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Incorporation of Multimodality Imaging in Radiosurgery Planning for Craniopharyngiomas: An Original Article

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Abstract

Background: Craniopharyngiomas arise in the pituitary gland or pituitary stalk and are among the rare benign tumors. However, craniopharyngiomas comprise the most common suprasellar tumors in children. Diagnosis of craniopharyngioma is typically based on clinical symptomatology due to involvement of neighbouring critical structures. Deficiencies of pituitary hormones, visual disturbances, obstructive hydrocephalus and cranial neuropathies may occur depending on lesion size, growth pattern, location and association with critical structures. Increased intracranial pressure may occur due to the mass effect, manifesting as headache, nausea and vomiting. Tumors compressing the optic chiasm may cause visual disturbances. While surgery is a primary therapeutic option for craniopharyngiomas, radiosurgery may offer a viable alternative or complementary treatment modality. Imaging has an indespensable role in craniopharyngioma radiosurgery. In this context, we assessed the use of multimodality imaging for target volume definition for craniopharyngioma radiosurgery in this study.

Methods: Fifteen patients receiving Stereotactic Radiosurgery (SRS) for craniopharyngioma at our department were studied. Target volumes for radiosurgery were determined by using the Computed Tomography (CT) simulation images only or by fusion of T1 gadolinium-enhanced Magnetic Resonance Imaging (MRI) acquired within 1 week before radiosurgical treatment, and a comparative assessment of target definition with CT-only and CT-MR fusion was performed.

Results: Mean target volumes were 6.1 cc (range: 3.2-14.7 cc) and 6.9 cc (range: 3.5-14.9 cc) for CT-only imaging and CT-MR fusion-based imaging, respectively.

Conclusion: Treatment planning for craniopharyngioma SRS may be improved by incorporation of MRI into the target determination process. Further research is warranted to investigate the role of multimodality imaging for target volume definition for craniopharyngioma SRS.

Keywords: Craniopharyngioma; Stereotactic Radiosurgery (SRS); Computed Tomography (CT); Magnetic Resonance Imaging (MRI); Target Volume

List of Abbreviations: SRS: Stereotactic Radiosurgery; CT: Computed Tomography; MRI: Magnetic Resonance Imaging

Introduction

Craniopharyngiomas arise in the pituitary gland or pituitary stalk and are among the rare benign tumors accounting for 1-3% of all intracranial neoplasms. Structurally, craniopharyngiomas may be purely solid, purely cystic or mixed solid and cystic. Craniopharyngiomas have a bimodal age distribution, but more commonly occur in children, with specific ethnic groups such as Japanese children having a higher incidence [1]. Craniopharyngiomas comprise the most common suprasellar tumors in children, accounting approximately 5% of all intracranial tumors and 10% of pediatric brain tumors [2]. Diagnosis of craniopharyngioma is typically based on clinical symptomatology due to involvement of neighbouring critical structures. Deficiencies of pituitary hormones, visual disturbances, obstructive hydrocephalus and cranial neuropathies may occur depending on lesion location, size, growth pattern and proximity to critical structures. Increased intracranial pressure may occur due to the mass effect, manifesting as headache, nausea and vomiting. Tumors compressing the optic chiasm may cause visual disturbances.

Surgery plays a central role in management of craniopharyngiomas with the primary goals of achieving maximal safe resection, rapid decompression, and improving visual functions. However, optimal surgical resection of craniopharyngiomas may be substantially hampered by the critical location of some tumors in the vicinity of critical neurovascular structures including the optic chiasm, cranial nerves and blood vessels. Another potential problem with surgical resection of craniopharyngiomas is the considerable rates of recurrence. Selected patients may benefit from multimodality management including surgery and radiation therapy for achieving an improved toxicity profile.

