields – used when treating bilaterally ie larynx
- **3D** – CT plan – used when treating unilaterally ie parotid, tonsil
- **IMRT** – used when prescribing different doses to different parts of H+N or when tumour is located near critical normal tissues ie spinal cord, optic chiasm, parotids

RT Dose

- Radical RT: **70 Gy/35#** (2 Gy/#) 5#/wk
  To all sites of disease (Primary and LN)

- Post Op RT: **60 Gy/30#**
  If Positive margin boost 6 Gy/3# to tumour bed

- Elective nodal irradiation instead of neck dissection with **50Gy/25 #** in 5 wks, can achieve local control rates of 90 %

IMRT Dose

	Dose
High Dose level PTV 1 - Gross disease (primary + involved LN)	70 Gy/35 # (2Gy/#)
Intermediate Dose level PTV2 (Areas of high clinical risk)	63 Gy /35# (1.8 Gy/#)
Low Dose level PTV 3 Elective dose	56 Gy/35# (1.6 Gy/#)

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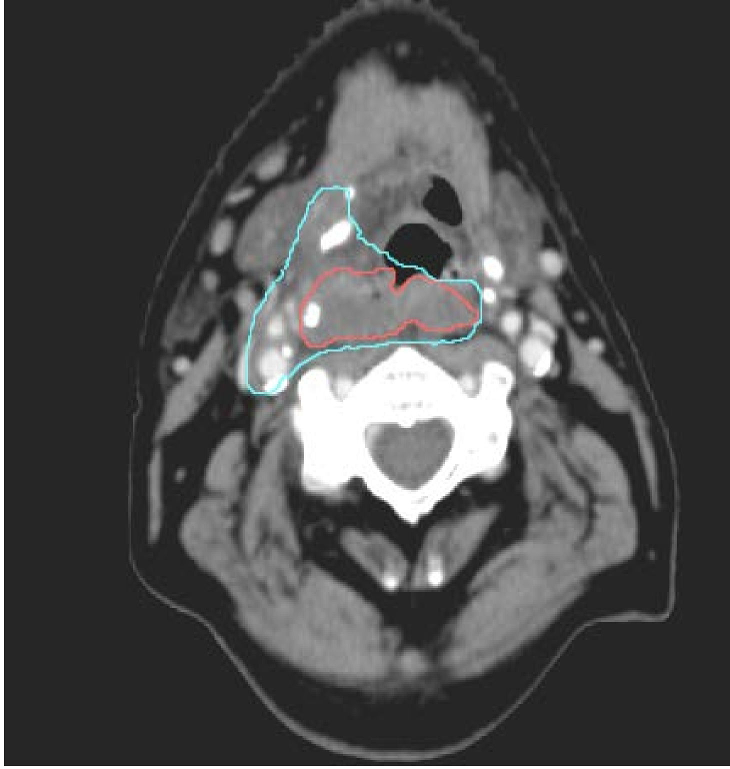
RT Treatment Planning
3D Planning CT



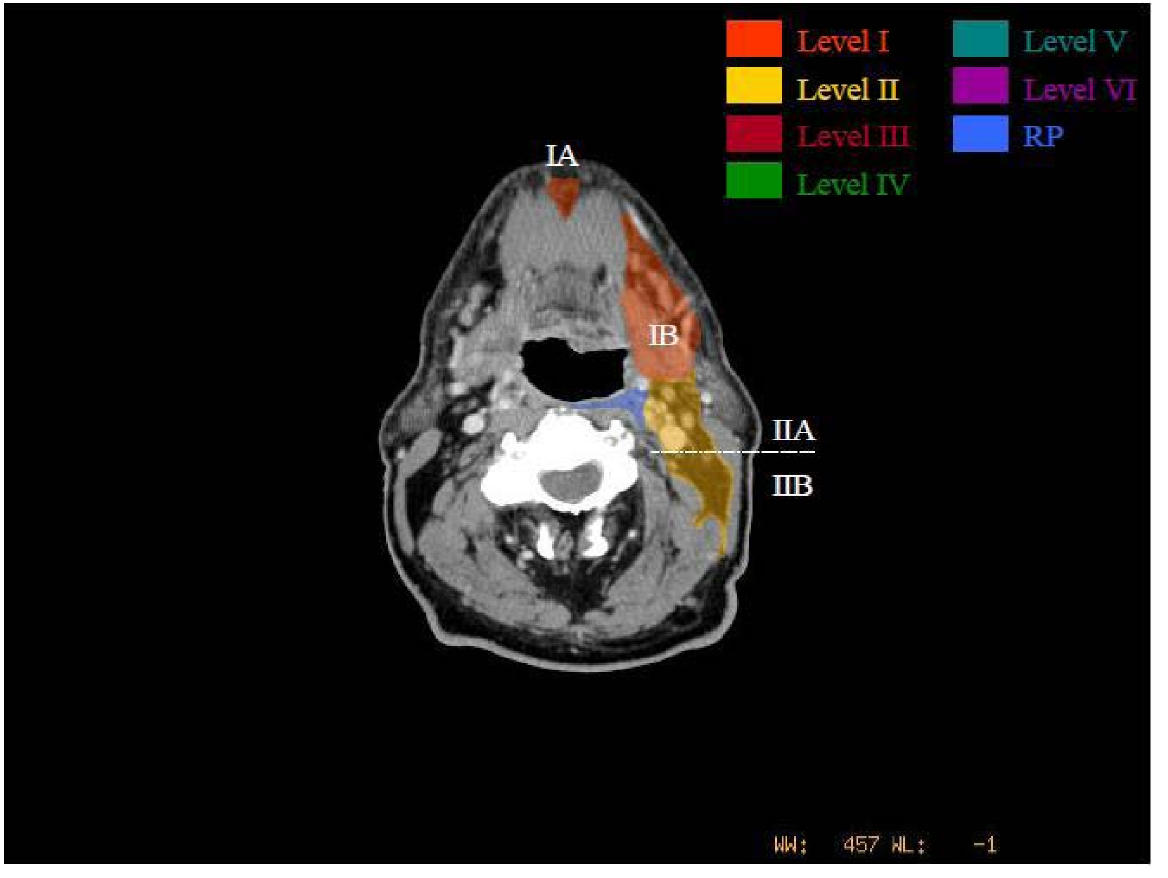
GTV – Gross Target Volume
-gross identifiable disease clinically or radiologically

CTV – Clinical Target Volume
includes areas at risk of subclinical spread

PTV – Planning Target Volume, allows for internal motion and set up error

Use of IV contrast

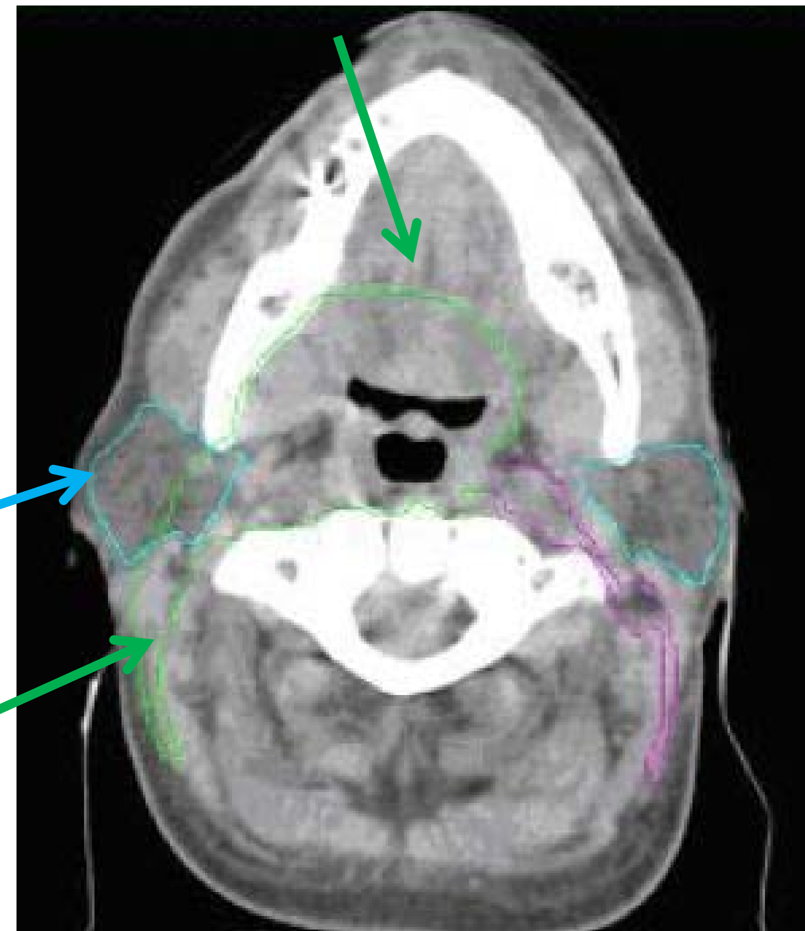
RT Treatment Planning
CTV – Lymph nodes



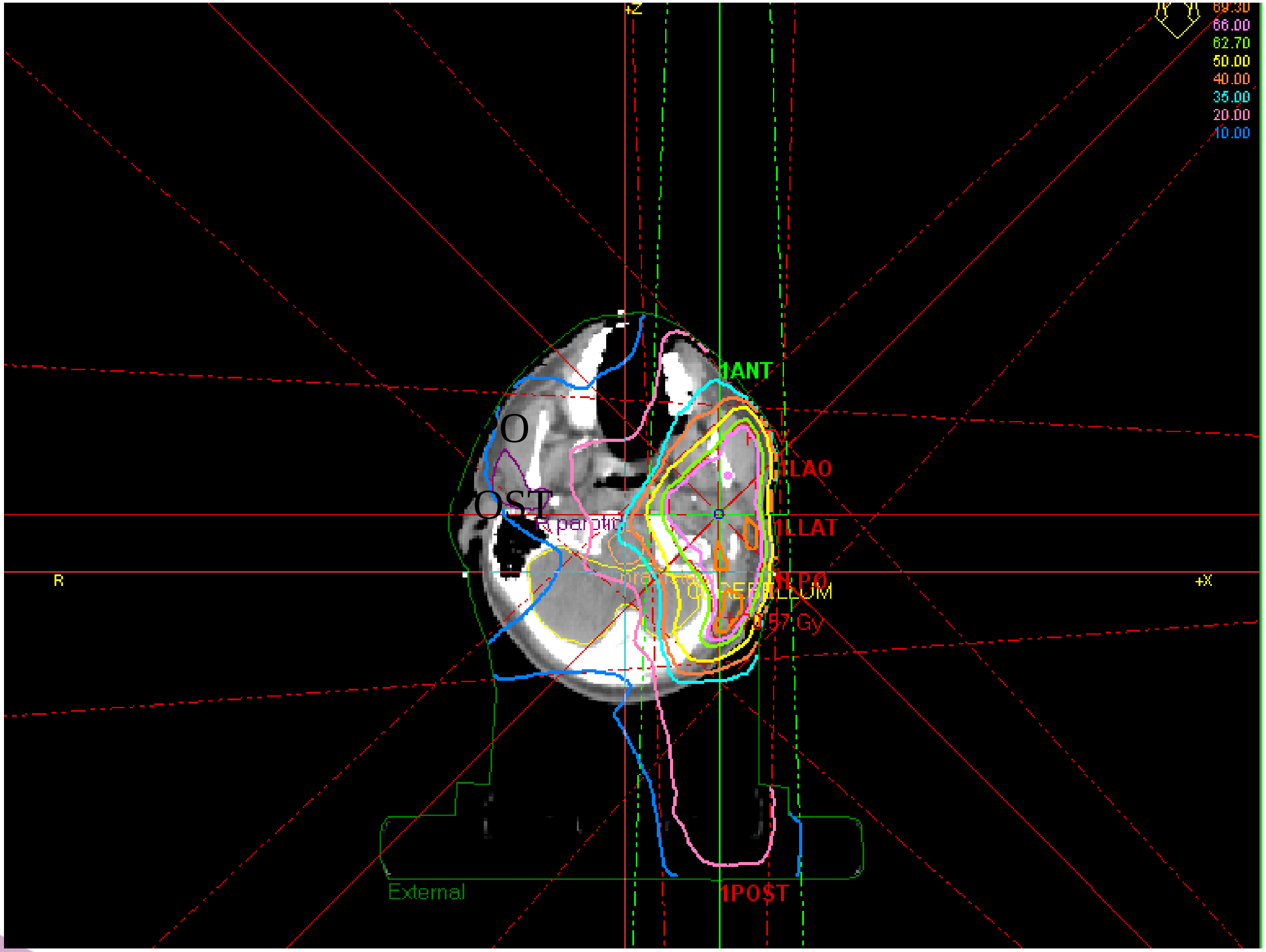
http://www.rtog.org/CoreLab/ContouringAtlases/HN.aspx

RT Treatment Planning
3D Planning CT

PTV Primary and Lymph Node Targets and normal tissues such as parotids and spinal cord are contoured



5 Field Beam arrangement and isodose distribution for well-lateralised target - parotid



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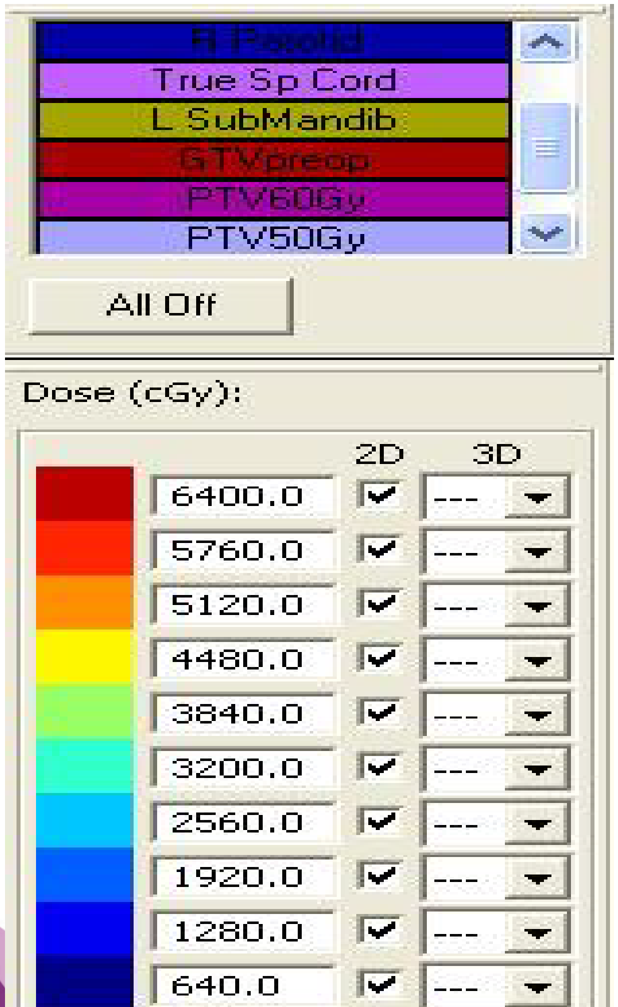
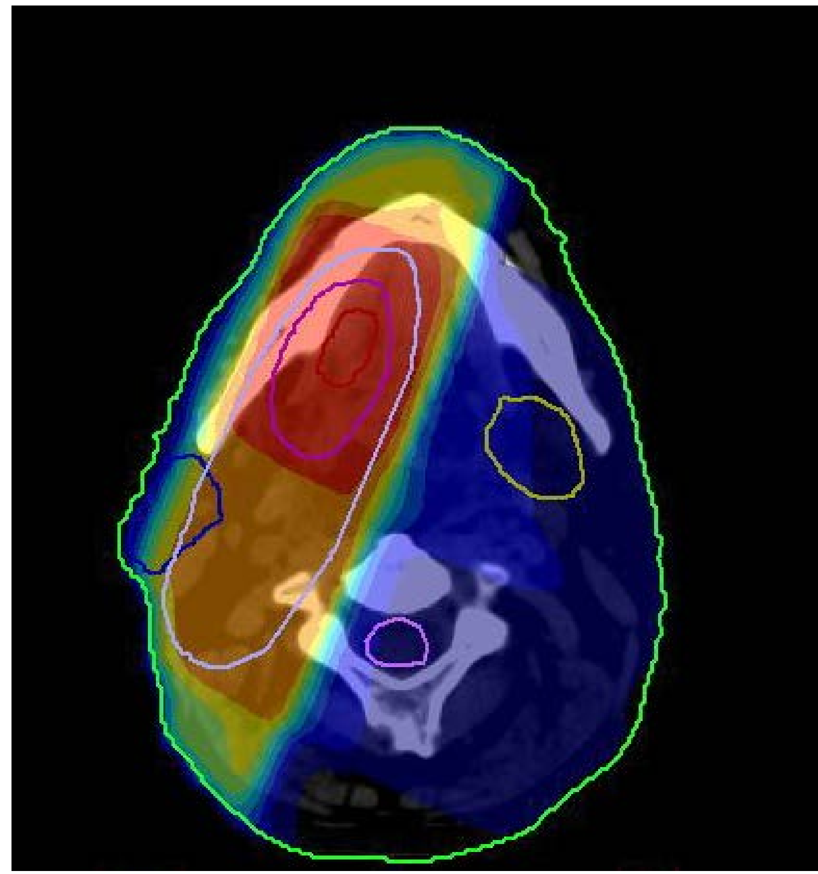
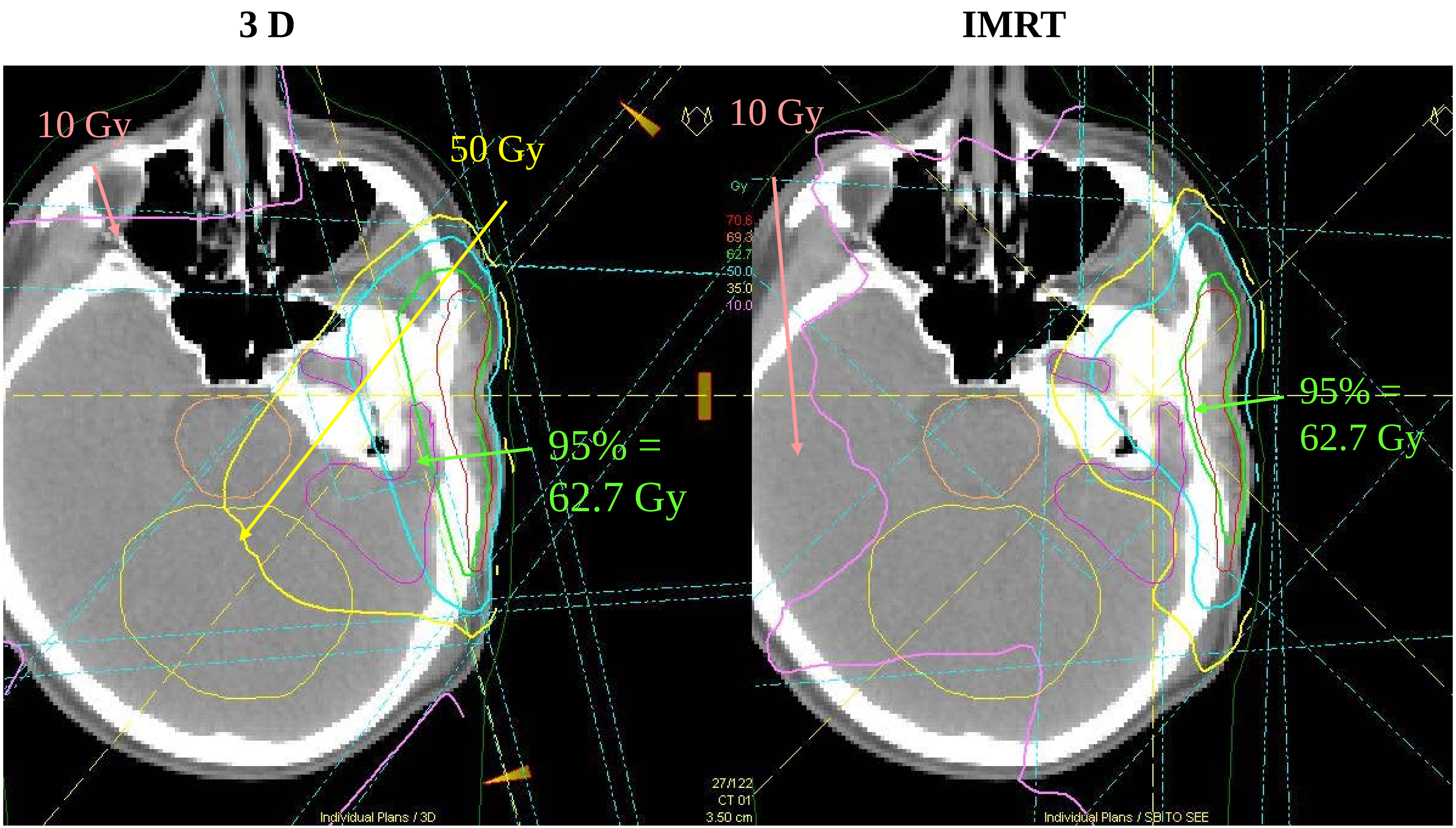
3D Radiotherapy Plan – Unilateral RT

Allows treatment of one side of neck, sparing of spinal cord and contralateral parotid





IMRT increases conformality and reduces dose to normal tissues ie Temporal Lobe + Brainstem



