CHOOSING AN INTENSITY-MODULATED RADIATION THERAPY TECHNIQUE IN THE TREATMENT OF HEAD-AND-NECK CANCER

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Purpose: With the emerging use of intensity-modulated radiation therapy (IMRT) in the treatment of head-and-neck cancer, selection of technique becomes a critical issue. The purpose of this article is to establish IMRT guidelines for head-and-neck cancer at a given institution.

Methods and Materials: Six common head-and-neck cancer cases were chosen to illustrate the points that must be considered when choosing between split-field (SF) IMRT, in which the low anterior neck (LAN) is treated with an anterior field, and the extended whole-field (EWF) IMRT in which the LAN is included with the IMRT fields. For each case, the gross tumor, clinical target, and planning target volumes and the surrounding critical normal tissues were delineated. Subsequently, the SF and EWF IMRT plans were compared using dosimetric parameters from dose–volume histograms.

Results: Target coverage and doses delivered to the critical normal structures were similar between the two different techniques. Cancer involving the nasopharynx and oropharynx are best treated with the SF IMRT technique to minimize the glottic larynx dose. The EWF IMRT technique is preferred in situations in which the glottic larynx is considered as a target, i.e., cancer of the larynx, hypopharynx, and unknown head-and-neck primary. When the gross disease extends inferiorly and close to the glottic larynx, EWF IMRT technique is also preferred.

Conclusion: Depending on the clinical scenario, different IMRT techniques and guidelines are suggested to determine a preferred IMRT technique. We found that having this treatment guideline when treating these tumors ensures a smoother flow for the busy clinic. © 2007 Elsevier Inc.

Intensity-modulated radiation therapy, Image-guided radiation therapy, Treatment techniques, Immobilization, Head and neck.

INTRODUCTION

Intensity-modulated radiation therapy (IMRT) in the treatment of head-and-neck cancer is increasingly being used in academic and community practices. This highly conformal method of treatment planning has brought forth tremendous enthusiasm to the treating physician as well as the treatment planner (1, 2). The use of IMRT allows the treatment planner to achieve dose distributions that are impossible with conventional two- and three-dimensional techniques. By targeting more precisely the irregularly shaped tumor volumes as well as minimizing doses delivered to the surrounding normal tissues, patients undergoing IMRT experience fewer treatment-related side effects, resulting in improved quality of life (3). Increasing numbers of academic institutions have reported excellent treatment outcomes when using parotid-sparing IMRT, and no evidence of compromised loco-regional control has been observed to date (4–6).

With the increasing prevalence of IMRT in the clinic, radiation oncologists are now confronted with the choice of optimal IMRT technique for different disease sites and clinical scenarios. One issue is whether patients with complex anatomy should undergo an extended whole-field (EWF) technique, in which the entire target volume is included in the IMRT plan, or a split-field (SF) IMRT technique, in which the target volumes superior to the vocal cords are treated with an IMRT plan while the lower neck nodes are treated with a conventional low anterior neck (LAN) field (7). Debates among radiation oncologists on which IMRT technique should be used for head-and-neck cancer have been ongoing. Concerns of failure at the matchline have prompted many centers to use the EWF IMRT technique even when no clinically involved lymph nodes exist in the region of the matchline (8). This concern could be caused by the treatment delivery system that is used at the center where it was not possible to have a perfect match between the IMRT fields and the LAN field. However, this has generated controversy among many who believed that an unnecessary dose of radiation was delivered to the nor-
nal nondiseased glottic larynx (9). Other experts in head-and-neck cancer advocate the SF IMRT technique (7, 10). Perhaps because of the delivery system used at these centers, no matchline problems are seen. In addition, in this SF IMRT technique, the normal vocal cords are typically situated beneath the cerrobend block or the multi-leaf collimator (MLC) and, therefore, receive minimal dose. Although no formal quality-of-life studies have been done to compare the voice quality between EWF IMRT vs. the SF IMRT technique, such a study is being considered. A study by Fung et al. (11) did evaluate the voice quality after external beam radiotherapy. The investigators compared patients who underwent irradiation for early-stage glottic tumors vs. patients who had wide-field radiation portals in whom the disease did not involve the glottic larynx. The investigators presented both objective and subjective evidence of vocal dysfunction in patients treated with wide-field radiation for nonlaryngeal tumors where the mean laryngeal dose was 50 Gy. This was especially evident for younger patients. It was concluded that the vocal dysfunction may increase with time (12).

