Differentiation of Lung Cancer and Radiation Fibrosis Using Magnetic Resonance Images: A Case Study

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We used magnetic resonance imaging to differentiate residual and recurrent lung cancer from the surrounding radiation pulmonary fibrosis in a 62-year-old patient. The cancer's signal intensity was greater than the fibrotic lung tissue's intensity in an ECG-gated image with relatively short repetition and echo times and, also, in images with long repetition and echo times.

(Key Words: lung cancer, radiation fibrosis, MRI)

INTRODUCTION

After lung cancer is treated with radiation therapy, residual and recurrent tumor are difficult to differentiate from the resulting radiation pulmonary fibrosis using conventional X-ray methods, i.e., chest radiographs and CT scans. An alternative diagnostic modality is magnetic resonance imaging (MRI). The case study, herein, shows that MRI can be used to distinguish residual and recurrent lung cancer from the surrounding radiation fibrosis.

CASE REPORT

A 62-year-old male was admitted in March, 1983 for the evaluation of a mass shadow in the right lower lobe with hilar and mediastinal adenopathy as seen in his chest X-ray and CT scan (Fig. 1). A transbronchial biopsy was performed, and the mass was diagnosed as mucocellular adenocarcinoma consistent with lung cancer of bronchial gland origin. Since the tumor invaded the right main bronchus from the mediastinal lymphnode, radiation therapy (60Gy) was given to the tumor and the mediastinum. The tumor partially responded to the treatment; however, viable tumor tissue was found in a biopsy specimen after completion of radiation therapy. Two months later, radiation pneumonitis developed and was followed by radiation fibrosis. As a result, the tumor was totally obscured by radiation fibrosis.

Afterward, the patient was in a stable condition. The right hilar fibrotic shadow appeared stable in chest radiographs and CT scans. An X-ray CT, taken 15 months after radiation therapy, showed typical fibrotic changes (Fig. 2). The fibrotic region, the dense consolidated area in Figure 2, conformed to the radiation port. From this image, we could not tell if there was residual tumor in the fibrosis.

In October 1984, seventeen months after radiation therapy, an MRI scan allowed us to differentiate the residual cancer from radiation fibrosis. An MRT-15A (Toshiba, Japan) with a resistive magnet (0.15T) was used for this study. The data was taken using the spin-echo (SE) technique (90°-T-180°) with a repetition time (TR) of 1500 msec and an echo time (TE) of 48 msec (SE1500/48). We used a 25 cm diameter surface coil to detect the NMR signal. The coil was placed beneath the patient's back.
Fig. 1  This CT scan shows the primary tumor in the superior segment of the right lower lobe (*) at the time of diagnosis.

Fig. 2  A CT scan, obtained 17 months after the completion of radiation therapy, shows dense consolidation with ectatic bronchi (△). Differentiation of the residual tumor from radiation fibrosis is impossible in this image.
to provide good signal intensity around the primary lesion with minimum respiratory motion artifact. In the MR image, the residual tumor was clearly a high-intensity mass in the lower intensity area at the primary site (Fig. 3). Due to the surface coil's sensitive region, the anterior part of the chest does not appear in this image.

The patient was well until 24 months after therapy. At this time a follow-up CT scan indicated enlargement of the consolidation in the posterior portion (Fig. 4). In October 1985, follow up MR images were obtained to confirm the tumor's recurrence. Spin-echo images were taken with TR = 2000 ms and TE = 110 ms (SE 2000/110) and also with ECG-gating. For the ECG-gated images, the repetition time, which was determined by the heart rate was 600 msec. TE was 30 msec. A saddle coil was used for NMR signal detection.

On the axial SE2000/110 image, the tumor was an enlarged high intensity mass at the primary site (Fig. 5). Since this image had fairly long repetition time and echo time, the higher signal intensity for the tumor indicates that the tumor has a longer T2 than muscle and radiation fibrosis. On the axial ECG-gated image (SE600/30), the tumor also had a higher signal intensity than fibrosis and muscle, but there was less contrast (Fig. 6). The sagittal ECG-gated image had a high intensity mass located in the superior segment of the lower lobe (Fig. 7). Radiation fibrosis with ectatic bronchi appeared as a region with lower intensity than the recurrent tumor. Using chest radiographs and CT scans, it was not possible to delineate these lesions.

