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Dose planning management of patients undergoing salvage whole brain radiation therapy after radiosurgery

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ABSTRACT

Dose or treatment planning management is necessary for the re-irradiation of intracranial relapses after focal irradiation, radiosurgery, or stereotactic radiotherapy. The current clinical guidelines for metastatic brain tumors are the use of focal irradiation if the patient presents with 4 lesions or less. Salvage treatments with the use of whole brain radiation therapy (WBRT) can then be used to limit disease progression if there is an intracranial relapse. However, salvage WBRT poses a number of challenges in dose planning to limit disease progression and preserve neurocognitive function. This work presents the dose planning management that addresses a method of delineating previously treated volumes, dose level matching, and the dose delivery techniques for WBRT.

Introduction

Metastatic brain tumors are a common progression of systemic cancers constituting about 20% to 40% of all intracranial malignant tumors.[1,2] The 5 major sources of metastatic brain tumors in decreasing occurrence are lung cancers, breast cancers, melanoma, tumor of unknown origin, and colorectal cancers. However, any malignant tumor can metastasize to the brain. The prognosis for such patients is poor, leading to death in most cases. Historical studies suggest that the median survival for patients with untreated brain metastases is approximately 1 month. The use of corticosteroids has been shown to double survival time, while the addition of whole brain radiotherapy (WBRT) can further palliate the symptoms and prolong survival to 6 months.[3,4]

The most common method of metastatic spread resulting in brain metastases is hematogenous. It is therefore presumed that the spread of cancer is throughout the entire brain. Hence, WBRT has long been considered the standard treatment.[5] However, concern for the decline of long-term neurocognitive function has been the major reason to replace WBRT with more focal treatments.[6-9]

For lesions that are accessible and symptomatic requiring urgent decompression, surgery is the treatment of choice for rapid debulking and associated symptom relief. It has been shown that the addition of WBRT to the surgical resection of brain metastases decreases death from neurologic causes and results in increased overall survival compared to WBRT alone. For patients with limited life expectancies, the development of radiation-induced neurologic deficits after WBRT is an important clinical outcome and a significant drawback. The current alternative option to WBRT is the use of focal irradiation with either radiosurgery or stereotactic radiotherapy.[1-3,10,11] In either treatment technique, focal high doses of radiation are delivered in a single or a few fractions to the lesions sparing adjacent tissue and thereby limiting neurocognitive decline.

The debate on the management of metastatic brain tumors using WBRT or focal irradiation has been on-going. National radiosurgical and radiation oncological societies have been advocating for the use of focal irradiation alone for 4 lesions or less.[10,11] Recently, the American Society of Radiation Oncology (ASTRO) recommended cancer patients with limited brain metastases who are less than 50 years old receive radiosurgery without WBRT, citing 13% survival improvement compared to those with WBRT.[11] The report by Hasan *et al.*[12] predicted that patients without WBRT are 3 times more likely to require salvage therapy. This is consistent with the work of Gorovets *et al.*[7] With this recent change in radiation oncology practice philosophy, intracranial relapses are now presented in the clinics for consideration of salvage WBRT as an option to limit the progression of the disease. This presentation is anticipated to be more frequent for the clinics

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in the very near future. The dose or treatment planning management is always a challenge for re-treatments in the ability to deliver palliative doses to the previous treated region without causing additional radiation toxicity. This work presents a method of delineating previously treated volumes, dose level matching, and the dose delivery techniques for salvage WBRT.

Materials and Methods

Dose planning management involving salvage WBRT requires additional precautionary measures to ensure the preservation of neurocognitive function of the brain. It is well understood that the physical cumulative doses of WBRT and previous treatment doses may exceed the tolerance dose of the brain. Hence, every attempt should be made to minimize irradiation of the previously treated volumes. This philosophy of dose planning management remains the same regardless of the source or the type of cancers.

As a case report, a woman who had left breast cancer 21 years ago was chosen to demonstrate our dose planning management. She had lumpectomy and axillary dissection followed by external beam radiation therapy and chemotherapy. Two months ago, she presented with 3 lesions (1.1 to 1.9 cm in diameters) in the posterior brain and was treated using focal irradiation at 40 Gy in 10 fractions with 2 irradiations seen explicitly in Figure 1. She returned a month later for the treatment of the parietal region (2.6 cm in diameter) and was given a dose of 40 Gy in 10 fractions. Two weeks after the completion of the treatments, positron emission tomography-computed tomography scans showed widespread metastatic lesions throughout the brain, and a salvage WBRT was planned.

Before computed tomography (CT) simulation, a decision was made to use the planning target volumes (PTVs) of the previous courses of focal irradiation as the outline of the previously treated volumes with the objective of minimizing additional doses to the irradiated volume. CT-simulation scans were taken with slice thickness of 3 mm from the head region down to the cervical spine. The CT image dataset was downloaded in the Eclipse workstation (version 11). Image fusion was performed with previous image dataset to transfer the PTVs from previous irradiation to the current CT scans for treatment planning as shown in Figure 2.

