Stereotactic body radiotherapy (SBRT) is a rapidly emerging technology that enhances radiation therapy delivery. It allows for tightly conformed treatment fields and accurate delivery even with moving targets in the body. SBRT is currently used most commonly in treatment of medically inoperable stage I non-small cell lung cancers, as well as lung, liver, and spinal metastases. Studies to date are encouraging for increased local control with acceptable patient tolerance. This article familiarizes nurses with the use of this new technology and proposes the potential nursing role in maximizing patient preparation and follow-up care.

Overview of Stereotactic Body Radiotherapy and the Nursing Role

At a Glance
- Stereotactic body radiotherapy (SBRT) is an emerging technology in cancer treatment offering possible improved patient outcomes; however, long-term or late effects still need to be assessed.
- SBRT research is ongoing and includes radiation dose escalation to establish optimal treatment parameters for patients with stage I non-small cell lung cancer, as well as lung, liver, and spinal metastases.
- Patients receiving SBRT are in radiation departments for fewer treatments than traditional radiation, necessitating the delivery of nursing care before and after treatment with other approaches.

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Stereotactic body radiotherapy (SBRT) is an emerging field of radiation therapy for treating tumors within the body. Traditionally, treatment of body tumors with radiation therapy is given in many small, daily doses primarily to reduce the potential for damage to normal tissue surrounding the tumor from ionizing radiation. Since the 1980s, advances in computer technology have resulted in the development of 3-D conformal treatment planning systems, which offer enhanced precision in defining the tumor (target) and reducing the radiation dose to the surrounding normal tissues. Further improvements in radiation beam delivery itself through intensity-modulated radiation therapy (IMRT) allows for even more precise shaping of radiation beams for treatment of irregularly shaped tumors (Chao, Perez, & Brady, 2002). Building on the technological advances of 3-D conformal radiotherapy and IMRT, SBRT is a hypofractionated delivery of radiotherapy, meaning the total dose of radiation is delivered in only one to five treatments. Hence, each dose is much larger than the standard daily radiation dose. This differentiates SBRT from conventional radiation given over many small doses with use of 3-D conformal planning and IMRT. Defining characteristics of SBRT include precise immobilization, the ability to reproduce accurate position from simulation to treatment, the ability to minimize normal tissue exposure, precise accounting of organ motion, extremely accurate targeting of the tumor and surrounding critical structures to avoid using stereotactic coordinates within the tumor or on the patient, and ablative dose fractionation delivered to the patient with subcentimeter accuracy (Timmerman, Kavanagh, Cho, Papiez, & Xing, 2007). This level of accuracy allows for the delivery of an ablative dose, which often is very high and not possible to deliver with standard radiotherapy because of potential for significant damage to surrounding normal tissue. This article will discuss how SBRT is beneficial to patients and outline the nursing care for patients receiving the treatment.

SBRT has its roots in stereotactic radiosurgery (SRS), which is a form of radiation therapy first conceived by neurosurgeon Lars Leksell, PhD, in 1951 (Slotman, Solberg, Wurm, & Verellen, 2006). SRS includes delivery of a high dose of radiation in a single fraction to a small target with great accuracy through the use of precise patient immobilization and localization of the target via a three-dimensional coordinate system. SRS was first used to treat brain lesions because of the ability to use a stereotactic coordinate system. SRS was first used to treat brain lesions because of the ability to use a stereotactic coordinate system. SRS was first used to treat brain lesions because of the ability to use a stereotactic coordinate system. SRS was first used to treat brain lesions because of the ability to use a stereotactic coordinate system. SRS was first used to treat brain lesions because of the ability to use a stereotactic coordinate system. SRS was first used to treat brain lesions because of the ability to use a stereotactic coordinate system.
imobilization frame tightly pinned to the patient’s skull, thereby fulfilling the requirements of precise immobilization and localization. With precise tumor localization, a minimal amount of normal tissue is in the planned treatment field, allowing for delivery of higher doses of radiation, with incremental improvement in tumor control with minimizing normal tissue dose.

In 1968, Leksell’s gamma knife treatment device, which uses multiple cobalt 60 radioactive sources, was added to the armament of available radiotherapy technologies (Slotman et al., 2006). The Gamma knife technology has continued to gain acceptance and is currently available in more than 100 sites throughout the world. Since the 1980s, radiosurgery equipment has been adapted for use on linear accelerators, which is the lead technology for standard radiation therapy (Slotman et al.). The efficacy of SRS has been confirmed in the past two decades by positive clinical studies for treatment of a variety of intracranial processes, including tumors, arteriovenous malformations, and trigeminal neuralgia (Song, Kavanagh, Benedict, & Schiefer, 2004).

