Functional image-based adaptive IMRT: dream or reality?

Vincent GREGOIRE, MD, PhD, Hon. FRCR

Radiation Oncology Dept. Head and Neck Oncology Program & Center for Molecular Imaging and Experimental Radiotherapy, Université Catholique de Louvain, St-Luc University Hospital, Brussels, Belgium
Oropharyngeal SCC
T2-N0-M0
SIB-IMRT: 30x2.3 Gy
30x1.85 Gy
Challenges in Head & Neck loco-regional treatment

• Target selection and delineation
• Adaptive IMRT: geometrical, biological & dosimetrically
  • which imaging modalities?
  • which biological pathways?
  • which volume/dose registration algorithms?
  • how frequently?
• Concomitant association with drugs and/or “small molecules”
Macroscopy

CAT Scan

$^{18}$F-FDG PET

Daisne et al, 2004
### How far are we from the truth?

#### TABLE 3

**GTVs in Patients with Laryngeal or Hypopharyngeal Tumors**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Tumor Site</th>
<th>T Stage</th>
<th>CT</th>
<th>MR Imaging</th>
<th>FDG PET</th>
<th>Surgical Specimen</th>
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<tbody>
<tr>
<td>1</td>
<td>PS</td>
<td>T4</td>
<td>47.7</td>
<td>36.3</td>
<td>19.3</td>
<td>NA</td>
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<tr>
<td>2</td>
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<td>T3</td>
<td>18.0</td>
<td>9.9</td>
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<tr>
<td>3</td>
<td>GL</td>
<td>T3</td>
<td>41.1</td>
<td>30.2</td>
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<td>NA</td>
</tr>
<tr>
<td>4</td>
<td>RC</td>
<td>T3</td>
<td>7.1</td>
<td>10.6</td>
<td>7.3</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>PS</td>
<td>T2</td>
<td>4.1</td>
<td>9.1</td>
<td>2.3</td>
<td>NA</td>
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<tr>
<td>6</td>
<td>SGL</td>
<td>T2</td>
<td>3.7</td>
<td>1.4</td>
<td>1.2</td>
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</tr>
<tr>
<td>7</td>
<td>SubGL</td>
<td>T3</td>
<td>5.8</td>
<td>7.0</td>
<td>3.2</td>
<td>NA</td>
</tr>
<tr>
<td>8</td>
<td>PS</td>
<td>T3</td>
<td>17.3</td>
<td>17.6</td>
<td>12.6</td>
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<tr>
<td>9</td>
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<td>T4</td>
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<td>T4</td>
<td>55.6</td>
<td>53.4</td>
<td>34.2</td>
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<tr>
<td>11</td>
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<td>1.9</td>
<td>2.4</td>
<td>3.4</td>
<td>2.2</td>
</tr>
<tr>
<td>12</td>
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<td>9.8</td>
<td>8.5</td>
<td>5.1</td>
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<tr>
<td>13</td>
<td>LAR</td>
<td>T4</td>
<td>41.0</td>
<td>58.4</td>
<td>30.2</td>
<td>30.9</td>
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<td>14</td>
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<td>4.1</td>
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<td>15</td>
<td>LAR</td>
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<td>14.6</td>
<td>22.0</td>
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<td>16</td>
<td>LAR</td>
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<td>22.0</td>
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<tr>
<td>17</td>
<td>LAR</td>
<td>T4</td>
<td>28.1</td>
<td>32.3</td>
<td>26.6</td>
<td>17.3</td>
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<tr>
<td>18</td>
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<td>T4</td>
<td>25.0</td>
<td>23.5</td>
<td>20.0</td>
<td>15.4</td>
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<td>19</td>
<td>LAR</td>
<td>T4</td>
<td>40.4</td>
<td>37.3</td>
<td>28.7</td>
<td>24.3</td>
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<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All patients (n = 19)</td>
<td></td>
<td></td>
<td>21.4</td>
<td>21.4</td>
<td>13.4*</td>
<td>NA</td>
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<tr>
<td>Patients with specimen available (n = 9)</td>
<td></td>
<td></td>
<td>20.8</td>
<td>23.8</td>
<td>16.3</td>
<td>12.6†</td>
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</table>

Note.—GL = glottic larynx, LAR = larynx without other specification, NA = not applicable, PS = pyriform sinus, RC = retro cricoid area, SGL = supraglottic larynx, SubGL = subglottic larynx.

