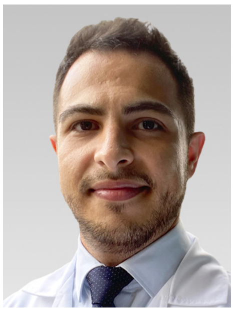
MR/Case Study

Radiotherapy Treatment Planning of a Brain Tumor Using a Canon Galan 3T MR

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Introduction

Brain cancer is a devastating disease that affects thousands of people worldwide. It manifests as a malignant tumor originating in the brain or spreading from other parts of the body. Given the brain's intricate nature and vital role in bodily functions, medical professionals face significant challenges in treating brain cancer. Radiotherapy, one of the most effective cancer treatments available, plays a crucial role in managing brain tumors as either a primary treatment or adjuvant therapy following surgery or chemotherapy. However, effective radiotherapy treatment planning necessitates precise information about the tumor's location, size, shape, and the surrounding brain structures.

Conventional treatment planning has relied on Computed Tomography (CT) to simulate the treatment process. However, CT imaging falls short of providing the necessary detailed and high-contrast visualization of tumors and internal organs. This deficiency can lead to missed tumor detections during diagnosis and toxicities due to poor organ delineation. To address these challenges, recent advancements in medical imaging, particularly Magnetic Resonance Imaging (MRI), have revolutionized the diagnosis and treatment planning for cancer patients undergoing therapy.

MRI offers detailed brain images, enabling healthcare providers to accurately locate tumors, and assess their size, shape, and proximity to critical structures. Consequently, this allows them to determine the most suitable course of treatment. Moreover, MRI serves as a non-invasive imaging technique to monitor the tumor's response to treatment over time, facilitating treatment adjustments and ensuring that patients receive the most appropriate and effective care throughout their cancer journey.

In this report, we have provided two case studies from patients treated for brain tumors who underwent a Canon Galan 3T MR-Simulator scan with a flat tabletop (to mimic the same treatment condition and facilitate the image registration process with CT planning). The exact same patient position (a flat couchtop with head scanned first) and immobilization devices (an Aquaplast mask with a headrest and a knee spongy cushion) were used to scan the patient for both CT and MR. Immobilization devices were used to minimize the motion artifacts and the same setup scans helped improve the uncertainties in image fusion.; Fusion of CT and MR provides complementary information for the clinical team as MR-Simulator is able to provide a better visualization of the lesions and the critical organs. Better organ delineations help increase the dose to the tumor and spare critical structures and organs at risk. Typical MRI sequences used in our institute for brain cases are sagittal (SG) 3D Fluid-Attenuated IR with Fat Saturation (FLAIR FS) in addition to axial 3D T1 Weighted pre- and post-contrast sequences. The details of the MRI sequences are provided in Table 1.

	SG 3D FLAIR FS	Axial 3D T1
Scanning sequence	Spin Echo, Inversion Recovery	Gradient Recalled, Inversion Recovery
MR acquisition type	3D	3D
Sequence name	FASE3D+5	FFE3D
Slice thickness (mm)	1.3 mm	1.0 mm
TR (ms)	5000.0 ms	6.8 ms
TE (ms)	510.0 ms	3.2 ms
Number of averages	1.0	1.0
Echo numbers	1.0	1.0
Spacing between slices (mm)	0.65 mm	0.5 mm
Number of phase encoding steps	56	120
Echo Train Length (ETL)	158	1
Flip angle (degree)	90	9
Spatial resolution (mm)	[0.5692, 0.5692]	[0.50, 0.50]

Table 1: Details of the MRI sequences used for a brain scan on a Canon Galan 3T MR-Simulator.

Case 1

History: A patient in their seventies was diagnosed with Glioblastoma (GBM) of the right temporal lobe. The patient underwent a right craniotomy with resection. It was recommended to administer RT to the right brain lesion using IMRT VMAT, with a total dose of 60Gy delivered in 30 fractions with a curative aim of treatment.

Imaging Findings: The MR images showed evidence of a large mass in the right anterior frontal and the post-operation MR images demonstrated persistent enhancement within the right temporal lobe consistent with residual tumor. The patient's MRI and CT scans are shown in Figure 1. The CT and MR images are fused to enhance the contouring process.

