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콘빔 CT를 이용한 전이성 뇌암의 영상 유도 방사선수술

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Cone-Beam CT Image-Guided Radiosurgery of Brain Metastasis : Technical Note and Clinical Application

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－Abstract－

Background : This study was performed to test feasibility of CBCT(cone-beam computerized tomography) guided radiosurgery.

Materials and Methods : We used CBCT which was mounted on a retractable arm at 90° to the treatment source. CBCT images were overlapped on the digitally reconstructed images from simulation CT scan. Then, 3 dimensional volumetric CT image matching was performed. If there were any positioning errors, automated patient re-positioning was done.

Results : A radiosurgery treatment plan was carried out with a set of specially designed multiple non-coplanar arcs. The goal of plan was to deliver single session 18 Gy at periphery of the target. We treated a patient with a solitary brain metastasis from left upper lung cancer. Serial imaging study for treatment response revealed a satisfactory result with no remarkable treatment related side effects.

Conclusion : CBCT image guided radiosurgery system is very simple and could be a convenient image guiding modality for stereotactic radiosurgery or fractionated radiotherapy with an acceptable geometric accuracy and radiation exposure.

Key Words : Cone-beam computerized tomography, Stereotactic radiosurgery, Brain metastasis

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Introduction

Stereotactic Radiosurgery (SRS) was used for the first time in 1951 by Dr. Lars Leksell.[1)] Radiosurgery is defined as a single-fraction technique that uses stereotactic principles for targeting and treatment of intracranial lesions through the use of multiple noncoplanar beams.[2)]

SRS is a multidisciplinary treatment modality that involves the use of a stereotactic frame with high-resolution collimation system and a high-resolution imaging system such as computerized tomography (CT) or magnetic resonance imaging (MRI). Recently developed Image-Guided Radiation Therapy (IGRT) system can be used to measure and correct positional errors for target localization and defining critical structures immediately prior to treatment delivery without stereotactic frame.[3)]

As on-board kV cone-beam computerized tomography (CBCT) imaging system is capable of producing images of soft tissue with excellent spatial resolution at acceptable radiation exposure, which can be a imaging modality to guide radiosurgery (RS) treatment setup with high precision comparable to the currently used frame-based positioning system for treatment setup.

In this study, we present technical performance of online CBCT image-guided treatment system with on-board imager (OBI, Varian Oncology, Palo Alto, CA, USA) that has been in routine use at the Andong Medical Group Cancer Center since May 2007, and evaluated clinical feasibility of image-guided SRS for a solitary brain metastasis with a thermoplastic mask fixation.

Materials and Methods

A. Image-guiding radiotherapy system

Our system is a 3 dimensional volume image matching technique of CBCT images from OBI system to digitally reconstructed CT images from CT simulator, permitting a prompt 3 dimensional verification and automatic correction with millimeter accuracy. The kilovoltage X-rays are generated by a conventional X-ray tube mounted on a retractable arm at 90° to the treatment source, and a 40 x 30 cm^2 flat-panel X-ray detector is mounted on opposite side of the kV tube of the Clinac iX (Varian Oncology, Palo Alto, CA, USA) linac (Fig. 1). CBCT images involve acquiring multiple kV radiographs as the gantry rotates through 360° of rotation.

Fig. 1. On-Board Imager™ kV imaging system of clinac ix.

B. Simulation CT scan

A simulation CT were performed with a wide-bore GE LightSpeed RT CT (GE, Milwaukee, Wisconsin, USA, Fig. 2) from the top of the skull to the skull base with the following scanning parameters: 120 kVp, 200mAs, 512 X 512 in-plane dimension, 0.672 mm pixel size, 33 X 33 cm^2 field of view, and 2.5 mm slice thickness.

Fig. 2. CT simulator.

C. CBCT Image-guided treatment setup (Fig. 3)

Step 1: CBCT images were overlapped on the digitally reconstructed images from simulation CT scan.

Step 2: On-line 3 dimensional volumetric CT image matching.

Step 3: Automated patient positioning.

Results

To minimize positional errors, we combined

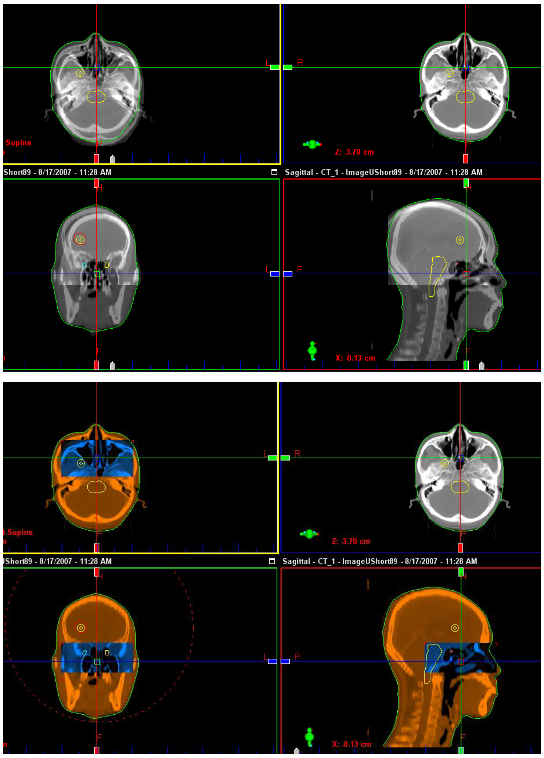

Fig. 3. CBCT Image-guided treatment setup(step 1 and 2).

simulation CT images of CT simulator and in-room kV CBCT images from OBI of the linac. Our image matching system consists of image fusion technique of digitally reconstructed radiographic images of SRS radiotherapy planning and OBI CBCT images, which guarantied prompt correction of setup error less than 1 mm, which took less than 10 minutes.