A treatment plan was generated on the Tomotherapy Treatment Planning System (version 4.3). After the PTVs of the previously treated volumes were delineated, the contour of the brain was outlined to serve as the PTV for the current WBRT planning. In addition, several organs-at-risk were also contoured. The treatment plan was performed using (1) a field width of 2.5 cm, (2) pitch of 0.43 and, (3) modulation factor of 2.5. After the treatment plan was generated and reviewed, 94.5% of the brain received 25 Gy in 10 fractions was prescribed.

Dose delivery was performed on the Tomotherapy Hi-Art (HT) system which is specially designed for intensity-modulated radiation therapy (IMRT). The system consists of a small 6 MV linear accelerator mounted on a ring gantry that rotates isocentrically around the patient as the patient moves through the bore yielding a helical path of radiation dose delivery. Although it looks like a helical CT scanner on the outside, the beam intensity is modulated using a binary collimator in the inside. The specially designed binary collimator has 2 banks and each bank has 64 leaves with a beamlet size of 0.626 cm giving a total field width of 40 cm. The binary collimator is computer controlled with the leaves sliding in and out of the slit aperture to provide temporal beam modulation. The leaf movement using pneumatic method is in pairs creating a beam length of either 1.0, 2.5, or 5.0 cm. The Tomotherapy system also has megavoltage-based CT imaging to provide image-guided radiation therapy capability for patient setup. Using this system, a total of 6314 MU was delivered in 436 seconds giving a total of 2.5 Gy per fraction to the whole brain. The total dose prescription for this patient was 17.50 Gy in 7 fractions.

Results

Figure 3 shows the isodose distributions of the salvage WBRT delivered using the Helical Tomotherapy unit. The red color wash represents the prescribed dose and the brown is at the 50% dose level. The large number of degrees of freedom (360° rotation) offers the ability to perform highly conformal dose distribution at the expense of dose inhomogeneity. As such, the dose deficit can be seen to be very conformal and deep at the previously treated volumes with the focal irradiation. The dose reduction at the previously treated volumes can be as low as 25% for the parietal region indicated by the blue color wash and 50% of the prescribed dose (brown color wash) at the other 2 lesions. The amount of dose reduction is dependent on the PTV size of the previously treated volumes. As the PTV size decreases, the amount of dose reduction also decreases based on the physics of beam transport. Another physical phenomenon shown in the figure is the dose inhomogeneity, which is more compared to the typical parallel-opposed field irradiation to the brain.

Discussion

Dose planning management for salvage WBRT can be very sophisticated depending on the individual case. As iterated above, the dose planning objective of the salvage WBRT is to limit disease progression while preserving neurocognitive function in the brain. This balance leads to the desire of delivering the biological dose up to the boundary and abuts the previously irradiated volume. So, the fundamental issue in dose planning is how to delineate the

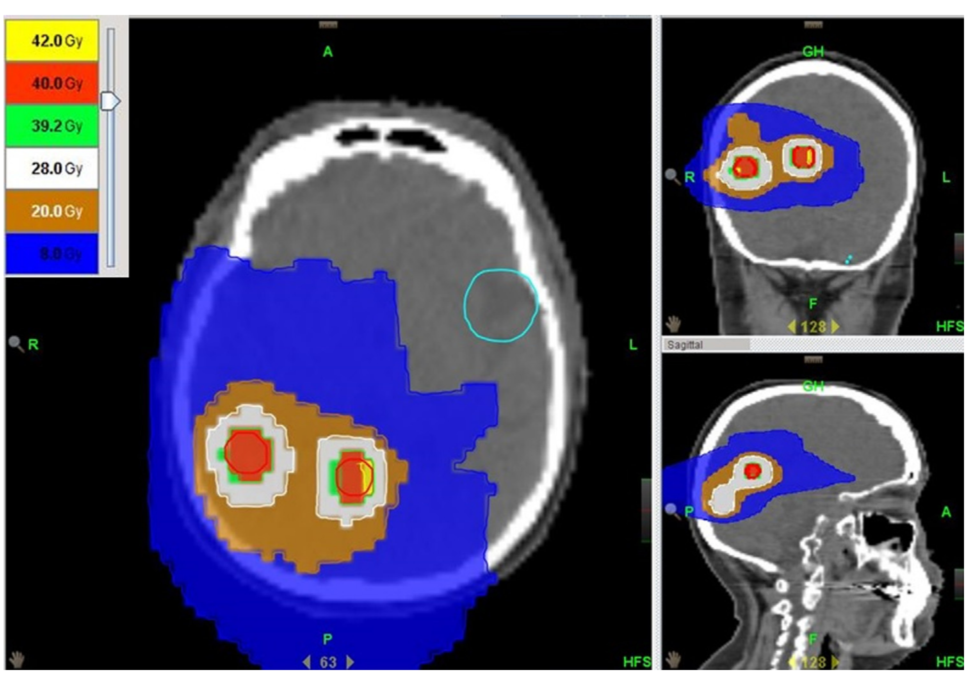

Fig. 1. Previously treated regions using focal radiations (see text for details). (Color version of figure is available online.)