Comparison of Cost Function of IMRT Optimization with RTP Research Tool Box (RTB)

Young Eun Ko, Byong Yong Yi, Sang Wook Lee, Seung Do Ahn,
Jong Hoon Kim, Eun Kyung Choi

Department of Radiation Oncology, Asan Medical Center, College of Medicine, University of Ulsan, Seoul, 138-736, Korea
e-mail: ilovefree7@hotmail.com

ABSTRCT

A PC based software, the RTP Research Tool Box (RTB), was developed for IMRT optimization research. The software was consisted of an image module, a beam registration module, a dose calculation module, a dose optimization module and a dose display module. The modules and the Graphical User Interface (GUI) were designed to easily amendable by negotiating the speed of performing tasks. Each module can be easily replaced to new functions for research purpose. IDL 5.5 (RSI, USA) language was used for this software. Five major modules enable one to perform the research on the dose calculation, on the dose optimization and on the objective function. The comparison of three cost functions, such as the uncomplicated tumor control probability (UTCP), the physical objective function and the pseudo-biological objective function, which was designed in this study, were performed with the RTB. The optimizations were compared to the simulated annealing and the gradient search optimization technique for all of the optimization objective functions. No significant differences were found among the objective functions with the dose gradient search technique. But the DVH analysis showed that the pseudo-biological objective function is superior to the physical objective function when with the simulated annealing for the optimization.

Keywords: Dose optimization, pseudo-biological objective function, physical objective function, UTCP

1. INTRODUCTION

Intensity modulation radiation therapy or IMRT allows one to achieve a better conformation of the high-dose region with the prescribed tumor target volume than the uniform beam therapy, especially in complex treatment situations[1,2]. In order to acquire the best IMRT optimization, various methods for the cost function of optimization have been used. The biological objective function (BOF) using the uncomplicated tumor control probability (UTCP) based on the tumor control probability (TCP) can be one of the applicants. It might be able to produce better results than the physical objective function (POF). However applying the BOF clinically is inconvenient with the well-known limitations, which are the needs for the whole treatment schedule information and the exact biological indices for each tissue[1]. Therefore to complement the BOF, the pseudo-biological objective function (PBOF) was introduced[3]. In this study, these two functions were applied to the optimization algorithm and subsequently the cost functions of the each algorithm were compared.

2. MATERIALS AND METHODS

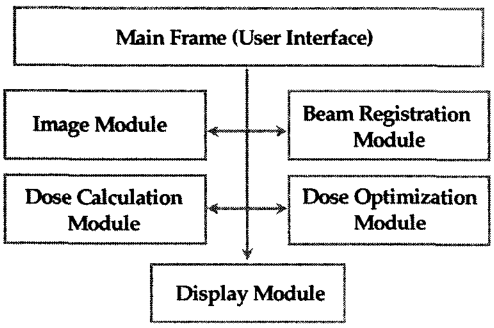

Fig.1. The RTB modules

The RTP research tool box or RTB[4,5] for IMRT optimization was designed. The five modules are completed independent, so as to modify each module easily wherever needed. The program efficiencies such as the calculation speed, the usage of memory and the convenience of use were sacrificed for the easy accessibility and the easy modification of each module. The POF which is expressed in terms of well-defined and measurable physical quantities, such as dose and volume, was defined as the mean square deviation between the calculated dose distribution and the prescription in the entire volume, which has to be minimized[2]. The POF is concerned only with dose and is using the minimum square law, which is generally used in the statistics[2,3]. That is, it finds out the figures that have the best results from the computer with inputting the dose delivery to the tumor and the maximum normal tissue tolerance dose previously.

The BOF calculates the biologic effect due to the dose delivered, instead of the dose itself, and plans treatment with the maximal effectiveness[1]. It calculates the TCP and the NTCP and searches the treatment conditions having the high TCP and low NTCP. Since the final results predict the treatment score in this method, the treatment effect can be acquired before treatment. Therefore if the probability of the side effect in the normal tissue from the planning is inevitably high or the TCP in the planning is low, the problems and possibilities can be predicted and then prepared before arising problems. The pseudo-biologic cost function has been designed for this study. The concept of the PBOF is introduced somewhere else[3]. Brief explain of the PBOF is follows. The PBOF consist of the TCI and the OSI. The target coverage index (TCI) is defined as,

$$TCI = \sum_i v_i Exp\left[-\frac{(\%D_i - 100)^2}{2s^2}\right] \quad , \qquad 0 \le TCI \le 1 \quad (1)$$

where, %Di is % isodose of i-th bin, vi is the volume of i-th bin and s is the tolerance of target dose, ±5 in case of 5%. The mathematical shape of TCI is similar to the TCP. The TCP counts the inhomogeneous dose distribution across the target area as preferable, but TCI not. The organ score index (OSI) is defined as,

$$OSI_k = \sum_i v_i Exp\left[-\left(\frac{\%DD_i}{\%LimDose}\right)^2 / 2s^2\right] \quad , \qquad 0 \le OSI_k \le 1$$

$$OSI = \prod_k \{1 - w_k(1 - OSI_k)\}, \qquad 0 \le OSI \le 1 \qquad (2)$$

where, OSI_k is the k-th organ score index and OSI the organ score indices for all of the OAR's. %DDi is isodose of i-th bin and %LimDose is the limiting dose that the organ can tolerate expressed as the percentage of the isodose. The parameters w and s are the importance of organ ($0 \le w \le 1$) and expectation of complication or importance of organ, respectively. The s depends on the meaning of the %LimDose. The objective pseudo biologic cost function may be expressed as,

$$PPS = TCI \times OSI \qquad 0 \le PPS \le 1 \qquad (3)$$

Optimization algorithm used with the gradient search optimization technique and simulated annealing.

