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Linac-based Stereotactic Body Radiation Therapy at Oncology Center of Hue Central Hospital

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Abstract: Stereotactic body radiation therapy (SBRT), (also stereotactic radiotherapy surgery—SRS and stereotactic radiotherapy—SRT) is one of radiotherapy techniques which entails precise delivery of high-dose in one fraction and several fractions, with tumor ablation and maximal normal-tissue sparing. This technique has been approved globally and performed based on Cyberknife, Gamma knife, Proton. SBRT/SRS technique has not been common in Vietnam because it requires high accuracy and synchronous facilities. Hue Central Hospital is the pioneer in Vietnam applying successfully Linac-based SBRT, SRS with imaging guide radiotherapy (IGRT). The study enrolled 70 patients (25 HCC, 5 lungs, 40 brains) underwent SBRT, SRS, SRT techniques. We applied volumetric arc therapy technique (VMAT) from 1 to 5 fractions (prescribed doses depended on sites and size of tumors). Radiation treatment was given on LINAC of Elekta AXESSE, planned by Monaco 5.11 version, IGRT by daily conebeam CT/XVI device and assured quality by Verisoft software, OCTAVIUS 4D/PTW system, CT Similation 4D of PHILIPS with breathing compressor. With three case reports, the aim of this study is to survey and assess treatment planning quality of SBRT for liver, lung and brain tumors.

Key words: SBRT, SRS, SRT technique.

1. Introduction

The aim of stereotactic radiotherapy surgery (SRS) is to deliver a high dose of radiation prescribed to the target volume and minimise the dose to surrounding normal tissues. For last decades, many advanced equipment and techniques have been developed and applied in clinical practice for improving the quality and effectiveness of the treatment. SRS techniques have been applied at Oncology Center, Hue Central Hospital of Vietnam for unresected tumors in brain, liver and lungs with the purpose of getting the accuracy and safety in treatment and improving quality of life for cancer patients.

This report's purpose: Introducing the technical specifications of the radiation therapy machine and its accessories and the process of SRS in the center.

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2. Materials, Devices and Methods

<u>Materials</u>

- Cancer patients were indicated SRS in Cancer Center, Hue Central Hospital of Vietnam.

<u>Devices</u>

- Elekta AXESSE Linac;
- 4D CT Simulation of PHILIPS with breathing compressor;
- IGRT by daily conebeam CT/XVI device;
- Planned by Monaco 5.11 version;
- Orfit, Bodyfit and Stereotactic immobilization devices;
- Assured quality by Verisoft software, 1,500 detectors, OCTAVIUS 4D/PTW system.

2.1 Axesse Linac

<u>Technical specifications</u>

- 3 levels of photon energy: 6 MV, 10 MV and 15 MV;

- 5 levels of electron energy: 6 Mev, 9 Mev, 12 Mev, 15 Mev and 18 Mev.

It is easy to select suitable energy level for each tumour site:

Multileaf collimator (MLC): 80 leaves with the thickness of 4 mm. Therefore the fields' edge is smooth.

2.2 Image Guided Radiation Therapy (IGRT)

- XVI is the image equipment using Kylovoltage (KV) X-ray energy. It is a separate imaging device fixed on the frame of the machine for taking Cone Beam CT (IGRT).
- The main goal of IGRT is to make radiotherapy more accurate by checking images of treatment planning CT and daily treatment CT.

2.3 Equipment for Patient Immobilization

In SRS the using of devices for patient immobilization is very important because patients are indicated the high dose of radiotherapy and small size fields, so the dose difference is very high among the tumour volume and organs at risk. At the center, Orfit, Bodyfit and brain stereotatic frame are available.

For abdominal area radiotherapy, abdomen compressor device is used to limit respiratory rate, so limit the movement of involved organs.

2.4 Measuring and Control Equipment (qa)

Quality Assurance (QA) is very important in ensuring the stable, safe and accurate operation of the system.

Fig. 1 LINAC of Axesse.