Although several centers have reported their findings for the EWF or the SF IMRT techniques, published guidelines regarding which is the more appropriate technique when treating different sites within the head and neck are lacking. Because of the complexity stated above concerning the use of IMRT in the treatment of head-and-neck cancer, we offer treatment guidelines focusing on the selection of IMRT technique. Six different cases of commonly seen head-and-neck cancers (Table 1) were chosen to illustrate which IMRT technique is preferred over another technique in a given clinical scenario. We anticipate that these guidelines will enable treating physicians to a priori select the most optimal IMRT approach. Doses delivered to the target volumes, surrounding normal structures, from EWF vs. SF IMRT technique are compared. The pros and cons of these two different head-and-neck IMRT techniques are discussed, and a systematic approach to determine the preferred IMRT treatment technique for a given head-and-neck cancer is suggested.

### Methods and Materials

**Patient characteristics**

Six different commonly seen head-and-neck cancer cases were chosen to illustrate choice of technique. It is our routine to have all patients undergo a computed tomography (CT) and/or magnetic resonance imaging (MRI) scan along with a positron emission tomography (PET) scan to verify the extent of disease before treatment unless medically contraindicated. Clinically involved lymph nodes are defined as $>1$ cm or any $\leq1$-cm lymph nodes with central necrosis detected on MRI or that are PET-avid (Table 1).

**Patient 1: Nasopharyngeal carcinoma, T1N1M0**

Patient 1 is a 54-year-old man who presented with a right neck mass in level II region near the parotid gland. At the outside institution, the patient was thought to have an unknown primary head-and-neck cancer and, therefore, underwent a right superficial parotidectomy along with an excisional biopsy of the level II lymph node that measured 3 cm. Pathologic findings revealed only disease involving the lymph node, which showed undifferentiated lymphepithelioma-like carcinoma. The patient was subsequently referred to our center for further evaluation. With MRI the nasopharynx and neck showed signal abnormality involving the right fossa of Rosenmuller as well as residual disease involving the right neck. Biopsy of the nasopharynx showed undifferentiated lymphoepithelioma-like carcinoma. There was no additional PET avid disease. The patient was staged as having T1N1M0 nasopharyngeal carcinoma and was subsequently treated with concurrent chemotheraphy with IMRT using the SF IMRT technique followed by adjuvant chemotherapy.

**Patient 2: Oropharyngeal carcinoma, T2N2bM0**

Patient 2 is a 58-year-old man who presented with an enlarged left level II lymph node measuring approximately 4 cm. Clinical examination as well as an MRI of the oropharynx and neck revealed a large lesion involving the left base of tongue extending to involve the pharyngeal wall. There was no extension to the vallecula and the epiglottis was not involved. An additional smaller lymph node measuring 1.5 cm was also found in the level II region. Biopsy of the base of the tongue showed invasive poorly differentiated squamous cell carcinoma. There was no additional PET-avid disease. The patient underwent concurrent chemotherapy with IMRT using the SF IMRT technique.

**Patient 3: Oropharyngeal cancer with enlarged $>3$ cm lymph nodes extending inferiorly to involve the low neck, T2N2bM0**

Patient 3 is a 47-year-old man who noted a large lump in his left neck. A CT scan generated at an outside institution revealed extensive cervical lymph nodes as well as disease involving the left palatine tonsil. An MRI of the oropharynx and neck showed markedly enlarged lymph nodes in the neck level involving levels I through V. The largest of these left-sided lymph nodes was in level II and measured approximately 4 cm. The palatine tonsil lesion extended to involve the left glossoptinal sulcus, left pharyngeal wall, left vallecular and the left epiglottis. A PET scan confirmed the above finding with no additional PET-avid disease. Pathologic findings revealed invasive poorly differentiated squamous cell carcinoma with basaloid features. The patient underwent concurrent chemotheraphy with IMRT using the SF IMRT technique.

