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ORIGINAL ARTICLE

Comparison of the dose to lung volume between supine and prone position during treatment planning*

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Abstract

Objective The aim of the study was to compare the dose to lung volume in the supine and prone position while designing CyberKnife treatment plans to treat metastatic tumors in the spinous processes of the thoracic vertebrae, and offer a reference for reducing damage to normal tissues.
Methods Nine cases of metastatic tumors in the spinous processes of the thoracic vertebrae were selected, and then we designed treatment plans based on the supine and prone positions and compared the results.
Results In contrast with the treatment plan based on the prone position, the one for the supine position required 14862–36337 MU more; the lung $D_{5\%}$ was 5.20–7.90 Gy higher; and the lung $D_{20\%}$ was 2.61–5.73 Gy higher. The difference of dose to spine volume between the two plans was –2.21–2.67 Gy; to the skin volume was –3.93–7.85 Gy; and to the esophagus was 0.28–6.39 Gy.
Conclusion The treatment plan based on the prone position of patients can better protect lung tissues than the one based on the supine position, and can also improve the availability of beams.
Key words: supine position; prone position; treatment planning; lung

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The CyberKnife is a stereotactic radiotherapy treatment device. The accelerator is equipped with emits 6 MV beams through circular collimators, highly focusing on tumors in a non-isocentral and non-coplanar manner. It can be used to treat tumors in any part of the body [1]. The image plate of CyberKnife G4 is floor-typed, namely, hidden in the floor, with the maximum angle of incidence reaching 22° below the horizontal level [2]. In the treatment of metastatic tumors in the spinous processes of the thoracic vertebrae in the supine position, the beams pass through lung, fat, skin, and other structures before reaching the tumors. The long pathway results in a relatively high dose to the lung volume [3]. The authors of this article designed treatment plans to tumors in these sites with patients in the supine or prone position, and compared doses to lung and other sensitive structures as well as monitoring the units that the two plans used. Our results could offer a reference for choosing a better position in treating such cases with the CyberKnife.

Patients and methods

Patients

Between February 2013 and April 2014, nine patients (six men, three women) with metastatic tumors in the spinous processes of the thoracic vertebrae received CyberKnife treatment at our center (Oncology Radiotherapy Center of 302 Military Hospital, Beijing, China). Age: 47–68 years old (median age: 52 years); tumor volume: 29.16–130.95 cm^3; tumor length: 3.6–11.9 cm.

Methods

The CyberKnife G4 treatment planning system MultiPlan 4.0 (ACCURAY, USA) was used to calculate an inverse beam tracking algorithm. The patients were scanned with computed tomography (CT) in the supine and prone positions, and the images were transferred to the CyberKnife Data Management System (CDMS). The system designed plans for the same patient in different positions [4]. The prescription dose was 50 Gy/5 F. The dose-limit of sensitive structures used the American

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Table 1 Contoured target volume in supine position and prone position

Lesions	1	2	3	4	5	6	7	8	9
Supine (cm^3)	29.16	49.99	54.99	56.35	61.28	95.59	101.44	126.22	129.21
Prone (cm^3)	29.93	49.01	53.42	55.61	62.93	96.71	103.80	122.32	130.95
Difference (%)	2.64	1.96	2.67	1.31	2.69	1.17	2.33	3.09	1.35

Table 2 Volume dose to sensitive structure volume

Cases	Supine position					Prone position				
	Length (cm)	MU	Spine (Gy)	Skin (Gy)	Esophagus (Gy)	Length (cm)	MU	Spine (Gy)	Skin (Gy)	Esophagus (Gy)
1	3.6	64925	18.58	23.71	3.22	3.6	38640	17.64	27.64	2.94
2	5.7	65774	23.94	30.28	7.74	5.7	42492	25.37	22.43	4.48
3	4.4	66019	23.42	32.82	7.15	4.4	29682	23.61	25.08	2.67
4	6.1	52200	23.52	33.08	7.35	6.1	37338	23.23	25.35	4.22
5	7.0	67210	23.52	34.55	6.61	7.0	49450	21.52	29.16	5.55
6	9.2	61302	23.69	35.00	12.50	9.2	50494	24.64	28.87	7.94
7	9.7	62280	25.75	38.63	16.66	9.7	43548	26.81	33.33	7.21
8	10.1	68877	25.73	38.23	8.82	10.1	49143	27.94	31.61	6.61
9	11.9	70454	28.03	40.15	13.63	11.9	51570	25.36	36.23	7.24

Association of Physicists in Medicine's Science Council (AAPM) TG 101 Report as a reference: spinal cord $D_{0.35\ cm^3} < 23$ Gy, esophagus $D_{5\ cm^3} < 19.5$ Gy, and skin $D_{10\ cm^3} < 36.5$ Gy [5]. Taking the inverse algorithm, when entering the tolerance dose limits of various sensitive structures, MultiPlan 4.0 calculated the dose using sequencing optimization [5]. We compared the volume dose to lung and other structures between the two plans based on the two positions. During planning, collimators of lesions 1 and 2 were 15 mm and 25 mm, collimators of lesions 3, 4, and 5 were 20 mm, 20 mm and 30 mm, lesions 6 and 7, 25 mm and 35 mm, and lesions 8 and 9, 30 mm and 40 mm, respectively. After delineating the same target, we found a 1.12–3.90 cm^3 (1.17%–3.09%) volume difference between the supine position and prone position (Table 1).

