Patterns-of-Care for Thoracic Stereotactic Body Radiotherapy among Practicing Radiation Oncologists in the United States

Megan E. Daly, MD, Julian R. Perks, PhD, and Allen M. Chen, MD

**Introduction:** Radiation oncologists were surveyed to assess practice patterns in the use of stereotactic body radiotherapy (SBRT) for lung cancer.

**Methods:** A customized patterns-of-care survey, consisting of 18 questions and two clinical scenarios, was e-mailed to 136 academic radiation oncologists and 768 community practitioners to evaluate the technical basis and delivery parameters associated with SBRT.

**Results:** A total of 117 surveys were evaluable. The cited delivery techniques included: static noncoplanar beams (48%), intensity-modulated radiotherapy (41%), rotational intensity-modulated radiotherapy (47%), dynamic conformal arcs (7%), and small-beam delivery with fiducial tracking (24%), with 46% using multiple techniques. The immobilization methods included: stereotactic frame (10%), alpha cradle or vacuum-lock system (52%), wingboard (3%), stereotactic frame with an alpha cradle or vacuum-lock system (11%); combination of devices (14%), or no immobilization (9%). Abdominal compression was used by 51% and respiratory gating by 31%. For a peripheral T1N0 tumor, the preferred doses included: 25 to 34 Gy in one fraction (1%); 54 to 60 Gy in three fractions (56%), 48 to 50 Gy in four fractions (18%), and 50 to 60 Gy in five fractions (25%). For a centrally located T1N0 tumor, 58% recommended SBRT outside a clinical protocol, with recommended doses ranging from 40 to 60 Gy in three to 10 fractions. The recommended interval to first surveillance imaging ranged from 6 weeks or lesser (32%) to 25 weeks or more (2%).

**Conclusions:** Considerable variation exists for thoracic SBRT with regard to dose selection, fractionation, immobilization, planning, management of central lesions, and surveillance. Ongoing prospective evaluation is recommended to identify best practices and provide continual process improvement.

**Key Words:** Lung cancer, Stereotactic body radiotherapy, Patterns-of-care.

(J Thorac Oncol. 2013;8: 202–207)

O ver the past decade, stereotactic body radiotherapy (SBRT) has emerged as the standard of care for medically inoperable patients with early-stage non–small-cell lung cancer (NSCLC). The first published reports using SBRT for thoracic tumors, originating from the Karolinska Institute1 and the National Defense Medical College of Japan,2 demonstrated promising clinical efficacy. Subsequent prospective trials established high rates of local control and low toxicity.3,4 Two landmark prospective trials, the Radiation Therapy Oncology Group (RTOG) 0236 and the Nordic Study Group Phase II, demonstrated local control exceeding 90% at 3 years using three-fraction regimens.5,6 With high-level, prospective evidence demonstrating impressive local control and low toxicity, SBRT has been widely and rapidly adopted by radiation oncology centers around the United States. An earlier survey performed by investigators at the University of California, San Diego, suggests that more than 60% of radiation oncologists in the United States have incorporated SBRT into their clinical practice for one or more anatomical sites, with the majority of SBRT practitioners (89%) treating lung cancer patients.7

With the widespread implementation of SBRT, a variety of dosimetric planning approaches, immobilization techniques, fractionation schemes, and surveillance strategies have emerged. As SBRT depends critically upon precise target localization and delivery of a high biologically effective dose per fraction with a steep dose gradient and tight margins, technical aspects of treatment, such as image guidance and motion management, are of particular relevance. Management of the subgroup of patients with centrally located (defined as within 2 cm of the proximal bronchial tree) tumors using SBRT also remains controversial after reports of unacceptable toxicity after treatment with 54 to 60 Gy in three fractions.8,9 The American Association of Physicists in Medicine (AAPM) Task Group 101 has outlined recommendations for immobilization, image guidance, and treatment delivery.10 However, rates of adherence to these guidelines are unknown. Given the many uncertainties regarding the technical planning and delivery of thoracic SBRT, the aim of the present study was to assess specific patterns-of-care across the United States, with a focus on planning strategies, motion management, dose and fractionation, and posttreatment surveillance.
Patterns-of-Care Survey

After procuring Institutional Review Board approval, a link to a customized, web-based patterns-of-care survey was e-mailed to 136 academic thoracic radiation oncologists and 768 community-based radiation oncologists. Survey recipients included all thoracic radiation oncologists practicing in the United States, as identified from academic department websites. Community-based practitioners were randomly selected from the American Society for Radiation Oncology website directory. Survey recipients included physicians practicing in all 50 states and Puerto Rico. The original survey included 18 multiple-choice questions followed by two clinical scenarios: a peripheral T1aN0 NSCLC and a centrally located T1aN0 NSCLC (Fig. 1A and B). The questions assessed respondents’ SBRT practice demographics, case volume, immobilization methods, planning technique, fractionation schedules, motion-management approach, target localization, and post-treatment surveillance strategy. The full contents of the survey are included in Appendix 1. The intended respondents were practitioners currently using SBRT. Responses were collected in aggregate between June 22, 2012 and April 4, 2012, with no personal identifiers.