**Patient 4: Supraglottic larynx cancer, T4aN2cM0**

Patient 4 is a 68-year-old man who presented to our clinic with a large exophytic lesion involving the supraglottic larynx along with multiple ipsilateral lymph nodes. With MRI of the neck a large mass involving the supraglottic larynx was revealed. The

### Table 1. Patient characteristics

<table>
<thead>
<tr>
<th>Site of disease</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasopharyngeal cancer</td>
<td>T1N1M0</td>
</tr>
<tr>
<td>Base-of-tongue cancer</td>
<td>T2N2bM0</td>
</tr>
<tr>
<td>Tonsil cancer with enlarged lymph nodes</td>
<td>T2N2bM0</td>
</tr>
<tr>
<td>Supraglottic larynx cancer</td>
<td>T4aN2cM0</td>
</tr>
<tr>
<td>Hypopharynx cancer</td>
<td>T3N2bM0</td>
</tr>
<tr>
<td>Unknown primary cancer of the head and neck</td>
<td>T4aN2cM0</td>
</tr>
</tbody>
</table>

Abbreviations: AJCC = American Joint Committee on Cancer.
Table 2. Dose specifications for head-and-neck cancer at Memorial Sloan-Kettering Cancer Center

<table>
<thead>
<tr>
<th>Target coverage</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV&lt;sub&gt;GTv&lt;/sub&gt; = 70 Gy</td>
<td>D95 = prescription dose</td>
</tr>
<tr>
<td>PTV&lt;sub&gt;CTVhigh&lt;/sub&gt; = 59.4 Gy</td>
<td>D95 = prescription dose</td>
</tr>
<tr>
<td>PTV&lt;sub&gt;CTVlow&lt;/sub&gt; = 54 Gy</td>
<td>D95 = prescription dose</td>
</tr>
<tr>
<td>Normal tissue constraint</td>
<td>Prescription</td>
</tr>
</tbody>
</table>
- Spinal cord | Dmax 45 Gy |
- Brain stem | Dmax 54 Gy |
- Optic nerves | Dmax 54 Gy |
- Optic chiasm | Dmax 54 Gy |
- Retina | Dmax 45 Gy |
- Cochlea | Dmax 50 Gy (D05 ≤ 55 Gy) |
- Parotid glands | Dmean ≤ 26 Gy |
- Oral cavity | Dmean 35-40 Gy |
- Brachial plexus | Dmax 65 Gy |
- D50 60 Gy |
- Larynx (when not involved) | Dmax ≤ 105% of prescription |
- Dmean 30-40 Gy |

Abbreviations: D95 = minimum dose to 95% of the volume; Dmax = dose to the maximum point; Dmean = mean dose; D05 = minimum dose to hotsie 5% of the volume.

Treatment planning

Treatment plans were designed using the Memorial Sloan-Kettering Cancer Center in-house treatment planning system and delivery was by means of a sliding window dynamic MLC technique using 6 MV photons (13, 14). Gantry, couch, and collimator angles were selected manually by the treatment planner. Plans were optimized with the goal of meeting the in-house dose specifications for both target volumes as well as critical normal tissue constraints (Table 2). When possible, a mean parotid dose of ≤ 26 Gy was achieved. In our previous publication, by Hunt et al. (15), we found it was difficult to achieve a mean parotid dose of ≤ 26 Gy when the parotid and the planning target volume (PTV) of the subclinical disease overlap was > 21%. We also found that parotid gland proximity to the high dose PTV of the gross tumor was associated with higher gland doses overall, but did not always preclude dosimetric sparing.

All 6 patients were immobilized with a thermoplastic head, neck, and shoulder mask to ensure accuracy and reproducibility of treatment (Fig. 1). The CT simulation with a scan thickness of 0.3 cm was performed in all patients. The treatment planning CT scan was used to define the gross target volume (GTV), clinical target volume (CTV), and PTV. The parotid glands, brachial plexus, larynx, cochlea, and optic structures, when relevant, were delineated slice by slice by the treating physician. Both the deep lobe and the superficial lobes of the parotid glands were contoured. The brachial plexus was defined from C5-T1 in between the anterior and middle scalene muscles. A margin of 5 mm around the fat plane that is seen between these two muscles was used to guide the brachial plexus contour. In the lower neck near T1, the subclavian artery was used to guide contouring of the brachial plexus. The larynx was defined by the boundaries of the true glottic larynx and included the arytenoids above and cricoid below. The cochlea is best seen on CT bone window by identifying the internal auditory canal. The cochlea is contoured with a 5-mm margin concentrically. No additional margins were given to the optic structures. All other structures, including brainstem (3–5 mm additional margin), spinal cord (entire bony canal), oral cavity (the entire oral cavity), and mandible (no additional margins) were delineated by the planner. The parotids were defined to be the entire gland whether or not PTV overlapped with the parotid gland. The PTV<sub>GTv</sub> received 70 Gy in 2.12-Gy fractions, whereas 59.4 Gy was pre-

Patient 5: Hypopharynx cancer, T3N2bM0

Patient 5 is a 70-year-old woman who developed dysphagia along with a left neck lymph node. With MRI of the neck a 4-cm soft tissue filling the entire left piriform sinus was shown extending to the left piriform sinus apex and the left paraglottic fat adjacent to the left true and false cords. There were multiple enlarged left neck nodes, largest measuring 2.3 cm. A PET scan failed to show any additional disease. The patient underwent concurrent chemotherapy with IMRT using the EWF IMRT technique.