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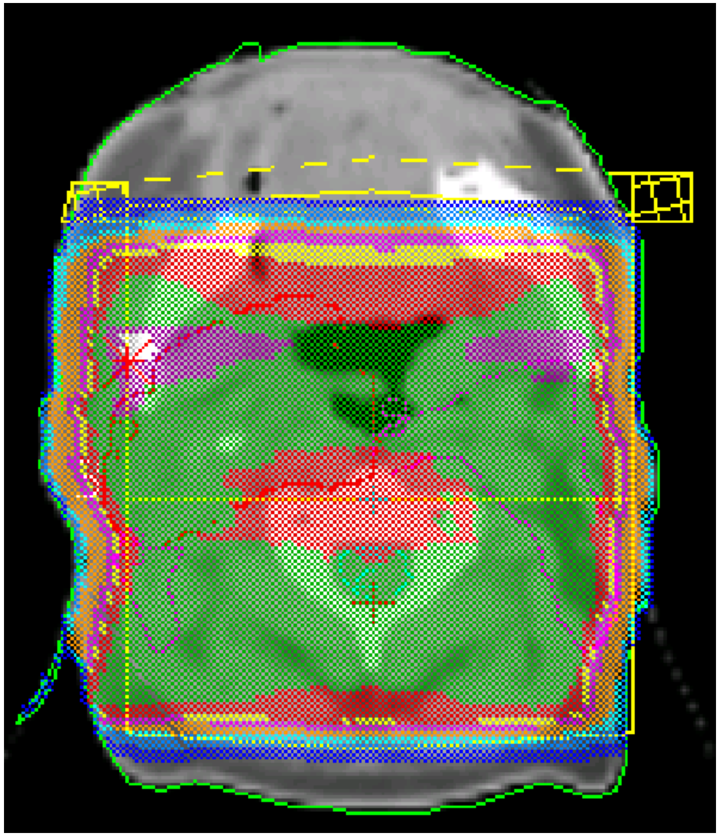
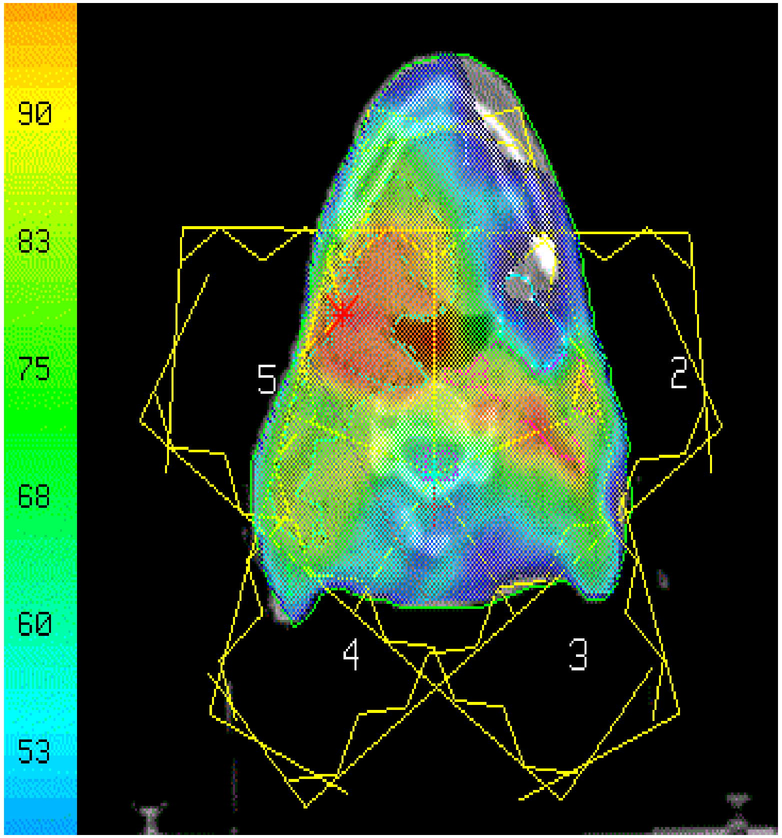
IMRT
Reducing parotid dose in Tonsillar Cancer

3D Parallel opposed fields

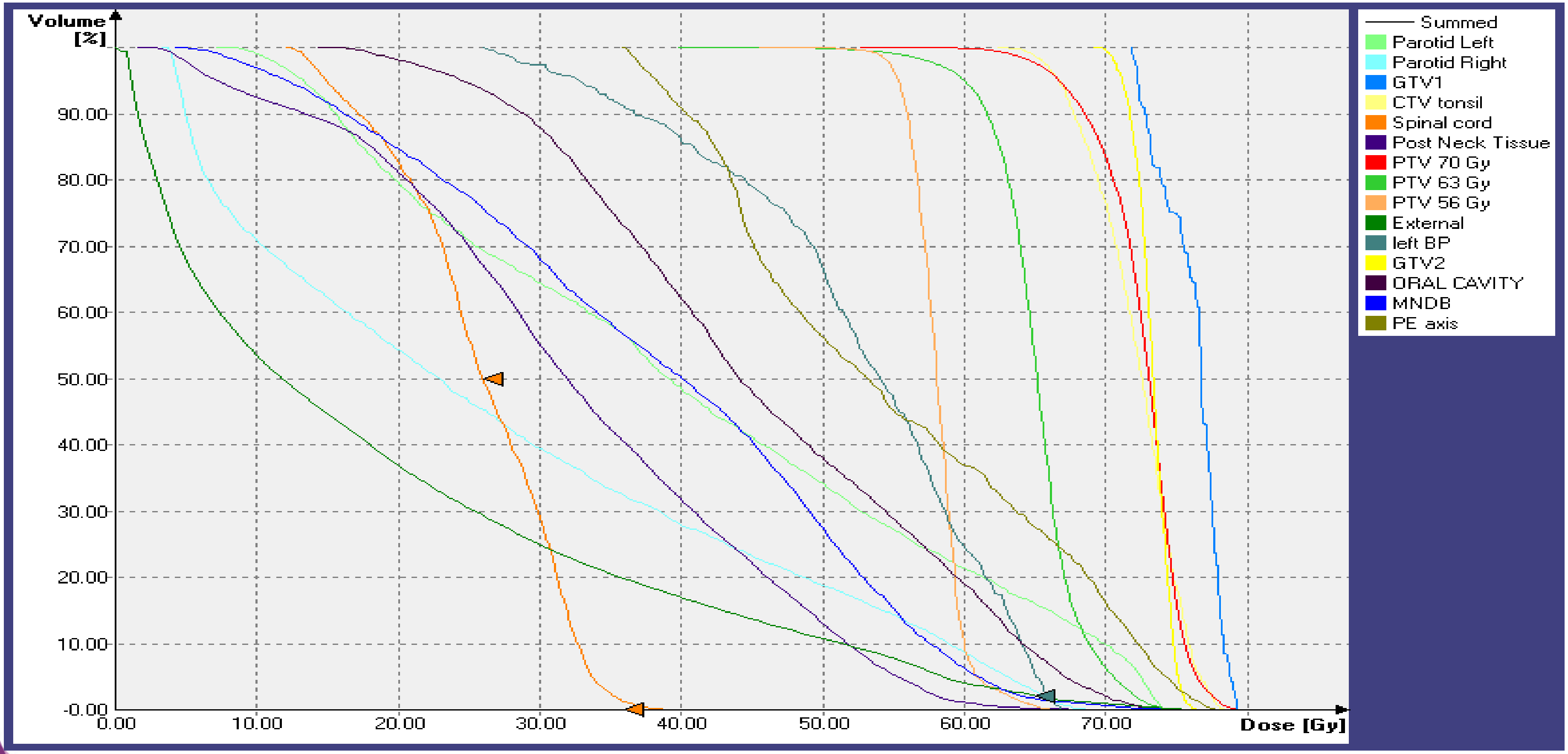


IMRT



Dose Volume Histogram

Shows dose received by different volumes of tissues



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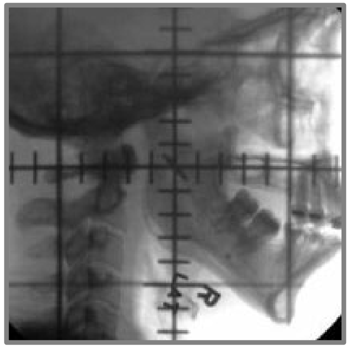
OARs

Optic Chiasm	D max < 54 Gy
Optic Nerve	D max < 54 -60 Gy
Lens	D max < 6 Gy
Retina	D max < 45 Gy
Cochlea	Mean Dose < 45 Gy
Brainstem	D max < 54 Gy
Spinal Cord	D max < 45 -50 Gy
Brachial Plexus	D max < 66 Gy
Mandible (excl PTV)	< 70 Gy
Parotid	Mean Dose < 25 Gy or V30 < 50%

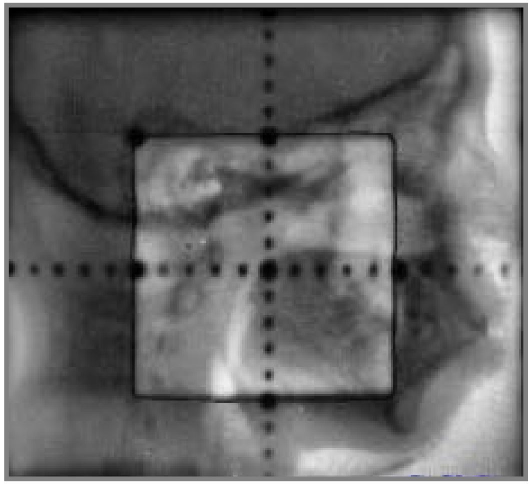
QUANTEC DATA - Int J Radiat Oncol Biol Phys 2010; 76 (3): Supplement

On Treatment Imaging

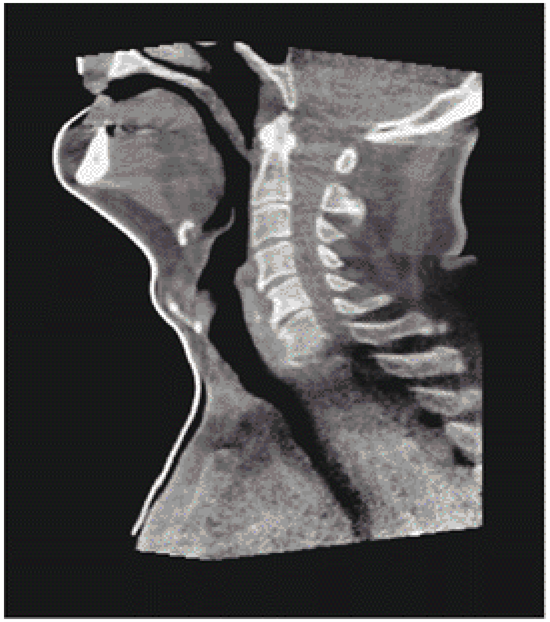
PORTs



EPIDs



CBCTs



General Overview

- Introduction
- Aetiology
- Presentation
- Investigations
- Staging
- Principles of Treatment
- **Side-effects of treatment**

RT Toxicity

- Acute (< 90 days)
  - During the course of treatment or
  - Within a few weeks after RT

- Late (> 90 days)
  - Emerge > 6 months / years after RT

- Many can be prevented by IMRT

Reactions Depend On:

- Total Dose and Total Volume of tissue irradiated
- Dose per Fraction/Treatment Time
- Treatment Planning (2D,3D,IMRT)
- Previous Treatment (ie. Sx)
- Anatomical Site (proximity to critical structures) +Individual Tolerance Doses of normal tissues
- Other Treatment Modalities (Chemotherapy increases mucositis)
- Co Morbidities - impaired vascularity – DM , HTN

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Early Effects

- Skin reaction: Erythema, Desquamation (dry + moist)
- Mucositis
- Xerostomia (dry mouth)
- Infection (Candidiasis - thrush)
- Altered taste
- Dysphagia, Odynophagia may result in weight loss
- Hoarseness (if larynx is treated)
- Tiredness / Fatigue

Skin Reaction

Erythema & Dry Desquamation

E45
Top: HC 1%

Moist Desquamation

Hydrocolloid sheets. E.g. Nugel Sheets.

Hydrogels in gel form.

Mepilex non-adherent dressings

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Mucositis

- Inflammatory reaction of the Oral Mucosa
- Onset - 2nd week of R/T
- Areas most affected
  - Lips, soft palate, buccal mucosa, lat. border of the tongue, floor of mouth
- Problems in swallowing and speaking
- Resolve usually within 6 weeks of completion of treatment

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Xerostomia

Salivary production decreases within 1st week RT

Severity depends on:

- Dose and fractionation of radiation
- No. of glands irradiated (unilateral or bilateral)
- Minor salivary glands assoc with resting saliva production

Glands most affected = Parotid

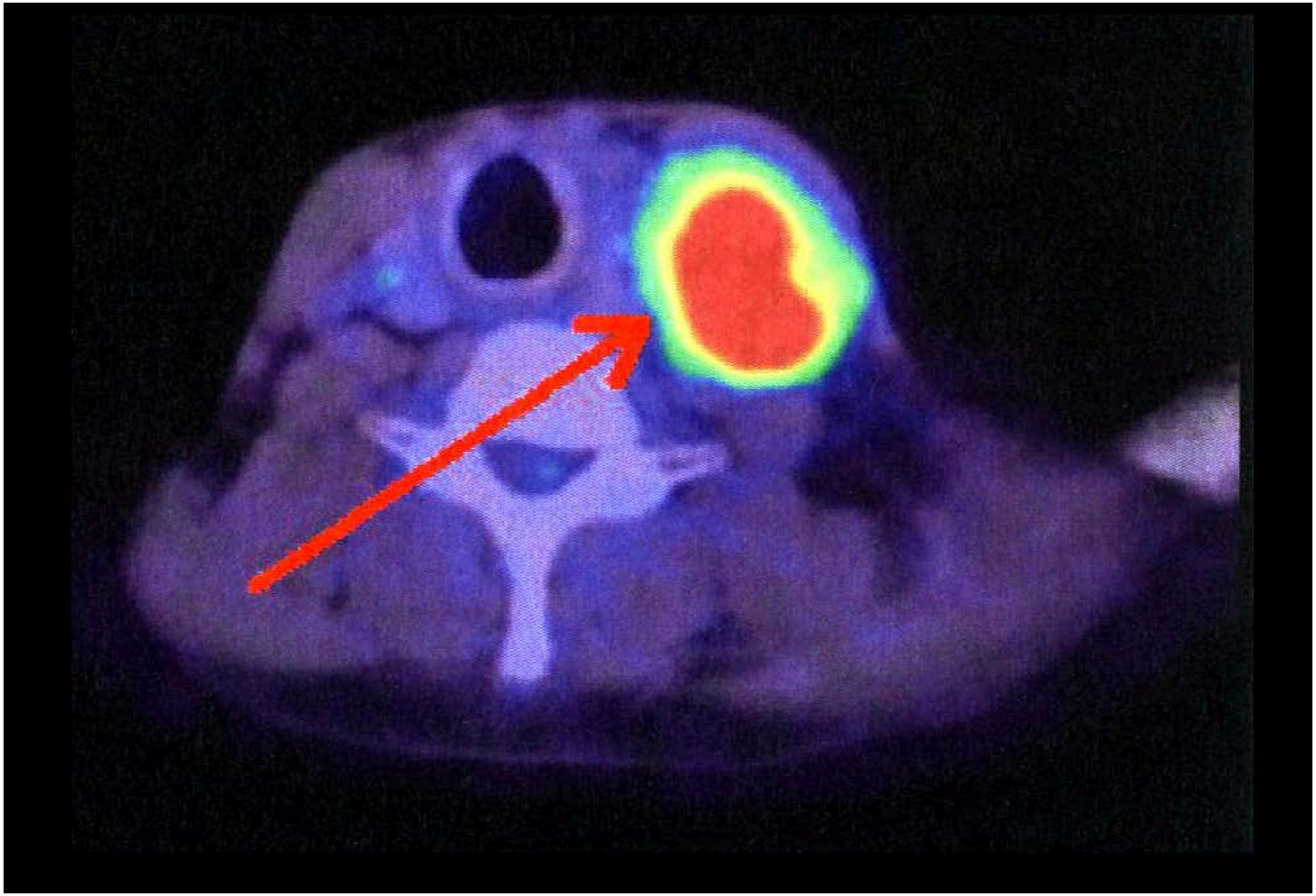
Loss of Salivary function complete and permanent after doses >35Gy

Significant evidence that IMRT prevents xerostomia

Late Effects

- Dental Demineralization/ “Radiation Caries”
- Trismus
- Osteoradionecrosis
- Dysphagia
- Skin – Sub mental fibrosis, Telangiectasia, Pigmentation
- Hypothyroidism
- Carotid artery injury
- Second malignancies –incidence 0.04%, latency >10 yrs

The end



Treatment planning for Head and Neck

Steven Buckney
Dublin, Ireland
David Sjöström
Herlev, Denmark

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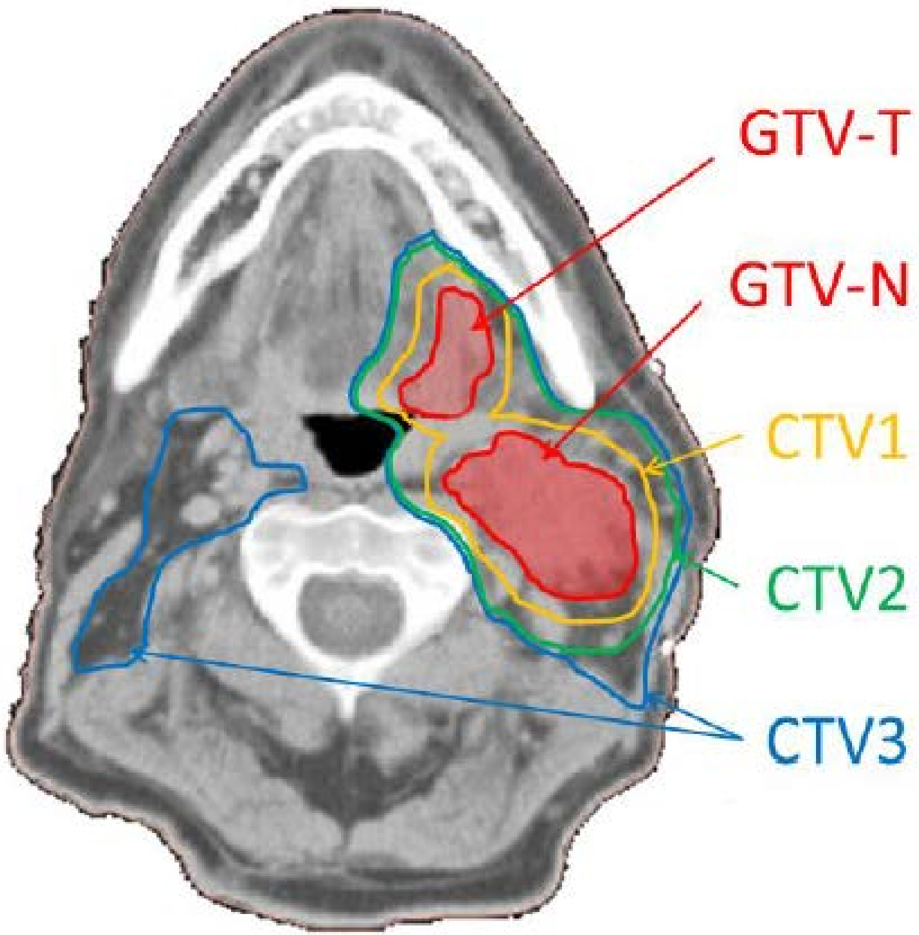
The challenge with HN treatment planning

The challenge with HN treatment planning

Many dose levels



Retningslinjer for strålebehandling i DAHANCA 2013.

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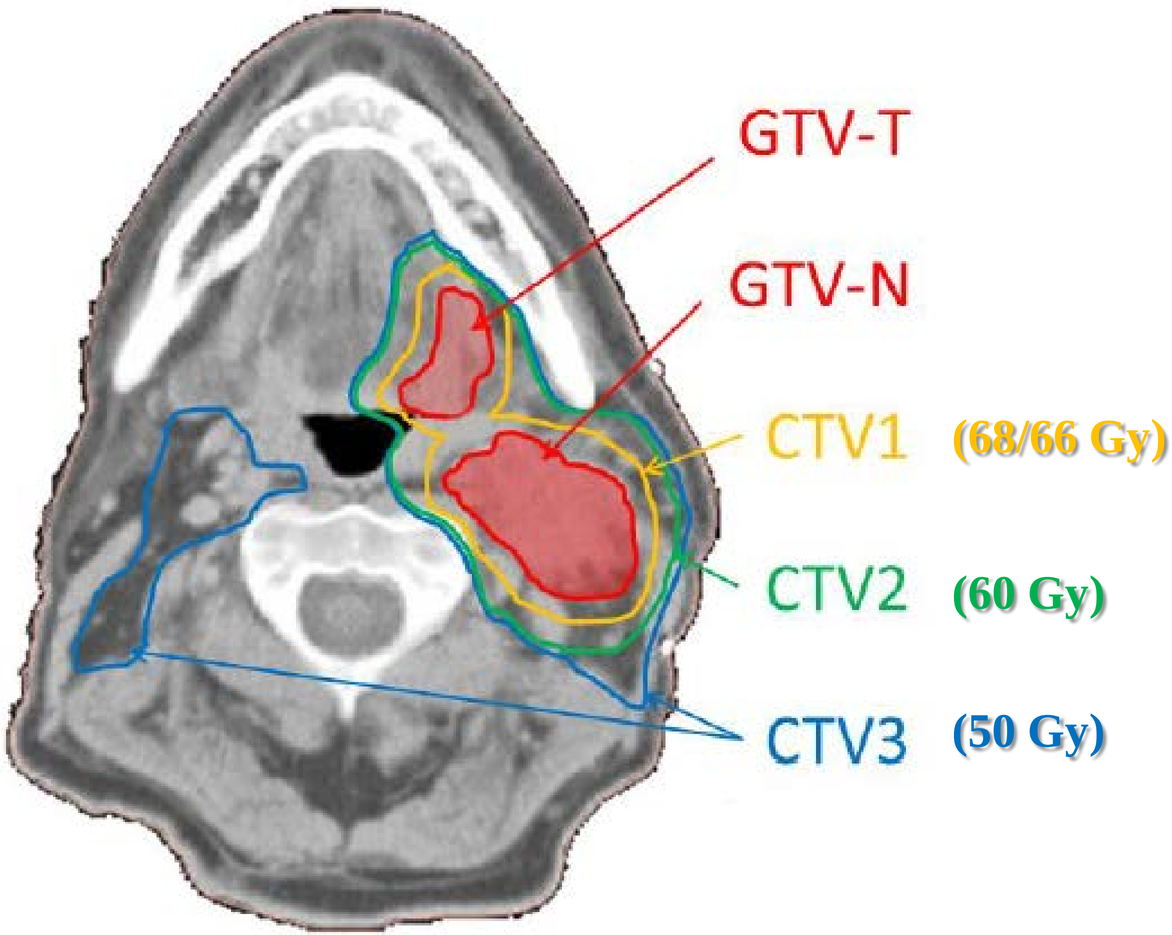
The challenge with HN treatment planning

High dose



Retningslinjer for strålebehandling i DAHANCA 2013.

