AAPM TG 104

In-room kV imaging

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Outline

• Background (Wong)
  – Many models
    • Room mounted, machine mounted
• Present Status (Jaffray)
• Future Direction (Yin)
Disclosure

• John Wong receives
  – royalty for on-board cone beam CT imaging
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In the beginning, well ... 1980

• 1980 – 1990; planning
  – CT-based dose calculations

• 1990 – 2000; delivery and uncertainty management
  – 3D conformal therapy (CRT)
  – IMRT
  – Adaptive RT

• 2000 -- ... era of IGRT
  – In room imaging, MV, ultrasound, kV
MV verification with Electronic Portal Imaging Devices

- Fast frame rate (+)
- High resolution (+)
- Bulky (-)
- Slow acquisition (-)
- Low resolution (-)
- Thin footprint (+)
Issues: radiographic verification

• What is the limit of setup accuracy based on bony landmark?
  – kV prescription; MV verification

• What is the optimal PTV margin for setup?
  – Population (institution) vs individual
  – Need for repeat imaging

• What is the actual dose delivered to the patient?
  – From 2D to 3D
Absorption Unsharpness: kV vs MV

50 kVp  
100 kVp  
6 MV
Absorption Unsharpness: kV vs MV

Transmission (scaled to full range)

X Position (mm)

-15 -10 -5 0 5 10 15

Transmission curves for different energies:
- 30 keV
- 50 keV
- 2 MeV
- 6 MV
- 100 kVp
- 50 kVp

Detector (M=1.05)
Daily vs weekly setup detection: 9 H&N patients

Alignment Comparison
(all treatments, 9 patients)

- Need for frequent imaging

\[ y = 0.67 + 0.69x \]
\[ r\text{-square} = 0.707 \]
What dose is delivered to the patient?

Dose reconstruction with portal dose image
ADAPTIVE CORRECTION:

1. Measured entrance fluence, $P_{en}$
   - Calculated portal dose distribution, $D_{c,i}$

2. Compare measured portal distribution $D_m$ and $D_{c,i}$
   - If $\frac{D_m}{D_{c,i}} < 1.0 \pm \epsilon$, calculate patient dose

3. If not, Correction according to "CT error" model
Using PDI – difference to estimate internal structural changes

- Simulated 3D lungs
  - $\rho$ (lung 1) = 0.2
  - $\rho$ (lung 2) = 0.3
Using PDI – difference to estimate internal structural changes

- Failed rotation
- *Need more projections*
- *kV imaging*

CT data

At time of Tx

Est’d data
On-board kV imaging is not new!!

PMH
Haynes Radiology
Dual Beam kV-MV Imaging (DBI) - 1
Dual Beam kV-MV Imaging (DBI) - 2
kV vs MV projection imaging for setup

(a)

(b)

(c)
Daily on-line correction
14 patients:
Lateral shifts
On-board kV imaging experience

• kV vs MV 2D setup error detection
  – No significant difference with rich anatomical information
• kV imaging dose is low
  – Frequent imaging (more exposure) is possible
• No information on soft tissue
  • Obvious !!! ---- kV CT → kV conebeam CT
DBI: Conebeam Acquisition, Lab Rats

Coronal

Sagittal
DBI

Conebeam Acquisition
Lab Rats
Voxel: 1.0x0.4x0.4 mm³
Matrix: 301x301x201
Imaging Parameters:
  125 kVp
  3.75 mAs/projection
  180 projections
  2°/projection
  $T_{acq} = 17$ min
  $T_{recon} = 2$ hr 30 min
On-board CBCT
Room mounted models

Digital Detector

kV x-ray tube
In-room tomographic system
(Varian ExaCT™ at MDACC)