Patient 6: Cancer of the head and neck with unknown primary, TxN2bM0

Patient 6 was a 75-year-old man who presented to our clinic with a right level II lymph node. The patient underwent direct laryngoscopy under anesthesia and multiple biopsy specimens were taken with no evidence of any disease. Both PET and MRI also failed to show any evidence of a primary disease. The patient underwent a right neck dissection and pathology reviewed three of 15 positive lymph nodes on level II, largest measuring 2.5 cm with no extracapsular extension. All other lymph nodes in levels I, III, IV, and V were all negative. The patient underwent postoperative radiation alone using the EWF IMRT technique.

Fig. 1. A patient immobilized with a head, neck, and shoulder mask.
scribed to the PTV of high-risk subclinical disease (PTV_{high risk}). A third dose of 54 Gy was prescribed to the PTV of low-risk subclinical disease (PTV_{low risk}).

Each of the six selected patients received treatment at our clinic, with either the EWF or SF IMRT technique depending on the site. The nasopharynx and oropharynx patients were treated with a SF technique. For oropharynx cancer with disease extending to the low neck, cancer of the larynx, hypopharynx, and unknown primary, EWF IMRT technique is used. Complimentary plans using the alternate technique were subsequently constructed for each of these six patients for purposes of analysis.

Planning technique for SF treatment

A description of the standard SF IMRT technique used at our institution has been previously reported (16). At simulation, a single isocenter is placed by the physician typically just above the arytenoids. This is also the location of the matchline between the IMRT plan, which is superior to the matchline/isocenter and the conventional anterior-posterior LAN field which is inferior to the matchline/isocenter. Beam angles for the IMRT plan are chosen depending on the geometry of the target volumes; the standard template calls for angles of 90°, 120°, 150°, 180°, 210°, 240°, and 270° (Fig. 2), although the planner may choose different angles at his or her discretion depending on the particular tumor site, extent, and geometry. A simultaneous integrated boost, also known as the dose painting IMRT technique, is our institution’s standard practice.

By convention, the IMRT part of the treatment plan is normalized such that the D95 of PTV_{GTV} (with a 0.5-cm buildup region excluded) is equal to the prescription dose for both the SF and the EWF IMRT technique. Since Patient 1 was involved in a Radiation Therapy Oncology Group nasopharyngeal carcinoma protocol, the normalization to this plan was slightly different to meet protocol criteria.

During optimization in the SF technique, the inferior jaw of the IMRT fields is extended 1 cm below the matchline. For target structures that lie within one or two slices of the matchline, an extended PTV (PTV_{E}) is created for optimization purposes in which the most inferior slice is duplicated inferiorly one or two slices past the matchline. Once the optimization is complete, the jaw is closed to its proper position thereby insuring that the matchline penumbra is due solely to the jaw and not to the optimization. Without this artificial jaw expansion, the optimization algorithm will attempt to deposit greater dose near the matchline to compensate for the lower fluence in the penumbra region. For patients where coverage to the skin is clinically indicated, a 5-mm bolus is placed to ensure adequate coverage.

The positioning of the jaw is especially important in the matchline region, since a change in jaw position implies a change in penumbra position within the field. A small change in the inferior jaw position of the IMRT region can mean a dose discrepancy on the order of 10% in the penumbra region. This is especially crucial when there is clinically apparent disease in the matchline region. With this technique, it is assumed that coverage in the region of the matchline is because of the combined effects of the IMRT fields and the single LAN field. This technique, therefore, is not suitable for patients who have clinically evident disease at the matchline. The EWF IMRT plan would be preferred over the SF IMRT technique in patients who have disease at the matchline described below.

Planning technique for EWF treatment

The EWF IMRT planning technique is similar to the SF IMRT technique except that the LAN nodes are included in the IMRT field. The standard beam arrangement for SF cases is unacceptable for two reasons, which both concern the LAN portion of the target. First, the inferior extent of the low neck target will require the lateral beams to treat through the shoulder which is undesirable. One way to address this issue is to use partial lateral fields that treat only a portion of the target above the shoulder. However, partial fields have the disadvantage of treating the target with the inferior penumbra of the beam and are sensitive to the calibration of the jaw position on the linear accelerator in the same way as the inferior jaws were in the SF IMRT technique. For this reason, if partial lateral fields are used, the inferior jaw setting of the two lateral fields are set so as to differ by at least 1 cm (Fig. 3).

