Automatic Planning Results Using a Novel Dose Prediction Tool

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Deciding on the underlying technology

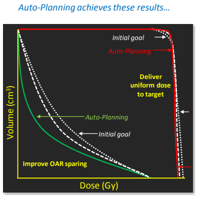
Compared trade-offs between various techniques

Knowledge-based	Multi-criteria optimization	Progressive Optimization
• Minimal user input required • Adapts to planning trade-offs **BUT** • Dependent on a knowledge base • Not flexible to inter-physician variability • Affected by variations in contouring • Does not address new knowledge on toxicity endpoints	• Provides trade-off analysis with interactive graphical interface **BUT** • Requires most physician time • Plan quality degrades in conversion • Does not lend to Standardization	• Minimal user input • Adaptable to protocol changes • No knowledge-based required • Dosimetric drivers not limited to DVH parameters **BUT** • No on-the-fly trade-off analysis • No historical information

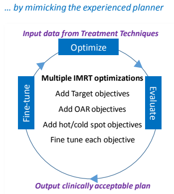
Progressive optimization algorithm

Drives target coverage and sparing to the limits

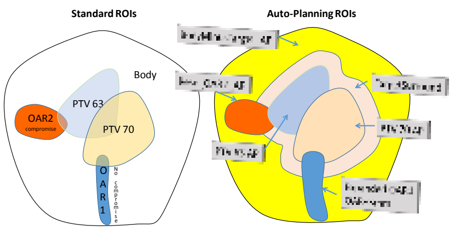
Auto-Planning achieves these results…



… by mimicking the experienced planner



Auto-Planning ROIs



Progressive optimization algorithm

Drives target coverage and sparing to the limits

Even with generic inputs, Auto-Planning pushes beyond what was requested

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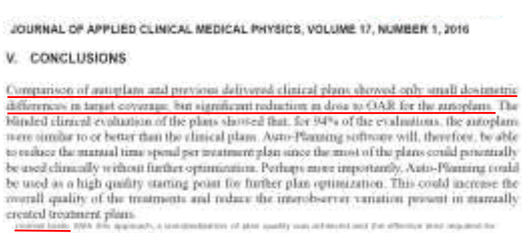
Progressive optimization algorithm

Validated Through Peer-Reviewed Research



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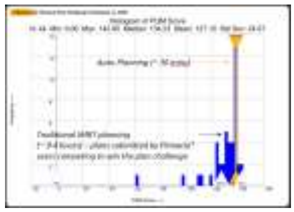
V. CONCLUSIONS

Comparison of autoplans and previous delivered clinical plans showed only small dosimetric differences in target coverage, but significant reduction in dose to OAR for the autoplans. The blinded clinical evaluation of the plans showed that, for 94% of the evaluations, the autoplans were similar to or better than the clinical plans. Auto-Planning software will, therefore, be able to reduce the manual time spend per treatment plan since the most of the plans could potentially be used clinically without further optimization. Perhaps more importantly, Auto-Planning could be used as a high quality starting point for further plan optimization. This could increase the overall quality of the treatments and reduce the interobserver variation present in manually created treatment plans.

Auto-Planning at the Pinnacle³ Plan Challenge

Better results than the median at a fraction of the time

- Plan Challenge commissioned by Philips in 2013 through ROR
- Blue bars indicate submitted scores by users generating manual plans
- Yellow triangle indicates score achieved by Auto-Planning – well above the mean score



Can we improve Auto-Planning results with patient-specific, ***personalized***, inputs?

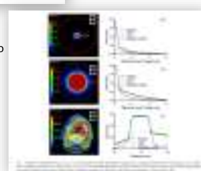
PlanIQ Feasibility

Providing achievable sparing goals

Clinical Goals Feasibility
- Distinguish between achievable and unachievable clinical goals
- Efficiently modify clinical goals prior to the planning process

Feasibility DVH™
- Patient specific DVH for targets and OAR with feasibility bands
- Optimizes treatment plan goals

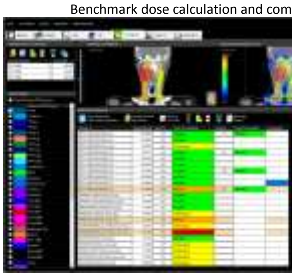

A method for a priori estimation of best feasible DVH for organs-at-risk: Validation for head and neck VMAT planning



- A proprietary, algorithm-based, dose falloff calculation
- Targets are assigned uniform prescription doses, with no reference to any particular beam arrangement
- A benchmark 3D dose built outside the targets is estimated using a series of energy specific dose spread calculations
- This benchmark dose is used to produce the "best possible sparing" FDVH for an OAR

