Spinal Cord Partial Block Technique Using Dynamic MLC

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ABSTRACT

The spinal cord dose is the one of the limiting factor for the radiation treatment of the head & neck (H&N) or the thorax region. Due to the fact that the cord is the elongated shaped structure, it is not an easy task to maintain the cord dose within the clinically acceptable dose range. To overcome this problem, the spinal cord partial block technique (PBT) with the dynamic Multi-Leaf Collimator (dMLC) has been developed. Three dimension (3D) conformal beam directions, which minimize the coverage of the normal organs such as the lung and the parotid gland, were chosen. The PBT field shape for each field was designed to shield the spinal cord with the dMLC. The transmission factors were determined by the forward calculation method. The plan comparisons between the conventional 3D conformal therapy plan and the PTB plan were performed to evaluate the validity of this technique. The conformity index (CI) and the dose volume histogram (DVH) were used as the plan comparison indices. A series of quality assurance (QA) was performed to guarantee the reliable treatment. The QA consisted of the film dosimetry for the verification of the dose distribution and the point measurements. The PBT plan always generated better results than the conventional 3D conformal plan. The PBT was proved to be useful for the H&N and thorax region.

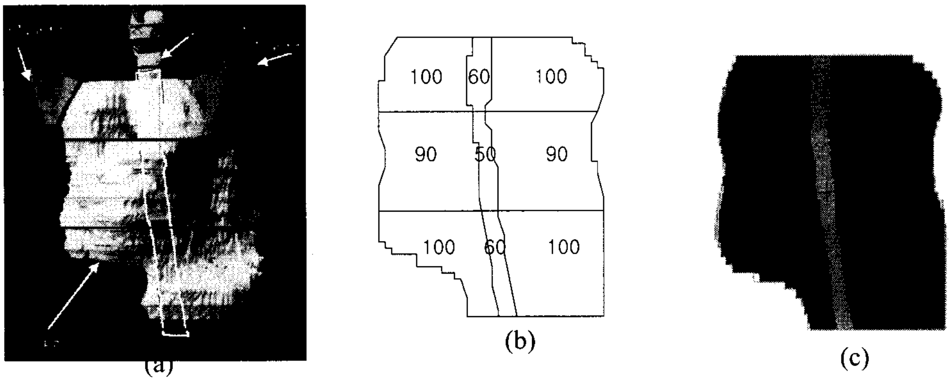
Keywords: Dynamic MLC, 3D conformal plan, forward calculation, Spinal cord

1. INTRODUCTION

Radiation treatment of head and neck (H&N) or the thorax poses a unique challenge to the radiation oncology treatment team, because the spinal cord is the elongated shaped structure and a critical dose-limiting structure. [1,2] In the H&N cancer, the planning target volume (PTV) reaches to a level below the shoulders, so it is difficult to deliver to the spinal cord below tolerance and to keep the clinically acceptable dose to the parotid gland and the lung, which have the radiation volume dependent feature[3]. Advances in imaging technology and computational power make the application of 3-dimensional(3D) treatment planning and conformal therapy possible. Such application utilizing the concept of inverse treatment planning and intensity-modulated radiation therapy (IMRT) has been proposed as a strategy to maximize dose delivery to PTV while keeping the acceptable levels of spinal cord dose[1]. Although the inverse treatment planning generates superior plans relative to the conventional techniques as demonstrated by comparing dose-volume histograms in terms of tumor coverage and normal structure sparing[4,5], it has some limitation to use in clinic field, such as performing the quality assurance and the inverse treatment planning itself. The spinal cord partial block technique (PBT) with the dynamic Multi-Leaf Collimator (dMLC) was developed using the conventional 3D conformal treatment planning system. It is the one of the technique of forward IMRT that the radiation intensity pattern was modulated manually. The characteristic features of PBT are the usage of transmission factors, which were applied to the field as the index of the field intensity. The advantage of PBT is an extension of the conventional 3D conformal treatment planning. The intensity modulated beam pattern was generated with the PBT for obtaining the optimal dose distribution. In this study, the clinical implementation of the spinal cord PBT was presented. The PBT plans were compared to the conventional 3D conformal therapy plan and the series of QA were performed to evaluate the validity of this technique.

2. MATERIALS AND METHODS

A several consecutive patients who have the H&N cancer were accrued for this study. The CT scans were obtained in a supine position using the CT simulator (AcQSim, Philips, USA). The slice thickness of the image was 0.5 cm and the acquired images were transferred via network to the RTP system (Render Plan, Elekta, USA). The radiation treatment plan was designed using PBT on the beam's eye view of the RTP



(a) (b) (c)

Fig. 1. Example of forward intensity modulated radiation field.

The first planning stage began with finding a beam orientation that encompassed all targets (fig.1a). All of the beam's orientations were decided to obtain the best coverage of the targets as like as the conventional 3D plan. The shapes and the weights of sub-fields on each radiation field were designed to keep the spinal cord dose within the clinically acceptable dose range (fig. 1b). The procedure of generating the intensity modulated radiation field is shown in figure 1 and figure 2.