A more common beam arrangement replaces the lateral fields with anterior oblique fields which avoid the shoulder. If the shoulder is still partially in the field it can be avoided by rotating the collimator or by forcing the optimization to station leaves over the shoulder. With this approach, it is possible to at least partially treat the low neck portion of the target with all the fields. Since the low neck portion of the target is primarily located anteriorly, it is desirable to use anterior beam arrangements in this portion of the target instead of the standard beam arrangement that is used for the SF technique. Some of the posterior oblique beams can, therefore, be replaced by beams in the region of their parallel-opposed counterparts. Taking into account the two issues discussed above, a typical 7-field beam arrangement for EWF is as follows: posterior beam angles of 150°, 180°, and 210°, and anterior oblique beam angles of 285°, 310°, 50°, and 75° in which the beams at 285° and 75° are blocking the shoulders as described above (Fig. 4). Again, as in the SF IMRT case, these angles are only suggested and the planner is free to change them as he or she chooses. Similar to the split field technique, the DVH calculations for the PTVs are done with the buildup region excluded.

Comparison of complimentary plans

Once treatment planning was completed, we subsequently compared the plans generated by the 2 different IMRT techniques, i.e., EWF vs. SF IMRT technique. Comparisons were made on PTV coverage as well as the ability of both techniques to respect the tolerance of the surrounding normal critical tissue. The inhomoge-
geneity of the plans, the delivery time of treatment were also compared. Because this is not a formal treatment planning study but rather an illustration of the factors which are important for the clinician when choosing the proper IMRT technique for head and neck, no attempt was made to create a superior complimentary plan relative to the one used clinically. Our intent is to enable the treating physician to *a priori* select the most optimal IMRT approach.

RESULTS AND DISCUSSION

**Nasopharynx and oropharynx (patients 1 and 2)**

Results are summarized in Table 3. Although we typically calculate DVHs when planning these cases for only the IMRT treatment, the contribution of the LAN and any electron boosts were included for the SF IMRT technique for comparison purposes. This is why the coverage shown for the PTVs in the SF IMRT technique is slightly higher than the prescription dose of 70 Gy. The planning time is somewhat subjective. We did not appreciate a difference in terms of the planning time between the two different techniques. In addition, no difference in terms of the homogeneity of the plans and the delivery time was observed.

Similar to the findings at the M. D. Anderson Cancer Center (7), we also found that target volume coverage was similar whether patients underwent EWF or SF IMRT treat-
ment for nasopharyngeal cancer (Fig. 5). Doses to the surrounding critical structures are similar except for the dose to the glottic larynx which was higher for the EWF plan (Table 3). These findings are also true for cancer of the oropharynx (Fig. 6). Despite plan optimization to minimize the dose delivered to the larynx in the EWF IMRT technique, the mean doses to the larynx were 30.7 Gy and 31.3 Gy for the nasopharyngeal case and the oropharyngeal case, respectively. Although contouring time is subjective between different centers as well as physicians, for a given physician, we found that the contouring time is increased by approximately 30 min when EWF IMRT technique is used. When we extended our IMRT fields to the low neck, we also needed to contour the brachial plexus to ensure that no

### Table 3. Extended whole-field (EWF) versus split-field (SF) intensity-modulated radiation therapy doses for each patient

