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Research article

Radiation Therapy (RT) target determination for irradiation of bone metastases with soft tissue component: Impact of multimodality imaging

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Abstract

Objective: Management options for bone metastases include surgical interventions, Radiation Therapy (RT), chemotherapy and other systemic and targeted agents. RT as external beam irradiation and by use of stereotactic radiotherapeutic approaches has been utilized for safe and efficacious management of bone metaseses. In the context of bone metastases with extraosseous soft tissue mass, the issue of irradiation target definition is a critical component of radiotherapeutic management for successful treatment. Herein, we evaluated target definition for irradiation of bone metastases with soft tissue component by incorporation of multimodality imaging.

Materials and methods: RT target definition for irradiation of bone metastases with soft tissue component was assessed in this study.

Results: Patients receiving palliative irradiation for bone metastases with soft tissue component were assessed for target volume determination. Treatment planning process was performed using the Elekta Precise treatment planning system (Elekta, UK) at our department. Definition of ground truth target volume was performed by the board certified radiation oncologists following meticulous evaluation, colleague peer review, collaboration, and ultimate consensus. Synergy (Elekta, UK) LINAC was used for irradiation. Comparative assessment in our study revealed that ground truth target volume was identical with target volume definition by CT-MR fusion based imaging.

Conclusion: Incorporation of multimodality imaging in target definition of bone metastases with soft tissue component may be utilized for improving the accuracy for precise RT despite the need for further supporting evidence.

Introduction

Bone metastases are among the frequent complications of systemic cancer, and a significant proportion of patients suffer from bone metastases during the course of their malignant disease [1]. Metastases may occur in the form of a single metastatic bone lesion, oligometastatic disease, multiple bone metastases, or visceral metastases with bone metastases. Most frequently affected site includes the vertebrae followed by femur, pelvic bones, ribs, sternum, humerus, and skull. While aymptomatic presentation may be present, affected patients may suffer from a variety of symptoms depending on metastatic disease location, extent and association with critical neurovascular structures. Skeletal related events due to bone metastases may include pain, compression of nerve roots and the spinal cord, hypercalcemia, myelophthisis, and pathological fractures which could lead to severe consequences and quality of life impairment.

Pain is a very frequent symptom of bone metastases [1,2]. Osteoclasts are thought to play significant role in pathophysiology, and injury of bone and nerve fibers may be responsible for occurrence of pain with both a nociceptive and neuropathic component [3-6].

Management options for bone metastases include surgical interventions, radiation therapy (RT), chemotherapy and

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other systemic and targeted agents [4-12]. RT as external beam irradiation and by use of stereotactic radiotherapeutic approaches has been utilized for safe and efficacious management of bone metaseses [4-12]. In the context of bone metastases with extraosseous soft tissue mass, the issue of irradiation target definition is a critical component of radiotherapeutic management for successful treatment. Herein, we evaluated target definition for irradiation of bone metastases with soft tissue component by incorporation of multimodality imaging.

Materials and methods

RT target definition for irradiation of bone metastases with soft tissue component was assessed in this study. Comparative analysis of Computed Tomographhy (CT)-only imaging and CT-magnetic resonance imaging (MRI) based target definition was performed to evaluate the impact of multimodality imaging. Ground truth target volume serving as the reference for actual treatment and comparison purposes was meticulously determined by board certified radiation oncologists following thorough evaluation, colleague peer review, collaboration, and ultimate consensus. All patients included in the study had histopathologically proven cancer diagnosis with radiological verification of bone metastases. Individualized patient assessment was performed to assess lesion size and localization, presenting symptoms, patient preferences, and contemplated outcomes of palliative treatment.

CT-simulator (GE Lightspeed RT, GE Healthcare, Chalfont St. Giles, UK) was utilized for RT simulation for all patients. Planning CT images were acquired and then transferred to the delineation workstation (SimMD, GE, UK) for outlining of target volume and organs at risk (OARs). Either CT-simulation images only or fused CT and MR images were utilized for target volume definition for radiotherapeutic management of bone metastases with soft tissue component. Contoured structure sets were transferred to the Elekta Precise treatment planning system (Elekta, UK) for radiation treatment planning. IGRT was routinely used by incorporating kilovoltage Cone Beam Computed Tomography (kV-CBCT) and X-ray Volumetric Imaging (XVI, Elekta, UK) for setup verification of each patient. Dose fractionation scheme included 30 Gy delivered in 10 fractions over 2 weeks, 20 Gy delivered in 5 fractions over 1 week, or 8 Gy delivered in a single fraction.

Target definition with CT only and with incorporation of CT-MR fusion based imaging was assessed comparatively. Also, patients were also assessed for age, gender, primary cancer diagnosis, location of metastases, and performance status.

Results

Patients receiving palliative irradiation for bone metastases with soft tissue component were assessed for target volume determination based on CT-only imaging and CT-MRI. Patient, tumor, and treatment charactheristics are summarized in Table 1.

Table 1: Patient, tumor and treatment characteristics.

