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Assessment of Computed Tomography (CT) And Magnetic Resonance Imaging (MRI) Based Radiosurgery Treatment Planning for Pituitary Adenomas

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Abstract

Aim: Pituitary adenomas are fairly common benign tumors which may be found in up to 20% of the general population. While a considerable proportion of patients harboring these benign tumors may be asymptomatic, symptoms may arise due to the mass effect on critical neurovascular structures including the optic nerves and chiasm, cavernous sinus, and normally functioning pituitary gland or stalk. Radiosurgery may be used as a viable therapeutic option for management of pituitary adenomas. Treatment planing for radiosurgery is typically performed by Computed Tomography (CT)-simulation, however, multimodality imaging may add to the accuracy of target contouring for pituitary adenomas. In this study, we evaluated the utility of multimodality imaging with CT and Magnetic Resonance Imaging (MRI) for radiosurgery treatment planning of pituitary adenomas.

Methods and Materials: The study group included 18 patients who received radiosurgery for pituitary adenoma at our department. A comparative assessment was performed to investigate the incorporation of MRI into radiosurgery treatment planning for pituitary adenomas.

Results: A total of 18 patients receiving radiosurgery for pituitary adenomas at our department were assessed for target volume definition by use of CT-only imaging and CT-MR fusion based imaging in this study. Mean target volume was 4.4 cc (range: 1.1-10.9 cc) on CT-only imaging, 4.7 cc (range: 1.2-11.1 cc) on CT-MR fusion based imaging, and 4.6 cc (range: 1.2-11.2 cc) on collaboration and consensus of treating radiation oncologists by using all available imaging data of the patients.

Conclusion: Ground truth target volume was identical to target determination based on CT-MR fusion based imaging in majority of our study group. MRI offers a viable imaging modality for pituitary adenoma target definition and may substantially improve accuracy and precision in target contouring for radiosurgery of pituitary adenomas.

Keywords: Pituitary adenoma; Stereotactic Radiosurgery (SRS); Fractionated Stereotactic Radiotherapy (FSRT); Hypofractionated Stereotactic Radiotherapy (HFSRT); Target definition; Computed Tomography (CT); Magnetic Resonance Imaging (MRI)

Introduction

Pituitary adenomas are fairly common benign tumors which may be found in up to 20% of the general population [1-3]. Categorization of pituitary adenomas is typically performed based on lesion size (microadenomas or macroadenomas) and hormon secretion status (functioning or nonfunctioning adenomas). While a considerable proportion of patients harboring these benign tumors may be asymptomatic, symptoms may arise due to the mass effect on critical neurovascular structures including the optic nerves and chiasm, cavernous sinus, and normally functioning pituitary gland or stalk. Occurring symptoms may profoundly deteriorate the affected patients' health status and quality of life, and prompt management may be considered. Medical treatment, surgery, and radiation therapy (RT) are among the therapeutic options for management of pituitary adenomas. Surgery is a primary mode of treatment for pituitary adenomas, however, some lesions may not be amenable to complete surgical removal due to their intimate association with vital neurovascular structures. From this aspect, RT may be considered as an alternative or complementary treatment modality utilized after partial surgical removal of pituitary adenomas. Another typical utilization of RT is for management of recurrences which may occur in a considerable proportion of patients even after successful initial management.

Radiosurgery in the form of Stereotactic Radiosurgery (SRS), Fractionated Stereotactic Radiation Therapy (FSRT), Hypofractionated Stereotactic Radiation Therapy (HFSRT), and Stereotactic Body Radiation Therapy (SBRT) has been judiciously utilized for management of several benign and malign conditions throughout the human body with encouraging therapeutic outcomes [4-22]. For management of pituitary adenomas, several studies reported the safety and efficacy of radiosurgery [8,23,24]. Due to the critical location of pituitary adenomas in close vicinity of several vital structures, achieving a favorable toxicity profile is a pertinent goal of RT as well as surgery. Treatment planing for radiosurgery is typically performed by Computed Tomography (CT)-simulation, however, multimodality imaging may add to the accuracy of target contouring for pituitary adenomas. In this study, we evaluated the utility of multimodality imaging with CT and Magnetic Resonance Imaging (MRI) for radiosurgery treatment planning of pituitary adenomas.

Materials and Methods

The study group included 18 patients who received radiosurgery for pituitary adenoma at our department. Written informed consent was provided for each patient before radiosurgical treatment. Decision making for radiosurgery was performed after thorough patient assessment by a multidisciplinary team of experts on neurosurgery, radiation oncology, and neuroradiology. Factors such as lesion size, location and association with critical structures, patient symptomatology, age, performance status and preferences were considered. All patients had thin slice MRI typically acquired within one week before radiosurgery. On treatment day, immobilization was secured by use of a stereotactic head frame which was affixed to the patients' skull under local anesthesia with 4 pins. Patients underwent CT-simulation at the CT-simulator (GE Lightspeed RT, GE Healthcare, Chalfont St. Giles, UK) at our department. Planning CT images were sent to the contouring workstation (SimMD, GE, UK) for delineation of the target and neighbouring critical structures such as the brainstem, optic nerves, optic chiasm, pituitary stalk, and pituitary gland. Target delineation was based on CT-simulation images only or fused CT and T1 gadolinium-enhanced MR images. A comparative assessment was performed to investigate the incorporation of MRI into radiosurgery treatment planning for pituitary adenomas. For actual treatment and comparison purposes, the ground truth target volume was generated after collaboration and consensus of treating radiation oncologists by using all available imaging data of the patients.

