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Evaluation of Target Volume Definition for Recurrent Paranasal Sinus Carcinoma (PSCA) Based on Multimodality Imaging

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Abstract

Objective: Radiation therapy (RT) planning for salvage management of recurrent paranasal sinus carcinoma (PSCa) should be performed carefully to achieve optimal results. From a radiation physics perspective, the head and neck region contains a lot of heterogeneity differences. The bony structures and the surrounding soft tissues, adipose tissue, and air have different electron densities.This heterogeneous environment may affect the radiation dose distribution depending on the amount, type and quality of the existing heterogeneity density. In this study, we assess the utility of multimodality imaging for radiotherapeutic management of recurrent PSCa in the salvage treatment setting.

Materials and methods: In the treatment planning system (TPS) unit, patient treatment dose calculation has been performed considering the electron density, computed tomography (CT) number and HU values in CT images by taking into account the tissue heterogeneity. Synergy (Elekta, UK) linear accelerator (LINAC) has been utilized for precise RT with routine incorporation of Image Guided Radiation Therapy (IGRT) techniques such as electronic digital portal imaging and kilovoltage cone beam CT for treatment verification.

Results: Treatment volume determination by CT-only imaging and by CT-MR fusion based imaging was assessed comparatively, and the ground truth target volume was found to be identical with target volume definition by CT-MR fusion based imaging as the main result of the study.

Conclusion: In conclusion, this study provides evidence for improved target and treatment volume definition for recurrent PSCa with incorporation of magnetic resonance imaging (MRI) in RT planning. Clearly, further study is warranted to shed light on this issue.

Keywords: Recurrent paranasal sinus carcinoma (PSCa); Radiation therapy (RT); Magnetic resonance imaging (MRI)

Introduction

Tumors of the nasal cavity and paranasal sinus are relatively rare and account for a small proportion among head and neck cancers [1-3]. Nevertheless, patients with paranasal sinus carcinoma (PSCa) may suffer from several symptoms depending on lesion size, location and association with surrounding critical structures. Typically, a profound deterioration in affected patients' quality of life may result from tumor invasion and disfiguration. Since critical parts associated with important functions are located within the head and neck region, PSCa may lead to functional, cosmetic, and psychosocial consequences. Also, aggressive treatment for these tumors may result in morbidity. Currently, surgery, radiation therapy (RT), and systemic treatments may be utilized alone or in combination with respect to disease setting, clinical stage, tumor and pathological characteristics. RT composes an integral part of management as part of initial treatment, as adjuvant therapy, or for salvage management of recurrent disease. Unfortunately, recurrence after initial management of PSCa may be observed in a significant proportion of patients, and salvage therapy is usually a complicated and complex procedure requiring utmost consideration and vigilance. Due to exposure of the affected region by previous therapies, treatment for salvage should be aimed at respecting the tolerance and radiation dose limits of critical structures within the treatment field while eliminating recurrent disease.

RT planning for salvage management of recurrent PSCa should be performed carefully to achieve optimal results. From a radiation physics perspective, the head and neck region contains a lot of heterogeneity differences. The bony structures and the surrounding soft tissues, adipose tissue, and air have different electron densities. This heterogeneous environment may affect the radiation dose distribution depending on the amount, type and quality of the existing heterogeneity density. The anatomy of irradiated patients may include irregular fields containing inhomogeneous environments of different densities and the dose distribution in the patient may differ from the standard dose distribution.

Introduction of novel and sophisticated technologies have paved the way for improved toxicity profiles by use of Intensity Modulated Radiation Therapy (IMRT), Image Guided Radiation Therapy (IGRT), Adaptive Radiation Therapy (ART) and many other contemporary RT approaches. In this study, we assess the utility of multimodality imaging for radiotherapeutic management of recurrent PSCa in the salvage treatment setting.

Materials and Methods

Multimodality imaging based RT target volume determination has been evaluated in this study for patients receiving salvage RT for recurrent PSCa. RT target volume definition by incorporation of magnetic resonance imaging (MRI) or by computed tomography (CT)-simulation images only has been assessed with comparative analysis. Ground truth target volume to be utilized for actual treatment and comparison purposes has been defined by an expert group after detailed assessment, colleague peer review, and consensus. In the salvage therapy setting, all patients have been meticulously evaluated by a multidisciplinary team of experts with consideration of lesion size, localization and association with surrounding critical structures, symptomatology, and expected outcomes of radiotherapeutic management.

