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Assessment of Multimodality Imaging for Target Volume Determination of Recurrent Who grade 3 Meningiomas

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Abstract

Objective: The role of radiation therapy (RT) has been well established as a viable therapeutic modality for WHO grade 2 or 3 meningiomas. However, there is paucity of data regarding optimal target definition for radiotherapeutic management of WHO grade 3 meningiomas. In this original research article, we shed light on this issue.

Materials and methods: Multimodality imaging based RT target volume determination has been evaluated in this study for patients receiving salvage RT for recurrent WHO grade 3 after initial management. RT target volume determination by incorporation of MRI or by CT-simulation images only has been evaluated comparatively.

Results: RT planning was performed by expert radiation physicists by taking into account the normal tissue dose constraints as per the guidelines of American Association of Physicists in Medicine (AAPM). Radiation dose calculation was performed by considering the electron density, CT number and HU values in CT images by considering tissue heterogeneity. Optimal target volume coverage was prioritized in RT planning with maintenance of normal tissue protection. Definition of ground truth target volume was performed by the expert group after thorough evaluation, collaborative assessment, colleague peer review, and consensus to be used for actual treatment and for comparative analysis. Treatment delivery was performed by Synergy (Elekta, UK) LINAC with routine incorporation of kilovoltage cone beam CT and electronic digital portal imaging. Target volume definition by CT-only imaging and by CT-MR fusion based imaging was comparatively evaluated, and the ground truth target volume was found to be identical with target volume determination by CT-MR fusion based imaging.

Conclusion: Our study suggests improved target definition for recurrent WHO grade 3 meningiomas by incorporation of MRI in RT planning process. Admittedly, further investigations addressing this issue are needed.

Keywords: Recurrent WHO grade 3 meningioma; Radiation therapy (RT); Magnetic resonance imaging (MRI)

Introduction

Meningiomas are the most frequent of intracranial benign tumors and account for a significant proportion of all intracranial neoplasms [1]. These dural-based tumors are thought to stem from arachnoid cap cells or meningothelial cells included in the arachnoid layer of the meninges [2,3]. While the incidence of meningiomas increases with age, the most common age of presentation is in the 6th to 8th decades of life [4]. Meningiomas are classified as benign, atypical, or anaplastic (malignant) as per the World Health Organization (WHO) classification scheme [2,4]. Anaplastic (malignant) meningioma, papillary meningioma, and rhabdoid meningioma are classified among the histological subtypes of WHO grade 3 meningioma [5]. Meningiomas may occur in a variety of locations within the central nervous system (CNS) with the most common location being the supratentorial region, followed by the base of skull and posterior fossa [5]. Benign meningiomas account for the majority of meningiomas and usually follow an indolent disease course. However, malignant meningiomas typically have a more aggressive disease pattern with high growth rate which reflects the clinical and histopathological features of malignancy.

Although malignant meningiomas account for less than 5% of all meningiomas, patients with this diagnosis may suffer from severe debilitating and life threatening signs and symptoms. Within this context, optimal diagnosis and management of these fast growing lesions is warranted.

Magnetic resonance imaging (MRI) is the current imaging modality of choice for detection of meningiomas. Nevertheless, imaging with computed tomography (CT) may aid in detection of hyperostosis of the neighboring bone, tumoral calcifications, and intraosseous growth of the tumor especially in the presence of skull base meningiomas [6]. MRI may be utilized for detection of the dural tail, if present, as a typical post-contrast linear thickening of the duramater adjacent to the meningioma lesion. MRI may allow for differentiating between intraaxial and extraaxial meningiomas and offers improved contrast differentiation. Meningiomas typically appear as exraaxial masses having well defined borders. There may be homogeneous contrast enhancement while areas of calcification or central necrosis may not show contrast enhancement.

Surgery is the principal treatment modality for management of meningiomas. Simpson reported an association between the aggressiveness of meningioma resection and subsequent tumor recurrences with description of 5 grades of meningioma removal in 1957 [7]. Since then, techniques have evolved and contemporary surgical approaches have been introduced. Nevertheless, recurrence may be observed particularly in the setting of high grade meningiomas. Radiation therapy (RT) in the form of conventionally fractionated RT or stereotactic radiosurgery (SRS) may be utilized as part of initial management, as adjuvant therapy, or for salvage treatment of recurrent meningiomas. The role of RT has been well established as a viable therapeutic modality for WHO grade 2 or 3 meningiomas [8-12]. However, there is paucity of data regarding optimal target definition for radiotherapeutic management of WHO grade 3 meningiomas. In this original research article, we shed light on this issue.