With a clear need in oncology to improve local control of deep-seated tumors, the concept of using SRS to achieve dose escalation and possible tumor ablation in the body was appealing; however, applying stereotactic techniques to treat extracranial sites has been very challenging. Immobilization and targeting are much more difficult because of a lack of fixed bony reference structures (e.g., the skull) and respiration-induced mobility of organs. For example, precisely targeting a small lung lesion that moves during respiratory without including a large amount of surrounding normal lung tissue in the radiation fields is difficult. Lax, Blommgren, Naslund, and Svanstrom (1994), of the Karolinska Institute in Stockholm, Sweden, were the first to report using a custom body cast with stereotactic coordinates for treatment of abdominal malignancies.

Technologic Advances

Many technologic advances have been made since the 1990s, resulting in rapidly expanded use of SBRT. The systems critical to SBRT include radiation delivery, localization, gating, computerized planning, immobilization, and the integration of these systems. Methods of body immobilization include a customized external vacuum-type body mold (Full Body Vac-Lok™ Cushion, Civco Medical Systems) (see Figure 1), a foam-based body mold (Alpha Cradle™, Smithers Medical Products, Inc.), and others. Sophisticated computer planning systems now integrate multiple types of diagnostic imaging (computed tomography [CT], magnetic resonance imaging [MRI], positron emission tomography [PET] scans) to accurately target tumor volumes and place dose constraints on surrounding critical structures as designated by the radiation oncologist. Intensity modulated radiotherapy (IMRT) treatment plans use multiple beams to tightly conform the intended prescribed dose to targets. Multileaf collimators are a device consisting of leaves of a material, usually tungsten, capable of blocking a particle beam. The leaves move in and out of the path of the radiation beam, shaping it to match the borders of the tumor targeted for therapy. As a result, beam-shaping ability is significantly enhanced with the refinement of multileaf collimators in the treatment machine.

Image-guided radiotherapy (IGRT) technology involves enhancements that ensure the accuracy of treatment delivery. These include respiratory gating systems that track and adjust to respiratory target motion in real time (see Figure 2). This can be accomplished with the use of infrared or video tracking of skin surface markers or x-rays to track implanted markers. Repositioning accuracy from planning to treatment previously was dependent on 2-D orthogonal x-rays of bony anatomy. New linear accelerators are equipped to take multiple kilovoltage (kV) cone-shaped images (cone beam CT) that digitally reproduce CT images of the target, which are then able to be viewed overlying the planning CT images to ensure accuracy in real time. Treatment table adjustments can then be made in real time with computer guidance. For example, a patient with a lung tumor can have a sensor placed on the upper abdomen to track respirations during treatment planning. The radiation beam then can be programmed to turn on and off to deliver the dose only during the phase of respiration when the target (tumor) is centered in the radiation beam. This precision allows for delivery of a few fractions of high-dose radiation while protecting surrounding normal lung tissue and other critical structures.

Results of Stereotactic Body Radiotherapy

SBRT is a resource-intensive process requiring appropriate patient selection to choose those most likely to benefit. Patient selection includes general principles of stereotactic radiosurgery, including limitations to small, discrete tumor targets with no intention of prophylactic coverage of the surrounding region to patients with limited metastatic disease. Patients’ physical and psychological limitations also must be considered in their ability to comply with the need for increased length of time required to be immobilized in the treatment position. To continue with a lung cancer example, an ideal candidate for SBRT may be an 80-year-old man with a new diagnosis of non-small cell lung cancer (NSCLC) with a solitary 2 cm right-upper-lobe nodule. He has poor pulmonary function with a forced expiratory volume in one second of 1 L and no evidence of metastatic disease by PET or CT staging. He is not a surgical candidate, and optimal radiation therapy for curative intent would need to be a high dose. To decrease the risk of compromising his poor pulmonary function, no elective mediastinal nodal treatment is indicated. Therefore, SBRT may be a realistic option for the patient.
A growing body of literature of phase I–II studies exists, with hundreds of radiation therapy sites throughout the world investigating the use of SBRT. Predominant sites of treatment studied to date include medically inoperable stage I NSCLC, as well as lung, liver, and spinal metastases. A representative sample of a few studies is described here.

