

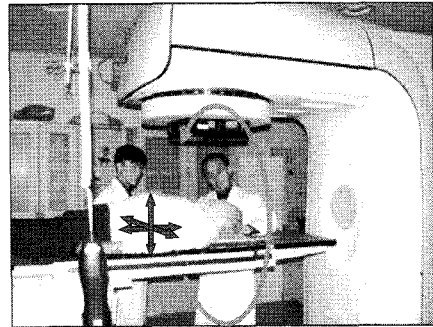
# Radiation Treatment Planning with PET/CT

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조 병 철

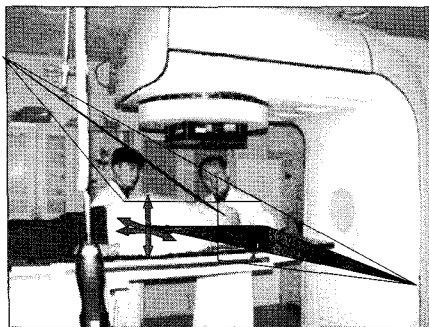
What is Radiation Therapy?



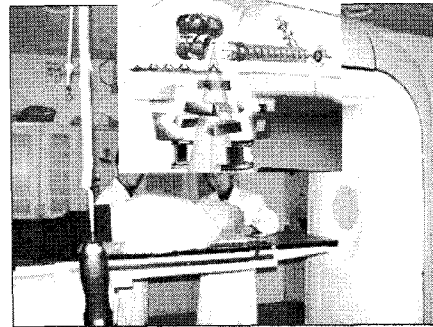
Linear Accelerator for  
Radiation Therapy



Linear Accelerator for  
Radiation Therapy




Linear Accelerator for  
Radiation Therapy




**Simulation**

1. Align Tumor at the Tx machine rotation center with fluoroscopy

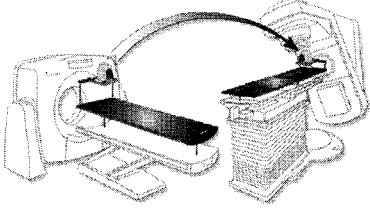



**Simulation**

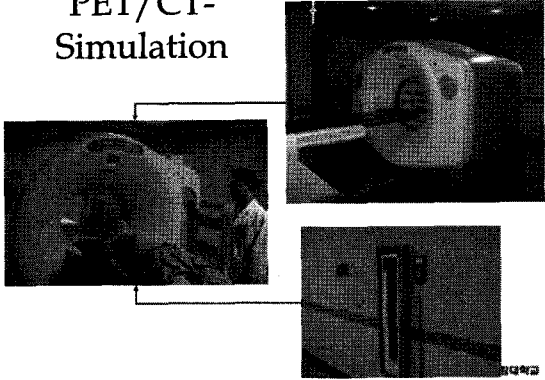

2. Mark at the patient skin for reference



**CT-Simulation**

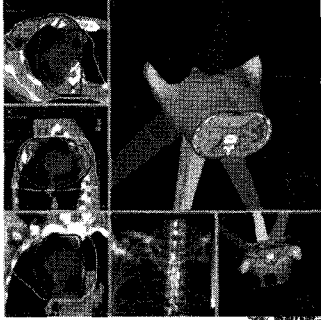




**PET/CT-Simulation**

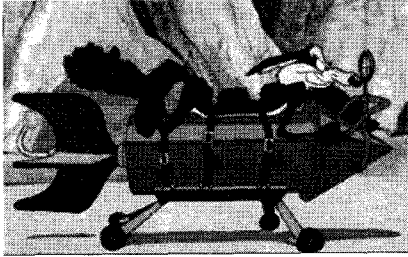

**Radiation Treatment Planning**

1. Target & Organ contouring
2. Beam arrangement
3. Dose calculation
4. Evaluation

**The Planning Dilemma**

Where is the real Target?

### Definitions of Tumor for Radiation Therapy

The volume (GTV) is the volume of the gross tumor as seen on the definition of the GTV. GTV, CTV, and PTV are defined as follows:

- Gross Tumor Volume (GTV)
- Volume of the Gross Tumor plus a margin for microscopic disease (CTV)
- Volume of the Gross Tumor plus a margin for setup error and organ motion (PTV)

Fig. 2.14. The volume (GTV) is the volume of the gross tumor as seen on the definition of the GTV. GTV, CTV, and PTV are defined as follows.

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### Impact of PET on RT planning

- Patient Management
- Size, Dosing, and Coverage of GTV and PTV
- Observer Variability in Defining GTV

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### Impact on Patient Management for NSCLC

- FDG-PET can change patient management, most frequently from radical RT to palliative treatment.

Mah, Caldwell, Ung et al. IJROBP 52, 2002  
In 7 of 30 (23%) of cases deemed suitable for radical

Bradley, Thorstad, Mutic, et al. IJROBP 59, 2004  
In 8 of 26 (31%) of cases deemed suitable for radical

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### GTV with CT alone

Is it tumor, atelectasis, pneumonitis, & normal mediastinal structure?

