Preliminary Experience of CyberKnife® Treatment of Primary Non-Small Cell Lung Cancer

Thiti Swangsilpa MD*, Pornpan Yongvithisatid MSc*, Kumutinee Pairat MSc*, Patchareporn Dechsupa MSc*, Mantana Dhanachai MD*, Somjai Dangprasert MD*, Ladawan Narkwong MD*, Chomporn Sitathanee MD*, Putipun Puataweepong MD*, Parmon Puddhikarant MD*, Chuleeporn Jiarpinitnun MD*, Patamintita Witoonpanich MD*, Taweesak Ukhumpun BSc*, Juthamat Khaophong BSc*

** Radiation Oncology Division, Department of Radiology, Faculty of Medicine, Ramathibodi Hospital, Bangkok, Thailand*

Objective: *Provide the effectiveness of treatment protocol, radiotherapy plan, technique, and early clinical results of inoperable primary non-small cell lung cancer (NSCLC) in patients who received CyberKnife® treatment at Ramathibodi Hospital.*

Material and Method: *Six cases of inoperable primary NSCLC patients were evaluated for tumor response after having received CyberKnife® treatment. The prescribed radiation dose was 45 gray (Gy) in three consecutive fractions for peripherally located tumor and 50 Gy in five fractions within two weeks for centrally located tumor (biological equivalent dose, BED, 112.5 Gy_{10}, and 100 Gy_{10}, respectively). The response to treatment was evaluated from roentgenographic study during follow-up period along with clinical outcome and adverse event.*

Results: *Overall response after the treatment was demonstrated in five cases with roentgenographic complete response (CR, disappearance of tumor) and partial response (PR, 50% decrease in size) in two and three cases, respectively without any severe adverse event. The treatment planning parameters demonstrated the effectiveness of radiation dose homogeneity and conformity coverage of the target volume.*

Conclusion: *This preliminary report has provided the effectiveness of treatment plan and local tumor controlled without severe adverse event for primary inoperable NSCLC patients receiving CyberKnife® treatment.*

Keywords: *CyberKnife®, Stereotactic body radiotherapy, Non-small cell lung cancer*

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Lung cancer is the most common cancer diagnosed worldwide with a high mortality rate. In Thailand, it is the leading cancer in males, and the fourth in females with less than 50% presented with localized disease at the time of diagnosis[1]. In Ramathibodi Hospital, lung cancer is the second leading cancer site in both sexes[2]. Non-small cell lung cancer (NSCLC) accounts for about 85% of lung cancer with surgery as the standard treatment modality, especially for early stage disease while radiotherapy is an alternative treatment in those that cannot receive or refuse surgery[3]. To gain the maximum local control rate by radiotherapy, radiation dose must be applied to the tumor as high as possible while keeping the dose as low as possible to surrounding normal tissue (or get maximum therapeutic ratio, which means the ratio between percentage of tumor controlled and normal tissue complication at the same radiation dose, need to be more than 1). Stereotactic body radiotherapy (SBRT) has been designed as an innovative radiotherapy to provide multiple radiation beams to conform high dose radiation to target volume, which can improve therapeutic ratio.

CyberKnife® is the linear accelerator six megavoltage (MV) modern frameless mounted on the robotic manipulator, image-guided by a pair of orthogonal x-ray sources and imaging panels, stereotactic radiotherapy system that can deliver multiple radiation beams from multiple angles directly to the target volume with very high dose radiation while sparing radiation dose effectively from surrounding normal tissues. When combined with the fiducial (gold seeds) markers and respiratory cycle tracking (Synchrony) system, CyberKnife® is suitable to improve local control rate of unresectable NSCLC by radiotherapy[4].

The objective of the present study was to provide the effectiveness of treatment protocol,

Correspondence to:
Swangsilpa T, Radiation Oncology Division, Department of Radiology, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok 10400, Thailand.
Phone: 0-2201-2295, Fax: 0-2201-1191
E-mail: swangsilpa@yahoo.com

radiotherapy plan, technique, and early clinical results of inoperable primary NSCLC patients whom received CyberKnife® treatment, paying attention to the therapeutic ratio, tumor response, and adverse event from treatment.

Material and Method

The present study was approved by the ethic clearance committee on human rights related to researches involving human subjects, Mahidol University; protocol number ID 02-55-38.