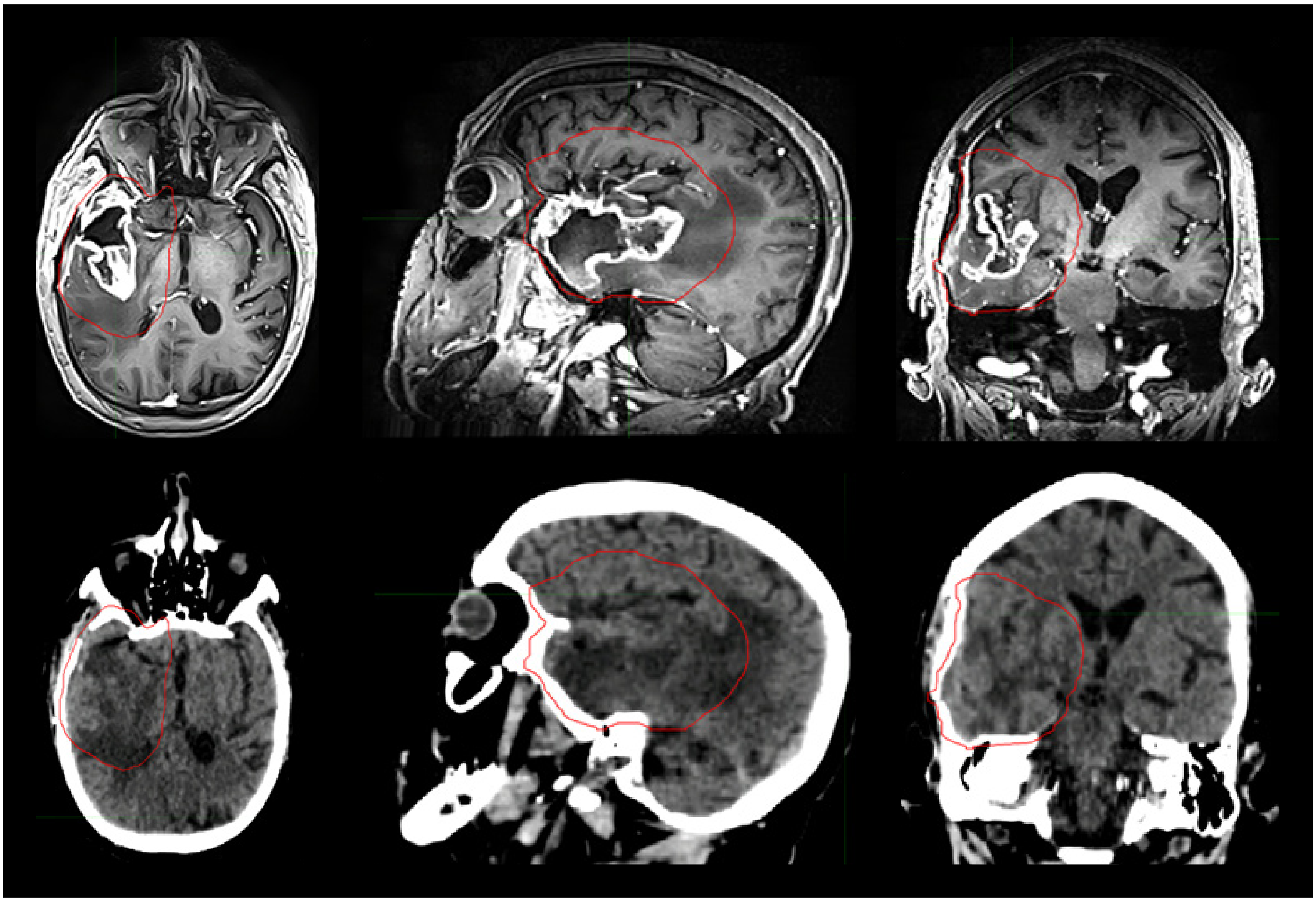

Figure 1: Axial 3D T1 post-contrast MRI and CT scans of the patient in 3 directions. The sagittal and coronal images were reformatted from the axial images. The red contour is the planning target volume (PTV).

Treatment: The primary goal of treatment is curative, with the approach being primary radiotherapy utilizing IMRT (VMAT) technique to the brain, with chemotherapy. The treatment consists of five weekly fractions, totaling 60 Gy.

For treatment planning, CT-Simulation was employed as the primary modality, while MR-Simulation was utilized as the secondary modality for contouring the target and organs at risk. This approach was necessary because CT lacks the ability to provide superb soft-tissue contrast. Figure 2 shows the CT and MRI images, as well as the fusion of the two modalities to leverage the complementary information from MRI during treatment planning. Additionally, Figure 2 displays the dosimetry plan, the planning target volume (PTV), and organs at risk (e.g., brainstem).