Results

A total of 18 patients receiving radiosurgery for pituitary adenomas at our department were assessed for target volume definition by use of CT-only imaging and CT-MR fusion based imaging in this study. Mean target volume was 4.4 cc (range: 1.1-10.9 cc) on CT-only imaging, 4.7 cc (range: 1.2-11.1 cc) on CT-MR fusion based imaging, and 4.6 cc (range: 1.2-11.2 cc) on collaboration and consensus of treating radiation oncologists by using all available imaging data of the patients. Ground truth target volume was identical to target determination based on CT-MR fusion based imaging in majority of the study group. Target volume delineation was optimized by adjustment of appropriate windows and levels for radiosurgery treatment planning. In treatment planning for radiosurgery, either a single 360-degree, double 360-degree arcs or five 180-degree arcs were used for optial sparing of critical structures surrounding the target. Arc Modulation Optimization Algorithm (AMOA) was utilized for achieving optimal target coverage and normal tissue sparing. Radiosurgery treatment planning was accomplished by use of ERGO ++ (CMS, Elekta, UK) radiosurgery planning system and treatment delivery was performed by using Synergy (Elekta, UK) Linear Accelerator (LINAC) with 6-MV photons. Median dose of radiosurgery was 13 Gy (range: 10-16 Gy) prescribed to the 85%-95% isodose line encompassing the target. Isocenter and setup verifications were performed by use of kV-CBCT (kilovoltage Cone Beam CT) and XVI (Xray Volumetric Imaging, Elekta, UK) system integrated into the LINAC gantry. All patients routinely received 8 mg intravenous dexamethasone with H2-antihistamines after radiosurgical treatment (Figure 1).

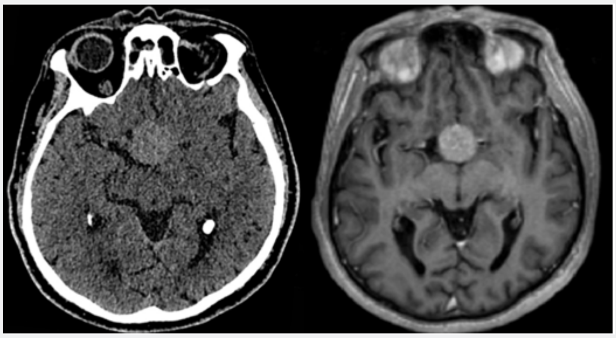

Figure 1: Treatment planning CT and MR images of a patient with pituitary adenoma.

Discussion

Pituitary adenomas may cause several symptoms depending on their location and association with surrounding critical structures. Therapeutic options for management typically include medical treatment, surgery, and RT. Management with complete surgical resection may be hampered due to the excessive risk of surgical complications particularly when the pituitary adenoma lesion is in close contact with the optic apparatus or vital neurovascular structures located in the cavernous sinus. RT offers a viable treatment modality and may be utilized for complementary or definitive management of pituitary adenomas in selected patients. Conventionally fractionated RT has been traditionally used for treatment of pituitary adenomas, however, radiosurgery in the form of SRS or HFSRT has emerged as a viable radiotherapeutic modality for management of well-

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defined lesions with small to moderate size. Primary advantage of radiosurgery is management of patients with a condensed treatment schedule by use of one or a few fractions while achieving steep dose gradients around the target resulting in optimal normal tissue sparing. Nevertheless, excessive toxicity is an important concern for management of pituitary adenomas with radiosurgery a well as surgical resection and achieving an improved toxicity profile is a pertinent goal of irradiation as well to avoid adverse radiation effects [25,26]. In this context, several strategies have been implemented for avoiding excessive treatment toxicity such as deferral of irradiation, proton therapy, and combined modality management including surgery followed by SRS [27-32].

An important aspect of precision radiosurgery is accurate definition of the target given the high fractional doses and steep dose gradients around the target in radiosurgical treatments. There may be interobserver variability in delineation of the target and critical structures which may lead to inadequate treatment and unexpected toxicity, emphasizing the need for vigilance in contouring of the pituitary adenoma target and relevant critical structures for achieving optimal radiosurgical outcomes [33-35]. While CT-simulation is a common practice for radiosurgery, incorporation of MRI may add to the accuracy of target definition. In our study, ground truth target volume was identical to target determination based on CT-MR fusion based imaging in majority of the patients. Our study supports the incorporation of MRI into radiosurgery target definition for improving the accuracy of treatment. In conclusion, MRI offers a viable imaging modality for pituitary adenoma target definition and may substantially improve accuracy and precision in target contouring for radiosurgery of pituitary adenomas.

Conflicts Interest

There are no conflicts of interest and no acknowledgements.

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