Characteristic	Number	%
Number of patients	20	
Median age (range)	63 (51-83) years	
Median KPS (range)	70 (50-100)	
Gender		
Male	11	55
Female	9	45
Primary tumor histology		
Prostate Ca	7	35
Breast Ca	6	30
Lung Ca	5	25
Other	2	10
Involved metastatic region		
hips and pelvis	8	40
lumbar spine	5	25
thoracic spine	4	20
lower limbs	2	10
other	1	10
Dose fractionation scheme		
30 Gy in 10 fractions over 2 weeks	12	60
20 Gy in 5 fractions over 1 week	6	30
8 Gy in 1 fraction	2	10

A total of 20 patients were included in the study. Median age was 63 years (range: 51-83 years). Eleven patients (55%) were male and 9 patients (45%) were female. Involved metastatic region included the hips and pelvis in 8 patients (40%), lumbar spine in 5 patients (25), thoracic spine in 4 patients (20%), lower limbs in 2 patients (10%), and other location in 1 patient (5%). Median Karnofsky Performance Status was 70 (range: 50-100). Primary diagnosis was prostate cancer, breast cancer, lung cancer, and other for 7 patients (35%), 6 patients (30%), 5 patients (25%), and 2 patients (10%), respectively. Dose fractionation scheme included 30 Gy delivered in 10 fractions over 2 weeks in 12 patients (60%), 20 Gy delivered in 5 fractions over 1 week in 6 patients (30%), or 8 Gy delivered in a single fraction in 2 patients (10%).

Treatment planning process was performed using the Elekta Precise treatment planning system (Elekta, UK) at our department. Sparing of OARs whilst encompassing the target volumes were primary objectives of optimized treatent planning. Definition of ground truth target volume was performed by the board certified radiation oncologists following meticulous evaluation, colleague peer review, collaboration, and ultimate consensus. Synergy (Elekta, UK) LINAC was used for irradiation. Comparative assessment in our study revealed that ground truth target volume was identical with target volume definition by CT-MR fusion based imaging and a 100% overlap was detected between CT-MR fusion based target volume definition and ground truth target volume determination by the board certified radiation oncologists following comprehensive assessment, collaboration, colleague peer review, and ultimate consensus.

Discussion

Bone metastases constitute a very frequent complication of advanced systemic cancer. Pain, hypercalcemia, spinal cord compression and related symptoms are among the potential

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consequences which may lead to profound deterioration in affected patients. Among the several promising therapeutic strategies, RT deserves utmost attention as a viable mode of palliative management. There has been extensive study for finding out the optimal radiotherapeutic approach and dose fractionation schemes, however, there seems to be no standard solution to fit all circumstances which indicates the importance of considering individual patient and disease characteristics in the decision making process.

Several factors may be considered in management such as performance status, treatment compliance, life expectancy, primary cancer diagnosis, localization of metastatic lesions, presence of soft tissue involvement, fractures or neurological deficits, and logistical issues. Source availability, staffing, and facility workload may also be taken into account. Clearly, the goal of management shoud include.

In the era of extremely focused irradiation techniques such as stereotactic body RT (SBRT), it has been more critical to define target volume accurately. From this standpoint, exploiting the advantages of multimodality imaging for precise target definition has been an indispensable component of successful patient management in the millenium era.

There have been several studies exploring the role of multimodality imaging in target definition for radiotherapeutic management of several entities [13-40]. Substantial progress has been achieved in recent years with adoption of adaptive RT strategies and modernized treatment delivery techniques and equipment with incorporation of Intensity Modulated Radiation Therapy (IMRT), Adaptive Radiation Therapy (ART), Breathing Adapted Radiation Therapy (BART), IGRT, automatic segmentation techniques, molecular imaging methods, and stereotactic irradiation approaches [41-75].

Regarding management of bone metastases, use of RT has been addressed for effective palliation [4-12]. With efficacious local and systemic treatment approaches, there have been improvements in survival of patients suffering from metastatic cancer. Longer life expectancy of patients has rendered quality of life a critical aspect of successful management. Contemporary radiotherapeutic strategies increase the importance of precise RT target definition for an improved therapeutic ratio. Within this context, incorporation of multimodality imaging in target definition of bone metastases with soft tissue component may be utilized for improving the accuracy for precise RT. Admittedly, definition of the ground truth target volume for utilization in actual treatment and comparison purposes may be considered as a critical issue prone to variations due to possible interobserver variations. In this study, board certified radiation oncologists have performed definition of ground truth target volume following detailed evaluation, colleague peer review, collaboration, and ultimate consensus to achieve optimal results.

Conclusion

Bone metastases comprise a common complication of systemic cancer. Avoidance of excessive radiation induced toxicity is a critical concern for radiotherapeutic management of bone metastases. Given the significant workload, there may be differences in practice patterns worldwide regarding the incorporation of image guidance and multimodality imaging techniques. From this aspect, our study may add to the literature with routine utilization of these contemporary strategies in patient management.

In conclusion, incorporation of multimodality imaging in target definition of bone metastases with soft tissue component may be utilized for improving the accuracy for precise RT despite the need for further supporting evidence.

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