Stereotactic radiosurgery (SRS) is a minimally invasive procedure that delivers high-dose radiation in a single fraction to a precisely targeted area in the brain. Its aim is to eradicate the cells in the targeted area with minimal effect on the adjacent normal brain tissue and critical structures. SRS is used for treating benign vascular lesions (e.g., arteriovenous malformations, venous angiomas), primary benign and malignant brain tumors (e.g., gliomas, acoustic neuromas), and brain metastases (Roland & Eston, 2002; Shin et al., 2002; Spiegelmann, Nissim, Menhel, Alezra, & Pfeffer, 2002). With increasing evidence of SRS efficacy, a growing number of facilities are using SRS; therefore, radiation oncology nurses must develop expertise in this area. Oncology nurses working in other settings, such as offices, clinics, and inpatient units, might have to prepare patients to undergo SRS and, therefore, must be knowledgeable about this type of treatment. This article provides an overview of the SRS procedure and describes the nursing role in caring for patients receiving SRS.

### Historical Perspective

SRS has been used since the early 1950s, when the first stereotactic instruments were developed by Lars Leksell. Equipment and techniques have evolved over the years, and two approaches for delivering SRS currently are used. The first approach uses a modified linear accelerator (LINAC) that produces x-ray beams, a stereotactic head ring is used for localization of the target area and immobilization during treatment. Radiation oncology nurses have a unique role in caring for patients receiving SRS. Prior to the procedure, a radiation oncology nurse assesses the patient, educates the patient and family about the procedure, and collaborates in the details of planning. On the day of treatment, the radiation oncology nurse assists with head ring placement, provides care and monitoring throughout the day, and provides discharge instructions. This article describes the SRS procedure, reviews possible side effects, and discusses the radiation oncology nursing role.

**Key Words**: radiosurgery, stereotactic techniques, neoplasm metastasis

### Clinical Uses in Oncology and Outcomes

SRS most commonly is used to treat brain metastases. The incidence of brain metastases is about 170,000 cases per year, and the median survival time without treatment is one month (Mehta & Tremont-Lukats, 2002). Whole brain radiation therapy (WBRT) has been the conventional treatment for brain metastases and increases median survival to three to six months (Mehta & Tremont-Lukats). With WBRT, symptom relief occurs in 50%–60% of patients and local control is achieved in 35%–40% of patients (Mehta & Tremont-Lukats). However, toxicities associated with WBRT may be significant. About 5% of patients experience progressive dementia, ataxia, urinary incontinence, and cortical atrophy (DeAngelis, Delattre, & Posner, 1989).

SRS and surgical resection provide two approaches to treating patients who have one to three symptomatic brain lesions. Compared to WBRT, SRS increases local control to 75%–90%, increases median survival to 8–10 months, and reduces toxicities, which may improve quality of life (Chang & Adler, 2001; Mehta & Tremont-Lukats, 2002). Surgical resection provides immediate relief of the mass effect on the surrounding normal brain tissues as well as diagnostic information (Larson, Flickinger, & Loeffler, 1993). However, the cost of surgical resection is 1.8 times more than SRS (Boyd & Mehta, 1999). Because it is an invasive procedure, surgical resection has an increased risk of bleeding, tumor seeding, infection, and brain injury.

SRS also may be used in combination with WBRT to treat brain metastases. Patients with a single lesion, with a diagnosis of non-small cell lung or any squamous cell carcinoma, and categorized as recursive partitioning analysis class I (younger than 65, a Karnofsky performance score [KPS] higher than or equal to 70) have a better response with SRS and WBRT than with WBRT alone. The benefit of SRS is 25%–30% improvement in median survival when combined with WBRT compared with WBRT alone.
to 70, controlled primary cancer, and no extracranial metastases) treated with WBRT and SRS had better local control, stable or improved KPS, and less steroid requirement than those treated with WBRT alone (Sperduto et al., 2002). The cause of death in patients with brain metastases generally is related to systemic progression of disease.

When used to treat metastatic disease, SRS generally is limited to patients with one to three small lesions, each less than or equal to 3 cm in diameter, and generally with a single isocenter per lesion (Larson et al., 1993). Multiple isocenters can be planned for tumors with large or irregular volumes. Proper selection of patients is key to obtaining good clinical outcomes. Variables that favor good prognosis include a KPS higher than 70, stable systemic disease, two or fewer solitary lesions, radiosensitive tumors, tumor size less than or equal to 3 cm, tumor volume of 2 cc or less, and age of 60 years or younger (Boyd & Mehta, 1999). The most important prognostic factor is the KPS at the time the brain metastasis is diagnosed (Patchell, 2002).