Prepared process for eligible patients

CyberKnife® has been settled down in Ramathibodi Hospital since 2008 while accepted SBRT protocol for primary NSCLC has been used since 2009. All patients must be excluded from thoracic surgeon as inoperable cases when consulted for CyberKnife® treatment. After having received treatment information with informed written consent, the patient would be evaluated for an understanding of regular breath cycle and breath holding controlled (can hold full expiration at least for 10 seconds). The baseline forced expiratory volume in one second (FEV 1) must be evaluated within two to four weeks before treatment to rule out severe obstructive pulmonary disease from treatment. The first step of treatment was fiducials implantation. Three to five fiducials (99.9% pure gold) were placed percutaneously through a CT-guided needle into or close to the tumor as the markers for image-guided tracking during the radiotherapy session by an interventional radiologist. After this procedure had been performed, the patient had to wait at least for 1 week, but not longer than one month, to make sure that all fiducials were fixed in place before the immobilized custom body cast device was done in a comfortable supine position. The treatment planning process was performed from the images of a fine-cut 1.5 mm CT scan of the whole lung in both contrasted and non-contrasted images (or at least 10 to 15 cm above and below fiducials position with minimum of 300 slices), while the patient was fixed in the body cast in full expiration-breath hold phase. The treatment would be started as early as possible after the treatment plan was accepted.

Radiotherapy planning delivery and definitions

The radiotherapy planning would be proceeded after finishing contouring of tumor and organs at risk. The detail of tumor contouring was defined as the gross tumor volume (GTV), clinical target volume (CTV) and planning target volume (PTV). The GTV was contoured from CT scan lung window images, which represented the real gross tumor. The CTV, which represented the extension of microscopic disease around gross tumor, was defined as the same volume as GTV. The PTV was expanded from GTV 2mm for lateral, anterior-posterior, and 4 mm for superior-inferior directions to compensate for any set up position error during the treatment delivery. The organs at risk (normal lungs, trachea, esophagus, heart, and spinal cord) were contoured for limited radiation dose to these structures referenced from hypofractionation data to minimize complications[5]. The treatment planning was generated by non-isocentric inverse-planning algorithm which was prescribed to the maximum isodose line, covered at 95% of the PTV (usually around 75 to 85% isodose line) at 45 gray (Gy) in three consecutive fractions for peripherally located tumor and 50 Gy in five fractions within two weeks for a centrally located tumor (biological equivalent dose, BED, 112.5 Gy_{10} and 100 Gy_{10}, respectively. This means radiobiology effectiveness for the tumor shows the same effects as receiving conventional radiotherapy for 112.5 and 100 Gy, respectively). The definition of peripherally located tumor is the tumor that is not close to the zone of proximal bronchial tree, and centrally located tumor is the tumor that is close to the zone of proximal bronchial tree[6]. The conformity of treatment plan was concerned from four treatment parameters: 1) the percentage of the target volume covered by the prescription isodose line, 2) Conformity Index (CI) which was the ratio of the total volume of tissue treated compared to the volume of the tumor treated, 3) Homogeneity Index (HI), which indicated the degree of uniformity of dose within the target volume, and 4) New Conformity Index (nCI) which was the CI multiplied by the ratio of the total target volume to the target volume received the prescription dose or more, and was used to describe the degree to which the prescribed isodose volume conforms to the shape and size of the target volume[7,8]. The present protocol was tried to keep these indexes for less than 1.5.

Follow-up schedule

After complete treatment, clinical evaluation including general appearance, daily activity and toxicity criteria from CTCAE v. 3.0 grading system[9] at second week, first, second, third, sixth, and twelfth month was provided for the first year of the follow-up period. Chest X-ray was performed at the first month

and after that if indicated. CT scan chest was evaluated for roentgenographic tumor response to treatment at second, sixth month and the first year after treatment. The definition of response criteria according to World Health Organization (WHO) was defined in Table 1[10]. Pulmonary function test and other investigations were considered when abnormally clinically suspected or indicated. After the first year, the patient would be suggested for semiannually follow-up until death.

Results

Six cases of primary NSCLC were treated with CyberKnife® during the past three years. The characteristics of patients and treatment planning parameters are demonstrated in Table 2 and 3, whereas status after treatment is shown in Table 4. The maximum radiation point dose to critical structures in five cases of centrally located tumor is demonstrated in Table 5, which was supposed to receive a higher dose than the one with peripheral disease. The complete treatment schedule was successfully provided in all patients. The radiation beams were taken more than 200 beams per treatment fraction, which took more than two hours for each treatment session. The treatment planning parameters from Table 1 demonstrated the effectiveness of radiation dose homogeneity and conformity coverage of the target volume. Overall response after treatment was seen in five cases (one case was still found stable disease, SD, decrease size less than 50%) with roentgenographic complete response (CR, disappearance of tumor) and partial response (PR, 50% decrease size) were demonstrated in two and three cases, respectively without any severe adverse event detected during immediate follow-up period (the pictures of tumor response from each case are shown in Fig. 1-6). Fibrosis of surrounding lung parenchyma was found in roentgenographic images of all patients but did not cause any respiratory problem. The detail of adverse event is shown in Table 6. Patients' survival was not related to tumor control because it was confounded by patient's age, other medical problems and disease status of the malignant disease. Two patients died from congestive heart failure (to be discussed later) and liver metastasis with septicemia. Two patients were lost to follow-up, while the last visit status was not good (one had brain metastasis at presentation and already received whole brain radiotherapy and chemotherapy, and the other one had hepatocellular carcinoma as second malignancy). Two patients with tumor control lived with dementia and renal failure from geriatric's disease.