3. RESULTS

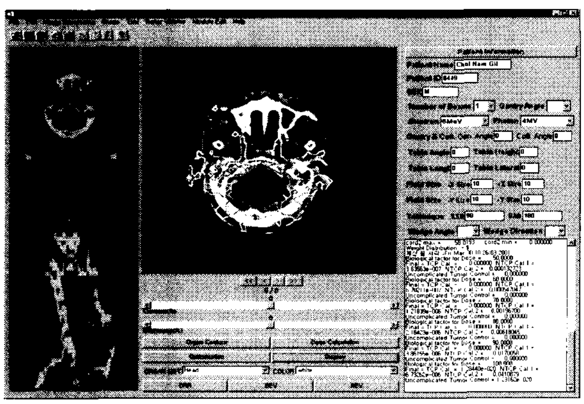

Fig. 2. The RTB developed in this study

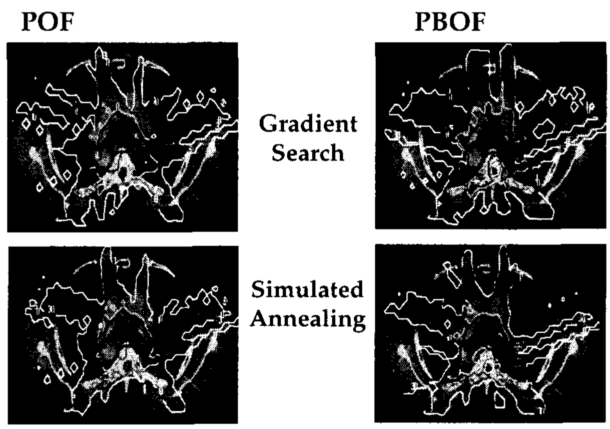

Fig. 3. The optimized results for the POF and the PBOF

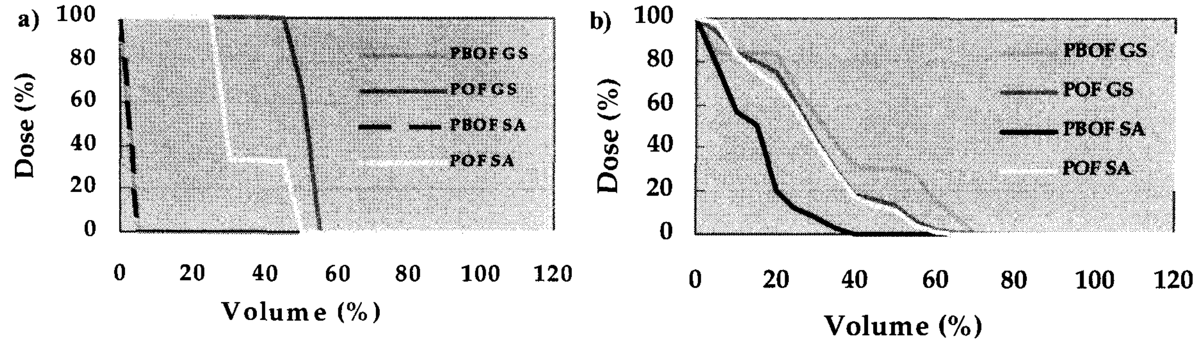

Fig. 4. DVH of a) cord and b)lung

Fig. 2 shows the graphic user interface of the RTB. The software consists of five modules. Each module can be easily modified since all of the modules are independent. Fig. 3 shows the optimized results of the all the object functions using gradient search optimization technique and simulated annealing technique. Fig. 4 shows the DVHs simulated annealing optimization algorithm of the critical organ. The PBOF showed superior results to the POF when with simulated annealing optimization algorithm

4. DISSCUSION AND CONCLUSION

We have a developed RTP research tool box and compared cost function of the IMRT optimization. The PBOF and the POF did not show significant differences with gradient search optimization algorithm, while the PBOF showed better results to the POF when with simulated annealing optimization algorithm. We could shows PBOF can be used as an IMRT objective function. It is good tool for treatment plan evaluation and comparison purpose.

ACKNOWLEDGEMENT

This project was supported by ministry of science & technology as a part of the Nuclear R&D (Research & development) program

REFERENCES

1. A. Brahme ,"Optimized radiation therapy based on radiobiological objectives", *Sem Rad Oncol*, 9(1), 34-47, 1999.
2. T. Borteld , "Optimized planning using physical objectives and constraints", *Sem Rad Oncol*, 9(1), 20-34, 1999.
3. B. Yi , Y. Chen , A.L. Boyer, "The Effects of Beamlet Sizes on IMRT Optimization" *in Proceedings of the ICCR*, Heidelberg, 305-307, 2000.
4. C.H. Min, B. Yi , E.K. Choi, J.H. Kim, S.D. Ahn , H. Chang , "The RTP Tool Box for RTP research", *Med. Phys.*,28(6),1205, 2001.
5. Leung LH, Chua DT, Wu PM., "A new tool for dose conformity evaluation of radiosurgery treatment plans", *Int. J. Radiat Oncol Biol Phys.*, 45(1) : 233-41, 1999.