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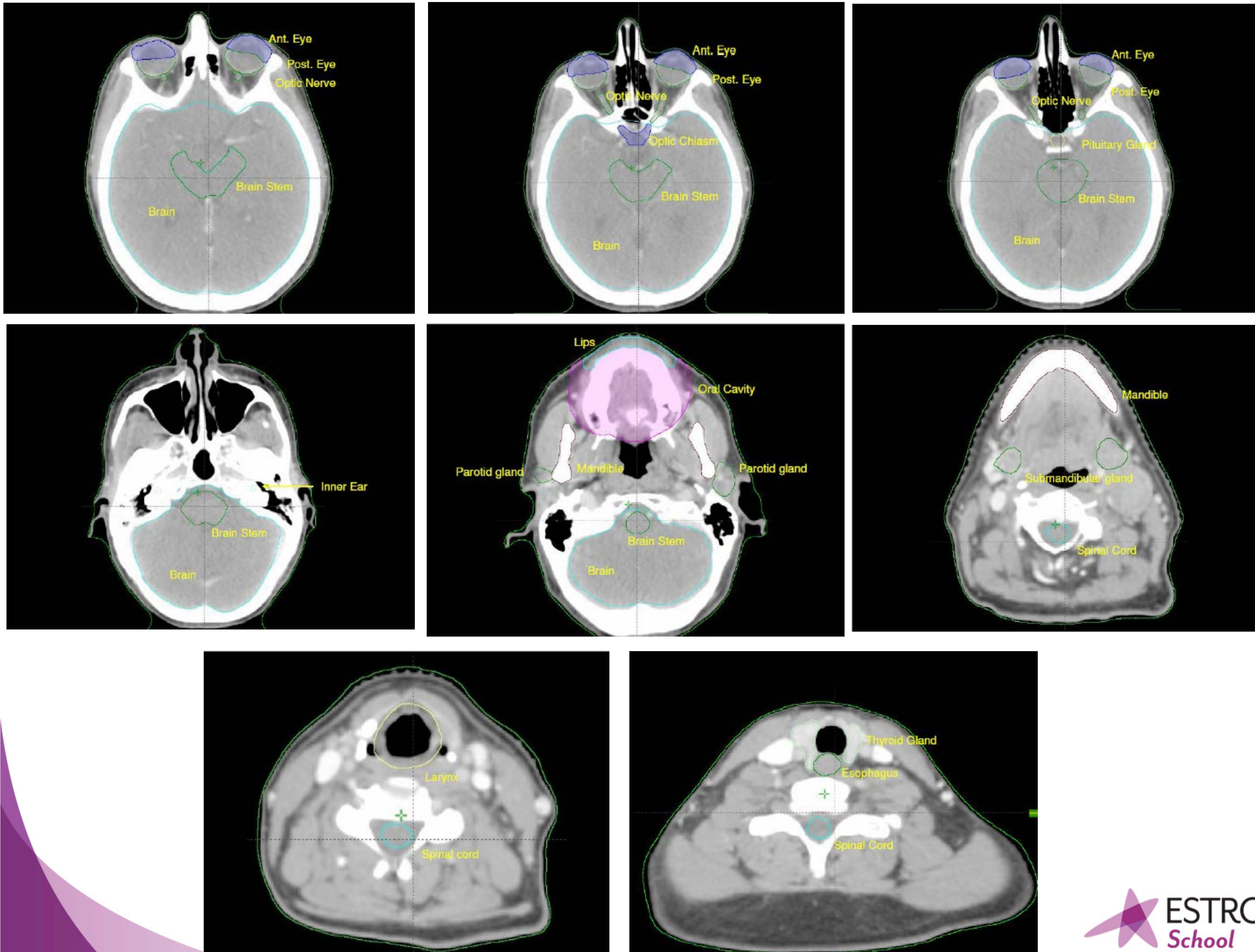
The challenge with HN treatment planning

Many critical structures (OAR)

Retningslinjer for strålebehandling i DAHANCA 2013.



Ant. Eye
Post. Eye
Optic Nerve
Brain Stem
Brain
Ant. Eye
Post. Eye
Optic Nerve
Optic Chiasm
Brain Stem
Brain
Ant. Eye
Post. Eye
Optic Nerve
Pituitary Gland
Brain Stem
Brain
Inner Ear
Brain Stem
Brain
Lips
Oral Cavity
Parotid gland
Mandible
Parotid gland
Brain Stem
Brain
Mandible
Submandibular gland
Spinal Cord
Larynx
Spinal cord
Thyroid Gland
Esophagus
Spinal Cord

The challenge with HN treatment planning

Compromises between dose to target and OAR

Priorities

1. Not exceed tolerance dose to the most critical (that can have lethal consequences) OAR (e.g. spinal cord and brain stem)
2. Dose coverage of GTV, CTV1
3. Not exceed tolerance to other critical (e.g. impair the vision and/or hearing) serial OAR (e.g. optic chiasm and inner ear)
4. Dose coverage of PTV1, PTV2, PTV3
5. Not exceed tolerance dose to other OAR that will influence the patient quality of life (e.g. parotid gland, mandible etc.)
6. Etc

Retningslinjer for strålebehandling i DAHANCA 2013.

OAR priorities

- Organs that are vital and have a higher priority than target coverage

- Serial organs that not necessary have higher priority than target coverage

- Parallel or serial organs with strong evidence that the complications can be severe

- Organs with poor evidence of complications and endpoints or organs where toxicity can be treated.

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OAR priorities

	Struktur	Dosisbegrænsning OAR [Gy]	Dosisbegrænsning PRV [Gy]	Kommentarer inkl. definition af organet	Referencer
ABSOLUT	Brain stem	D_{max} ≤ 54Gy	D_{max} ≤ 60Gy	Ved behandling af ≤10 cm^3 af OAR til max 59 Gy er risikoen meget lille for neurologiske skader, hvorfor det kan gøres for at få targetdækning, efter patientinformation. Indtegning: Foramen magnum til bunden af 3. ventrikel (da kranielle afgrænsning er usikker)	Mayo et al. IJROBP vol 76 (3) S36-S41, 2010
	Spinal cord	D_{max} ≤ 45Gy	D_{max} ≤ 50Gy	Ved dosis op til 60 Gy er risikoen estimeret til 6 % hvorfor små overdoseringer kan tillades for at opnå targetdækning, efter patientinformation. Indtegning: Medulla spinalis, *ikke* canalis spinalis	Kirkpatrick et al. IJROBP 76 (3) s42-9, 2010
SKAL	Anterior eye (conjunctiva, gl. lacrimalis, cornea, iris)*	D_{max}≤30Gy	D_{max}≤35Gy	Selv ved overskridelser af andre constraints til synsbanerne er forreste øje værd at spare pga. af muligheden for at bevare øjet in situ. Ved svært tørt øje ender det ofte med at øjet må fjernes. *Øjets linser fremgår ikke af listen som et risikoorgan. De er beliggende inden i et eksisterende OAR og evt. specifikke bivirkninger kan behandles.	Jeganathan et al. IJROBP 79 (3) 650-9, 2011 DAHANCA 2004
	Chiasm and optic nerve	D_{max} ≤ 54Gy	D_{max}≤ 60Gy	Dmax ≤ 55 Gy medfører meget lille risiko, hvorfor doser 50-55 (-60 Gy => 7% risiko) Gy kan bruges for at få targetdækning efter patientinformation	Mayo et al IJROBP 76 (3) S28-35, 2010 RTOG0615
	Posterior eye (retina)	D_{max}≤ 45Gy	D_{max}≤ 50Gy	Retinopati kan optræde allerede efter 30 Gy, hvorfor dosis skal være så lav som mulig. Til gengæld er der en volumeneffekt, så f.eks. laterale retina kan forsøges skånet separat	DAHANCA 2004 Jeganathan et al. IJROBP 79 (3) 650-9, 2011

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OAR priorities

BØR	Cochlea	$D_{mean} \leq 45Gy$ og $D_{95\%} \leq 55Gy$	Cochlea indtegnes (opklaring i os temporale anteriort for canalis auditoria interna). Risiko for klinisk høretab måske 15% ved middeldoser ≤47 Gy *når strålebehandling gives med cisplatin*.	Bhandare et al. IJROBP 76 (3) S pp S50-57, 2010; Chan et al IJROBP 73, (5) 1335-1342, 2009; Hichcock et al IJROBP 73 (3) 779-88, 2009
	Parotid gland	1) Kontralateral parotis: $D_{mean} \leq 20Gy$ 2) Begge parotider: $D_{mean} \leq 26Gy$	Der ses en gradvis reduktion i funktion efter doser fra 10 til 40 Gy, hvorfor middeldosis skal tilstræbes så lav som mulig	DAHANCA 2004 Deasy et al IJROBP 76 (3) S58-63, 2010
	Mandible	Hotspots i mandiblen bør undgås		*Int J Radiat Oncol Biol Phys*. 2010 April ; 76(5): 1333–1338

OAR priorities

KAN	Pituitary gland	$D_{mean} \leq 30Gy$	Ingen tærskeldosis. Hormonforstyrrelser ses ved >30 Gy og kan medføre endokrinologisk kontrol	Darzy et al. Pituitary (2009) 12;40-50
	Brain	$D_{max} \leq 60Gy$	Ved Dmax=72 Gy er risikoen for nekrose 5% efter 5 år. Kognitive forstyrrelser kan ses ved lavere doser. Hele hjernen indtegnes.	Lawrence et al. IJROBP vol 76 (3) S20-27, 2010
	Submandibular gland	$D_{mean} \leq 35Gy$	Submandibularis er en del af level Ib og skal kun forsøges skånet hvis level I og II ikke er target på relevante side	Deasy et al IJROBP 76 (3) S58-63, 2010
	Oral cavity	$D_{mean} \leq 30Gy$ for ikke involverede del af mundhulen	Indtegning: Frie tunge, mundbund, kinder og hårde gane	RTOG 1016
	Lips	$D_{mean} \leq 20Gy$		RTOG 1016
	Larynx	$D_{mean} \leq 44$ Gy	Indtegning: larynx med arytenoidea fra os hyoideum til cartilago cricoidea	Rancanti et al. IJROBP 76 (3) s64-69, 2010
	Thyroid gland	$D_{mean} \leq 40$ Gy	Der er tilsyneladende ingen specifik tærskeldosis, men usikkerhed i litteraturen om bl.a. endepunkt. Ved overskridelse af nævnte tærskeldosis da evt. TSH kontrol efter lokale retningslinjer.	Garcia-Serra AJCO 28, (3) June 2005 p 255-8 Boomsma R&O 99(2011)1-5
	Esophagus	$D_{mean} \leq 30Gy$	Underkant af cartilago cricoidea til overkanten af manubrium	RTOG 1016

DAHANCA

- Danish Head and Neck Cancer Group

DAHANCA.dk

Danish Head and Neck Cancer Group

| Home | News | Organisation | Guidelines | Protocols | Forms | Publications | DATHYRCA | Links |

Guidelines

- DAHANCA/EORTC guidelines for scoring and classification of p16-immunohistochemistry in HPV-related oropharyngeal cancer
- Nationale retningslinjer vedrørende Karcinommetastase på halsen fra ukendt primærtumor 2013
- DAHANCA stråleretningslinjer 2013
- Nationale retningslinier for pharynx- og larynxcancer 2011
- Nationale retningslinjer for behandling og pleje ved recidiv eller primært fremskreden hoved-halscancer 2010
- Nationale retningslinjer for spytkirtler 2010
- Nationale retningslinjer for thyroideacancer 2010
- Karcinom i næse og bihuler - nationale retningslinier for udredning, behandling og rehabilitering (ver. 1.1 - 26.03.09)
- Pakkeforløb for hoved-halskræft
- Oversigt over tilrettelæggelsen af pakkeforløb for hoved-halskræft

- DAHANCA Vejledende retningslinier for udredning og behandling af patienter med hoved-halskræft 04/11 2007
- DAHANCA Anbefalinger af billeddiagnostiske undersøgelser 05/10 2007
- DAHANCA Retningslinier for spytkirtelkræft udredning og behandling 05/10 2007
- DAHANCA Retningslinier for stråleregimer 22/03 2007
-
- RETNINGSLINIER FOR STRÅLEBEHANDLING AF HOVED-HALS CANCER 2002
- RETNINGSLINIER FOR STRÅLEBEHANDLING AF HOVED-HALS CANCER 2004 inkl. IMRT
- Atlas_neck_CTV.pdf
- Table_neck_CTV.pdf
- Behandling af orale planocellulære karcinomer
- Dahanca retningslinjer for konkommitant cisplatinbehandling 13.03.07

- Vejledning i udarbejdelse af referenceprogrammer - sundhedsstyrelsen

Såfremt linkene ikke virker, brug da højreklik + "gem som"

Last updated8-28-2013

Web-editor: Jens Overgaard

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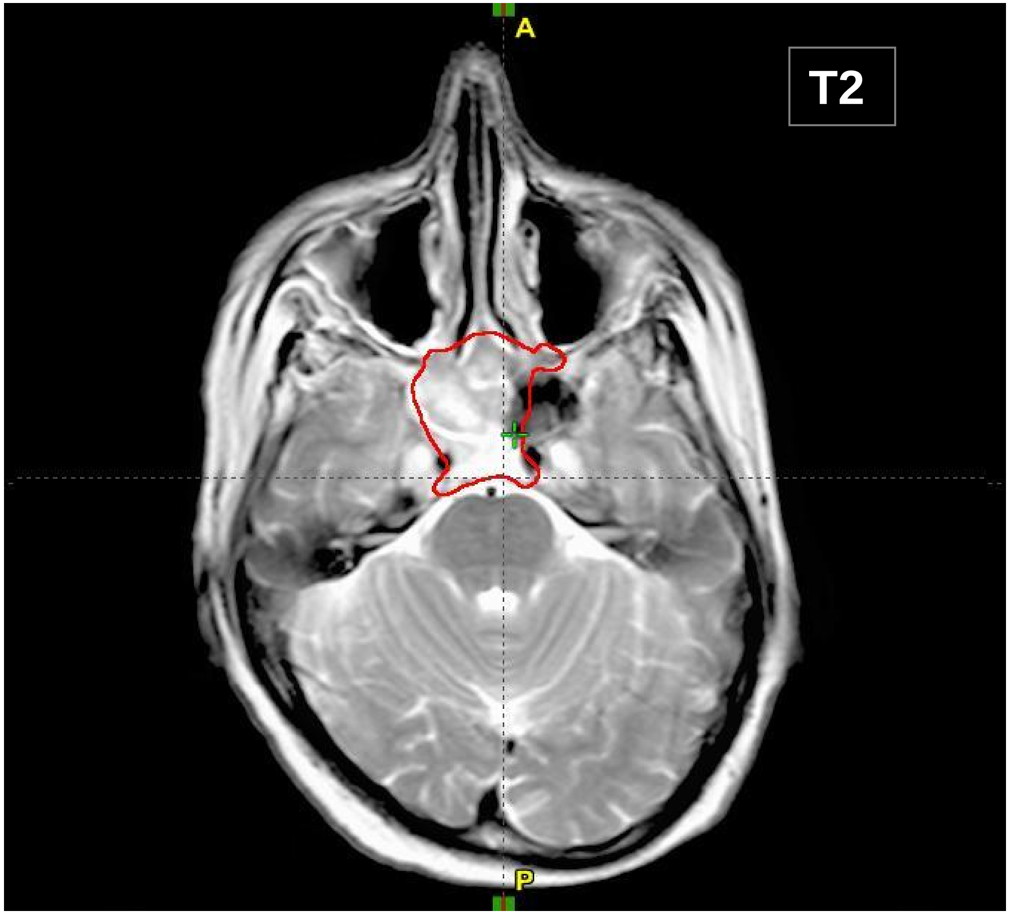
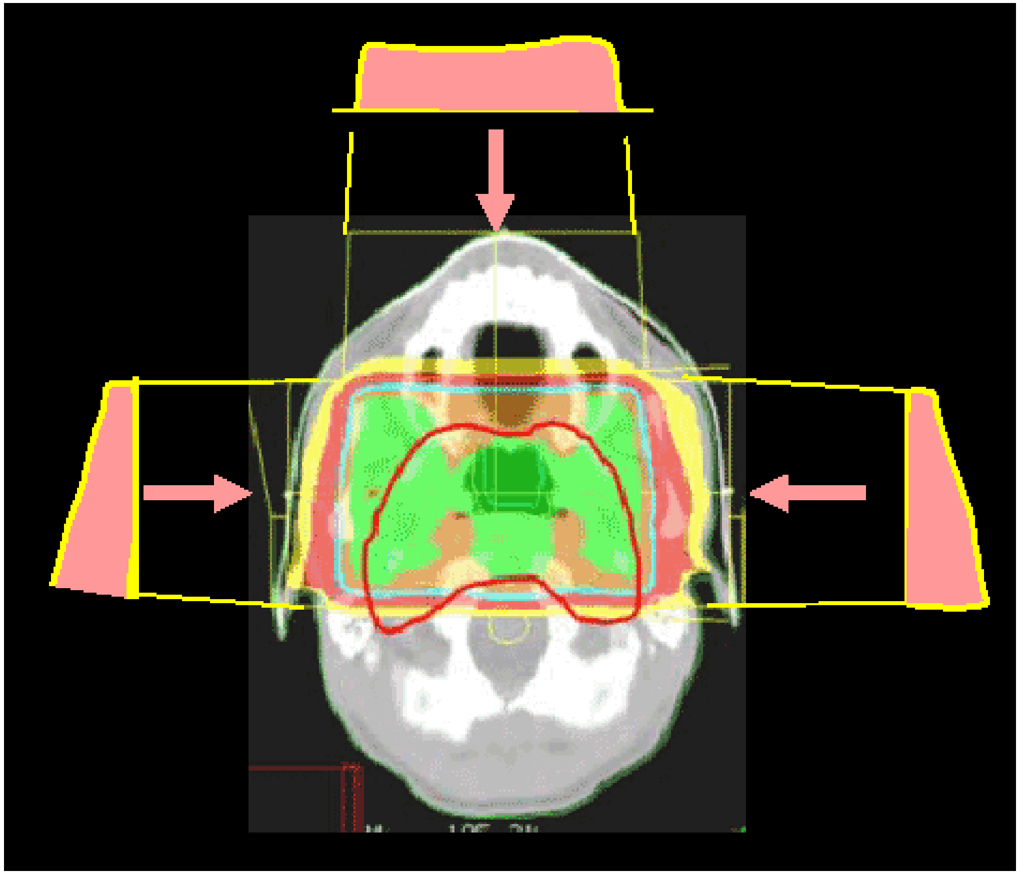
Delineation

Reminder:
T1: water black, fat white
T2: water white, fat black

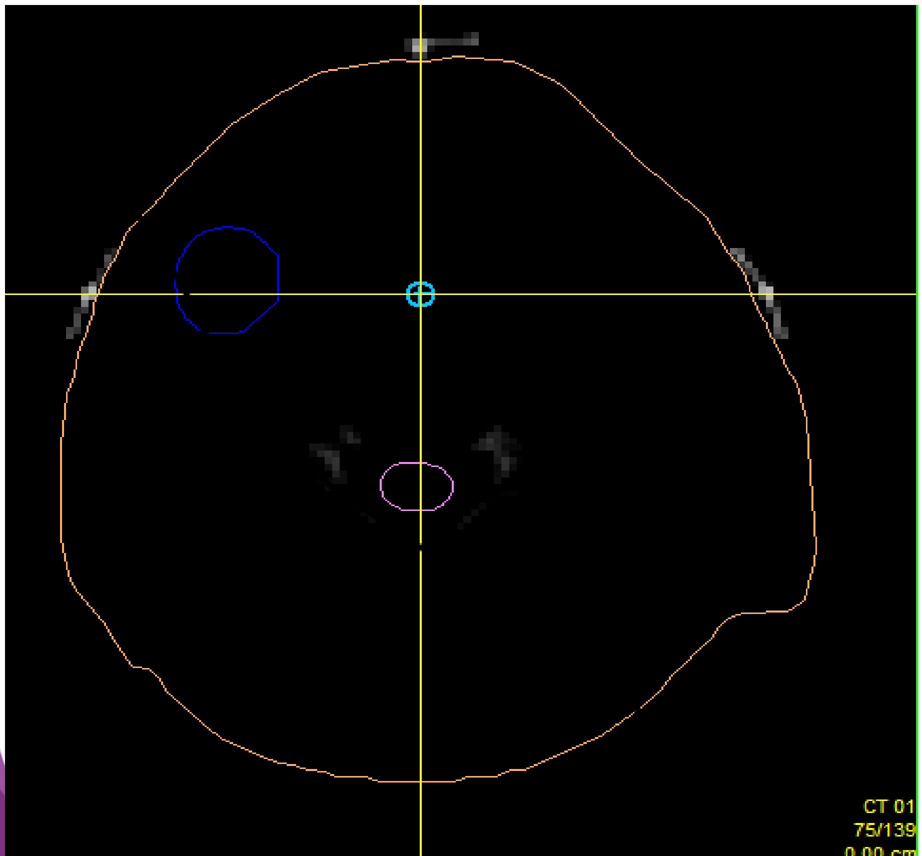
- Based on CT and MR (T1+K og T2)
- Radiologist and Oncologist delineate target. Oncologist delineate elective lymph nodes. RTT/Oncologist delineate OAR.