Table 1. Definition of best response according to World Health Organization (WHO) criteria

Best response	WHO change in sum of products
Compete response (CR)	Disappearance; confirmed at 4 weeks
Partial response (PR)	50% decrease; confirmed at 4 wks
Stable disease (SD)	Neither PR nor PD criteria met
Progressive disease (PD)	25% increase; no CR, PR, or SD documented beforeincreased disease

Table 2. Histopathological characteristics and TNM staging of patients

Case No.	Pathology	TNM (stage)	FEV1* (liters)	Underlying disease or condition
1	Adenosquamous cell CA	T2aN0M0; IB	0.95	COPD
2	Adeno CA	T2aN0M0; IB	1.50	DM, HT, CAD
3	Squamous cell CA	T2aN0M0; IB	1.30	COPD,CVD,HT
4	Compatible with NSCLC	T2bN0M0; IIA	1.18	COPD,CAD,DM,HT
5	Compatible with NSCLC	T2aN0M0; IB	1.60	Secondary HCC,Cirrhosis, old TB
6	Compatible with NSCLC	T2aN0M1b; IV	NA	Single brain metastasis; received WBRT, SRS and chemotherapy

CA = carcinoma; NSCLC = non-small cell lung cancer; COPD = chronic obstructive pulmonary disease; DM = diabetes mellitius; HT = hypertension; CAD = coronary arterial disease; CVD = cerebrovascular disease; HCC = hepatocellular carcinoma; TB = tuberculosis; WBRT = whole brain radiotherapy; SRS = stereotactic radiosurgery; NA = not analyzed
FEV1*: case No. 1-5 were evaluated as high to moderate risk for major operation

Table 3. Patient's characteristic and treatment planning parameters

Case No.	Sex (year)	Age	Site	Maximum diameter (cm)	PTV (cc)	CI	HI	nCI	% coverage at prescribed isodose line	No. of nodes/ beams per fraction
1	M	83	C	3.9	21.28	1.47	1.25	1.49	99.00% at 80%	66/273
2	M	78	C	5.0	87.00	1.42	1.33	1.44	98.56% at 75%	82/280
3	M	81	P	3.6	17.50	1.89	1.25	1.96	96.60% at 80%	71/232
4	M	79	C	5.7	70.63	1.49	1.22	1.53	97.00% at 82%	81/271
5	M	68	C	5.0	26.20	1.75	1.20	1.77	98.80% at 83%	80/251
6	F	34	C	4.4	31.30	1.48	1.32	1.48	99.84% at 76%	52/253
Mean		70.5		4.6	42.32	1.58	1.26	1.61	98.30% at 79%	72/260

M = male; F = female; C = centrally located tumor; P = peripherally located tumor; size = maximum diameter; PTV = planning target volume; CI = conformity index, try to keep < 1.5; HI = homogeneity index, try to keep < 1.5; nCI = new conformity index, try to keep < 1.5; node = the position of the linear accelerator focal spot

Table 4. Patient's status after treatment

Case No.	Patient's status	Tumor response	Duration of follow-up	Notation
1	Alive	CR	3 years	Dementia
2	Dead	PR	1.5 year	Cardiac failure
3	Alive	CR	2 years	Renal failure
4	Dead	PR	1 year	Brain, liver metastasis and septicemia
5	Unknown	PR	1 month	HCC treatment
6	Unknown	SD	4 months	Progressive brain metastasis

CR = disappearance of tumor; PR = 50% decrease size of tumor; SD = decrease size less than 50%; HCC = hepatocellular carcinoma
Case No. 6 received chemotherapy
Case No. 2 and 4 did not received systemic treatment due to poor performance status
Case No.4 and 6 received whole brain radiotherapy

Table 5. Critical structures received maximum radiation point dose (Gy) for centrally lesions

