Radiation Therapy workflow

- Imaging
- 3D modeling
- Treatment planning
- RT setup and immobilization
- 4D modeling
- 4D planning
- 4D imaging
- Gated to planning
- Adaptive therapy (imagery, planning, delivery)
- 3D/4D CBCT

Case study – TrueBeam 6 MV FFF RapidArc Tx of a Lung SBRT

Supine Craniospinal Irradiation with RA

Available Imaging Tools

Spatial resolution
- XLCT
- XFCT
- PET
- SPECT
- CT
- MRI

Optical imaging
- US
- MRSI

Radioluminescence & X-ray Luminescence CT

Principle
- PET and SPECT scanners
- Optical
- Ionizing radiation
- Portal imaging
- Dosimetry
- Scintillation counting
- High-energy physics

Current applications
- PET and SPECT scanners
- Optical
- Ionizing radiation
- Portal imaging
- Dosimetry
- Scintillation counting
- High-energy physics

CT Molecular Imaging using QD and nanophosphors

Pratx, Sun, Carpenter & Xing, Optics Letters, 2011.

Modification of QD710-Dendron with a dimeric RGD peptide, RGD2. B: Excellent solubility and monodispersity in aqueous solution for the QD710-Dendron (left) and QD710-RGD2 (right). C: TEM image of QD710-RGD2. D: UV absorbance and NIRF of the QD710-Dendron (bottom) and QD710-RGD2 (top). In vivo NIRF imaging of QD710-RGD2 (active targeting, E) and QD710-Dendron (passive targeting, F) in mice bearing SKOV3 tumor (Cheng's lab).

@01-258_via99-011_hepatoma_onscreen
### Photon yield vs dose

Varian 100keV fluoro

![Photon yield vs dose](image)

### Multiplexing

(a) Schematics of the locations of each type of RLNP. The inactive particles are indicated with the abbreviation (Ctrl).

(b,c) The unmixed signal from the BaYF₄:Tb and BaYF₄:Eu particles, respectively. (d) The unmixed multiplexed image with colorbars for the relative concentrations of BaYF₄:Tb and BaYF₄:Eu.

(Chapman et al., 2012)

![Multiplexing](image)

### X-ray induced optical luminescence images

<table>
<thead>
<tr>
<th>Blank</th>
<th>Water</th>
<th>ssDNA-Agₓ</th>
<th>Lyszyme-Auₓ</th>
<th>BSA-Au₂₅</th>
</tr>
</thead>
</table>

![X-ray induced optical luminescence images](image)

---

@01-258_via99-011_hepatoma-onscreen
Reconstruction: ML-EM

Noise from counting statistics:

Log-likelihood:

\[ \log p(y|\theta) = \sum_{i=1}^{n} -y_i + m_i \log(y_i) - \log(m_i) \]

maximize \( f(\theta) = \sum_{i=1}^{n} -y_i + m_i \log(y_i) \)

subject to \( y = Ax \)

Expectation-Maximization:

\[ \frac{1}{n} \sum_{i=1}^{n} \frac{m_i}{\gamma + 1} \]

Molecular sensitivity = 0.3 pM @ 1cGy

Spatially Encoded Light Emission

X-ray Luminescence Tomography

Excitation fields

@01-258_via99-011_hepatoma_onscreen
Spatial resolution ~ 1 mm

Reconstruction & linearity

Sinogram

Simulation vs Experiment

X-ray Fluorescence Molecular CT Imaging

@01-258_via99-011_hepatoma_onscreen
X-ray Fluorescence Molecular CT Imaging

M. Balazova, Y. Kuang, G. Pratx, L. Xing, X-ray Fluorescence Molecular CT Imaging, IEEE Trans Med Imag., 2012

Fig. 1. (left) Proposed XFCT/CT system. (top) Physical mechanism of X-ray fluorescence from K-shell electrons.

K. Yu et al, AAPM 2012 (best paper in imaging)

Overcoming Compton Scatter

K. Yu et al, AAPM 2012 (best paper in imaging)

Multiplexing

K. Yu et al, AAPM 2012 (best paper in imaging)

@01-258_via99-011_hepatoma_onscreen
Summary

- Interaction of X-ray with endogenous or exogenous media provides the basis for X-ray molecular imaging.
- Highly sensitive and specific X-ray molecular imaging is possible.
- XFCT, XLCT and XACT are a few examples of X-ray molecular/physiological imaging that are being developed at Stanford.

@01-258_via99-011_hepatoma_onscreen