IMRT for H&N Cancer

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Outline

• Treatment and QA Techniques
• Target Determination and Delineation
• Clinical Results
• Ongoing Study

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Fabrication of Non-invasive Immobilization
Thermoplastic Mask for IMRT

CT Simulation for H&N IMRT
Outline

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Target Determination
What to Shoot?

Clinical Target Volume Determination for Head and Neck IMRT

<table>
<thead>
<tr>
<th>Tumor Site</th>
<th>Clinical Presentation</th>
<th>CTV1 (70Gy/35fx)</th>
<th>CTV2 (63Gy/35fx)</th>
<th>CTV3 (56Gy/35fx)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>T1-2N0</td>
<td>GTVp</td>
<td>GTVp+n</td>
<td>GTVp+n</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>T1-2N0</td>
<td>GTVp</td>
<td>GTVp+n</td>
<td>GTVp+n</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larynx</td>
<td>T1-2N0</td>
<td>GTVp</td>
<td>GTVp+n</td>
<td>GTVp+n</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Target Delineation

Nodal Target for Head and Neck IMRT

For N0 neck, which one will you pick?

Target Delineation of Clinically N+/N- Necks in Patients Receiving Definitive IMRT

Chao et al., IJROBP 53:1174, 2002
Incidence of Extracapsular Extension of Metastatic Neck Node by Size

<table>
<thead>
<tr>
<th>Nodal size</th>
<th>&lt;1cm</th>
<th>1-3cm</th>
<th>&gt;3cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annyas 1979</td>
<td>23%</td>
<td>53%</td>
<td>74%</td>
</tr>
<tr>
<td>Johnson 1981</td>
<td>-</td>
<td>65%</td>
<td>75%</td>
</tr>
<tr>
<td>Carter 1987</td>
<td>17%</td>
<td>83%</td>
<td>95%</td>
</tr>
<tr>
<td>Hirabayashi 1991</td>
<td>43%</td>
<td>-</td>
<td>81%</td>
</tr>
</tbody>
</table>

Target Delineation of Clinically N+/N- Necks in Patients Receiving Definitive IMRT

Examples

T2N2bM0 SCC of Tonsillar Fossa

IMRT Target Dose Specification
T2N1M0 SCC of Base of the Tongue

Target Delineation of BOT Carcinoma

Post-operative IMRT

Sensitivity and Specificity of CT and MRI in Detecting Clinically Negative but Pathologically Positive Neck Nodes

<table>
<thead>
<tr>
<th>Author</th>
<th>Modality</th>
<th>Pt. No.</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stern 1990</td>
<td>CT</td>
<td>53</td>
<td>40%</td>
<td>92%</td>
</tr>
<tr>
<td>Friedman 1990</td>
<td>CT</td>
<td>68</td>
<td>68%</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>MRI</td>
<td>16</td>
<td>80%</td>
<td>82%</td>
</tr>
<tr>
<td>Moreau 1990</td>
<td>CT</td>
<td>32</td>
<td>50%</td>
<td>86%</td>
</tr>
<tr>
<td>Van den Bickel</td>
<td>CT</td>
<td>49</td>
<td>78%</td>
<td>86%</td>
</tr>
<tr>
<td>1993</td>
<td>MRI</td>
<td>55</td>
<td>88%</td>
<td>83%</td>
</tr>
<tr>
<td>Righi 1997</td>
<td>CT</td>
<td>32</td>
<td>50%</td>
<td>86%</td>
</tr>
</tbody>
</table>

MR Fusion for NPC Target Delineation
Target Delineation of Critical Structures

IMRT is “quid pro quo”
“something for something”
More Efficient??

• Class Solution
• Sharing Experience

www.imrttarget.org
Therapeutic Outcome of Oropharyngeal Carcinoma

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Median F/U</th>
<th>2yr LC</th>
<th>2yr DFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Def. CRT</td>
<td>153</td>
<td>3.5 yr (1.6-17.7)</td>
<td>68.3%</td>
</tr>
<tr>
<td>Def. IMRT</td>
<td>12</td>
<td>2 yr (1-3)</td>
<td>87.5%</td>
</tr>
<tr>
<td>Post-op CRT</td>
<td>142</td>
<td>3.9 yr (1.3-19.8)</td>
<td>75.7%</td>
</tr>
<tr>
<td>Post-op IMRT</td>
<td>14</td>
<td>2.2 yr (1.3-3.2)</td>
<td>100%</td>
</tr>
</tbody>
</table>

Chao et al. Radiotherapy & Oncology, 2001

Therapeutic Outcomes of Published Head and Neck IMRT Series

<table>
<thead>
<tr>
<th>Author</th>
<th>IMRT Planning</th>
<th>N Subsite</th>
<th>LC (%)</th>
<th>LRC (%)</th>
<th>OS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butler</td>
<td>Inverse planning</td>
<td>20</td>
<td>Multiple</td>
<td>N/A</td>
<td>85*</td>
</tr>
<tr>
<td>Dawson</td>
<td>Forward planning</td>
<td>58</td>
<td>Multiple</td>
<td>N/A</td>
<td>79 (2-y)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75 (5-y)</td>
</tr>
<tr>
<td>Lee</td>
<td>Inverse and forward</td>
<td>67</td>
<td>NPC</td>
<td>97 (4-y)</td>
<td>98 (4-y)</td>
</tr>
<tr>
<td>Chao</td>
<td>Inverse planning</td>
<td>126</td>
<td>Multiple</td>
<td>92 (3-y)</td>
<td>83 (3-y)</td>
</tr>
</tbody>
</table>

