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STEREOTACTIC IRRADIATION OF LUNG CANCER

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ABSTRACT

Objective: To investigate the best stereotactic irradiation (STI) technique in treatment of small lung tumors, using dose-volume statistics. Methods: Dose-volume histogram (DVH) of the study phantom consisting of CT using the software of FOCUS-3D planning system. The beam was a 6MV X-ray from a Varian 2300C. The analysis data of Dose-volume statistics was from the technique used for: (1) 2–12 arcs; (2) 20°–45° separation angle of arcs; (3) 80°–160° of gantry rotation. Then we studied the difference of DVH with various irradiation techniques and the influence of target positions and field size by calculated to the distribution of dose from 20%–90% of the six targets in the lung with 3×3 cm^2, 4×4 cm^2 and 5×5 cm^2 field size. Results: The volume irradiated pulmonary tissue was the smallest using a six non-coplanar 120° arcs with 30° separation between arcs in the hypothetical set up, the non-coplanar SRI was superiority than conventional one's. The six targets were chosen in the right lung, the volume was the largest in geometric center and was decreased in hilus, bottom, anterior chest wall, lateral wall and apex of the lung in such an order. The DVH had significant change with an increasing field size. Conclusion: the irradiation damage of normal pulmonary tissue was the lowest using the six non-coplanar 120° arcs with a 30° separation between arcs by <5×5 cm^2 field and the position of target was not a restricting factor.

Key words: Stereotactic irradiation, Lung, Dose-volume histogram, Radiotherapy

Brain metastases of various primary tumors, including lung cancers, were treated with stereotactic irradiation (STI) with local control rates of approximately 85%, suggesting that high-dose STI for primary tumors would also result in better local control than conventional radiotherapy. The excellent initial response of lung tumors treated with hypofractionated high dose STI with very few complications, has been reported recently by Uematsu et al..[1]

The advantages and disadvantages of STI compared with conventional radiotherapy and the comparison among various techniques of STI have been discussed by several authors for brain lesions using dose-volume histogram (DVH) analyses.[2-4] However, there were few DVH analyses dealing with STI for extra-cranial tumors, such as lung tumor. In this study, we want to confirm whether STI suitable for small lung tumors, to investigate the superiority of STI by comparing several treatment techniques and approach the influence of target position and size using dose volume statistics.

MATERIALS AND METHODS

Dose volume histogram was calculated using commercially available software (FOCUS-3D planning system, CMS, USA). The dose distribution was calculated using a 6MV X-ray from a Varian 2300C. No special collimator was used.

Computed tomography (CT) of the chest of a normal volunteer in supine position from 5cm above the apex of the lung to 3cm below the bottom of the lung was chosen to act as a study phantom (Figure 1). The CT input data for calculation of DVH are 512×512×75 samples. The CT data consisted of a contiguous 5 mm thickness with an interspace distance of 5 mm; the section of the target area was a contiguous 3mm thickness with an interspace distance of 3 mm. Both lungs contour were digitized on each CT slice. The volume of lung used in this study was 3145 cm^3 (right lung=1635 cm^3 and left lung=1510 cm^3) under free-breathing conditions calculated by the planning system using CT images. Three dimensional

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dose distribution was calculated with 1.0×1.0×1.0 mm^3 voxels. The density of the normal tissue of the lung was calculated using the conversion table of CT number. The density of the target volume was defined to be 1.0. The dose of the target center was normalized to 100%. Distribution of the dose values in the lung was then generated, and then the 20%–90% dose of the peripheral target volume was calculated in the lung tissues and frequency distribution was the DVH that may be plotted in integral form. All the data referenced in this paper are derived from this integral DVH.

Analyses in this study are divided into three sections:

Hypothetical Set up Analysis

In this section, we regarded the reconstructed chest CT volume as a phantom. Only a 4×4 cm^2 field was used in this section of study. The location of the target volume was assumed to be the approximate geometric center of the right lung at 2cm below and 7 cm to the right of the carina and 7.5 cm from the posterior surface of the right lung. Conventional single-plane and multiple arcs were used for the section. Multiple arcs required a three dimensional non-coplanar technique: Rotation angles of the gantry were tested from 80° to 160° with a step of 20°. Rotation angles are increased symmetrically from the horizontal line. Tested number of arcs were two, three, five, six and eight. Tested separation angles are between arcs (separation angles of patient couch) were 20°, 25°, 30°, 35° and 45°. Patient couch is positioned evenly at couch angles starting at a couch angle of -60° and -80° for the number of arcs of 3–6 and 8 respectively (Figure 1). The purpose of study is to investigate the optimum techniques of SRI in hypothetical condition.