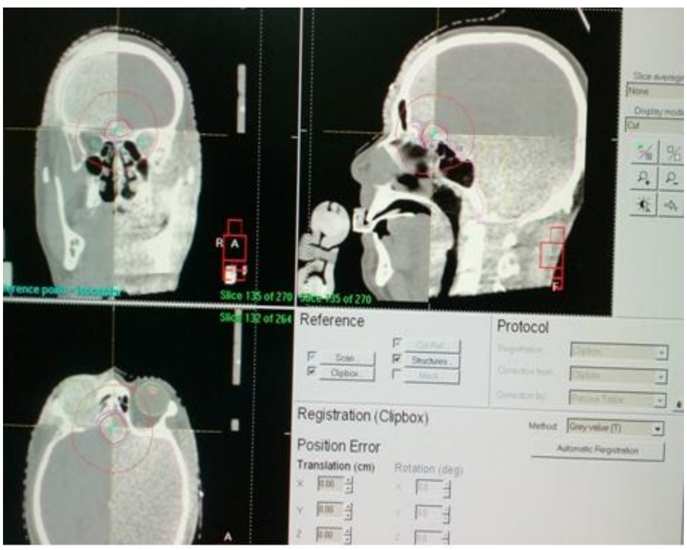


Fig. 2 Cone Beam CT at the treatment.

- In order to identify exactly the real dose into the target volume, it's necessary to use dose measure and control equipments. The Detector 1500, OCTAVIUS 4D phantom and Verisort software are available at the center.

- MEPHYSTO software and water phantom: to collect beam data.
- UNIDOS: to measure absolute dose.
- QUICKCHECK: Daily checking of dose rate, flatness and symmetry of the beam.
- PENTA GUIDED PHANTOM: Measure radiation field, laser, XVI.

2.5 Methods

Technique applied: Volume modulated Arc Therapy (VMAT):

- Inverse planning process by the Monte Carlo algorithm;
- Using 6MV beam and SAD.

After selecting the dose parameters of dose, beams, the specific dose distribution of elemental beams will be made via computer software. Algorithms are implemented through the principle of bilateral convolution. Because of continuous motion of the MLCs, beams are created with planned sizes.

In the planning process, it is sure that the optimal dose must be reached at the volume of the tumor but minimized dose at surrounding organs. Based on the identified clinical target volume (CTV), planned target volume (PTV) and organs at riesk (OARs), we made and evaluated the plans by three axial, coronal ans sagittal images and by the dose volume histogram (DVH).

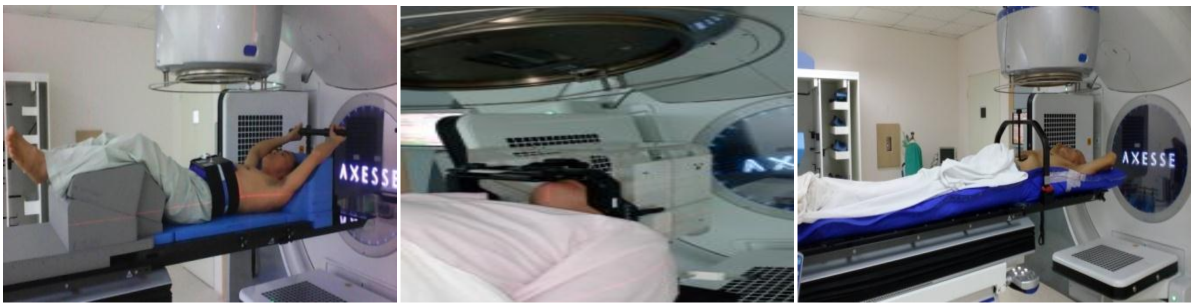


Fig. 3 Patient immobilization at the treatment.

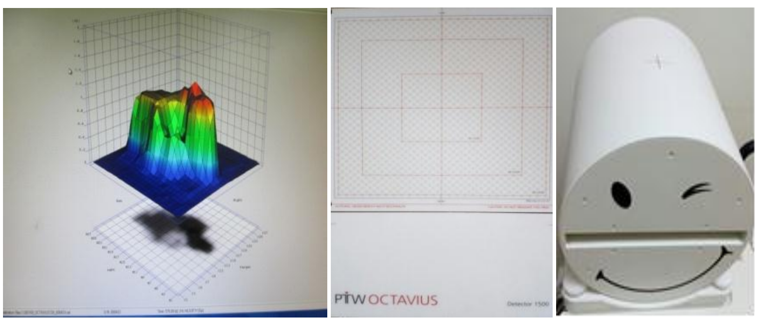
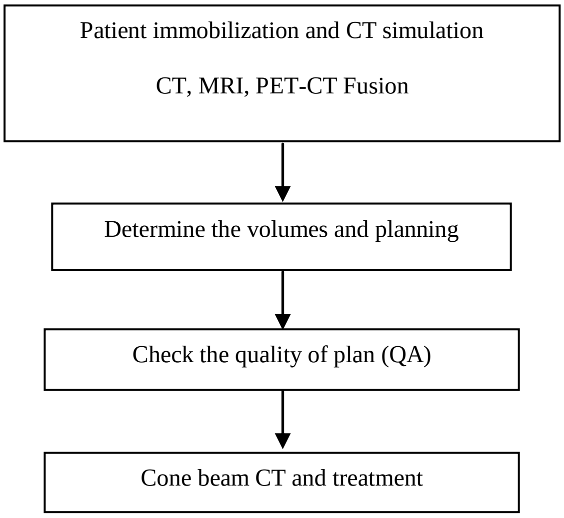