PlanIQ Feasibility

Benchmark dose calculation and comparison to goals



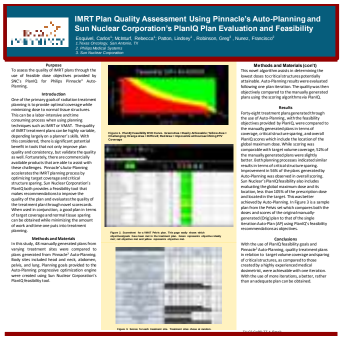
- In the top left are the target doses
- Target doses are used to generate PlanIQ Benchmark Dose in the middle image above
- PlanIQ Benchmark dose is overlaid on OARs to give FDVH on the right above
- On the left are the goals from the protocol and information on how feasible the goals are

PlanIQ Feasibility

Personalizing planning objectives

Drill-down report on achievability for each individual structure

- Red – impossible without sacrificing tumor coverage (also described as FDVH(0))
- Orange – difficult to achieve (FDVH(0.1))
- Yellow – challenging
- Green – easy
- Gray dotted line – represents a "Feasibility number" in this case it shows 0.22 – can be set to any value via "slider bar"



IMRT Plan Quality Assessment Using Pinnacle's Auto-Planning and Sun Nuclear Corporation's PlanIQ Plan Evaluation and Feasibility

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2. Philips Medical Systems
3. Sun Nuclear Corporation

Purpose

To assess the quality of IMRT plans through the use of feasible dose objectives provided by SNC's PlanIQ for Philips Pinnacle³ Auto-Planning.

Introduction

One of the primary goals of radiation treatment planning is to provide optimal coverage while minimizing dose to normal tissue structures. This can be a labor-intensive and time consuming process when using planning techniques such as IMRT or VMAT. The quality of IMRT treatment plans can be highly variable, depending largely on a planner's skills. With this considered, there is significant potential benefit in tools that not only improve plan quality and consistency, but validate the quality as well. Fortunately, there are commercially available products that are able to assist with these challenges. Pinnacle's Auto-Planning accelerates the IMRT planning process by optimizing target coverage and critical structure sparing. Sun Nuclear Corporation's PlanIQ both provides a Feasibility tool that makes recommendations to improve the quality of the plan and evaluates the quality of the treatment plan through novel scorecards. When used in conjunction, a good plan in terms of target coverage and normal tissue sparing can be obtained while minimizing the amount of work and time one puts into treatment planning.

Methods and Materials

In this study, 48 manually generated plans from varying treatment sites were compared to plans generated from Pinnacle³ Auto-Planning. Body sites included head and neck, abdomen, pelvis, and lung. Planning goals provided to the Auto-Planning progressive optimization engine were created using Sun Nuclear Corporation's PlanIQ feasibility tool.

Figure 1. PlanIQ Feasibility DVH Curve. Green Area = Easily Achievable; Yellow Area = Challenging; Orange Area = Difficult; Red Area = Impossible without sacrificing PTV Coverage

Figure 2. Scoresheet for a VMAT Pelvis plan. This page easily shows which objectives/goals have been met in the treatment plan. Green represents objective ideally met; red objective met and yellow represents objective met.

Figure 3. Scores for each treatment site. Treatment sites chose at random.

Methods and Materials (con't)

This novel algorithm assists in determining the lowest doses to critical structures potentially attainable. Auto-Planning results were evaluated following one plan iteration. The quality was then objectively compared to the manually generated plans using the scoring algorithms via PlanIQ.

Results

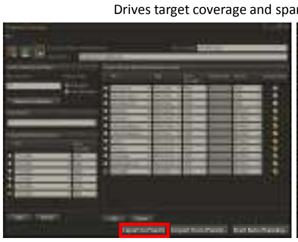
Forty-eight treatment plans generated through the use of Auto-Planning, with the feasibility objectives provided by PlanIQ, were compared to the manually generated plans in terms of coverage, critical structure sparing, and overall PlanIQ scores which include the location of the global maximum dose. While scoring was comparable with target volume coverage, 52% of the manually generated plans were slightly better. Both planning processes indicated similar results in terms of critical structure sparing. Improvement in 56% of the plans generated by Auto-Planning was observed in overall scoring. Sun Nuclear's PlanIQ feasibility also includes evaluating the global maximum dose and its location, less than 105% of the prescription dose and located in the target. This was better achieved by Auto-Planning. In Figure 3 is a sample plan from the Pelvis set which compares both the doses and scores of the original manually-generated (Orig) plan to that of the single iteration Auto-Plan (AP) using PlanIQ's feasibility recommendations as objectives.