* In the comparison with CT and MR imaging, *P* < .01 (for both).

† In the comparison with CT, MR imaging, and PET, *P* = .003, .001, and .06, respectively.
The “ground truth” GTV

<table>
<thead>
<tr>
<th></th>
<th>Vol (ml)</th>
<th>Mismatch_x/CT</th>
<th>Mismatch_x/MR</th>
<th>Mismatch_x/PET</th>
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<tr>
<td>CT</td>
<td>20.8</td>
<td>26%</td>
<td>48%</td>
<td>81%</td>
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<tr>
<td>MR</td>
<td>23.8</td>
<td>45%</td>
<td>-</td>
<td>67%</td>
</tr>
<tr>
<td>FDG-PET</td>
<td>16.3*</td>
<td>17%</td>
<td>15%</td>
<td>-</td>
</tr>
<tr>
<td>Macro</td>
<td>12.6*</td>
<td>10%</td>
<td>9%</td>
<td>13%</td>
</tr>
</tbody>
</table>

*p<0.05 (Wilcoxon rank test)

Daisne *et al*, 2004
Image-Guided Radiation Therapy in HNSCC

Impact of imaging modality on dose distribution

CT-based target volume  FDG PET-based target volume

Geets et al, 2006
Validation protocol in locally advanced HNSCC

Use of functional imaging with PET for target volume delineation in 3D-CRT/IMRT for head and neck tumors

Prof. V. Grégoire, UCL St-Luc, Brussels, Belgium
Prof. E. Lartigau, COL, Lille, France
Dr. JF Daisnes, Cliniques St-Elisabeth, Namur, Belgium
The Cathedral of Rouen

C. Monet, 1894
PRE-R/
(Week 2)

WEEK 3
(Week 4)

WEEK 5
• 10 patients with stage III-IV pharyngo-laryngeal SCC treated by CT-RT

• Images acquired before R/ and during RT after means doses of 14, 25, 35 and 45 Gy.
Image-Guided Radiation Therapy in HNSCC
The 4th dimension …

FDG-PET

0 Gy

50 Gy

IAEA
April 2009

Geets et al, 2003
PET image segmentation during RxTh

J. Lee & X. Geets, 2005
Impact on dose distribution

P<0.001

IAEA
April 2009

Geets, 2007
Impact on dose distribution

Classic CT-based planning  Adaptive PET-based planning

SIB-IMRT
30x2.3 Gy
30x1.85 Gy

<table>
<thead>
<tr>
<th>Planning</th>
<th>$V_{10}$</th>
<th>$V_{50}$</th>
<th>$V_{80}$</th>
<th>$V_{90}$</th>
<th>$V_{95}$</th>
<th>$V_{100}$</th>
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<tbody>
<tr>
<td>Classic CT-based</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Adaptive CT-based</td>
<td>99%</td>
<td>100%</td>
<td>100%</td>
<td>85%</td>
<td>80%</td>
<td>66%</td>
</tr>
<tr>
<td>Classic PET-based</td>
<td>99%</td>
<td>99%</td>
<td>98%</td>
<td>83%</td>
<td>82%</td>
<td>81%</td>
</tr>
<tr>
<td>Adaptive PET-based</td>
<td>99%</td>
<td>100%</td>
<td>98%</td>
<td>73%</td>
<td>67%</td>
<td>58%</td>
</tr>
</tbody>
</table>

P<0.001

Geets, 2007
Variation in therapeutic CTVs during RT-CH…

Mean slope: -1.46% / treat day (p<0.05)
Medial shift: 0.91mm after 25# (p<0.05)

Mean slope: -2.55% / treat day (p<0.05)
Lateral shift: 1.52mm after 25# (p<0.05)

IAEA
April 2009

Castadot & Lee, 2008
Mean slope: -0.47% / treat day (p<0.05)
No shift

Mean slope: -0.41% / treat day (p<0.05)
Medial shift: 1.76mm after 25# (p<0.05)

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April 2009

Castadot & Lee, 2008
Variation in parotid volumes during RT-CH...