<table>
<thead>
<tr>
<th>Dose (Gy)</th>
<th>1 (SF) EWF/SF</th>
<th>2 (SF) EWF/SF</th>
<th>3 (EWF) EWF/SF</th>
<th>4 (EWF) EWF/SF</th>
<th>5 (SF) EWF/SF</th>
<th>6 (EWF) EWF/SF</th>
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<tr>
<td>PTV70 D95</td>
<td>71.3/70.3</td>
<td>70.0/71.1</td>
<td>68.7/70.4</td>
<td>70.0/71.5</td>
<td>70.0/70.8</td>
<td>70.0/70.2</td>
</tr>
<tr>
<td>PTV70 D05</td>
<td>74.9/74.1</td>
<td>75.0/76.2</td>
<td>76.0/78.1</td>
<td>76.2/78.9</td>
<td>74.4/75.5</td>
<td>72.6/73.0</td>
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<tr>
<td>PTV59.4 D95</td>
<td>59.4/59.5</td>
<td>59.9/60.4</td>
<td>58.7/58.3</td>
<td>59.5/59.7</td>
<td>58.6/56.0</td>
<td>58.3/58.8</td>
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<tr>
<td>PTV59.4 D05</td>
<td>67.4/69.1</td>
<td>68.9/70.2</td>
<td>71.0/73.8</td>
<td>68.9/72.0</td>
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<td>67.1/68.1</td>
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<td>PTV54 D95</td>
<td>NA</td>
<td>52.9/54.2</td>
<td>54.0/NA</td>
<td>53.3/53.6</td>
<td>52.6/53.0</td>
<td>53.2/54.9</td>
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<tr>
<td>PTV54 D05</td>
<td>NA</td>
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<td>56.8/NA</td>
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<td>59.7/60.1</td>
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<tr>
<td>Cord Dmax</td>
<td>38.7/48.4</td>
<td>44.3/47.3</td>
<td>44.8/46.8</td>
<td>43.1/46.6</td>
<td>42.4/42.9</td>
<td>40.0/41.4</td>
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<td>Brastem Dmax</td>
<td>52.5/52.4</td>
<td>46.5/48.3</td>
<td>48.2/50.1</td>
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<td>46.6/47.8</td>
<td>40.6/42.4</td>
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<td>R Parotid Dmean</td>
<td>35.7/36.4</td>
<td>18.4/20.1</td>
<td>26.0/24.3</td>
<td>21.9/23.9</td>
<td>24.5/24.5</td>
<td>22.0/23.9</td>
</tr>
<tr>
<td>L Parotid Dmean</td>
<td>24.4/25.6</td>
<td>24.0/25.2</td>
<td>26.0/25.9</td>
<td>20.6/23.1</td>
<td>25.5/25.8</td>
<td>20.7/21.3</td>
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<td>Oral Cav. Dmean</td>
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<td>36.2/41.0</td>
<td>32.0/32.0</td>
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<td>R Cochlea Dmax</td>
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<td>46.7/49.6</td>
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<td>48.3/50.5</td>
<td>48.1/46.6</td>
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<td>29.5/35.0</td>
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<td>Mandible Dmax</td>
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<tr>
<td>Larynx Dmax</td>
<td>51.5/46.3</td>
<td>42.1/54.7</td>
<td>70.1/71.4</td>
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<td>74.3/76.0</td>
<td>64.0/63.9</td>
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<tr>
<td>Larynx Dmean</td>
<td>30.7/10.6</td>
<td>31.3/19.0</td>
<td>61.1/26.7</td>
<td>NA</td>
<td>69.0/69.6</td>
<td>61.3/61.2</td>
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<tr>
<td>R Plexus Dmax</td>
<td>64.8/52.6</td>
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</tbody>
</table>

**Abbreviations:** D95 = minimum dose to 95% of the volume; D05 = minimum dose to hottest 5% of the volume; Dmax = dose to the maximum point; Dmean = mean dose.

Clinically treated plan is in parentheses next to patient number.

Fig. 5. A coronal isodose distribution for Patient 1 (nasopharyngeal cancer) for both the extended whole-field intensity-modulated radiotherapy (a) and the split-field (SF) intensity-modulated radiotherapy (IMRT) (b) techniques. The red and yellow lines represent 70 Gy and 59.4 Gy respectively. The dose below the isocenter for the SF IMRT technique for this patient and the remaining patients is caused by the conventional low anterior neck (LAN) field and any electron boosts that may be necessary. Notice that the blue isodose line for the SF IMRT technique represents 50.4 Gy which is the standard dose used in the conventional LAN field. Figure appears in color online.
unwarranted hotspots were situated directly over the brachial plexus as result of the EWF IMRT plan. Therefore, for oropharyngeal and nasopharyngeal cases where the lymph nodes are not situated near the larynx, we prefer using the SF IMRT technique where the matchline is situated just above the arytenoids.

**Enlarged > 3 cm multiple lymph nodes extending to involve the low neck (Patient 3)**

When multiple clinically involved enlarged > 3 cm lymph nodes are detected in the low neck, the EWF IMRT technique ensures adequate target volume coverage by the 70-Gy isodose line. In the older conventional treatment where a LAN field is used, an en face electron field or fields are typically used to boost these enlarged > 3 cm lymph nodes to 70 Gy. There is always uncertainty of the dose in the boost region when dealing with photons and electrons. In addition, at our institution it is no longer our routine policy to perform a planned neck dissection. Typically 3 months after the completion of radiotherapy, the neck is evaluated by a PET/CT scan. If there is no evidence of residual disease, the neck will be observed. Therefore, we aim to ensure maximum coverage of these enlarged > 3 cm lymph nodes by using dose painting IMRT to boost these gross nodes to 70 Gy in attempt to achieve a complete response and avoid the morbidity associated with neck dissection.