Case No.	Trachea	Bronchus	Esophagus	Spinal cord	Pericardium	Great vessel
1	10.67	8.35	4.49	11.07	13.58	61.59
2	13.89	41.92	24.11	11.67	52.21	54.95
4	28.30	42.33	24.31	19.43	NA	NA
5	6.96	15.08	11.10	10.96	8.29	NA
6	NA	NA	33.27	9.66	40.10	46.03
Limited dose[4]	38.00	38.00	35.00	30.00	38.00	53.00

Limited dose = maximum dose limitation to each critical structure

Table 6. Adverse events grading from CyberKnife® treatment

Cases	Skin and subcutaneous tissues	Respiratory disorders	Cardiac disorders	Vascular disorders	Esophagitis	Myelitis
All cases	1*	1**	1*	1*	1*	1*

1* = asymptomatic
1** = radiologic pulmonary fibrosis < 25% of lung volume

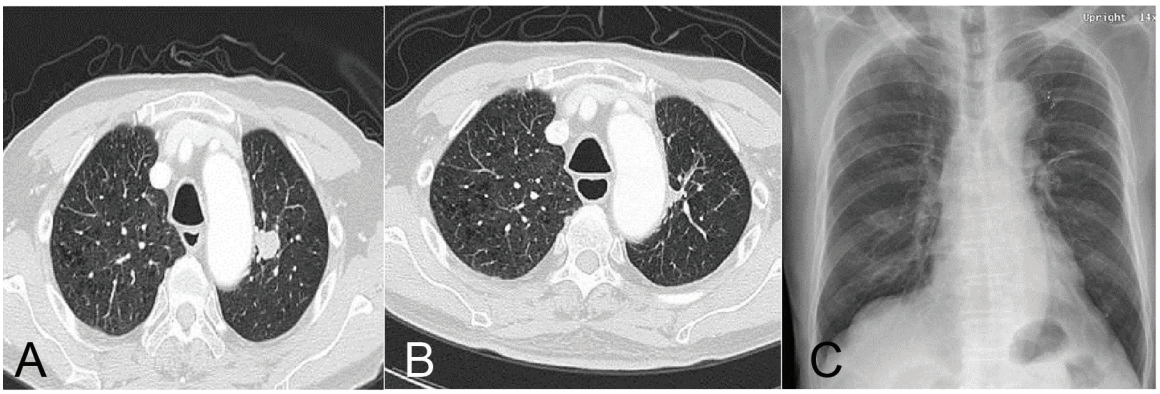

Fig. 1 Case No. 1
A) CT scan before treatment of centrally lesion, maximum diameter 3.9 cm
B) CT scan 1-year after treatment, no tumor seen, fibrosis at tumorsite (maximum response, CR)
C) CXR 3-year after treatment, no evidence of disease

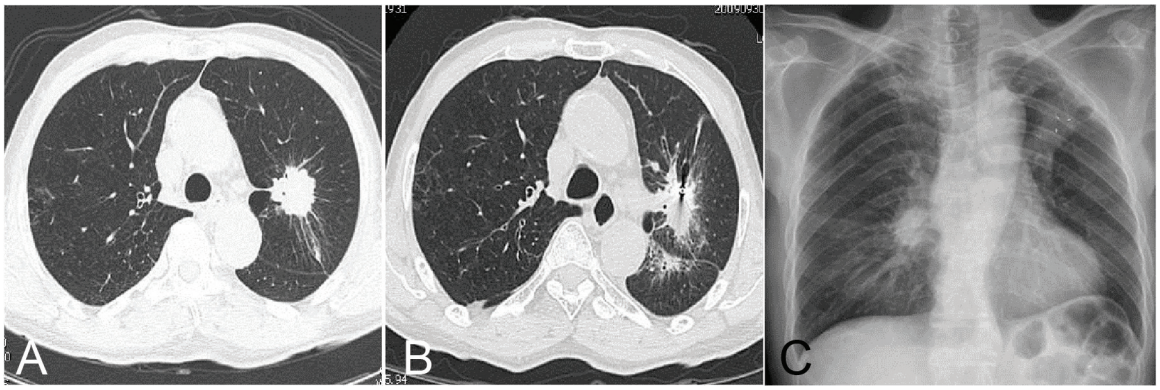

Fig. 2 Case No. 2
A) CT scan before treatment of centrally lesion, maximum diameter 5.0 cm
B) CT scan 9-month after treatment, partial response with lung fibrosis (maximum response, PR)
C) CXR 2-year after treatment, suspected new lesion at contralateral hilar node