Conventional 3DCRT

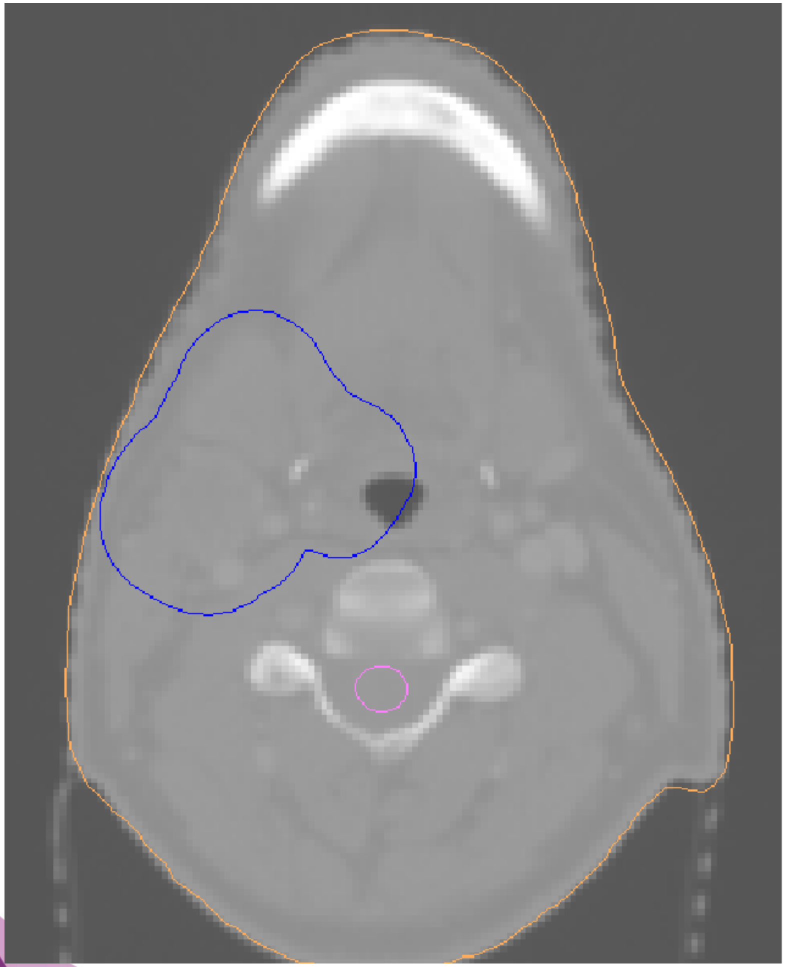


Reference Point



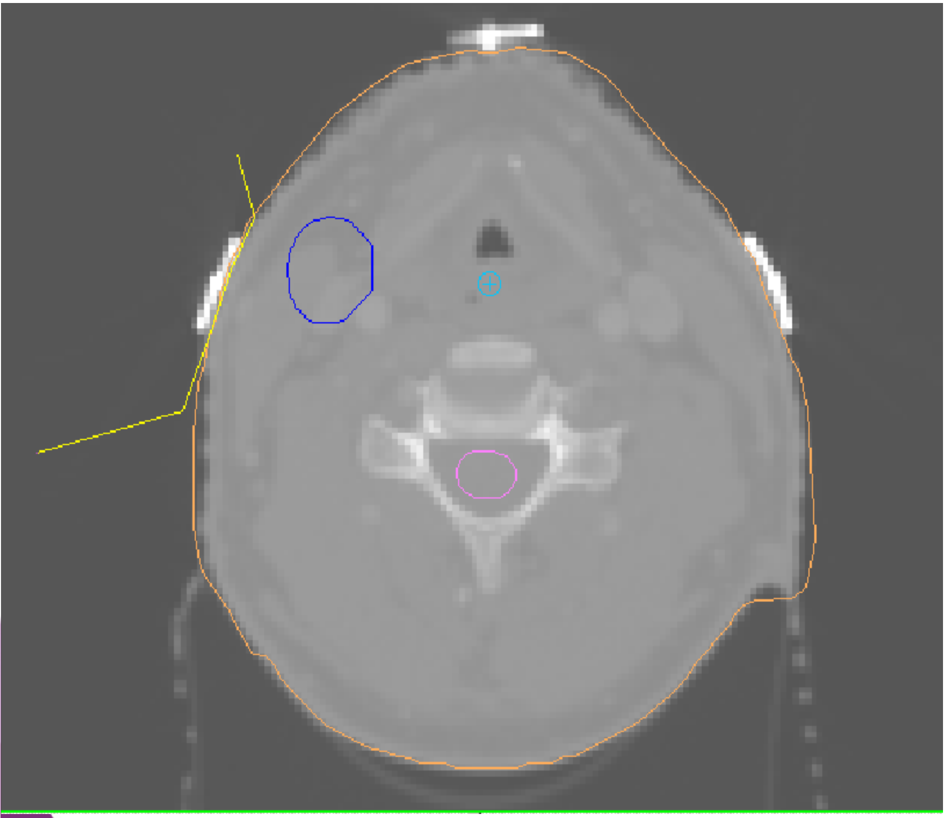
- CT isocentre
- On midline and laterally near target
- Anatomically stable part of patient
- Avoid areas of changes in contour of mask

Outlining Contour



- Contour needs to be tidied and include mask
- Modify external to exclude fiducial markers and artefacts
- Fiducial markers are high density material which influence distribution

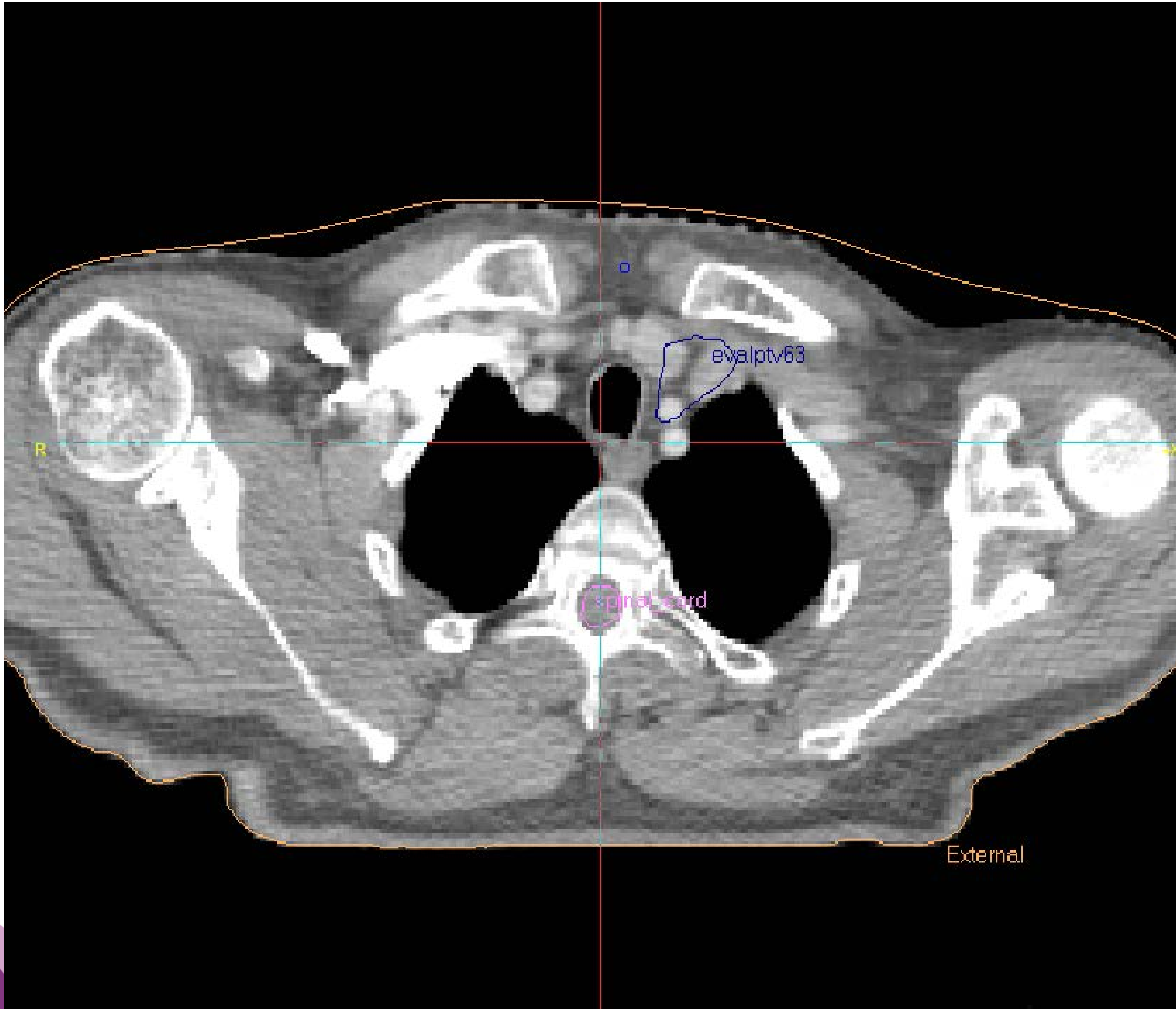
Outlining Contour – Remove fiducials

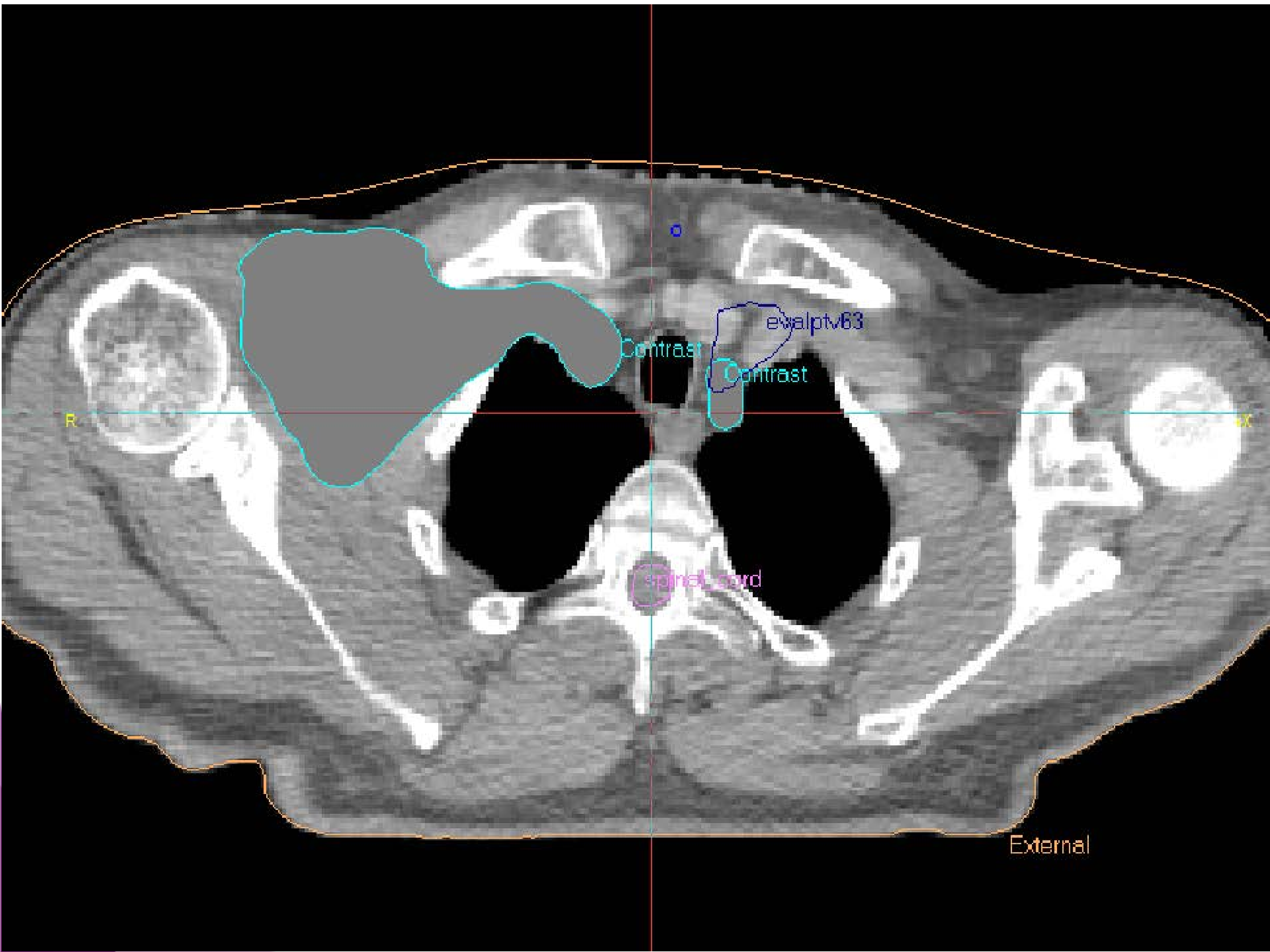


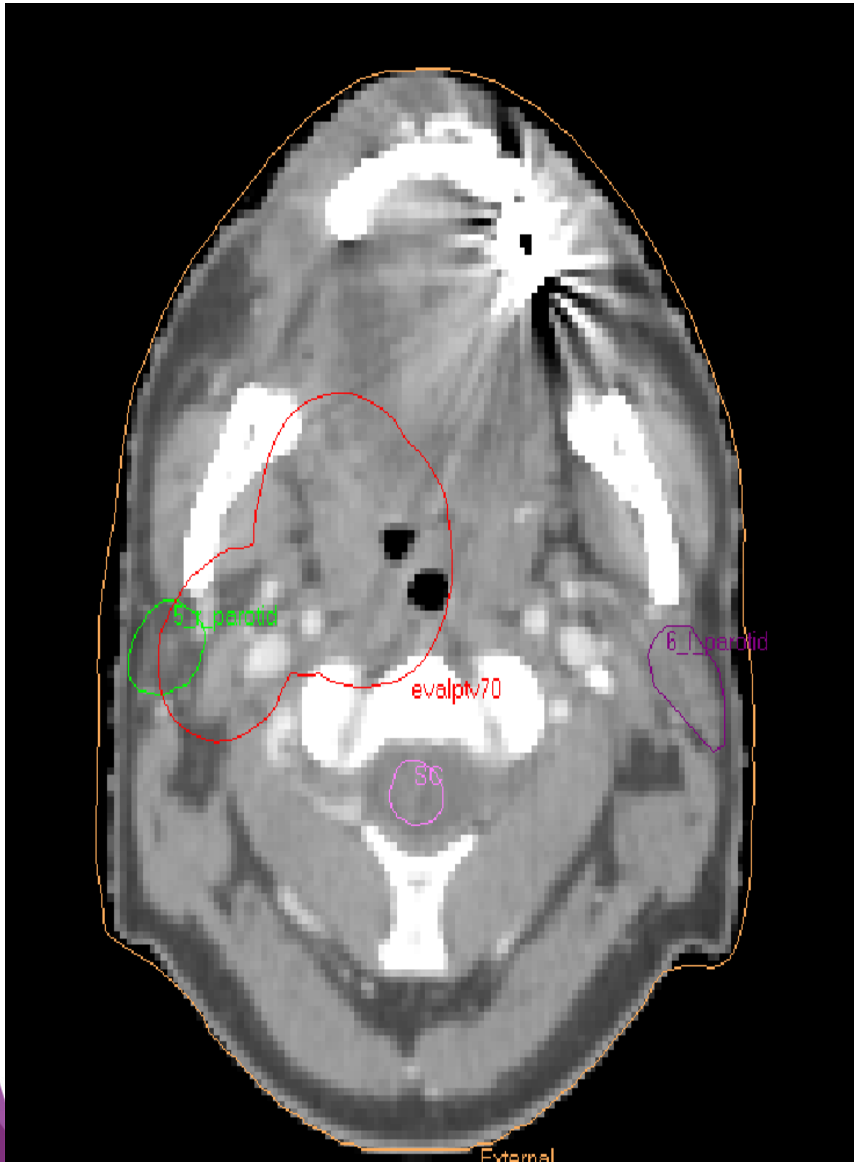
- Fiducial markers are removed for treatment
- Need to be removed from plan calculation
- Wire outlined and given density of 0

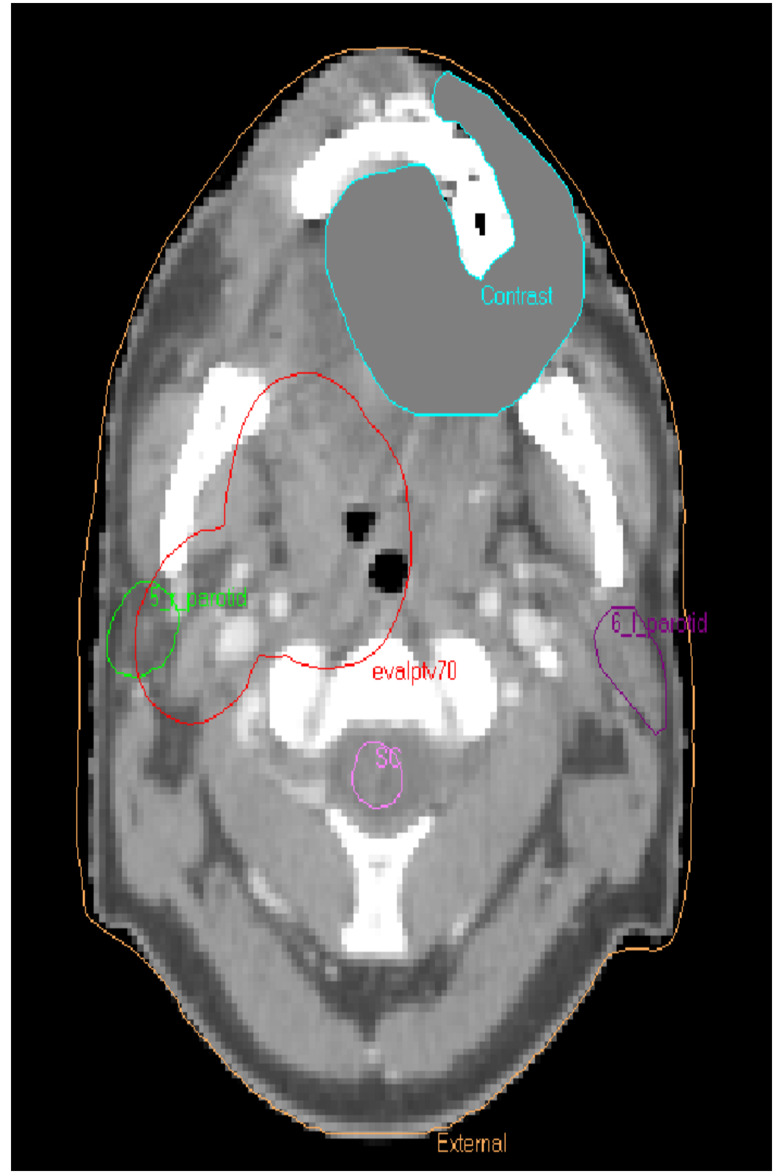
Contrast and Artefacts

- IV contrast may be used during CT for head and neck patients. This must be accounted for when planning.
- Create a volume which covers any contrast in and around the treatment area.
- Remove areas of bone, lung, airways from this.
- Give unit density of 1 to the contrast in this region
- If necessary, use a similar technique to remove artefact caused by dental filling or other high density regions, eg shunts

