The EPID Strikes Back

Novel Applications for Current EPID Technology

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Disclosures

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Novel Applications for Current EPID Technology

2d
EPID – QA tools
RT verification
RT real-time adjustment

3d
MV-CBCT
3d fluoroscopy & dose estimation

Dose
(topic of next presentation by Dr. Greer)
EPID vs kV: key features and imaging dose

- Good image quality (contrast)
- Decreased quality with MV on (scatter)
- Additional dose to the patient

\[ s \propto \frac{Z_{eff}}{E^3} \]

\[ s \propto \rho_e \]

- Poor image quality (contrast)
- What you see is what you treat
- No imaging dose


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(topic of next presentation by Dr. Greer)
EPID as a QA tool

- Radiation isocenter verification
- MLC QA

Flatness & Symmetry (and many other tasks)

EPID as a QA tool

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Flatness & Symmetry (and many other tasks)

Motion assessment during RT

- ITV typically contoured on 4DCT
- 4DCT depicts only short snapshot
- 4DCT can have motion artifacts

Exhale
Inhale

Extended ITV expansion

Exhale
Inhale
**EPID fiducial tracking 3DCRT (Liver SBRT)**

- **DRR**
- **EPID (0.7 fps)**


**EPID fiducial tracking IMRT / VMAT**

- **MLC motion**
- **Limited visibility**

Y Ma et al., Four-dimensional inverse treatment planning with inclusion of implanted fiducials in IMRT segmented fields. *Med Phys* 36, 2215 (2009)

Y Yue et al., 3D fiducial motion tracking using limited MV projections in arc therapy. *Med Phys* 38, 3222 (2011)

Incorporate prior knowledge to overcome missing observations

**EPID markerless tracking (Lung SBRT)**

1. Automatically identify multiple landmarks

   - **Mean tracking error**
   - Phantom $\Delta < 1\text{mm}$
   - Patient $\Delta < 2\text{mm}$

2. Multiple template matching and average displacement calculation
   - Robust for deformation and partial occlusions
   - Difficult with MLC motion

Rottmann et al., A multi-region algorithm for markerless beam’s-eye-view lung tumor tracking. *PMB* 2010
Rottmann et al., Real-time soft tissue motion estimation for lung SBRT using soft tissue motion estimation. *PMB* 2013
Novel Applications for Current EPID Technology

- Introduction
- 2d: EPID - QA tools, RT verification, RT real-time adjustment
- 3d: MV CBCT, 3d fluoroscopy & dose estimation
- Dose: (topic of next presentation by Dr. Greer)

EPID driven motion mitigation during RT

- MLC leaf adjustment
- Leaf position calculation
- Prediction
- Real-time motion estimation
- Frame grabber

Using markerless EPID tracking to drive MLC

- Assess motion
- Some intermediate steps...
- Mitigate motion
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(topic of next presentation by Dr. Greer)

3D fluoroscopy during RT delivery

real-time EPID (in-treatment)

4DCT (pre-treatment)

→

3D in-treatment image estimation

Pre-treatment: motion model generation

Deformation vector fields (DVF)

Find DVF base vectors

4DCT (all phases)

DVF(1)

DVF(2)

DVF(3)

DVF(t)

PCA

DVF basis \( e_l, e_2, ..., e_k \)

Example: generate CT at time \( t \) from reference CT

4DCT (ref phase)

DVF(t)

\( \text{ref phase} \)

CT(t)

DVF(t) can be described with only 2-3 numbers \( (w_1, w_2, w_3) \)
In-treatment: 3D fluoroscopy estimation

1. Acquire EPID images in real-time

2. Find DVF to best match [DRR-EPID]

Application: delivered dose accumulation

Application: delivered dose accumulation

Tumor tracking and delivered dose calc

Beam tracking delivery (XCAT)  Dose accumulation (on ref phase)
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**dose**

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**MV-CBCT**

**Pro:**
- Readily available on LINAC
- Treatment geometry
- Low metal artefacts
- Treatment energy used → treatment planning on-the-fly

**Contra:**
- Inferior image contrast (contouring)
- Imaging dose (detector dependent)

MV-CBCT

- Hip prosthesis
- Spinal metal implant

Hansen et al, 2006, IJROBP 66(2), 323-326

J Pouliot et al, 2006

(Figure references)
Summary

• Verification during RT, negligible imaging dose
  – Fiducials and markerless (e.g. lung SBRT)
• Convenient QA tools replacing films
• In-treatment volumetric imaging & 3d delivered dose
• MV-CBCT: metal artifact reduction, image dose?

THANKS
... Questions?