CT-simulator (GE Lightspeed RT, GE Healthcare, Chalfont St. Giles, UK) has been used for RT simulation and treatment planning. Planning CT images have been acquired at the CT-simulator and were consequently transferred to the contouring workstation (SimMD, GE, UK) via the network for delineation of treatment volumes and normal tissues. Either CT-simulation images only or fused CT and MR images have been utilized for target volume determination. Target volume determination with CT only and with incorporation of CT-MR fusion was assessed comparatively.

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

Results

RT planning has been performed by expert radiation physicists with utmost consideration of critical organ dose constraints and guidelines of American Association of Physicists in Medicine (AAPM). Radiation dose calculation has been performed with consideration of electron density, CT number and HU values in CT images by taking into account the tissue heterogeneity. Priority was given for optimal target volume coverage whilst maintaining critical organ sparing. Determination of ground truth target volume has been performed by an expert group following detailed collaborative assessment, colleague peer review, and consensus to be used for actual treatment and for comparative analysis. Treatment delivery was accomplished by Synergy (Elekta, UK) LINAC with routine incorporation of IGRT techniques of kilovoltage cone beam CT and electronic digital portal imaging. Treatment volume determination by CT-only imaging and by CT-MR fusion based imaging was assessed comparatively, and the ground truth target volume was found to be identical with target volume definition by CT-MR fusion based imaging as the main result of the study.

Discussion

Due to critical location of PSCa in vicinity of several critical structures associated with important body functions, salvage radiotherapeutic management of these tumors is rather complex. Critical organ dose constraints should be rigorously respected, and RT planning for salvage management of recurrent PSCa should be performed vigilantly to achieve optimal results. The head and neck region contains a lot of heterogeneity differences which may have seveal implications from a radiation physics perspective. Different electron densities of the bony structures and the surrounding soft tissues, adipose tissue, and air may significantly affect the radiation dose distribution depending on the amount, type and quality of the existing heterogeneity density. Typically, the anatomy of irradiated patients include irregular treatment fields including inhomogeneous environments of different densities and the dose distribution in the patient may differ from the standard dose distribution.

Precision in treatment volume definition has emerged as an indispensable component of contemporary RT strategies. Radiosurgical applications have paved the way for precisely focused irradiation of well-defined targets through excellent stereotactic immobilization and image guidance. However, accuracy and precision in target volume definition has gained utmost importance to avoid geographic misses, treatment failures, and radiation induced adverse effects. Within this context, there has been an emerging requirement for achieving improved target definition. IGRT techniques may assist in improved target localization, and utilization of matched CT and MR images may provide accurate target volume definition for state of the art RT.

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Image resolution and contrast of CT and MRI are different in the human body. While bone-air density differences may be distinguished better in CT, soft tissue differences may be distinguished better in MRI [4-6]. There has been accumulating data supporting the utility of multimodality imaging based treatment volume determination for a variety of indications [7-38]. From this perspective, this study may add to the growing body of evidence regarding the incorporation of multimodality imaging based target definition for recurrent PSCa management with salvage RT.

Indeed, introduction of state of the art therapeutic strategies led to improved toxicity profile of irradiation. Utilization of higher radiation doses may improve treatment outcomes for recurrent PSCa, however, accuracy in target definition is very critical. The millenium era has witnessed several advances in the radiation oncology discipline with incorporation of sophisticated treatment equipment and adaptive RT approaches, IMRT, IGRT, Adaptive Radiation Therapy (ART), Breathing Adapted Radiation Therapy (BART), molecular imaging methods, automatic segmentation techniques, and stereotactic RT [39-76]. In conclusion, this study provides evidence for improved target and treatment volume definition for recurrent PSCa with incorporation of MRI in RT planning. Clearly, further study is warranted to shed light on this issue.

Conflict of Interest

There are no conflicts of interest and no acknowledgements.

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