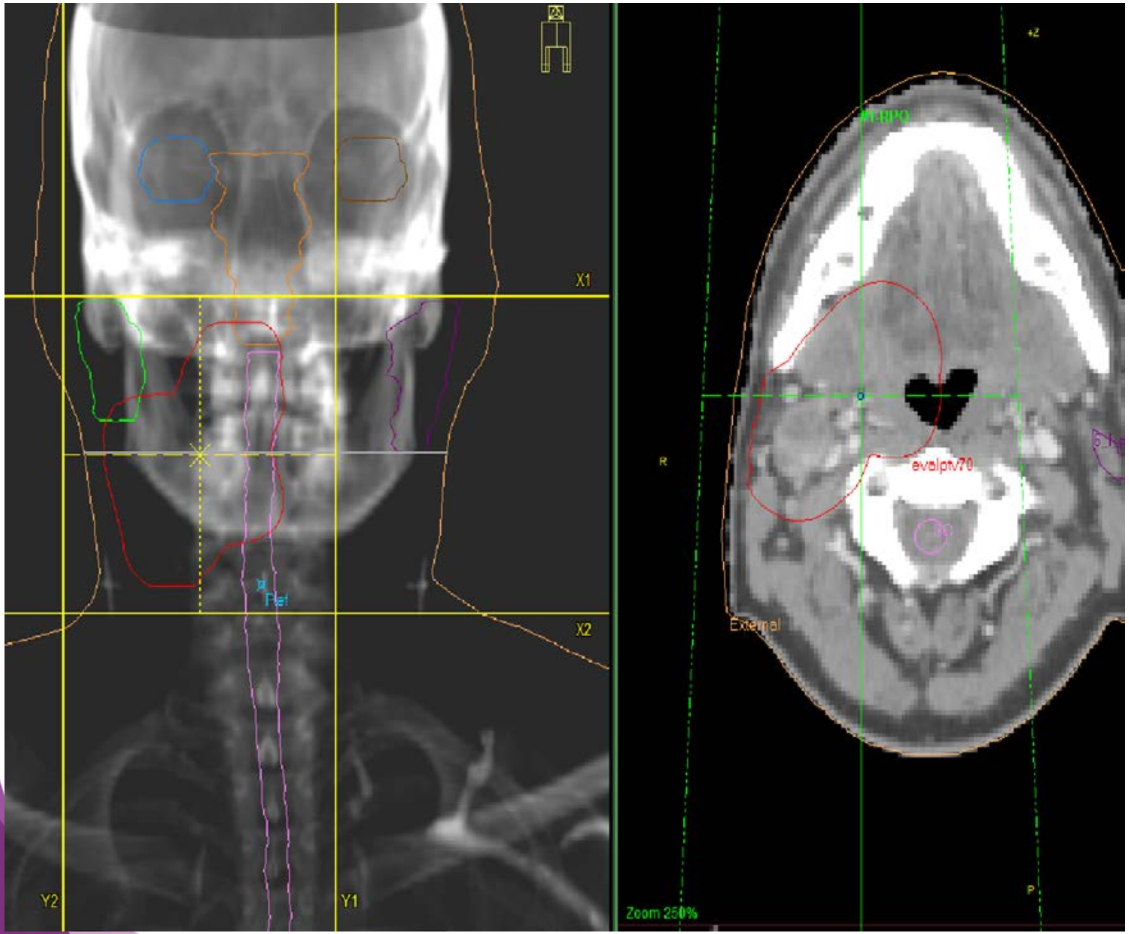

evalptv63
R
External


evalptv63
Contrast
Contrast
R
L
spinal_cord
External


5_r_parotid
6_l_parotid
evalptv70
SC
External


Contrast
5_r_parotid
6_l_parotid
evalptv70
SC
External

Isocentre Placement



Three options

- At reference point
- At centre of the PTV
- At a standard move from reference point

Isocentre Placement 2

- Reference point

    will not need moves/verification

    not always suitable for ipsilateral target

- Centre of PTV

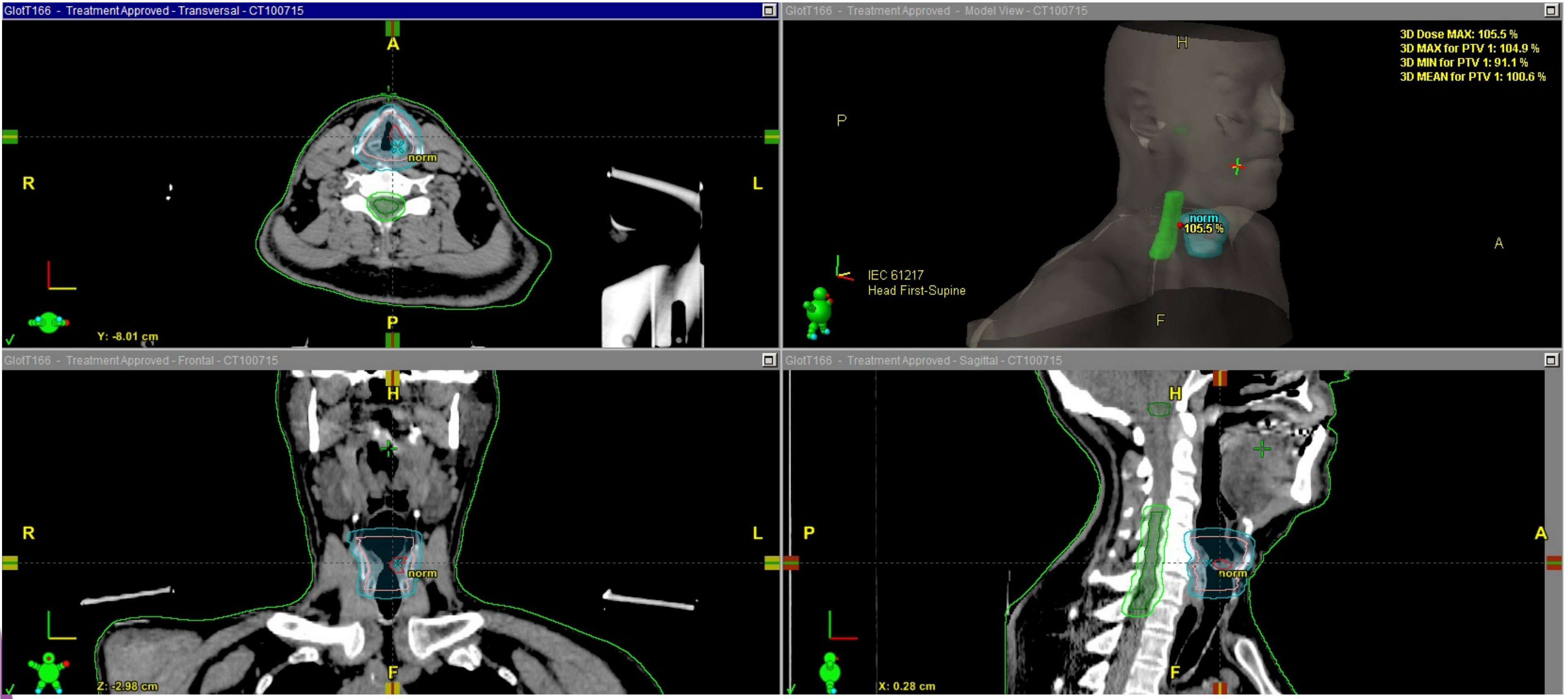
    will require daily moves in all directions and verification

- Standard moves

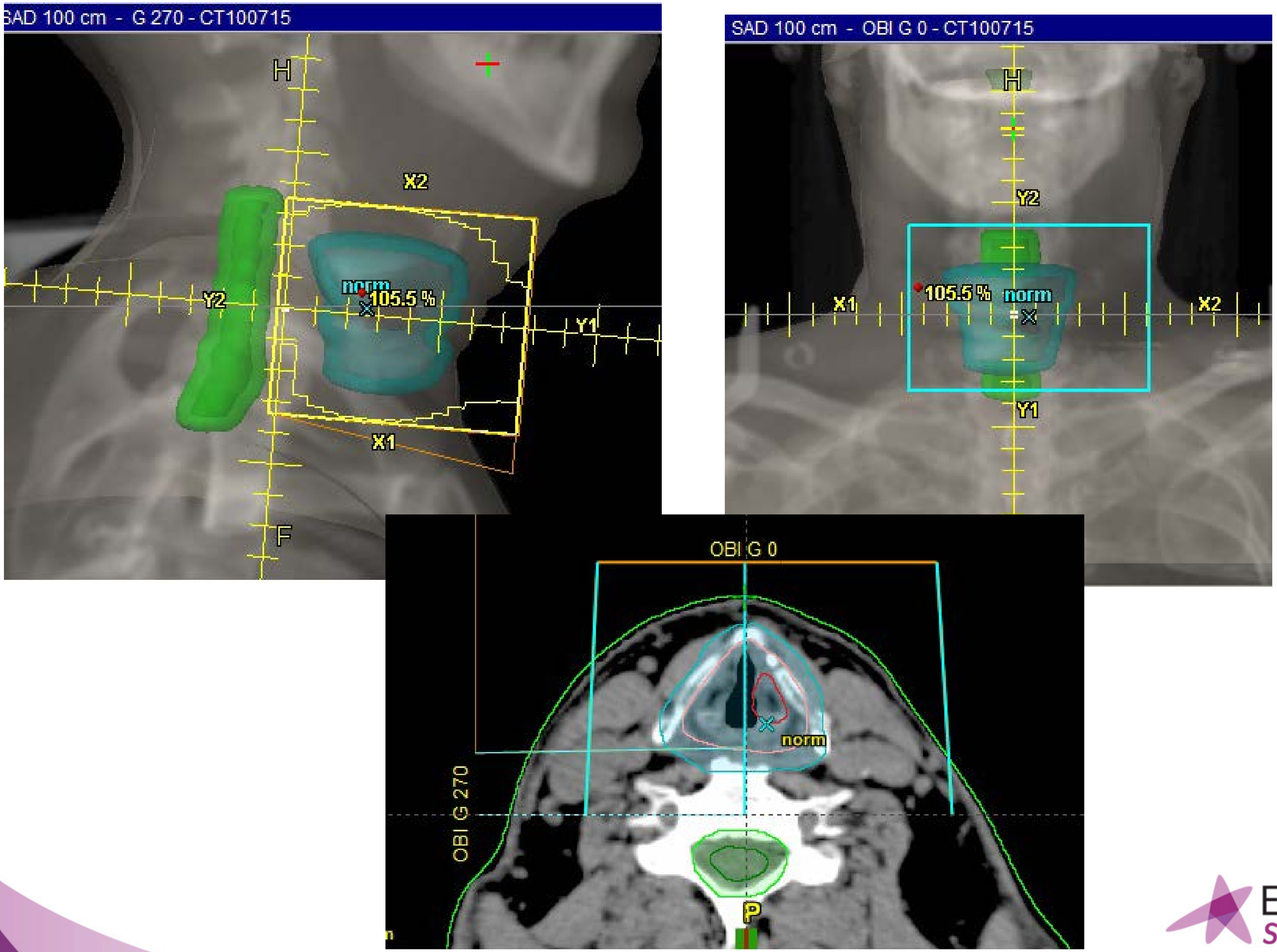
    will require moves daily and verification but can be made in whole numbers and only in required directions

- For ease of set-up and accuracy no moves from ref. point is the ideal (high proportion of errors in RT are in relation to moves) however if needed try to keep them standard