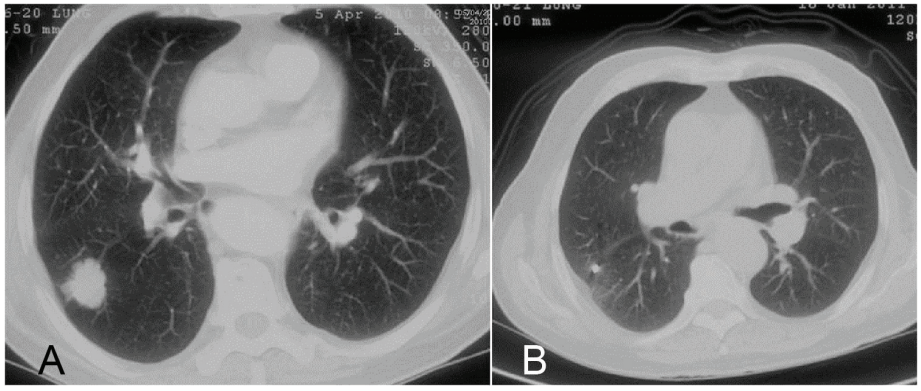

Fig. 3 Case No. 3
A) CT scan before treatment of peripherally lesion, maximum diameter 3.6 cm
B) CT scan 9-month after treatment, show fiducial at tumor site, no lesion seen (maximum response,CR)

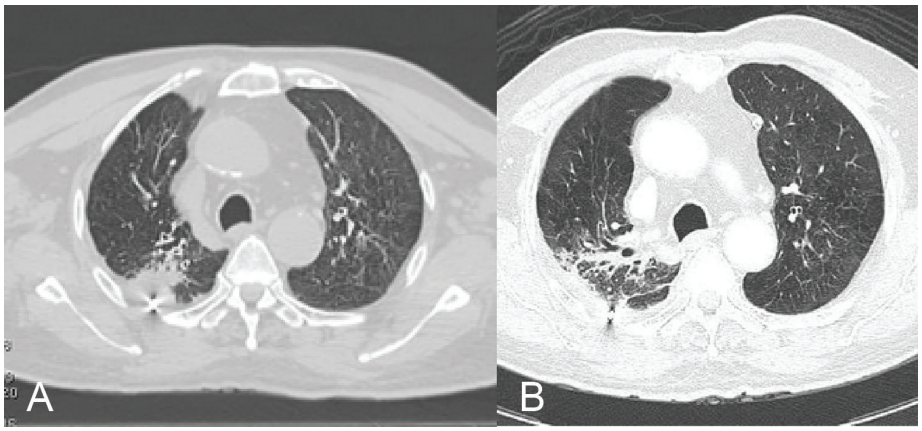

Fig. 4 Case No. 4
A) CT scan before treatment of centrally lesion, maximum diameter 5.7 cm
B) CT scan 8-month after treatment, partial response with lung fibrosis (maximum response, PR)

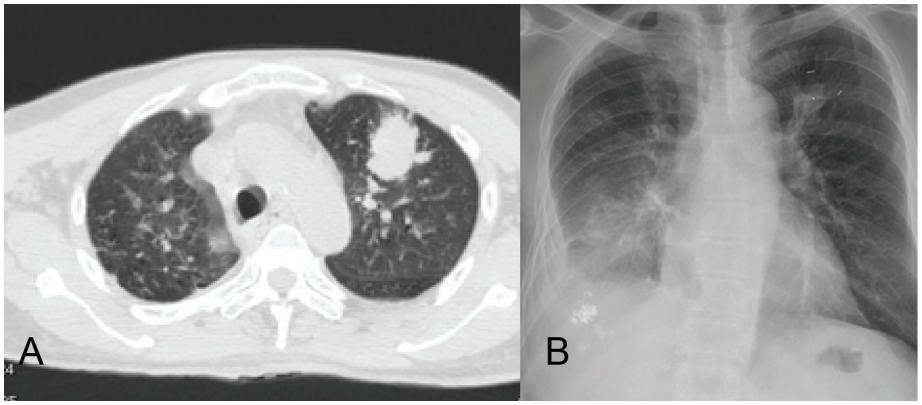

Fig. 5 Case No. 5
A) CT scan before treatment of centrally lesion, maximum diameter 5.0 cm
B) CXR 1-month after treatment, partial response before loss to follow-up (also seen lipiodal stain in liver)

