Daily Localization Using KV/CBCT

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Objectives

- Understand the latest commercially available technologies for in-room kV radiography, fluoroscopy, and cone-beam CT and their basic imaging principles
- Understand the basic clinical imaging applications for daily localization
- Understand the basic system limitations and QA components of a comprehensive QA program

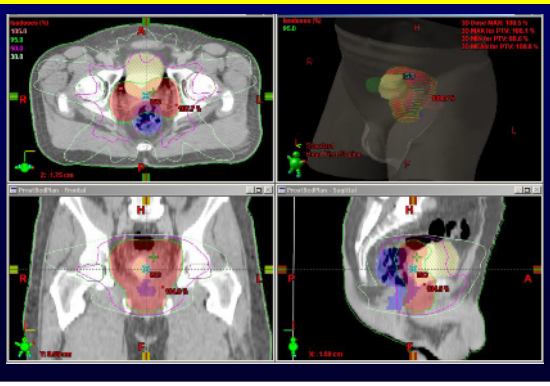
Acknowledgements

- Invitation from the program committee
- Members of Radiation Oncology Department at Duke University Medical Center
- Duke University Medical Center has a master research agreement with Varian Medical Systems

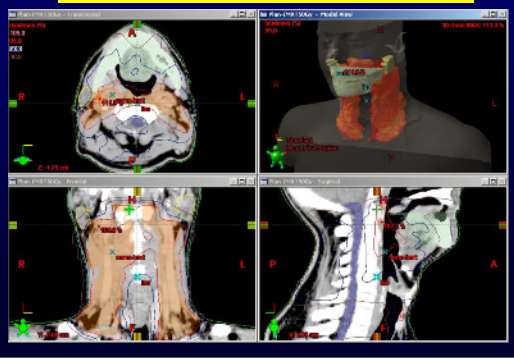
Outlines of the Talk

- Introduction
- Imaging Systems and Methods
- Clinical Applications
- Image Quality (Dr. Siewerdsen)
- Quality Assurance (Dr. Moseley)

Why In-Room – Prostate IMRT Case



Why In-Room: H&N Case



Why In-Room: Improving Precision and Accuracy

Accurate but not precise	Precise but not accurate	Precise and accurate
IGRT	IMRT	IGRT+IMRT

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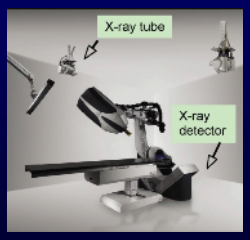
On-Board kV X-ray Imaging

- *Room-Mounted System*
- *Gantry-Mounted System*
- *Mobile Systems*

Room-Mounted X-Ray Systems



CyberKnife® imaging system

Novalis® imaging system

Gantry-Mounted X-Ray Systems

Elekta Synergy® system

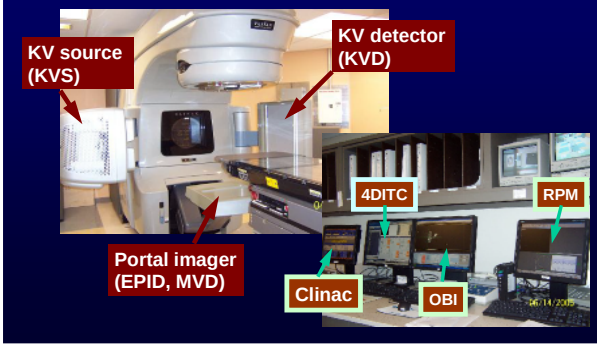
Varian Trilogy™ system

"Mobile" Systems

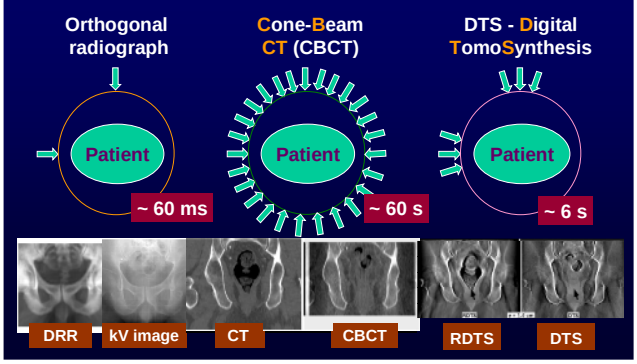
Varian ExaCT™ at MDACC

Siemens C-arm system

Duke On-Board Imager (OBI)