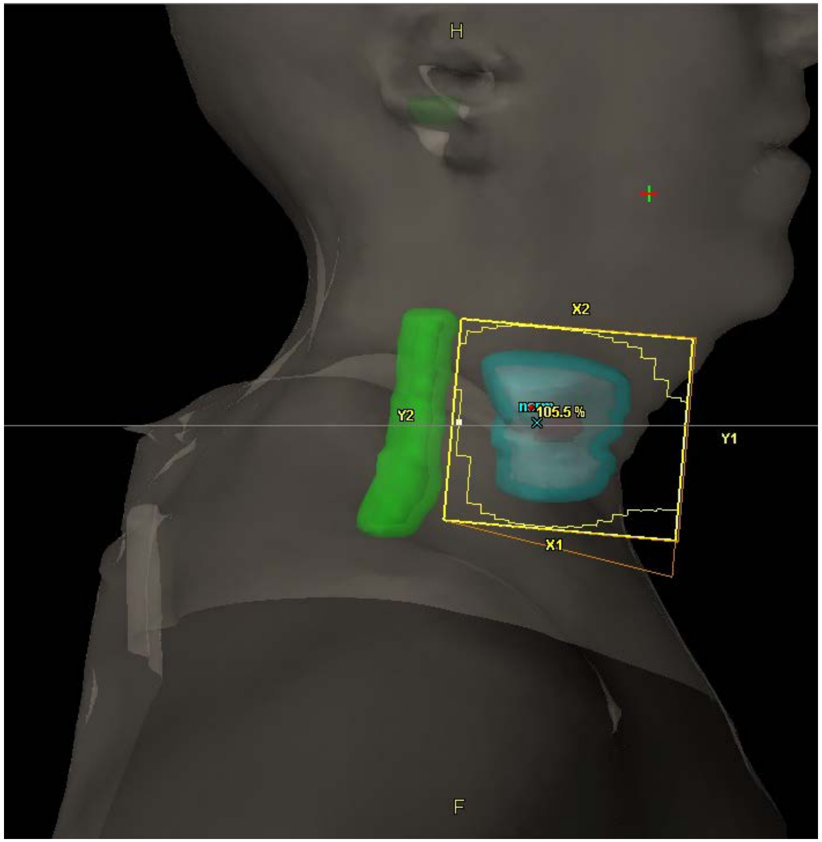
Glottis T1 - delineation

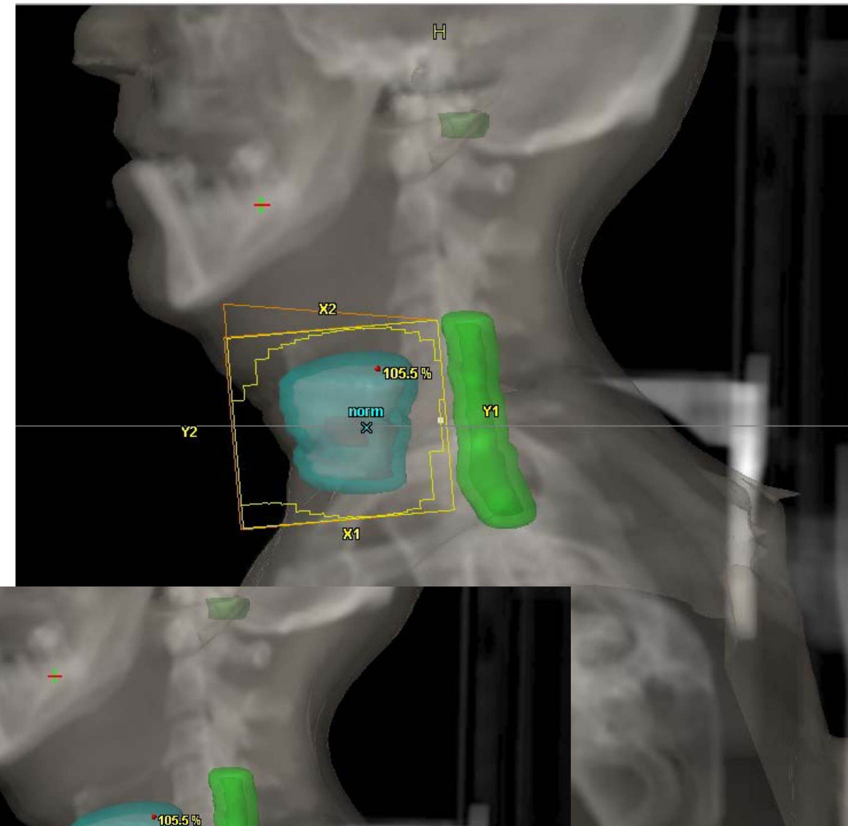


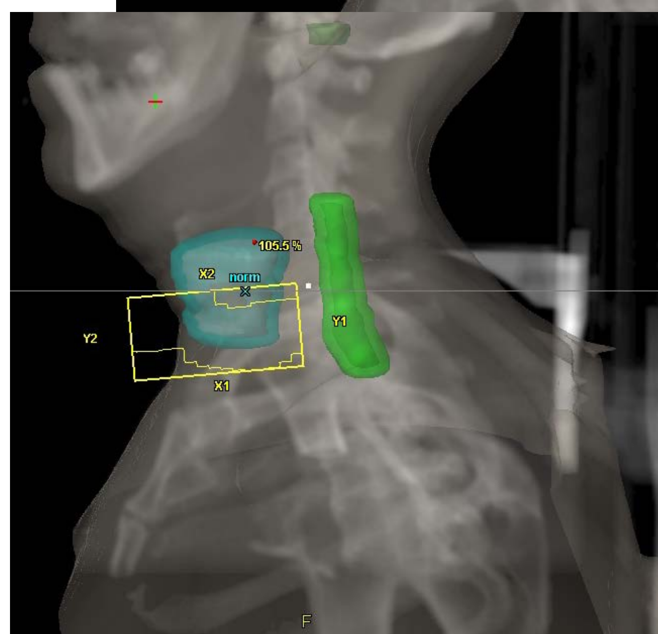
Glottis T1 - isocenter



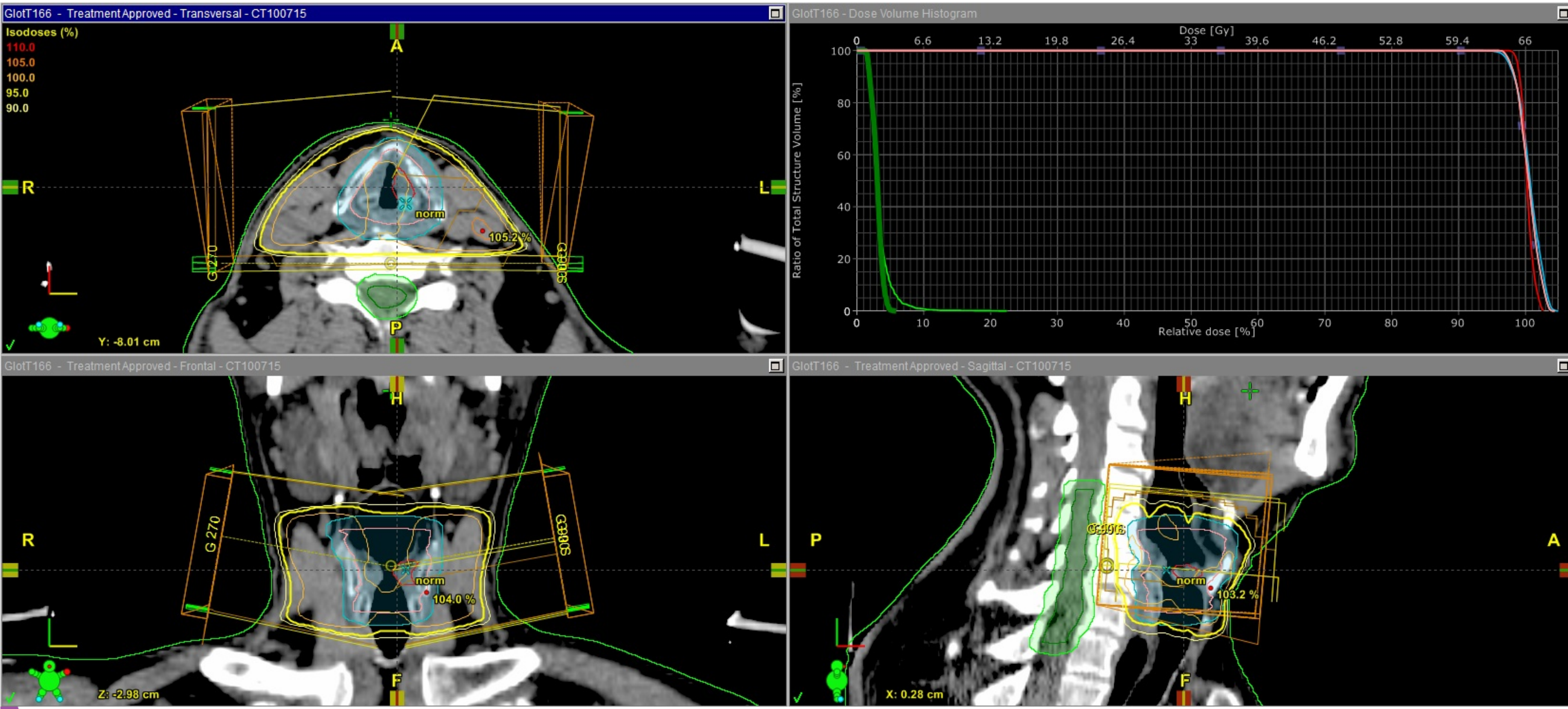
Glottis T1 – treatment fields



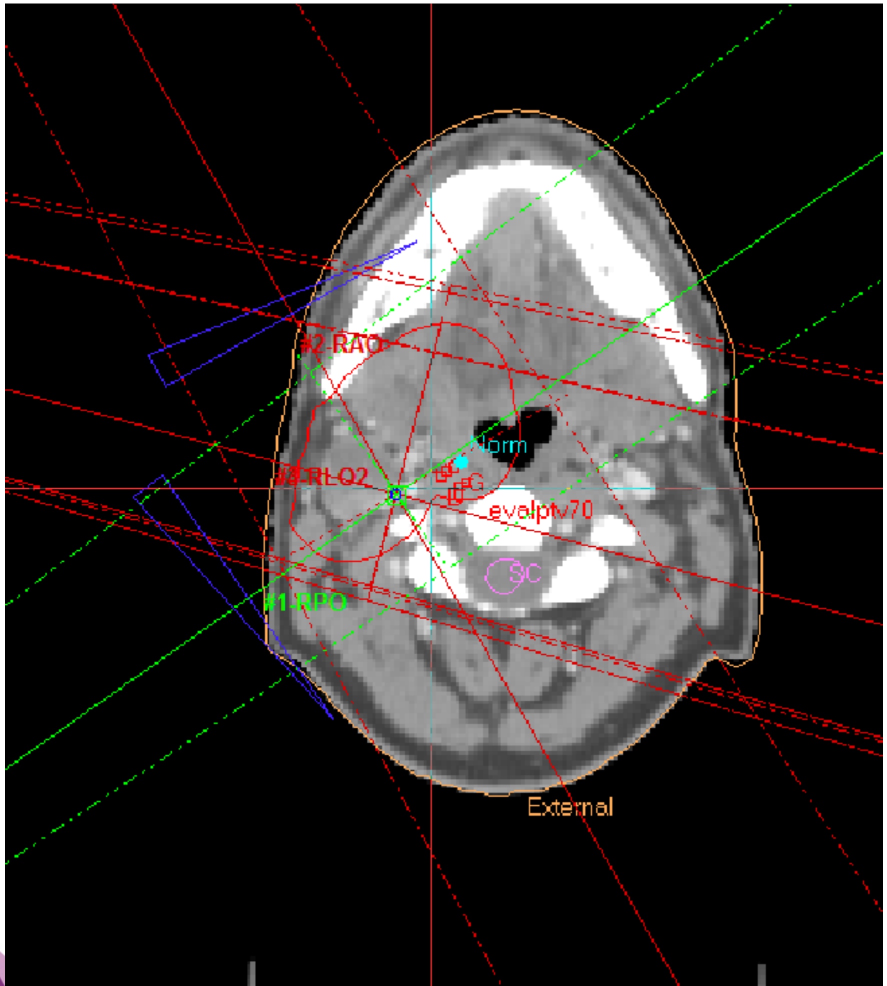




Glottis T1 – dose distribution



Beam Arrangements



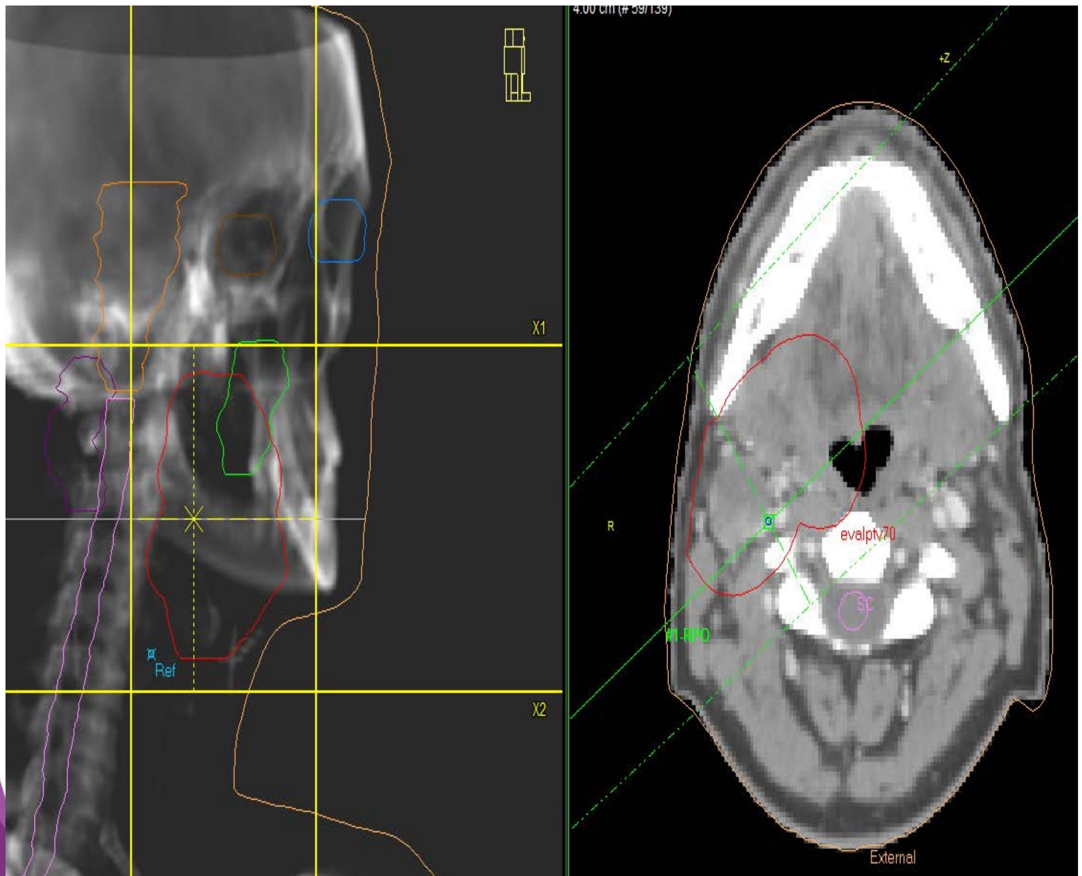
For an ipsilateral target the standard approach is anterior oblique, posterior oblique and low weighted lateral (can be direct or oblique)

Wedges on the ant and post have thick ends together

The lateral fields have wedge thick end inf

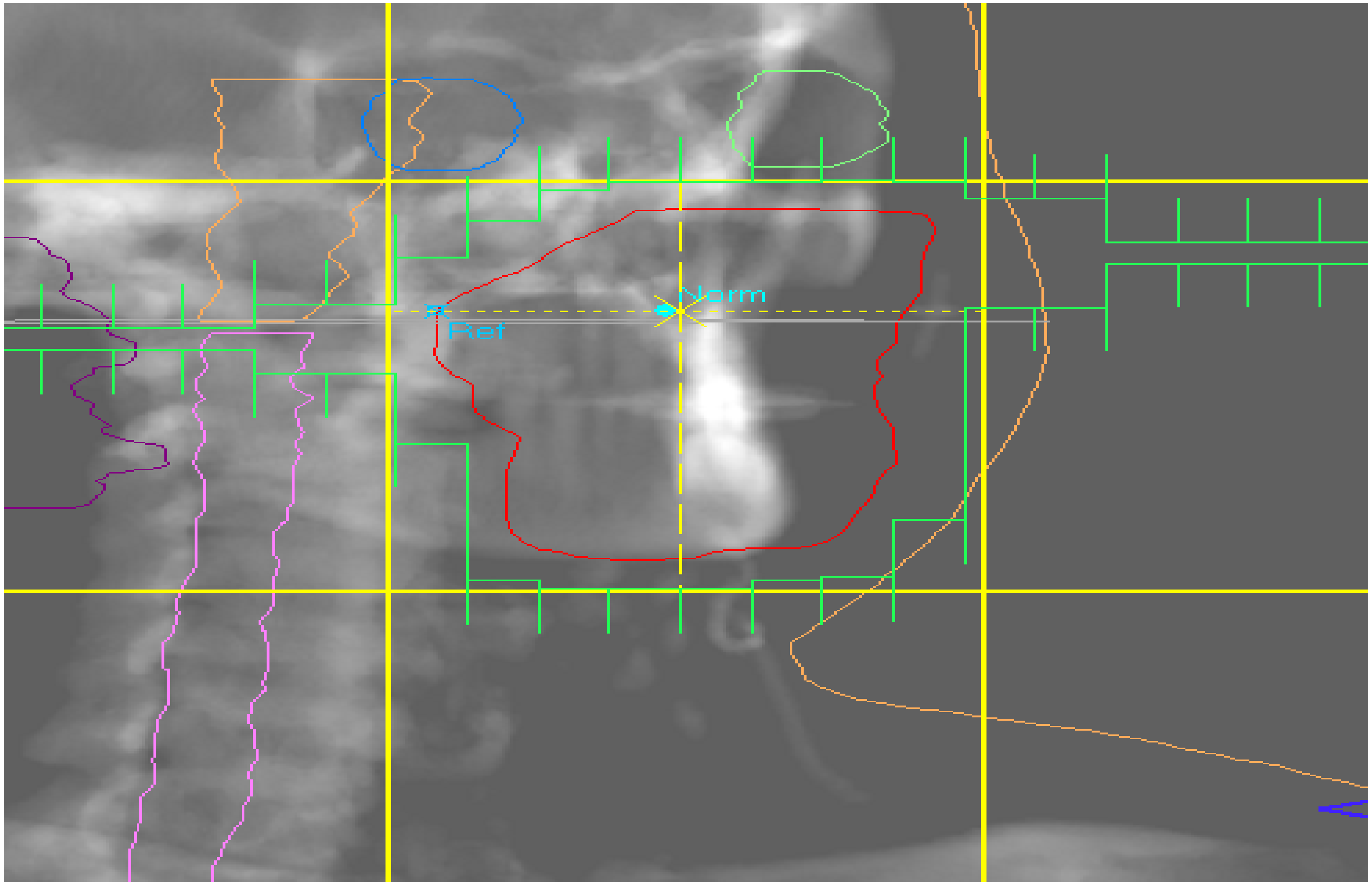
6MV appropriate for this case

Posterior Oblique Beam (RPO)

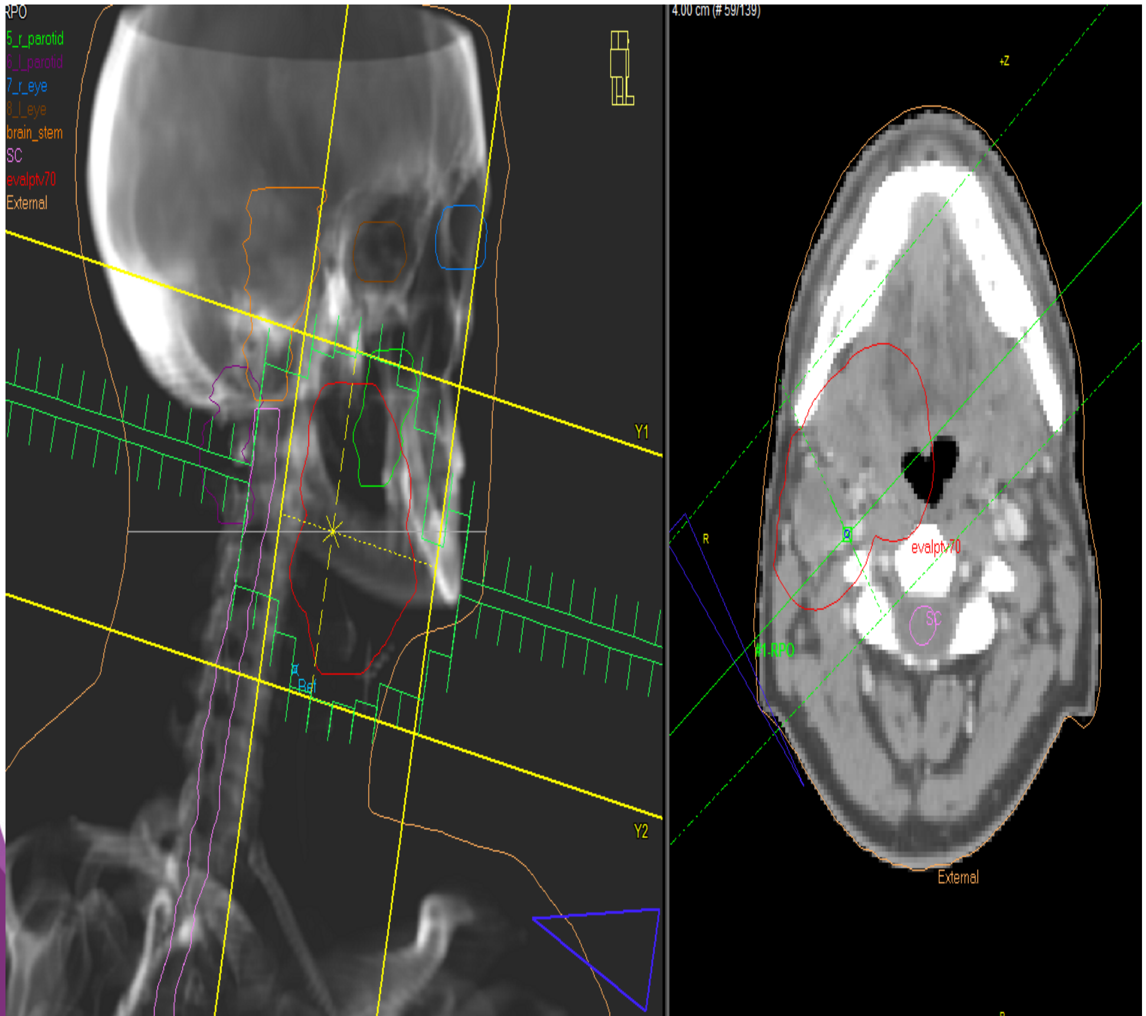


- Use gantry angle to avoid spinal cord
- It is necessary for at least one main field to avoid the spinal cord
- Try to avoid the opposite parotid and eye

RPO beam close to eyes



Collimator / Floor Angles



- If there are **NO** junctioning fields (eg lower ant neck) collimator tilt can be applied to avoid the cord or other OARs
- Floor angles can be used to avoid the eyes
- Make sure beams are achievable on set

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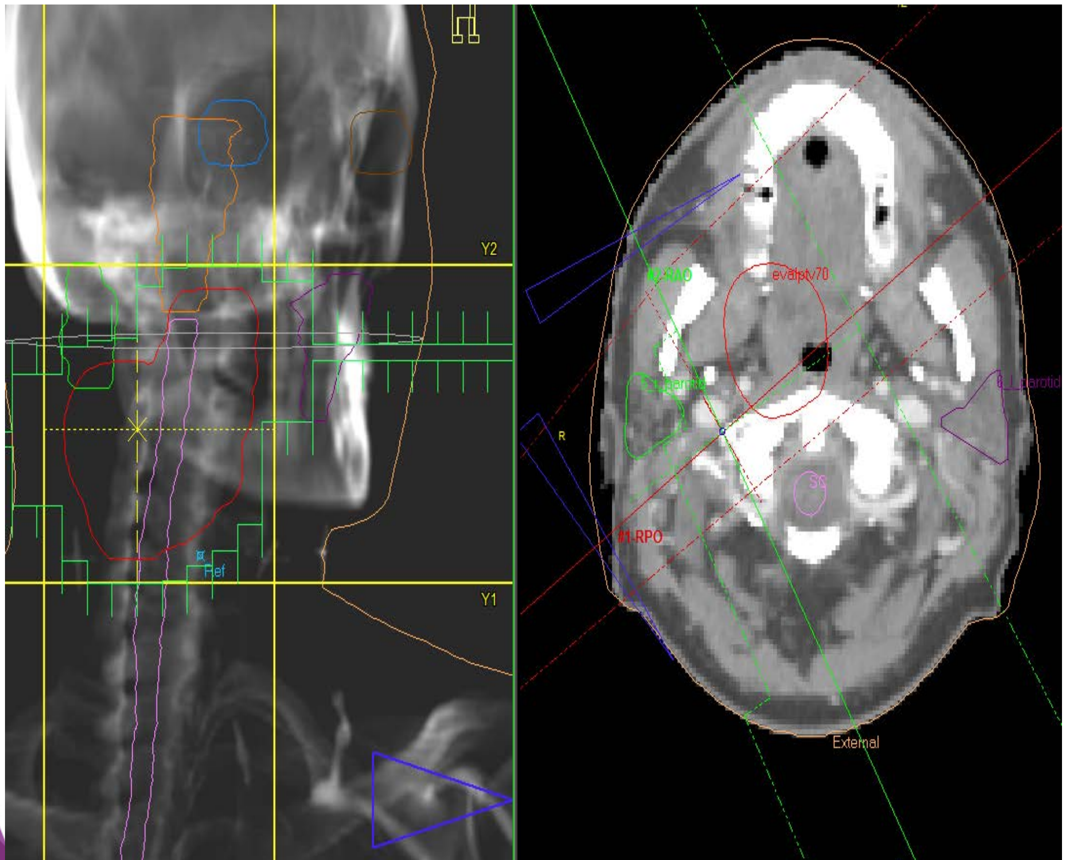
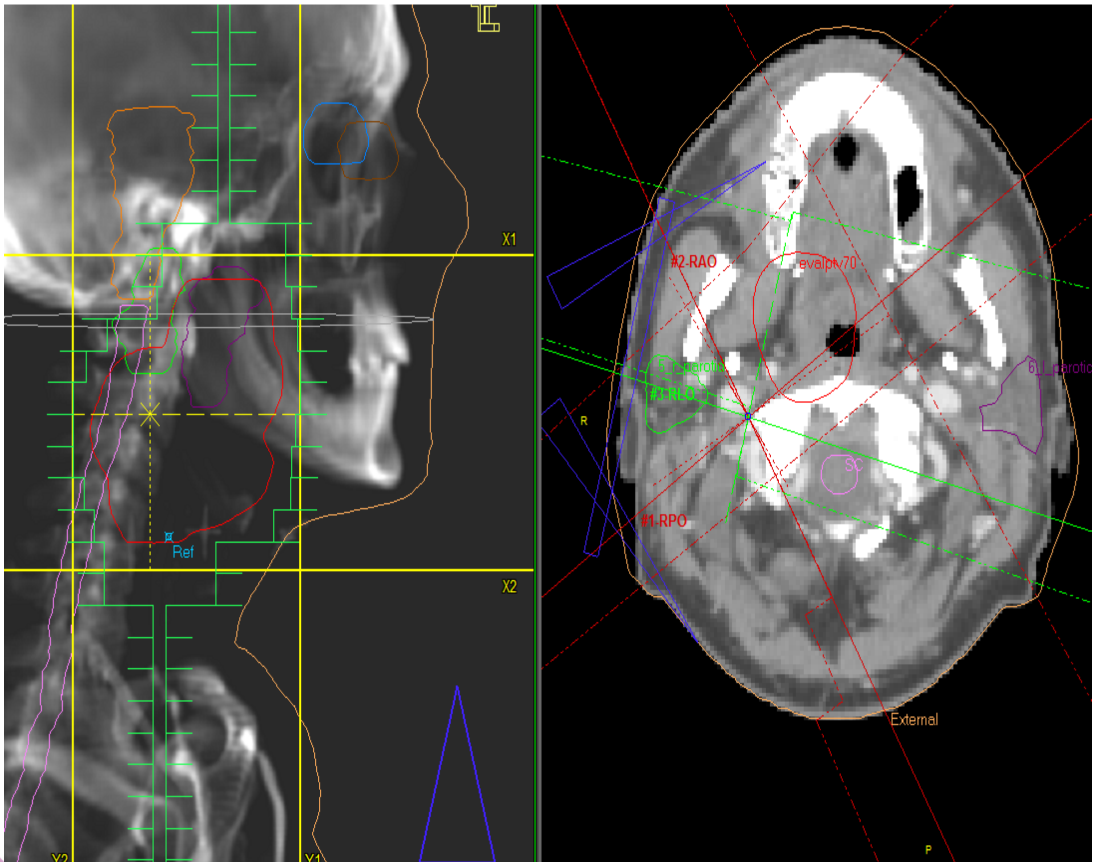
Anterior Oblique Beam (RAO)



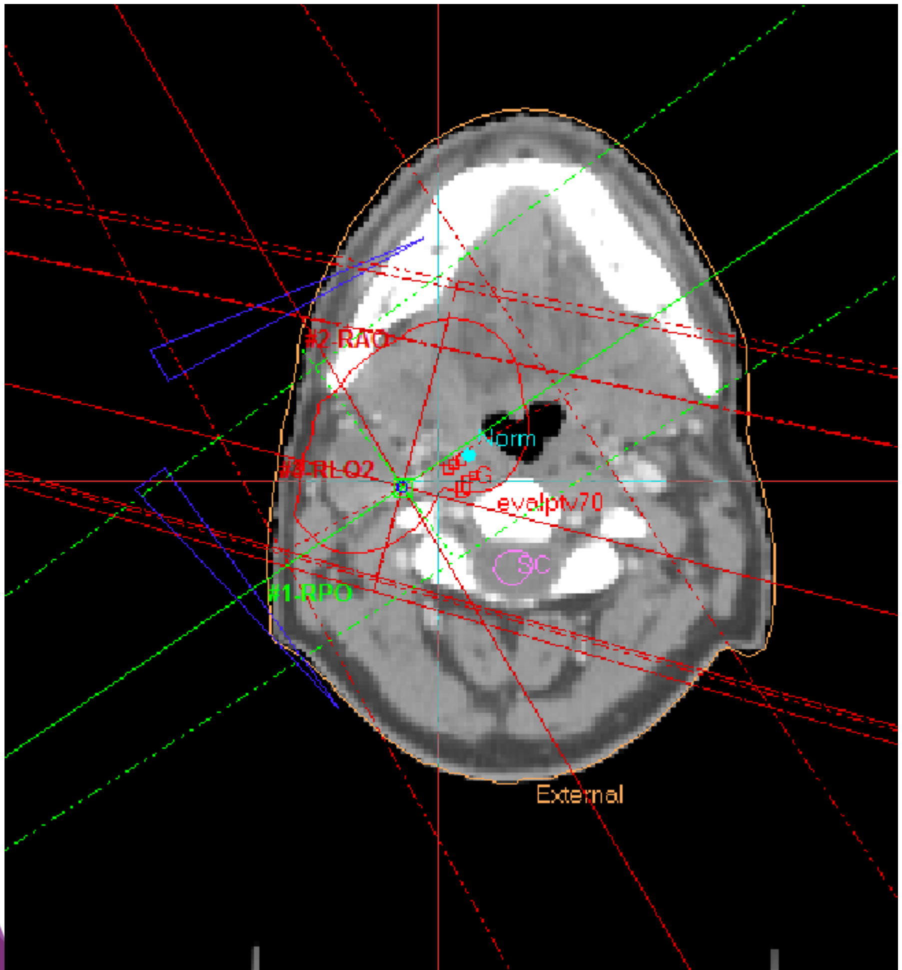
- Will generally go through cord
- Avoid the opposite parotid and the oral cavity as much as possible

Lateral Beam (RLO)



- Can be direct or oblique
- Gantry angle falls between other 2 fields
- Often goes through cord and opposite parotid
- Always low weighted
- May need a 2nd beam to allow for segments later