Radiosurgery has been judiciously used for management of craniopharyngiomas both in the primary and recurrent disease setting either as a definitive or complementary treatment modality [3-5]. Imaging has an indespensable role in target definition for craniopharyngioma radiosurgery. In this context, radiosurgery target volumes defined by using Computed Tomography (CT) images only were compared with target volumes defined by both CT and Magnetic Resonance Imaging (MRI) in this study to assess the impact of multimodality imaging on target volume definition for radiosurgery of craniopharyngiomas.

Methods

Fifteen patients receiving stereotactic radiosurgery (SRS) for craniopharyngioma at our department were studied. All patients gave written informed consent for radiosurgical treatment, and treatment with radiosurgery was decided after thorough evaluation of patients by a multidisciplinary team of experts from neuroradiology, radiation oncology and neurosurgery.

The stereotactic head frame was affixed to the patients' skull with 4 pins under local anesthesia on treatment day. All patients then underwent computed tomography (CT) simulation at the CT simulator (GE Lightspeed RT, GE Healthcare, Chalfont St. Giles, UK) available at our department. Contrast-enhanced planning CT images were acquired and sent to the contouring workstation (SimMD, GE, UK) for delineation of craniopharyngioma target volumes and neighbouring critical structures. Target volumes for radiosurgery were determined by using the CT simulation images only or by fusion of T1 gadolinium-enhanced MRI acquired within 1 week before radiosurgical treatment, and a comparative assessment of target definition with CT-only and CT-MR fusion was performed. Definition of ground truth target volume for each patient has been performed after colleague peer review and consensus of board-certified radiation oncologists. Target volume delineation on planning CT and MR images was optimized by selection of appropriate windows and levels in treatment planning for craniopharyngioma SRS. Improved precision in contouring was targeted by using coronal and sagittal images in addition to axial images of the patients. Arc modulation optimization algorithm (AMOA) was used for optimization of target volume coverage whilst maintaining sparing of critical structures. ERGO ++ (CMS, Elekta, UK) radiosurgery planning system was used in treatment planning, and single dose radiosurgery was delivered with the Synergy (Elekta, UK) Linear Accelerator (LINAC) available at our department. kV-CBCT (kilovoltage Cone Beam CT) and XVI (X-ray Volumetric Imaging, Elekta, UK) were routinely used as Image Guided Radiation Therapy (IGRT) techniques for treatment verification. Dexamethasone with H2-antihistamines was used for all patients after treatment.

Results

Characteristic	Number	%
Diagnosis Craniopharyngioma	 15	 100
Gender Male Female	 9 6	 60 40
Surgical intervention Biopsy Subtotal excision Total excision	 1 11 3	 6.7 73.3 20
Structural composition Solid Cystic Mixed	 7 3 5	 46.7 20 33.3
Lesion location Intrasellar Suprasellar Both intrasellar and suprasellar	 1 5 9	 6.7 33.3 60
Number of patients	15	
Median age (range)	29 (13-65) years	
Median dose (range)	13 (10-16) Gy	
Median prescription isodose line (range)	90% (80% -95%)	

Table 1: Patient, Treatment and Tumor Characterisitics

A total of 15 patients treated with craniopharyngioma radiosurgery at our department were assessed for determination of target volumes for SRS using CT-only imaging and CT-MR fusion-based imaging. Median age was 29 (13-65) years. Nine patients (60%) were male and 6 patients (40%) were female. Surgical intervention was biopsy for 1 patient (6.7%), subtotal excision for 11 patients (73.3%), and total excision for 3 patients (20%). Structural composition of the craniopharyngioma lesions was solid in 7 patients

(46.7%), cystic in 3 patients (20%) and mixed in 5 patients (33.3%). Lesions were located at the intrasellar region for 1 patient (6.7%), suprasellar region for 5 patients (33.3%) and both intrasellar and suprasellar regions for 9 patients (60%). Median dose was 13 (10-16) Gy prescribed to the 80% -95% isodose line. Patient, treatment and tumor characteristics are shown on Table 1.

