Impact of PET on Radiation Therapy Planning

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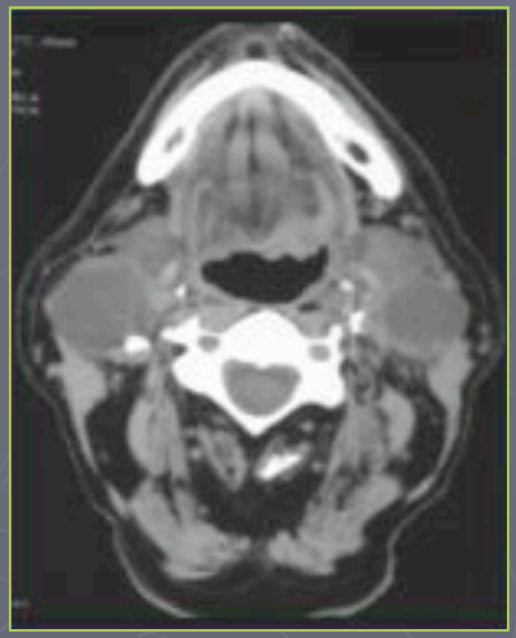
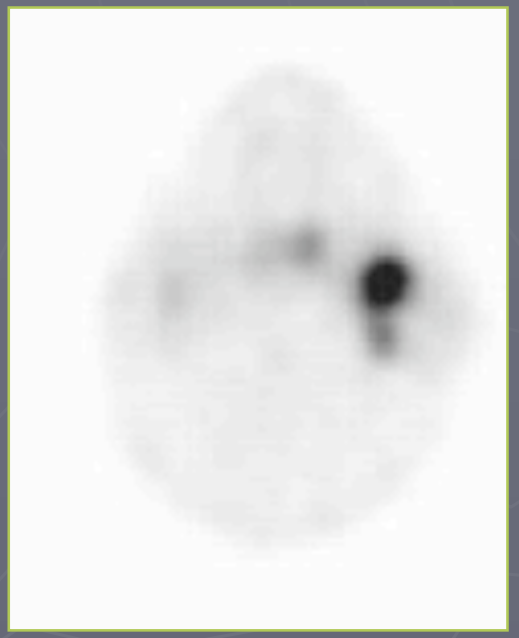
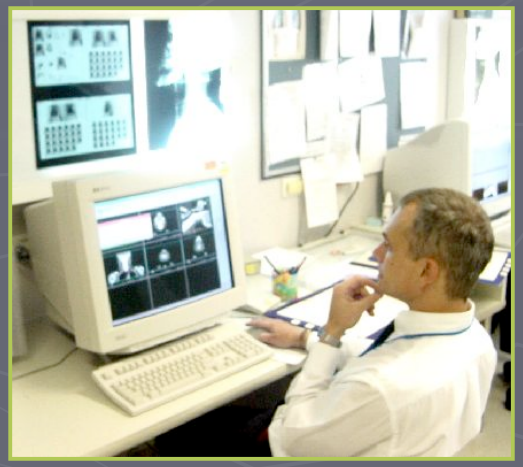
Peter Mac
EXCELLENCE INNOVATION COMPASSION

MONASH University

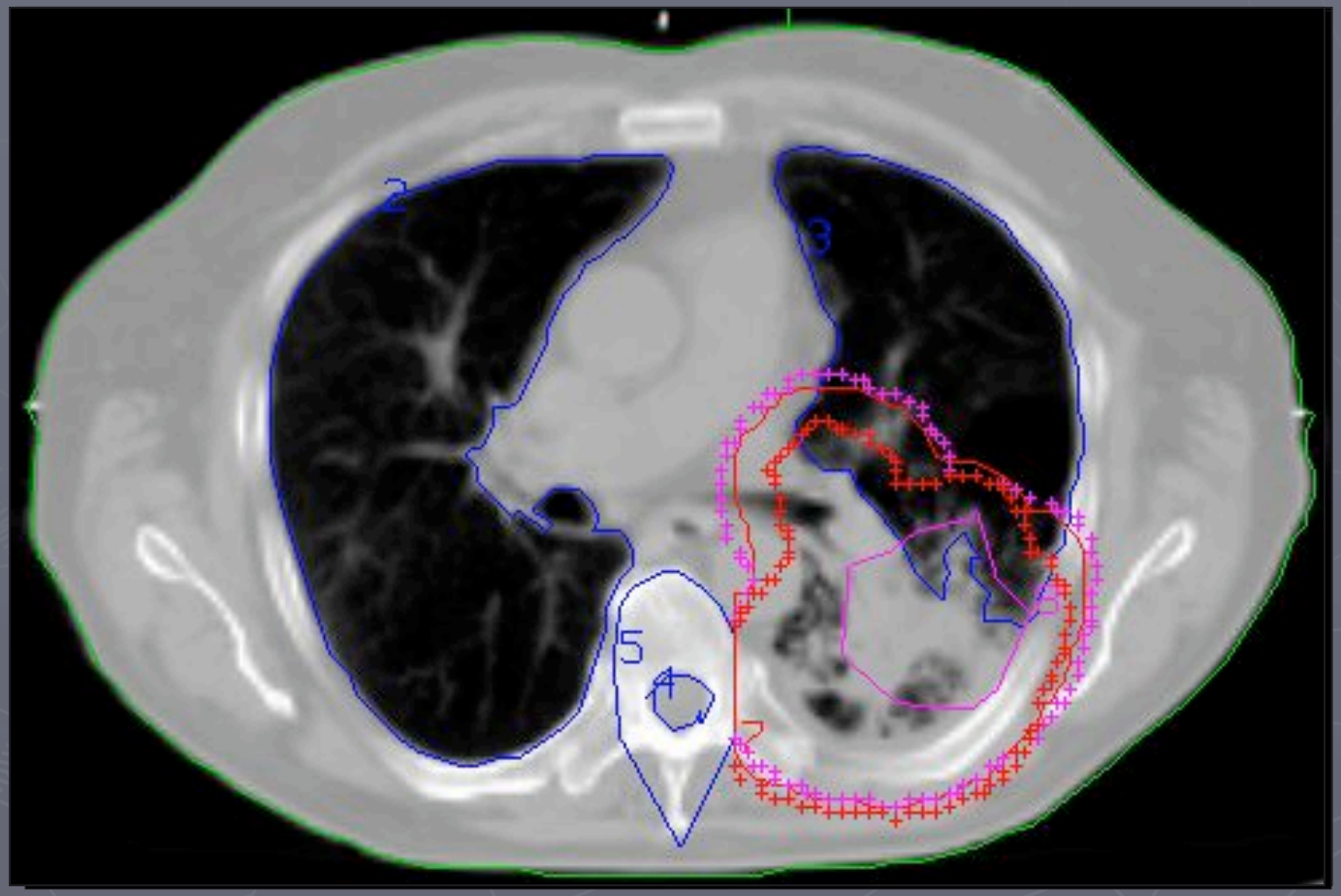
Visual registration (1998)



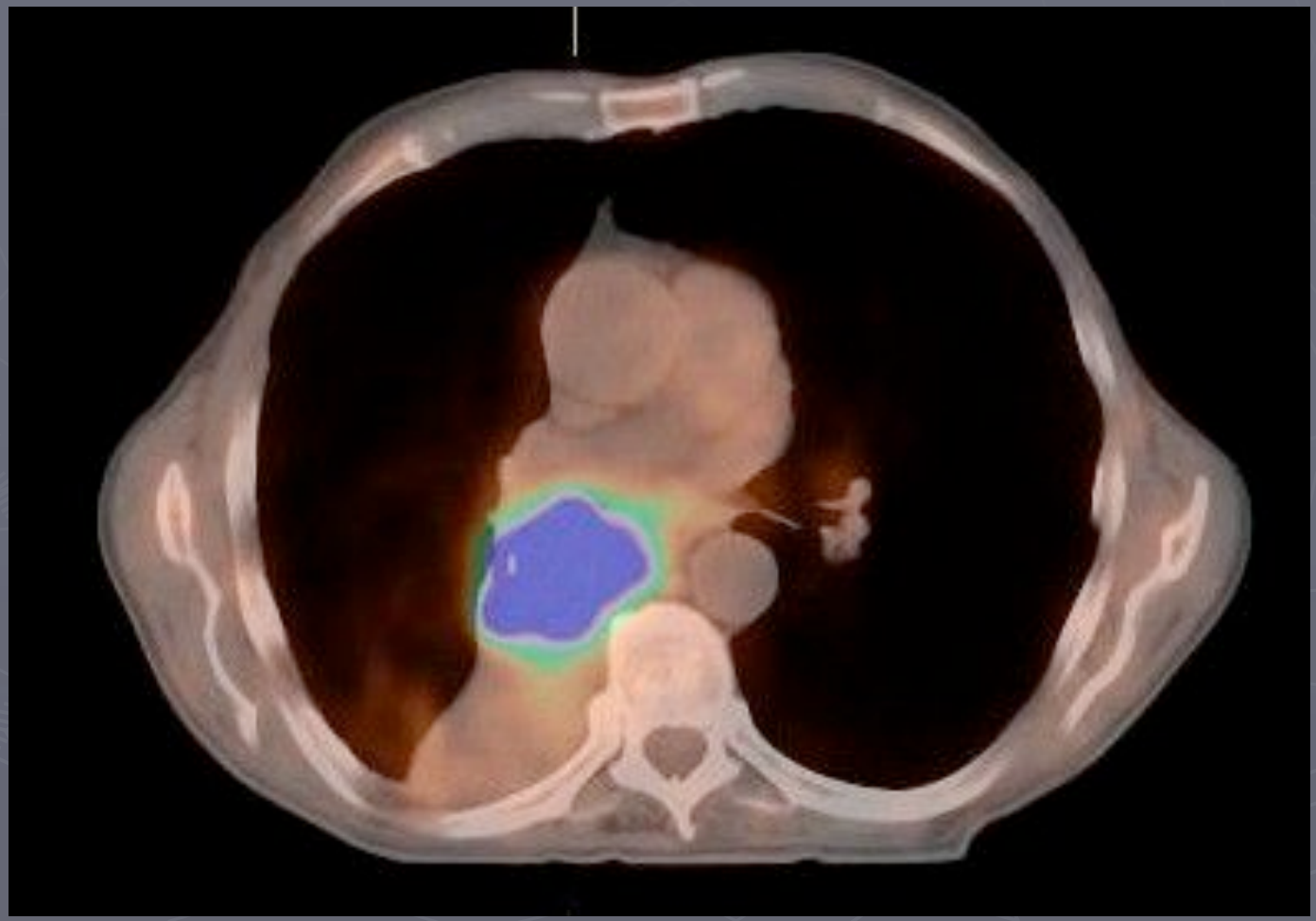




Digital registration (2000)

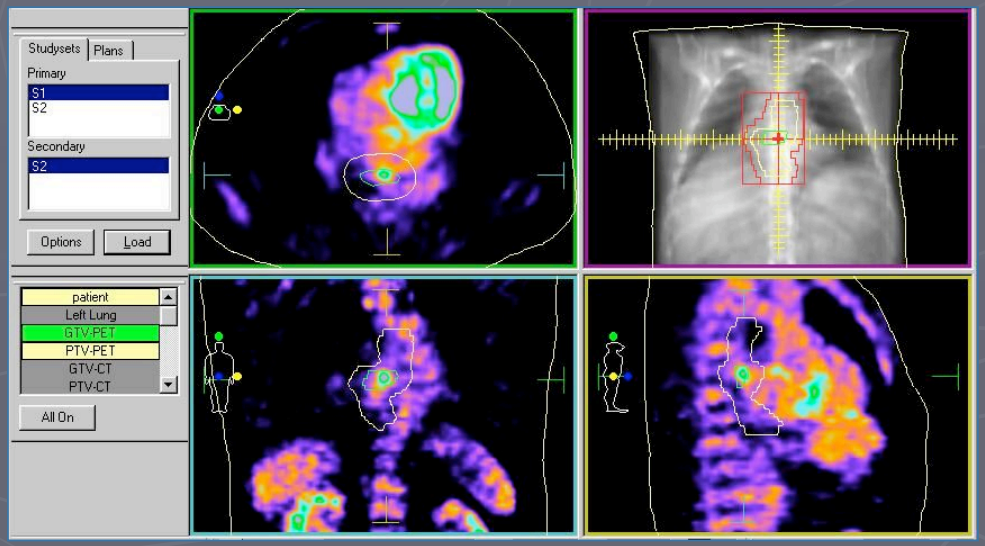


Co-registration (2003)



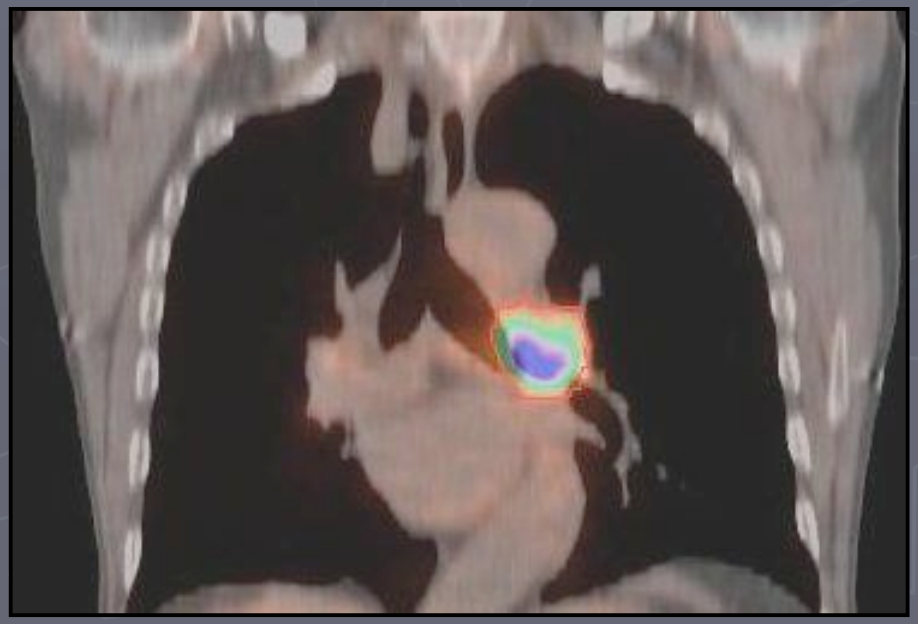
Clinical applications

- Lung
- Oesophagus
- Cervix
- H&N
- Sarcoma
- Haematology
- Paediatrics



PET/CT

- Prospective RT studies
  - Non-small cell lung cancer
  - Oesophageal cancer



Aims

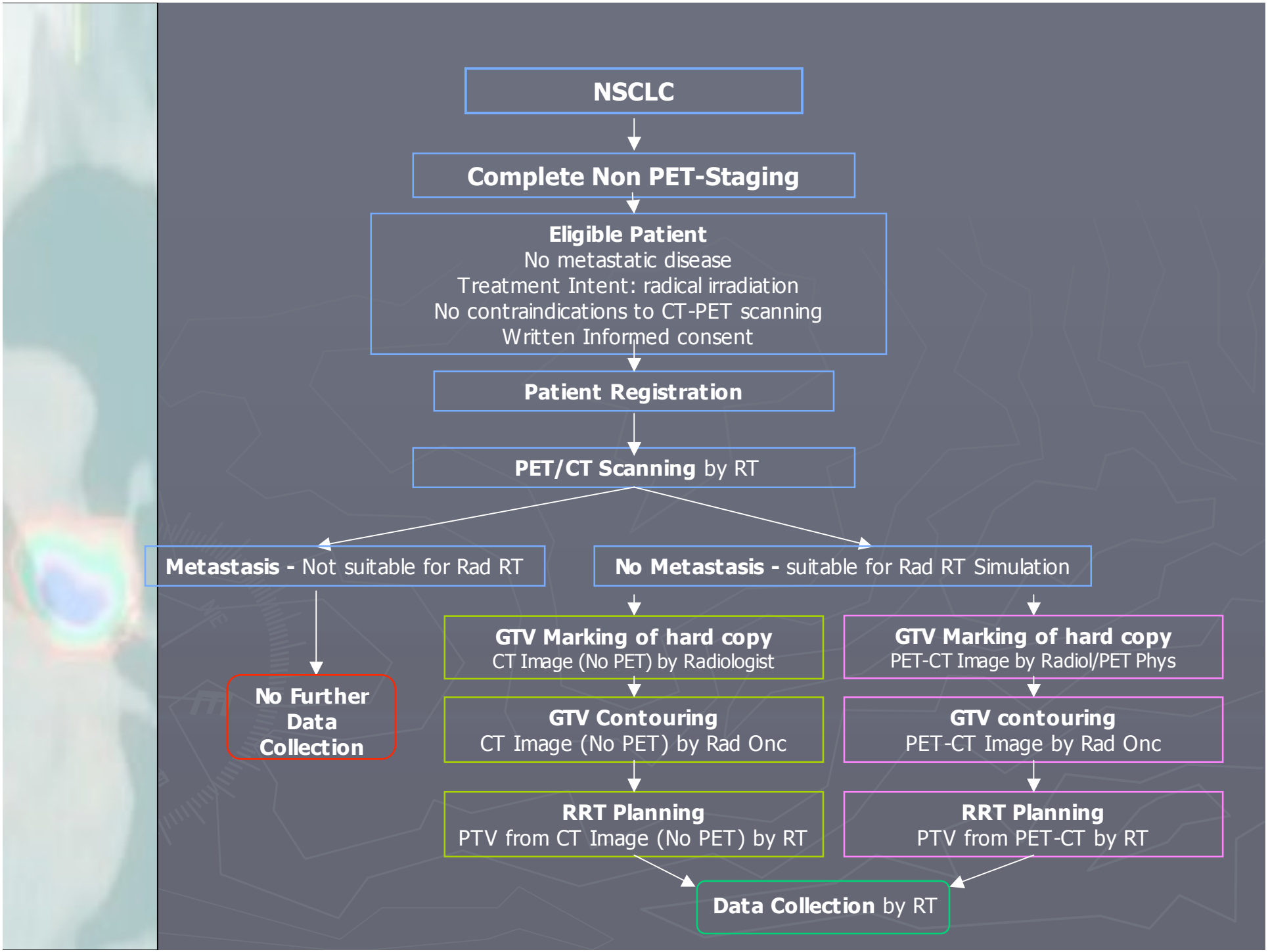
- Impact of fused PET/CT images on RTP
- Comparing PET/CT to CT alone
  - Geographic miss of FDG-avid tumour
    - Proportion of patients
    - Degree of geographic miss
  - Tumour & normal tissue doses