Calculation Points

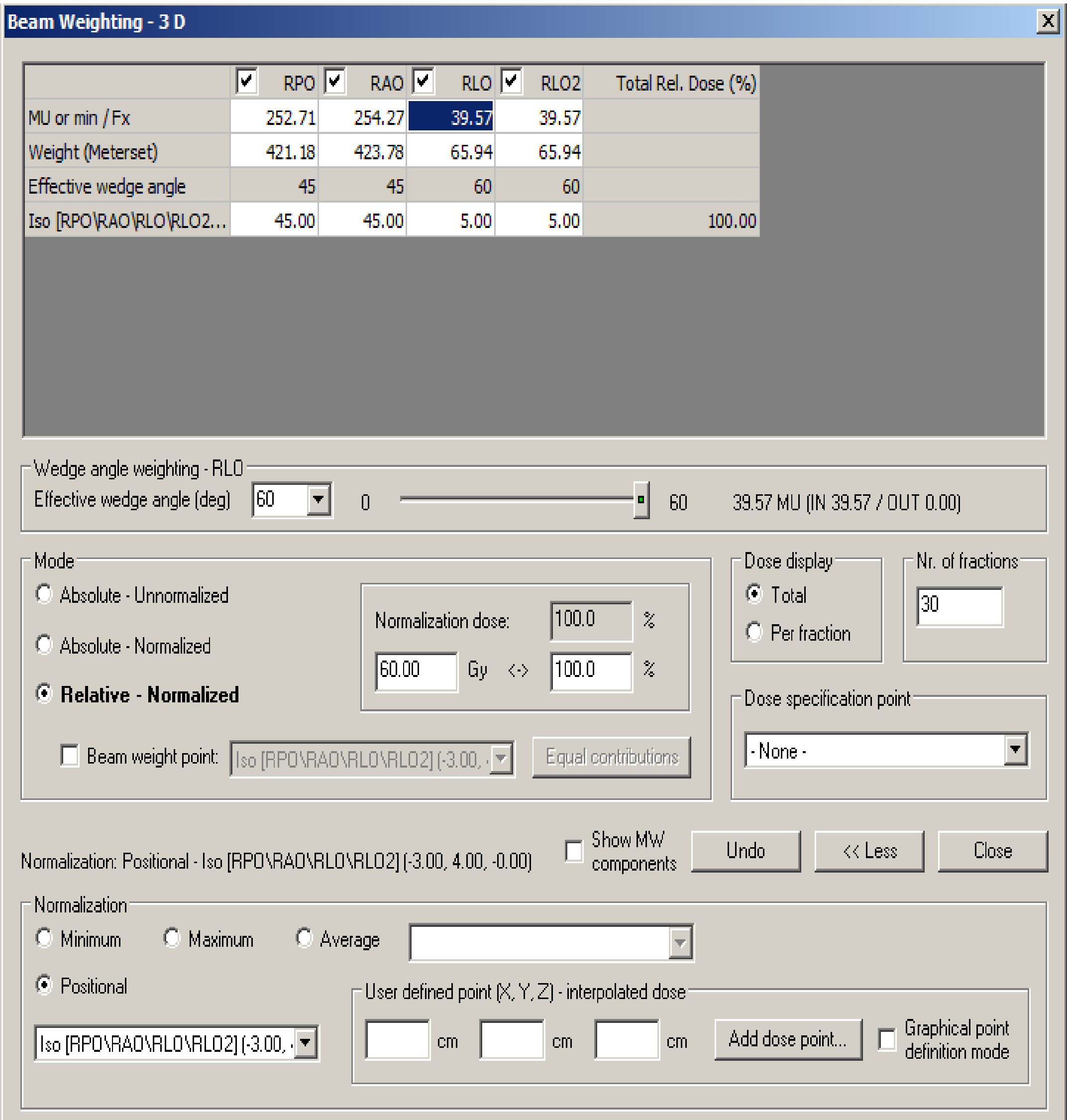


Normalisation point is where 100% of prescribed dose occurs

Potential normalisation points are placed around centre of volume

For standard beams (non half beam blocked beams) the isocentre can be used for normalisation

Dose Weighting



Start with 45% to each main field and 5% to each lateral field

Lateral fields require full or no wedge due to their low MUs

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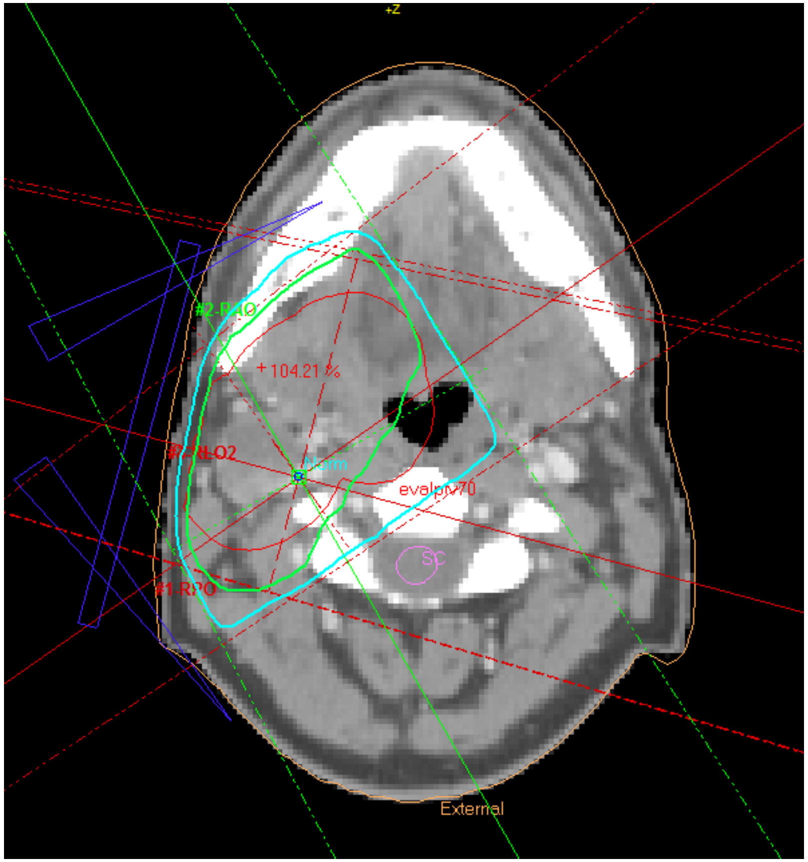
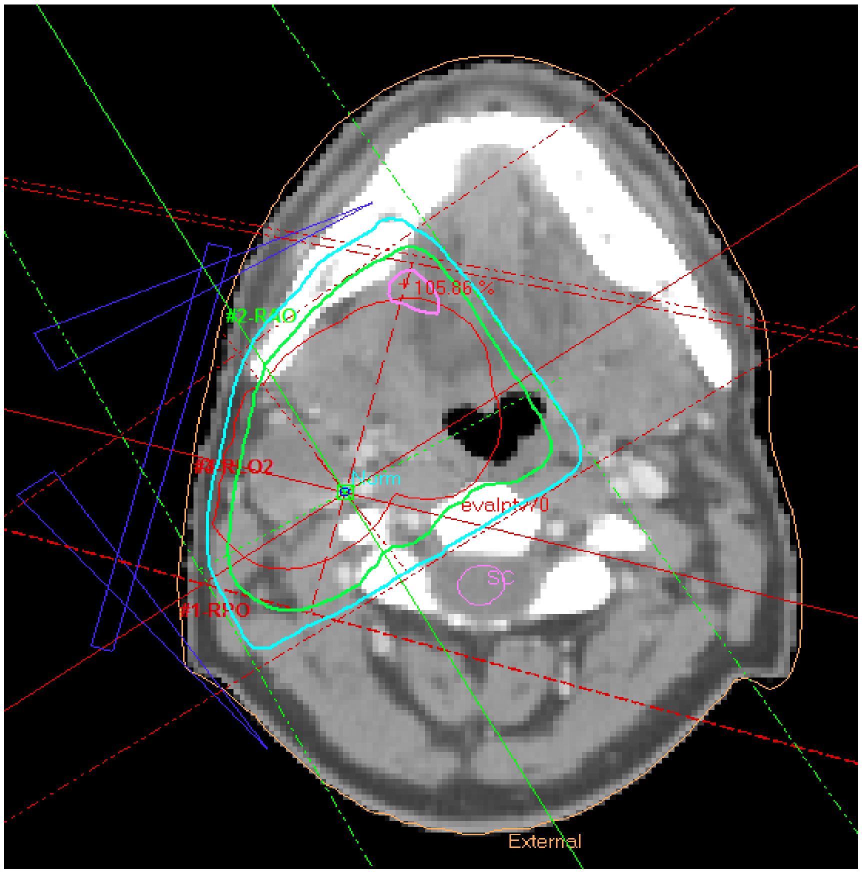
First Distribution



Not covering medially at the central axis (CAX)

Try increasing the wedge on main RAO and RPO fields

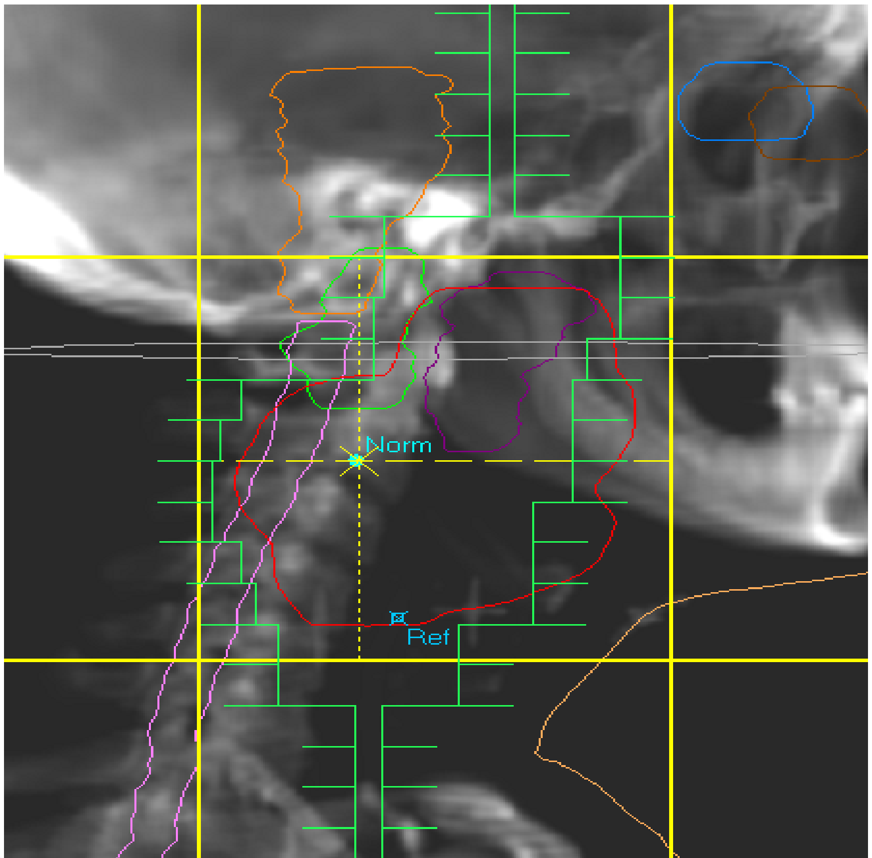
Increased Wedges



Fixes the coverage at CAX

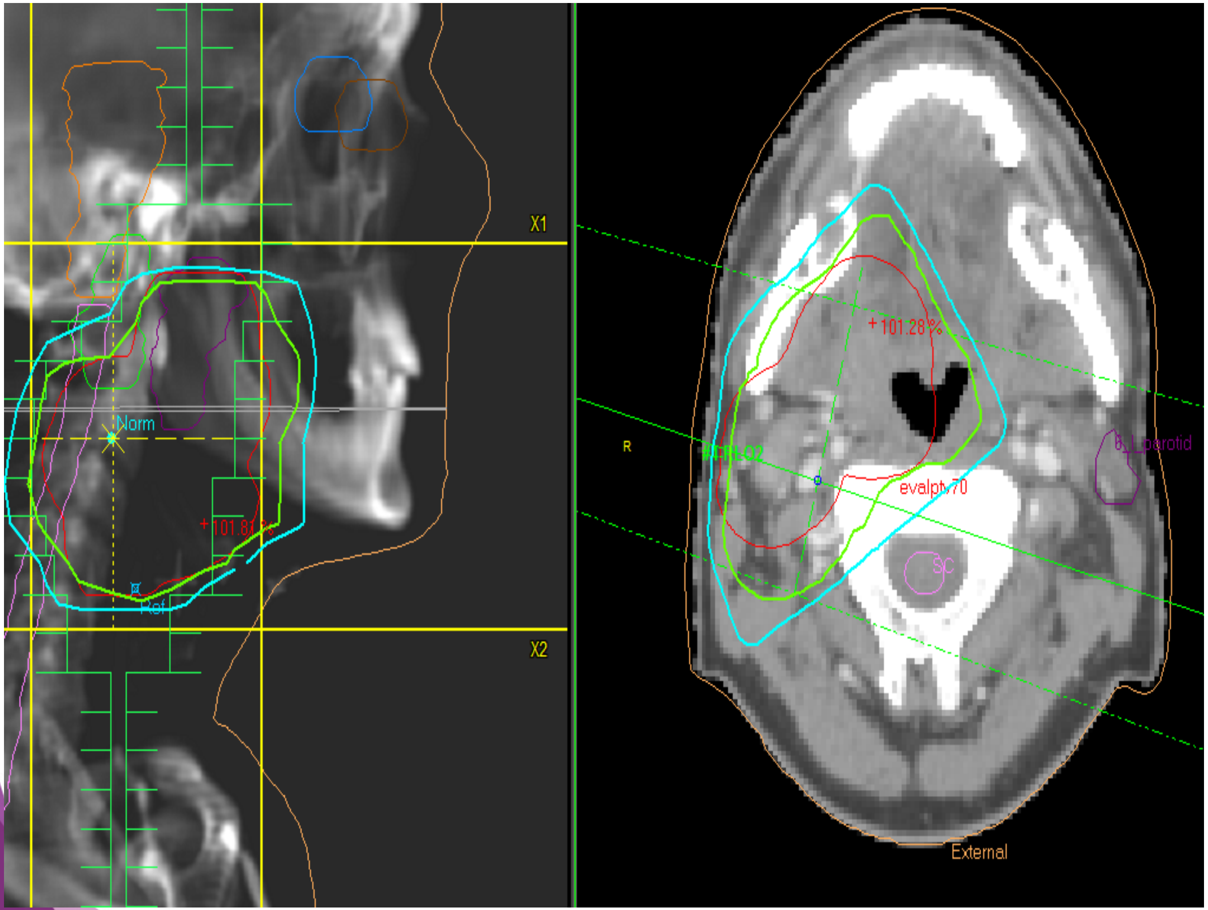
Hot spot now appears anteriorly (105%)

Segments on RLO field



- Use MLC to shield hot area/OARs whilst not affecting 95% PTV coverage
- Use one of two RLO fields (weighted 5% each)
- Alternatively can use segment beams on RAO/RPO field as required

Distribution After Segments



Reduces 103% in area under shielding

See anterior edge of field showing shielding

Summary

- 3D usually used for ipsilateral targets
- Standard technique is AO/PO/LO
- Avoid spinal cord while limiting dose to oral cavity, parotid, eyes, lens etc
- All-In-One technique can be used to treat primary volume and LAN without junctioning
- If OARs are not avoidable we need to move to IMRT option

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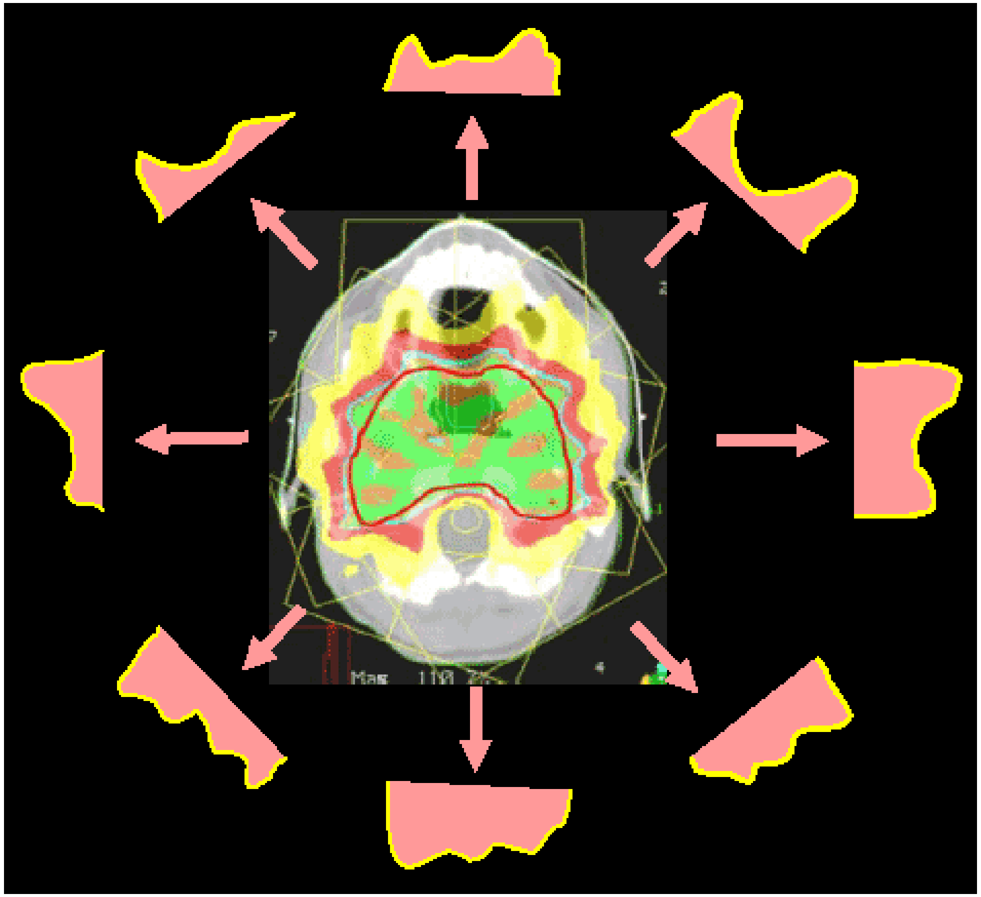
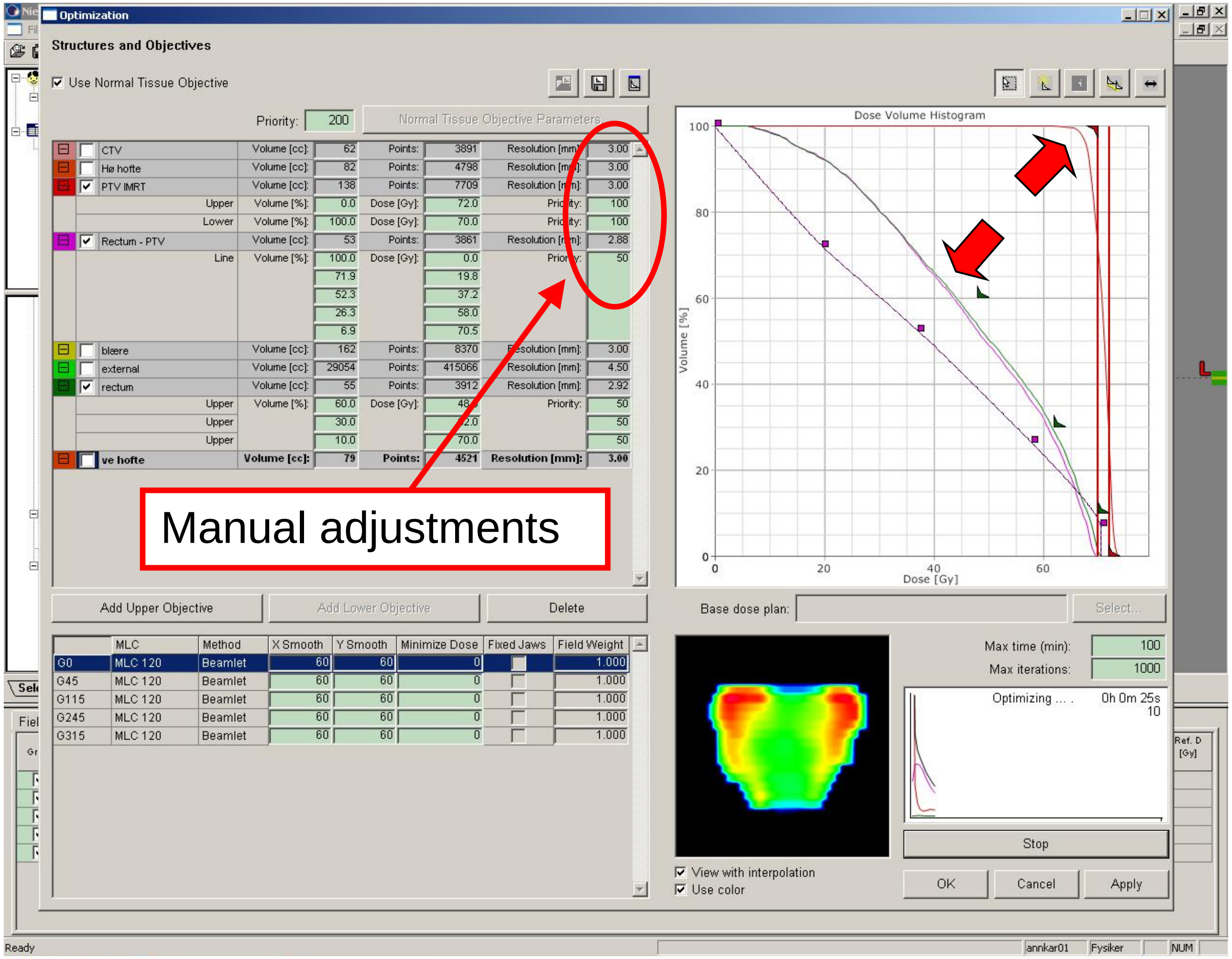
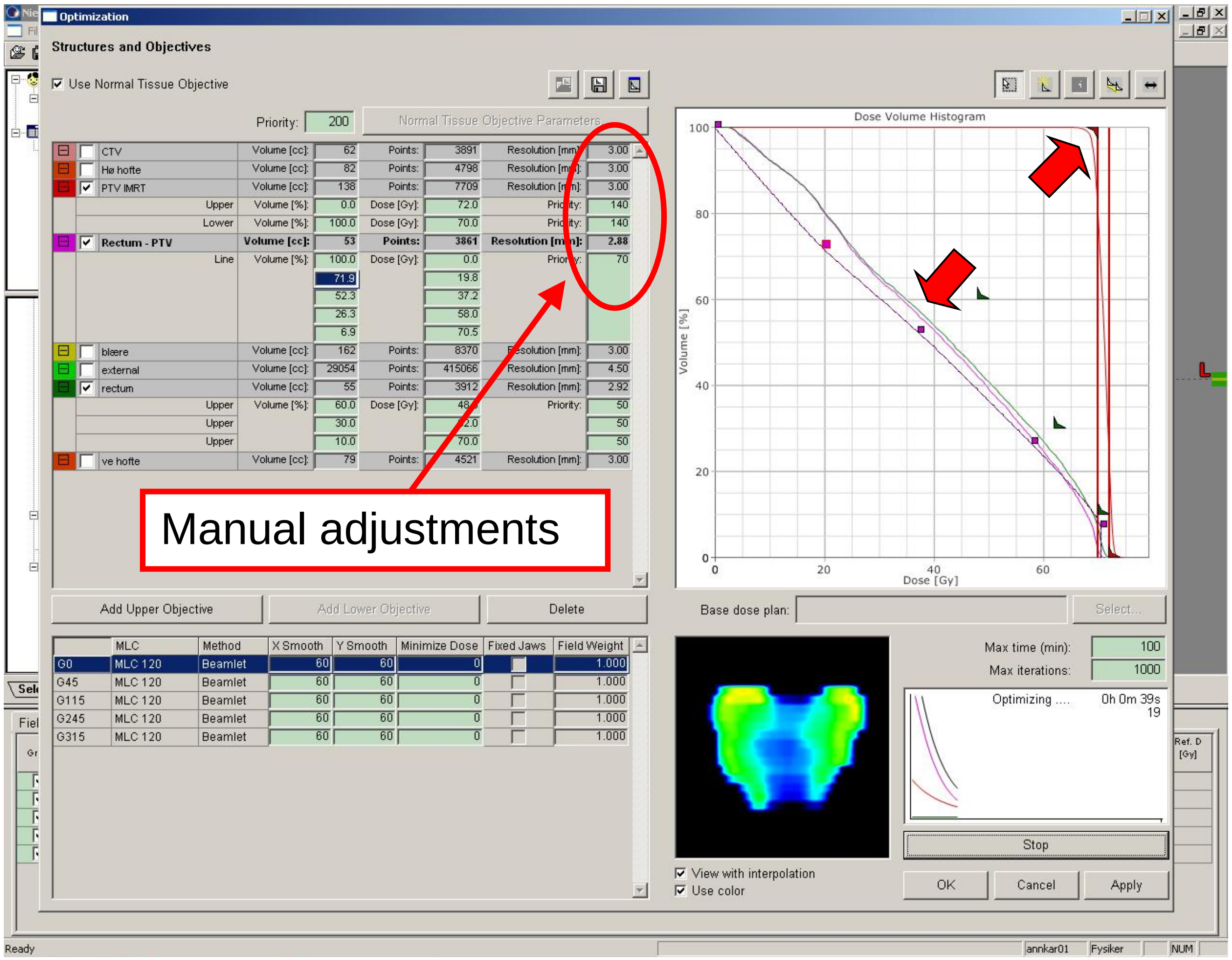
Inverse treatment planning (IMRT/VMAT)