Statistical Analysis

Surveys were considered evaluable if at least one question was answered, and if the respondent indicated that he/she performed SBRT as a part of their practice. Survey results are indicated in the percentage of evaluable responses for each question. Two by two contingency tables were used to assess differences between survey responses of specific groups using Fisher’s exact test, with a two-tailed significance level of p value of 0.05 or lesser. All calculations were performed with GraphPad (GraphPad Software, Inc. La Jolla, CA).

RESULTS

Respondent Demographics

A total of 117 surveys were evaluable among 46 academic physicians (39%), 58 community physicians (50%), and 13 hybrid or other (11%), for a response rate of 13%. Survey respondents practiced in 36 different states and in the District of Columbia. Ninety-four percent of the physicians surveyed were board certified. Fourteen percent have practiced for less than 2 years and 49% for 10 or more years. Eighteen percent performed fewer than five SBRT cases in a year, whereas 28% performed more than 30 cases in a year. Full respondent demographics are outlined in Table 1.

Immobilization and Treatment Planning

The reported methods of immobilization include stereotactic body frame alone (10%), alpha cradle or vacuum-lock
system alone (52%), wingboard alone (3%), stereotactic body frame with an alpha cradle or vacuum-lock system (11%), combination of devices (14%), or no immobilization (9%). All respondents who reported not using a patient immobilization device used multiple small-beam delivery systems with tumor and/or fiducial tracking. Seventy-eight percent of respondents performed a patient-specific quality assurance check volumetrically, whereas 3% prescribed to a point. Eighty-five percent of surveyed physicians preferred computed tomography (CT) before each fraction, whereas 14% also obtained a mid-fraction CT, 2% obtained a CT at completion of each fraction, and 2% obtained a CT both mid- and posttreatment. Twenty-four percent used real-time fiducial tracking, 2% obtained an orthogonal kilovoltage image pair alone, and 1% used electronic portal imaging alone. Fluoroscopy was performed before each fraction by 13% and for select cases by 7%, to assess diaphragm or tumor motion.

### Clinical Case Management

The first clinical scenario described a 79-year-old male patient with a 1.5 cm, peripherally located grade 2 adenocarcinoma of the left upper lobe of the lung, positioned 1.2 cm from the chest wall (Fig. 1A). The preferred fractionation schemes ranged from 25 to 34 Gy in one fraction (1%) to 50 to 60 Gy in five fractions (25%), with the 54 to 60 Gy in three fractions selected most frequently (56%).

The second clinical scenario presented a 72-year-old man with a medically inoperable 1.8 cm right upper lobe, central squamous cell carcinoma, located 1.0 cm from the trachea and touching the mediastinal pleura (Fig. 1B). Ninety-nine percent of respondents recommended staging beyond computed tomography (CT) for a central lesion, including positron emission tomography (PET) alone (14%), PET with pathologic mediastinal staging through mediastinoscopy or endobronchial ultrasound only if abnormalities by PET (53%), and PET with pathologic staging of the mediastinum regardless of PET findings (32%). Assuming a negative mediastinal workup, 58% of respondents recommended SBRT in the absence of a clinical protocol. An additional 23% would offer SBRT on clinical protocol, and 18% would only offer conventional fractionation. Among those advocating SBRT, recommended doses ranged from 54 to 60 Gy in three fractions (7%), to 60 Gy in eight to 10 fractions (9%), with 50 to 55 Gy in five selected frequently (65%). Fractionation preferences for the peripheral and central cases are summarized in Figure 2. No difference in comfort delivering SBRT to a central lesion off-protocol was noted between academic practitioners and those in community or hybrid practices (p = 0.84), between those in practice for 10 years or more compared with those in practice for more than 10 years (p = 0.45), or between those treating 20 or more lung SBRT cases in a year and those treating fewer than 20 cases in a year (p = 0.24).

The recommended interval from completion of SBRT to the first follow-up imaging study ranged from 6 weeks or lesser (32%) to 25 weeks or more (2%). Forty-two percent of surveyed physicians preferred computed tomography (CT) alone for surveillance, 24% prefer PET or CT, and 34% obtained both. No significant difference in likelihood to obtain PET or CT surveillance was identified between academic and private or hybrid practitioners (p = 0.18). Details of surveillance strategies are summarized in Table 3.

