



The EPID Strikes Back

Novel Applications for Current EPID Technology

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Disclosures and acknowledgements

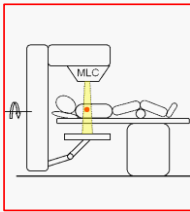
Disclosures

- Varian MRA grant

Acknowledgements

- Boston group (Berbeco et al, Williams et al)
- JH Lewis et al, S Dhou, P Mishra, M Hurwitz, W Cai, S St James
- Radiation Physics Laboratory (Keall et al), Australia

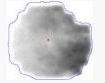
Novel Applications for Current EPID Technology



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

gantry

OBI
x,z

couch

dx

- $\sigma \propto \left(\frac{Z_{eff}}{E}\right)^3$
- Good image quality (contrast)
- Decreased quality with MV on (scatter)
- Additional dose to the patient

gantry

couch

EPID x,y

dz

clearance > 15cm

- $\sigma \propto \rho_e^-$
- Poor image quality (contrast)
- What you see is what you treat
- No imaging dose

Kilby et al 2003, Phys. Med. Biol. 48 3117-3128 -- Rottmann et al 2010, Phys Med Biol Vol. 55(18), pp. 5585-5598

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EPID vs kV: key features and imaging dose

gantry

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Kilby et al 2003, Phys. Med. Biol. 48 3117-3128 -- Rottmann et al 2010, Phys Med Biol Vol. 55(18), pp. 5585-5598

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
dose

(topic of next presentation by Dr. Greer)

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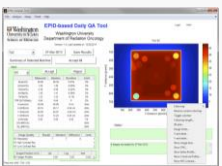
EPID as a QA tool

Radiation isocenter verification



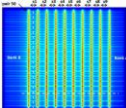
Rowshanfaraz et al, Med. Phys. 38, 3963 (2011)

Flatness & Symmetry (and many other tasks)



Sun et al, Med. Phys. 42, 5584 (2015)

MLC QA picket fence




A Agnew et al, Phys. Med. Biol. 59 N49 (2014)

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


MV-CBCT

3d fluoroscopy & dose estimation



dose




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Motion assessment during RT

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

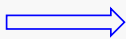



Exhale




Inhale

Extended
ITV
expansion





Exhale

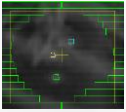


Inhale


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EPID fiducial tracking 3DCRT (Liver SBRT)

DRR




EPID (0.7 fps)






LoG filter to segment fiducials


Day 1: -2.3 mm




Day 2: -1.0 mm




Day 3: -2.7 mm




Day 4: -4.4 mm




Day 5: -7.6 mm



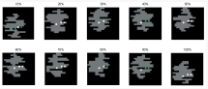
Park SJ et al., Automatic marker detection and 3D position reconstruction using cine EPID for SBRT verification. Med Phys 36(10) 4536-4546. (2009)

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

EPID fiducial tracking IMRT / VMAT



MLC motion
→ limited visibility




fiducial visibility aim included in IMRT plan optimization



incorporate prior knowledge

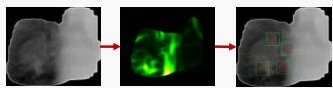
Using prior knowledge to overcome missing observations

Y Ma et al., Four-dimensional inverse treatment planning with inclusion of implanted fiducials in IMRT segmented fields. Med. Phys. 36, 2215 (2009)
Y Tsai et al., 3-D fiducial motion tracking using limited MV projections in arc therapy. Med Phys. 38, 3222 (2011)

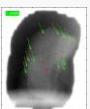
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EPID markerless tracking (Lung SBRT)

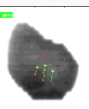
1. Automatically identify multiple landmarks



Mean tracking error

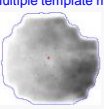


Phantom $\Delta < 1\text{mm}$




Patient $\Delta < 2\text{mm}$

2. Multiple template matching and average displacement calc



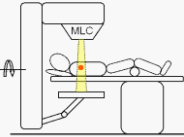
- Robust for deformation and partial occlusions
- Difficult with MLC motion

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 tumors during radiotherapy delivery. MedPhys 2013

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- RT real-time adjustment

3d

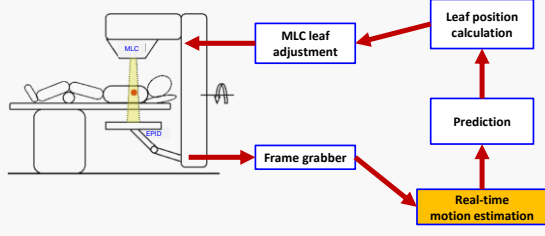
- MV-CBCT
- 3d fluoroscopy & dose estimation

dose

(topic of next presentation by Dr. Greer)

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EPID driven motion mitigation during RT



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Using markerless EPID tracking to drive MLC

assess motion

some intermediate steps ...

mitigate motion

RTV

GTV

Rottmann et al 2013, Phys Med Biol. 21:58(12):4195-204

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Novel Applications for Current EPID Technology

Introduction

2d

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3D fluoroscopy during RT delivery

real-time EPID (in-treatment)

4DCT (pre-treatment)

3D in-treatment image estimation

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Pre-treatment: motion model generation

Deformation vector fields (DVF)

4DCT (all phases)

4DCT (ref phase)

DVF(t)

Find DVF base vectors

DVF(t₁)
DVF(t₂)
...
DVF(t_N)

PCA

DVF basis $e^{v_1}, e^{v_2}, \dots, e^{v_N}$

$DVF(t) = DVF + w_1 e^{v_1} + w_2 e^{v_2} + w_3 e^{v_3}$

Example: generate CT at time t from reference CT

ref phase

DVF(t)

CT(t)

DVF(t) can be described with only 2-3 numbers (w_1, w_2, w_3)

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In-treatment: 3D fluoroscopy estimation

1. Acquire EPID images in real-time

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

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Application: delivered dose accumulation

2d EPID 3D fluoroscopic images (time resolved) Calculate delivered dose (on reference phase)

P Mishra et al. Estimation of time-varying volumetric treatment images and 3D tumor localization from single MV cine EPID images. Medical Physics. 2014; 41 (8): 081713

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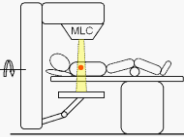
Tumor tracking and delivered dose calc

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

courtesy of Christopher Williams

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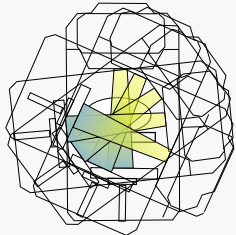
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MV-CBCT



Pro:

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

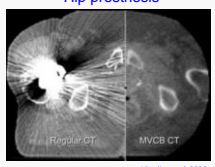
Contra:

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

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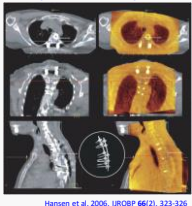
MV-CBCT

Hip prosthesis



J. Pouliot et al, 2006

Spinal metal implant



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

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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?



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