Advanced CIS Course
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Paper Presentation #1

# DATA-DRIVEN APPROACH TO GENERATING ACHIEVABLE DOSE–VOLUME HISTOGRAM OBJECTIVES IN IMRT

---- A Paper By BINBIN WU, PH.D.,FRANCESCO RICCHETTI, M.D., GIUSEPPE SANGUINETI, M.D., et al

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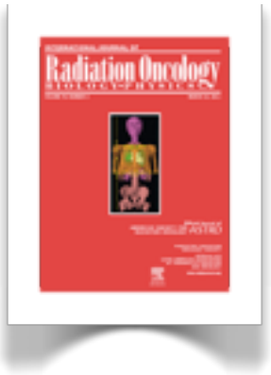

# 1. Common Features

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PHYSICS CONTRIBUTION

DATA-DRIVEN APPROACH TO GENERATING ACHIEVABLE DOSE–VOLUME HISTOGRAM OBJECTIVES IN INTENSITY-MODULATED RADIOTHERAPY PLANNING

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Purpose: To propose a method of intensity-modulated radiotherapy (IMRT) planning that generates achievable dose–volume histogram (DVH) objectives using a database containing geometric and dosimetric information of previous patients.

Methods and Materials: The overlap volume histogram (OVH) is used to compare the spatial relationships between the organs at risk and targets of a new patient with those of previous patients in a database. From the OVH analysis, the DVH objectives of the new patient were generated from the database and used as the initial planning goals. In a retrospective OVH-assisted planning demonstration, 15 patients were randomly selected from a database containing clinical plans (CPs) of 91 previous head-and-neck patients treated by a three-level IMRT-simultaneous integrated boost technique. OVH-assisted plans (OPs) were planned in a leave-one-out manner by a planner who had no knowledge of CPs. Thus, DVH objectives of an OP were generated from a subdatabase containing the information of the other 90 patients. These DVH objectives were then used as the initial planning goals in IMRT optimization. Planning efficiency was evaluated by the number of clicks of the "Start Optimization" button in the course of planning. Although the Pinnacle$^3$ treatment planning system allows planners to interactively adjust the DVH parameters during optimization, planners in our institution have never used this function in planning.

Results: The average clicks required for completing the CP and OP was 27.6 and 1.9, respectively ($p < .00001$); three OPs were finished within a single click. Ten more patient's cord + 4 mm reached the sparing goal $D_{0.3cc} \leq 44$ Gy ($p < .0001$), where $D_{0.3cc}$ represents the dose corresponding to 0.1 cc. For planning target volume uniformity, conformity, and other organ at risk sparing, the OPs were at least comparable with the CPs. Additionally, the averages of $D_{0.3cc}$ to the cord + 4 mm decreased by 6.9 Gy ($p < .0001$); averages of $D_{0.3cc}$ to the brainstem decreased by 7.7 Gy ($p < .005$). The averages of $V(30\,\text{Gy})$ to the contralateral parotid decreased by 8.7% ($p < .0001$), where $V(30\,\text{Gy})$ represents the percentage volume corresponding to 30 Gy.

Conclusion: The method heralds the possibility of automated IMRT planning. © 2010 Elsevier Inc.



Intensity-modulated radiotherapy, IMRT, overlap volume histogram, OVH, head-and-neck, database.