Radiographic Imaging Options



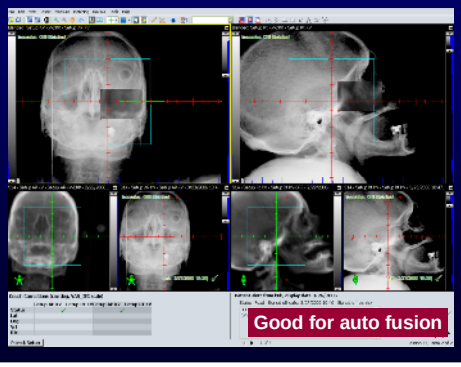
Radiographic Imaging Techniques

- 2-D radiographic imaging
- 2-D fluoroscopic imaging
- 3-D cone-beam imaging
- Limited scan angle 3-D digital tomosynthesis
- Respiratory-gated imaging

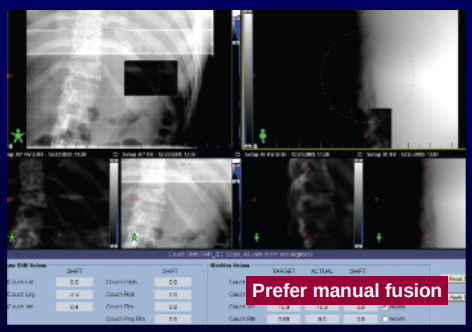
Clinical Applications

- Correction Strategies
  - Off-line Correction
  - On-line Correction
- Image Fusion
  - Manual
  - Automatic