The Radiation Techniques

In this study, we compared of the volume of the lung received in 20%–90% dose curve with 4×4 cm^2 field, using parallel opposed two fields, coplanar three fields, one arc rotation 360°, non-coplanar 4–6 arcs quoting the optimum techniques of SRI in hypothetical set up analysis, approached the difference of DVH of the various irradiated techniques and suggested the reasonable irradiation techniques in practice.

The Influence of Target Position and Size

In this study, It were calculated to the distribution of dose from 20% to 90% of the six targets in the apex, the hilus, the periphyral area near the anterior chest wall, the lateral wall, the bottom and center of the right lung with 3×3 cm^2, 4×4 cm^2 and 5×5 cm^2 fields, using the optimum techniques of SRI in the hypothetical set up analysis. We wanted to confirm the influence of the location of the target and field size via compare of the difference of volume received in 20%–90% dose curves.

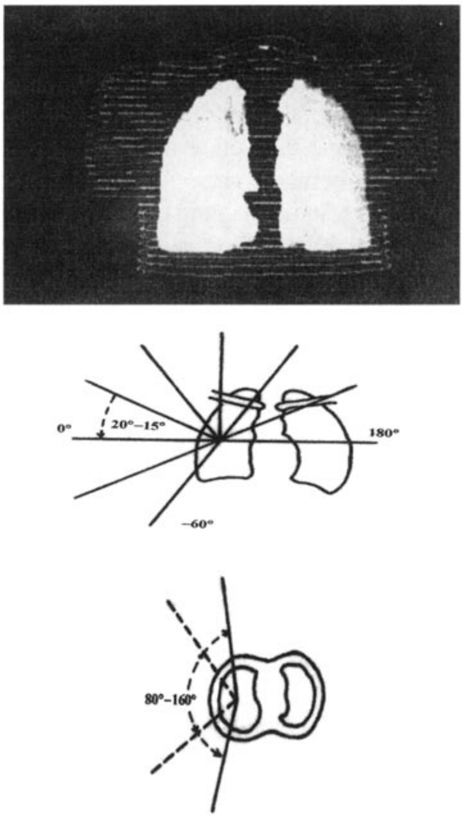

Fig. 1. 1a: The reconstructed three-dimensional phantom; 1b: 1–12 arcs, from -60° to 180° couch rotation degree and 20°–45° separation between two arcs's sketch map; 1c: 80°–160° rotation angle of gantry

RESULTS

Hypothetical Set up Analysis

The Figure 2 shows the dose-volume relationship for two-arcs irradiation at couch angles of -30° and 30° using rotation angles of gantry of 80°, 100°, 120°, 140° and 160°, respectively. The Y axis for this figure and all subsequent figures referred to the volume of both lungs. The technique that used rotation angles of 120° irradiated smaller volume of lung received 20% to 90% of the prescribed dose than other rotation angles (Figure 2). Using the 120° arcs, 30° separation angle between arcs, the DVH of 1–8 arcs are shown in Figure 3. The technique that used six arcs irradiated smaller volume of lung that received 20% to 90% of the prescribed dose than other techniques (Figure 3). Using 120° arcs, the DVH for varying separation angle between arcs are shown in Figure 4 and 5. The X axis for this and subsequent figures referred to the total rotation angles of couch which was a product of the separation angles between arcs and the number of corresponding arcs minus one. The number of arcs was 2–12 using 20°, 25°, 30°, 35° and 45° of separation angle between arcs respectively. Figure 4 shows that regarding the 20% isodose surface, technique using a total rotation angle of couch of 150° irradiate less volume than other rotation angles for each separation angle between arcs. A 30° couch separation was the smallest volume than the other's. Figure 5 shows that regarding the 50% isodose curve, the same technique irradiated smaller volume than technique with other degrees for each separation angle between arcs. Total rotation angle of couch of 150° was consistent with six arcs using a 30° separation angle of arcs.