Immediately after the diagnosis of recurrence of lung cancer, the patient was admitted because of spiking fever. A blood culture revealed Enterococcus bacteremia. A metastatic abdominal mass was diagnosed and the tumor was successfully resected. The patient received an additional 50 Gy irradiation to the chest then was treated with combination chemotherapy. In November 1986, a brain metastasis and regrowth of the abdominal tumor was diagnosed. The patient died in April, 1987.

**Fig. 3** An MR image (TR = 1500 ms, TE = 48 ms) shows a high intensity mass at the site of the primary lesion (★). The mass has higher signal intensity than the adjacent muscle (★) and radiation fibrosis (□). The signal from the anterior part of the chest was not detected with the surface coil.
Fig. 4 A CT scan obtained 24 months after irradiation. An enlarged posterior part of the mass suggests tumor recurrence (*).

Fig. 5 The MR image (TR = 2000 ms, TE = 110 ms) shows an enlarged high signal intensity mass. The signal intensity of the radiation fibrosis has decayed to almost zero in this image with long TE. Again, the mass has a much higher signal intensity than the muscle.
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Fig. 6 The ECG-gated axial MR image (TR = 600 ms, TE = 30 ms). Although the tumor mass has higher signal intensity than the radiation fibrosis and muscle, the contrast is less pronounced in this short TR, short TE image.

Fig. 7 The ECG-gated sagittal image (TR = 600 ms, TE = 30 ms) contains a high signal intensity mass (*) in the radiation fibrosis.
DISCUSSION

This case study demonstrated that residual and recurrent tumor have higher signal intensities than lung tissue with radiation fibrosis. In the follow up MR images, we found that the high signal intensity mass located at the primary tumor site was enlarged, but the region with lower signal intensity (the radiation fibrosis) remained stable. Although this study lacks histological proof by open biopsy, it clearly indicates the difference in MR signal intensity between lung cancer and radiation fibrosis. Chest radiographs and CT scans did not allow us to delineate these pathologies.

Although normal lungs are difficult to image due to low proton density and respiratory motion, imaging of diseased lungs for diagnostic purposes is feasible since diseased lung have increased water density and decreased mobility. Pathological changes in the lung, such as consolidation and atelectasis, increase the tissue density (g lung tissue/cm³). Also, inflammation and edema increase the tissue’s water content (g H₂O/g dry lung weight). In this study, the irradiated lung tissue exhibited a higher signal intensity than normal lung tissue mainly due to increased tissue density. In addition to increased water density, diseased lungs are less mobile than normal lungs, thus images of diseased lung contain less motion artifact.

A case study by Glazer et al. also discussed differentiation of radiation fibrosis from recurrent lung cancer (1, 2). They suggest that MRI may be useful for monitoring lung cancer patients after radiation therapy. In their study, Glazer et al. compared the signal intensity ratios of mass/muscle and radiation fibrosis/muscle for various irradiated tumors and found a higher ratio for untreated and recurrent tumors than for fibrosis (1). This was true for images with long repetition time and echo time.

Table 1 shows measured signal intensities for tumor, muscle, and radiation fibrosis which were obtained from the MR image films of this patient using a densitometer (PDA65, Sakurai, Japan). The films had the same scale factor, window and center. An average of 10 measurements for each tissue type was obtained. The values in Table 1 are normalized to muscle signal intensity. These measurements show the relationship tumor > muscle > radiation fibrosis for both the SE600/30 and the SE2000/110 images. The tissue contrast was poor in the SE600/30 image.

The problem remaining for discussion is specificity for signal intensity of various pathologies. Glazer et al. found that acute radiation pneumonitis, infection, hemorrhage, and sometimes even pulmonary radiation fibrosis had signal intensity similar to that of neoplasm (1). However they did not prove the histology and relaxation times of these lesions. In our previous studies, relaxation times $T_1$ and $T_2$ in vitro indicated significant differences in various pathologies related to human lung cancer (3) and irradiated rat lungs (4). The $T_1$ and $T_2$ for fibrotic lung caused by longstanding obstructive pneumonia were significantly shorter than viable lung cancer (3). Lungs with radiation fibrosis had significantly shorter $T_1$ and $T_2$ values than lungs with radiation pneumonitis (4). To characterize the pathologies in MRI, further studies are necessary to prove the relationship between MR signal intensity and histology using cases with pathological proof for the lesions.

REFERENCES
2) Glazer HS, Levitt RG, Lee JKT, Emami B, Gronemeyer S and Murphy WA. Differentiation of radiation fibrosis from recurrent pulmonary neoplasm by magnetic resonance imaging. AJR 143: 729–730, 1984

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