**Figure 7** is an example of an oropharyngeal case with multiple clinically involved low neck nodes, levels I through V. This gentleman has a large tonsil tumor extending inferiorly to involve the left glossoptinal sulcus, left pharyngeal wall, left vallecular, and the left epiglottis. We elected to treat this patient with EWF IMRT technique to ensure coverage not only of the primary tumor site but also the neck nodes. All gross disease both at the primary site as well as the neck was encompassed by the 70-Gy isodose line. The maximum point dose to the left brachial plexus was 64.9 Gy, the D05 was 59.9 Gy, and the mean dose was 56.7 Gy. A complimentary plan was done where the matchline was placed just above the arytenoids. There was matching of the IMRT fields with the LAN field through the clinically involved neck nodes. The LAN received 50.4 Gy and multiple en face electron fields were used to boost the grossly positive lymph nodes in the low neck. The maximum point dose, D05, and mean dose to the left brachial plexus was 68.7 Gy, 55.1 Gy, and 48.7 Gy, respectively, because of the electron boost. Given that there is really no major difference to the brachial plexus and that one can be more certain of the coverage at the primary site and the neck, the EWF IMRT technique is preferred over SF IMRT technique with matching electrons for patients who present with clinically positive nodes involving the low neck.

**Larynx and hypopharynx (Patients 4 and 5)**

In conventional radiotherapy, the matchline for larynx or hypopharynx cases typically is at the most inferior extent of the cricoid cartilage. Head positioning is often difficult, as many patients have difficulty hyperextending their neck and keeping their shoulder as low as possible during simulation and treatment. The IMRT technique is therefore ideal for these cases. When we first launched IMRT for larynx and hypopharynx tumors, we used the SF IMRT technique. These plans were complicated by the need to ensure that the typical “spinal cord” block that is placed on the lateral fields with the conventional techniques is placed over many or all IMRT fields (typically seven to nine fields) (Fig. 8). The “spinal cord” block is important as it further ensures no overlap over the spinal cord at the matchline. Given these considerations, the EWF IMRT approach is the preferred IMRT technique (Figs. 9 and 10). With the EWF IMRT
technique, no matchline block is necessary on the IMRT fields as there are no overlap concerns for the spinal cord. In addition, a more homogenous plan can be achieved with excellent target volume coverage. This is in contrast with the SF IMRT plan where near the region of the matchline and the “spinal cord” block, the target volume coverage is compromised (Fig. 8).

Unknown primary (Patient 6)
Lastly, cancer of an unknown primary site within the head and neck often poses a challenge for the radiation oncologist. Typically, all potential primary sites from nasopharynx to hypopharynx are treated using EWF IMRT. Preliminary data by Klem et al. (17) from Memorial Sloan-Kettering Cancer Center has shown excellent neck control rates with very acceptable toxicities. The EWF IMRT technique is preferred over the SF IMRT technique with similar reasons stated above for laryngeal and hypopharyngeal tumors. Typically the glottic larynx is contoured and a constraint is placed to ensure no excessive hot spots are found within the volume (Fig. 11).

Spinal cord dose
In addition to concerns of failure at the matchline, a related concern about the SF IMRT approach is that there are dosimetric uncertainties regarding the spinal cord dose with the potential for irreversible toxicity. This is a valid concern that can be appropriately addressed by careful planning. In our study, plans were optimized such that the spinal cord dose for the SF and EWF IMRT plans were as close as possible. When the DVHs were generated to compare the plans, the dose contributions from the LAN field and SF field were considered cumulatively. The effect was additive. If the cord maximum was in the IMRT field, the LAN field contributed scatter and transmission. Conversely, if the maximum cord point was instead in the LAN field, the

Fig. 7. Extended whole-field intensity-modulated radiotherapy (IMRT) (a) and split-field (SF) intensity-modulated radiotherapy (b) isodose distributions for a case with low-lying bulky lymph nodes (Patient 3). The red, yellow, and green lines represent 70-Gy, 59.4-Gy, and 54-Gy isodose lines, respectively. The blue line in the SF distribution represents the 50.4-Gy isodose line for the conventional low anterior neck (LAN) field. An LAN electron boost was required for the SF IMRT. Figure appears in color online.