NSCLC

- CT
  - Anatomical information
  - Spatial information
  - Electron densities
- PET
  - Sensitivity & specificity
    - tumour extension into soft tissues
    - demarcating between tumour and atelectatic lung
    - lymph nodes

Methods

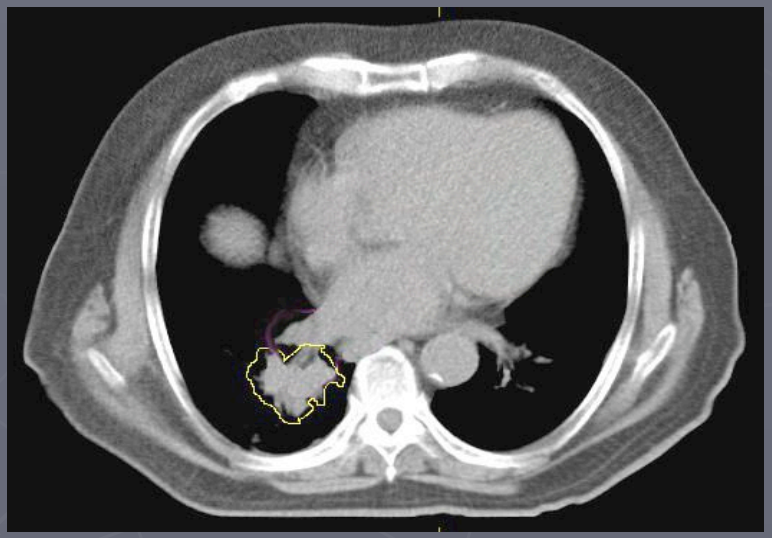
- 50 consecutive patients
- Eligible for radical radiation therapy
  - Non-PET staging
- GE Discovery LS© PET/CT


NSCLC
Complete Non PET-Staging
Eligible Patient
No metastatic disease
Treatment Intent: radical irradiation
No contraindications to CT-PET scanning
Written Informed consent
Patient Registration
PET/CT Scanning by RT
Metastasis - Not suitable for Rad RT
No Metastasis - suitable for Rad RT Simulation
No Further Data Collection
GTV Marking of hard copy
CT Image (No PET) by Radiologist
GTV Marking of hard copy
PET-CT Image by Radiol/PET Phys
GTV Contouring
CT Image (No PET) by Rad Onc
GTV contouring
PET-CT Image by Rad Onc
RRT Planning
PTV from CT Image (No PET) by RT
RRT Planning
PTV from PET-CT by RT
Data Collection by RT

Stabilisation

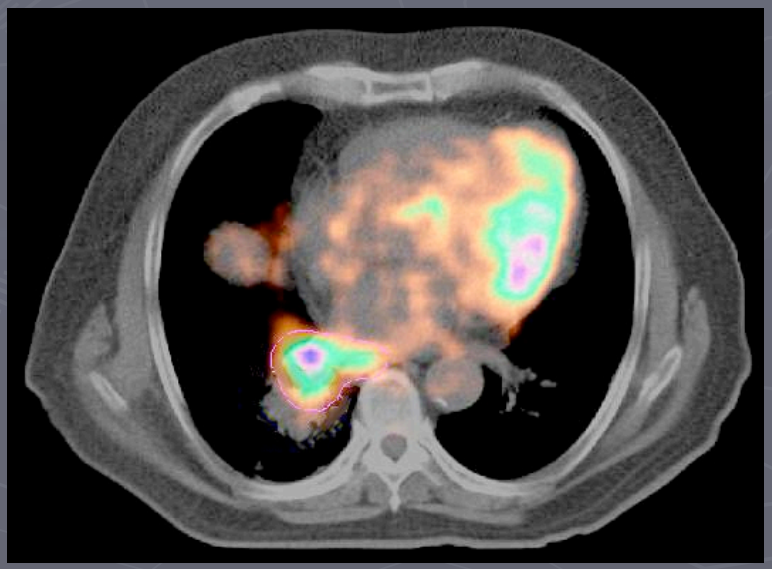
Radio-opaque markers

Gross tumour delineation



GTV based on CT alone

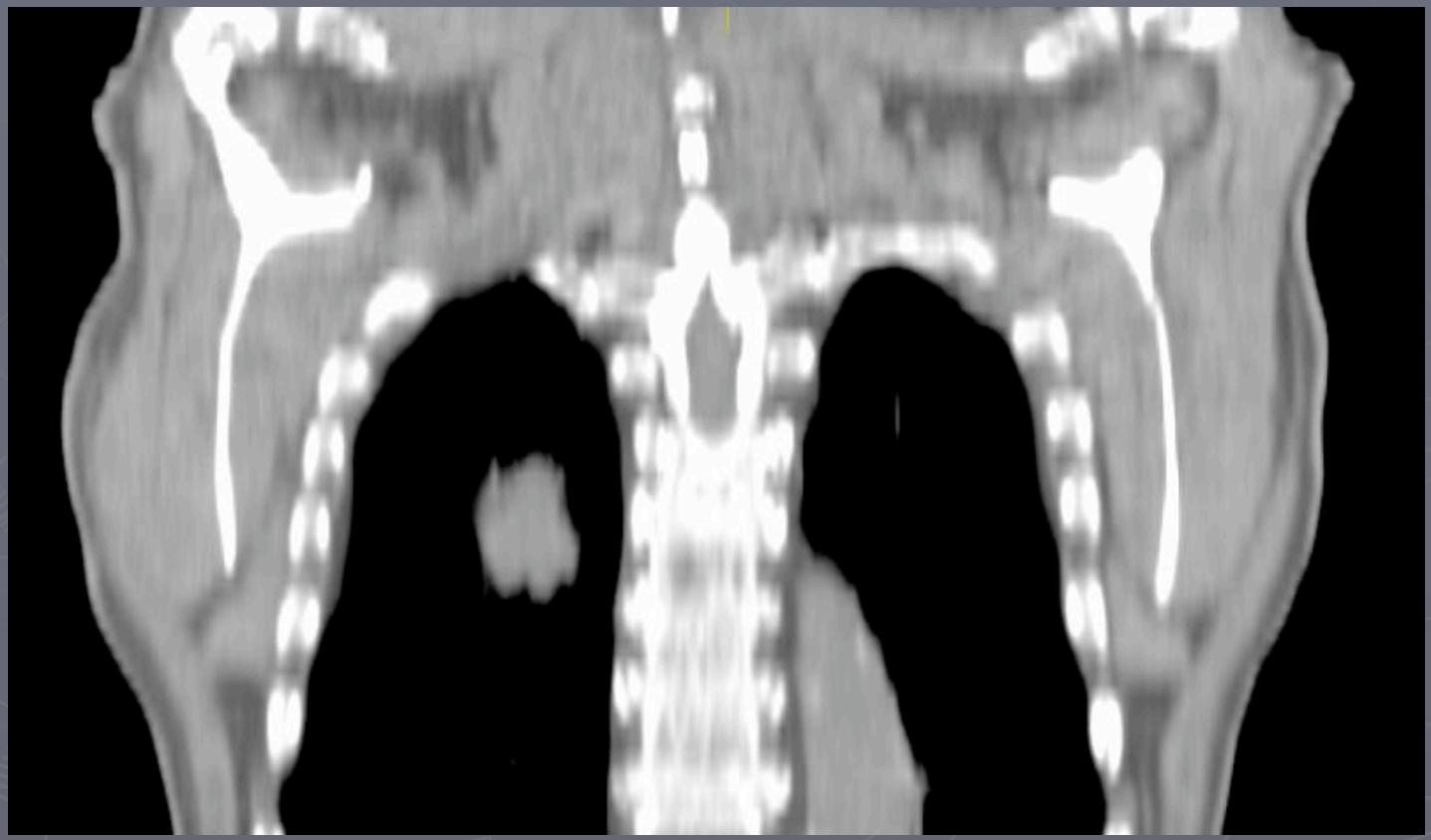
"GTV-CT"



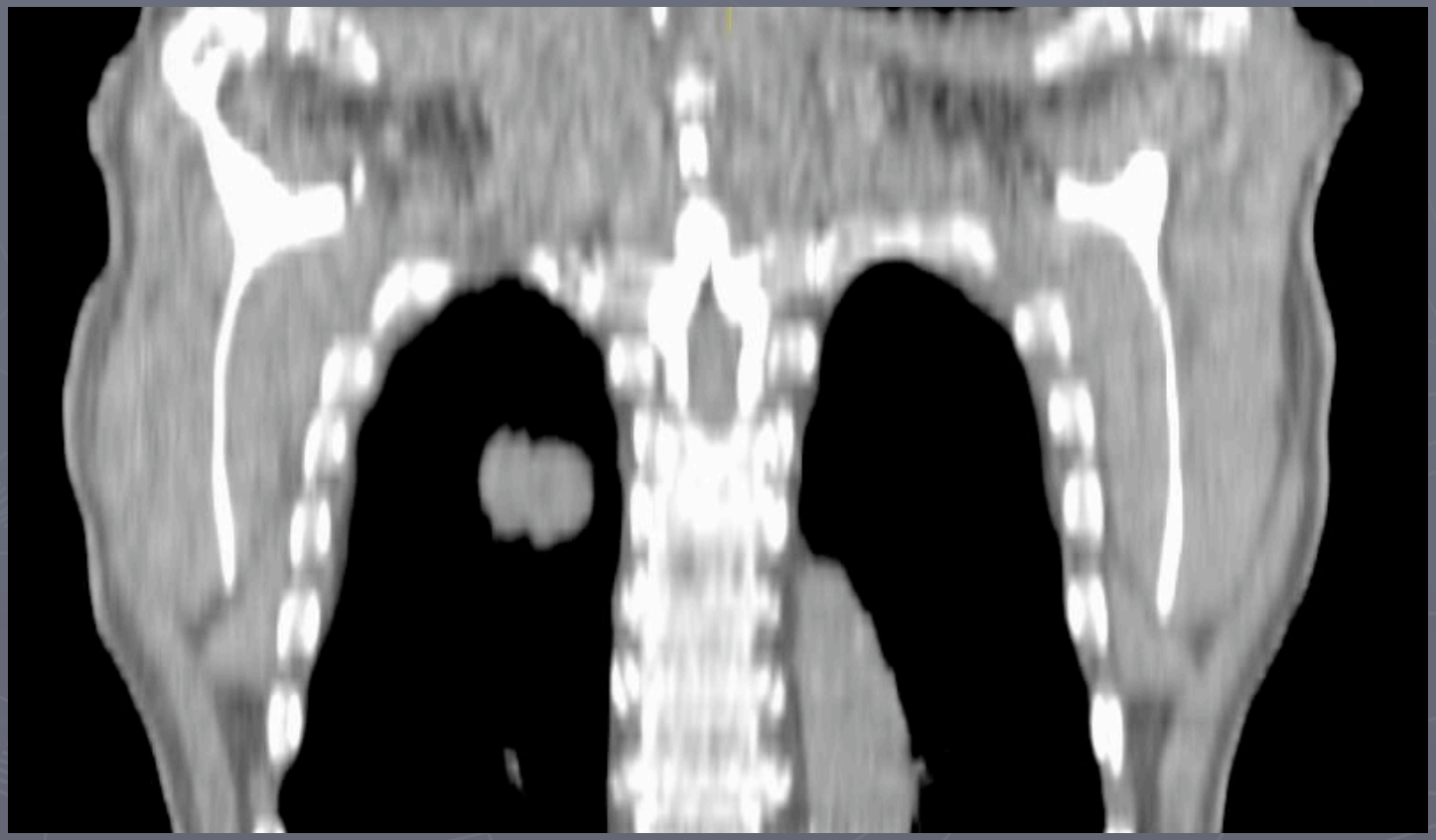
GTV based on combined CT & PET

"GTV-PET"