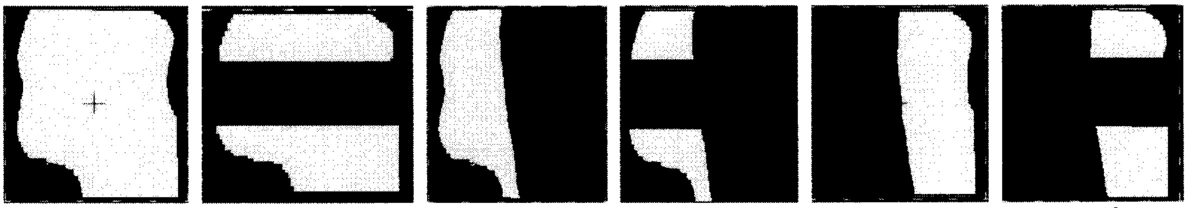

(a) (b) (c) (d) (e) (f)

Fig. 2. Design of d-MLC generated from fig.1

Figure 1c is the simulated image that generated from the d-MLC in the figure 2. It could use to evaluate the plan using the d-MLC. Figure 2 shows the example of the design of a PBT field generated from RTP plan in figure 1. The field consists of 6 sub-fields, of which monitor units were decided by the transmission factors designed in figure 1a. The first field shape is designed to encompass the PTV including the spinal cord and the normal structure (fig.2a). The other sub-field were shaped to shield the normal structure. The fraction of the sub-field was settled to keep the spinal cord dose, while the PTV dose was achieved to the clinical level (fig.2c, 2d). After all of sub-fields were designed, the plan was calculated to weight the fields using forward calculation method. Figure 2b, 2d, 2f were the result of the sub-fields that compensate the central region. To assess the adequacy of the PBT used for patient treatment, the plan generated from PBT was compared to a retrospectively generated conventional radiation plan for each patient. The DVH to the PTV, the spinal cord, the left and the right parotid glands were compared as index of plan evaluation in the plan comparison. The QA of the PBT plan were performed using the phantom plan, which was designed using the same intensity pattern to solid water phantom to obtain the isodose distribution. The treatment field verification and the dose distribution evaluation were performed using the using the film dosimetry systems. The film (X-omat, Kodak, USA) was irradiated as the phantom plan.

3. RESULTS

Dose characteristics judged to be clinically important were the mean and minimal dose to the targets, volumes of under-dosage within targets, the maximum dose received by the noninvolved tissue, as well as the volume of noninvolved tissue receiving a high dose[6]. Table 1 show the doses delivered to PTV and normal structure by the PBT plans and by the conventional plan. Although the dose to PTV were little, a significant gain was achieved with PBT plans regarding the keeping the spinal cord dose and the normal structure receiving low dose than conventional plans in table 1. Figure 3 shows the DVH, which is the plan comparison between the PBT plan and the conventional plan. The solid lines are the DVH of the PBT plan and the dotted lines are the DVH of the conventional plan. The dose to the PTV seems to be achieved to the planning goal of the clinical demand in the all the plans. Noticeable improvement in the sparing the normal organ were observed with PBT plan

		PTV	Spinal cord	RT-parotid G	LT-parotid G
Conventional plans	Avg.(Max)	98 (116)	66 (101)	67 (104)	70 (105)
P B T plans	Avg.(Max)	92 (106)	41 (62)	51 (102)	63 (102)

Table. 1. Dose delivered to PTV a normal structure by PBT plans and by convention plans.

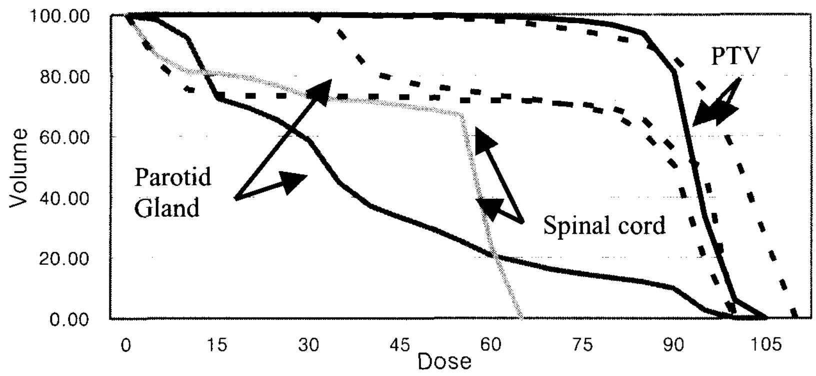


Fig. 3. The DVH comparison of each organ. Solid lines indicate the DVH's from the PBT plan, while dotted lines from the conventional plan.

4. DISCUSSION

The spinal cord PBT with the dynamic Multi-Leaf Collimator (dMLC) has been developed to improve the treatment of the H&N region. The PBT plan could be designed by the forward calculation method in the conventional RTP system. The PTB plan was shown that noticeable improvement in the sparing the normal organs, which have the radiation volume dependent. It was shown that the PBT plan was the practical technique to treat the H&N as well as the thorax regions.

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