Dose Distribution Comparison between Arc Radiation Therapy and Tomotherapy

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ABSTRACT

This study tries to compare dose distribution between arc radiation therapy and Tomotherapy, which are main radiation therapy modalities. The subjects of this study are lung cancer patients. For planning target volume (PTV), a dose of 60.0 Gy was set as a basis. The PTVmean of Arc was 61.04 Gy, and that of Tomotherapy was 58.50 Gy. The total lung capacities of Arc and Tomotherapy were 3.0 Gy and 4.24 Gy, respectively. The mean heart doses of Arc and Tomotherapy were 0.13 and 0.34, respectively; the mean trachea dose of Arc and Tomotherapy were 1.35 and 2.58, respectively; the mean esophagus dose of Arc and Tomotherapy were 0.41 and 0.86, respectively; the mean spinal cord dose of Arc and Tomotherapy were 3.65 and 4.68, respectively. With regard to the appropriateness of therapeutic effect in DHV, both modalities seemed appropriate. Tomotherapy protected normal tissues better than Arc radiation therapy. In Tomotherapy, patients need to have treatment long in a limited space. If such a point is overcome, Tomotherapy is better. Otherwise, Arc radiation therapy can be applied. This study was conducted with treatment planning images. Therefore, the results of this study are different from actual treatment results. If more research is conducted to overcome the limitation, the effects of radiation therapy are expected to increase further.

Keywords: Non-Small Lung Cancer, Radiation Therapy, IMRT

I. INTRODUCTION

The basic purpose of the radiation therapy for lung cancer is to give the minimum dose to normal tissues and make the prescribed dose absorbed in tumor tissues[1]. With the beginning of such principle, radiation therapy has been developed into two-dimensional therapy, into three-dimensional CT, and into intensity-modulated radiation therapy (IMRT).

These days, it has been developed into respiratory-gated radiation therapy and into tracking radiation therapy.

Lung cancer is a main cause for cancer-related deaths in the world from developing countries to developed countries. Since 1997, the Korean incidence rate of lung cancer has bee on the constant rise[2]. To make the prescribed dose suitable to primary focus absorbed at the time of lung cancer radiation therapy, it is possible to give off unnecessary direct or indirect radiation to normal lung tissues, which causes radioactive toxin and side effects[3]. These side effects

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include secondary lung cancer incidence, and illnesses caused by the overdose distribution to adjacent organs, such as myocarditis and myelitis. With the improvement in radiation therapy technologies, these side effects come to be overcome.

As a typical high-precision radiation therapy, there is intensity-modulated radiation therapy (IMRT). It is possible to use a linear accelerator for medical purpose and to apply a Tomotherapy based technique[4].

With Tomotherapy, it is possible to do Megavoltage CT (MVCT) scanning before radiation therapy, and then to observe images for Image Guided Radiation Therapy (IGRT). Therefore, the method is the latest therapeutic technique to do IMRT and IGRT at the same time[5].

There is a report that Arc therapy using a linear accelerator has better dose distribution than conventional 3D Conformal Radiotherapy or IMRT[6].

In this study, as radiation therapy is applied to a small lung tumor in lung tissues, the dose distributions of modulated VMAT and of Helical Tomotherapy are analyzed. Based on the values of indications, including the absorbed doses of tumor and adjacent normal issues, the absorbed dose value per volume of tissues, and dose volume histogram (DVH), the optimal radiation technique tried to be found.

II. MATERIAL AND METHODS

1. Subjects and equipment of experiment

The subjects of experiment are the patients diagnosed with non small cell lung cancer (NSCLC). Their images are used as data.

As experiment equipment, SENSATION OPEN CT of SIEMENS was applied for simulation therapy on Fig. 1 For image acquisition, the slice thickness of 2mm was used. Treatment regions were set by radiologists. Based on GTV, the 2 mm region was expanded, which was set as PTV(Margin followed the hospital's instructions).

As a linear accelerator used in the experiment, Truebeam version 2.7(VARIAN) was applied to conduct m-VMAT on Fig. 2 As a Tomotherapy system Fig. 3, Helical Tomotherapy was used.