## INTRODUCTION

Intensity-modulated radiotherapy (IMRT) is an inverse treatment planning process that optimizes the intensity distribution for each of a set of beams according to the dose–volume histogram (DVH) objectives chosen by planners (1). The DVH objectives guide the planning software in scoring the tradeoffs between target coverage and organ at risk (OAR) sparing. However, the DVH objectives that account for the tradeoffs for a specific patient are often unknown before planning. Currently, an IMRT plan tailored to a specific patient requires many rounds of optimization. The planner usually applies population-based DVH objectives at the beginning (2). The planner then progressively improves the plan until it becomes clinically acceptable by repeatedly adjusting the DVH objectives in each optimization round according to personal experience and clinical feedbacks. It


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# 2. Brief Overview

- Purpose is to achieve optimized IMRT planning
- Propose of a novel method for IMRT planning using dosimetric parameter (OVH) implemented in a database
- Results Shown IMRT planning became faster and can actually spare more volume of Organs At Risk(OAR) at points of interest
- Conclusion is the method heralds automated IMRT planning

# 3. Reason For Selecting

Fundamental Idea Proposed For The Project

**SELECTION**

Concept of Dynamic Previous Data Reuse

Interesting Concept In Introducing OVH

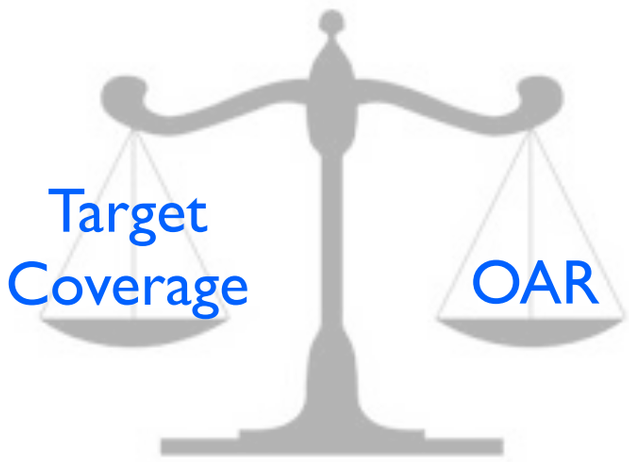
Clinical Decision Making Process Involved

Novelty in Database Usage -- Realtime in Clinical Setting

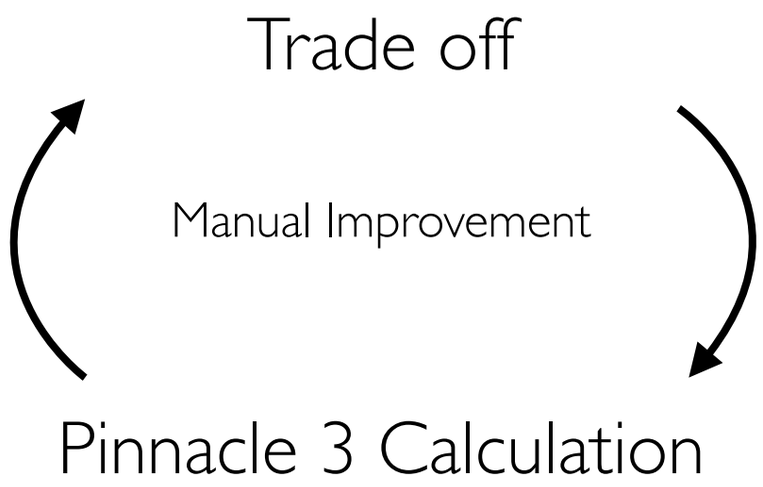
# 4. Background (1)

## --Problems in Current Setting

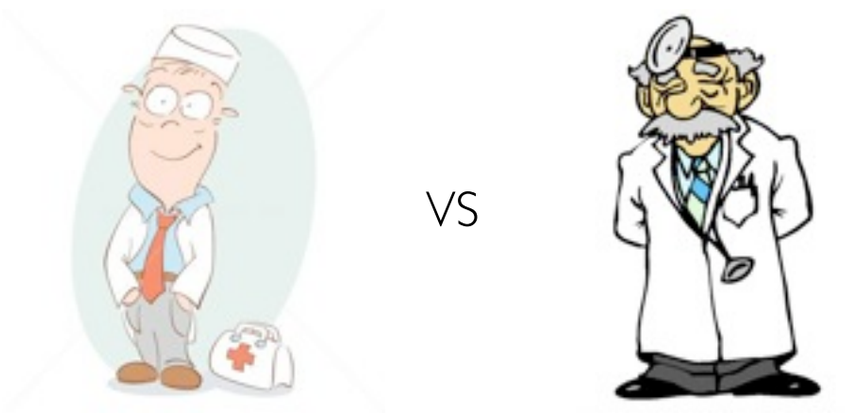
### (1) What Is The Tradeoff Point of IMRT?