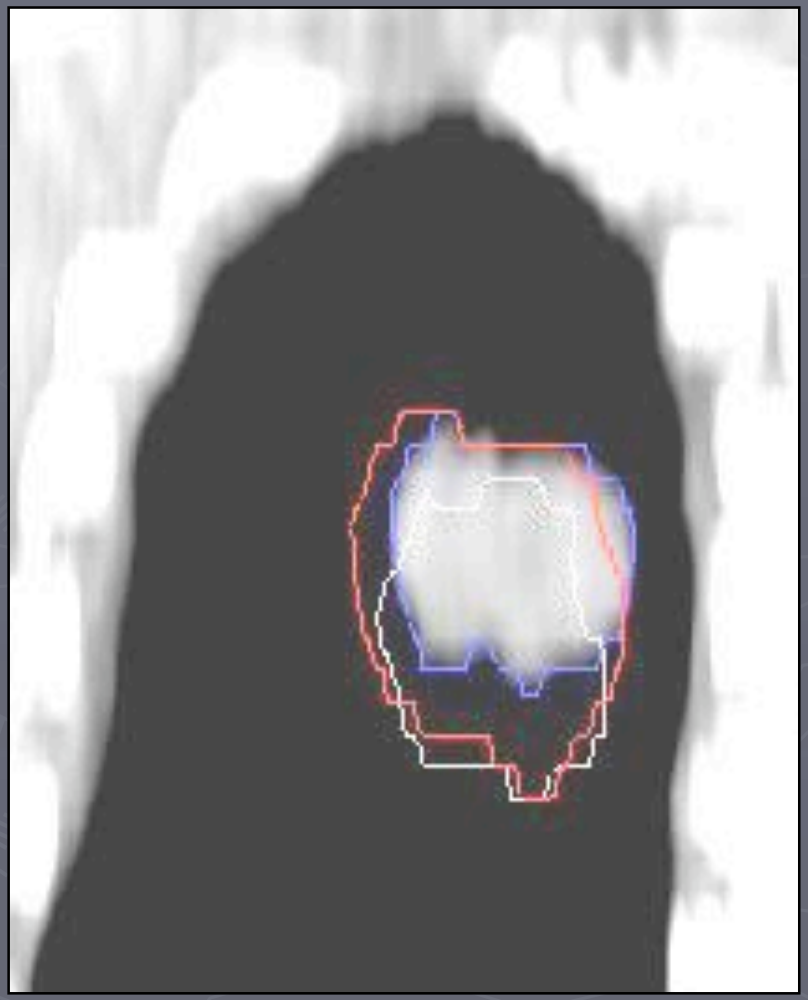
Respiratory motion



Respiratory motion



Respiratory motion



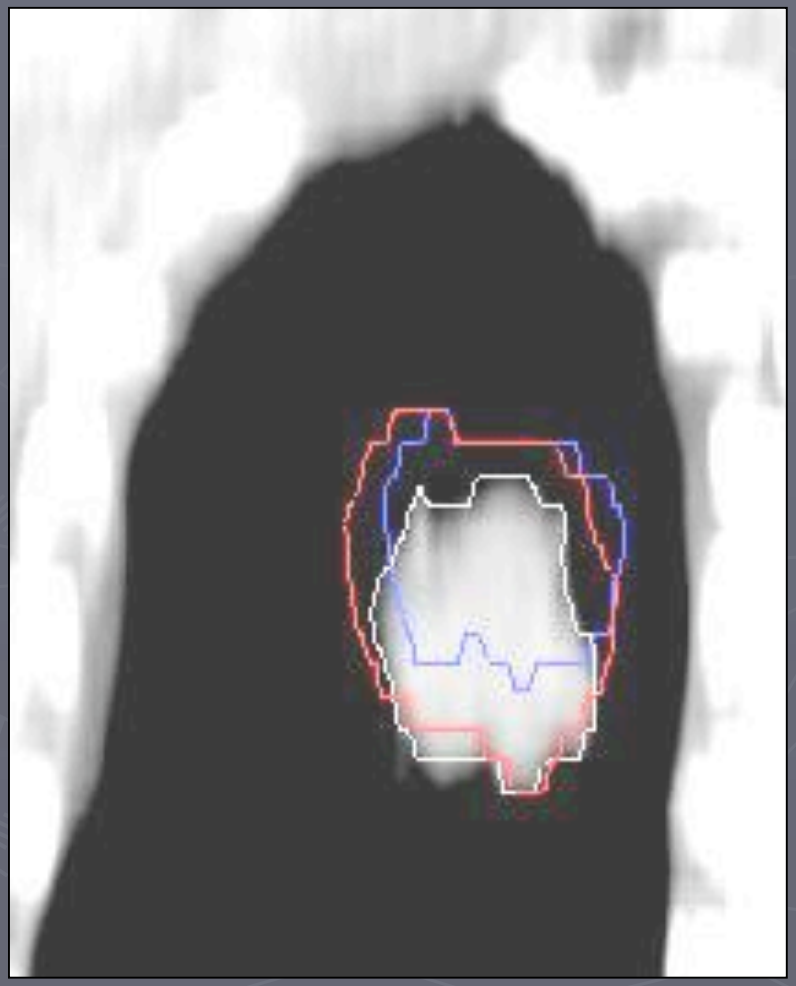
CT expiration

GTV CT expiration

GTV CT inspiration

GTV PET

Respiratory motion



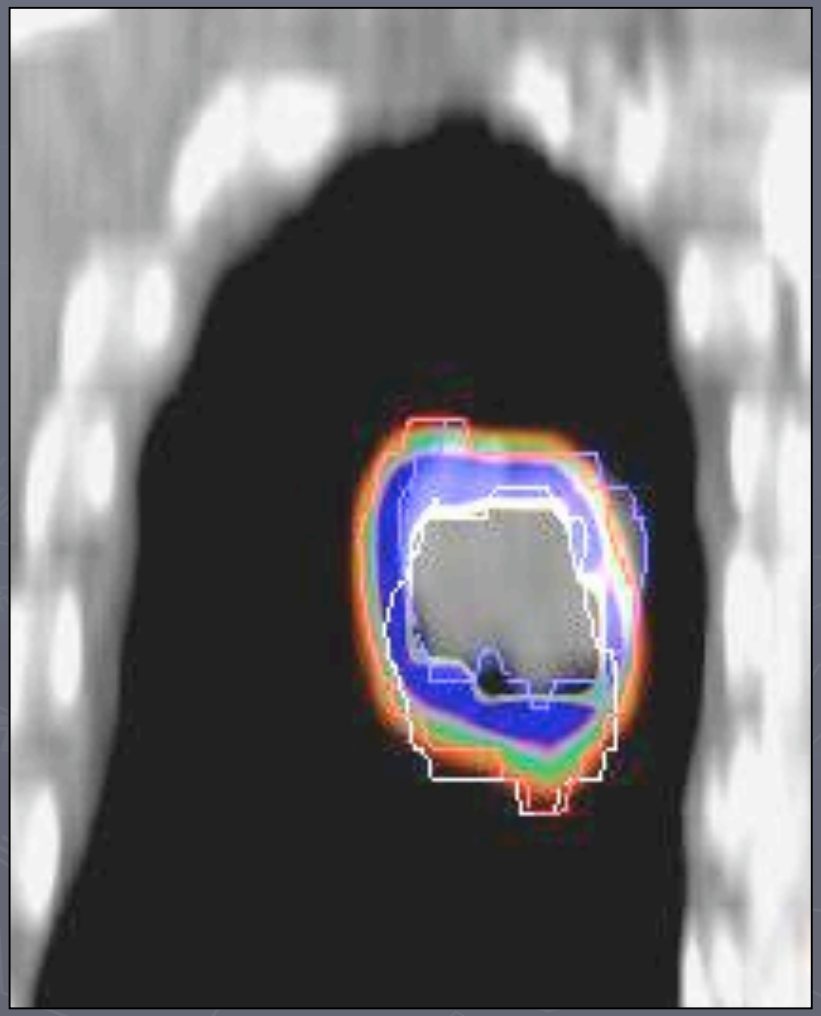
CT inspiration

GTV CT expiration

GTV CT inspiration

GTV PET

Respiratory motion



PET GTV

GTV CT expiration

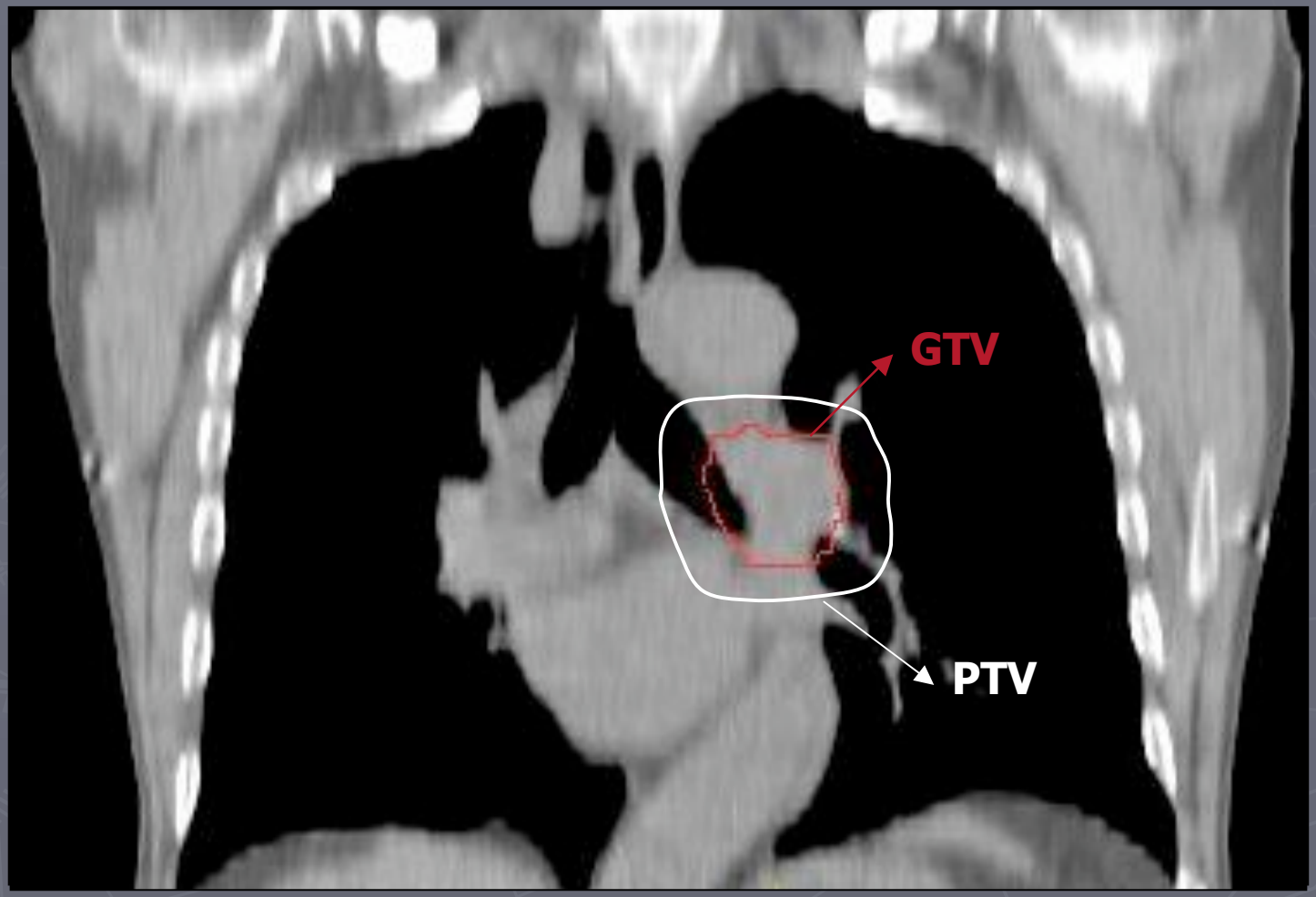
GTV CT inspiration

GTV PET

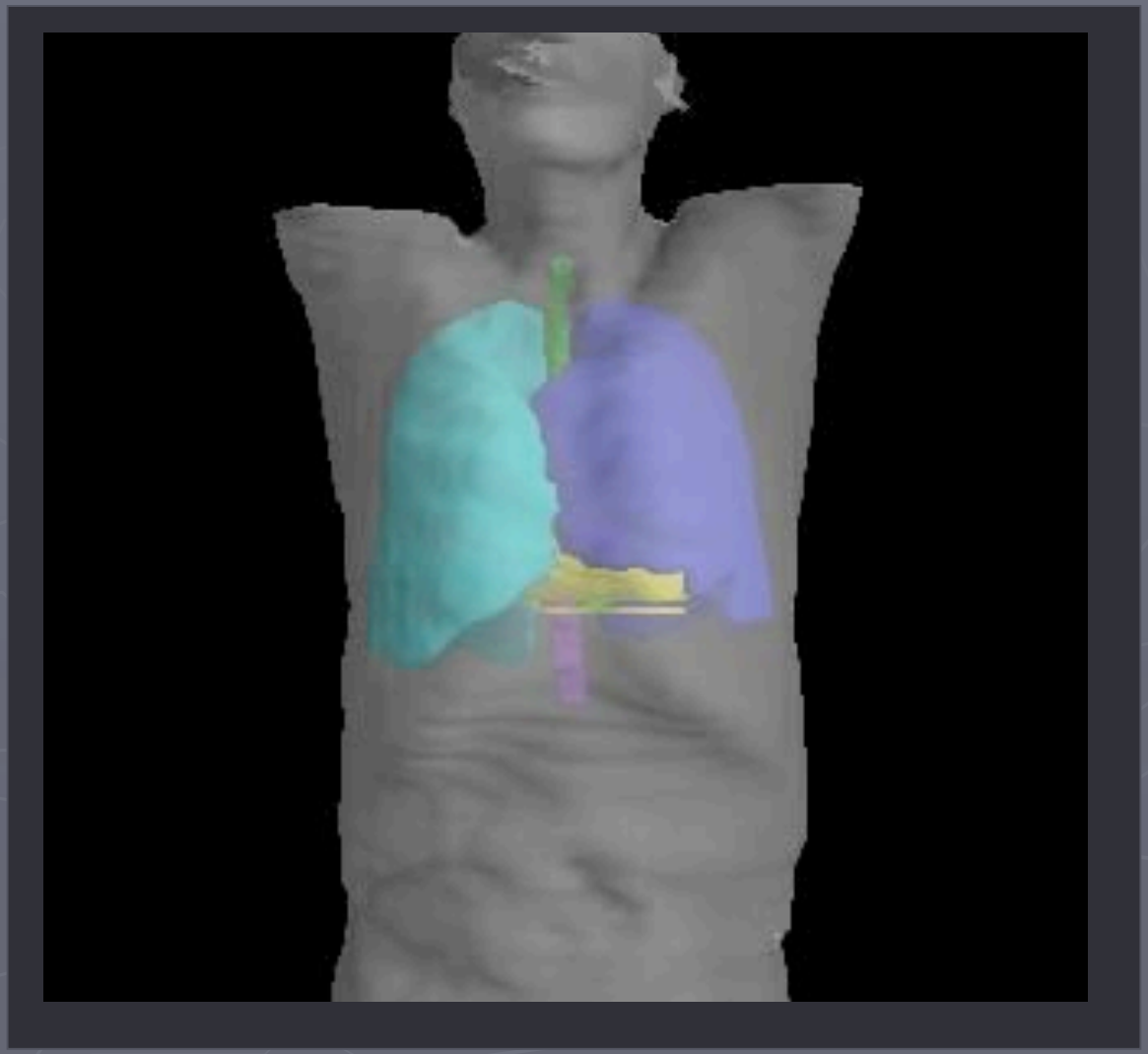
Planning target volume

- CT alone
  - Simulation with flouroscopy to measure range of motion
- PET/CT
  - Extended acquisition time accounts for respiratory motion

Methods



Methods

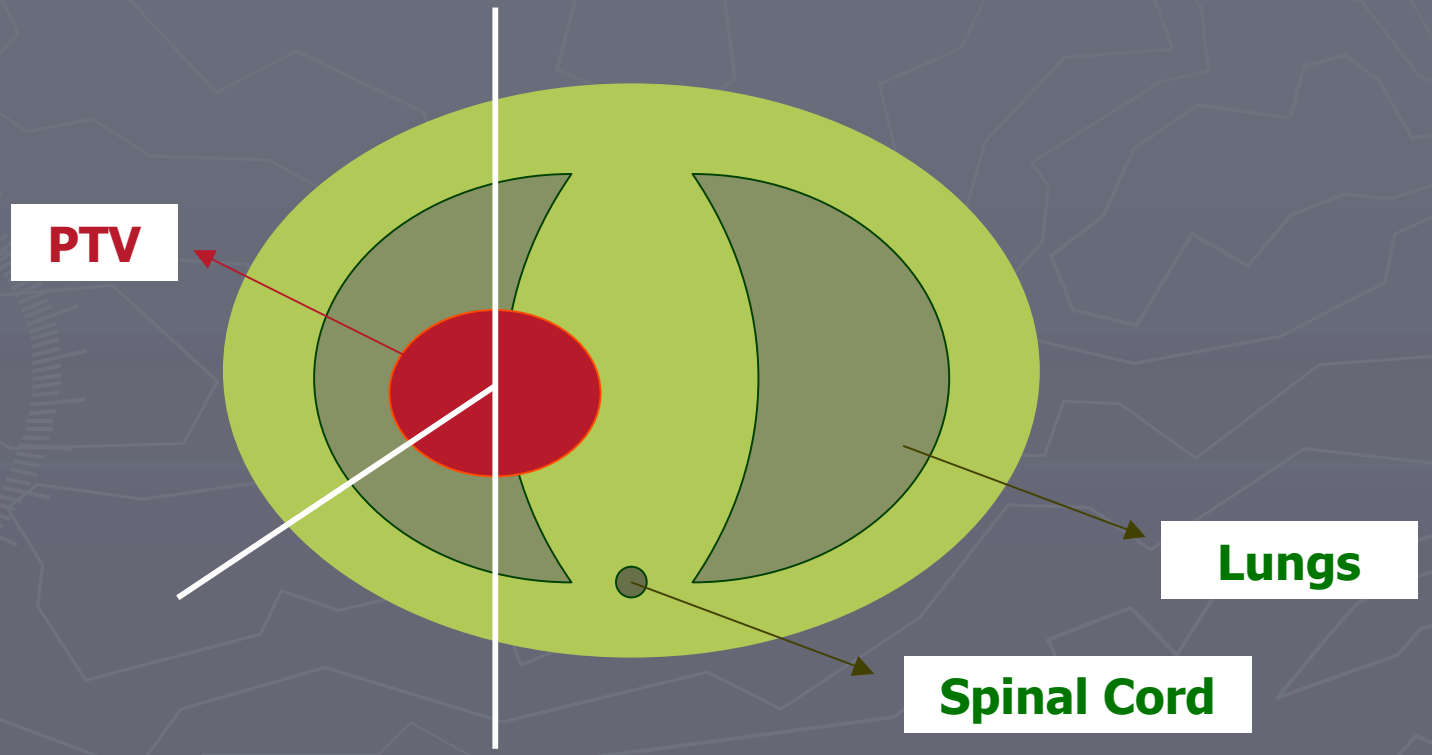


Methods

- CT alone & PET/CT PTV
- CMS Xio Version 4.2.0
- Class solution beam arrangements
- Fast superposition algorithm
- Isocentric treatment
- Varian linac
  - 6MV photons
  - 120-leaf Millennium multi-leaf collimator
  - Enhanced dynamic wedge