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### Example: FDG-PET decreased the target volume

CT contour  
PET contour

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### Reduction of inter-observer variation

CT alone  
PET/CT

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### Case: Target Definition

(M/69),  
Unresectable  
NSCLC

→ Staging by  
PET/CT  
→ RT planning  
with PET/CT

CT contour

PET contour

### Case: Target Definition

PET tracer  
activities  
enables  
distinguishing and  
segmenting real  
biological  
target volume  
(BTV)

CT contour

PET contour

### Case: Target Definition

(M/69), Unresectable NSCLC, Planning with PET/CT  
→ 70 Gy with 3 fields to PTV\_CTbased versus PTV\_FDgbased

### Case: Target Definition

By model of Kwa,  
Volume factor=1  
Sloping factor=0.3  
D50=30.56y

NTCP for  
right and both lung  
was greatly  
different.

### Different Viewpoints on PET/CT Imaging Procedure

- Viewpoint of Nuclear Medicine (CT corrected PET)
  - CT used for attenuation correction
  - CT assists NM doctors in the interpretation of images
  - [CT transmission → PET emission → AC Reconstruction → FUSION → Interpretation]
- Viewpoint of Radiation Oncology (PET plus CT)
  - CT used as primary image for radiation dose calculation
  - PET assists RO doctors in the delineation of target volume
  - [CT transmission → PET reconstructed → CT enhanced]

FUSION → ROI and Target delineation → RT Planning

### HUSH PET/CT System

Discovery ST, Image acquisition

DICOM connectivity

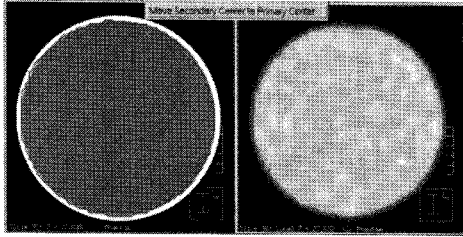
Syntegra, Image Registration

Syntegra, Contouring

Pinnacle3, Virtual simulation & Dose calculation

Treatment Delivery

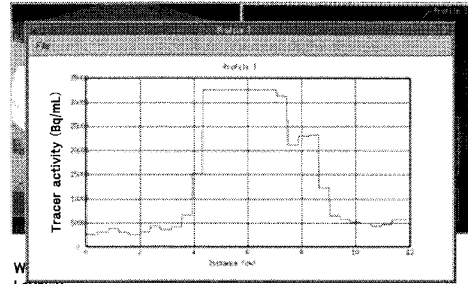
**HUSH PET/CT IGRT System**  
- Phantom study on PET/CT Registration



- Initial hardware coregistered images : 2~3 mm (half of oblique pixel dimensions)
- After aligning pixel center : ~ 1mm



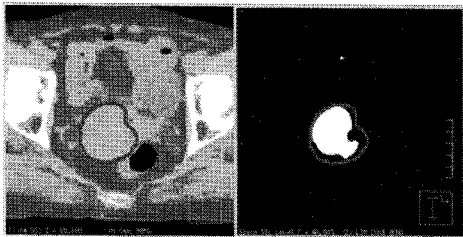
**Problems in PET/CT IGRT, setting the level & window**



Level=0  
Window=1



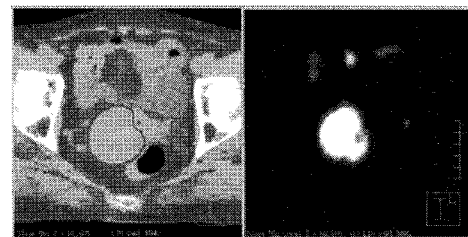
**Problems in PET/CT IGRT, setting the level & window**



Window & level setting for PET-guided contouring  
Level=0.36 → 0.50 → 0.60 → 0.70 → 0.80  
Window=0.08



**Problems in PET/CT IGRT, setting the level & window**



Window & level setting for PET-guided contouring  
Level=0.36  
Window=0.08 → 0.2 → 0.4 → 0.6



**HUSH PET/CT IGRT System**  
- Target Delineation Method



**Different Rules for Contour Definition**


**TABLE 3**  
Results of GTV Delineation Following Different Philosophies for Contour Definition: Patients with Clearly CT-Defined Tumors

Patient no.	SLV <sub>max</sub>	GTV <sub>max</sub>		GTV <sub>1/2</sub>		GTV <sub>1/3</sub>		GTV <sub>1/4</sub>		GTV <sub>max</sub>			
		Volume (mL)	Radius (cm)	Volume (mL)	Radius (cm)	Volume (mL)	Radius (cm)	Volume (mL)	Radius (cm)	Volume (mL)	Radius (cm)		
2	50.1	154.2	3.40	151.1	3.30	56.3	2.39	62.0	3.20	66.4	3.31	135.0	2.78
5	6.1	39.2	2.17	39.0	1.90	41.4	2.15	42.4	1.84	52.3	2.42	25.9	1.67
7	13.7	9.5	1.3	—	—	5.7	1.11	2.2	0.96	8.8	1.3	17.6	1.3
9	12.2	32.3	2.22	35.5	2.04	14.1	1.60	19.4	1.72	12.7	1.45	15.5	1.70
16	18.3	67.6	3.53	42.7	2.17	13.2	1.47	33.1	1.72	52.0	1.87	15.3	2.22
Mean	14.7	66.6	2.33	64.8	2.36	26.1	1.72	28.8	1.72	25.7	1.69	24.6	1.94

\*Radius values were calculated from volumes as sphere radii.