Fig. 4 System of dose measure and control equipments of the LINAC.

Process of radiation therapy



Anatomy of tumour

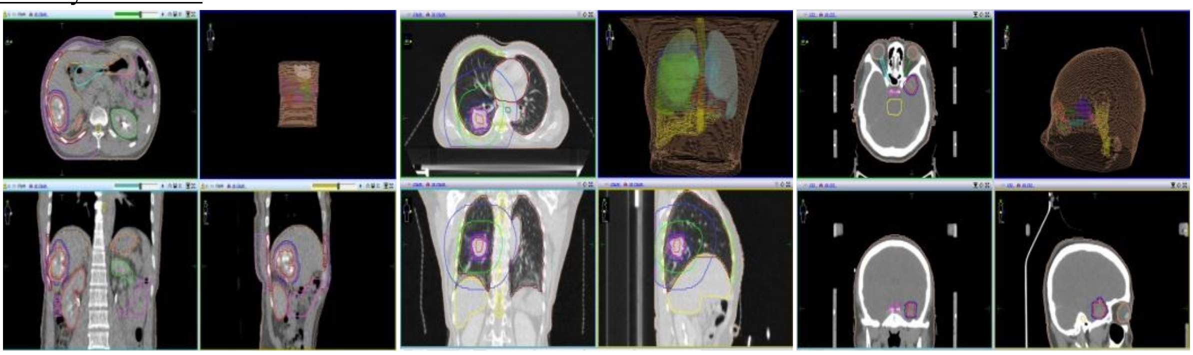


Fig. 5 Stimulated CT images of patients.

Target volumes delineation and planning

- Radiation Oncologists make contouring tumour, target volumes ans OARs based on CT, MRI, PET-CT images.
- Treatment planning using inverse planning by the Monte Carlo algorithm.
- After selecting the dose parameters of dose, beams' rotating arc, the specific dose distribution of elemental beams will be made via computer software. Algorithms are implemented through the principle of bilateral convolution. Because of continuous motion of the MLCs, beams are created with planned sizes.
- After selecting the dose parameters, rotating arc of the beam, the specific dose distribution of the corresponding elemental beams will be made via computer software. Algorithms are implemented through the convolution principle. Because the motion of the MLCs is continuous and the camera body is rotating around the patient, it is possible to create beams of arbitrary size.
- During the planning process, ensure that the optimal dose is reached at the volume of the tumor and reduce the dose of the surrounding healthy organization. Based on the clinical beer volume (CTV), planned beer volume (PTV) and the endangered organisms identified, we examined and compared three axial or coronal images, sagittal and on the dose (DVH) plot of the plan. If the criteria listed in Table 1 and Table 2 were met, the plan would be approved.

Check the quality of plan (QA)

Creating QA plan on the selected plan, calibrating the plan on the LINAC using verisoft software, Detector 1500, Phantom OCTAVIUS 4D. Plan will be approved when the gamma index reaches over 95%.

Conebeam CT and treatment

- The patient position set-up was made correctly like in the simulation. Isocenter was adjusted as the plan. Cone Beam CT was taken by the XVI imaging device.

- Using the Hexapod system (moving).

3. Results and Discussion

3.1 Case Report

Liver SBRT

- VMAT technique with the rotating arc gantry of 1400 (00-2200).
- Using 6MV beam and SAD.
- The dose of 45 Gy, 5 fractions of 900 cGy daily.
- The dose prescribed depends on the site and size of the tumour, range of 27.5 Gy-50 Gy/5Fx.
- The practical guideline of RTOG 1112, Update version: May 7, 2013.

Table 1 showed that, organs at risk received the radiation dose at safe level, lower than their limited dose.

Dose at skin was higher than the limited dose because the tumour site was close to the chest wall.