Mean target volumes were 6.1 cc (range: 3.2-14.7 cc) and 6.9 cc (range: 3.5-14.9 cc) for CT-only imaging and CT-MR fusion-based imaging, respectively. Ground truth target volume defined after colleague peer review and consensus of treating radiation oncologists was found to be identical to target determination based on CT-MR fusion-based imaging in 13 out of the 15 patients (86.7%). Figure 1 shows coronal planning CT and MR images of a patient with craniopharyngioma.

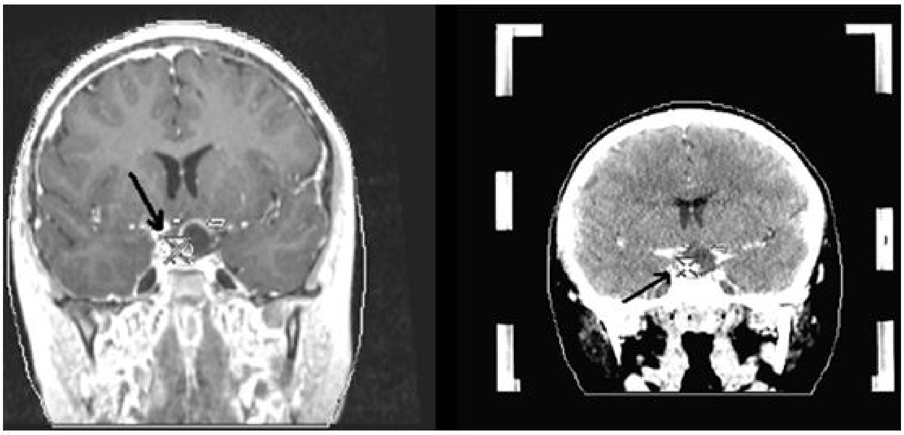

Figure 1: Coronal Planning CT and MR Images of a Patient with Craniopharyngioma Demonstrating the Target Volume (black arrow)

Discussion

Optimal management of craniopharyngiomas has yet to be defined. While surgery is a main therapeutic modality to achieve optimal treatment in selected patients, surgical complications may be hazardous particularly when the craniopharyngioma lesion is in intimate association with vital neurovascular structures. Radiosurgery has been a viable treatment modality for various benign and malign brain disorders [5-23].

In the context of craniopharyngiomas, radiosurgery in the form of SRS or fractionated SRS has emerged as a viable treatment option in the setting of recurrent disease or as an alternative or adjunct to surgery for selected patients [3-5,24-29]. Target volume determination for craniopharyngioma radiosurgery plays a central role in radiosurgery treatment planning. CT may superiorly detect bony invasion of the lesions; however, MR imaging adds to the accuracy of target definition by providing improved visualization for optimal radiosurgery target localization. In our study, we found that definition of ground truth target volume decided by colleague peer review and consensus of the treating radiation oncologists was identical to target determination based on CT-MR fusion-based imaging in 86.7% of the patients, supporting a critical role of MRI for radiosurgery target definition as supported by several studies [30-32]. Although not including patients with craniopharyngioma, other studies by our group assessing target definition for radiosurgery typically reported larger target volumes with incorporation of MRI into the treatment planning process [30-32]. In a series of patients treated with radiosurgery for meningiomas, we have found that median target volume was 8.1 cc (range: 2.3-31.8 cc) with CT-only imaging and 8.6 cc (range: 2.4-32.7 cc) with CT-MR fusion based imaging [31]. In another study on radiosurgery of arteriovenous malformations, target volumes were 4.9 cc (range: 1.3-15.9 cc) on CT-only imaging and 5.7 cc (range: 1.4-16.7 cc) on CT-MR fusion based imaging [32].

Conclusion

In conclusion, treatment planning for craniopharyngioma SRS may be improved by incorporation of MRI into the target determination process. Further research is warranted to investigate the role of multimodality imaging for target volume definition for craniopharyngioma SRS.

Conflict of Interest Statement

There are no conflicts of interest.

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