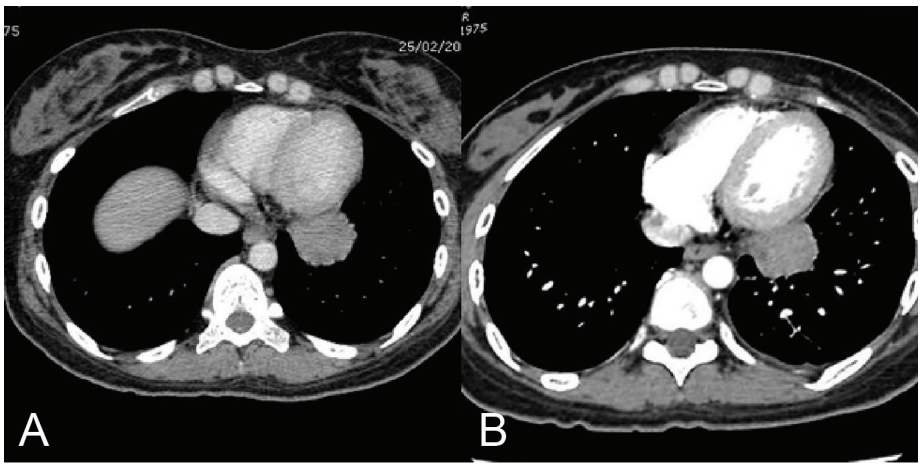

Fig. 6 Case No. 6
A) CT scan before treatment of centrally lesion, maximum diameter 4.4 cm
B) CT scan 2-month after treatment, stable disease before loss to follow-up

Discussion

Since 1980, definitive conventional radiotherapy for unresectable NSCLC with the total tumor dose of 50 to 60 Gy has proven to provide better tumor control and 2-year survival rate than with a lower level radiation dose[11]. A better tumor response and patient's survival rate is expected if radiation dose could be pushed to more than 60 Gy along with the modification of radiotherapy fractionation and technology. However, the treatment toxicity is still a challenging problem to be solved[12-15]. Based on the knowledge of radiobiology of NSCLC about tumor control probability related to radiation dose, it is clear that radiation dose over 100 Gy delivered in a very short period of time, which is called ablative dose radiation, would achieve the best local progression-free survival[16]. The advantage of ablative dose radiotherapy for tumor cells is stopping cellular division and function while overwhelming tumor repair with the possibility to cause severe late complications at the same time[5]. For early stage NSCLC, the relationship between medium to high BED (range 83.2-146 Gy) and efficacy of SBRT has provided improvement of patient's overall survival compared to low BED[17]. The knowledge of radiobiology and radiation pathology of normal tissues has also been applied to modify appropriate radiation dose fractionation so as to minimize complication[18-20]. Lung parechymal tissue is classified as the parallel functioning subunits (FSUs) characterized by redundancy of function and large inherent reserves, which meant that no matter how large the radiotherapy dose was applied to lung parenchyma, severe toxicity could be avoided by limiting of treatment volume, because the undamaged FSUs could maintain the organ function. This idea has been applied with the concept of "critical volume model". This concept proposed that any radiation dose given beyond the normal tissue threshold dose would not add additional toxicity when given in a small treatment volume. This is well suited for ablative dose radiotherapy and innovative SBRT for NSCLC located in lung parenchyma (peripheral location)[21,22]. Contrast to the serial FSUs, the effect was different for tissues in mediastinal structure (central location), to which radiation damage in one FSUs could express damage to the whole organ. This meant that radiation dose applied to this area must be kept lower than to peripheral location to avoid severe toxicity to critical structures. The tumor motion from respiration during treatment session has been challenged as the major problem when applied ablative dose radiotherapy for NSCLC. This was the reason why SBRT with CyberKnife® had been selected as the treatment of choice for the capability to conform the highest radiation dose around tumor while much sparing radiation dose from surrounding normal tissues. It is combined with real time respiratory tracking technique to deal with tumor and organ motion from respiration during treatment session.

The present study was limited in the number of patients because of the strict assessment criteria before treatment and the long-term follow-up period, which was limited mostly from patient's status. This preliminary result has shown the advantage of primary tumor control with effectiveness of conformity and homogeneity of radiation dose distribution with CyberKnife® without severe adverse event. Five out of six cases had diseases located in the central zone and the treatment plan was more difficult to manage than in peripheral zone, except for one case that had a stable disease after treatment. In that case, the tumor was attached posteriorly and close to the heart that made the treatment plan was very difficult to provide good coverage dose. Concerned about tumor control while avoiding severe adverse event in this area, the protocol was designed to keep the value of BED 100 Gy_{10} and spread out the dose into five fractions that were supposed to minimize severe toxicity to prevent a serious problem in the peripheral zone. The roentgenographic CR seemed to be associated with small tumor volume. Tumor size was previously reported as one of the factors associated with local control by SBRT[23]. Due to the financial problem of Thailand population-based, PET/CT imaging was not included in the process of treatment schedule although it could provide more information of real tumor size for improved treatment planning and differential diagnosis of lung fibrosis from residual or progressive tumor after treatment.

