Study of IMFAST^{TM} Segmentation Algorithm with CORVUS TPS for Intensity Modulated Radiation Therapy

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The IMRT planning depends on the algorithm of each planning system and MLC performance of each Linac system. Yonsei Cancer Center introduced an IMRT System at the beginning of February, 2002. The system consists of CORVUS (Nomos, U.S.A.) treatment planning system, LANTIS, PRIMEVIEW and PRIMART (Siemens, U.S.A) linac system. The optimization of CORVUS planning system with PRIMART is an important task to make a desirable quality treatment plan. Our *Step & Shoot* IMRT system uses Finite Size Pencil Beams (FSPB) dose model, simulated annealing optimization algorithm and IMFAST segmentation algorithm. We constructed treatment plans for four different patient cases with two basic beamlet sizes, 1.0×1.0 cm^2 and 0.5×1.0 cm^2, and four intensity steps, 5%, 10%, 20%, 33%. Each case's plan was evaluated with the dose volume histograms of target volumes and delivery efficiencies. The patient case of small target volume is sensitive at the change of intensity map's segmentation and it highlighted an effective treatment plan at marrow intensity step and small basic projection beamlet.

Key words: Intensity modulated radiation therapy (IMRT), Finite size pencil beams (FSPB), Dose volume histogram (DVH), Multileaf collimator (MLC), Step & shoot

INTRODUCTION

The intensity modulated radiation therapy has revolutionized the implementation of conformal treatment. It can serve excellent tumor coverage and preserve critical organs.[1] Our clinic center has the experience of Radiation therapy since 1937 and we introduced IMRT system to achieve more effective radiation treatment at the beginning of 2002. The adopted system was the "*segmental*" or "*step & shoot*" MLC treatment technique that has been widely used to deliver IMRT treatment designed by dose optimization algorithm.[2,3] The installed CORVUS (NOMOS, U.S.A.) treatment planning system uses Finite Size Pencil Beams (FSPB) dose model, simulated annealing method[4] for dose optimization algorithm and IMFASTTM,[5] a leaf segmentation algorithm developed by Siemens. PRIMART (Siemens, U.S.A.) linac is designed only for 6MV x-ray IMRT.

The stop & shoot MLC technique offers simplicity in both treatment dosimetry and accelerator control, and therefore has an obvious practical appeal to the radiation therapy community. Despite these benefits, however, the technique still have some practical issues that require long treatment delivery time[3] at large volume routine clinical implementation. A good resolution gives smooth intensity map and better conformality but poor delivery efficiency. Actually, the intensity resolution is represented by two resolutions: the number of intensity steps, i.e. intensity level resolution, and the spatial resolution of the intensity map.

The purpose of this study is to investigate the facts affecting the quality and efficiency[6] of the

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IMFAST generated segmentation technique.

MATERIALS AND METHODS

The MLC of PRIMART (Siemens) is designed with 29 pairs of opposed leaves. The inner 27 pairs of leaves individually projects a beam width of 10 mm and the outer most pairs produce a width of 65 mm providing a field size of 40 cm long.[7] Fig. 1 shows the MLC of PRIMART.

The CORVUS has prescription mode to order a treatment plan. It is consisted of Planning Goals & Optimization, Immobilizer & Localizer and Treatment Machine & Delivery Options (Fig. 2).[8] Here, we only considered beamlet size and intensity step on the intensity map. The combination of MLCs and jaws can make the minimum field of 3 mm (MLCs)×10 mm (jaws). We used PRIMART 6 MV MLC (1.0×1.0 cm^2) and PRIMART 6 MV MLC (0.5×1.0 cm^2) for Treatment Machine mode,[4] and 5%, 10%, 20% and 33% Leaf Transmission sets that modulate the beam intensity on the field.

We sampled four different patient cases to check the general property of segmentation algorithm. Treatment region, target volume, and goal dose of target for each case are shown in Table 1.

We constructed IMRT planning with the following conditions. First, we made a standard treatment plan with 1.0×1.0 cm^2 beamlet at SAD 100 cm and 20% intensity step. Second, we made additional four treatment plans which combined under considerations of delivery cost with different beamlets and intensity steps, (1.0×1.0 cm^2, 5%), (1.0×1.0 cm^2, 10%), (0.5×1.0 cm^2, 20%), and (0.5×1.0 cm^2, 33%) for each case. Plans were normalized at 95% target volume and 100% goal dose and compared.