Materials and Methods

Multimodality imaging based RT target volume determination has been evaluated in this study for patients receiving salvage RT for recurrent WHO grade 3 after initial management. RT target volume determination by incorporation of MRI or by CT-simulation images only has been evaluated comparatively. Ground truth target volume serving as the reference for actual treatment and for comparison purposes has been determined by an expert group after thorough evaluation, detailed assessment, colleague peer review, and consensus. In the salvage therapy setting, patients have been thoroughly assessed by a multidisciplinary team of experts taking into account the lesion size, localization and association with surrounding normal tissues, symptomatology, and contemplated results of irradiation.

In the treatment planning system (TPS) unit, patient treatment dose calculation was performed by taking into account the electron density, CT number and HU values in CT images by considering tissue heterogeneity. Synergy (Elekta, UK) linear accelerator (LINAC) was used for precise irradiation with routine incorporation of Image Guided RT (IGRT) techniques including electronic digital portal imaging and kilovoltage cone beam CT.

CT-simulator (GE Lightspeed RT, GE Healthcare, Chalfont St. Giles, UK) was utilized for RT simulation and treatment planning. Planning CT images were acquired at the CT-simulator and were then sent to the delineation workstation (SimMD, GE, UK) via the network for contouring of treatment volumes and critical structures. Either CT-simulation images only or fused CT and MR images have been used for target definition. Target volume definition by CT only and with incorporation of CT-MR fusion was evaluated with comparative analysis.

Results

For the purpose of this study, RT planning was performed by expert radiation physicists by taking into account the normal tissue dose constraints as per the guidelines of American Association of Physicists in Medicine (AAPM). Radiation dose calculation was performed by considering the electron density, CT number and HU values in CT images by considering tissue heterogeneity. Optimal target volume coverage was prioritized in RT planning with maintenance of normal tissue protection. Definition of ground truth target volume was performed by the expert group after thorough evaluation, collaborative assessment, colleague peer review, and consensus to be used for actual treatment and for comparative analysis. Treatment delivery was performed by Synergy (Elekta, UK) LINAC with routine incorporation of kilovoltage cone beam CT and electronic digital portal imaging. Target volume definition by CT-only imaging and by CT-MR fusion based imaging was comparatively evaluated, and the ground truth target volume was found to be identical with target volume determination by CT-MR fusion based imaging.

Discussion

Although relatively rare, WHO grade 3 meningiomas may follow an aggressive disease course despite rigorous management. Recurrences may be observed, and salvage therapy may be rather complicated by initial therapies which may limit the administration of aggressive management. However, recent technological advances have paved the way for focused irradiation of well defined targets under robust immobilization and image guidance. Nevertheless, accuracy in target volume determination has emerged as a critical part of state of the art RT approaches. Radiosurgery has become a relatively newer radiotherapeutic alternative with excellent tumor localization and immobilization. Relatively reduced margins around the target volume in sophisticated RT techniques has rendered target definition more

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important to avoid geographic misses or untowards irradiation effects. IGRT techniques have clearly contributed to improvements in target localization, and combined use of matched CT and MR images may improve precision in target volume definition for contemporary radiotherapeutic strategies.

Image resolution and contrast provided by CT and MRI may show differences throughout the human body. Bone-air density differences may be distinguished better in CT, and soft tissue differences may be distinguished better by use of MRI [13-15]. There is growing body of evidence suggesting the superiority of multimodality imaging based target definition for many indications [16-47]. Within this context, our study may add to accumulating data about the incorporation of multimodality imaging based target definition for salvage radiotherapeutic management of recurrent WHO grade 3 meningiomas.

Admittedly, introduction of contemporary treatment approaches contributed to improving the toxicity profile of radiation delivery. Using higher radiation doses may typically contribute to better treatment outcomes for recurrent WHO grade 3 meningiomas, however, precision in target definition is of utmost importance. Millenium era has witnessed unprecedented improvements in the radiation oncology discipline including adaptive RT approaches, IGRT, Intensity Modulated RT (IMRT), Adaptive Radiation Therapy (ART), Breathing Adapted Radiation Therapy (BART), molecular imaging methods, automatic segmentation techniques, and stereotactic RT [48-84].

Conclusion

In conclusion, our study suggests improved target definition for recurrent WHO grade 3 meningiomas by incorporation of MRI in RT planning process. Clearly, further investigations addressing this issue are needed.

Conflict of Interest

There are no conflicts of interest and no acknowledgements.

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