SRS also has been used to treat patients with glioblastoma multiforme. SRS followed by conventional radiotherapy and chemotherapy (carmustine) was compared to radiotherapy with carmustine chemotherapy in a prospective study. The addition of SRS was not found to improve the survival rate of patients with glioblastoma multiforme (Souhami et al., 2002).

**Radiobiology and Toxicities**

As high-energy SRS x-ray beams transfer energy to tissues, a direct effect occurs on DNA molecules and an indirect effect as ionization of water in the cells produces reactive chemicals resulting in alteration of DNA structure (Posner, 1995). When cells accumulate radiation damage and are unable to repair themselves, they cannot go through mitosis, leading to loss of ability to replicate and cell death. Radiation also can cause narrowing of the blood vessels, which obliterates nutrients to the tissues and leads to cell necrosis (Posner).

Radiobiologic effects on proliferating tumor cells and normal parenchymal cells within the target account for the desired clinical outcome and the toxicities of SRS. Proliferating tissues have an early response, whereas surrounding normal tissues have a late response. Neurologic toxicity from SRS may be classified as acute, subacute, or chronic (Boyd & Mehta, 1999). Acute side effects are caused by cerebral edema or bleeding and generally occur 24–48 hours after treatment. Presenting symptoms include headache, nausea and vomiting, or seizure (Boyd & Mehta; Kagohashi, Satoh, Homma, Obitsu, & Sekizawa, 2002).

Subacute toxicities are those that occur in the first six months after SRS. Destruction of proliferating tissue and death of tumor cells may cause persistent cerebral edema in surrounding tissues, presenting as a worsening or recurrence of the initial neurologic symptoms. Patients also may develop temporary alopecia of the scalp in areas that received at least 4.4 Gy of radiation (Boyd & Mehta, 1999). However, hair usually grows back in two to eight weeks (Shaw, Coffey, & Dinapoli, 1995).

Chronic toxicities occur six months or longer after SRS. The risk of chronic toxicities increases in patients who have a large tumor volume, multiple isocenters, a high radiosurgical dose, prior or concurrent whole brain irradiation, treatment with certain chemotherapy agents, and other underlying, associated medical problems (Shaw et al., 1995). Radiocarcinosis, a mass of unab sorbed dead tumor cells, occurs in less than 10% of patients (Shaw et al.) and may present as a worsening of neurologic symptoms. A positron emission tomography scan of the brain or brain magnetic resonance imaging (MRI) spectroscopy is helpful in differentiating between tumor progression and radiation necrosis. Surgical resection sometimes is necessary to relieve symptoms. Other chronic toxicities include risk of permanent injury to nerve tracts, such as the brain stem or the optic pathways.

**Preparation**

Nurses assume the primary responsibility for patients’ preparation: assessing them, educating patients and families about the procedure, and collaborating in the details of SRS planning.

**Assessment**

Assessment is focused to identify the physical and psychosocial needs of patients and includes current neurologic symptoms as well as those originally caused by the brain lesion, medical problems that may affect treatment (e.g., renal dysfunction, hyperglycemia, use of anticoagulants, problems related to body positioning), current medications, allergy history, who patients live with, and who is available to provide help at home (see Figure 1).

**Education**

Educating patients and families includes showing a videotape, providing a booklet, and giving detailed verbal instructions about SRS (see Figure 2 for an example). Nurses in some SRS treatment centers show patients the head ring and give them a tour of the treatment area. Nurses working in outpatient and inpatient settings can begin teaching patients about SRS and provide written information or photographs.

A competent adult must accompany each patient on the day of the procedure and for 24 hours afterwards to observe the patient and provide assistance. If a patient is unable to identify someone who can help, referral to a visiting nurse service for a companion or overnight admission to the hospital may be necessary. Transportation to and from the hospital also should be arranged in advance.

**Planning**

Nurses ensure that imaging and laboratory tests are ordered and results are reviewed. MRI is performed within two weeks.
Description of Stereotactic Radiosurgery (SRS) Procedure
- Location and time of arrival
- Description of events to happen on the day of SRS: frame placement, computerized tomography scan, planning, SRS treatment
- Description of patient sensations throughout the day

Patient Preparation
- Wash hair the night before or the morning of the procedure.
- Food and fluid restrictions: no food after midnight, clear liquids until 6 am, and nothing by mouth except for medications (may vary by institution)
- Wear comfortable clothing.
- Bring magazines, videotapes, or board games to help pass the time.
- Bring a competent adult.
- Arrange for transportation.

Prior to SRS, and patients may need a complete blood count, coagulation studies, and a metabolic panel. For patients on antiseizure medication, serum drug levels should be obtained.