Clinical target volume, planning target volume and critical organs were contoured on the simulation CT scan with a commercially available 3D radiotherapy planning system, Eclipse (Varian Oncology, Palo Alto, CA, USA), and we planned to deliver single

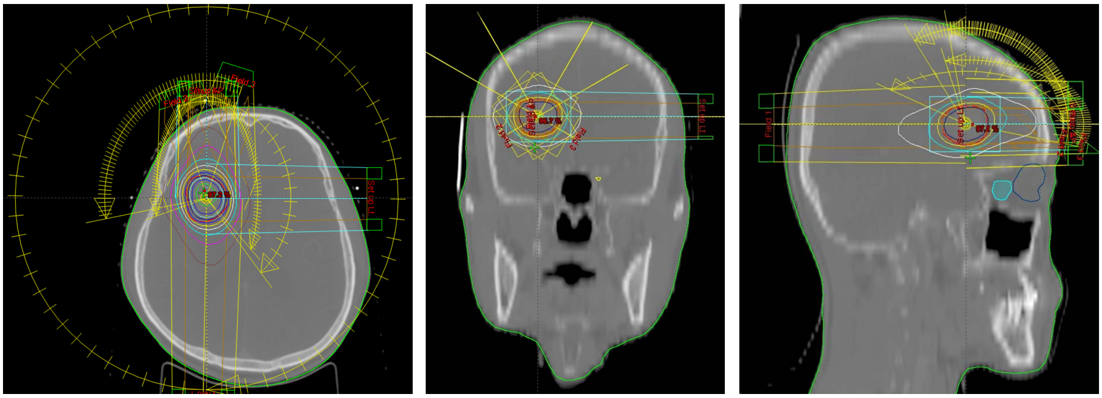

Fig. 4. Axial, coronal, and sagittal dose distribution.

Fig. 5. Millennium™ multileaf Collimator.

session 18 Gy at periphery of the metastatic lesion (Fig. 4).

A radiosurgery treatment plan was carried out with a set of specially designed multiple non-coplanar arcs, modified Shin's Arcs, using computer controlled mini MLC(multi-leaf collimator) of the linac, millennium MLC-120, which would be feasible to produce sharp dose gradients near brain target to avoid nearby critical structures (Fig. 5).[4]

We treated a 63-year old man, who presented to the internist with recently developed voice

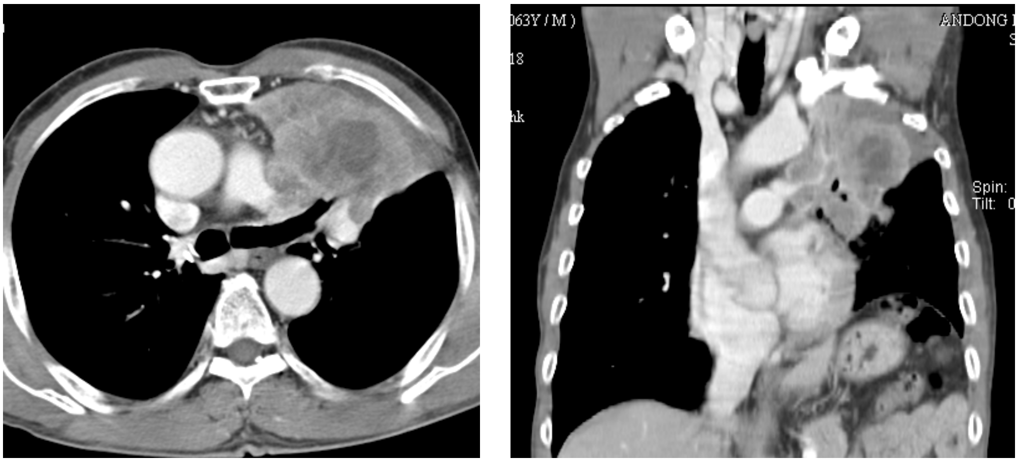

Fig. 6. CT images showed a huge heterogeneous mass on left upper lung.