Nestle U et al. J Nucl Med 46(8) 2005





 Dr. J. Kubota (Co-Editor, Head, Dept. of PET, Jikei Univ. School of Medicine, Tokyo, Japan)

doi:10.1054/j.gr.2003.10.047

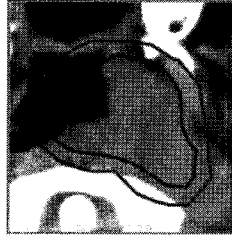
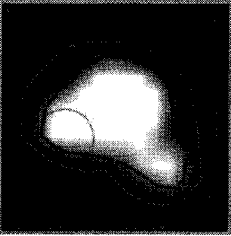
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**EDITORIAL**

**FRG: PET IN RADIOOTHERAPY TREATMENT PLANNING: PANDORA'S BOX?**


- **WHAT IS THE OPTIMAL PET VOLUME FOR RADIATION THERAPY?**
- **WHO NEEDS TO CONTOUR THE PET VOLUME—THE RADIATION ONCOLOGIST OR THE NUCLEAR MEDICINE PHYSICIAN?**
- **WILL TREATMENT OF PET-DEFINED TUMOR IMPROVE OUTCOME?**
- **WHAT ABOUT TUMORS THAT ARE POSITIVE ON CT BUT NEGATIVE ON PET AND VICE VERSA?**

## Spatial Resolution Issue

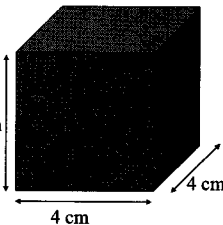



PET-based Contour      The resolution is only 3.75 mm  
 → Interpolated by bi-linear algorithm

PET-based Contour after 3D Expansion of One Pixel

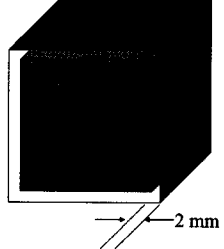


## Spatial Resolution Issue




4 cm  
4 cm  
4 cm

$PTV = 4 \times 4 \times 4 \text{ cm}^3 = 64 \text{ cc}$

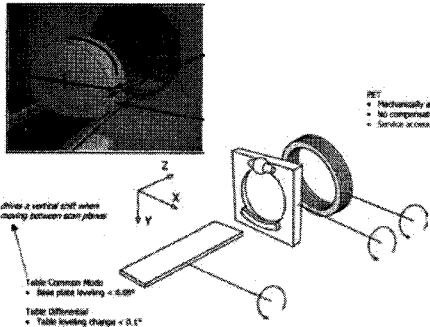


2 mm

$PTV' = 4.4 \times 4.4 \times 4.4 \text{ cm}^3 = 85 \text{ cc} \Rightarrow 33\% \text{ increased}$




## PET/CT & Table Alignment



**PET**


- Mechanically aligned to 0.15°
- No compensative element
- Service in Case alignment < 0.25°

drives a vertical shift when clamping between scan planes  
 Table Common Mode  
 • Base plate leveling < 0.05°  
 Table Differential  
 • Table leveling change < 0.1° (showing from CT to PET)

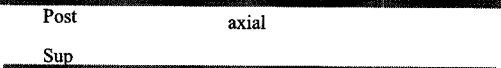


## PET/CT & Table Alignment

Ant




Post

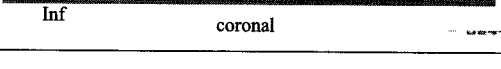


axial


Sup



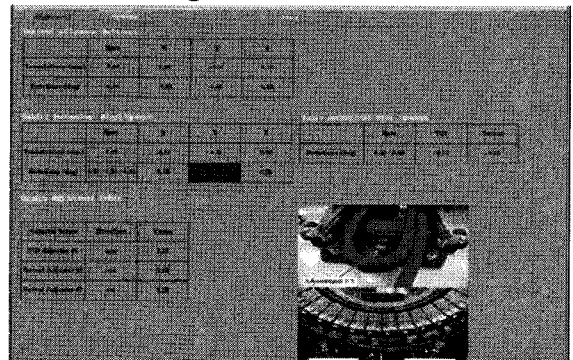
Inf



coronal



## Misalignment Check Tool



## Summary

- PET/CT provides metabolic and anatomic information.
- PET/CT provides accurate co-registered data for RT planning.
- For RT, positional accuracy is important.
- The role of PET in RTP is just began, more experiences are necessary.



*MEMO*