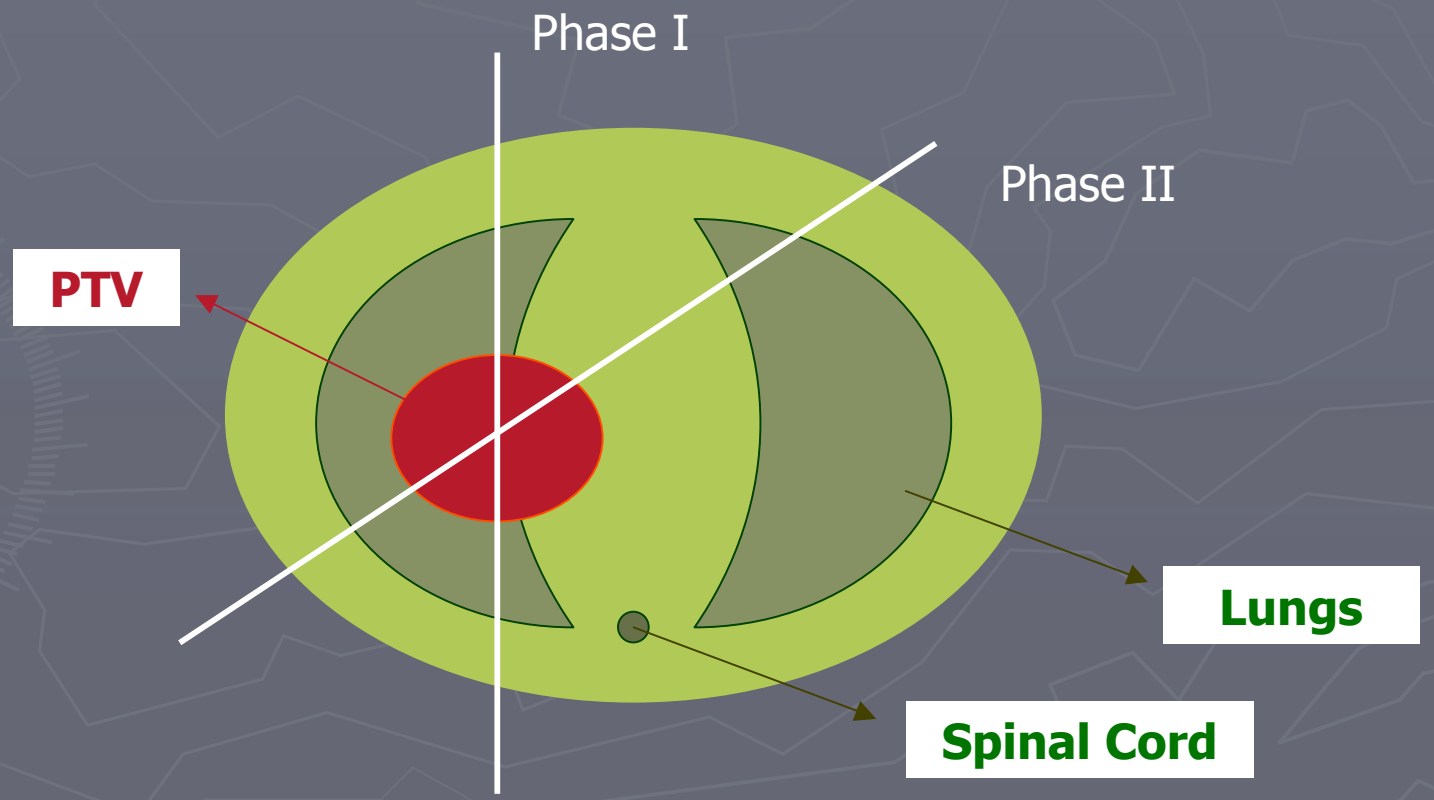
Methods

- Conventional Three-Field



Methods

- Conventional Four-Field

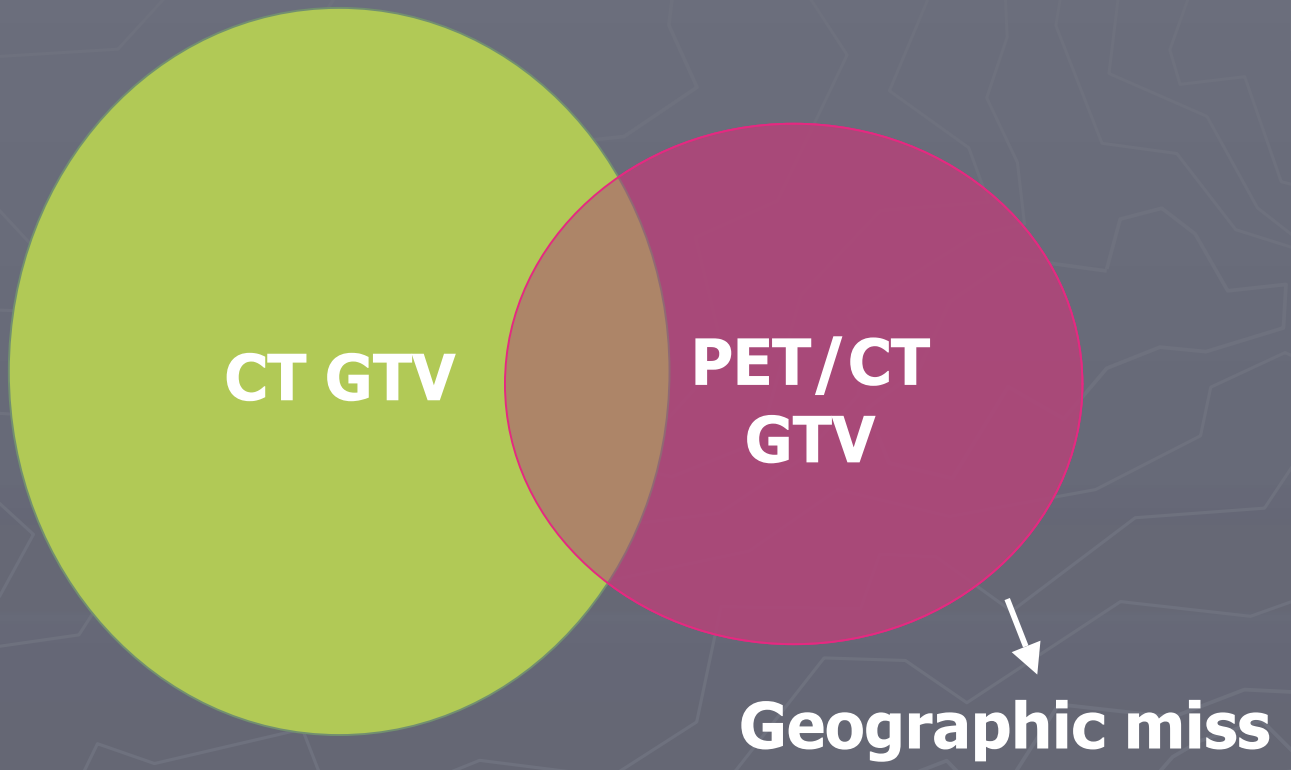


Preliminary analysis

- 19 patients recruited
- 2 patients – metastatic dx on PET
- 5 patients – intrathoracic dx too extensive for RRT