Inverse treatment planning (IMRT/VMAT)



Inverse treatment planning (IMRT/VMAT)



David Sjöström

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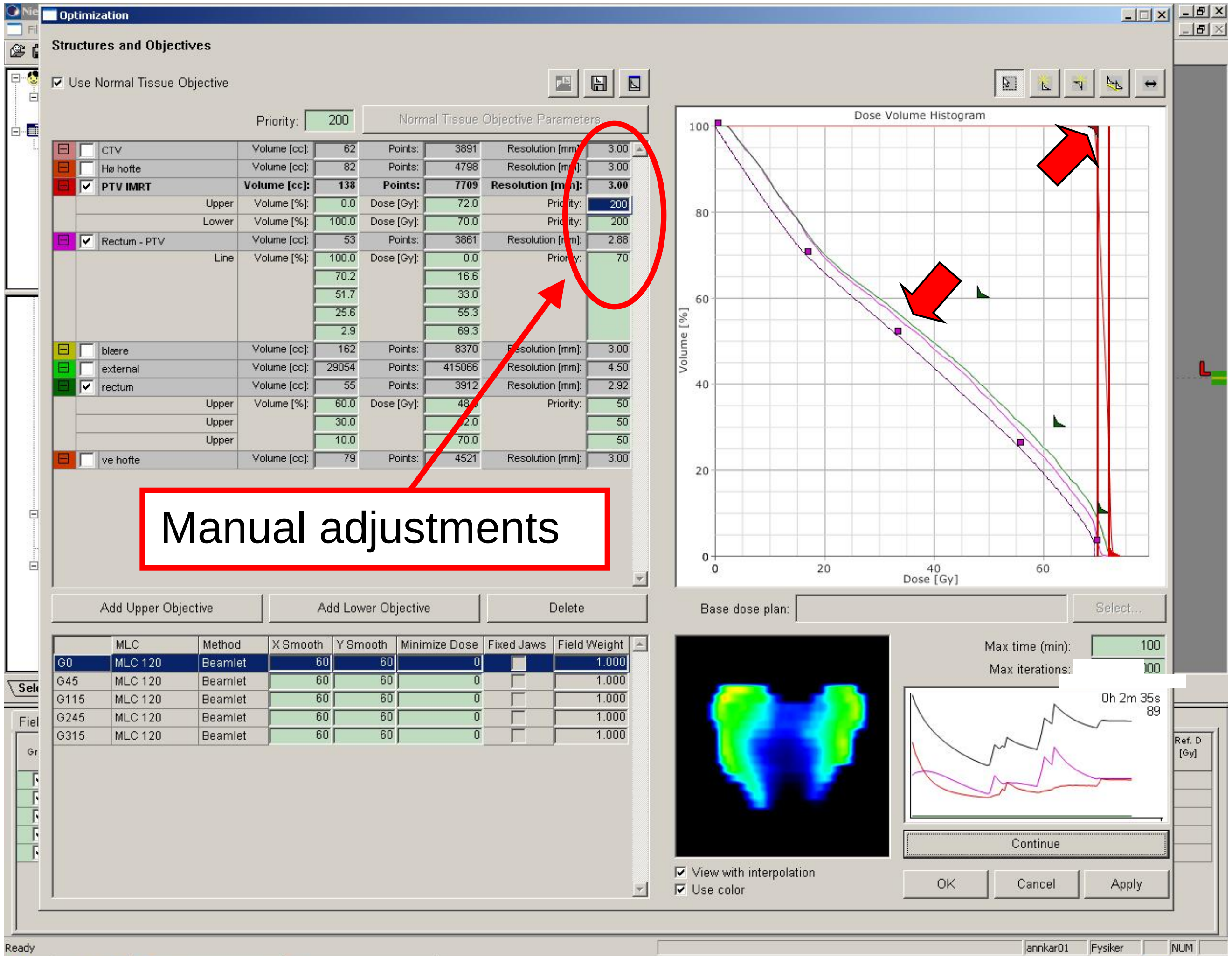
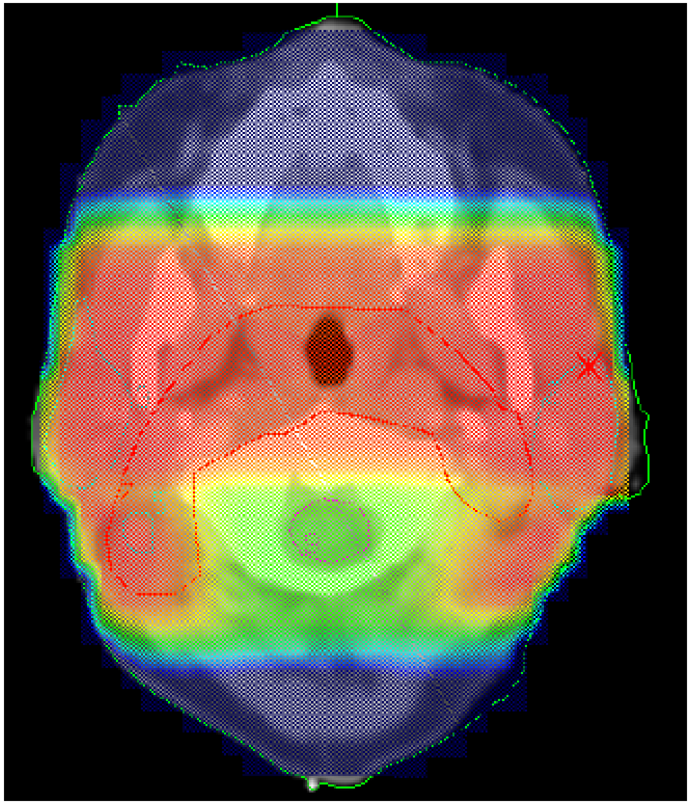
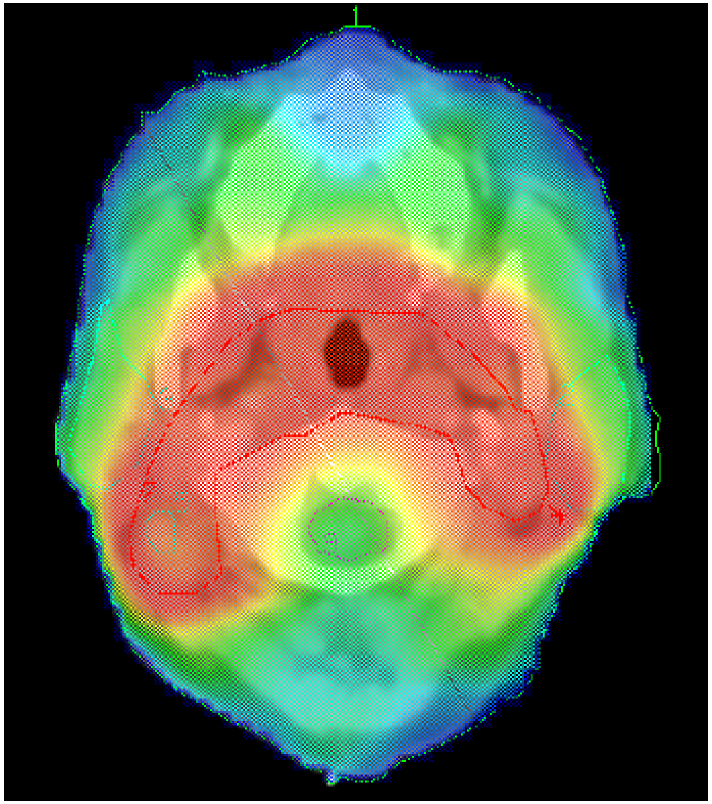
September 2014

Inverse treatment planning (IMRT/VMAT)



Conventional 3DCRT compared to IMRT





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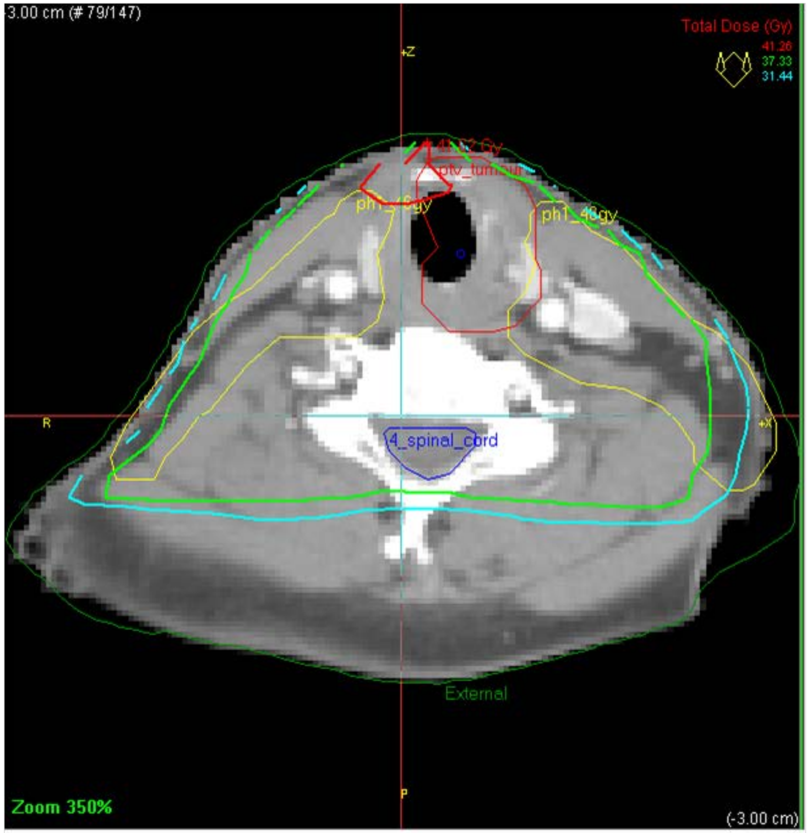
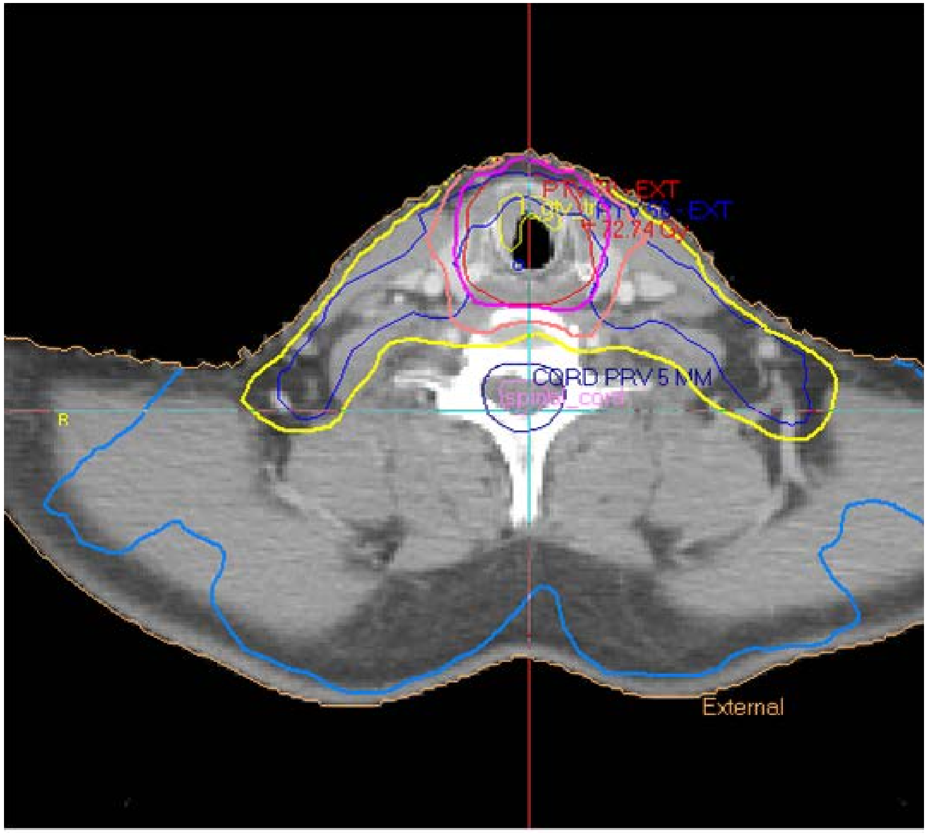
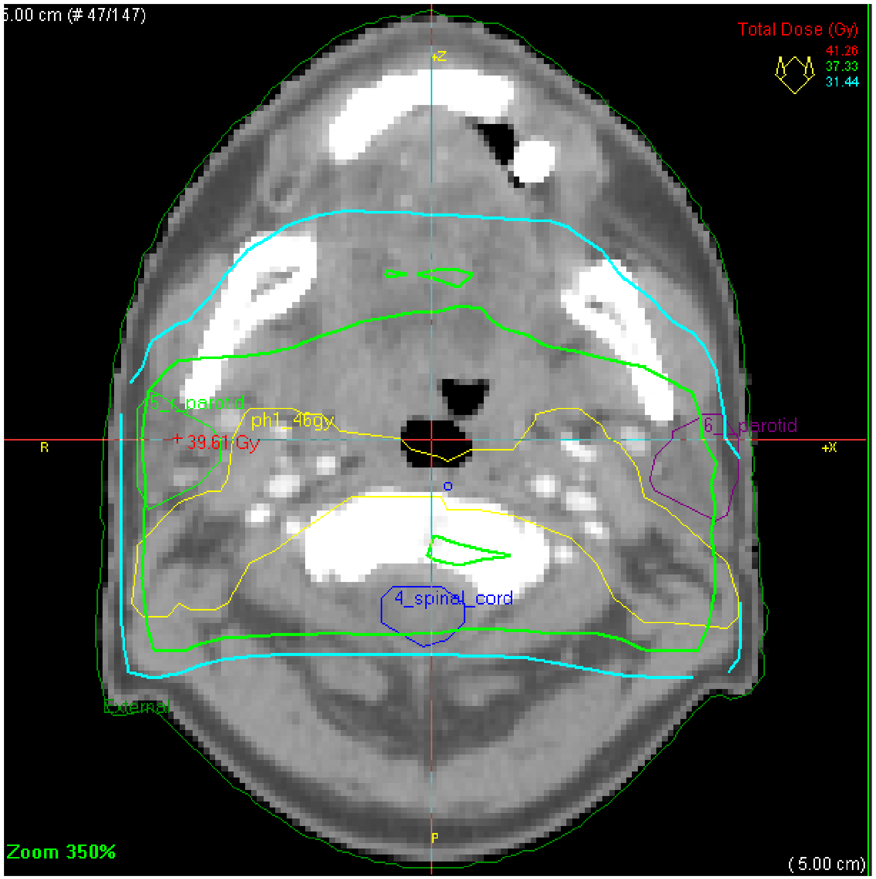
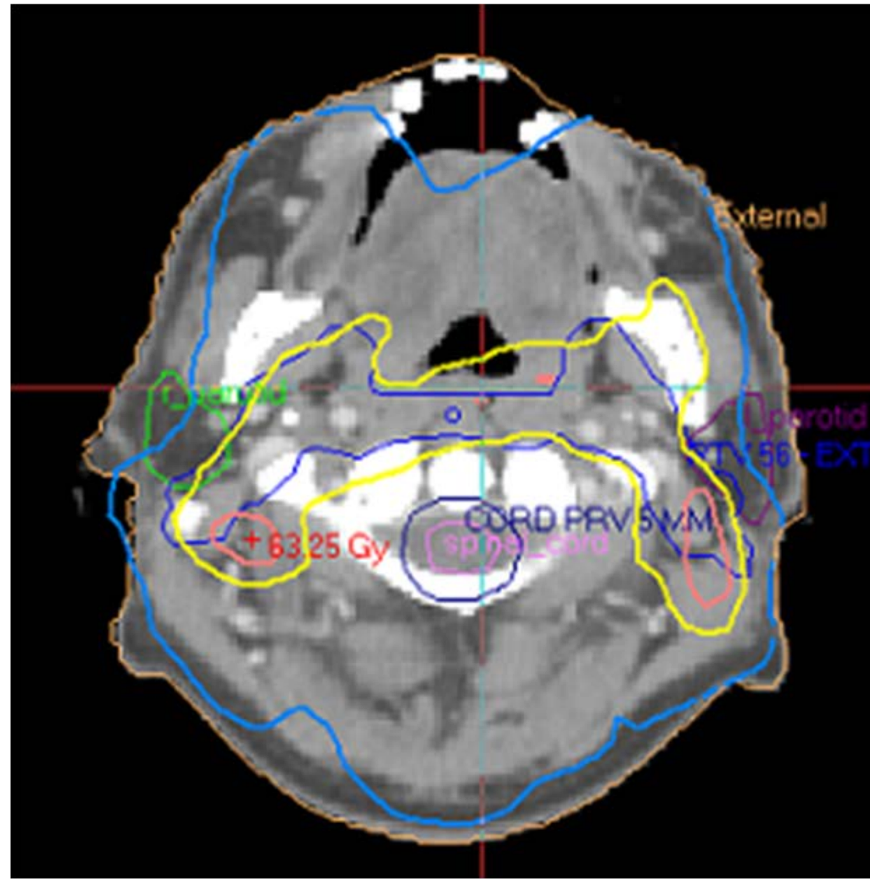
Straight Lats and IMRT Plan





Straight Lats and IMRT Plan





Thank you for your attention

Questions?