Lung SBRT

- Using 6MV beam and SAD.
- The dose of 54 Gy, 3 fractions of 1,800 cGy.
- The dose prescribed depends on the site and size of the tumour, range of 34 Gy-60 Gy/3-5Fx.
- The practical guideline of RTOG 0813.

Table 2 showed that basic calculating standards of the plan were met.

Tables 3 and 4 showed that organs at risk received the radiation dose at safe level, lower than their limited dose.

Dose at skin and chest wall was higher than the limited doses because the tumour site was close to the chest wall.

Brain SRS

- The dose of 16Gy/1 fraction.
- The dose prescribed depends on the site and size of the tumour, range of 15 Gy-20 Gy/1-3Fx.
- The practical guideline of RTOG 0320.

Table 5 showed that basic calculating standards of the plan were met.

Table 1 Prescription dose.

Prescription dose	Liver (minus GTV) mean dose		
	Per protocol	Variation acceptable	Deviation unacceptable
50 Gy	≤13.0 Gy	13-13.2 Gy	>13.2 Gy
45 Gy	≤14.5 Gy	14.5-14.7Gy	>14.7 Gy
40 Gy	≤15.0 Gy	15-15.2 Gy	>15.2 Gy
35 Gy	≤15.5 Gy	15.5-15.7Gy	>15.7 Gy
30 Gy	≤16.0 Gy	16-16.2 Gy	>16.2 Gy
27.5 Gy	≤17.0 Gy	17-17.2 Gy	>17.2 Gy

Table 2 Dose limits OARs.

Non-liver OARs	Per protocol	Dose plan
Esophagus max (to 0.5 cc)	3,200 cGy	540 cGy
Stomach max (to 0.5 cc)	3,000 cGy	874 cGy
Duodenum max (to 0.5 cc)	3,000 cGy	1,955 cGy
Small bowel max (to 0.5 cc)	3,200 cGy	2,249 cGy
Cord +5mm (to 0.5 cc)	2,500 cGy	1,036 cGy
Kedney L: mean dose	≤1,000 cGy	208 cGy
Kedney R: mean dose	≤1,000 cGy	538 cGy
Heart max (30 cc)	<3,000 cGy	290 cGy
Chest wall max (0.5 cc)	<5,000 cGy	4,893 cGy
Skin (external) max (0.5 cc)	<3,200 cGy	4,624 cGy
Liver (minus GTV) mean dose	< 1,450 cGy	1,310 cGy

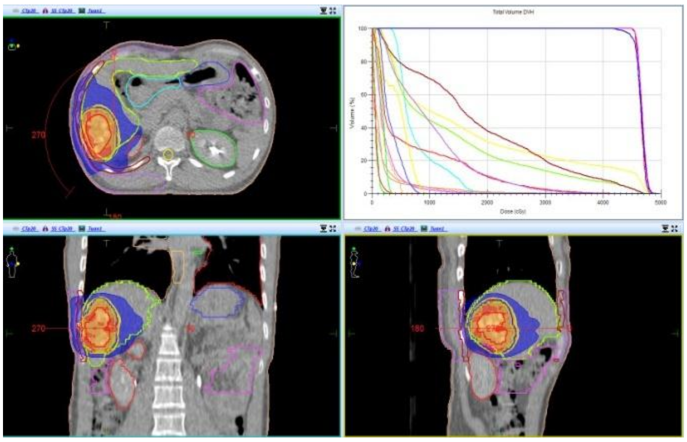


Fig. 6 Isodose curve shown on CT images (liver).

Table 3 Conformality of prescribed dose for calculations based on deposition of photon beam energy in heterogeneous tissue.

PTV volume (cc)		Ratio of prescription isodose volume to the PTV volume			Ratio of 50% prescription isodose volume to the PTV volume, R50%			Maximum dose (in % of dose prescribed) at 2 cm from PTV in any direction, D2cm (Gy)			Percent of lung receiving 20 Gy total or more, V20 (%)		
		Deviation			Deviation			Deviation			Deviation		
	Dose plan	None	Minor	Dose plan	None	Minor	Dose plan	None	Minor	Dose plan	None	Dose	Dose plan
1.8		<1.2	<1.5		<5.9	<7.5		<50	<57		<10	<15	
3.8		<1.2	<1.5		<5.5	<6.5		<50	<57		<10	<15	
7.4		<1.2	<1.5		<5.1	<6.0		<50	<58		<10	<15	
13.2		<1.2	<1.5		<4.7	<5.8		<50	<58		<10	<15	
22.0		<1.2	<1.5		<4.5	<5.5		<54	<63		<10	<15	
34.0		<1.2	<1.5		<4.3	<5.3		<58	<68		<10	<15	
50.0		<1.2	<1.5		<4.0	<5.0		<62	<77		<10	<15	
70.0		<1.2	<1.5		<3.5	<4.8		<66	<86		<10	<15	
95.0		<1.2	<1.5		<3.3	<4.4		<70	<89		<10	<15	
126.0	116	<1.2	<1.5	1.04	<3.1	<4.0	3.9	<73	>91	86	<10	<15	12
163.0		<1.2	<1.5		<2.9	<3.7		<77	>94		<10	<15	