As a radiation treatment planning system in the experiment, ECLIPCE Version: 15.1 of Varian, and as Tomotherapy, Accuray Precision TM Version: 1.1.1.1 were used.

Fig. 1. CT Simulation(Siemens Sensation open CT).

Fig. 2. Medical Linac.

Fig. 3. Helical Tomotherpy.

2. Prescribed dose

In both of the two therapy methods, after treatment regions were selected, a prescribed dose was set to 60Gy. This prescribed dose is the actual one applied to patients in hospital. As for the detailed planning of each radiation method, VMAT employed VMAT: 3-Arc; its use energy was 10 MV; its dose rate was 2400; its prescribed dose was 60 Gy(12Gy, 5fx).

Tomotherapy used 6MV Modulation Factor 3.0, and Pitch 0.43; its Field width was 2.5 cm; its Jaw Mode was Dynamic; its dose rate was 1180.

3. Selection of normal tissues

As adjacent normal organs, all lung, the heart, the trachea, the esophagus, and the spinal cord were selected. With regard to tolerance dose, the esophagus had 34.0 Gy; the liver 28.0 Gy; the spinal cord 45.0 Gy. As normal lung volumes, V5 < 60-65%, V10 < 30%, and V20 < 20-25% were set up.

III. RESULT

1. Dose Coverage

Fig. 4 and Fig. 5 are images showing the axial of VMAT and Tomotherapy, respectively. Fig. 6 and Fig. 7 are images showing the coronal plane of VMAT and Tomotherapy, respectively.

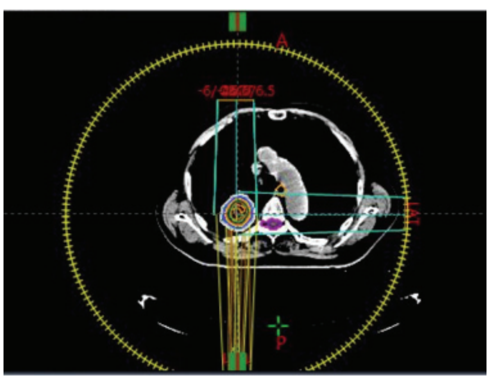

Fig. 4. Arc Dose Coverage - Axial Image.

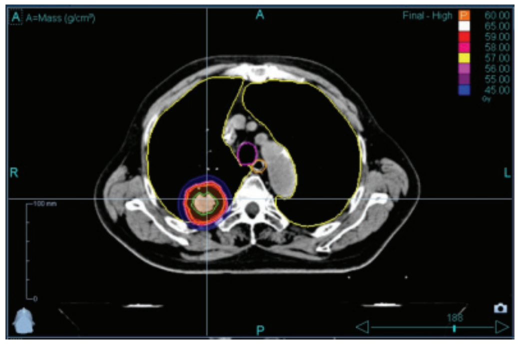

Fig. 5. Tomotherapy Dose Coverage - Axial Image.

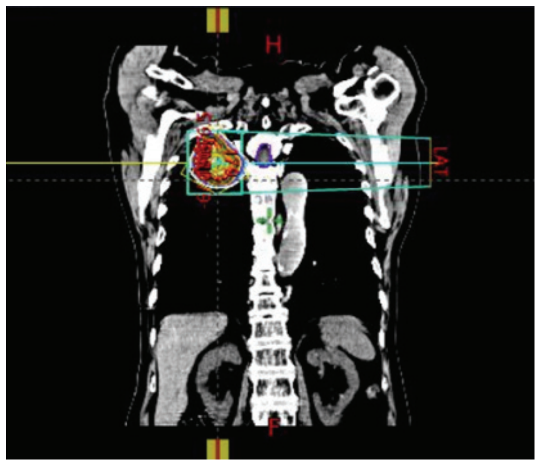

Fig. 6. Arc Dose Coverage - Coronal Image.