### (2) Long Planning Process



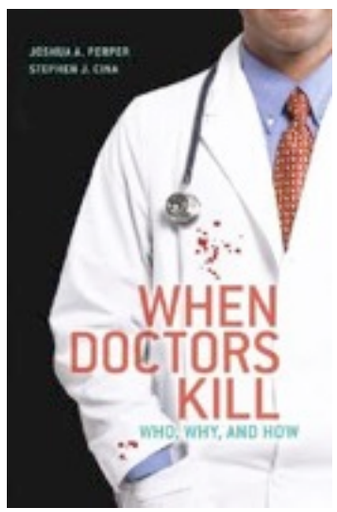

### (3) Planning Variations



VS

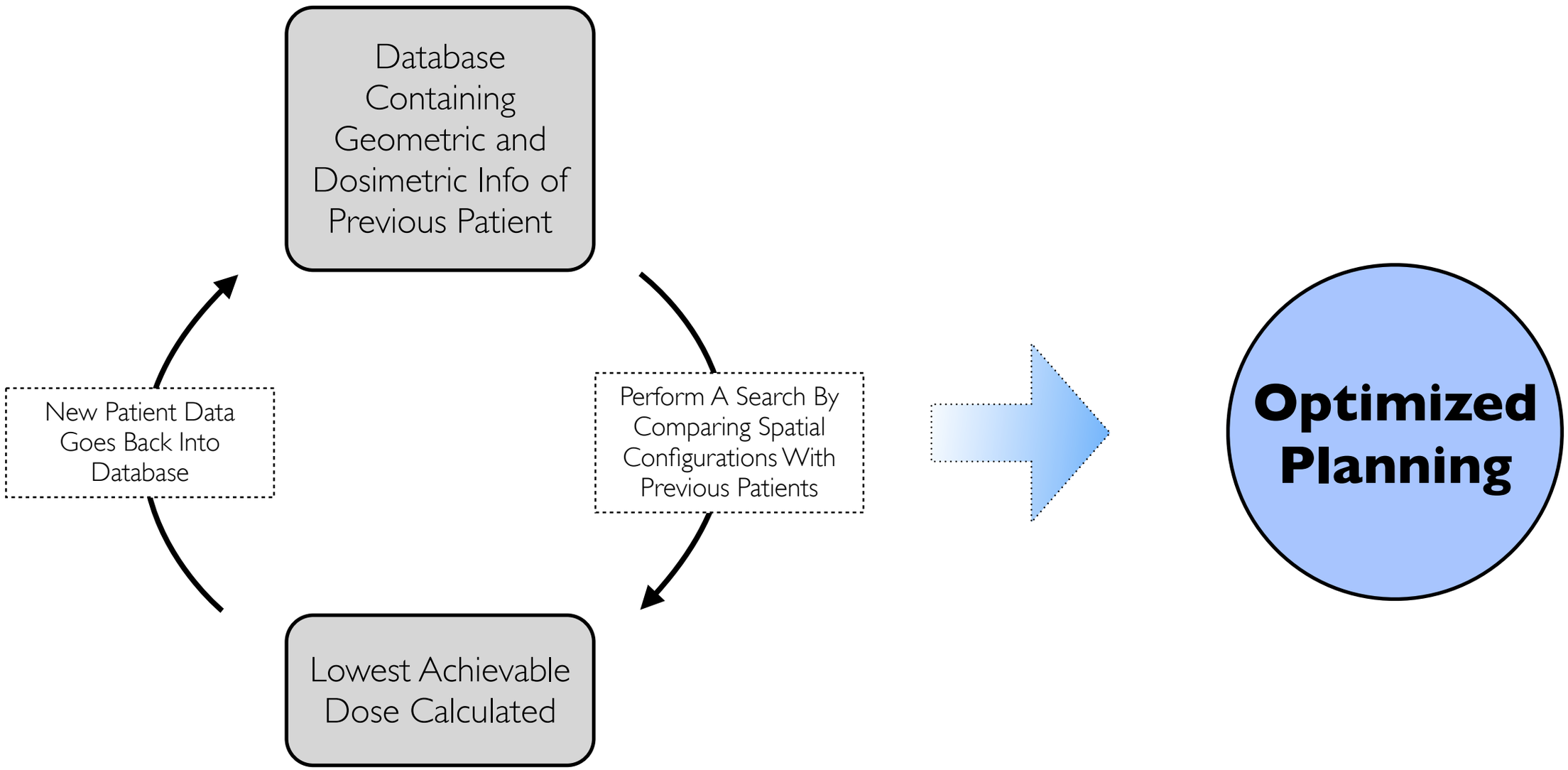
Unexperienced versus Experienced

### (4) Not Optimized Plan

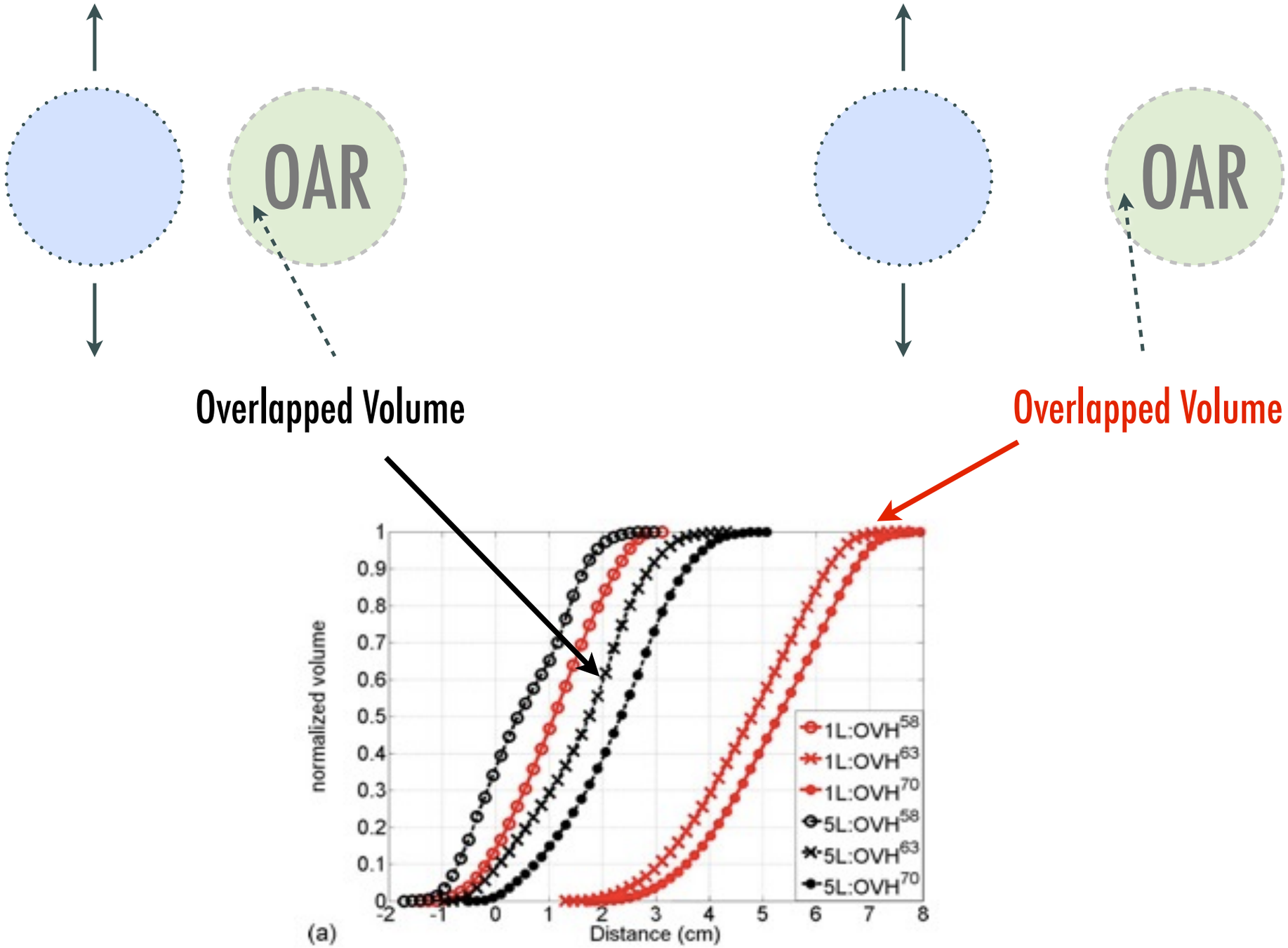


