The use of an Ideal Planning Assistant on the inverse planning of lung patients

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Introduction

The basic essentials of treatment planning can be broken down into three simple steps: simulation of the patient, planning, and treatment delivery. The Ideal Planning Assistant (IPA) aims to aid physicians and dosimetrists in the "planning" step. Most, if not all, IMRT plans are evaluated with a set of objectives that list goals for obtaining target volume coverage and organs at risk (OAR) sparing; they are also evaluated by reviewing the dose volume histogram (DVH). There is no one definitive plan that needs to be achieved; multiple plans for the same patient can be created and be considered acceptable for treatment. These plans are known as local minimums and can be viewed in Figure 1. The goal of IPA is to reach what is known as the "global minimum".

The IPA software uses raytracing algorithm to create a theoretical plan that allows for complete planning target volume (PTV) coverage while minimalizing dose to OARs based on the objectives and preferences. The purpose of this plan is meant to pull the plan from a local minimum to the global minimum.

(1) Lung cancer has the largest death rate among all possible cancer sites as well as having one of the largest incidence rates in 2018. Therefore, it is paramount that we look for any possible way to improve treatment plans for patients diagnosed with lung cancer. 10 lung cancer patients who were previously treated with volumetric arc therapy (VMAT), were selected. (2) VMAT plans, a type of intensity modulated radiation therapy (IMRT), were chosen due to their tendency to have better conformity to the PTV compared to "step n shoot" IMRT plans. All plans are carried out using VMAT.

By utilizing the DVH created by the IPA plan, a global minimum treatment plan can be closer to being achieved, allowing for a better plan than without the use of IPA.

Purpose

To see if IPA is able to aid the planner in achieving ALARA (as low as reasonably achievable) during the planning process.

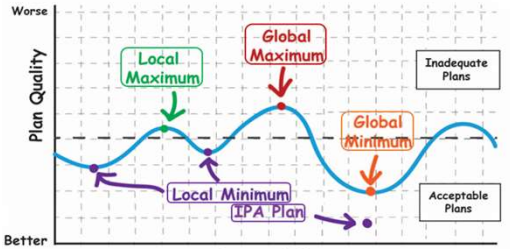

Figure 1. Treatment plans graphed based on plan quality

Figure 2. IPA planning screen

$$\text{Conformity Index (CI)} = \frac{V95\%}{Volume\ of\ PTV}$$

$$\text{Homogeneity Index (HI)} = \frac{D2\% - D98\%}{D50\%}$$

$$\text{Mean Dose} = \frac{\sum_{j=1}^{N} Dj}{N}$$

Equations used to calculate the CI, HI, and mean dose

Materials & Methods

10 cancer patients who were previously treated with VMAT were selected for this retrospective study. The criteria for a patient was for them to have either the entirety or a portion of their PTV in one or both of the lungs. These patients were then brought into IPA to be reviewed by a physician. The same physician used the IPA software as seen in Figure 2 to create an IPA plan for all 10 patients. Once the plan was created, the same patient was then exported to Pinnacle for planning.

Two types of plans were created on Pinnacle v16.2 planning system and used the same Elekta machine. The non-IPA VMAT plans were created first. All isocenters, beam energies, arc angles, and collimator angles were chosen based on the location of the PTV. All plans used two arcs, the first being clockwise and the second being counterclockwise. Each plan was given 90 minutes of optimization time to create a plan. The time did not begin until the start of the first optimization. If an optimization was still continuing once the 90 minutes were up, it was allowed to continue until it finished. The primary goal for each plan was PTV coverage; aiming to get 100% of the prescription to cover at least 95% of the PTV while limiting the 105% volume. Once the PTV coverage was satisfactory, ALARA (As low as reasonably achievable) was implemented to lower the dose to the OARs. This continued until the 90 minutes were up. The resulting plans were named N90, designating that they are non-IPA. The same patients then had a separate plan created for them using IPA. These "I90" plans all had the same couch overrides, isocenter coordinates, beam energies, arc angles, and collimator angles as their corresponding N90 plans did. The only difference between the two plans is that the I90 plans had the IPA DVH as an end goal to aim for. Like with the N90 plans, the 90 minute time period started with the first optimization. The primary goal was to acquire PTV coverage. Once that was obtained, ALARA was implemented just as before. Now that there is a reference for each OAR, the structures were able to be pushed more brazenly than before along with the objectives that helped in maintaining PTV coverage. Planning ended once the 90 minute time limit was up, if the plan was still optimizing at this time, it was allowed to finish before stopping there.