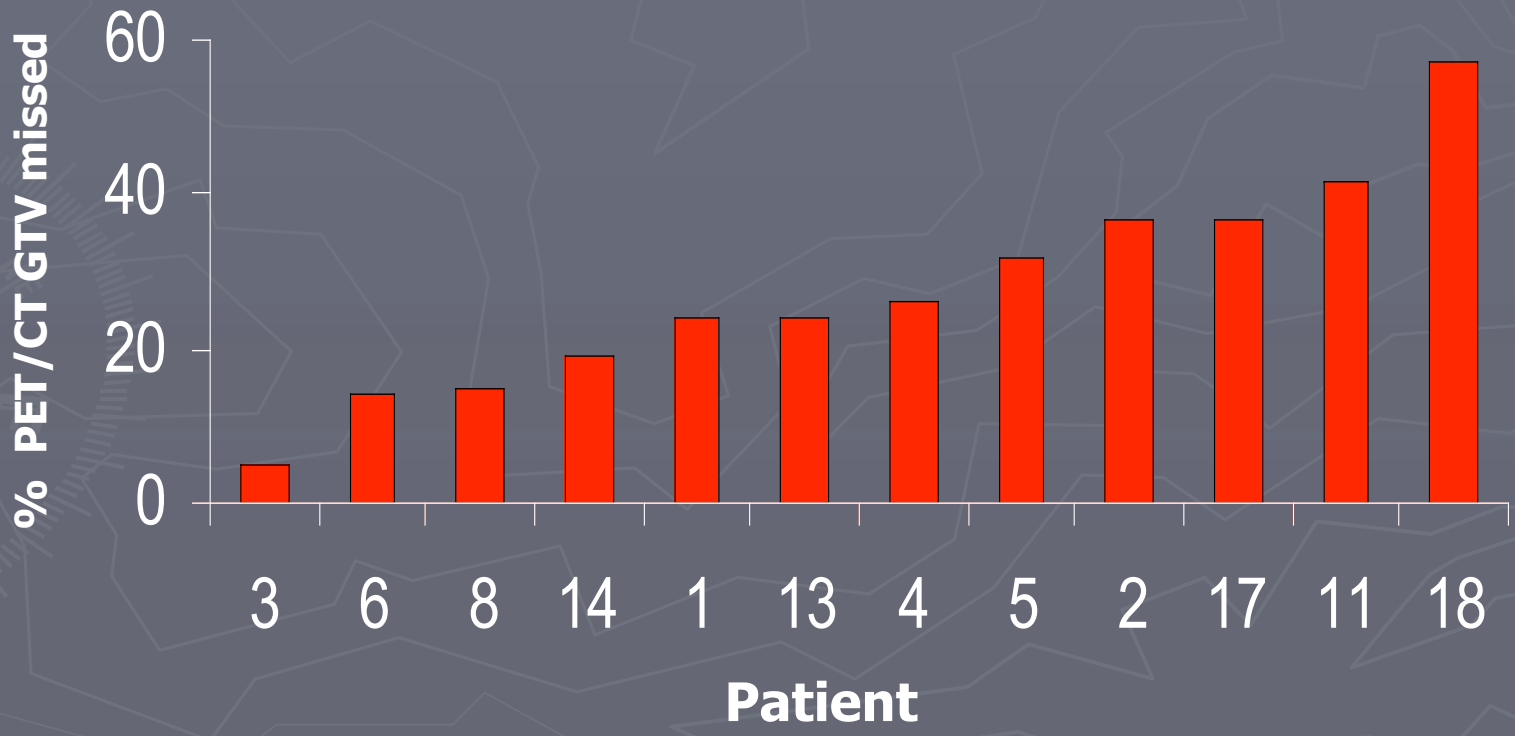
=> 12 patients RRT

Type 1 Geographic miss

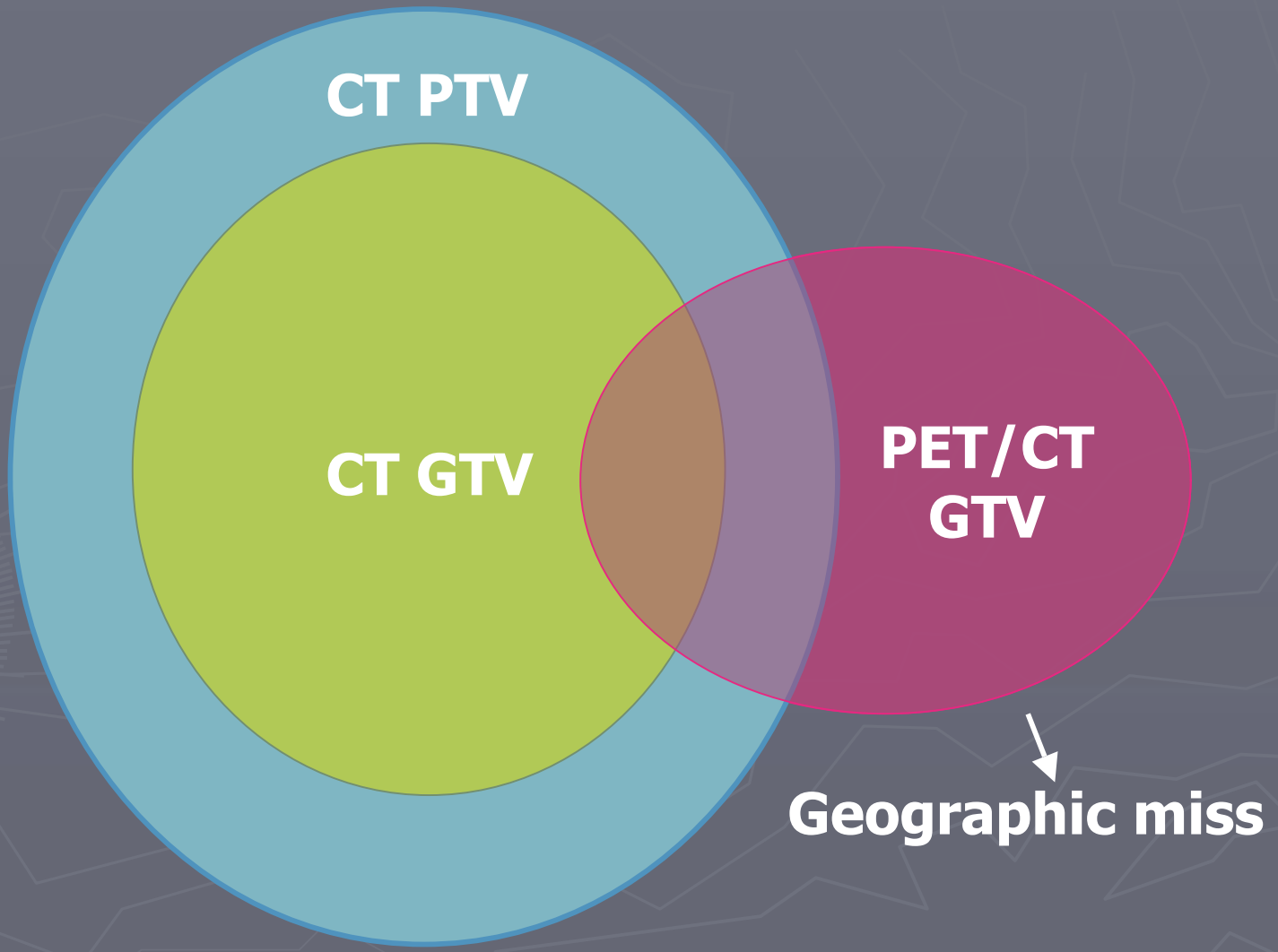


Type 1 Geographic miss

- "% PET/CT GTV lying outside CT GTV"
- 100% cases

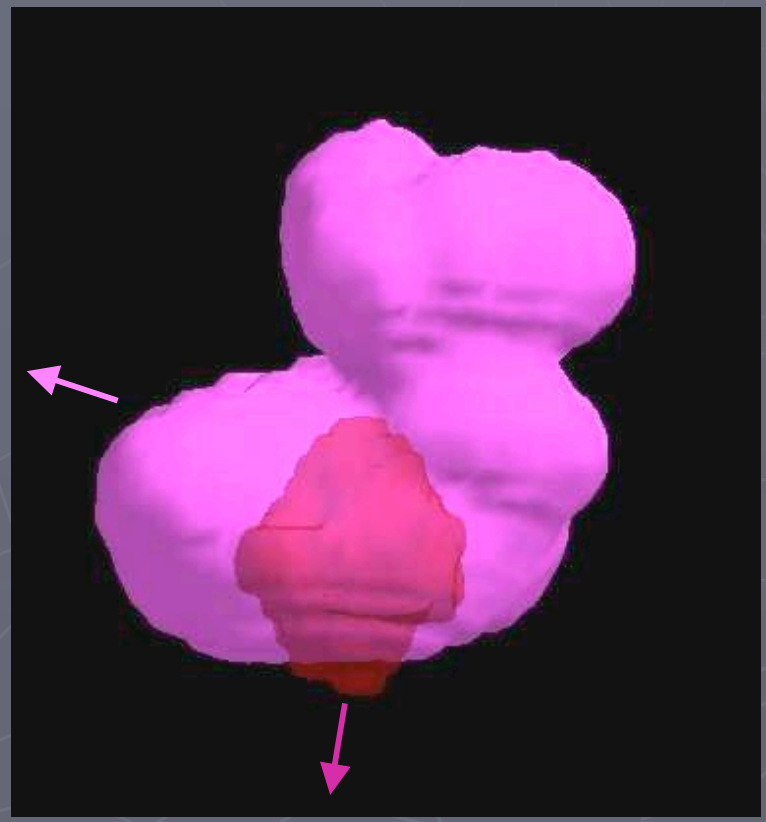


Type 2 Geographic miss

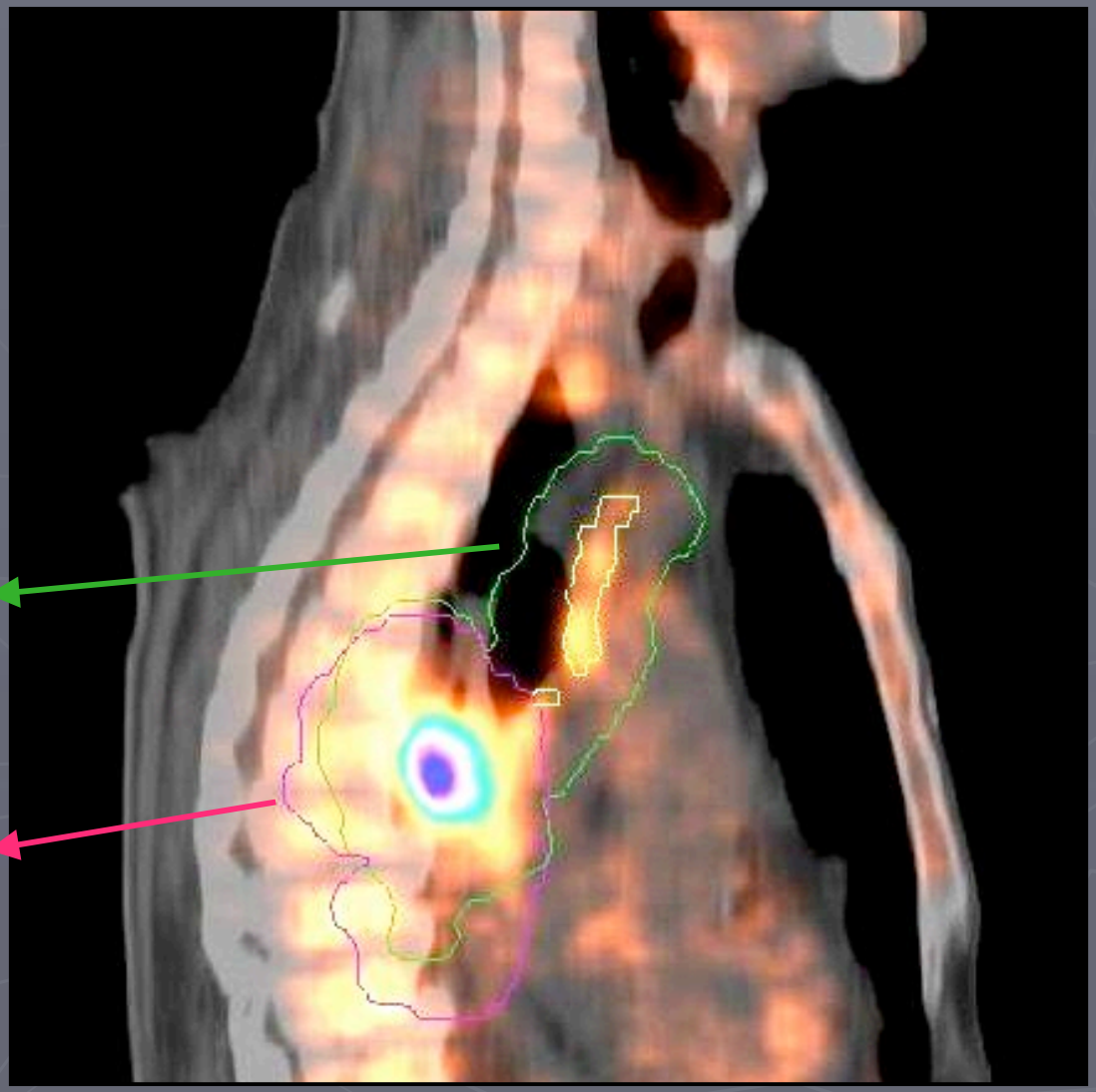


Type 2 Geographic miss

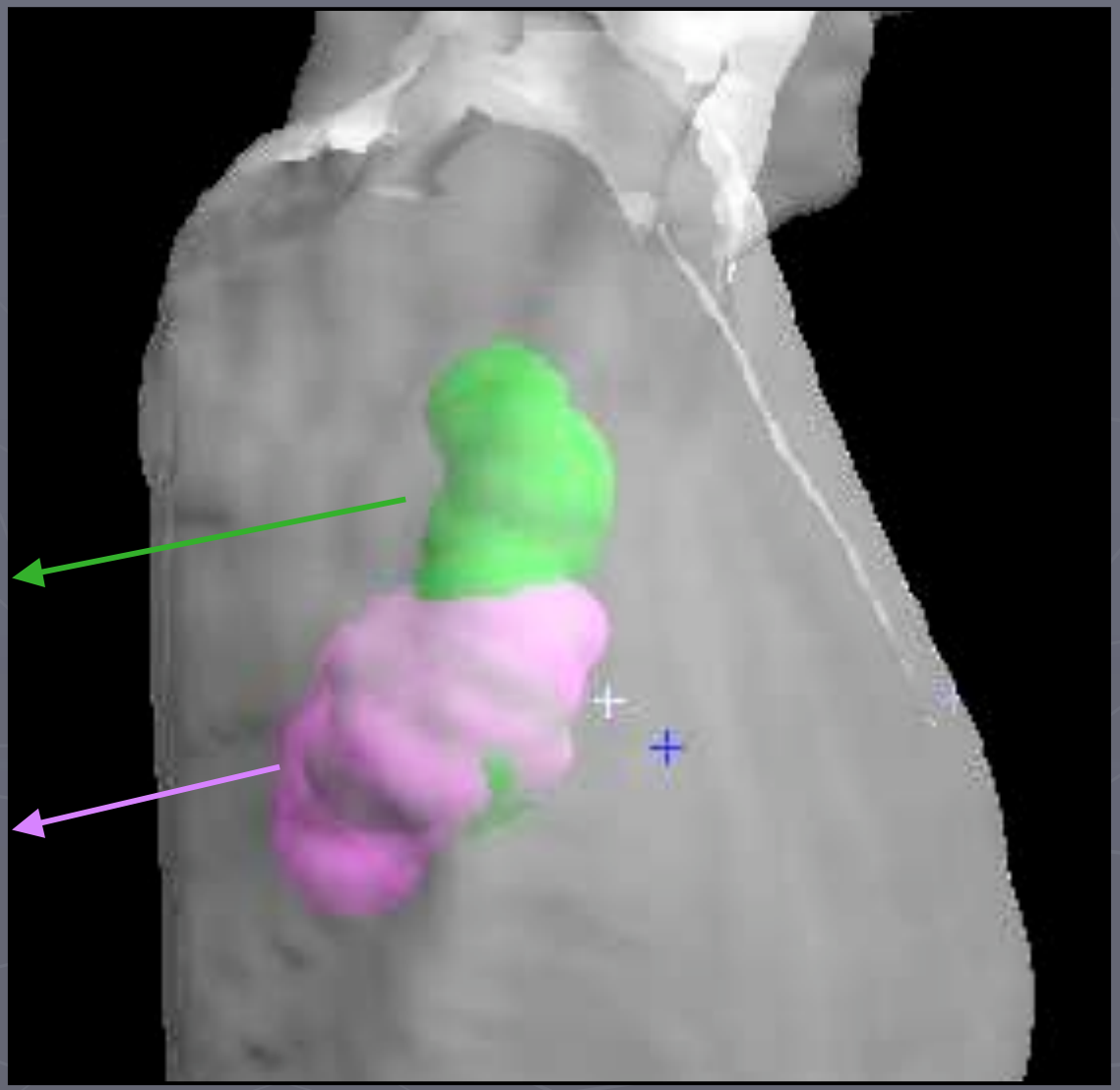
- "% PET/CT GTV lying outside CT PTV"
- 3 (25%) cases