Song et al. (2004) described seven studies of stage I NSCLC patients treated with SBRT conducted from 2001–2003. The studies demonstrated efficacy and safety with local tumor control of 80%–100% in subjects with median follow-up of 8–20 months. Even in light of the short follow-up duration, these local control rates are high and compare favorably with rates for conventional treatment. In a phase II trial, Timmerman et al. (2006) treated 70 stage I (T1 or T2 < 7 cm) patients with NSCLC receiving SBRT doses of 60–66 Gy total in three fractions. With a median follow-up of 17.5 months, Kaplan-Meier local control rate at two years was 95% compared to 55%–70% with standard radiation therapy. Median overall survival was 32.6 months with 54.7% two-year overall survival. Grade 1–2 toxicities consisting mostly of fatigue, radiation pneumonitis, and musculoskeletal discomfort were reported in 83% of the patients. Grade 3 or 4 toxicity occurred in eight patients, consisting of decline in pulmonary function tests, pneumonias, pleural effusion, apnea, and skin reaction. SBRT was believed to contribute to six patient deaths related to bacterial pneumonia, pericardial effusion, and massive hemothysis. Analysis of the patients experiencing grade 3 or 4 toxicity showed that tumor location was highly predictive, with toxicity more prevalent in tumors near central airways than in peripheral tumors (Timmerman et al., 2006).

Schefter et al. (2006) reported results of a phase I and II trial of patients with pulmonary metastases treated with SBRT. Twenty-five patients (the majority previously treated with chemotherapy for primary colorectal, kidney, sarcoma, head and neck and lung cancers) with one to three discrete lung metastases were treated with SBRT with doses escalated to 60 Gy total in three fractions. No dose-limiting toxicity was noted in the original 12 phase I patients, with 4 alive at analysis, a median 21 months from study enrollment. Multiple grade 1–2 toxicities were reported, including esophagitis, pain, nausea, dermatitis, and cough. Deaths ranged from 4.0–20.3 months from registration with a median of 10.7 months. The phase II cohort of 14 patients had no dose-limiting toxicity at three to six months follow-up. The authors concluded that radiobiologically potent doses of SBRT are well tolerated with minimal early toxicity. The phase II trial is ongoing and will continue to assess for late effects as well as evaluate local control rates.

Katz et al. (2007) reported retrospectively on local control rates and toxicities of 60 patients treated with hypofractionated SBRT for liver metastasis. The preferred treatment schedule was 50 Gy in 5 Gy fractions over two weeks, with specific dose constraints to normal liver volume. The authors noted the most common side effects were fatigue and nausea, with 28% experiencing grade 1–2 elevation of liver function tests. No grade 3 or 4 hepatic toxicity was noted. At the three month evaluation, 5 patients had a complete radiographic response, 15 had partial response, and 33 had stable disease. SBRT was believed to contribute to six patient deaths related to bacterial pneumonia, pericardial effusion, and massive hemothysis. Analysis of the patients experiencing grade 3 or 4 toxicity showed that tumor location was highly predictive, with toxicity more prevalent in tumors near central airways than in peripheral tumors (Timmerman et al., 2006).

Figure 2. Timed Radiation Delivery During Respiratory Cycle

The spinal cord and vertebrae are particularly suitable for SBRT or SRS because of lack of target movement during breathing. Ryu et al. (2003) demonstrated the feasibility of performing spinal SRS on 10 patients with spinal metastasis from primary lung, breast, prostate, multiple myeloma, and Hodgkin disease, using noninvasive patient immobilization, image-guided, shaped-beam radiosurgery with accuracy and precision. Although efficacy was not the primary goal, all evaluable patients had significant pain relief. No acute or late radiation toxicity was clinically detected during a mean follow-up of six months. Gibbs et al. (2007) treated 74 patients with 102 spinal metastases with 16–25 Gy in one to five fractions using the CyberKnife® (Accuray Inc.) system. Pain was by far the most prevalent pretreatment symptom. With a mean follow-up of nine months, 84% of the symptomatic patients (n = 62) reported “improvement or resolution of symptoms”
after treatment (p. 188). Severe, treatment-related myelopathy developed in three patients; no predictor of the complication could be identified on multivariate analysis. Gerszten, Burton, Ozhassouglu, and Welsch (2007) reported results from 500 cases of spinal metastases treated with radiosurgery at a single institution. Again the most common presenting symptom was pain. With a median follow-up of 21 months (range 3–53), 86% had long-term improvement in their pain and 88% had long-term radiographic control. The authors reported no clinically detectable evidence of spinal cord injury. Post-treatment MRI also failed to demonstrate radiation-induced spinal cord toxicity. Overall SBRT shows promise of improved tumor treatment with acceptable toxicity profiles, and will continue to be used and studied in a higher percentage of patients in radiation centers.