Materials and Methods
Chao et al. IJROBP 2003

- From 2/97 to 12/00
- 126 head and neck patients (96 male, 30 female)
- Median age 56 (range 13-84 years)
- 52 definitive, 74 postop
- 35 definitive IMRT patients received chemotherapy
- Median follow-up 29 months (range 19-62)
Materials and Methods

- Primary site
  - Oropharynx: 63
  - Oral cavity: 15
  - NPX: 12
  - Para. & nasal cav: 9
  - Larynx: 7
  - HPV: 8
  - Other sites: 3
- Def IMRT
  - 72.64±4.83 Gy to CTV1
  - 64.34±5.15 Gy to CTV2
- Postop IMRT
  - 68.53±4.71 Gy to CTV1
  - 60.95±5.33 Gy to CTV2
- T stages
  - T1: 19
  - T2: 33
  - T3: 27
  - T4: 38
- N stages
  - N0: 30
  - N1: 26
  - N2: 61
  - N3: 9
- AJCC staging
  - Stage I: 5
  - Stage II: 8
  - Stage III: 26
  - Stage IV: 78

Head and Neck IMRT - Results

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Def IMRT</th>
<th>Postop IMRT</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-year LRC</td>
<td>85</td>
<td>85</td>
<td>92</td>
<td>p=0.05</td>
</tr>
<tr>
<td>2-year OS</td>
<td>97</td>
<td>97</td>
<td>98</td>
<td>p=0.01</td>
</tr>
</tbody>
</table>

What Have We Learned?

- We observed no parotid or dermal failure.
- Satisfactory local-regional control in CTV2.
- Local failure predominantly within high dose regions
- Need to discern radioresistant subpopulation within CTV1

Outline

- Treatment and QA Techniques
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Biological Modifiers

Increase Volume
Decrease Volume

Dose Escalation
Dose Reduction

Refine Target Volume
Bigger or Smaller?

CT-FDG PET Imaging Co-registration for IMRT Target Delineation

CT-FDG PET Imaging Co-registration for IMRT Target Delineation

Marginal Failure or In-field Failure?

Marginal Failure
Better Target Delineation

Better Target Delineation
Biological Causes

Marginal Failure
In-field Failure

Biological Causes

Imaging Targets of Tumor Geno- and Pheno-type

Gene expression
Receptor, kinase
DNA Synthesis
Energy Metabolism
Blood Flow and Hypoxia

Marginal Failure
Better Target Delineation

In-field Failure

N- N+

Marginal Failure
Better Target Delineation

In-field Failure

N- N+

Marginal Failure
Better Target Delineation

In-field Failure

N- N+
A Target Coverage Scoring Function for IMRT Planning
-Based on the Probability of Gross Disease, Microscopic Tumor Extension and Lymph Node Metastasis

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¹M.D. Anderson Cancer Center
²Washington University Medical School
³University of Florida
A Score Function to Discriminate Probability of Microscopic Extension from Gross Tumor & Lymph Node Metastasis for Voxels within CTV

Probability of Tumor Extension vs. Distance

Probability of Nodal Metastasis vs. Distance in H&N Cancers

Score Function of Gross Disease, Microscopic Extension, and Nodal Metastasis

Problem (Example 2)

Lack of Spatial Information in DVH-based Optimization Algorithms

Plan 3

Gross tumor

Metastatic Node

Significantly Sparing Left Parotid
**Summary**

- Treatment and QA Techniques
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**Solution #1**

2-D Histograms for Dose-Volume-Tumor Extension/Metastasis Probability by Scoring Function

**Solution #2**

Relative Residual Tumor Burden: Voxel (RRTB) & Integral (IRRTB)

\[ RRTB_i = \sum_{ijk} \frac{SF_{Model}^{ijk}}{SF_{D}} \]

Where \( RRTB \) is the Relative Residual Tumor Burden of the \( i \)-th voxel, \( SF_{Model}^{ijk} \) is the surviving fraction of the model, \( SF_{D} \) is the prescribed surviving fraction, \( a \) and \( b \) are radioresistance parameters (\( a = 0.29 \) Gy\(^{-1} \) and \( b = 0.029 \) Gy\(^{-2} \)), \( D_{ij} \) is the total plan dose of the \( i \)-th voxel, and \( n \) is the number of fractions.

**Solution #3**

Plan 3

Underdosed volume located in the lower risk regions

**Plan 4**

Gross tumor

Significantly Spared Right Parotid

Metastatic Node

**Plan 4**

2-D Histograms for Dose Distribution

Underdosed volume located in the higher risk regions

**Solution #2**

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