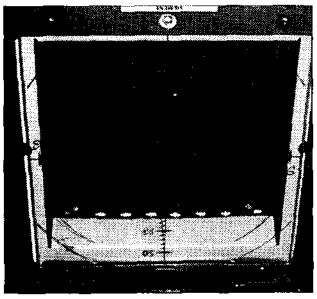

Fig. 1. PRIMART MLC.

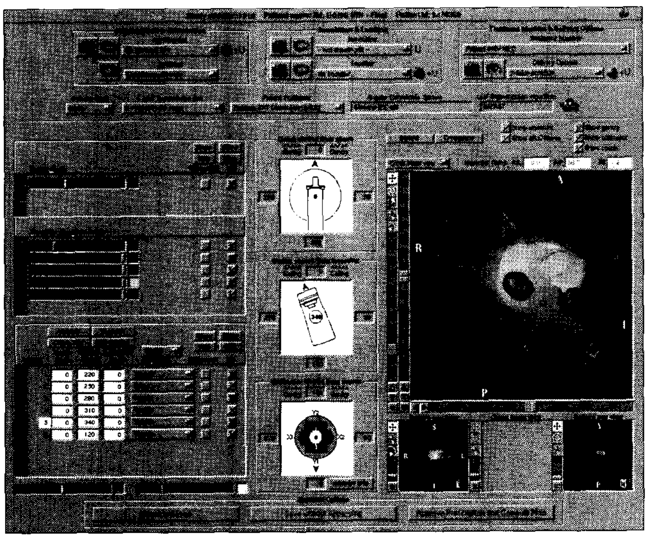

Fig. 2. Treatment machine & delivery options on CORVUS window.

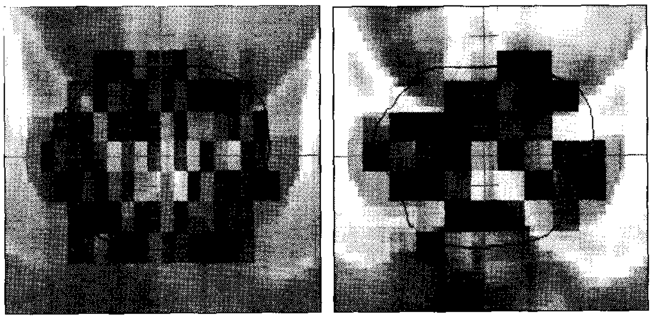

Fig. 3. An example of planned intensity map at gantry 0 degree. The right is 1.0×1.0 cm^2 beamlet and the left 0.5×1.0 cm^2.

Table 1. Patient Cases

Case	Tx. region	Target vol. (cc)	Goal dose (Gy)
1	Chest	52.5	45
2	Head	99.5	68
3	Head	172.9	60
4	Abdomen	489.9	54

RESULTS

1. Dos Volume Histogram of Target

Fig. 4 to 7 show the Integral and differential DVH[9] of PTV for four patient cases. Case 1 has relatively small target volume among the four patient cases. We applied six fields. The planning of 0.5×1.0 cm^2 beamlet and 20% intensity step shows the best performance for the comformality of target and the dose homogeneity (Fig. 4).

Case 2 was planned with 9 fields and shows similar result with case 1 (Fig. 5).

Case 3 has larger target volume than case 1 and 2. 9 fields were set for planning. There was insignificant difference between the DVHs of plans. 1.0 ×1.0 cm^2 beamlet and 10% intensity step option gave enhanced plan than the others. The dose volume histogram of target at case 4 is showed in Fig. 7. This case has the biggest target volume among the all patient cases sampled and the number of portal designed was six. There was no dramatic difference between the each plan for maximum, minimum, mean and standard deviation of target dose conformality. 1.0×1.0 cm^2 beamlet at 10% intensity step shows reasonable performance.