The three types of plans assessed are the original unarchived plan (Historical), the plan optimized without IPA (N90), and the plan optimized with IPA (I90). The Homogeneity and Conformity index were calculated for all the plans and averaged. A two tailed t-test was used to compare these averages from both the N90 and historical plans to the I90 plans. A p-value <.05 was considered statistically significant. The minimum, mean, and maximum values were found for each OAR present in all the treatment plans. These values are listed by plan type and patient number. The means for each specific OAR were averaged and compared between the three types of plans as shown in Table 1. These averages were also compared by a two tailed t-test with a p-value <.05 being considered as statistically significant.

	Mean		
	Hist	N90	I90
Lung R	14.29578	16.10479	15.5417
Lung L	17.84205	20.81675	19.58627
Total Lung	13.87266	16.21631	15.38042
Heart	13.70626	12.91856	11.62924
Esophagus	23.50417	26.45348	24.85286
Spinal Cord	15.0619	11.52113	8.543662

Table 1. The averaged mean doses in Gray for all plan types; Green: lowest dose, Yellow: 2nd lowest dose, Red: highest dose

Results

The HI and CI both showed minor improvements for most I90 plans compared to the N90 plans, but were not considered statistically significant. The HI and CI did however show a statistical significance between the I90 and the historical plans as shown in Table 2. On average, the IPA plans had a reduction in mean dose for the spinal cord and heart compared to the historical plans and a reduction in mean dose for the spinal cord, lungs, heart, and esophagus compared to the N90 plans. The structures that were considered statistically significant can be seen in Table 3.

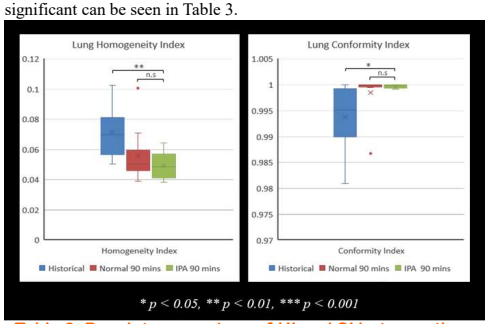

Table 2. Boxplot comparison of HI and CI between the three types of plans; n.s. = not significant

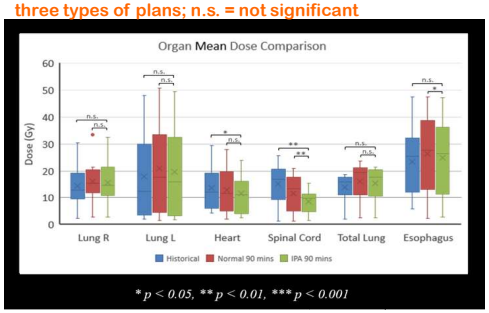

Table 3. Boxplot comparison of organ mean dose between the three types of plans; n.s. = not significant

Conclusion

It was considered significant that the I90 plans had greater CIs and lower HIs compared to the historical plans. This could be due to the primary goal for the 90 minute plans being PTV coverage. It is likely the historical plans traded PTV coverage for lung sparing, which can be seen in the organ mean dose comparison. However, a major factor to consider is that the historical plans had more than just 90 minutes to create their plans. Perhaps given more time, the I90 and N90 plans could have reduced the lung mean dose to a greater extent. Overall, in a 90 minute time period, the I90 plans demonstrated that on average, the critical structure mean doses with IPA compared to non-IPA plans were reduced. IPA has demonstrated that it can be helpful as a reference tool, but further research should be conducted to see if it can still be of aid given longer time allotments for planning.

References

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