Mean slope: -0.93% / treat day (p<0.05)
Medial shift: 3.21mm after 25# (p<0.05)

Mean slope: -1.03% / treat day (p<0.05)
No shift

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April 2009

Castadot & Lee, 2008
Total Dose really received by each volume element of the patient

Castadot & Lee, 2008
Dose distribution after adaptive RT-CH (n=5)

<table>
<thead>
<tr>
<th></th>
<th>« Classical » CT-based</th>
<th>« Classical » PET-based</th>
<th>« Real » CT-based</th>
<th>« Real » PET-based</th>
<th>Adaptive CT-based</th>
<th>Adaptive PET-based</th>
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<tr>
<td>Homolat Parotid D_{mean} (Gy)</td>
<td>22.05</td>
<td>21.63</td>
<td>23.80</td>
<td>23.27</td>
<td>22.91</td>
<td>22.09</td>
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<td>Heterolat Parotid D_{mean} (Gy)</td>
<td>18.15</td>
<td>20.00</td>
<td>18.52</td>
<td>19.34</td>
<td>18.57</td>
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<td>SC D_{2} (Gy)</td>
<td>39.49</td>
<td>39.76</td>
<td>41</td>
<td>42.04</td>
<td>37.90</td>
<td>38.26</td>
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<td>Larynx D_{5} (Gy)</td>
<td>65.63</td>
<td>66.33</td>
<td>65.37</td>
<td>66.35</td>
<td>65.57</td>
<td>65.37</td>
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<td>Oral cavity D_{mean} (Gy)</td>
<td>37.80</td>
<td>35.18</td>
<td>38.79</td>
<td>36.16</td>
<td>36.01</td>
<td>33.35</td>
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<td>Mandible D_{2} (Gy)</td>
<td>60.59</td>
<td>57.51</td>
<td>59.52</td>
<td>56.77</td>
<td>58.30</td>
<td>57.27</td>
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<tr>
<td>Homolat Submax gl D_{mean} (Gy)</td>
<td>65.04</td>
<td>62.96</td>
<td>65.52</td>
<td>63.59</td>
<td>64.57</td>
<td>63.09</td>
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<tr>
<td>Heterolat Submax gl D_{mean} (Gy)</td>
<td>54.92</td>
<td>53.77</td>
<td>54.97</td>
<td>53.63</td>
<td>55.11</td>
<td>54.58</td>
</tr>
<tr>
<td>Skin V_{65Gy} (cc)</td>
<td>11.66</td>
<td>8.78</td>
<td>12.08</td>
<td>9.25</td>
<td>10.25</td>
<td>7.24</td>
</tr>
<tr>
<td>V_{95%} (cc)</td>
<td>308.89</td>
<td>297.00</td>
<td>400.11</td>
<td>327.56</td>
<td>311.39</td>
<td>254.40</td>
</tr>
</tbody>
</table>
Which biological pathways? …
The dream …
The reality…

- Adaptive IMRT: geometrical, biological & dosimetrical
  - which imaging modalities??
  - which biological pathways??
  - which volume/dose registration algorithms??
  - how frequently??
Acknowledgements

• Communication and Remote Sensing Lab.  
  Adriana PARRAGA, Eng.  
  Benoît MACQ, Eng., Ph.D.

• ENT and Head & Neck surgery  
  Marc HAMOIR, M.D.
  Emmanuel COCHE, M.D.
  Thierry DUPREZ, M.D.
  Max LONNEUX, M.D.

• Imaging  
  Hervé REYCHLER, M.D., D.M.D.

• Oral & Maxillo-Facial surgery  
  Pierre MAHY, M.D.
  Birgit WEYNAND, M.D.

• Pathology  
  Anne BOL, Ph.D.
  Daniel LABARE, Ph.D.

• PET laboratory  
  Nicholas CHRISTIAN, M.D.
  Pierre CASTADOT, M.D.
  Xavier GEETS, M.D., Ph.D.
  John LEE, eng., Ph.D.
  Pierre SCALLIET, M.D., Ph.D.