Fig. 8. A hypopharynx case planned with the split-field (SF) intensity-modulated radiotherapy technique (Patient 5). The multi-leaf collimator leaves were manually pulled in at the matchline to avoid matching over the spinal cord. Figure appears in color online.
same phenomenon occurred, but to a larger extent since there were significantly more monitor units in the IMRT field. As Table 3 indicates, cord dose in the SF IMRT plans was always higher than that of the EWF plans, but always clinically acceptable by our standards (maximum point dose, < 50 Gy). As a result, we believe that the potential for slightly higher cord doses in the SF case does not constitute sufficient reason to treat exclusively with EWF IMRT.

**Mandible dose**

The maximum point dose to the mandible was higher for all patients treated with SF IMRT. In some situations, it was above our tolerance dose of 70 Gy, but this was a very small point that could not be seen in the graphical plan. For Patient 3, the maximal point dose was 76.5 Gy, but the D05 to the mandible was 59.1 Gy. This was considered clinically acceptable.

**Cochlea dose**

Both cochlea doses differed significantly for Patient 1. In this patient, the cochlea was not constrained in the clinical plan, so these differences are expected. In all patients in which the cochlea was part of the optimization, cochlea dose, albeit slightly higher in most cases for the SF IMRT...
scenario, was below tolerance for both techniques. Thus, although differences existed, they were not thought to be clinically significant.

**Prescription isodose lines**

Some have noted that prescription isodose lines are typically higher with EWF IMRT. Dabaja et al. has suggested that EWF IMRT plans have higher prescription isodose lines and therefore less heterogeneity compared with the SF IMRT technique, perhaps as a result of the increased volume over which dose can be distributed outside of the critical structures (7). At our institution, our prescription is such that 100% is always assigned to the lowest prescription dose, i.e., 54 Gy. We typically normalize these plans such that the D95 of PTV70 is equal to prescription, i.e., 70 Gy or 130%. The quality of target coverage is determined by the D95 of the lower dose volumes as well their respective D05 and maximum dose values. To assess heterogeneity, it is appropriate to compare the D05 values of both techniques. As Table 2 shows, the average D05 for PTV70, PTV59.4, and PTV 54 is 74.8/75.3, 68.5/69.9, and 59.4/62.1 for EWF/SF respectively. The slight increase in D05 for SF IMRT can be explained by extra transmission of the LAN field but does not represent any intrinsic advantage with respect to IMRT technique. In addition, it is important to keep in mind that the PTV59.4 and PTV54 volumes in particular are larger for the EWF IMRT plans since the intensity modulated component extends inferiorly through the LAN region. A heterogeneity comparison of the IMRT portion of the plan may favor SF IMRT plans because of different volumes. Because of these factors, we believe that heterogeneity is not significantly different for the two IMRT techniques.

**CONCLUSION**

In a busy clinic where time is of great importance, it is crucial to have head-and-neck cancer treatment guidelines focusing on the selection of IMRT technique. Although EWF and SF IMRT techniques can both result in adequate target volume coverage as well as avoidance of critical structures, the main advantage of SF IMRT technique is in its ability to minimize the dose delivered to the larynx, which is necessary to ensure good voice quality and function. At our institution, tumors other than larynx, hypopharynx, and unknown primary, are typically treated with the SF IMRT technique with the attempt to minimize the dose delivered to the larynx. Laryngeal, hypopharyngeal, and unknown primary carcinomas of the head and neck are treated with the EWF IMRT technique, as the larynx is one of the targets that need to be contoured. We ask our planner to minimize the hot spots delivered to the glottic larynx. In situations in which the enlarged > 3 cm lymph nodes extend inferiorly to involve the low neck, regardless of the primary site of the head-and-neck cancer, we prefer the EWF IMRT technique to ensure adequate coverage of the gross tumor while not exceeding a mean dose of 30 to 35 Gy to the glottic larynx, recognizing that it is not possible to reach this dose range in some situations. It is critical to ensure that when EWF IMRT technique is used, the maximum point dose to the brachial plexus is limited to 65 Gy and the D05 is limited to 60 Gy. Although there may be subtle dosimetric differences with respect to spinal cord, cochlea, and mandibular doses between the two techniques, we have not found these to be significant. Finally, we have shown that both approaches result in relatively homogeneous plans.
REFERENCES