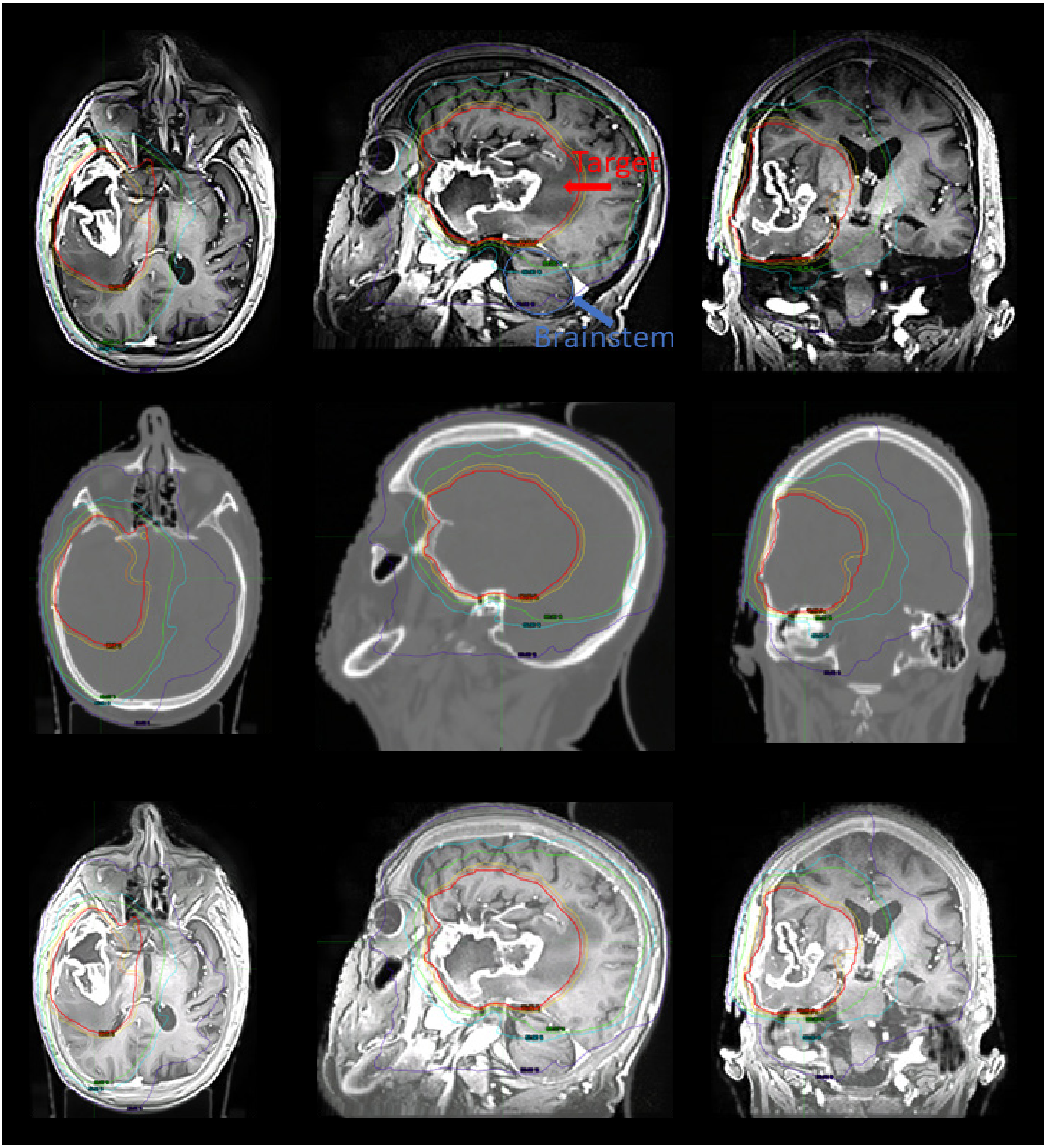

Figure 2: The dosimetry map on MRI, CT images, and the fusion of two modalities in three axes. The target and brain stem are shown with arrows.

Case 2

History: A patient in their early seventies with a medical history of prostate cancer treated with low dose rate seed implant and prostatectomy presented with symptoms of memory changes, falling, and left visual field deficit. The patient was diagnosed with multifocal right-sided GBM involving parietal and temporal lobes. Per the neurosurgery team evaluation, the lesion is poorly amenable to surgical resection, and as such the patient is being considered for definitive chemoradiotherapy.

Imaging Findings: Brain MRI was performed, revealing a large heterogenous mass extending into the left cerebral hemisphere, peripherally enhancing with areas of central necrosis concerning for high-grade glioma. MRI and CT scans of the patient for the three lesions are shown in Figure 3. CT was unable to detect enhanced areas.