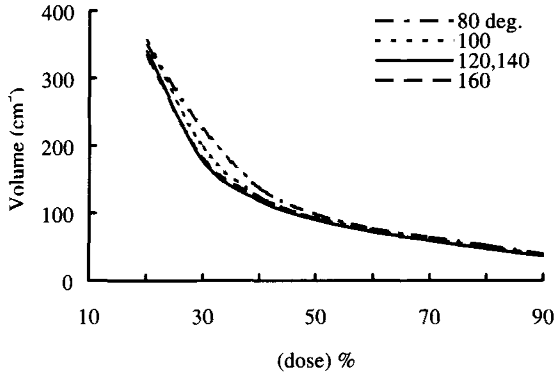

Fig. 2. DVH of 80°–160° two arcs, with -30° and 30° separation between two arcs with 4x4cm^{2}field.

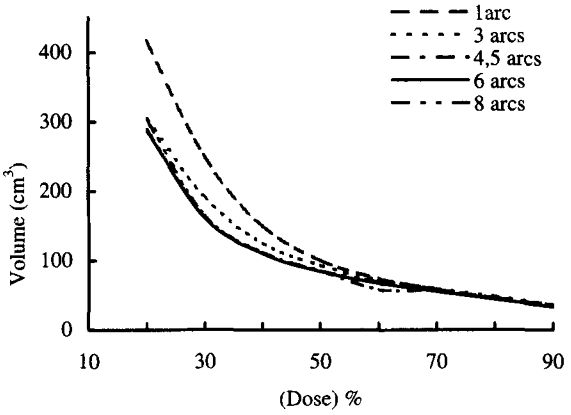

Fig. 3. DVH for 1–8 arcs with a 30° separation between arcs using a rotation angle of gantry of 120° for the 4x4 cm^2 field.

Consequently, six non-coplanar 120° arcs with a 30° separation between arcs, starting from the couch angle of -60° achieves the smallest lung volume which receives 20% to 90% of prescribed dose in the hypothetical set up analysis.

The Difference of Radiation Techniques

Figure 6 shows the difference of DVH with irradiation techniques. The volume received in 20%–90% dose is decreased in parallel opposed fields, coplanar three fields, one arc and 4–6 arcs order. The technique of multiple arcs is 120° arcs with 30° separation between arcs. The volume with the technique of non-coplanars 4–6 arcs is decreased at least one time than parallel opposed two fields in the range 40% dose curves. It is over two times in the range over 60% dose curve. The very small difference between four arcs and six arcs are shown in the range of 20%–30% dose curves (Figure 6).

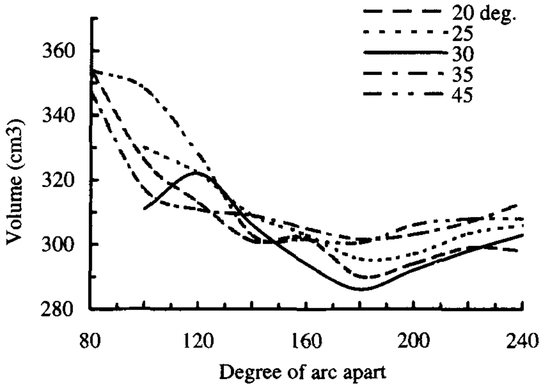

Fig. 4. The 20% dose curve using six 120° arcs with 20°, 25°, 30°, 35° and 45° separation between arcs, the arc apart covered 80°–240° couch span for the 4x4 cm^2 field.

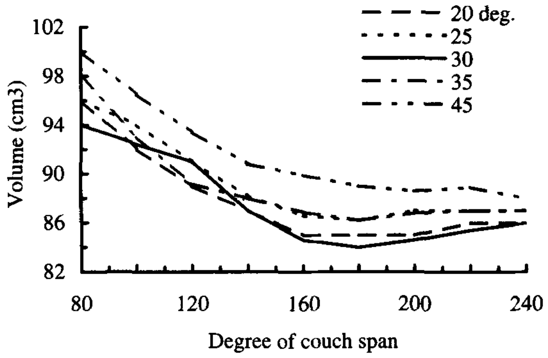

Fig. 5. The 50% dose curve using six 120° arcs with 20°, 25°, 30°, 35° and 45° separation between arcs, the arc apart covered 80°–240° couch span for the 4x4 cm^2 field.