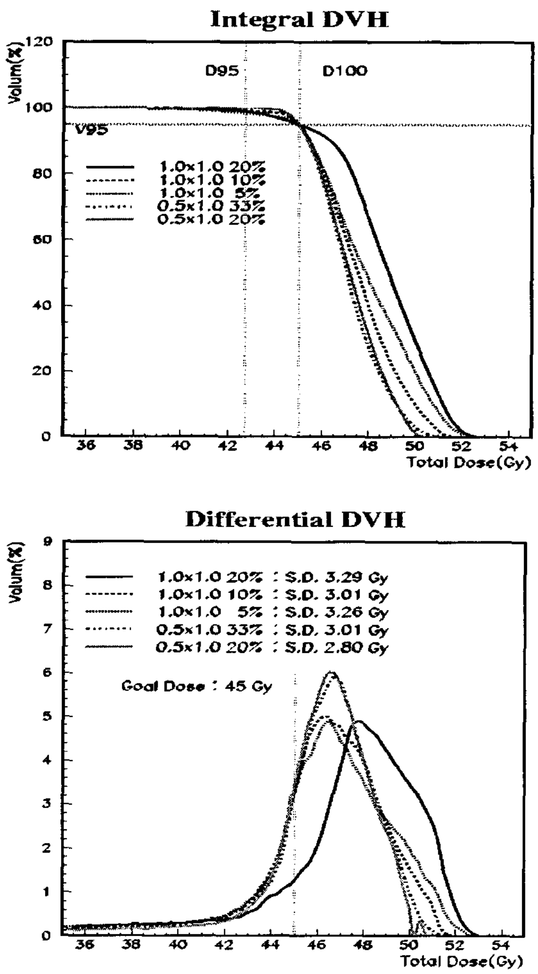

Fig. 4. Integral & differential DVH of case 1. Target Vol. is 53 cc.

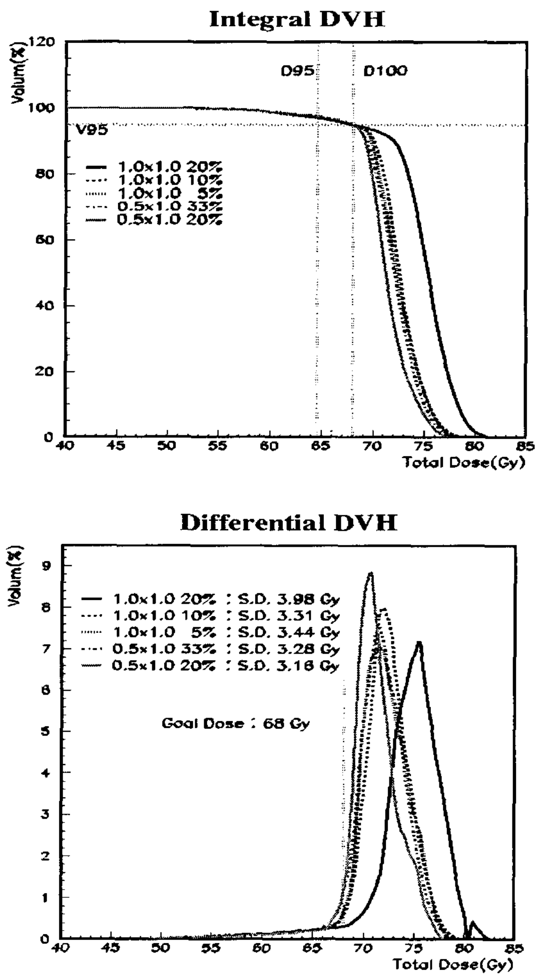

Fig. 5. Integral & differential DVH of case 2. Target Vol. is 99 cc.