Table 4 OAR constraints(serial).

Serial tissue	Volume	Volume Max (Gy)		Max point dose (Gy)	
		Per protocol	Dose plan	Per protocol	Dose plan
Spinal cord	<0.5 cc	18 Gy	0.33 cc	22 Gy	21 Gy
Esophagus	<5 cc	21 Gy	0 cc	27 Gy	16 Gy
Heart	<15 cc	24 Gy	0.5 cc	30 Gy	28 Gy
Chest wall	<30 cc	30 Gy	120 cc	30 Gy	
Skin	<10 cc	22.5 Gy	15 cc	24 Gy	49 Gy

Table 5 OAR constraints (parallel).

Parallel tissue	Critical volume (cc)	Dose plan	Critical volume dose Max (Gy)
Lung (right & left)	1,500 cc	1,548 cc	10.5 Gy
Lung (right & left)	1,000 cc	1,366 cc	11.4 Gy
Liver	700 cc	987 cc	Gy

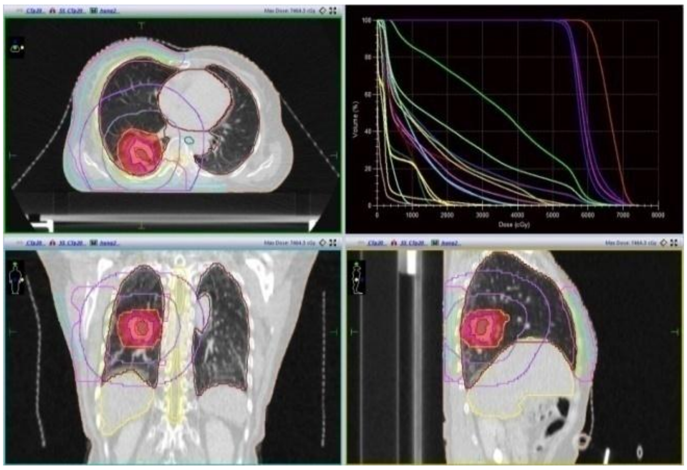


Fig. 7 Isodose curve shown on CT images (lung).

Table 6 Plan scoring criteria for brain.

	Per protocol	Variation acceptable	Dose plan
Dose homogeneity MD/PD	No deviation: ≤2	Minor deviation: >2 but ≤2.5	1.5
Dose conformity: PI/TV	No deviation: Between 1.0 & 2.0	Minor deviation: ≥9 but< 1.0 or > 2.0 but ≤3.5	1.2
Target coverage	No deviation: $V_{90\%} \geq 100$	Minor deviation: $V_{80\%} \geq 100$	100%
The prescription isodose surface must be >50% & <90% of maximum dose			63%

Notes. MD is maximun dose, PD is prescription dose, PI is prescription isodose volume and TV is target volume.

Table 7 Dose limit OARs.

Organ	Dose limit	Dose limit	Dose plan
Brainstem	No deviation: Max ≤ 12.5 Gy & 0.5 cc < 10 Gy	Minor deviation: Max 15 Gy & 0.5 cc < 10 Gy	48 cGy – 0 cc
Chiasm	No deviation: Max <8 Gy	Minor deviation: < 10 Gy & 0.2 cc < 8 Gy	714 cGy – 0 cc
Optic nerves	No deviation: Max <8 Gy	Minor deviation: < 10 Gy & 0.2 cc < 8 Gy	727 cGy – 0 cc
Cochlea	No deviation: Max <9 Gy	Minor deviation: Max < 10 Gy	98 cGy