The Influence of Target Position and Siz

Using six non-coplanar 120° arcs with 30° separationbetween arcs. Dose-volume histogram differ greatly in the change of the field size from 3x3 cm^2 to 5x5 cm^2. Six targets in the apex, the hilus, the peripheral area near the anterior chest wall, the lateral wall, the bottom and center of the right lung which was used in hypothetical analysis were chosen to investigate the influence of the location and volume of the targets (Figure 7). The volume irradiated lung tissue is the largest in geometric center and was decreased in hilus, bottom, anterior chest wall, lateral wall and apex of the lung order. The volume dose curve did not change significantly when comparing the targets in various location for a 3x3 cm^2 field, but with increasing field size, the differences become apparent.

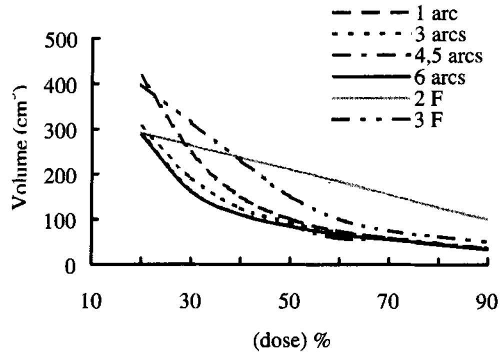

Fig. 6. Relationship between percent dose and actual volume of both lungs by 4x4 cm^2 field using parallel opposed fields (2F), coplanar three fields (3F), one arc (1A), and non-coplanar 3–6 arcs (3A, 4A, 5A and 6A).

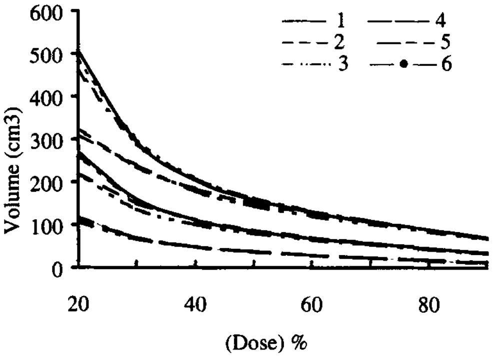

Fig. 7. Dose-volume histogram of different target position 1: hilus, 2: lung base, 3: middle periphery, 4: apex, 5: middle anterior) for 3x3 cm^2, 4x4 cm^2 and 5x5 cm^2 field.

DISCUSSION

The radiosensitivity of the lung is known to be high, so it is important to limit the use of irradiation of the lung to small volumes or low doses.[5, 6] The local relapse rate of the most common non-small cell cancer has been shown to be 32% to 83% with radiotherapy and chemotherapy.[7,8] Three-dimensional conformal radiotherapy (3-D CRT) of lung tumors has been suggested as a useful technique for improving the therapeutic ratio of high-dose radiotherapy for lung tumors.

Our results suggested that the technique using six 120° arcs with 30° separation between arcs was the optimum scheme for STI of lung tumors in the hypothetical set up analysis.

If the rotation degree of gantry was over 120°, the volume received in 20%–90% dose curve is increased since overlap of beams will decrease the benefit with an increase in the total rotation angle. A separation angle between arcs of less than 30° was not show to be better than 30°, because the range of overlap dose in near the target area was larger. The results of DVH suggested that the techniques of non-coplanar surprised to conventional irradiation techniques (Figure 6). The volume irradiated lung tissue with the technique of non-coplanars 4–6 arcs was decreased at least one time than parallel opposed two field's, in the range 40% dose curves. It was over two times in the range over 60% dose curve.

Although the volume of irradiated lung tissue has a small difference (Figure 7), the study of six targets shows that the location of tumor is not negative factor for STI of lung tumors. But the dose of extra pulmonary tissue closed to the target must be measured and checked in practice, for example: the spine's dose must be measured when the target located in paravertebra.

The influence of size of field is enormous for DVH. For a 3x3 cm^2 and 4x4 cm^2 field, the difference in DVH was mainly shown in the range of less than 30% dose curve, but the difference was discovered in the range of less than 60% with the 5x5 cm^2 field. Although the difference was very small in the range of 50%–60% dose only, this difference could induce the difference in the incidence of radiation pneumonitis. It was confirmed that a small-target should have more benefit when treating the lung tumors by techniques of SRI.

In conclusion: the irradiation damage of pulmonary tissue was the lowest using the six non-coplanar 120° arcs with a 30° separation between arcs by <5x5 cm^2 field and the position of target was not restricted factor for SRI the lung tumor. We suggested that the four non-coplanar 120° arcs with a 30° separation between arcs is the optimum technique in practical SRI the lung tumors.

Acknowledgments

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