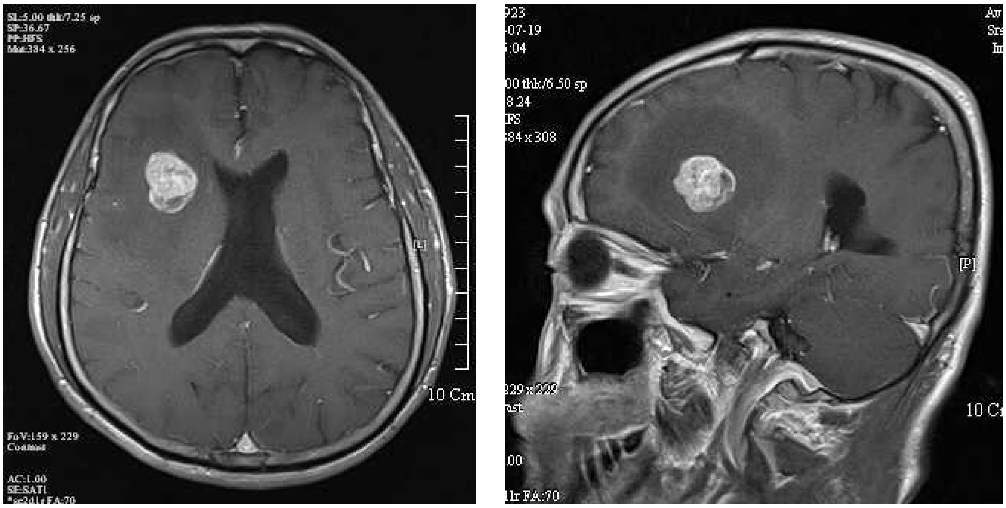

Fig. 7. MR images showed a well defined mass with peritumoral edema on right frontal lobe of the brain.

color change and headache. Chest CT showed a huge mass on left upper lobe with direct invasion to ipsilateral mediastinum and main pulmonary artery (Fig. 6). A bronchoscopic examination and biopsy was performed and positive for adenocarcinoma of the lung. Brain MRI showed a 2 cm sized spherical mass in right frontal area with considerable vasogenic edema around the mass (Fig. 7).

The treatment method was 860° multiple non-coplanar converging arcs to produce sharper dose gradients around the mass and avoid surrounding critical structures. The patient received a single 18 Gy irradiation with no treatment related adverse reactions, and discharged after 2 days' admission.

Discussion

In parallel with the development of imaging technology, SRS has been widely introduced as a safe and effective radiotherapy modality for the treatment of benign and malignant brain lesions.[3] Unfortunately intracranial target could not be seen by 2 dimensional megavoltage or kV portal images.

Jaffray et al.[5] have proposed the kV-CBCT system, which was to integrate a kV X-ray source and a large area flat panel detector on a standard linac allowing radiography, fluoroscopy, and CBCT. Based on phantom studies, they illustrated the fully volumetric characteristics of the CBCT data, showing excellent spatial resolution in all 3 dimensions, and the system provided submillimeter spatial resolution and a lowest readily detectable contrast at 47 Hounsfield units.

Immobilization techniques for intracranial targets can be classified in minimally invasive (typically for single fraction SRS) and noninvasive or relocatable systems (typically for multiple fraction stereotactic radiotherapy).[6] Recently, various image-guiding systems have been widely introduced as a targetting method of radiation delivery for high precision radiotherapy including 3 dimensional conformal radiotherapy (3D CRT), intensity-modulated radiation therapy (IMRT), and SRS.[7-9]

In this study, we used CBCT of Clinac iX linac to visualize brain parenchyma and skull bones for image guidance of SRS treatment positional setup. This technique eliminated the need for fiducial marker in patients or other invasive frame-based immobilization. It took less than 10 minutes for treatment setup and setup error was less than 1 mm.

In summary, our kV CBCT image-guided RS treatment is very simple and could be a convenient image guiding modality of a frameless SRS treatment or fractionated radiotherapy for cancers of the brain, lung, liver, and prostate with an acceptable geometric accuracy and radiation exposure.

요 약

배경 : 본 연구는 선형가속기에 장착된 콘빔 CT를 이용한 방사선수술의 기술적인 면을 평가하기위해 수행되었다.

재료 및 방법 : 방사선치료실 안에서 방사선 조사 직전에 방사선치료기에 부착된 콘빔 CT를 이용하여 획득한 3차원 CT영상과 치료계획용 CT 영상을 비교하여 정확한 종양의 위치를 확인한 후 방사선절제술을 시행하였다.

결과 : 3차원 치료계획용 컴퓨터를 이용하여 방사선절제술을 계획하였고, 여러개의 non-coplanar arc 빔을 사용하였다. 치료계획의 목표는 표적의 변연부에 18 Gy를 1회에 조사하도록 하였다. 본연구에서는 단일 병소의 뇌전이가 있는 환자를 대상으로 하였다. 고정창치로 thermoplatic mask만을 사용함으로써 환자의 불편함은 거의 없었다. 추적 검사상에 치료와 연관된 부작용은 없었다.

결론 : 본 연구는 최근에 도입된 영상 유도 장치인 콘빔 CT를 이용하여 정확한 종양의 위치를 확인한 후 방사선절제술을 시행한 것으로, 향후 여러 부위의 종양의 치료에 적용할 수 있을 것으로 생각된다.

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