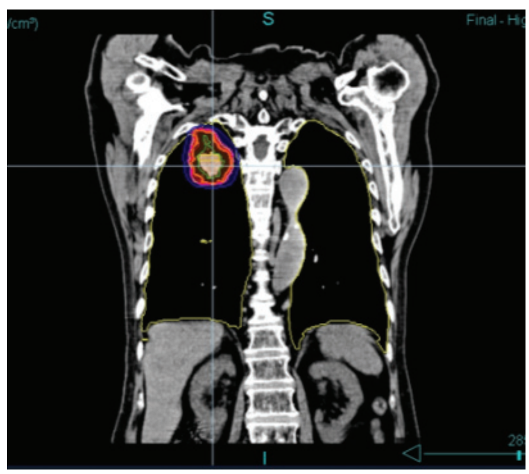

Fig. 7. Tomotherapy Dose Coverage - Coronal Image

Fig. 8 and Fig. 9 are images showing the sagittal plane of VMAT and Tomotherapy, respectively. The pattern of dose coverage was similar for both treatments, and the protection of normal tissues appeared to be good, In addition, also it appears to be in good conformity of tumor tissue prescribed dose.

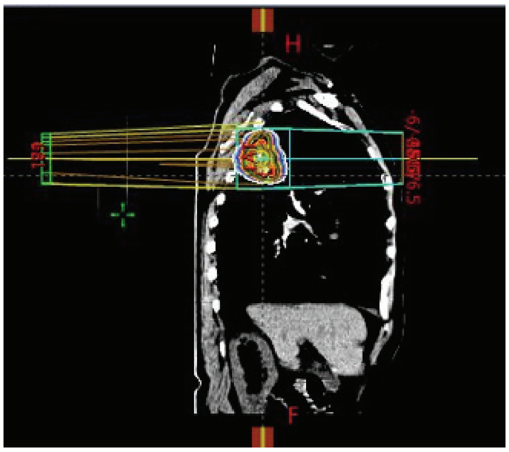

Fig. 8. mARC Dose Coverage - Sagittal Image.

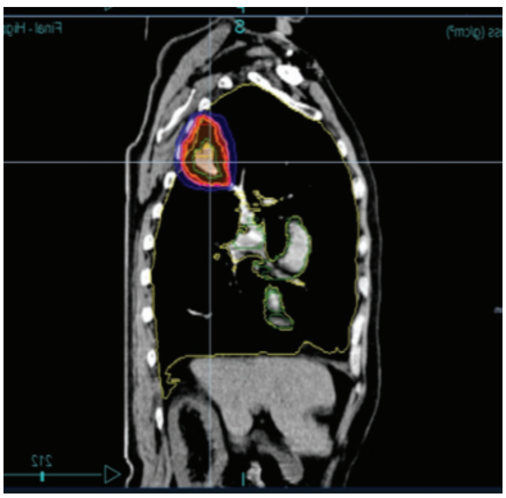
Fig. 9. ARC Dose Coverage - Sagittal Image.

2. Analysis on comparison parameter

The absorbed dose in PTV volume was observed. As shown in Table 1, the average absorbed dose of Arc radiation therapy was 58.50 Gy, and that of Tomotherapy was 61.04 Gy. The maximum absorbed doses of these methods were 63.35 Gy and 63.85 Gy, respectively.

Table 1. Planning Target Volume Dose (unit : Gy)

	Min	Mean	Max
Arc	49.18	58.50	63.35
Tomotherapy	57.16	61.04	63.85

With regard to the mean of the absorbed doses of normal tissues, all lung had 3.0 Gy, the heart 0.13 Gy, the trachea 1.35 Gy the esophagus 0.41 Gy, and the spinal cord 3.65 Gy. In Tomotherapy, the values of these parameters were 4.24 Gy, 0.34 Gy, 2.58 Gy, 0.86 Gy, and 4.68 Gy, respectively. The minimum doses and maximum doses of organs are presented in Table 2.

Table 2. Normal Tissue's Absorbed Dose (unit : Gy)

	Min		Mean		Max	
	Arc	Tomo	Arc	Tomo	Arc	Tomo
Total lung	0.1	0.05	3.00	4.24	62.19	63.85
Heart	0.6	0.07	0.13	0.34	1.17	1.94
Trachea	0.25	0.49	1.35	2.58	7.13	11.82
Esophagus	0.17	0.27	0.41	0.86	1.55	6.14
Spinal cord	0	0.04	3.65	4.68	23.49	23.72

3. DVH analysis

Fig. 10 and Fig. 11 illustrate the DVH comparison between Arc radiation therapy and Tomotherapy. The red line means PTV, the green line the body, the blue line the 4th Rib, the light purple line the trachea, the dark purple the spinal cord, and the yellow line the total long.