# 4. Background (2)

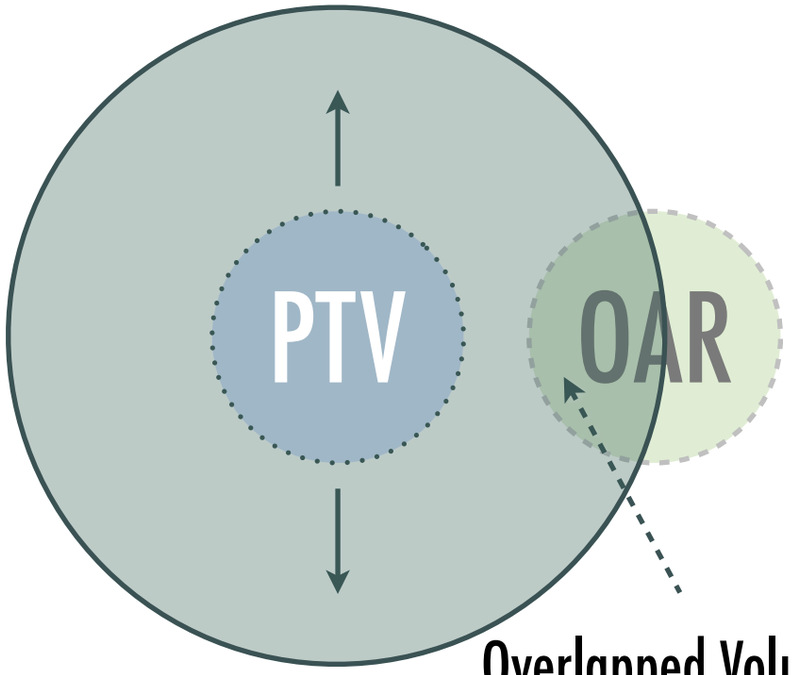
## --Proposed Approach