In case No. 2, who died from congestive heart failure, the problem of the maximum radiation point dose above normal tissue tolerance dose was suspected at pericardium and great vessel. This might cause pericarditis or aneurysm as a result of late effect. However, when checking the maximum dose volume constraints of those normal tissues (as in reference 4), the prescribed radiation dose calculated from dose volume histogram was still limited in an acceptable range. The other problem was the difficulty to conform radiation dose to the tumor while avoiding dose to critical structures. This is because the very large tumor was attached to cardiovascular structures. For patient

factor, this case had a history of coronary arterial disease and hypertension, which was still in the program of the cardiologist. Considering all factors, it was not possible to conclude if the cause of death was from radiation effect or his own medical problems.

Conclusion

This is the first report in Thailand that has demonstrated the clinical results of radiotherapy plan and tumor response from a CyberKnife® treatment protocol in Ramathibodi Hospital, which is supposed to be the choice of radiotherapy for unresectable primary NSCLC. Although there were some limitations for patients who could receive CyberKnife® (such as patient's performance status and cooperation during treatment session), this modern radiotherapy technique was still appropriate for medically inoperable patients, especially with centrally located tumor and patients with few alternative treatment options for primary NSCLC.

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Potential conflicts of interest

None.

References

1. Attasara P, Buasom R. Hospital-based cancer registry 2010. Bangkok: National Cancer Institute, Department of Medical Service, Ministry of Public Health; 2011.
2. Subhadharaphandu T, Wilailak S, Sirachainant E. Cancer report 2009. Bangkok: Ramathibodi Cancer Registry, Faculty of Medicine, Ramathibodi Hospital, Mahidol University; 2009.
3. Eradat J, Abtin F, Gutierrez A, Suh R. Evaluation of treatment response after nonoperative therapy for early-stage non-small cell lung carcinoma. Cancer J 2011; 17: 38-48.
4. Gibbs IC, Loo BW Jr. CyberKnife stereotactic ablative radiotherapy for lung tumors. Technol Cancer Res Treat 2010; 9: 589-96.
5. Timmerman RD. An overview of hypofractionation and introduction to this issue of seminars in radiation oncology. Semin Radiat Oncol 2008; 18: 215-22.
6. Timmerman R, McGarry R, Yiannoutsos C, Papiez L, Tudor K, DeLuca J, et al. Excessive toxicity when treating central tumors in a phase II study of stereotactic body radiation therapy for medically inoperable early-stage lung cancer. J Clin Oncol 2006; 24: 4833-9.
7. Shaw E, Kline R, Gillin M, Souhami L, Hirschfeld A, Dinapoli R, et al. Radiation Therapy Oncology Group: radiosurgery quality assurance guidelines. Int J Radiat Oncol Biol Phys 1993; 27: 1231-9.
8. Paddick I. A simple scoring ratio to index the conformity of radiosurgical treatment plans. Technical note. J Neurosurg 2000; 93 (Suppl 3): 219-22.
9. U.S. Department of Health and Human Services, National Institutes of Health National Cancer Institute. Common terminology criteria for adverse events (CTCAE). Version 4.0. Bethesda, MD: NIH publication; 2009.
10. Therasse P, Arbuck SG, Eisenhauer EA, Wanders J, Kaplan RS, Rubinstein L, et al. New guidelines to evaluate the response to treatment in solid tumors. European Organization for Research and Treatment of Cancer, National Cancer Institute of the United States, National Cancer Institute of Canada. J Natl Cancer Inst 2000; 92: 205-16.
11. Perez CA, Stanley K, Rubin P, Kramer S, Brady L, Perez-Tamayo R, et al. A prospective randomized study of various irradiation doses and fractionation schedules in the treatment of inoperable non-oat-cell carcinoma of the lung. Preliminary report by the Radiation Therapy Oncology Group. Cancer 1980; 45: 2744-53.
12. Sibley GS. Radiotherapy for patients with medically inoperable Stage I nonsmall cell lung carcinoma: smaller volumes and higher doses—a review. Cancer 1998; 82: 433-8.
13. Rowell NP, Williams CJ. Radical radiotherapy for stage I/II non-small cell lung cancer in patients not sufficiently fit for or declining surgery (medically inoperable): a systematic review. Thorax 2001; 56: 628-38.
14. Le QT, Petrik DW. Nonsurgical therapy for stages I and II non-small cell lung cancer. Hematol Oncol Clin North Am 2005; 19: 237-61.
15. Bradley J. A review of radiation dose escalation trials for non-small cell lung cancer within the Radiation Therapy Oncology Group. Semin Oncol 2005; 32 (2 Suppl 3): S111-3.
16. Mehta M, Scrimger R, Mackie R, Paliwal B, Chappell R, Fowler J. A new approach to dose escalation in non-small-cell lung cancer. Int J Radiat Oncol Biol Phys 2001; 49: 23-33.
17. Zhang J, Yang F, Li B, Li H, Liu J, Huang W,