Nurses review patient medications and collaborate with individuals with prescriptive authority if drug modification is needed. Table 1 summarizes the implications for specific medications. Allergies also are identified during planning. Patients with mild allergies to IV contrast may need premedication with steroids and diphenhydramine prior to a computerized tomography (CT) scan. Patients who have had severe allergies to IV contrast should not receive contrast.

Location of the lesion also has an impact in planning care. If the lesion is in the motor cortex, patients are at high risk for seizures (Boyd & Mehta, 1999). For these patients, nurses must ensure that antiseizure medication is at a therapeutic level, and an overnight admission to the hospital for observation may be required. If the lesion is near the posterior fossa or close to the fourth ventricle, patients are at high risk for nausea and vomiting after treatment. A prophylactic antianemic may be prescribed and should be given one hour before SRS treatment. If the lesion is in the cerebellum or an acoustic neuroma is being treated, patients are at risk for balance and coordination impairment and, therefore, injury. A safe environment is imperative. If the lesion is near the optic chiasm, a risk of blindness exists. Last, nurses should review patients’ charts to ensure that preprocedure orders are written and that signed consents for SRS and IV contrast questionnaires are present.

The Day of the Procedure

Head Ring Placement

Before a patient arrives, equipment and supplies are gathered (see Figure 3). The patient arrives at the SRS suite early in the morning. An assessment is performed to ensure that no changes in the patient’s clinical condition have occurred. An anxiolytic may be given about 30 minutes prior to head ring placement if needed, and an IV is started.

The Brown-Roberts-Well head ring, with four attached posts (see Figure 4), is placed by the radiation oncologist and neurosurgeon with the patient sitting in a chair. The nurse assists throughout the procedure. The head ring position depends on the location of the lesion as determined by the radiation oncologist and neurosurgeon. The patient’s skin is prepped, and the physician injects a local anesthetic. The patient may feel a burning sensation that will last about five minutes. After the effect of the anesthetic sets in, the head ring is secured to the skull by screwing a pin through each post (see Figure 5). The patient usually feels mild pressure; additional anesthetic is administered as needed if the patient feels pain. After the head ring is secured, two wrenches are pinned to the patient’s clothing in case emergency removal is needed.

Table 1. Medications and Implications Related to Stereotactic Radiosurgery (SRS)

<table>
<thead>
<tr>
<th>Medications</th>
<th>Implications</th>
<th>Nursing Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticoagulants (e.g., warfarin, heparin, aspirin)</td>
<td>Risk for bleeding at pin site or at intracranial target of SRS treatment</td>
<td>Advise patients to avoid aspirin for seven days before the procedure and for two to three days after it. Check with individuals with prescriptive authority about holding medication or switching to low-molecular-weight heparin. Monitor coagulation studies (usually done on the morning of the procedure).</td>
</tr>
<tr>
<td>Antiseizure medications</td>
<td>Risk for seizure if levels are subtherapeutic</td>
<td>If the dose is subtherapeutic, adjust it and repeat on the morning of the procedure.</td>
</tr>
<tr>
<td>Steroids</td>
<td>Risk of hyperglycemia</td>
<td>If patient is diabetic or has elevated glucose levels, consider endocrinology consult.</td>
</tr>
<tr>
<td>Metformin</td>
<td>Risk of renal insufficiency after IV contrast, which can lead to toxicity from metformin</td>
<td>Hold metformin on the day of SRS and for two days after. Repeat blood urea nitrogen and creatinine levels two days after SRS before resuming medication.</td>
</tr>
<tr>
<td>Chemotherapy</td>
<td>Risk of bleeding and infection</td>
<td>Monitor complete blood count. If the patient is neutropenic, anemic, or thrombocytopenic, consult with treatment team regarding treatment plan.</td>
</tr>
</tbody>
</table>

Table 1 summarizes the implications for specific medications. Allergies also are identified during planning. Patients with mild allergies to IV contrast may need premedication with steroids and diphenhydramine prior to a computerized tomography (CT) scan. Patients who have had severe allergies to IV contrast should not receive contrast.
Computerized Tomography Scan

After the head ring is positioned, a CT scan is performed with the patient in a supine position with the head ring secured to the couch (the CT scan table) for immobilization. A depth helmet is placed on the head ring, and measurements are taken of the distance from the helmet to the cranium (see Figure 6). These measurements are repeated prior to treatment to ensure that the head ring has not shifted. A stereotactic localizer then is attached to the head ring (see Figure 7). CT images of the brain are taken at 3 mm slice thicknesses. The localizer rods are visible on each image of the CT scan and are used as reference points to determine stereotactic coordinates when planning treatment (see Figure 8).