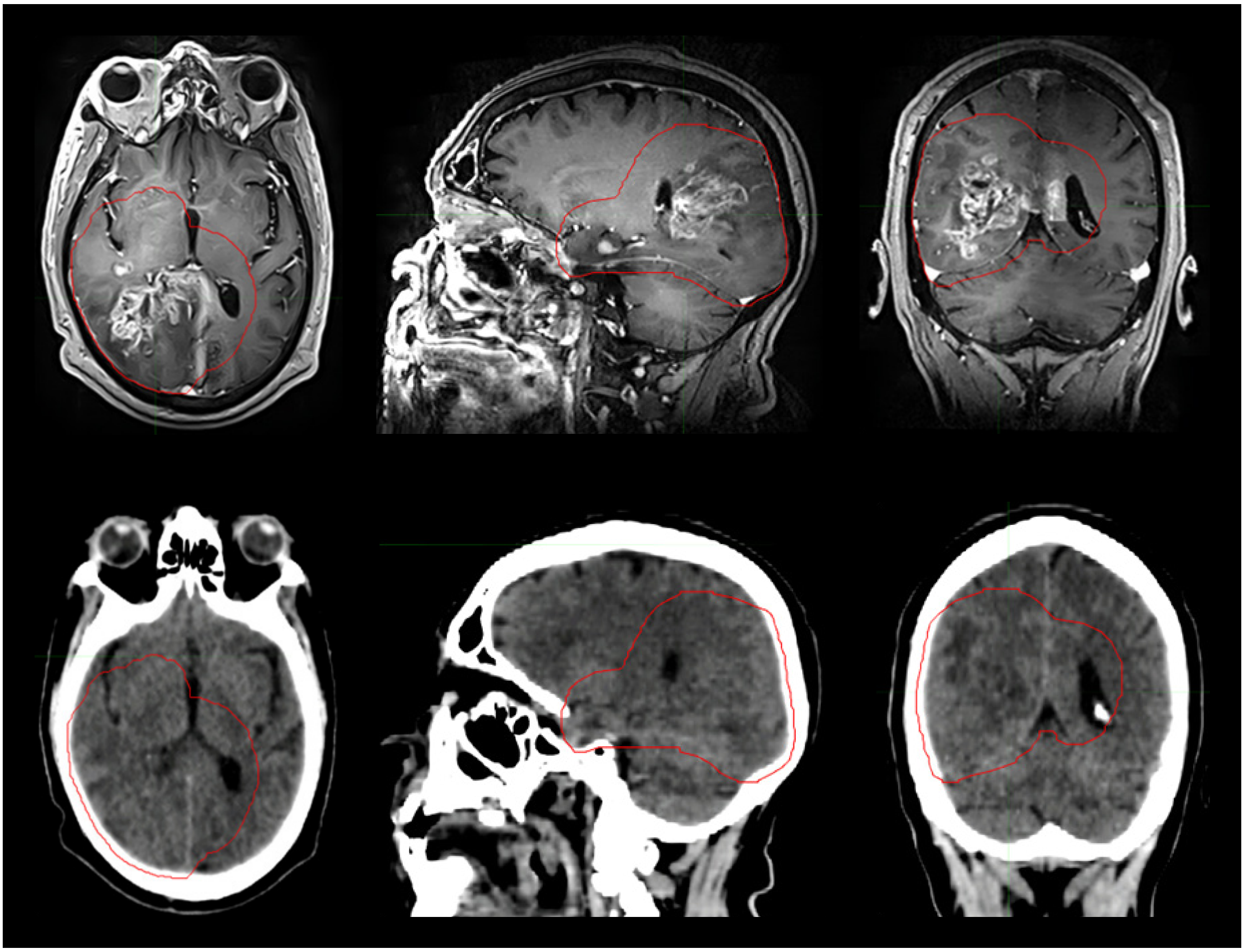

Figure 3: Red contours in the CT and MR images are the PTV. CT is unable to detect lesions.

Treatment: The patient was planned to undergo radiation therapy as the primary treatment with the aim of definitively treating the detected lesions. The treatment plan involved utilizing the IMRT technique (VMAT) to deliver a total dose of 60 Gy in 30 fractions to the right brain. The dosimetry map is shown in Figure 4. Critical organs (e.g., brainstem) and the tumor cannot be seen or segmented on CT datasets.