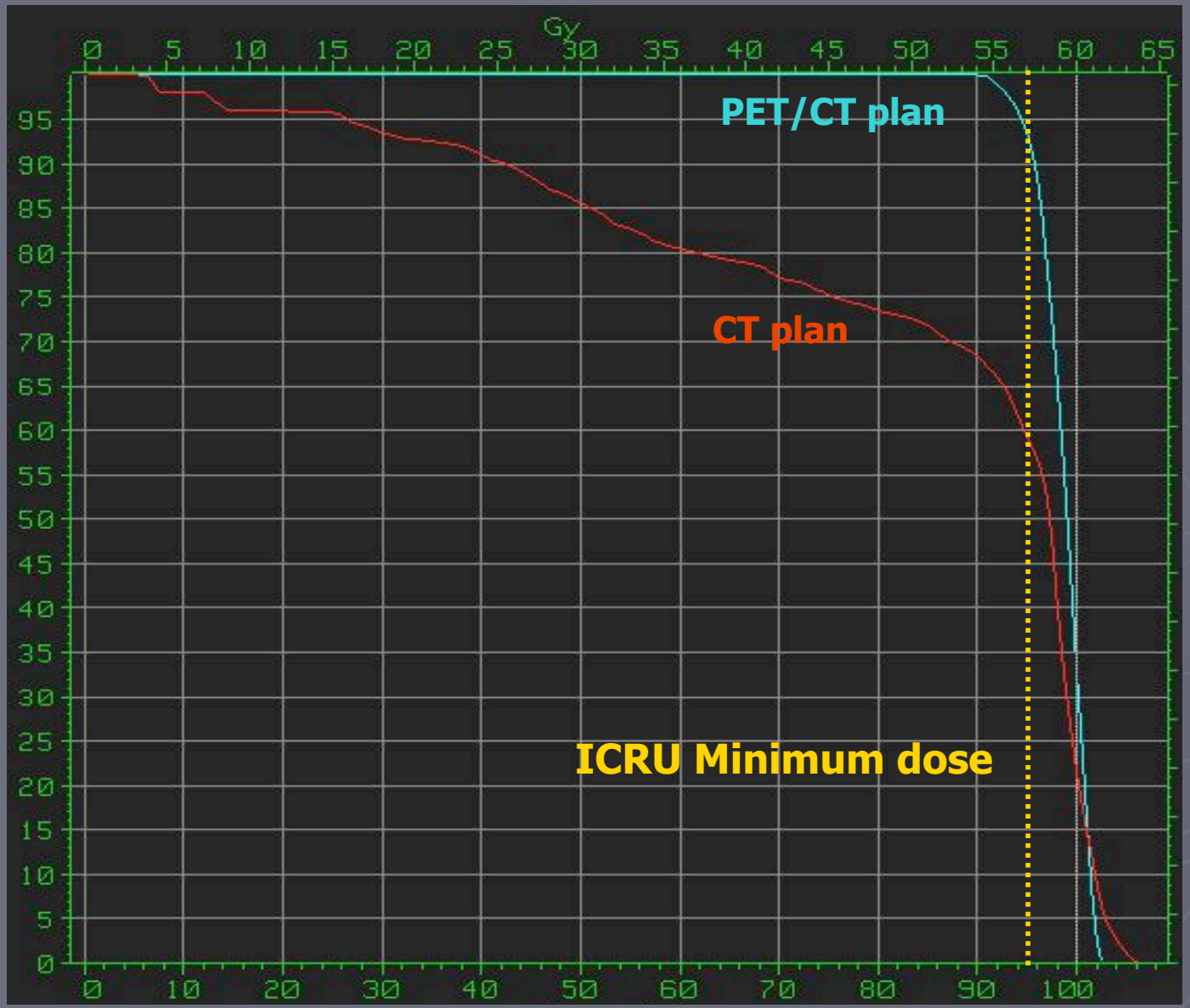
Geographic miss



Geographic miss



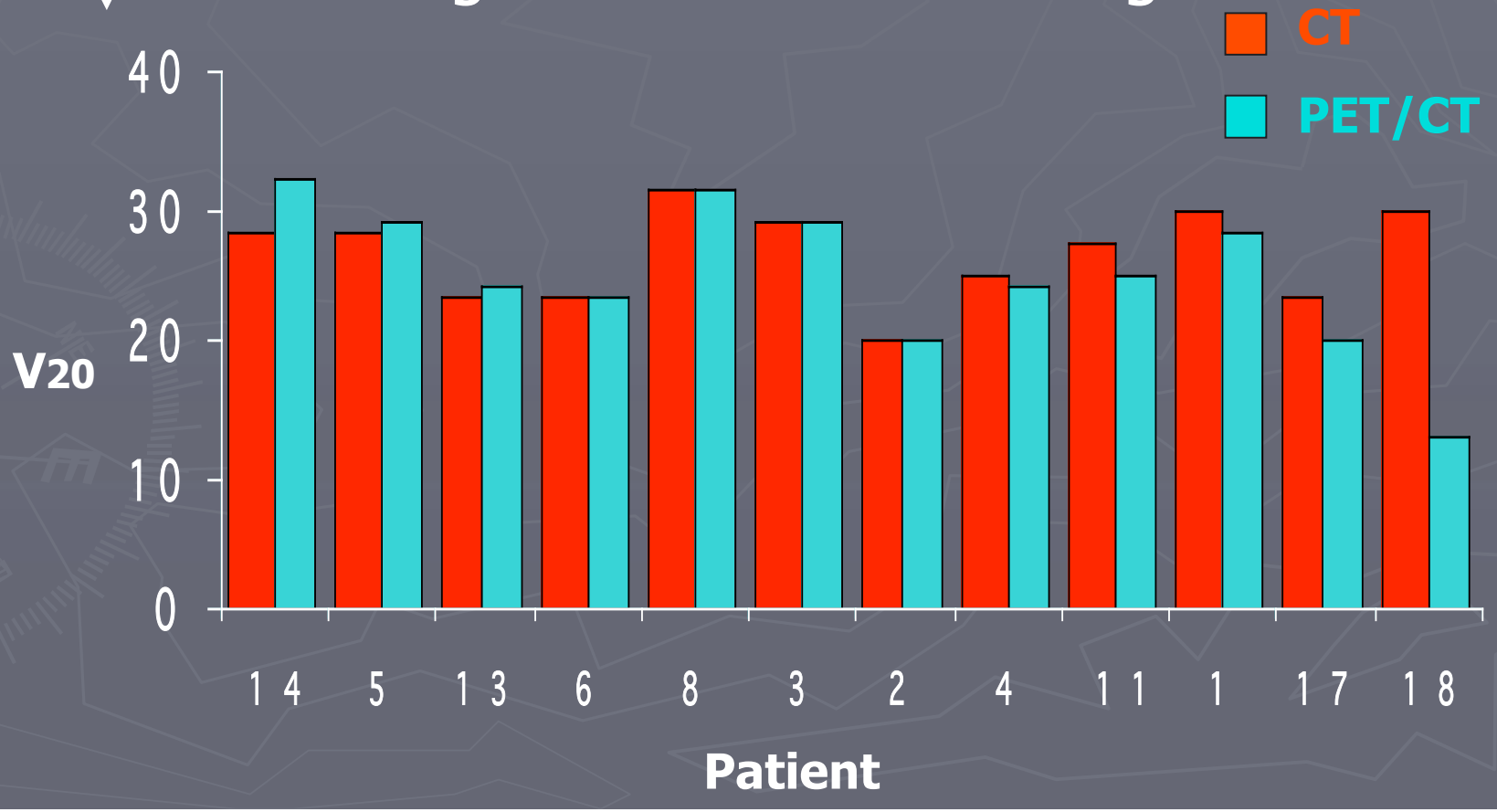
RT plan comparison for PET/CT PTV

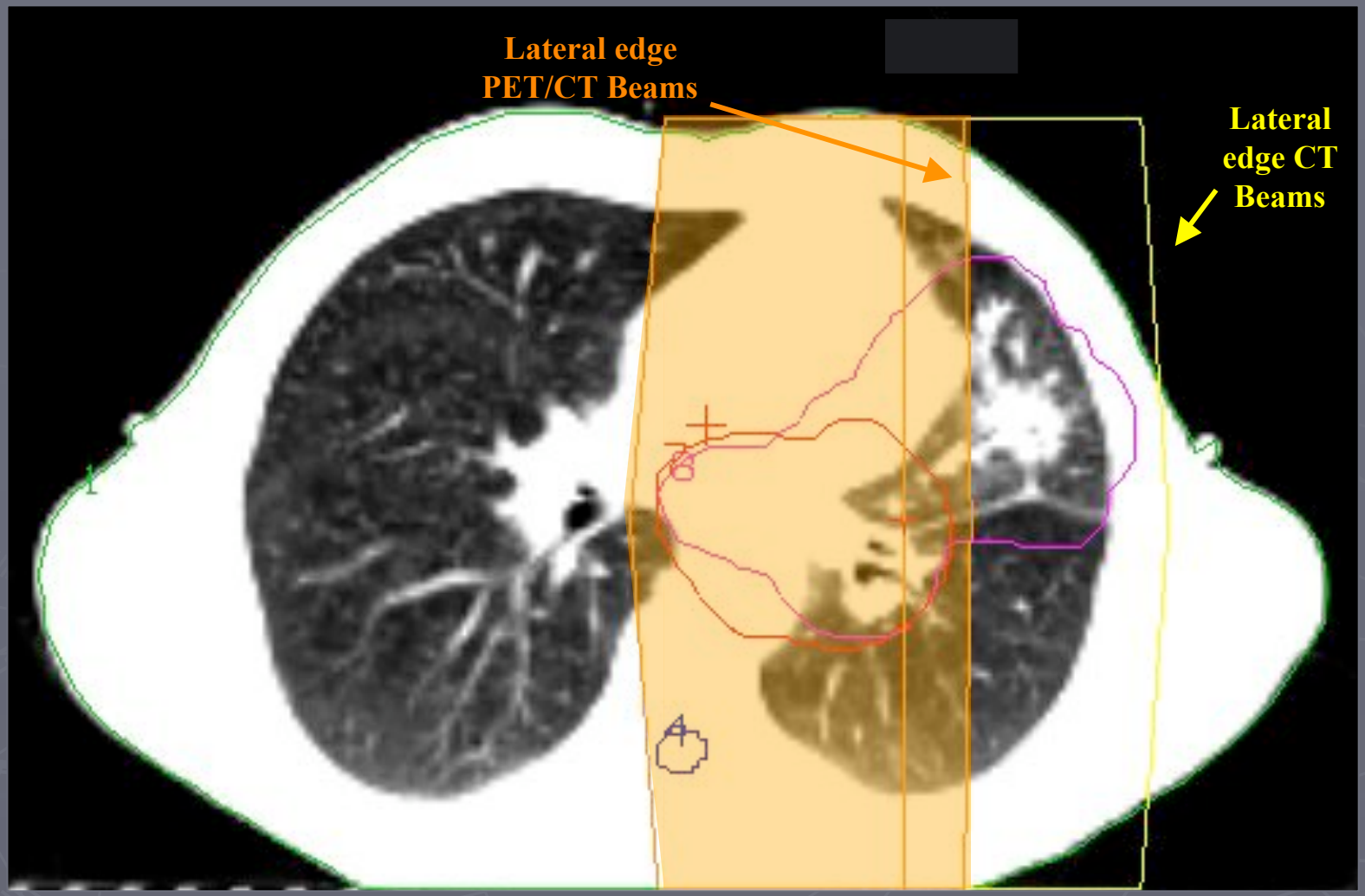


Lung dose V_{20}

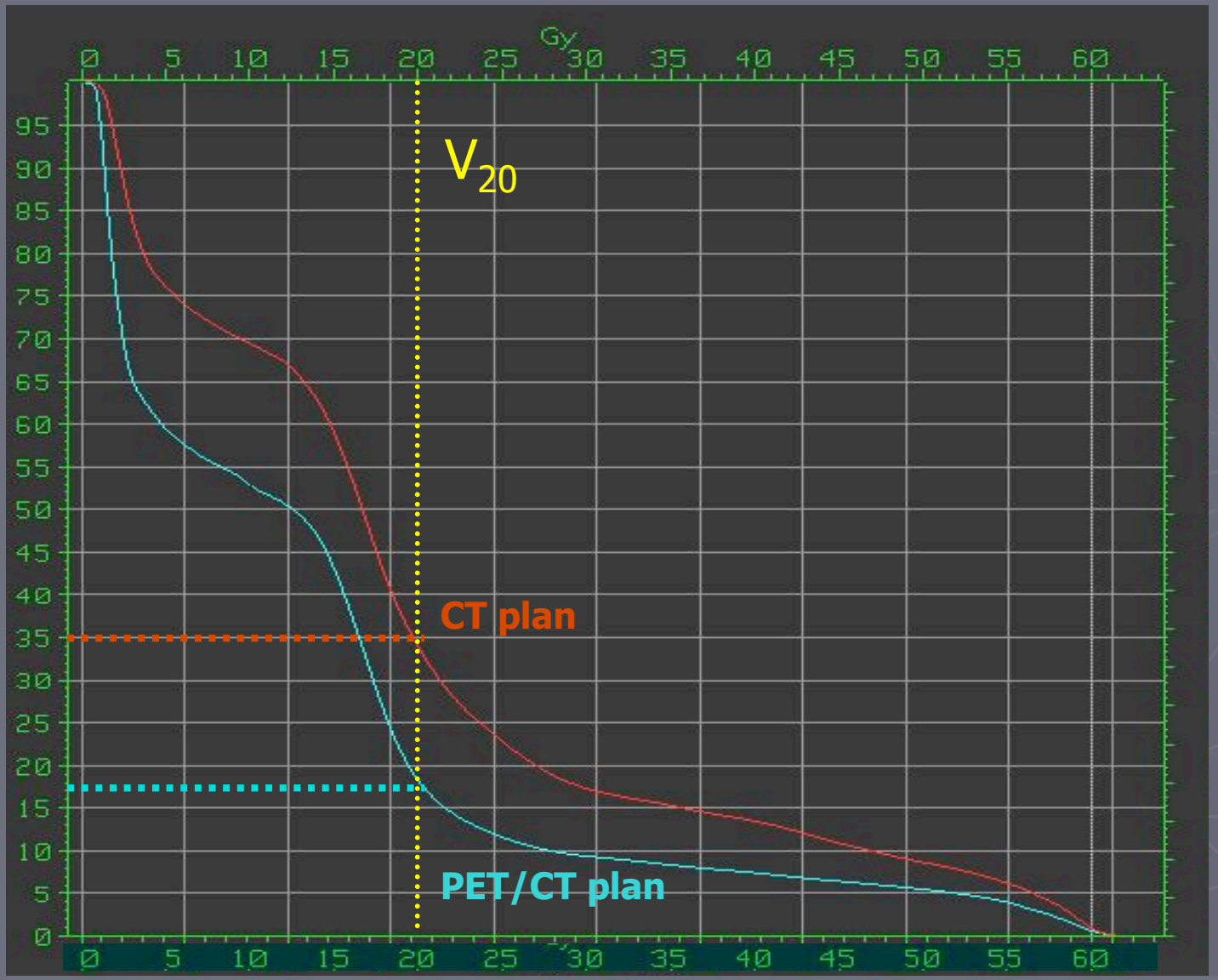
↑ PET identified gross disease

↓ PET distinguished atelectatic lung



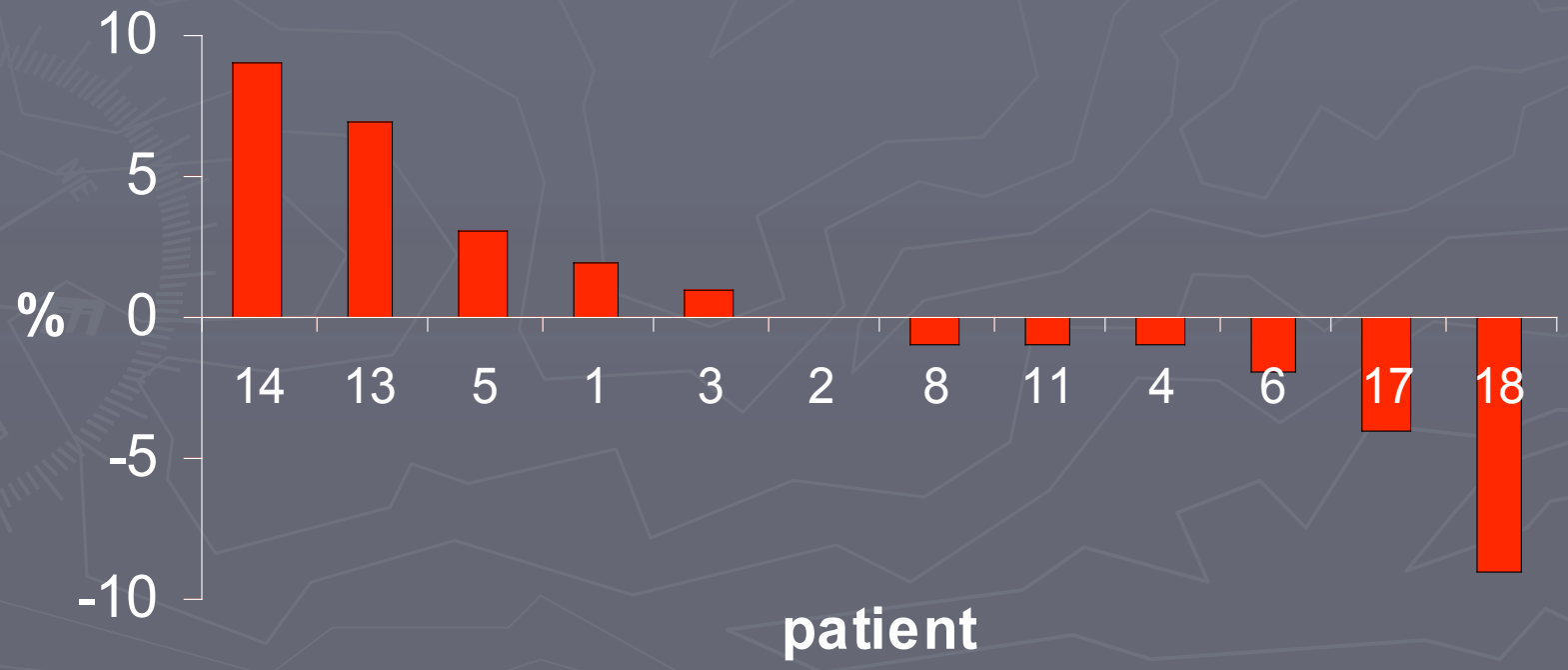

Lateral edge
PET/CT Beams
Lateral
edge CT
Beams
PET/CT PTV
CT PTV

RT plan comparison for lung dose



Mean oesophagus dose

- PET identified 'new' mediastinal nodes
- If enlarged nodes identified by CT are not PET avid



Conclusion

- GTV based on CT alone excluded PET-avid disease in 100% of patients
- In 25% of patients this would have resulted in a true geographic miss
- The addition of PET information for NSCLC allows more accurate definition of the GTV & lymph nodes
- PET information is of particular help in defining atelectatic lung

NSCLC dose optimisation

PET/CT => Increased confidence

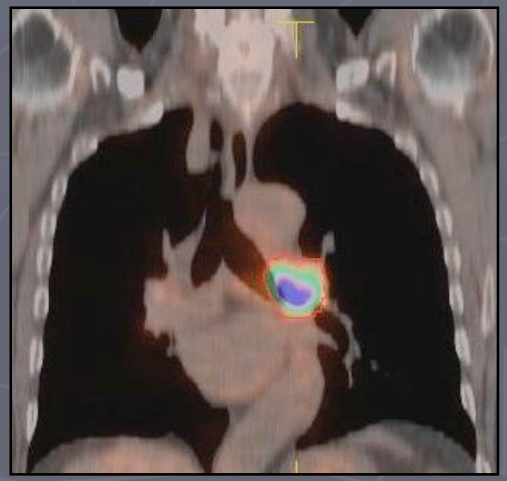
Three dimensional conformal radiation therapy (3DCRT)

Dose optimisation

Improved patient outcomes

Hypothesis

Innovative 3DCRT will facilitate the delivery of increased dose to the metabolic target volume for NSCLC without exceeding evidence-based dose constraints to surrounding normal tissues.

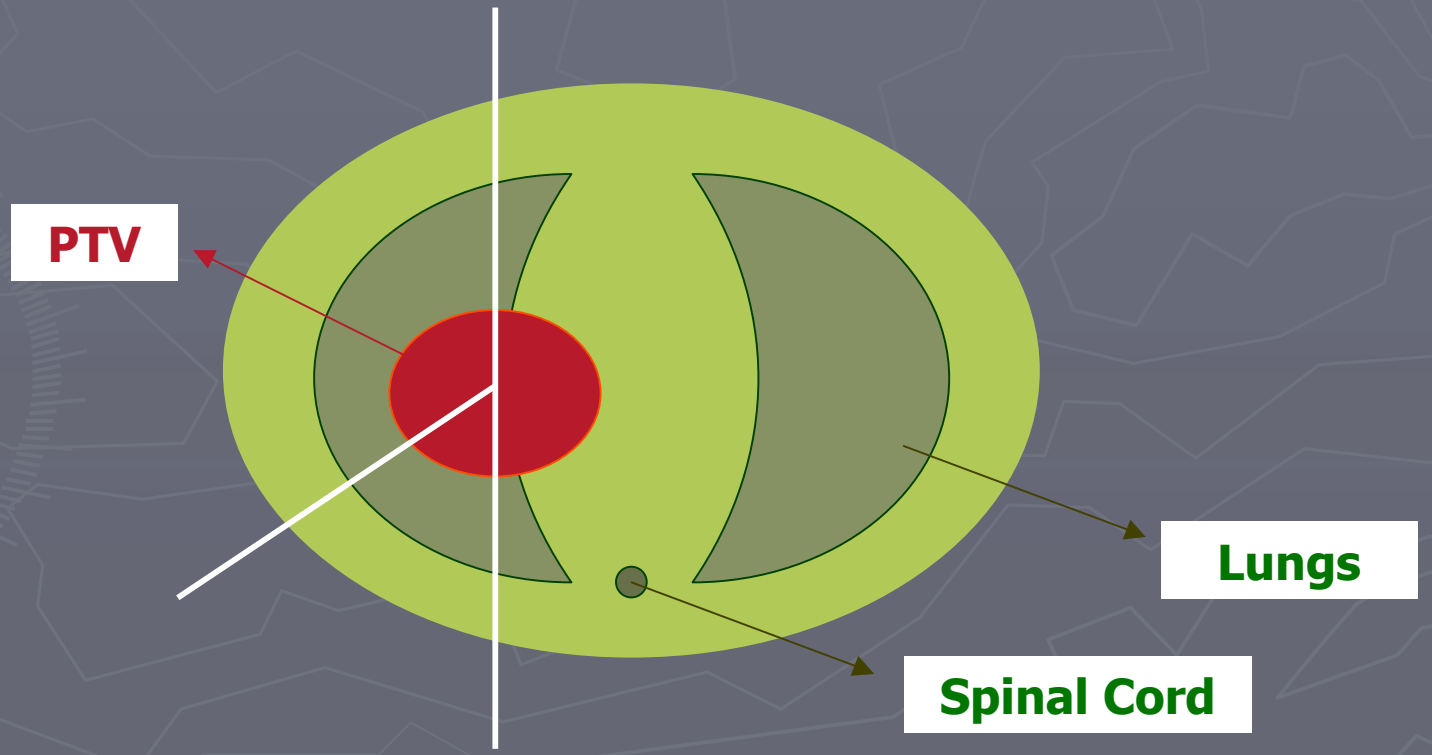


Primary Aim

To establish and compare the maximum theoretical dose of radiation that can be delivered to the FDG-avid tumour (GTV) using three radiation therapy techniques.