Treatment Planning With the Linear Accelerator System

CT data are transferred electronically to a treatment planning computer and digitally fused with MRI images taken previously. A radiation oncologist, neurosurgeon, and physicist collaborate to select the optimal way to treat the target volume with the least dose to normal brain tissues. An isocenter is selected as the central point of the target. Multiple isocenters may be selected for a large target with an irregular shape or near a critical structure (e.g., optic chiasm, optic nerves, brain stem) (Boyd & Mehta, 1999). A virtual three-dimensional model of the target lesion and surrounding critical structures is created. The size and shape of the tumor are considered to determine the size of the collimator aperture and radiation beam and to define the multiple arc and gantry positions to be used with each isocenter. As many as 9–12 noncoplanar beams can be directed from different directions, all overlapping and converging at the isocenter (see Figure 9). This ensures that the desired dose is distributed uniformly across the target volume with a rapid fall-off of dose outside the target, maximizing clinical effect and minimizing complications. The amount of time for treatment planning depends on the complexity of the plan but generally is several hours.

Patient Waiting

After CT scanning, the patient is transferred to a waiting area (see Figure 10). The
The patient may have breakfast and lunch but usually is allowed nothing by mouth after lunch. Some SRS treatment centers allow ice chips or a clear liquid diet. Food is restricted to prevent aspiration during the procedure. Throughout the day, the patient is assessed for comfort. With the frame in place, peripheral vision is compromised, so the patient is accompanied at all times when ambulating. When the effect of the anxiolytic wears off, discharge instructions are provided.

Generally, one dose of dexamethasone (10 mg orally) is given in the morning with breakfast to prevent cerebral edema that may occur after SRS. For headache or mild pain, acetaminophen is given. For patients who are highly anxious, an anxiolytic may be given prior to treatment. An antiemetic may be indicated based on the location of the lesion being treated.

**Treatment Administration With a Linear Accelerator System**

Before treatment is administered, the physicist prepares the treatment room (see Figure 11). A micromultileaf collimation unit is installed on the LINAC gantry (see Figure 12). The collimation unit is attached to the LINAC and contains dozens of tiny leaves (which are similar to blocks made of metal) that move in and out to conform the shape of the radiation beam to the shape of the target (the tumor).

After calibration of the treatment machine and quality-control checks are completed, the patient is positioned on the couch, the head ring is secured to the couch to immobilize the patient (see Figure 13), and measurements with the depth helmet are rechecked to ensure that the head ring has not shifted. Laser lights are aligned to position the treatment isocenter to the LINAC isocenter.

During treatment, the patient stays in the same position while the gantry rotates around the couch for each beam. Treatment time depends on the number of isocenters to be treated; each isocenter requires 30–40 minutes. Music is played during treatment, and the patient is observed throughout with the video monitor and reassured intermittently through the intercom.

**Post-Treatment**

After treatment, the head ring is removed by the neurosurgery team. An antibiotic ointment is applied to the pin sites, and bandages are placed on the frontal sites. The pin sites might bleed slightly immediately after frame removal. Application of pressure with a gauze pad usually controls this, although, in rare cases, the site must be sutured.

Vital signs are assessed, and the patient is observed for any neurologic changes. Patients may experience a mild headache or a feeling of head pressure; acetaminophen is effective in treating these. Instructions are reviewed, and the patient is discharged after about an hour.

Discharge instructions include care of the pin sites, monitoring and prevention of side effects, and a plan for follow-up. See Figure 14 for specific instructions. The patient is called the day after the SRS procedure to assess for acute complications and to reinforce all discharge instructions.

SRS, with or without WBRT, is being used increasingly for patients with metastatic brain tumors. Radiation oncology...
nurses play a key role as liaisons among radiation oncology, neurosurgery, and neuro-oncology staff to ensure collaboration in the planning and implementation of care.

FOR STEREOTACTIC RADIOSURGERY TREATMENT


References


Care of Pin Sites

- Remove bandages and shower the following day; then leave pin sites open to the air.
- Apply antibiotic ointment twice daily until sites are healed, which generally takes five days.
- Apply cold compresses three times a day if swelling occurs, which usually resolves in five days.
- Notify treatment center if you experience a persistent headache, nausea, vomiting, worsening of neurologic symptoms, or seizure.
- Take dexamethasone exactly as directed. The dose usually is tapered (a smaller amount is taken each day).

Monitoring for Side Effects

- A possible side effect is brain swelling. Notify the treatment center if you experience a persistent headache, nausea, vomiting, worsening of neurologic symptoms, or seizure.
- Take dexamethasone exactly as directed. The dose usually is tapered (a smaller amount is taken each day).

Follow-Up Schedule

- Please schedule a radiation oncology follow-up visit on .
- A magnetic resonance imaging scan of the brain is usually performed six to eight weeks after stereotactic radiosurgery to evaluate response.

Figure 14. Discharge Instructions

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