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Whole-brain hippocampal sparing radiation therapy: Volume-modulated arc therapy *vs* intensity-modulated radiation therapy case study

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ABSTRACT

The hippocampus is responsible for memory and cognitive function. An ongoing phase II clinical trial suggests that sparing dose to the hippocampus during whole-brain radiation therapy can help preserve a patient's neurocognitive function. Progressive research and advancements in treatment techniques have made treatment planning more sophisticated but beneficial for patients undergoing treatment. The aim of this study is to evaluate and compare hippocampal sparing whole-brain (HS-WB) radiation therapy treatment planning techniques using volume-modulated arc therapy (VMAT) and intensity-modulated radiation therapy (IMRT). We randomly selected 3 patients to compare different treatment techniques that could be used for reducing dose to the hippocampal region. We created 2 treatment plans, a VMAT and an IMRT, from each patient's data set and planned on the Eclipse 11.0 treatment planning system (TPS). A total of 6 plans (3 IMRT and 3 VMAT) were created and evaluated for this case study. The physician contoured the hippocampus as per the Radiation Therapy Oncology Group (RTOG) 0933 protocol atlas. The organs at risk (OR) were contoured and evaluated for the plan comparison, which included the spinal cord, optic chiasm, the right and left eyes, lenses, and optic nerves. Both treatment plans produced adequate coverage on the planning target volume (PTV) while significantly reducing dose to the hippocampal region. The VMAT treatment plans produced a more homogenous dose distribution throughout the PTV while decreasing the maximum point dose to the target. However, both treatment techniques demonstrated hippocampal sparing when irradiating the whole brain.

Introduction

The hippocampus is a centrally located structure in the brain responsible for memory and cognitive function. Historically, this region eluded researchers until extensive studies began in the 19th century to discover its functionality.[1] The purpose of the hippocampus has been revealed through intensive research over the past 30 years and has become the most studied group of neurons in the brain.[2]

Metastatic tumors of the brain are the most common intracranial malignancy in the adult population.[3] Historically, brain metastases were treated with radiotherapy using right and left lateral fields. This treatment technique encompassed the entire region of the brain, treating everything within the cerebral cortex with high-voltage radiation. Though this treatment has been beneficial to reduce intracranial pressure, sparing a region like the hippocampus can dramatically improve a patient's mental function.[4]

Radiation therapy can be debilitating for patients to overcome and the effects are irreversible, making the improvement of patient care even more pertinent.[5] There have been many advancements in radiotherapy and the way cancer treatment is approached. It has become more commonplace to treat patients diagnosed with cancers notorious for metastasizing to the brain with prophylactic whole-brain radiation. This makes it imperative that treatment methods be further improved to help these patients have a better quality of life and retain their acuity.

There are ongoing clinical studies, such as the Radiation Therapy Oncology Group (RTOG) 0933 phase II trial, suggesting that limiting the dose of radiation to the hippocampus can

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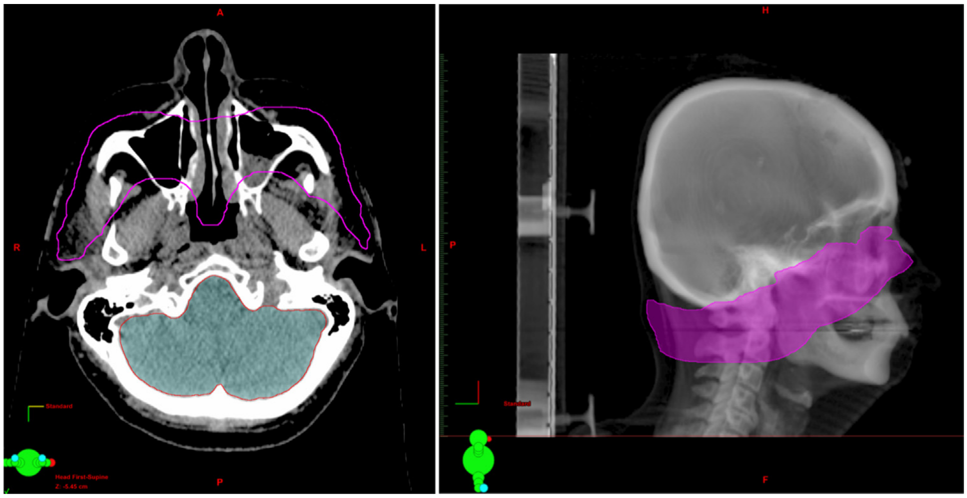