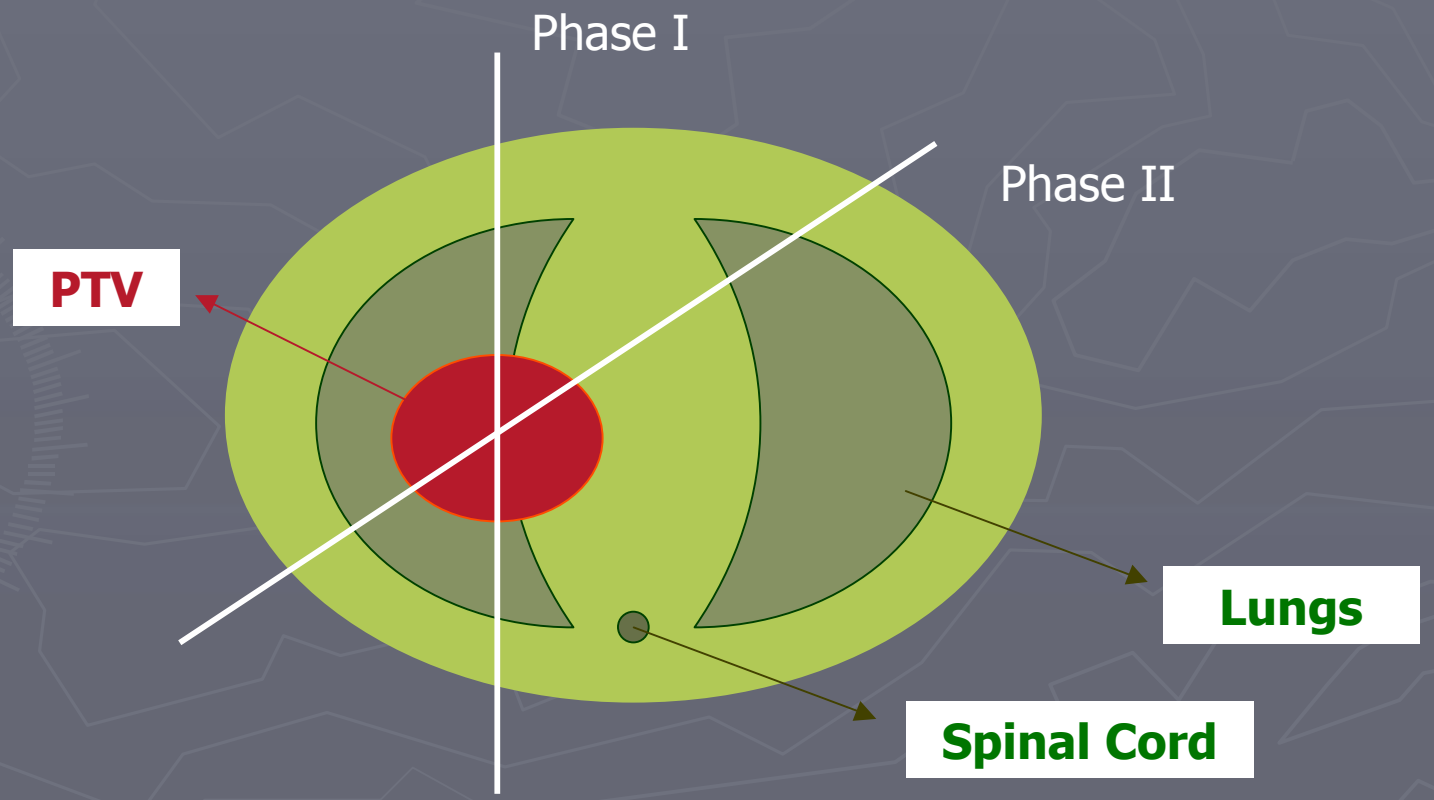
Methods

- Conventional Three-Field



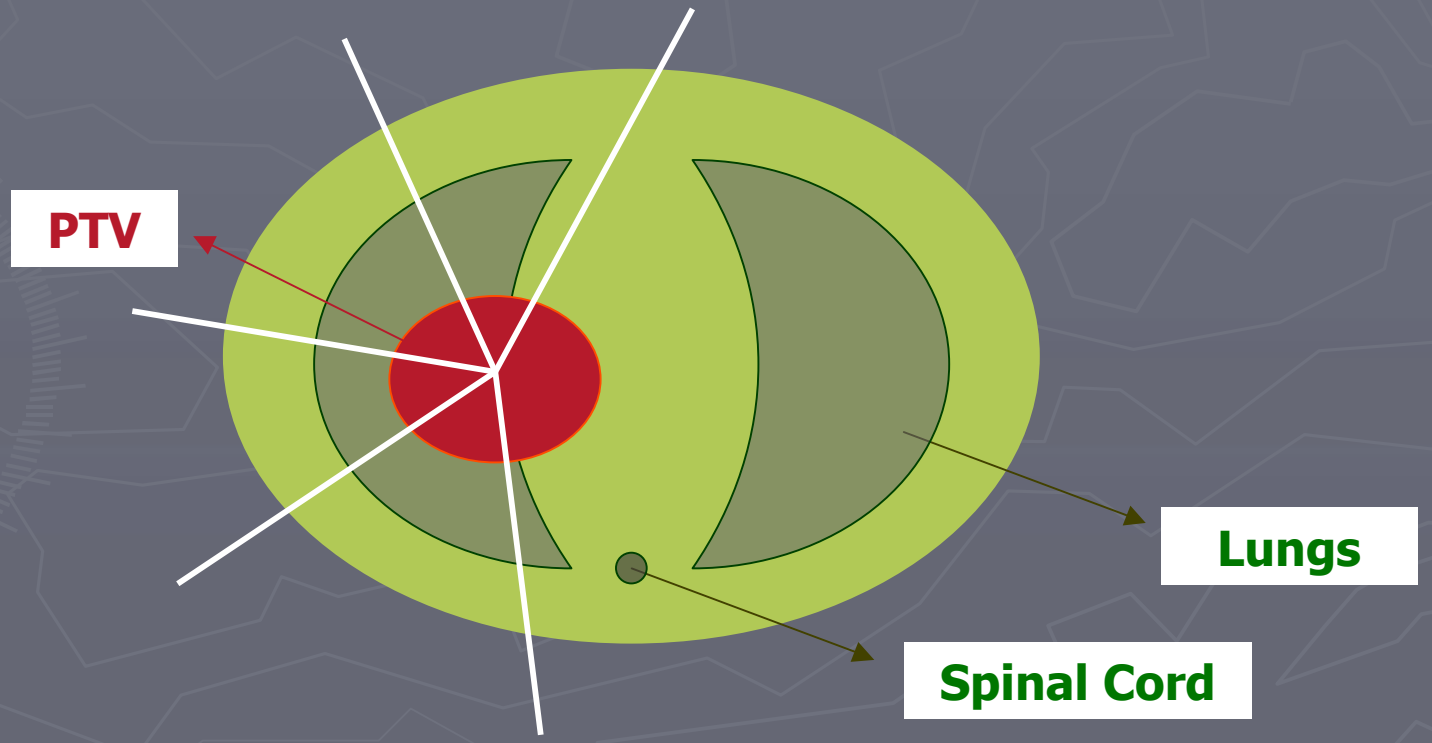
Methods

- Conventional Four-Field



Methods

- Innovative 3DCRT



Methods

Phase I: PET/CT PTV

Results

	3-Field	4-Field	Innovative
60Gy	19 (95%)	18 (90%)	20 (100%)
>60Gy	15 (75%)	9 (45%)	19 (95%)
>80Gy	5 (25%)	5 (25%)	15 (75%)
>100Gy	4 (20%)	2 (10%)	9 (45%)
120Gy	1 (5%)	1 (5%)	4 (20%)

N=20

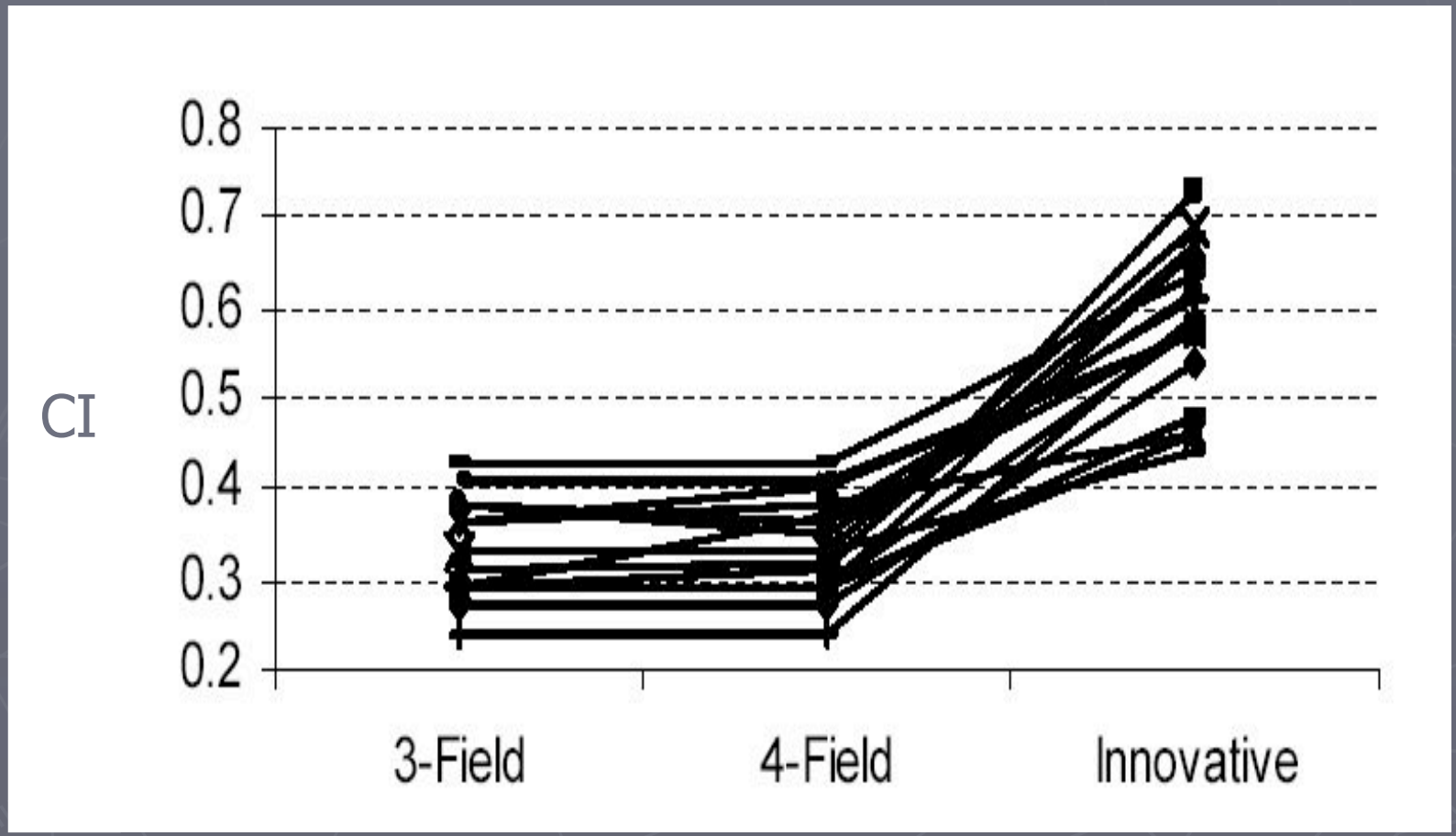
Results

	3-Field	4-Field	Innovative
Mean escalated dose	76.4Gy	74.0Gy	97.8Gy
± SD	19.5Gy	20.5Gy	16.4Gy

$P < 0.0005$

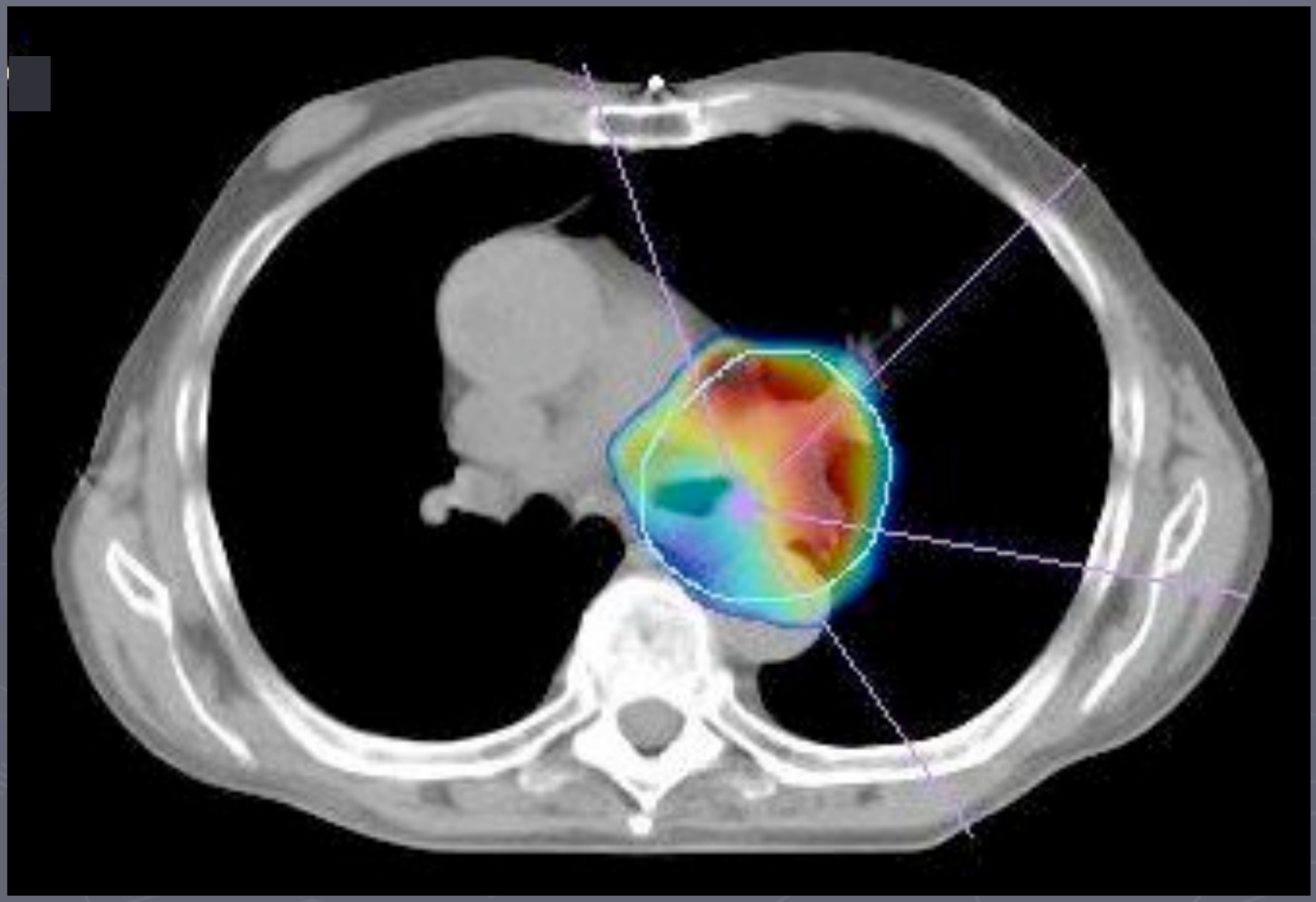
Results

Conformity Index



$P < 0.0005$

Results



Patient #13	57Gy (-5%)	63.5Gy (+7%)

Conclusion

Innovative 3DCRT facilitated

- Increased dose conformity
- Increased dose delivery
  - Acceptable normal tissue doses

Future direction

- Clinical dose escalation study
- Respiratory gated simulation & treatment
- Multi-slice CT scanner
- On-board imaging

Validation studies

- Inter-observer variability
  - To examine variation in TV delineation by ROs, radiologists & PET physicians.
  - To test current guidelines used for the PET/CT studies.
- Inter-planner variabililty
  - To examine variation in dosimetry performed by a group of RTs.
  - To test current guidelines used for the PET/CT studies.

Oesophageal cancer

- CT
  - Anatomical information
  - Spatial information
  - Electron densities
  - Radial extent of gross tumour
- PET
  - Sensitivity & specificity
    - Cranial & caudal extent of gross tumour
    - Lymph nodes

Oesophageal cancer

- No previous studies using a combined PET/CT scanner
- No previously published studies evaluating the impact of integrating CT with PET images for RT planning of oesophageal cancer

Hypothesis

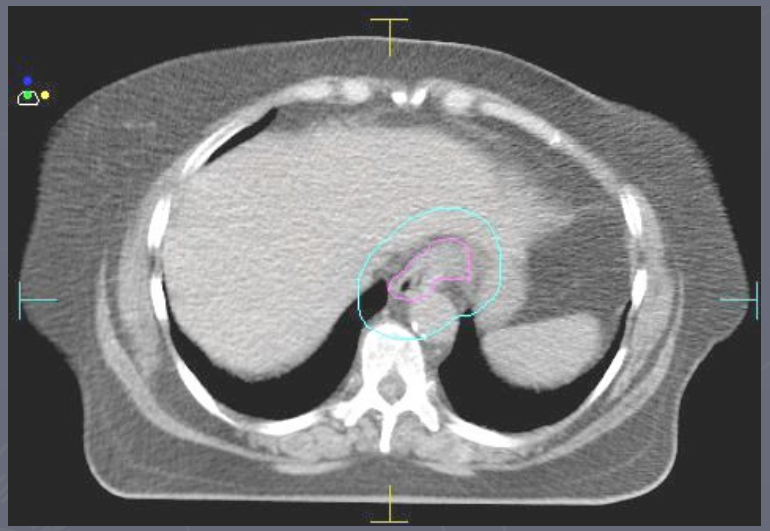
The incorporation of PET-CT information will impact on RT planning for patients with oesophageal cancer through more accurate localization of the GTV, particularly with respect to the upper and lower extent of the primary tumour, as well as better definition of involved regional lymph nodes.

Preliminary analysis

- 15 patients recruited
- 5 patients – metastatic dx on PET

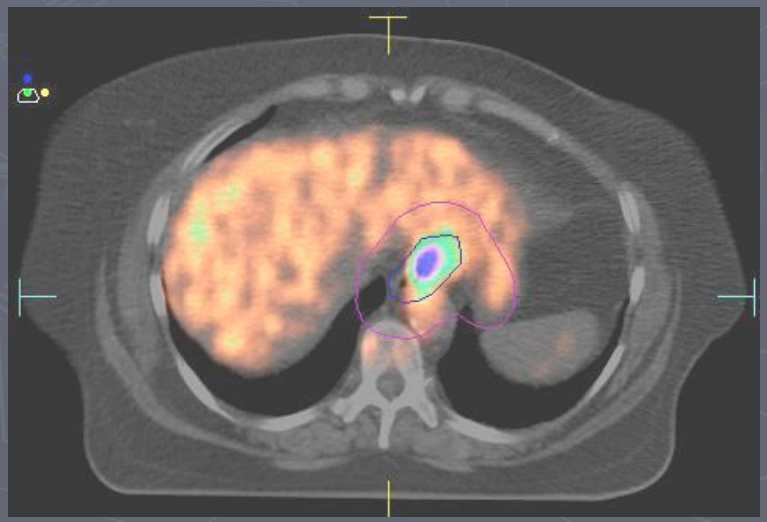
=> 10 patients RRT

Preliminary analysis



PTV based on CT alone

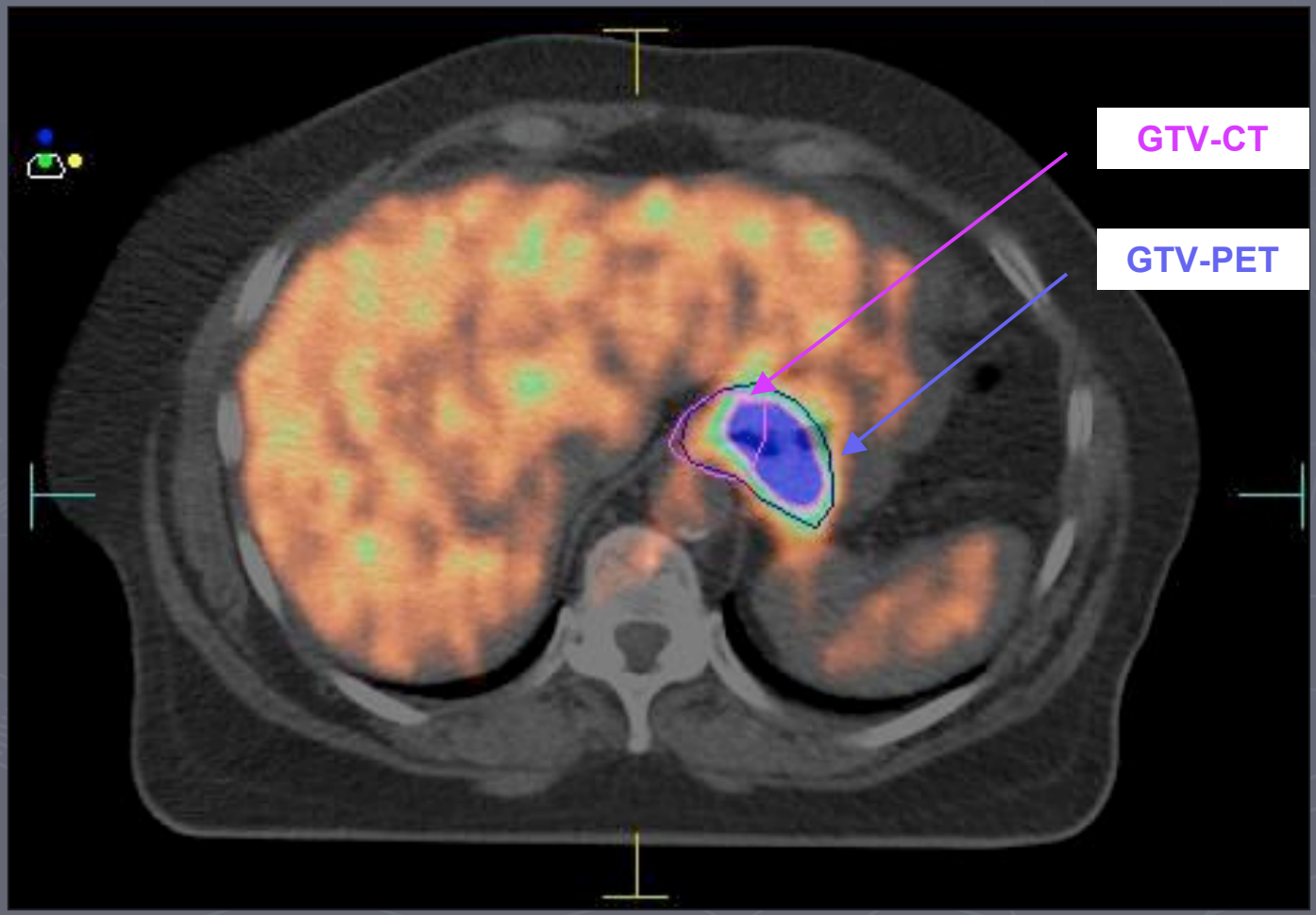
"PTV-CT"



