SHORT COMMUNICATION

A technique to increase the treatment plan indices in GammaKnife: A retrospective study

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ABSTRACT

The study was to find the optimal values of priority in the inverse planning module of Leksell GammaPlan which would give better treatment plan indices in GammaKnife SRS. The study showed that the best optimised setting of the weighting or priority in the inverse planning module of Leksell GammaPlan were 0.6 for coverage, 0.3 for gradient index and 0.5 for beam on time. Inverse plans (Hybrid Inverse Plan, HIP) which were made using this optimal priority setting were compared with forward plans (FP) with all 95% coverage. The results showed that the average selectivity index (SI) was 83.05±9.68 for FP and 85.35±8.03 for HIP. So, SI improved in the HIP technique by about 2.3% compare to FP. Similarly, average gradient index (GI) for FP and HIP were respectively 2.82±0.23 and 2.76±0.33. And the average beam on time (BT) of FP and HIP were, respectively, 48.15±23.14 min and 48.35±18.09 min. So, all plan indices show improvement in the hybrid inverse planning technique over forward plans. Consequently, this will improve the quality of patient treatment in GammaKnife.

Keywords: GammaKnife, inverse planning, forward planning, gradient index, selectivity index

INTRODUCTION

GammaKnife is a specialised dedicated stereotactic intracranial radiosurgery device for the treatment of various tumours and malformations in the human head. It was first designed by Lars Leksell of the Karolinska Institute in Stockholm with the medical physicist Börje Larsson of the Gustaf Werner Institute, University of Uppsala. Over the course of time various GammaKnife models have evolved. At present it has four models currently in use around the world. They are the U, B, and C models, and the new Perfexion model. Inside the GammaKnife units of models U, B and C, there are an array of 201 encapsulated Co-60 sources and 192 Co-60 sources in the Perfexion model which are aligned with a collimation system [1,4]. The activity of each source is approximately 30 Ci. In the Perfexion model these 192 sources are arranged in eight sectors in the collimator assembly. Unlike the old model, it
has three collimator sizes namely 4mm, 8mm and 16mm. The treatment planning in the conventional method of forward planning technique involves the placement of multiple shots which are a combinations of different shot sizes, location and weight to cover the entire tumour volume. It is an iterative process of trial and error method and when the treatment volume is small, the treatment plan may only require one or two shots of radiation. For such cases, treatment planning is typically simple. The planning process, however, becomes much more complex for both irregularly shaped tumours and tumours that are large in size [2]. This cumbersome problem was addressed by the introduction of Inverse Treatment Planning in the Leksell GammaPlan treatment planning system. The Inverse Treatment Planning software module for Leksell GammaPlan facilitates the creation of inverse plans for GammaKnife radiosurgery. It comprises two independent functions: filling and optimization. The filling function makes a preliminary plan of the dose distribution of a given target volume. Optimization improves the preliminary plan by searching for a minimum of the goal function. Planning times are considerably reduced and a good plan can be completed in minutes, even for complex cases. Users can fully exploit the strengths of Leksell GammaKnife® Perfexion™ with Inverse Planning by creating optimal plans that employ composite shots based on the unique sector design of the collimation system [3]. Inverse Planning makes it possible for even less-experienced users to quickly and easily create optimal treatment plans, while effectively managing a large number of variables.

**MATERIALS AND METHODS**

A MRI scan of a patient was selected from the database in Leksell GammaPlan treatment planning system (Leksell GammaPlan version 10.1.1) for planning purposes to establish optimal setting of weighting or priority in inverse planning module. A treatment plan is considered to be a good plan if it has good indices. So it must have good coverage (Cov), good selectivity index (SI), good gradient index (GI) (< 3) and minimal beam on time (BT). As mentioned above the inverse treatment planning module comprises both filling and optimization. The filling of the shots in the tumour volume can be done by selecting either the composites of the three collimators which will be a mix of 4mm, 8mm and 16mm shots depending upon the tumour size or by selecting only one type of the three. When using composite shots priority or weighting can be given to large or small collimator shots. In the optimization the relative weighting or priority of coverage, selectivity, gradient index and beam on time can be set to any value between 0 and 1. It also has optimization restriction where it can be used for locking collimator selection, position and sector blocking. To get the best setting value of the weighting or priority in Inverse planning setting module for a good treatment plan using inverse planning, three steps were followed. In the first step, inverse treatment plans were made by filling and optimizing the shots with gradient index (GI) and beam on time (BT) keeping constant to default values and coverage setting changes from 0 to 1 in steps of 0.1 in the inverse planning setting module. The resulted plan indices were noted and plotted (Figure 1A). In the second step, similar plans were made by changing gradient index from 0 to 1 in steps of 0.1 keeping other setting to default values. The plot of the various plan indices from this step were shown in Figure 2B. And in the third step, beam on setting were changes from 0 to 1 in same steps of 0.1 and coverage and gradient index relative importance were kept constant to the default values. The plan indices of the resulted plans were shown in Figure 1C. From these three Figure 1 (A, B and C), the best optimised setting in the relative importance of the inverse planning setting module are 0.6 for coverage, 0.3 for gradient index and 0.5 for beam on time. Then MRI datasets of 20 meningioma patients who were treated in GammaKnife were selected from the gamma plan treatment planning system for this retrospective study. Plans