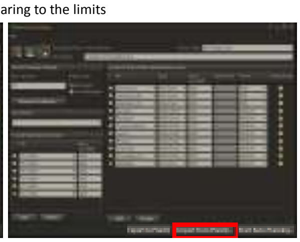
Conclusions

With the use of PlanIQ feasibility goals and Pinnacle³ Auto-Planning, quality treatment plans in relation to target volume coverage and sparing of critical structures, as compared to those created by a highly experienced medical dosimetrist, were achievable with one iteration. With the use of more iterations, a better, rather than an adequate plan can be obtained.

Progressive optimization algorithm

Drives target coverage and sparing to the limits

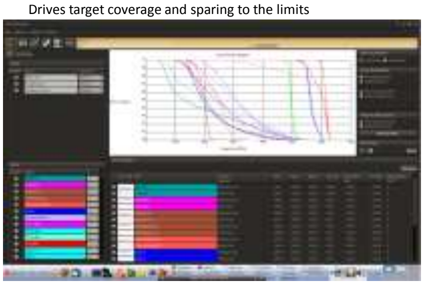




- Use Feasibility number of 0.22 as goal – Auto-Planning designed to push down
- If the protocol number is lower than this, use the protocol number
- If neither goal is not close to achievable – remove it if possible (Submandibula_R)

Progressive optimization algorithm

Drives target coverage and sparing to the limits



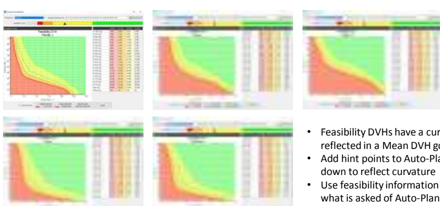
Feasibility driven results

Drives target coverage and sparing to the limits

- Auto-Planning still pushes many structures below feasibility numbers – SpinalCord, Brainstem_03, Parotid_L, Esophagus_Up
- Other structures (Larynx, Pharynx, Oral Cavity well within protocol guidelines, but not matching feasibility)
- Great results, but can we make them better?

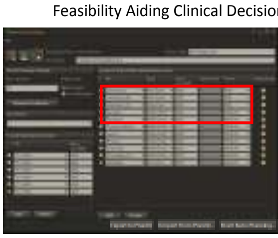
Progressive optimization algorithm

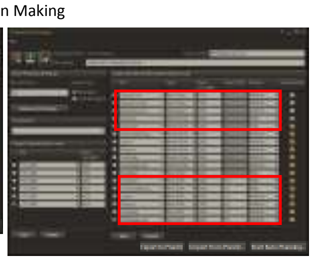
Drives target coverage and sparing to the limits



- Feasibility DVHs have a curvature that is not reflected in a Mean DVH goal
- Add hint points to Auto-Planning to have it drive down to reflect curvature
- Use feasibility information to drive priorities and what is asked of Auto-Planning

Feasibility Aiding Clinical Decision Making





- Add Max DVH Points to reflect FDVH curvature
- Change priorities based on Feasibility
- Remove structures that have no chance of being spared – in this case Submandibula_R already removed

Average results over 10 cases

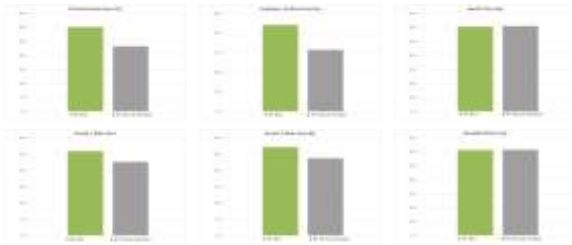
- 3 cases PAROTID_R not feasible to be spared
- 1 case PAROTID_L not feasible to be spared
- 7 case SUBMANDIBULA_L not feasible to be spared
- 5 case SUBMANDIBULA_R not feasible to be spared
- 1 case LARYNX not feasible to be spared

Average results over 10 cases

- Used NRG-002 HN Protocol for analysis, target homogeneity decreased when pushing sparing with Feasibility, however still well within allowed values in protocol

Average results over 10 cases

Average results over 10 cases



Automatic Planning with Dose Prediction

Conclusions

- Auto-Planning alone has been shown through peer-reviewed research to improve plan quality
- Personalizing Auto-Planning inputs through PlanIQ Feasibility based dose objectives can further improve OAR sparing
- PlanIQ Feasibility can improve up-front clinical decision making prior to plan creation by
  - Preventing optimization against unachievable goals
  - Providing more complete information on achievable goals based on patient geometry
  - Improving goal priority setting (high, medium, low) prior to planning based on patient geometry

PHILIPS

Thank you