Lung Cancer

Posttreatment Imaging: Radiation Therapy and Imaging Findings

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KEYWORDS

• Lung cancer • Radiation therapy • Proton therapy • Tumor recurrence

KEY POINTS

- Radiation therapy is important in the treatment of patients with lung cancer and is being used with both palliative and curative intent.
- Imaging findings of radiation-induced lung injury are divided into an acute phase (radiation pneumonitis) and a chronic phase (radiation fibrosis).
- Newer methods of radiation therapy delivery techniques result in nontraditional patterns of radiation changes to the lungs and surrounding organs.
- Knowledge of the radiation treatment plan and technique, and the temporal evolution of radiation-induced lung injury, is important to identify manifestations of radiation-induced lung injury and differentiate them from tumor recurrence or infection.

INTRODUCTION

Radiation therapy (RT) is important in the treatment of patients with lung cancer and is being used with both palliative and curative intent. However, a potential limitation in the delivery of tumoricidal radiation dose is the presence of surrounding radiation-sensitive critical organs. Advances in radiotherapy techniques such as 3-dimensional conformal RT (3D-CRT), intensity-modulated radiotherapy (IMRT), stereotactic body radiotherapy (SBRT), and proton therapy allow for the precise delivery of radiation to the tumor by conforming the radiation dose to the tumor, and have improved locoregional control and survival in patients with non–small cell lung cancer (NSCLC). More sophisticated radiotherapy techniques such as 4-dimensional (4D) computed tomography (CT) imaging, mitigate tumor motion owing to respiration during radiation delivery and ensure accurate and optimal delivery of radiation dose to the tumor.

In this review, we discuss the different radiation delivery techniques available to treat NSCLC, the typical radiologic manifestations of conventional RT, and the different patterns of lung injury and

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temporal evolution that can be encountered in clinical practice when the newer radiotherapy techniques are used. Knowledge of the radiation delivery technique used, the completion date of therapy, and the radiologic manifestations of radiation-induced lung injury are important in facilitating appropriate interpretation of imaging studies and preventing misinterpretation of radiation-induced lung injury as infection or recurrence of malignancy.

RADIATION TREATMENT PLANNING TERMINOLOGY

In RT planning for lung cancer, the determination of the target volume is standardized and uses defined concentric target volume delineations on imaging. The gross tumor volume outlines visible malignancy, including any involved nodes. The clinical target volume is an added margin around the gross tumor volume to include potential microscopic disease and the internal target volume is an additional margin added around the clinical target volume to account for tumor movement during treatment as a result of respiratory motion. The planning target volume is the final volume treatment plan and is added around the clinical target volume to account for differences in patient positioning during treatment.

RADIATION DOSE AND FRACTIONATION IN THE TREATMENT OF LUNG CANCER

Increasing the radiation dose and or decreasing the time interval between radiation delivery increases tumor damage. However, this step results in increased injury to adjacent normal tissues. This injury can be mitigated by dividing the overall radiation dose into fractions. Currently, for patients with inoperable stage III NSCLC, the standard treatment is 60 to 66 Gy, given in a single fraction per day (2 Gy/fraction), 5 days a week, over a period of 6 weeks with concurrent chemotherapy.[1] Decreasing the number of fractions, in the appropriate clinical scenario, can be effective in tumor treatment, is well-tolerated, and is convenient for the patient. In this regard, SBRT is an extreme form of hypofractionation and delivers the entire radiation dose in daily fractions over 5 or less days.

RADIOTHERAPY DELIVERY TECHNIQUES

Conventional RT uses a limited number of treatment fields without conformal planning and typically delivers a high radiation dose to a large volume of normal tissue outside the planning target volume. High precision dose techniques such as 3D-CRT, IMRT, SBRT, and intensity-modulated proton therapy enable precise delivery of a larger radiation dose to the target and have improved local tumor control.[2,3] Additionally, the improved ability to conform the radiation dose delivered to the tumor reduces toxicity and facilitates dose escalation whereby target dose is increased while injury to normal tissue is limited.

Three-dimensional CRT, based on a 3D computer planning system of coplanar and noncoplanar beams reconstructed from CT data, delivers a maximal conformed radiation dose to the tumor with relative sparing of normal tissues. IMRT increases the 3D technique by using advanced treatment planning algorithms and multileaf collimators.[4–6] SBRT uses a technique similar to 3D-CRT or IMRT to deliver a hypofractionated high dose (10–34 Gy per fraction) to the tumor in 5 days or less. SBRT has an in-field control rate of approximately 90% and a severe toxicity rate of less than 10%.[7–9] SBRT is currently being used with curative intent in medically inoperable patients with NSCLC manifesting as small peripheral tumors without nodal metastasis, as well as to treat patients with metastases from extrathoracic malignancies.[10–13] Proton therapy uses subatomic particles with a positive electric charge to deliver a therapeutic dose to a precise depth (as defined by the Bragg peak) and reduces or eliminates radiation dose to normal tissues. The reduced lateral scatter and sharp dose drop of the proton beam allows delivery of a high-conformal dose without injury to vital structures such as the spinal cord.[14,15] Furthermore, because proton therapy can be delivered precisely to avoid previously radiated normal tissue, it is used to retreat patients with recurrent NSCLC.[16,17]

FOUR-DIMENSIONAL COMPUTED TOMOGRAPHY TECHNIQUE

The accurate delivery of radiation dose to the primary tumor can be degraded by respiratory motion. To mitigate tumor motion, the RT target volume is usually increased by adding the internal target volume to the treatment plan. However, a personalized assessment of tumor movement owing to respiratory motion is recommended over the use of standard treatment planning margins, because lung tumors can have complex motion patterns. Furthermore, many tumors move less than 1 cm and hence require smaller treatment volumes.[18] The use of respiration-correlated CT or 4D-CT for planning RT in conjunction with 3D-CRT, IMRT, and proton therapy is standard for incorporating tumor motion into treatment planning and further improves the target delineation and effectiveness of radiotherapy