The prescribed doses for tumors in both methods met 60 Gy. Arc and Tomotherapy PTV DVH curve is normalizdtion in precribed dose Normal tissues also showed a remarkably low damage probability. Nevertheless, in the comparison, Tomotherapy had a higher possibility to defend normal tissues than Arc radiation therapy so that it showed a higher therapeutic ratio.

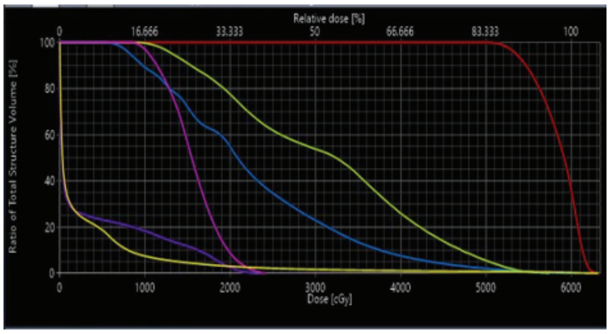

Fig. 10. Dose Volume Histogram (Arc).

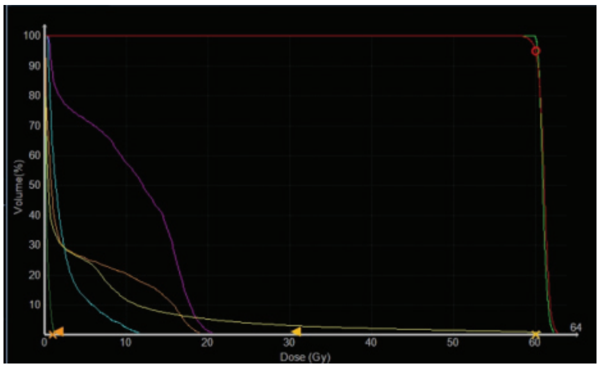

Fig. 11. Dose Volume Histogram (Tomotherapy).

IV. DISCUSSION

Radiation therapy has been developed in the way of controlling local tumors and defending normal tissues efficiently. In other words, radiation therapy is aimed at securing a good spatial dose distribution for treatment.

For the outcomes of radical radiation therapy for lung cancer, a dose of 60 Gy is applied to Stage III NSCLC through fractionated irradiation, usually. Its five-year survival rate is known to be less than 5% [7-9].

For effective radiation therapy, radiation therapy techniques have been advanced. Along with that, combination therapy methods, such as anticancer therapy and thermotherapy, have been developed. In particular, radiation therapy has been developed into 3D therapy, into IMRT, and into Tomotherapy. Recently, it has been advanced into Proton Therapy and targeted therapy.

It was announced that three-dimensional conformal radiotherapy (3DCRT), compared to 2D conventional therapy, is capable of distributing a dose to tumors in the most ideal way and protecting normal tissues. It was reported that the 3DCRT would increase a local control rate and a survival rate[10]. In previous studies on the DVH based comparison between 3DCRT and 2D conventional therapy, it was reported that it is possible to protect adjacent normal tissues and to irradiate up to 80 Gy for the target volume. The Radiation Therapy Oncology Group (RTOG) conducted phase-I and phase-II clinical studies with the use of 3DCRT by increasing a dose up to 90 Gy in line with the percentage of lung volume with more than 20 Gy. As such, the increase in the lung cancer survival rate in three-dimensional radiation therapy has been researched[11].

Domestically, based on three-dimensional radiation therapy, mArc radiation therapy, Tomotherapy, and IMRT, which are high-precision radiation therapy methods, were researched. As a result, it was reported that all Tomotherapy, IMRT, and mArc methods were excellent, and that patients' psychological state or economic condition was decisive[12].