### DISCUSSION

The aims of the present study were to assess current practice patterns for thoracic SBRT among radiation oncologists practicing in the United States, with a focus on technical planning and delivery parameters in the setting of clinical
decision making. The survey did not attempt to assess the prevalence of SBRT use, which has already been evaluated by several published surveys. A balanced blend of academic thoracic specialists and community practitioners responded, with caseloads ranging from less than five to more than thirty thoracic SBRT cases in a year.

Treatment planning approaches, immobilization, and motion-management strategies varied significantly among respondents, with many using multiple treatment platforms and approaches to motion management. The majority of respondents reported immobilization with a stereotactic body frame or a rigid pillow device (vacuum-lock or alpha cradle), consistent with guidelines from current RTOG protocols. Image guidance strategies varied significantly, ranging from two-dimensional portal imaging alone to pre-, mid-, and posttreatment volumetric CT. More than three quarters of respondents used 4DCT simulation to assist with internal target volume delineation. Because variations in immobilization, simulation, motion management, and image guidance definitely have implications as to the appropriate internal target volume and planning target volume margins, the practice of adopting margins adequate in clinical trials, using more rigorous immobilization and image guidance, may be inappropriate for centers with less rigorous strategies.

Care should be taken when implementing protocol-based guidelines for target volumes and normal tissue constraints if the immobilization and image guidance from those protocols are not used. The AAPM Task Group 101 report outlines best practice guidelines for the implementation of SBRT, and suggests that volumetric image guidance strategies coupled with “integrated image-based monitoring systems or aggressive immobilization” are mandatory. Our data suggest that not all centers adhere to the AAPM guidelines.

Treatment planning with static noncoplanar beams, as used in the early studies from Indiana University and the RTOG, remained the most often observed approach. However, approaches involving beam modulation, including static and rotational IMRT, were heavily used (41% and 47%, respectively). Multiple small-beam delivery systems with fiducial tracking were used by nearly a quarter of respondents. Early concerns regarding the interplay of intensity-modulated beams and a moving target seem unfounded, given the recent dosimetric analyses with four-dimensional dose modeling suggesting that the impact is negligible, even with large doses per fraction. The widespread use of intensity-modulated planning strategies suggests that such concerns are abating among practitioners. Survey results suggested that heterogeneity correction has been widely adopted and that virtually all practitioners (97%) now prescribe dose volumetrically. Both these steps are important toward accurately and consistently reporting delivered dose.

Current National Comprehensive Cancer Network guidelines for thoracic SBRT list a range of suggested fractionation schemes. For peripherally located tumors, these include 25 to 34 Gy in one fraction for small tumors (<2 cm) located less than 1 cm from the chest wall, 45 to 60 Gy in three fractions, 48 to 50 Gy in four fractions, and 50 to 55 Gy in five fractions. Recommended regimens for central tumors include 48 to 50 Gy in four fractions, 50 to 55 Gy in five fractions, and 60 to 70 Gy in eight to 10 fractions. The recommendation for more protracted regimens for centrally located tumors largely stems from the results of a phase II trial performed at Indiana University, demonstrating excess toxicity with delivery of 60 to 66 Gy in three fractions to centrally located tumors. However, subsequent efforts to identify

### Table 3. Surveillance Strategies

<table>
<thead>
<tr>
<th>Interval to first surveillance scan (weeks)</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;4</td>
<td>2%</td>
</tr>
<tr>
<td>4–6</td>
<td>30%</td>
</tr>
<tr>
<td>7–10</td>
<td>23%</td>
</tr>
<tr>
<td>11–16</td>
<td>41%</td>
</tr>
<tr>
<td>17–24</td>
<td>2%</td>
</tr>
<tr>
<td>≥25</td>
<td>2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Preferred surveillance study</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>42%</td>
</tr>
<tr>
<td>PET/CT</td>
<td>24%</td>
</tr>
<tr>
<td>CT and PET/CT</td>
<td>34%</td>
</tr>
</tbody>
</table>

CT, computed tomography; PET, positron emission tomography.
strategies for centrally located tumors suggest that more pro-
terated regimens of four to eight fractions are both safe and
efficacious.14–19 The currently accruing RTOG 0813 protocol
will assess a five-fraction dose-escalation scheme for centrally
located tumors. Our data confirm that, although a sizeable
minority of practitioners remain hesitant to implement SBRT
for centrally located tumors outside the setting of a clinical
trial, more than half (59%) of them would recommend SBRT
for a central tumor off-protocol, and 93% of those who did,
preferred a regimen of four or more fractions.