Results

We used the same collimator, prescription dose, and tumor coverage rate to design the two plans based on the supine and prone position. The results were shown in Table 2. Compared with the prone position, the supine position required 14862–36337 MU (28.47%–55.04%) more, but had lower availability of beams. The differences of dose to spine volume were: 0.94, –1.43, –0.19, 0.29, 2.00, –0.95, –1.06, –2.21, and 2.26 Gy, with an absolute percentage difference of 0.32%–8.5%. These results showed that there was little difference between the two positions. The differences of dose to skin volume were: –3.93, 7.85, 7.74, 7.73, 5.39, 6.13, 5.30, 6.62, and 3.92 Gy. The differences of dose to esophagus were: 0.28, 3.26, 4.48, 3.13, 0.56, 4.56, 9.45, 2.21, and 6.39 Gy.

In the supine position, beams reached tumors from the direction of the lung, while in the prone position, beams reached them from the skin, which resulted in difference doses to the lung volume, as shown in Tables 3 and 4. From the tables, we could see that the dose to lung volume in the supine position was significantly higher than that in the prone position. Compared with the prone position, the doses to $D_{5\%}$ volume in the supine position were 7.53, 6.16, 7.90, 6.34, 6.58, 5.20, 6.72, 5.92, and 6.78 Gy higher to $D_{20\%}$, 3.67, 2.61, 4.34, 4.93, 3.30, 5.31, 5.84, 5.15, and 5.73 Gy higher. The data also showed that as the tumor volume increased, the dose to lung volume increased in either the supine or prone position.

Discussion

The CyberKnife is a stereotactic radiotherapy device with image-guidance and real-time tracking. With its image plate hidden in the floor, it has 160 nodes and 1920 incident angles [6]. The accelerator of the CyberKnife is carried by the robotic arm with six degrees of freedom, the lowest incident angle of which can reach 22° below the horizontal level, while the gantry of normal accelerators can rotate 360° around the patient [7]. For metastatic tumors in the spinous processes of the thoracic vertebrae, different positions will affect the dose to lung volume and availability of beams, because of the limit of the incident angle of the CyberKnife. The authors designed treatment plans to the same tumor in two different patient positions and compared the results.

The lowest incident angle of CyberKnife is –22°. When a patient is in a supine position, because of the limit of the angle, most beams cannot enter from the backside, which has the shortest pathway; instead, the beams reach the

Table 3 Dose to lung volume in supine position (Gy)

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
$D_{5\%}$	12.82	13.79	16.17	16.90	18.38	19.28	21.21	21.32	22.72
$D_{10\%}$	9.61	11.01	12.50	13.38	13.97	16.42	17.42	18.38	18.93
$D_{20\%}$	6.41	7.28	8.82	9.85	9.55	12.85	13.63	13.97	15.15
$D_{30\%}$	3.84	4.68	6.61	7.04	7.35	10.07	10.60	11.00	12.87
$D_{40\%}$	3.70	4.11	5.88	5.92	5.98	7.85	9.09	9.55	11.36
$D_{50\%}$	2.52	3.64	4.41	4.62	4.71	6.42	7.57	8.08	9.84

Table 4 Dose to lung volume in prone position (Gy)

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
$D_{5\%}$	5.29	7.63	8.27	10.56	11.80	14.08	14.49	15.40	15.94
$D_{10\%}$	4.11	5.55	5.12	7.04	8.33	10.56	10.86	11.76	12.31
$D_{20\%}$	2.74	4.67	4.48	4.92	6.25	7.54	7.79	8.82	9.42
$D_{30\%}$	1.76	2.78	3.84	3.52	4.86	5.83	6.52	7.35	7.97
$D_{40\%}$	1.17	2.08	3.20	2.81	3.98	4.92	5.07	5.88	6.52
$D_{50\%}$	1.02	1.38	2.56	2.11	3.22	4.22	4.34	5.14	5.79

tumors through the lung tissues. When a patient is in a prone position, most beams can directly reach tumors in the spinous processes of thoracic vertebrae from skin and muscle, avoiding passing through lung tissues. If beams pass through lung tissues excessively, the dose to lung volume will increase, as well as the risk of radiation pneumonitis [7]. From Tables 3 and 4, it could be seen that the dose to lung tissue volume in the prone position was obviously lower than that in the supine position. Therefore, the prone position has a distinct advantage in protecting lung tissues. Shifting from the supine position to the prone position, the dose to lung volume $D_{5\%}$ had decreased 5.20–7.90 Gy, and $D_{20\%}$ had decreased 2.61–5.73 Gy. The prone position greatly reduced the dose to the lung volume of patients. The results of two plans for treating the same tumor in two different positions showed that the dose to lung volume in the prone position was significantly lower than that in the supine position, and that we could use the prone position when treating tumors in these sites with the CyberKnife, to reduce the exposure dose to the lung tissues of patients.

The attenuation of beams is closely related to the pathway length: the longer the pathway is, the greater the attenuation is and the lower the availability of beams [8]. When the patient is in a supine position, beams pass through lung tissues to reach tumors, which is a long pathway resulting in a waste of beam. In the prone position, beams pass through skin and relatively little lung tissue to reach tumors, which is a short pathway resulting in a reduced beam attenuation [9–10]. Table 2 showed that the monitor units of the prone position were 14862–36337 MU less than that of the supine position, while the availability of beams was 28.47%–55.04% higher. Therefore, the prone position could greatly improve the availability of beams. The difference in the dose to the spine volume between the two positions is relatively small, but the prone position can better protect skin and esophagus than the supine position.

In conclusion, for CyberKnife treatment planning to metastatic tumors in the spinous processes of thoracic vertebrae, compared with the supine position, the prone position can better protect lung tissues and improve the availability of beams.

Conflicts of interest

The authors indicated no potential conflicts of interest.

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