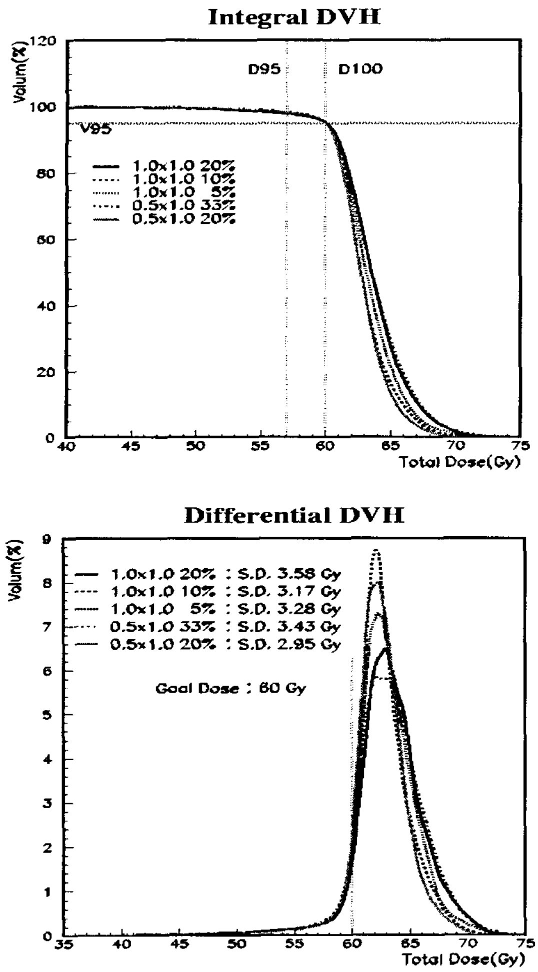

Fig. 6. Integral & differential DVH of case 3. Target Vol. is 173 cc.

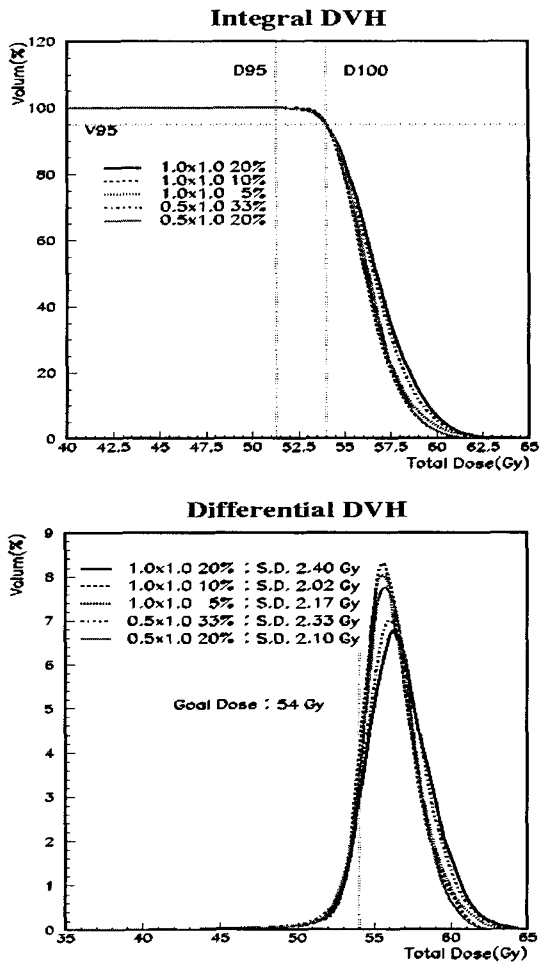

Fig. 7. Integral & differential DVH of case 4. Target Vol. is 490 cc.

2. Treatment Delivery Efficiency

We normalized the total MU and the segment number of each plan to 1.0×1.0 cm^2 spatial resolution and 20% intensity step for comparison. The treatment delivery of each standard plan is showed in Table 2. Generally, the treatment delivery time takes about 20 min at 100 segments on PRIMART linac with the IM-MAXX™, IMRT Field Sequencer treatment option.

Fig. 8 shows the comparison of treatment delivery with total monitor unit and number of segment for various segmentation options. The lower part plot of Fig. 8 shows the comparison of number of segment.

Table 2. Selection of Intensity Modulation Option

Intensity step	Basic beamlet size	
	1.0×1.0 cm^2	0.5×1.0 cm^2
5%	O	X
10%	O	X
20%	O	O
33%	X	O

The cases with same beamlet size option's revealed almost equal total monitor unit values. However, 0.5 $\times1.0$ cm^2 beamlet size options had two or three times greater monitor units than 1.0×1.0 cm^2.

Fine spatial resolution and narrow intensity step cause segment number to increase. The option of 0.5

Table 3. Treatment Delivery at Each Standard Plan

	Standard Treatment Plan (1.0×1.0 cm^2, 20% intensity step)		
Case	Total MU	Segments	Fields
1	1287	48	6
2	1688	113	9
3	1412	80	9
4	1350	65	6