PTV based on combined CT & PET

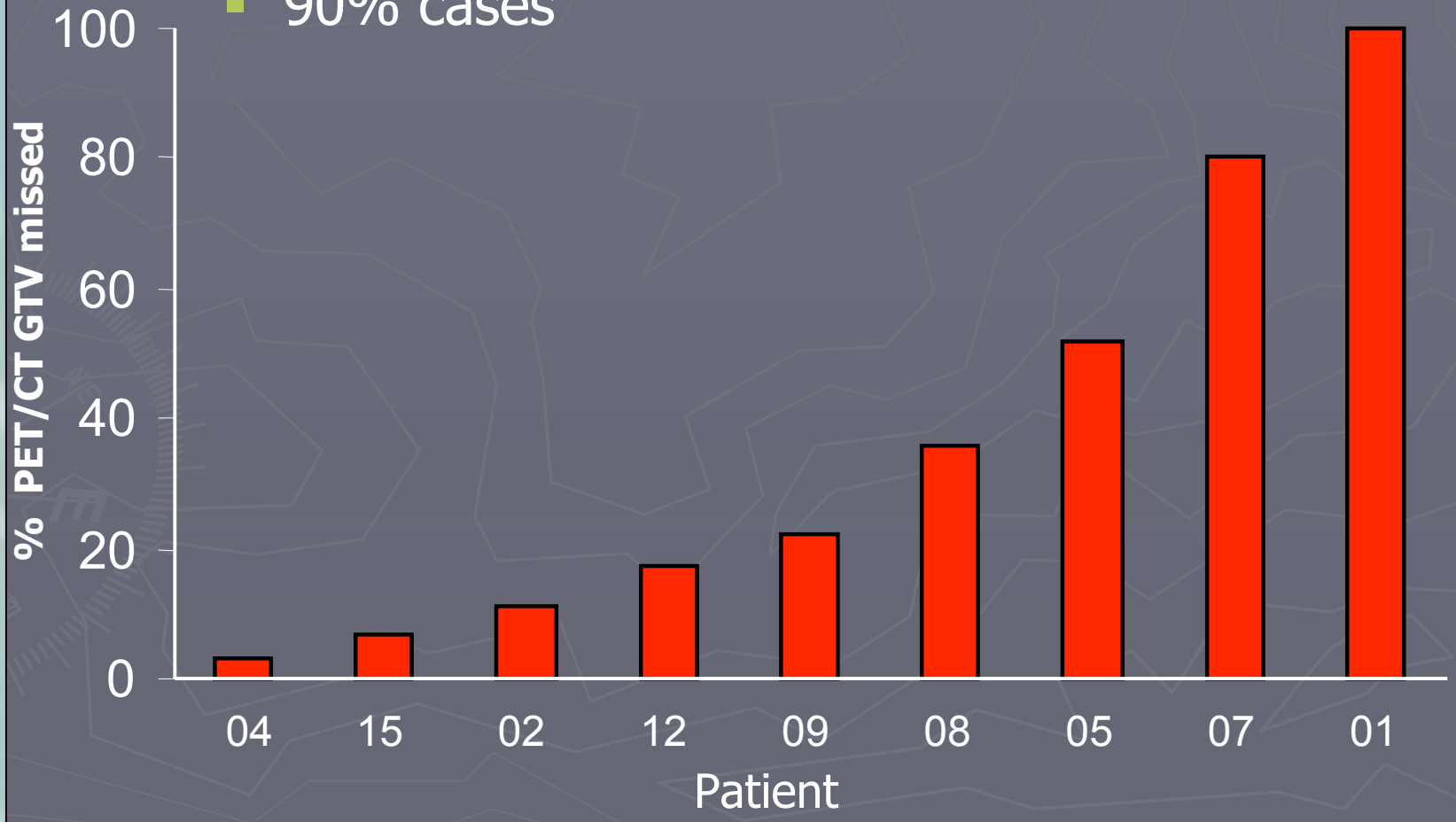
"PTV-PET"

Type 1 Geographic miss

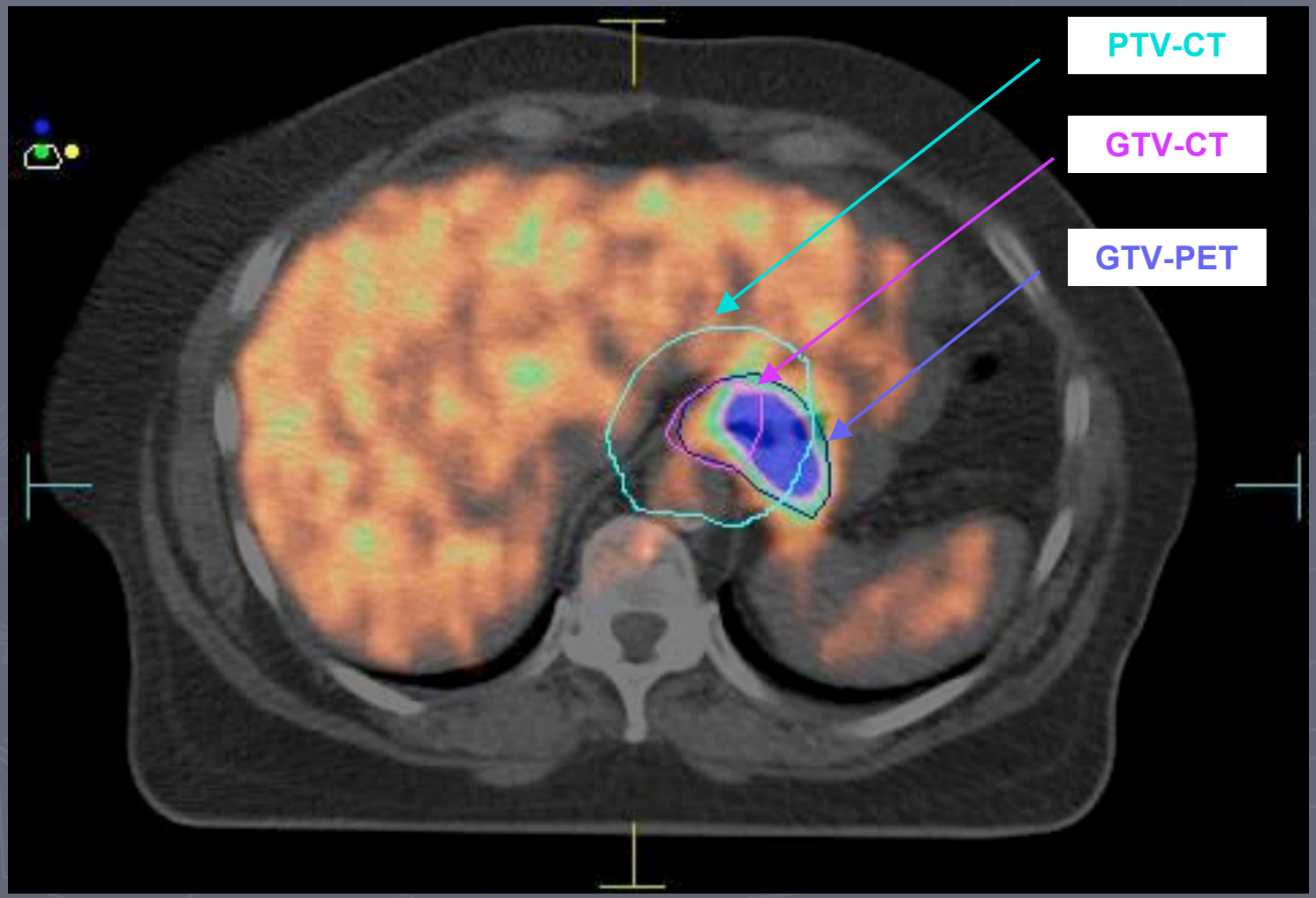


Type 1 Geographic miss

- "% PET/CT GTV lying outside CT GTV"
- 90% cases

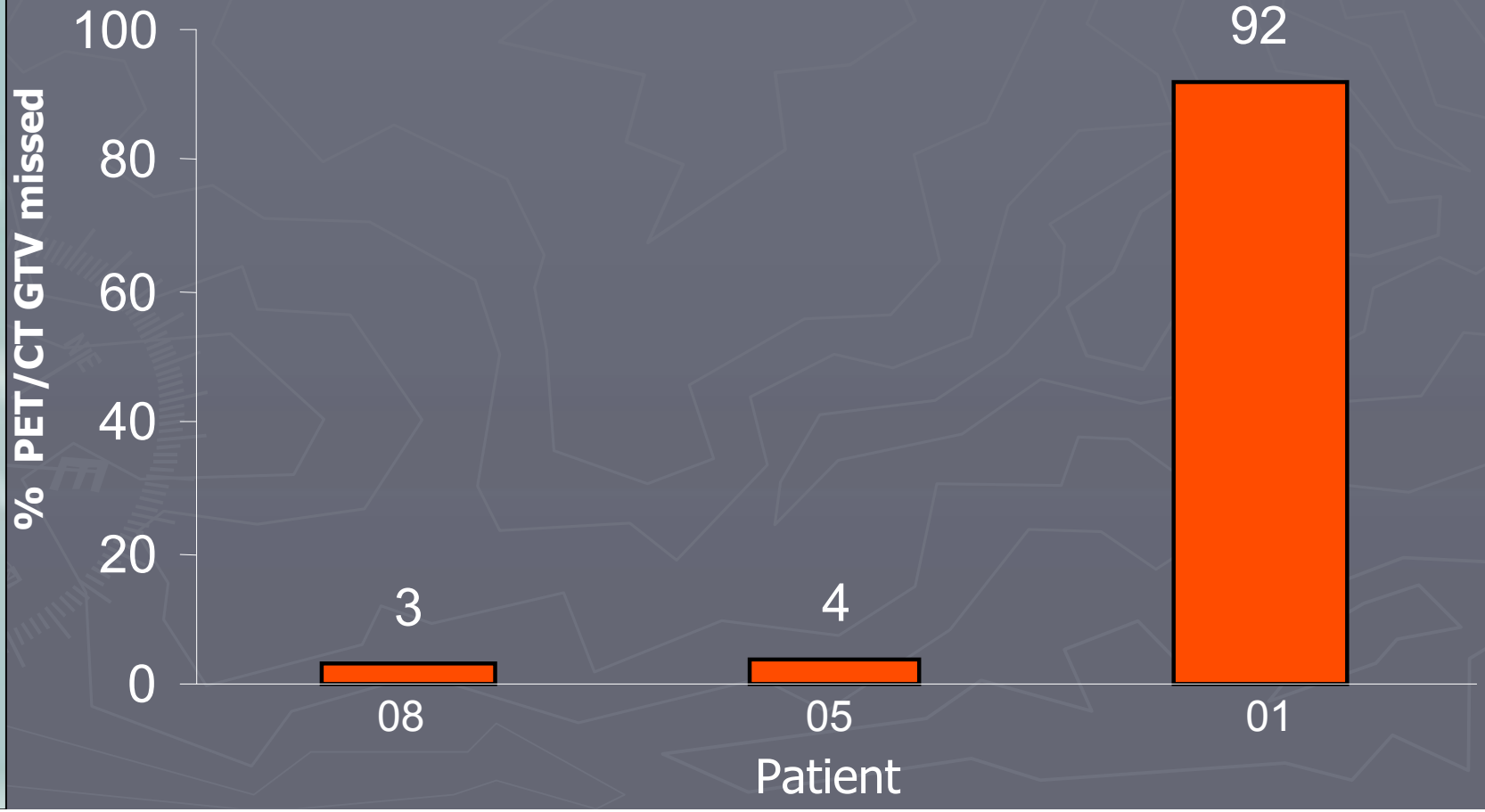


Type 2 Geographic miss

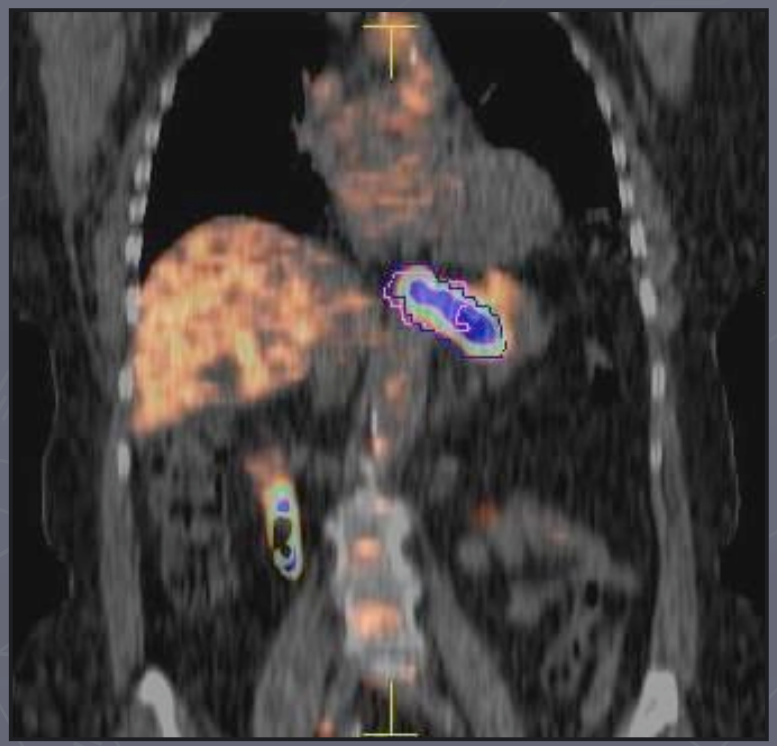


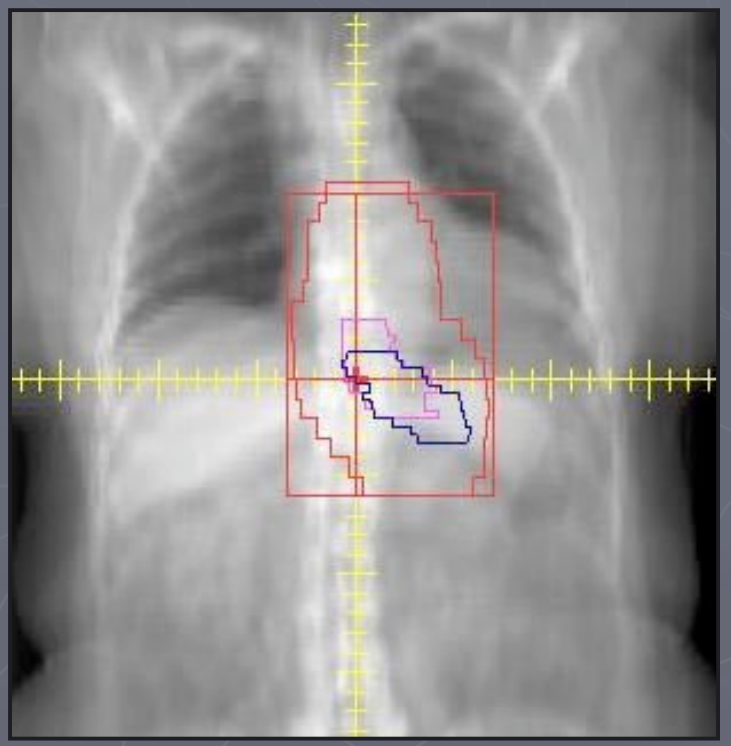
Type 2 Geographic miss

- "% PET/CT GTV lying outside CT PTV"
- 30% cases



Geographic miss





Comparison of cranial and caudal limits

Conclusion

- GTV based on CT alone excluded PET-avid disease in 90% of patients
- In 30% of patients this would have resulted in a geographic miss
- The addition of PET information for Ca Oesophagus allows more accurate definition of the GTV
- PET information is of particular help in defining the cranial & caudal extent of the GTV

Acknowledgements

- Radiation Oncology
  - Michael MacManus
  - Mike Bayne
  - David Ball
  - Trevor Leong
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  - Robin Cassumbhoy
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  - Judy Andrews
  - Natalie Fimmell
  - Craig Everitt
  - Andrea Paneghel
  - Sara Condron
- Centre for Biostatistics and Clinical Trials
  - Kally Yuen
  - Deborah Cruikshank