**Nursing Implications**

Although multiple studies demonstrate good patient tolerance to SBRT with few high-grade toxicities, lower-grade toxicities are more common and correspond to expected toxicities of radiation therapy delivered in a standard daily fractionation. Clearly, potential for developing more serious toxicities with increased use of SBRT and in dose escalation trials remains. Evidence-based standards for nursing care of SBRT patients have not yet been established. Current care recommendations at the authors’ institution focus on consistent pretreatment patient and family education, assessment of potential barriers in the patient’s ability to undergo the procedure, and short-term follow-up. A standardized checklist currently is in use for patients receiving cranial SRS. An adapted form is proposed for use with patients receiving SBRT (see Figure 3). Because of expert assessment skills and their ability to facilitate the use of new treatment technologies into practice, advanced practice nurses (APNs) may best serve this population. Pretreatment education includes possible site-specific side effects of SBRT and management of those effects. As SBRT is an outpatient therapy, patients in particular need to be educated about reporting of symptoms to their healthcare team. Unlike standard fractionated radiotherapy delivered over weeks, which allows for more face-to-face nursing assessment, SBRT fractionation (one to five days) may require more patient assessment via the telephone. A follow-up phone call is appropriate within a few days following completion of therapy with further calls dependent on the patient’s status. In the example of the patient with NSCLC, the patient should be assessed for possible bronchial, esophageal, or lung inflammation or signs or symptoms of pneumonia after completion of SBRT. Symptoms could include cough, shortness of breath, chest pain or dysphagia, and fever. The oncology nurse is well suited to facilitate this type of communication (Cox & Wilson, 2003).

Depending of the amount of technology used and difficulty with target localization, SBRT may require up to 90 minutes for completion of a single treatment. This is a much longer time of being immobilized than for traditional radiation therapy. Therefore, nursing assessment of potential patient barriers is needed to ensure optimal compliance. This may include need for pain and anxiety relief, bowel and bladder control problems, or limitations in ability to follow verbal instructions. With expected growth in the use of SBRT in radiation centers, APNs also will develop education and symptom management protocols and facilitate translation of them for use by the radiation oncology nurses in their routine practice. The APN also can assist with coordination of all the disciplines involved from treatment planning through delivery of SBRT. Lastly, the APN may assist with data management for standard of care patients and patients enrolled in clinical trials, which will be essential in continuing to assess response and treatment complications of SBRT as its use is expanded.

**The Novalis Tx®**

SBRT is being performed throughout the world using a variety of radiation delivery systems, such as Cyberknife, Trilogy™ (Varian), and Artiste™ (Seimens). In a recent development, two major manufacturers of radiation therapy systems, Varian Medical Systems and BrainLab AG, collaborated to produce one state-of-the-art treatment system. The Novalis Tx® combines the most successful technologies from both companies (see Figure 4). In 2008, the Novalis Tx began to be installed in treatment centers around the world. The Department of Radiation Oncology at Duke University was the first center to begin operating the system in February 2008.1

1To find a local Novalis Tx treatment center, visit www.shapedbeamsurgery.com.
The Novalis Tx unique advances include a faster dose delivery rate, which reduces treatment time; more precise high-definition beam shaping (HD 120 multileaf collimator); and increased options in beam energies to improve treatment to deep-seated tumors while sparing surrounding healthy tissue. Image guidance is enhanced with an ExacTrac® X-Ray 6D system (BrainLab AG), which uses high-resolution x-rays to pinpoint and track internal tumor sites seconds before treatment and robotically correct any patient set-up errors (BrainLab, 2008). With multiple choices in planning, localization, gating, and delivery systems, a challenge for radiation oncologists, collaborating physicists, and radiation therapists using the Novalis Tx, will be using a system that has the capability to individualize treatments to produce the best patient outcome in a variety of tumor types and locations.

Conclusion

Stereotactic body radiotherapy is an exciting advancement in cancer treatment for use in a variety of patients with curative and palliative intent. Challenges in using the technology include needing a better understanding of the radiobiology of high-dose partial organ treatment. Further clinical trials are needed to determine the optimal prescription, dose distribution and normal tissue constraints. Ultimately, the radiation oncologist must determine optimal patient selection and appropriate use of this emerging technology. The role of nursing care for this population also is emerging. Although SBRT is advantageous for patients and families because of much decreased time spent in the radiation therapy department, nursing care must be provided in a way that best assures maximal patient preparation and follow-up care.

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