The absorbed doses of tumor tissues and normal tissues were analyzed. As a result, for tumor tissues, the average absorbed doses of Arc and Tomotherapy were 58.50 Gy and 61.04 Gy, respectively. Therefore, there was no big association between a type of therapy method Radiation therapy has been developed in the way of controlling local tumors and defending normal tissues efficiently. In other words, radiation therapy is aimed at securing a good spatial dose distribution for treatment.

For the outcomes of radical radiation therapy for lung cancer, a dose of 60 Gy is applied to Stage III NSCLC through fractionated irradiation, usually. Its five-year survival rate is known to be less than 5%.

The main causes of the low therapy outcome are known to the low local control rate (15%) based on 60 Gy, and local recurrence and thereby high distant metastasis[7-9].and the absorbed dose to tumor tissues.

A previous study warned that an inaccurate prescribed dose is likely to facilitate cancer recurrence, and is dangerous[13]. It is also reported that radiation absorption to lung tissues causes pneumonia, pulmonary infarction, and pulmonary fibrosis[14]. It is known that in lung cancer therapy, exposure of radiation to normal organs adjacent to lung, such as the esophagus, the liver, and the trachea, causes secondary carcinogenesis, hypofunction, esophagitis, or esophageal perforation. In particular, exposure to the spinal cord as a critical organ causes lower limb paralysis and life shortening[15,16].

According to the comparison between two radiation therapy methods, both of them were excellent for the incidence rate of side effects in normal tissues. The result is also the same as that in the previous study[12]. Nevertheless, Tomotherapy had a little more advantage over Arc radiation therapy in terms of dose distribution, and had a little better dose coverage for PTV and dose volume histogram. Given that there was no noticeable difference between Arc radiation therapy and Tomotherapy, the two methods were excellent for protecting normal tissues and their absorption rates of prescribed dose to tumor tissues were met within an error range (± 3%). In Tomotherapy, it takes long to do radiation therapy, and a patient needs to have treatment in a closed space. For this reason, Arc radiation therapy is more effective for patients who have claustrophobia or have difficulty taking a position long.

The results of this study are simply based on treatment planning. They have a big limitation in the point that it is necessary to apply them to patients actually and to track and observe actual side effects of patients. Given that lung regions are wide, a dose of exposure to adjacent organs is different depending on lung regions.

To overcome these limitations, it is necessary to expand a research scope and to secure a broad range of information.

V. CONCLUSION

Radiation therapy methods for NSCLC were classified, and treatment planning was established. As a result, Arc radiation therapy and Tomotherapy gave an appropriate prescribed dose to tumor tissues and showed a preventive dose for normal tissues. Therefore, the two radiation therapy methods are considered effective.

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아크치료기법과 토모테라피치료의 선량분포 비교

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요 약

방사선 치료 시 주로 쓰이는 Arc 치료기법과 Tomotherapy 치료법의 선량적인 측면에서 상호 비교하고자 한다. 대상자는 폐암의 환자를 대상으로 하여 치료계획용적에 60.0 Gy를 처방선량을 기준으로 설정하였다. PTVmean는 Arc의 경우 61.04 Gy, Tomotherapy가 58.50 Gy, 이었다. 전체 폐용적(total lung)은 각각 3.0 Gy, 4.24 Gy, 심장(heart)은 0.13, 0.34, 기도(trachea)는 1.35, 2.58, 식도(Esophagus)는 0.41, 0.86, 척수는 3.65, 4.68의 평균선량을 보였다. DHV 곡선상 치료효과의 적합성은 모두 적합해 보였으며 둘 중에는 Tomotherpy의 치료법이 정상조직 방호적인 측면에서 우세한 것으로 나타났다. 제한적인 공간에서 오랜시간 치료를 받아야 하는 점을 극복한다면 tomotherapy치료가 우세하지만 그렇지 않은 경우 Arc 치료로 진행해도 무방할 것으로 사료된다. 본 연구는 치료계획 영상으로 분석한 것으로 실제 치료의 결과와 다르다는 제한점이 있다. 이러한 제한점을 극복하고자 더 많은 연구를 진행한다면 방사선 치료의 효과는 더욱 상승할 것으로 사료된다.

중심단어: 토모테라피, 아크치료, 방사선치료

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