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Early detection of acute radiation-induced lung injury with multi-section CT perfusion imaging: An initial experience

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AIM: To explore the value of 64-section computed tomography (CT) perfusion imaging (CTPI) in the early diagnosis of acute radiation-induced lung injury (ARILI).

MATERIALS AND METHODS: Fifty-one patients with oesophageal cancers or malignant thymomas received postoperative radiation therapy with a 60–62 Gy dose and underwent CTPI at pre- and post-radiation therapy time points (week 0, week 4, week 8, and week 12 respectively). The CTPI values were prospectively compared and analysed in order to evaluate the diagnostic utility of CTPI in the early diagnosis of ARILI.

RESULTS: Eighteen cases (18/51) of ARILI were diagnosed. The mean values of relative regional blood flow (rrBF), relative regional volume (rrBV), and relative regional permeability surface (rrPS) in the ARILI group were correspondingly higher than those of the non-ARILI group. At week 4, rrBF, rrBV, and rrPS in the ARILI group were significantly higher than those at pre-radiation (each $p < 0.05$). In the non-ARILI group, rrBF and rrBV were higher than those at pre-radiation (each $p < 0.05$); however, rrPS was not statistically different from that of pre-irradiation. Applying the diagnostic threshold value of rrPS = 1.22, the sensitivity, specificity, and positive and negative predictive values of CTPI for early diagnosis of ARILI were better than those of CT.

CONCLUSION: CTPI metrics may reflect haemodynamic changes in the post-irradiation lung and can detect cases of early ARILI that appear normal at CT. CTPI is a promising technique for early diagnosis of ARILI.

Introduction

Radiation-induced lung injury (RILI) is one of the important common complications occurring during or after the thoracic radiotherapy, and it is a major limiting factor for radiation therapy, demanding increased awareness and

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early clinical recognition.[1–3] Acute RILI (ARILI) is defined by the US Radiation Therapy Oncology Group (RTOG) as RILI occurring within 90 days after commencement of radiotherapy,[4] and its overall incidence ranges from 5–50% within about 1–6 months post-radiotherapy.[5–7] Currently, ARILI is diagnosed with severity scoring based on comprehensive clinical evaluation including conventional radiological examinations.[4] To the authors' knowledge, manifestations of ARILI at computed tomography (CT) are considered to be the most objective and reliable evidence for diagnosis of this entity.[8–11] However, major challenges exist in using serial CT for assessing pulmonary changes after radiation.[10] In most cases when ARILI is detected at CT, the radiotherapy course is in its final stages or has been completed. Then, it is too late to modify or readjust the therapeutic schedule, and consequently, irreversible changes in lung tissue are already present. It has been recently noted that morphological changes usually occur later than functional alteration or metabolic response.[12,13] Furthermore, it is often difficult to predict the true extent of pneumonitis after completion of therapy in individual patients, and this may limit reliability of CT in early diagnosis of ARILI for treatment planning.[14] Hence, early detection of ARILI is instrumental for early intervention or therapy modification. It is assumed that functional alterations, such as regional changes of capillary status, emerge earlier than the anatomical–morphological manifestations after irradiation[6,15]; thus CT perfusion imaging (CTPI), rather than conventional CT,[16,17] may more effectively detect the early changes of lung tissue, especially pulmonary capillary permeability. To date, there are few reports of the early diagnosis of RILI using CT perfusion in the literature. The purpose of the present study was to evaluate the feasibility of early detection of ARILI using CTPI.

Materials and methods

Patients

Patients with upper oesophageal cancers or malignant thymomas scheduled for postoperative radiotherapy during the period June 2007 to May 2012 were prospectively screened and selected, and then underwent CT and CTPI examinations for this study. All patients received three-dimensional conformal radiotherapy (3D-CRT) using a linear accelerator (Primus M, Siemens, Erlangon, Germany). Inclusion criteria were as follows: (1) total irradiation dose of 60–62 Gy; (2) radiation dose rate: 2 Gy/2 days; (3) course of radiotherapy approximately 8 weeks; (4) V20 (defined as the percentage of pulmonary volume irradiated to >20 Gy, i.e., the percentage of lung volume receiving more than 20 Gy dose in total lung volume) was limited between 20–25%; (5) no combined chemotherapy history; (6) no pulmonary diseases, such as chronic bronchitis, emphysema, pulmonary tuberculosis, acute inflammation, hilar lymph node metastasis, involvement of pulmonary hilar vessels, and no congenital or acquired disease of pulmonary blood vessels. Therapy was completed as scheduled in all cases.

According to the above criteria, 51 patients (29 men and 22 women; age 43–70 years, median age 59 years) who received postoperative radiation therapy for oesophageal cancers or malignant thymomas met the requirements and were included in the study.

All selected patients underwent CT and CTPI examination pre- and post-radiotherapy, namely on week 0, week 4, week 8, and week 12. This study was approved by the Ethics Review Committee of our hospital (The First Affiliated Hospital of Suzhou University) and all the patients agreed to and signed the informed consent form. All patients survived longer than 12 months (after radiotherapy) and were examined on follow-up visits.

CT and 64-section CTPI scanning

Using a Siemens SOMATOM Definition 64 spiral CT machine, a lung scan was performed with the standard body CTPI application. In order to make sure that there was no motion during the CTPI procedure, all patients were given respiratory training prior to the scans so that they were able to maintain approximately 18 s of breath-holding.

CTPI was performed after acquiring the thoracic topogram and choosing the DynMulti protocol for body perfusion. Eighteen seconds of end-inspiratory breath-holding was used when the scan was performed simultaneously. The CT scan region was limited to the radiotherapy region, including the main pulmonary artery or level 1 and level 2 branches when possible. Forty millilitres of iohexol (300 mg iodine/ml; Omnipaque, GE company, Shanghai, China) was injected intravenously via an antecubital vein at 6 ml/s with 5 s delay. Scanning parameters of CTPI: 120 kV tube voltage, 80 mAs tube current, 0.33 S/R rotation speed, 360°/rotation, 1 s scan period, recon four sections per period, 7.2 mm section thickness and interval, 512 × 512 matrix, and 320 mm × 320 mm field of view (FOV). CT was performed immediately after CTPI with the following parameters: volume scan of the whole lung was completed within 5–7 s of quiet end-inspiratory breath-holding, with a tube voltage of 120 kV and tube current of 100 mAs; 8 and 2 mm section thicknesses were used for reconstruction of chest CT and CT images, respectively.

Post-processing for the CTPI data

All raw data acquired via the Syngo CT workstation were processed with body CTP software, using the maximum slope model to calculate perfusion parameters. Drawing of the region of interest (ROI) was performed based on radiation field: ROIs were separately drawn in irradiated- and non-irradiated lung tissue with the consistent margin spacing of 5 mm with respect to pleura, heart, and edges of the radiation field, while avoiding great vessels. The regional blood flow, volume, and permeability surface (rBF, rBV, and rPS) of the regional lung tissue of irradiated and non-irradiated area were measured, respectively. Individual measurement differences, measurement errors, and other