Fig. 1. The 2-cm optimization ring avoidance structure (shown in pink) from the axial (left) and sagittal (right) planes. (Color version of figure is available online.)

preserve a patient's memory. This case study was conducted to compare 2 treatment techniques that are commonly used to spare the hippocampi, volume-modulated arc therapy (VMAT) and intensity-modulated radiation therapy (IMRT).

Case Description

Patient selection and setup

The 3 randomly selected patients previously treated by a common physician were enrolled for this treatment-comparison case study. All 3 patients had a previous primary cancer diagnosis that had metastasized and infiltrated the brain. Each patient was prescribed a palliative dose of radiation (30 Gy) to the whole brain with the goal of sparing the hippocampal region.

The patients were placed in a supine position and scanned, head first, in a General Electric computed tomography (CT) scanner. The head was placed on a head rest as per the patient's individual comfort to ensure treatment reproducibility. An aquaplast mask was formed around the face and head to decrease patient movement. Reference marks were placed on the mask for daily setup reproducibility.

Target delineation

A magnetization prepared rapid gradient echo (MP-RAGE) magnetic resonance imaging (MRI) was used to delineate the hippocampus for each patient. This MRI technique is used to enhance specific structures for physicians to outline. From an MP-RAGE image study, there is an improved contrast between the white and gray matter within the brain.[6] The MP-RAGE MRI was fused with the treatment planning CT data set using the Varian Eclipse 11.0 treatment planning system (TPS). The hippocampus was contoured by the physician for the 3 selected patients. The physician contoured the hippocampus according to the RTOG 0933 contouring atlas protocol.[7]

The organs at risk (OR) contoured for this study include the hippocampi, brain, eyes, lenses, optic nerves, and the spinal cord. Optimization structures were also contoured for treatment planning purposes, which would allow the TPS to better avoid placing dose within these regions. The optimization structures included a 0.5-cm margin around the physician-contoured hippocampal region and a 2-cm ring avoidance structure around the brain that encompassed below the base of skull as well as the eyes and lenses.

The hippocampus avoidance structure was created by expanding the hippocampus by 0.25 cm in all directions. To obtain a 0.5-cm margin around the hippocampus, a new structure was created and named the planning target volume (PTV). To make this structure the brain was cropped from the hippocampus avoidance structure by 0.25 cm, thus creating the PTV with a 0.5-cm margin around the hippocampus.

The ring structure was contoured by expanding the brain by 4 cm, and then cropping the ring away from the PTV by 2 cm. This structure gave a 2-cm margin around the PTV and an avoidance structure to use for optimization purposes. An example depicting the ring avoidance structure that was created for optimization can be seen in Fig. 1. The image shows the avoidance ring on a CT data set from the axial and sagittal planes.

Treatment planning

The planning process for VMAT and IMRT hippocampal sparing whole-brain irradiation is very similar. The beams are positioned to adequately cover the entire surface of the target volume and

Table 1
Beam arrangement for IMRT treatment plans

Beam	Gantry	Couch	Collimator
1	10	45	0
2	60	45	0
3	130	45	0
4	170	45	0
5	220	45	0
6	270	45	0
7	320	45	0
8	290	0	45
9	330	0	45

Table 2
Beam arrangement for VMAT plan for patient 1

Beam	Rotation	Couch	Collimator
1	CW: 181 to 80	350	15
2	CCW: 5 to 181	310	330
3	CW: 181 to 179	0	345
4	CCW: 179 to 355	50	30

CW = clockwise; CCW = counter clockwise.