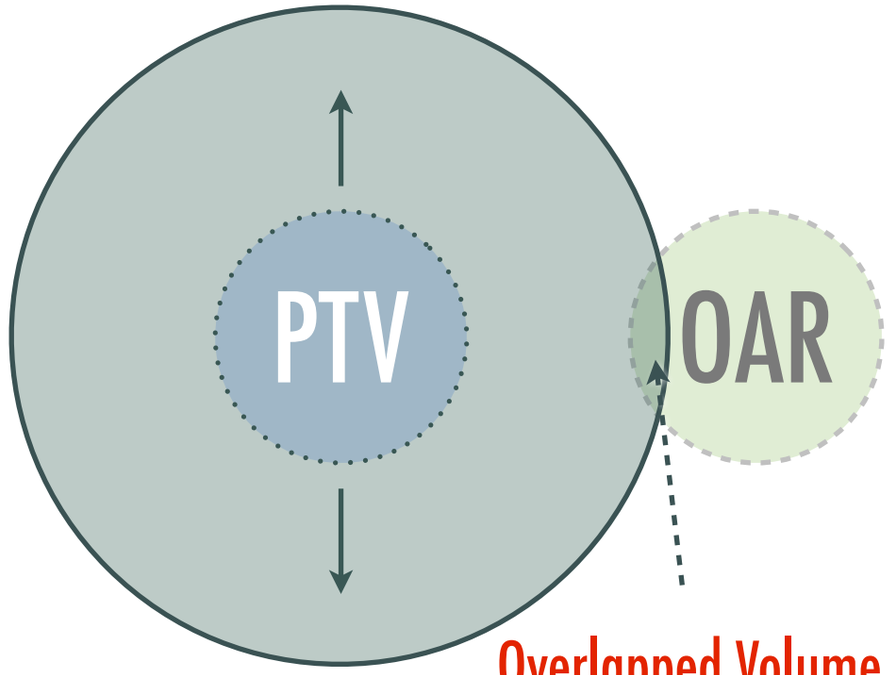
# 5. Method Used (1)



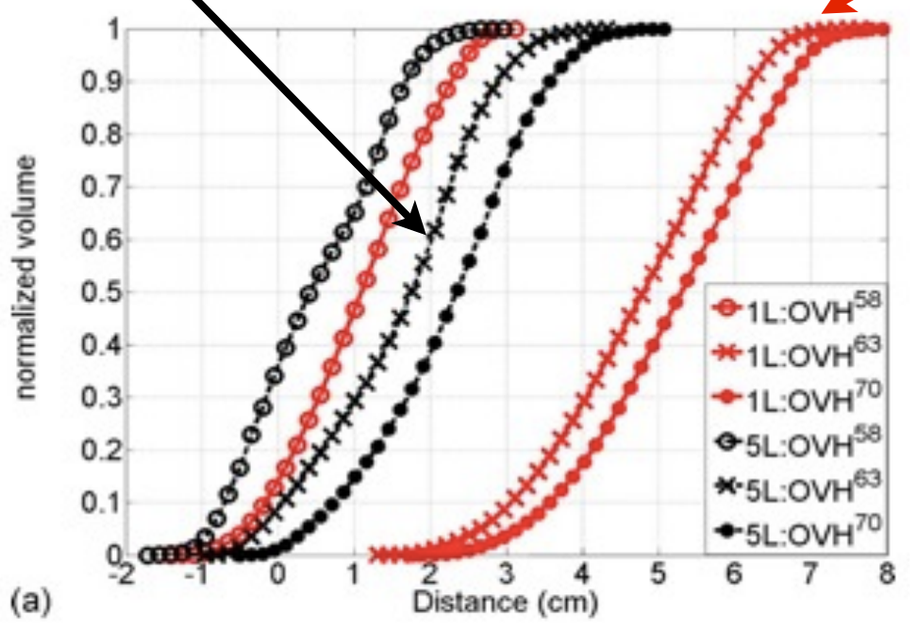
# 5. Method Used (1)