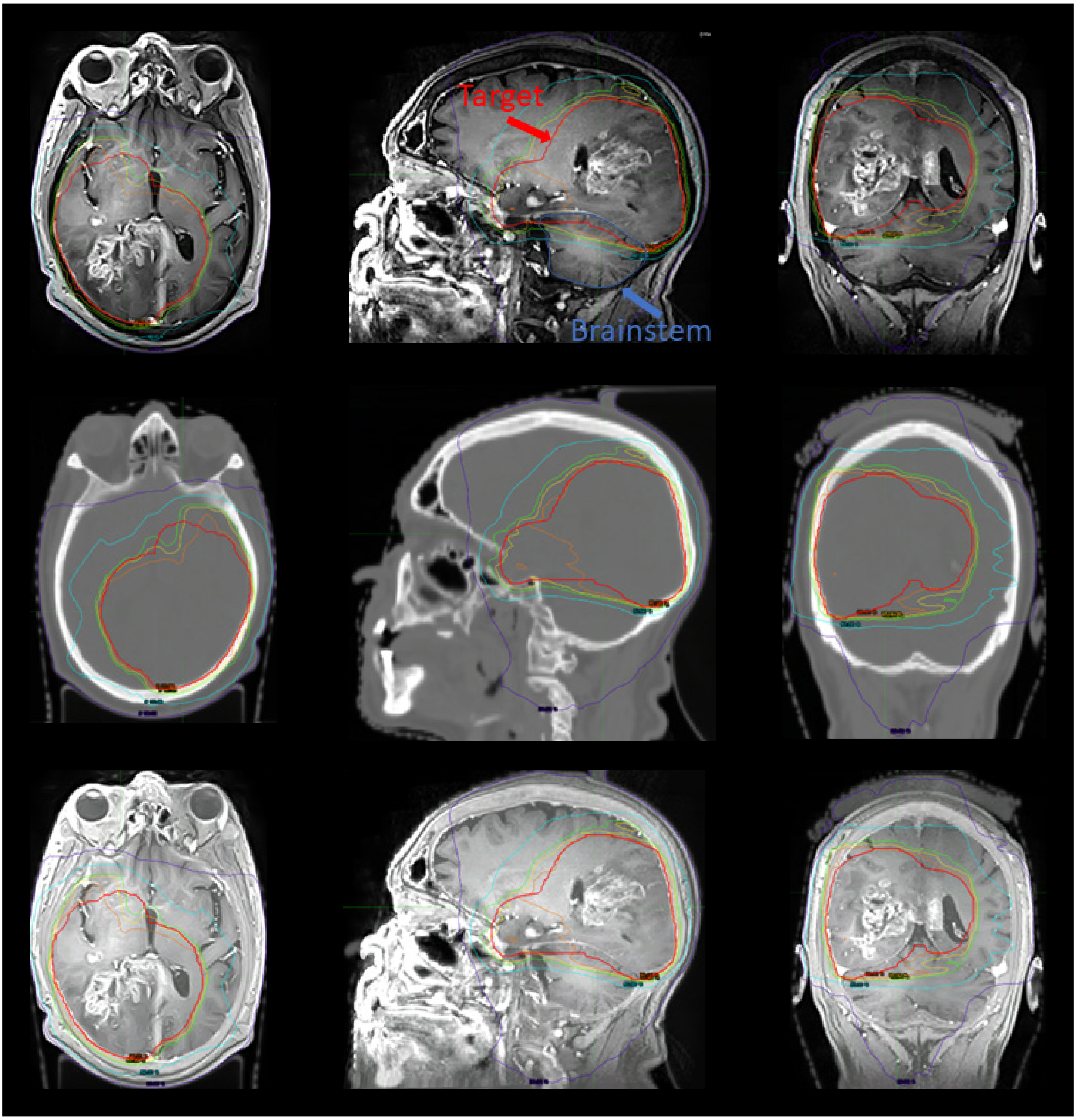

Figure 4: The dosimetry map on MRI, CT images, and the fusion of the two modalities in three axes. The target and brain stem are shown with arrows.

Conclusion

CT alone fails to capture critical information necessary for contouring the target and organs at risk in brain cancer patients. However, when CT and MRI are fused, clinicians benefit from the enhanced accuracy and precision provided by MRI. This fusion allows for more precise segmentation of the tumor and organs at risk. The high precision of MRI aids in safeguarding critical organs during treatment which reduces the toxicity and enhances targeting the tumor during radiotherapy treatment. Moreover, using a flat tabletop setup in both CT and MR scans mimics the treatment room condition and minimizes both motion artifacts and registration uncertainties. Finally, integrating MRI into the process saves valuable time that would otherwise be spent contouring a low-contrast CT image. This time can instead be utilized to enhance treatment delivery and optimize patient care.

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