et al. Which is the optimal biologically effective dose of stereotactic body radiotherapy for Stage I non-small-cell lung cancer? A meta-analysis. Int J Radiat Oncol Biol Phys 2011; 81: e305-16.
18. Wolbarst AB, Chin LM, Svensson GK. Optimization of radiation therapy: integral-response of a model biological system. Int J Radiat Oncol Biol Phys 1982; 8: 1761-9.
19. Timmerman RD, Lohr F. Normal tissue dose constraints applied in lung stereotactic body radiation therapy. In: Kavanagh BD, Timmerman R, editors. Stereotactic body radiation therapy. Philadelphia: Lippincott Williams & Wilkins; 2005: 29-38.
20. Milano MT, Constine LS, Okunieff P. Normal tissue toxicity after small field hypofractionated stereotactic body radiation. Radiat Oncol 2008; 3: 36.
21. Yaes RJ, Kalend A. Local stem cell depletion model for radiation myelitis. Int J Radiat Oncol Biol Phys 1988; 14: 1247-59.
22. Niemierko A, Goitein M. Modeling of normal tissue response to radiation: the critical volume model. Int J Radiat Oncol Biol Phys 1993; 25: 135-45.
23. Chi A, Liao Z, Nguyen NP, Xu J, Stea B, Komaki R. Systemic review of the patterns of failure following stereotactic body radiation therapy in early-stage non-small-cell lung cancer: clinical implications. Radiother Oncol 2010; 94: 1-11.

รายงานเบื้องต้นของการใช้ Cyber Knife® ในการรักษามะเร็งปอดชนิด non-small cell

ธิติ สว่างศิลป์, พรพรรณ ยงวิทิตสถิต, กุมุทิน ไพรัตน์, พัชรีพร เดชสุภา, มัณฑนา ธนะไชย, สมใจ แดงประเสริฐ, ลดาวัลย์ นาควงษ์, ชมพร สีตะธนี, พุฒิพรรณ พัวทวีพงศ์, ภรมน พุทธิการันต์, ชุลีพร เจียรพินิจนันท์, ปฐมิณฑิตา วิฑูรพณิชย์, ประเสริฐ อัศวประเทืองกุล, จุฑามาศ ขาวผ่อง

วัตถุประสงค์: *เพื่อนำเสนอประสิทธิภาพของแผนการรักษา, การวางแผนและเทคนิคทางรังสีรักษาและผลเบื้องต้นทางคลินิกในการรักษามะเร็งปอดชนิด non-small cell (NSCLC) ที่ไม่สามารถผ่าตัดได้ด้วยเครื่อง Cyber knife® ที่โรงพยาบาลรามาธิบดี*

วัสดุและวิธีการ: *ผู้ป่วยมะเร็งปอดชนิด NSCLC 6 ราย ได้รับการประเมินตอบสนองหลังได้รับการรักษาด้วย Cyber knife® ปริมาณรังสีที่ใช้เท่ากับ 45 เกรย์ ใน 3 ครั้ง สำหรับรอยโรคบริเวณ peripheral และ 50 เกรย์ ใน 5 ครั้ง ภายใน 2 สัปดาห์ สำหรับรอยโรคบริเวณ central (เทียบเท่า biological equivalent dose ที่ 112.5 และ 110 เกรย์ 10 ตามลำดับ) การตอบสนองการรักษาประเมินจากภาพรังสีร่วมกับผลทางคลินิกและผลข้างเคียง*

ผลการศึกษา: *พบผลการตอบสนองโดยรวมในผู้ป่วย 5 ใน 6 ราย โดยแบ่งเป็นการตอบสนองสมบูรณ์ 2 ราย และตอบสนองบางส่วน 3 ราย และไม่มีผลข้างเคียงที่รุนแรง แผนการรักษาแสดงถึงประสิทธิภาพในการฉายรังสีที่มีปริมาณรังสีสม่ำเสมอและครอบคลุมเป้าหมายได้อย่างดี*

สรุป: *รายงานเบื้องต้นนี้แสดงให้เห็นประสิทธิภาพของการวางแผนการรักษาและการควบคุมโรคโดยไม่เกิดผลข้างเคียงที่รุนแรงสำหรับมะเร็งปอดชนิด NSCLC ที่ไม่สามารถผ่าตัดได้ด้วยเครื่อง Cyber knife®*