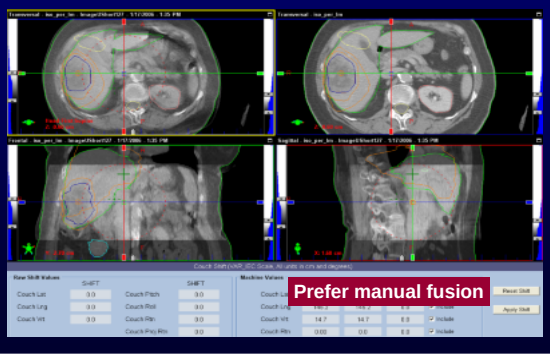
2-D Radiographic Imaging



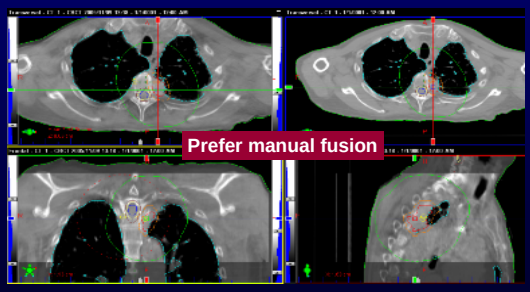
2-D Radiographic Imaging



3-D CBCT for Soft Tissue

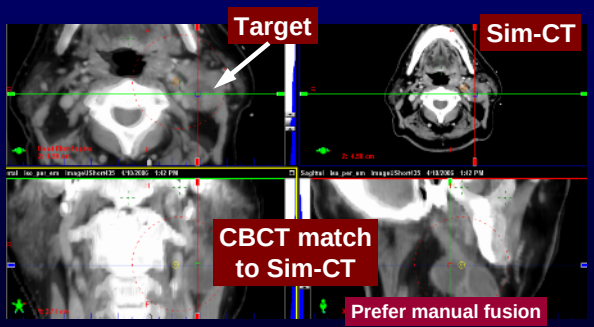


3-D CBCT for Soft Tissue

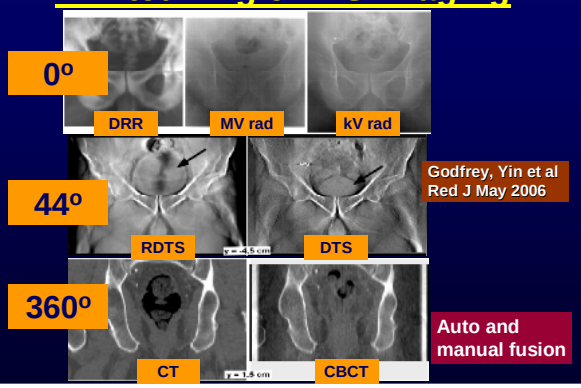


Reference image Portal image

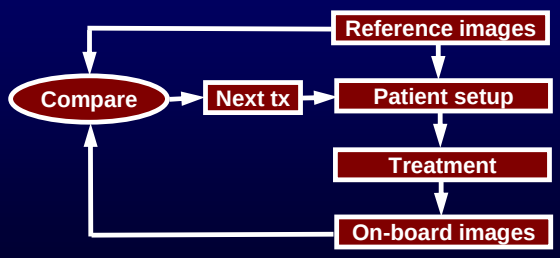
3-D CBCT for Soft Tissue



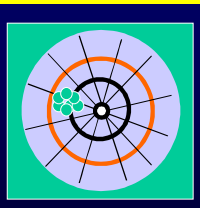
Limited Angle DTS Imaging



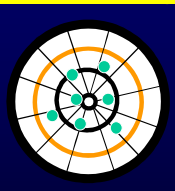
Off-Line Portal Verification



What Will Off-Line Verification Do for Precision and Accuracy?



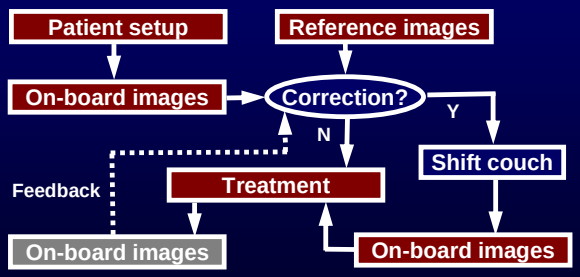
Systematic error



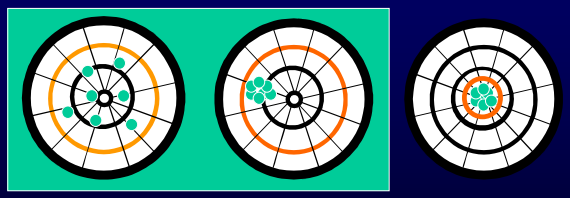
Random error

Accurate but not precise!!!!

On-Line Portal Verification



What Will On-Line Verification Do for Precision and Accuracy?



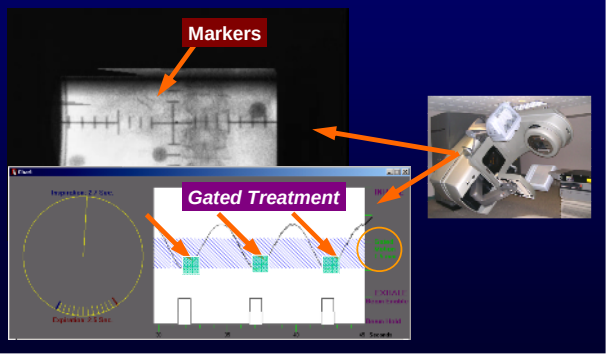
Random error | Systematic error | Systematic & Random error

Both Accurate and Precise!!!

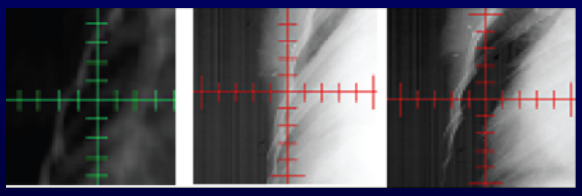
Imaging for Respiratory-Gated Treatment

- Anatomical imaging
  - Breath-hold
  - Gated treatment
  - Real-time portal verification
- Dosimetric imaging
  - Intensity map

4-D Fluoroscopic Imaging

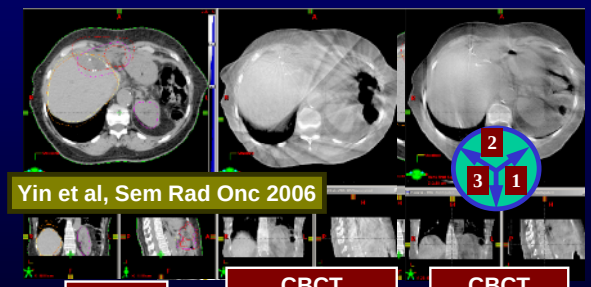


Breath-Hold Treatment Localization



DRR (breath-hold) | kV (free-breathing) | kV (breath-hold)