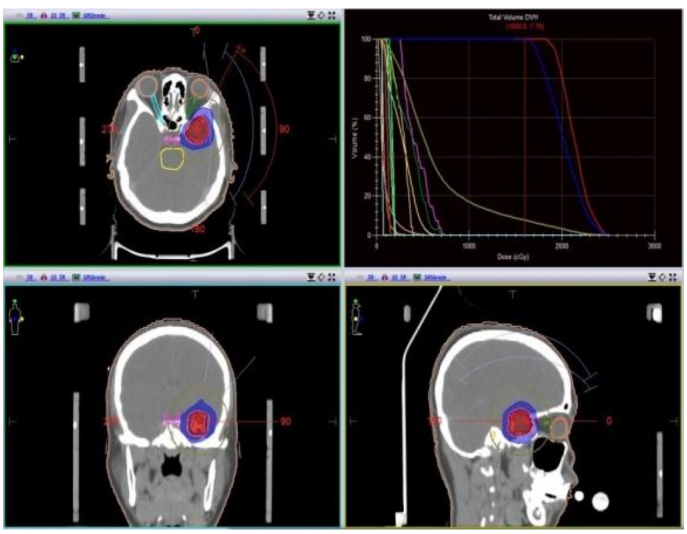


Fig. 8 Isodose curve shown on CT images (brain).

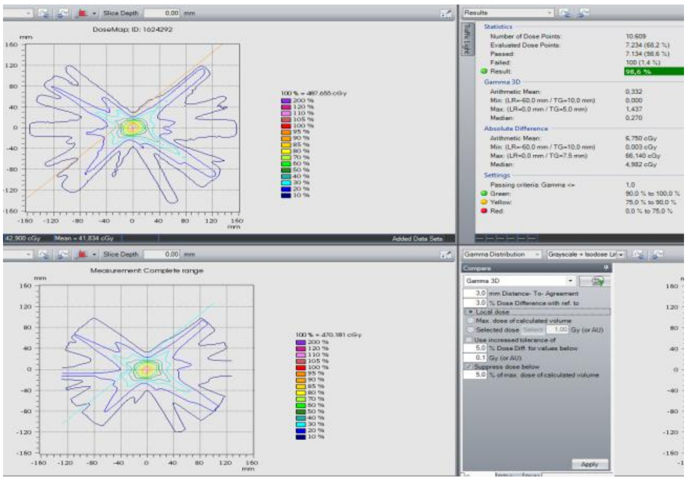


Fig. 9 The results of the dose measurement on the LINAC.

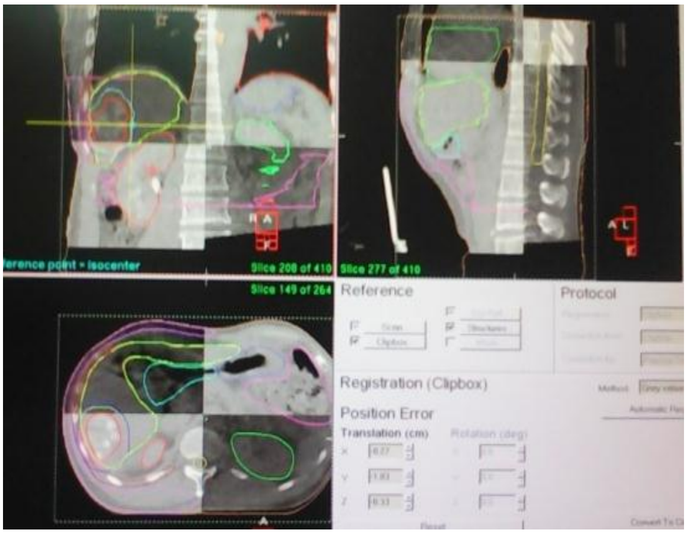


Fig. 10 Cone Beam CT images before treatment.

Table 6 showed that organs at risk received the radiation dose at safe level, lower than their limited dose.

3.2 Check the Quality of the Plan (QA)

Quality Assurance (QA) is very important in ensuring the stable, safe and accurate operation of the system.

In order to identify exactly the real dose into the target volume, it's necessary to use dose measure and control equipments.

3.3 Cone Beam CT

To consider if the patient position set-up is the same as planned CT, cone beam CT was taken before the treatment by XVI or IviewGT systems. Information was transferred back to the Mosaiq software after the radiation oncologist completed the check, and then transferred again to the LINAC for treatment.

4. Conclusion

SBRT (SRS/SRT) technique gets much advantages in clinical practice, ensuring delivering prescribed dose to the target and minimizing dose to the surrounding normal tissues, so it requires high accuracy and synchronous facilities. Although it takes much time for planning, the duration of treatment is short. This is an accurate and safe technique in modern radiation therapy.

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