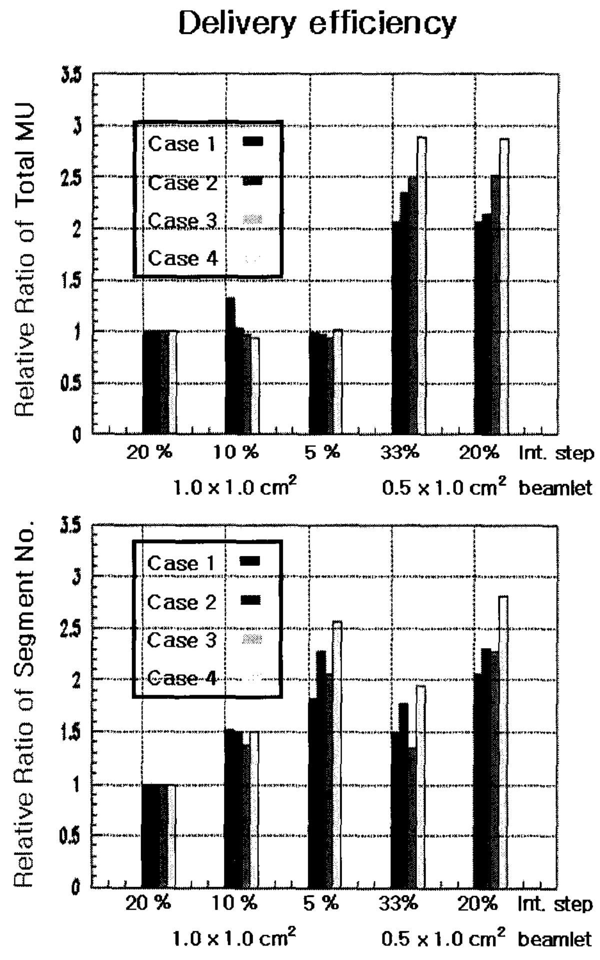

Fig. 8. Comparison of Treatment Delivery Efficiency.

×1.0 cm^2 beamlet and 20% intensity step shows 2 or 3 times of segment number of the 1.0×1.0 cm^2 and 20% option.

DISCUSSIONS AND CONCLUSION

We have evaluated the performance of IMFAST™ segmentation algorithm which is widely used for IMRT implementation at Siemens linac. Although the comparison of target DVH with the different intensity map's spatial resolution and intensity step doesn't demonstrate a dramatic change, the case of small target volume has desirable overall quality at higher intensity resolution option with reasonable cost of treatment delivery. The total monitor unit only depends on the basic field size of intensity map. The number of Segment depends on the both, the intensity step and the field size of intensity map.

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세기조절 방사선 치료에서 CORVUS TPS를 이용한 IMFAST™ Segmentation Algorithm의 연구

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이세병 · 박진호 · 조광한 · 이창걸 · 이 석 · 추성실 · 표홍렬 · 서창옥

세기조절 방사선 치료는 각각의 치료계획 시스템의 도스 최적화 알고리즘과 선형 가속기의 조합에 따라 다양하게 최적의 성능을 발휘 할 수 있다. 연세 암센터는 효과적인 방사선치료를 위하여 2002년 2월에 세기조절 방사선 치료 시스템을 도입하여 운영 중에 있으며 도입된 시스템은 CORVUS (Nomos, 미국) 치료계획 시스템과 LANTIS, PRIMEVIEW, PRIMART (Siemens, 미국)의 선형가속기 시스템으로 구성되어 있다. 최적화된 치료를 위해서는 CORVUS 치료계획기와 PRIMART 선형가속기의 적절한 조합 조건을 찾아 적용하는 것이 중요한 일이다. 이 Step & Shoot 방식의 세기조절 방사선 치료기는 Finite Size Pencil Beams (FSPB) 도스모델과 simulated annealing method의 도스 최적화 알고리즘 및 IMFAST의 segmentation 알고리즘을 사용하고 있다. 본 연구는 segmentation 알고리듬에 관한 것으로 두개의 기본 beamlet 크기(1.0×1.0 cm^2 와 0.5×1.0 cm^2)와 4가지의 빔 세기 단계(5%, 10%, 20%, 33%)의 option을 4명의 상이한 환자 case에 대하여 적용하고 비교해 보았다. 상대적으로 작은 target 부피를 갖는 경우 TPS상의 segmentation의 설정에 민감하게 target 도스분포가 변하였으며 작은 beamlet일수록 intensity step을 작게 할수록 최적의 도스분포를 보여주었다.

중심단어 : 세기조절 방사선 치료(IMRT), Finite Size Pencil Beams (FSPB), Step & shoot Dose Volume Histogram (DVH), multileaf collimator (MLC)