Breath-Hold CBCT



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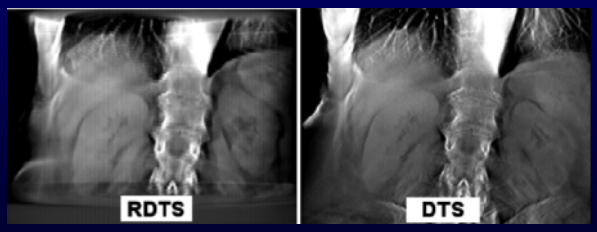
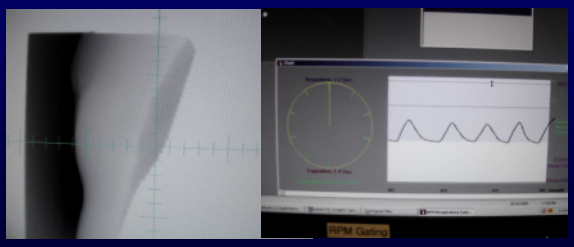
Sim CT | CBCT Free-breathing | CBCT Breath hold

Breath-Hold Digital Tomosynthesis

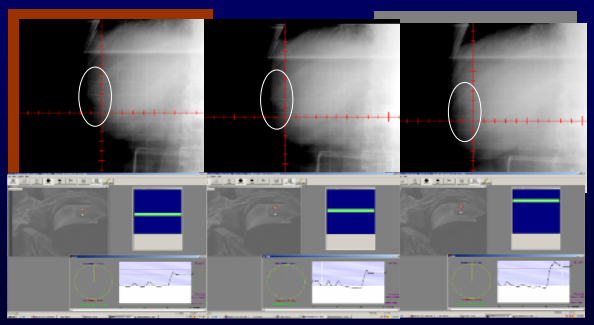


Breath Real-Time Portal Verification

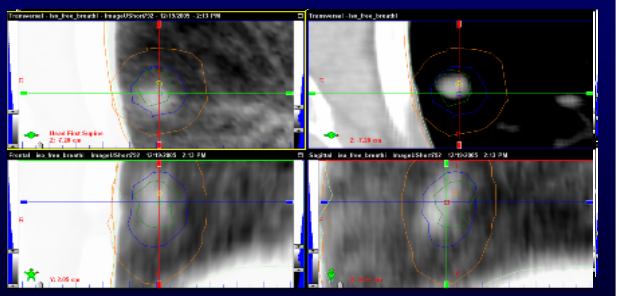


20 portal images in cine mode with < 1 s interval

Liver - Effect of Breath-Hold



Free-Breath ITV Verification with CBCT



Patient setup after correction

Total Treatment Time for IGRT

Patient setup in the room	2 – 5 min
OBI kV/kV or MV/kV imaging	~ 1 min
2D2D matching analysis	2 – 5 min
CBCT imaging	3 min
3D3D matching analysis	2 – 5 min
Re-positioning	~ 1 min
Treatment delivery	10 – 15 min
Total treatment time for IGRT with CBCT	20 – 35 min
Total treatment time for IGRT without CBCT	15 – 25 min

Hardware Requirements

Planning image data:

- CT images: 0.514 MB/image
- MR images: 0.188 MB/image
- PET images: 0.034 MB/image

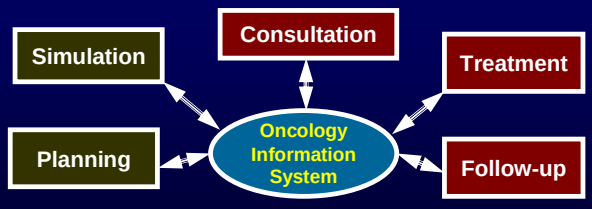
Localization/verification image data:

- kV image: 1.54 MB (1024x768x2)
- MV image: 0.386 MB (512x384x2)
- DRR image: 0.514 MB (512x512x2)
- CBCT images: 28 MB (55 x 0.512 MB)