For the presented peripheral lesion, the most often
selected dose was the three-fraction regimen of 54 to 60 Gy
used by RTOG 0236. Interestingly, despite the convenience,
the reported safety and efficacy,4,2021 and inclusion in the
National Comprehensive Cancer Network guidelines as an
appropriate treatment option, a single-fraction regimen of
25 to 34 Gy was selected by only 1% of respondents for the
small, peripheral tumor. Publication of the randomized RTOG
0915, comparing 34 Gy in a single fraction or 48 Gy in four
fractions and closed to accrual as of March 2011, should pro-
vide much-awaited randomized evidence as to the preferred
fractionation scheme for peripheral tumors.

Few evidence-based guidelines exist as to the optimal
posttreatment surveillance strategy, and correspondingly, sur-
vey respondents report varying approaches. The optimal tim-
ing of posttreatment imaging remains an open question, and
respondents ranged from less than 4 to 25 weeks or more as
their preferred first posttreatment imaging study. Thirty-two
percent of respondents, however, report first surveillance
imaging within the first 6 weeks. Few specific data exist to
determine optimal timing of the first posttreatment imaging.
However, reports from published prospective trials suggesting
failure within the first 3 months are exceedingly rare,3,5,6,14,21
and correspondingly, that restaging within the first 3 months has
evident evidence-based support. Further prospective evalua-
tions of the optimal surveillance approach are sorely needed.
The integration of posttreatment PET or CT was advocated
in the first 3 months are exceedingly rare,3,5,6,14,21
and correspondingly, that restaging within the first 3 months has
evident evidence-based support. Further prospective evalua-
tions of the optimal surveillance approach are sorely needed.

The limitations of the present study include a potentially
biased respondent pool, as academic thoracic radiation
oncologists were specifically selected as survey recipients.
In addition, the fairly low overall response rate of only 13%
may create additional bias, as physicians with certain practice
patterns may have elected to respond. We identified academic
survey respondents on the basis of a thoracic disease site focus,
which likely increased our survey yield among academic
practitioners, whereas community practitioners were
randomly identified from the American Society for Radiation
Oncology directory, and very likely included many physicians
not currently performing SBRT. Thus, not surprisingly, the
response rate among academic physicians was significantly
higher than among community physicians, adding an
additional potential selection bias. Future survey efforts could
include additional measures to increase response rate, such as
additional contact with nonresponders through e-mail or
phone, or incentivizing response. In addition, respondents were
allowed to select multiple options for questions dealing with
treatment planning, motion management, and immobilization,
which led to some difficulties in interpretation. Nonetheless,
the survey results provide a provocative indication of the wide
range of practice patterns currently in use for thoracic SBRT.

CONCLUSIONS

Considerable physician variation exists in the technical
delivery of thoracic SBRT with respect to such factors as dose
selection, fractionation, immobilization, planning methods,
management of central lesions, and follow-up strategy. Our
findings highlight the need for not only continual evaluation
and refinement of the SBRT process, but also for standardization
of the planning and delivery process, which may better
guide physicians in clinical practice. Until then, ongoing and
future prospective trials should better delineate optimal frac-
tionation schemes and posttreatment surveillance approaches.

REFERENCES

1. Blomgren H, Lax I, Näslund I, Svanström R. Stereotactic high dose frac-
tion radiation therapy of extracranial tumors using an accelerator. Clinical
modified stereotactic radiation therapy for lung carcinoma patients: a pre-
3. McGarry RC, Papiez L, Williams M, Whitford T, Timmerman RD. Stereotactic
lung radiation therapy of early-stage non-small-cell lung carci-
5. Timmerman R, Paulus R, Galvin J, et al. Stereotactic body radiation ther-
apy for inoperable early stage lung cancer. JAMA 2010;303:1070–1076.
phase II trial of medically inoperable stage I non-small-cell lung can-
7. Pan H, Simpson DR, Meld LK, Mundt AJ, Lawson JD. A survey of
stereotactic body radiotherapy use in the United States. Cancer
treating central tumors in a phase II study of stereotactic body radiation
9. Corrado MN, Haas AR, Rengan R. Central-airway necrosis after stere-
10. Benedict SH, Yenice KM, Followill D, et al. Stereotactic body radio-
Practice Patterns of Lung Stereotactic Body Radiation Therapy in the
stereotactic body radiotherapy treatment using image-modulated radio-
13. Network NCC: NCCN Clinical Practice Guidelines in Oncology: non-
ey of stereotactic body radiotherapy for early-stage non-small-cell lung
15. Haasbeek CJ, Lagerwaard FJ, Slotman BJ, Senan S. Outcomes of stereo-


