CHANGES IN LUNG PERFUSION DISTRIBUTION DUE TO RADIATION IN LUNG CANCER PATIENTS TREATED WITH 3D CONFORMAL RADIATION THERAPY AND STEREOTACTIC BODY RADIATION THERAPY

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Abstract

Purpose: To compare correlations between radiation and perfusion damage in lung cancer patients treated with 3D conformal radiation therapy (CRT) (both radical and palliative intent) and stereotactic body radiation therapy (SBRT).

Materials/Methods: Thirteen non-small cell lung cancer patients receiving radiation therapy were included in this study. Eight of them were treated using 3D-CRT with palliative or radical intent (prescription doses 30–43Gy and 50–63Gy respectively, conventional fractionation). Five patients were treated with SBRT (prescription dose is 48Gy to the edge of the PTV in 4 fractions). Perfusion single-photon emission tomography (SPECT) scans using 99mTc were performed before RT and 2–3 months after RT. These scans were used to assess the change in lung perfusion, i.e. blood flow, as an effect of radiation on the normal lung during RT. Dose and corresponding percentage reduction in the SPECT intensity were used to establish dose-response curves (DRC).

Results: Large inter-patient variation in dose-response of lung perfusion was found in all three groups. Reperfusion was common, especially in patients treated with palliative CRT. Meaningful DRC for perfusion change after RT cannot be established in this group. Meanwhile the dose-response in radical CRT and SBRT groups was pronounced and DRC were consistent. DRC from these two groups indicates about 1% reduction in lung perfusion per Gy in total dose delivered to the lung, irrespective of dose per fraction.

Keywords—lung perfusion, SPECT, Sereotactic body radiation therapy, 3D conformal radiation therapy, Radiation penumonitis

I. PURPOSE/OBJECTIVE(S):

Radiation effect of lung perfusion change after RT in conventional dose fractionation schemes has been well studied [1]. However, the effect of hypofractionated treatment such as SBRT on lung perfusion has not been reported. It is known that tumor and, in particular, normal tissue dose-response following hypofractionated RT is different compared to conventional fractionation. In this study, we aim to compare the correlation of dose with perfusion reduction in three different patient groups, e.g. patients treated with palliative, radical 3D-CRT and SBRT.

II. MATERIALS/METHODS:

Thirteen non-small cell lung cancer patients gave formal consent to participate in this study. This includes three patients treated with palliative intent (30Gy/10 and 40Gy/15 fractions), five patients treated with radical intent (50Gy/20, 60Gy/30 and 63Gy/35 fractions) and five patients treated with SBRT (48Gy to the PTV margin in 4 fractions).

For all patients, 99mTc macroaggregated albumin (MAA) SPECT scans were performed before RT and 2–3 months after RT. Patients were scanned in treatment position for both the planning CT and the perfusion SPECT scans. These perfusion SPECT images were used to assess the change in lung perfusion, i.e. blood flow, as an effect of radiation on the normal lung during RT.

Assuming that SPECT represents relative distribution of perfusion in lung, a region of interest (ROI) was segmented as both lungs minus gross tumor volume (GTV). “Iso-dose” volumes in this ROI were segmented according to the voxel dose with a 2 Gy increment. SPECT counts in each “iso-dose” volume were summed up in pre-RT and post-RT scans, respectively. Dose and corresponding percentage reduction in the SPECT counts were used to establish dose-response curve (DRC). Those “iso-dose” volumes smaller than 10cc were not used in this study due to the uncertainties of SPECT counts in the small volumes and associated variations in the dose-response curve.

\[ DRC(Dose) = \left(1 - \frac{post - RT\ SPECT\ counts}{pre - RT\ SPECT\ counts}\right) \times 100\% \]

Since tracer counts from SPECT images represents relative lung perfusion, the pre/post treatment SPECT images of each patient was renormalized assuming that lung perfusion in a low dose and high SPECT counts volume was not affected by the radiation. Thus, this will lead to a DRC curve
starting from 0Gy giving 0% change of perfusion in each patient. Dose-response data of patients in the same RT group were averaged fitted to a linear regression model.

III. RESULTS:

A large inter-patient variation of DRC curve parameters has been observed in all three groups. Reperfusion (increased perfusion in the high-dose region) after RT was common in patients receiving palliative RT, thus a consistent dose-response was not seen in this group. One patient each in the radical CRT and SBRT group was also found with re-perfusion and excluded from the DRC analysis.

A. Patients treated with palliative intent 3D-CRT

The DRC obtained from this group is not meaningful because no clear trend in change in perfusion as a function of dose was observed. In fact, increase in perfusion was seen in lung volumes receiving high doses, figure 1.

This is likely due to the re-perfusion effect. Figure 2 shows pre- and post-RT SPECT data superimposed on the planning CT for a patient treated with a palliative intent. No perfusion in the right lung was seen pre-RT, possibly due to tumor compression on the artery. After the RT, tumor regression and re-opening of blood vessel, increased perfusion in the right lung was seen, although it received substantial RT dose.

B. Patients treated with radical 3D-CRT and SBRT

A consistent correlation of dose and perfusion reduction can be observed in both groups.

It was found that in both groups, the slope of the DRC were very close. In general, 1Gy will likely to cause 1.1% and 1% reduction in perfusion in the radical 3D-CRT and SBRT group, respectively.

In the radical 3D-CRT treatment, patients were treated with approximately 2Gy per fraction in at least 25 fractions, whereas SBRT patients were treated with only 4 fractions. Thus in the volume receiving similar total dose, dose per fraction was at least six times larger in the SBRT group. However, our finding suggests that in spite of the large difference in fraction dose, reductions in perfusion are quite close, i.e. DRC of both groups have the same slope at about 1% reduction per Gy. This suggests that about 50% reduction of lung perfusion at 50Gy level, which is also consistent with the results reported from other groups [1].