Typical CT-based plan size: 50-200 MB

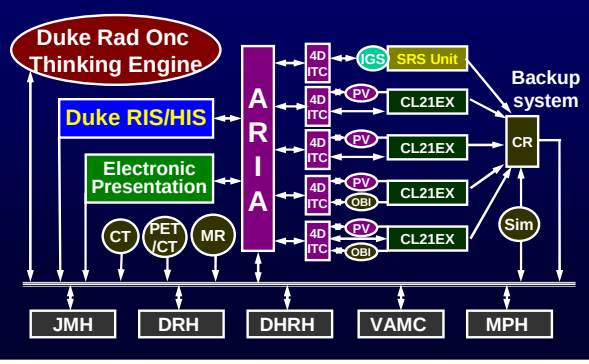
Typical IGRT patient fold size: 600MB-2GB

Information Integration



- Computation (Seconds, minutes?)
- Speed (Seconds?)
- Accessibility (Anywhere?)
- Quality assurance (Pre-, on-line? after?)

Planned Duke Integration



Question 1

Which of the following imaging systems is not used for real-time on-board imaging in the treatment room for patient positioning and target localization?

A. The 2-D kV x-ray imaging system with a single detector/tube combination, fixed to the treatment room
B. The 2-D kV x-ray imaging system with a single detector/tube combination, mounted to the gantry orthogonal to the portal imager
C. The orthogonal kV x-ray imaging system with dual detectors/tubes, fixed to the treatment room
D. The ultrasound imaging with an optical localization device
E. The slice-by-slice tomographic imaging device with MV beams

Question 1

Which of the following imaging systems is not used for real-time on-board imaging in the treatment room for patient positioning and target localization?

35% A. The 2-D kV x-ray imaging system with a single detector/tube combination, fixed to the treatment room
2% B. The 2-D kV x-ray imaging system with a single detector/tube combination, mounted to the gantry orthogonal to the portal imager
2% C. The orthogonal kV x-ray imaging system with dual detectors/tubes, fixed to the treatment room
50% D. The ultrasound imaging with an optical localization device
12% E. The slice-by-slice tomographic imaging device with MV beams

Question 2

Which of the following imaging systems can be used to generate on-board cone-beam CT images in the treatment room for patient positioning and target localization?

A. The 2-D kV x-ray imaging system with a single detector/tube combination, fixed to the treatment room
B. The 2-D kV x-ray imaging system with a single detector/tube combination, mounted to the gantry orthogonal to the portal imager
C. The orthogonal kV x-ray imaging system with dual detectors/tubes
D. The CT-on-the-Rail device in the treatment
E. The slice-by-slice tomographic treatment unit

Question 2

Which of the following imaging systems can be used to generate on-board cone-beam CT images in the treatment room for patient positioning and target localization?

12% A. The 2-D kV x-ray imaging system with a single detector/tube combination, fixed to the treatment room

67% B. The 2-D kV x-ray imaging system with a single detector/tube combination, mounted to the gantry orthogonal to the portal imager

7% C. The orthogonal kV x-ray imaging system with dual detectors/tubes

7% D. The CT-on-the-Rail device in the treatment

7% E. The slice-by-slice tomographic treatment unit

Question 3

The time needed for acquiring projections around 360-degree gantry rotation to reconstruct on-board cone-beam CT data is about one minute. The reason is:

A. The manufacturers are not able to rotate the gantry faster than this speed

B. The engineering limitation prohibits any speed faster than this speed

C. The IEC recommends a speed limitation for the treatment gantry rotation

D. Both therapists and patients like this speed

E. The limitation of data acquisition of the detector signals

Question 3

The time needed for acquiring projections around 360-degree gantry rotation to reconstruct on-board cone-beam CT data is about one minute. The reason is:

5% A. The manufacturers are not able to rotate the gantry faster than this speed

3% B. The engineering limitation prohibits any speed faster than this speed

78% C. The IEC recommends a speed limitation for the treatment gantry rotation

1% D. Both therapists and patients like this speed

13% E. The limitation of data acquisition of the detector signals

Continued by
Dr. Jeffrey H. Siewerdsen