![Figure 1. Plots of Optimal coverage (Cov) setting at 0.6 (A), Optimal gradient index (GI) setting at 0.3 (B) and optimal beam on time (BT) setting at 0.5 (C) without compromising other indices.](image-url)
were made with the forward and inverse planning technique using the so obtained weighting or priority setting for each of the 20 patients with all plans 95% coverage. The inverse planning in this study was not totally 100% inverse planning technique but was a combination of inverse and forward planning technique. So it was called a hybrid inverse planning (HIP) technique. The comparisons of the plan indices between forward and hybrid inverse plans were shown in the Figure 2 and Table 1 where Figure 2, A, B and C, respectively, represented selectivity index, gradient index and beam on time.

RESULTS

The best optimised setting of coverage in weighting or priority of the inverse treatment planning module was found to be 0.6 at which the other indices have not been affected much (Figure 1A). Similarly, the settings for the gradient index and beam on time were respectively 0.3 and 0.5 (Figure 1 B and C). From the study it was found that the best optimised setting of the weighting or priority in the inverse planning module of Leksell GammaPlan were 0.6 for coverage, 0.3 for gradient index and 0.5 for beam on time. The selectivity index and coverage are complementary and are inversely related. The sum of coverage and selectivity is always one. Figure 2 and Table 1 show the comparison of various indices of the treatment plans made between forward planning (FP) and hybrid inverse planning (HIP) techniques for the same target coverage of 95% for these 20 patients. From Figure 2A and Table 1 show that the average SI were 83.05±9.68 for FP and 85.35±8.03 for HIP. So, SI improved in the HIP technique by about 2.3% compare to FP. Similarly, average GI for FP and HIP were respectively 2.82±0.23 and 2.76±0.33. And the average BT of FP and HIP were respectively 48.15±23.14 min and 48.35±18.09 min. So, all the indices show improvement in the hybrid inverse planning technique.

DISCUSSION

The hybrid inverse planning technique which is a combination of inverse planning and forward planning gives better treatment plan indices compare to the forward planning approaches in GammaKnife GammaPlan treatment planning system. From the results it showed that the average SI of 20 plans were improved in the HIP technique by about 2.3% compare to FP. Similarly, average GI and BT also showed improvement in HIP technique compare to FP technique (Figure 2 and Table 1). So, all the indices show improvement in the hybrid inverse planning technique. One drawback of this technique being treatment approval not allowed if some of the shots have very short beam on time (>0.10 s approximately). So those shots need to be removed manually after checking the corresponding beam on time in the protocol print preview.

Table 1. Comparisons of average plan indices between forward planning (FP) hybrid inverse planning (HIP) of 20 patients

| Plan Indices | Selectivity Index | Gradient Index | Beam on Time | No. of Shots |
|--------------|-------------------|----------------|--------------|--------------|
| | FP | HIP | FP | HIP | FP | HIP | FP | HIP |
| Avg±SD       | 83.05±9.68        | 85.35±8.03     | 2.82±0.23    | 2.76±0.33    | 96.55±55.47  | 92.50±40.95  | 48.15±23.14  | 48.35±18.09 |
CONCLUSIONS

This new method of hybrid inverse planning with the above values of coverage, gradient index and beam on time in the inverse planning module setting gives better GammaKnife treatment plans in terms of selectivity index, gradient index and beam on time. Consequently, this will improve the quality of patient treatment in GammaKnife.

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The authors have nothing to disclose.

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