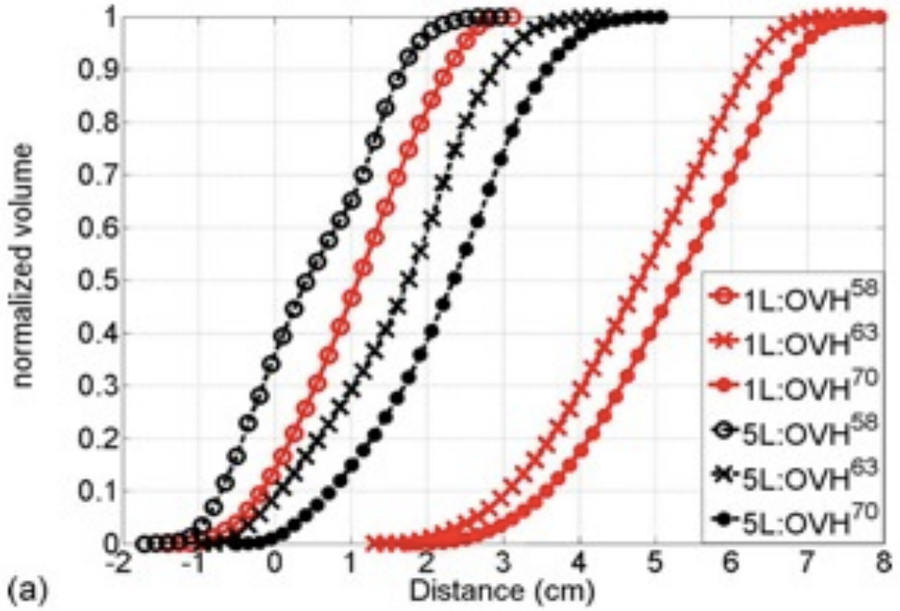

Overlapped Volume

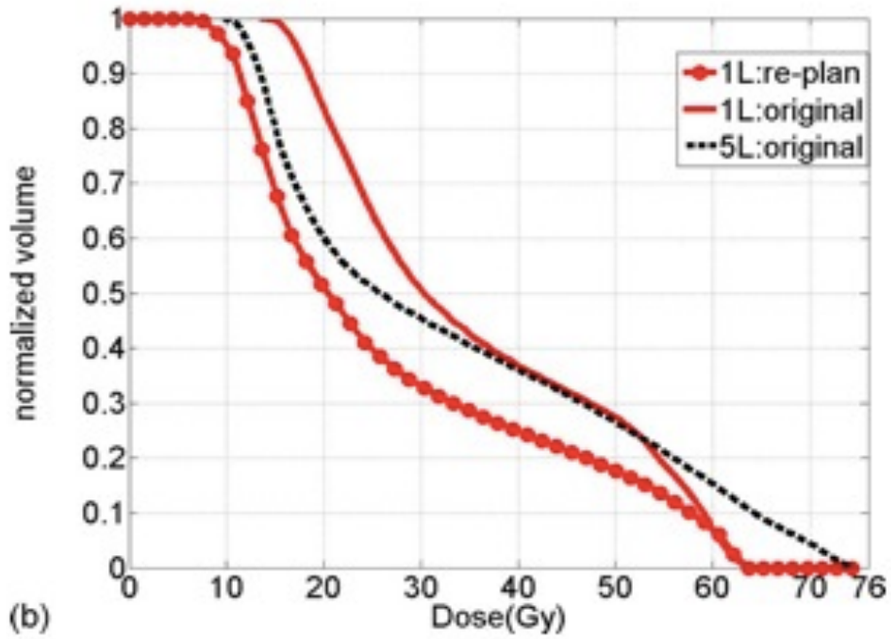



Overlapped Volume



# 5. Method Used (2)




OVH ⟶ DVH

For two OARs OAR1 and OAR2, if r1 >= r2 for a certain percentage volume v, OAR2 will be closer to the target at that v. D1 <= D2 will be expected where D represents the dose of the organ at the percentage volume v.

# 5. Method Used (3)

Specifically, to generate Dv,n, the OVH of that selected OAR at v, rv,n was used to query the database to find a group of previous patients, i, whose OARs' OVH values at v, rv,i were smaller than those of rv,n. Next, the minimum of Dv among the groupof previous patients was chosen as the initial planning goal for Dv,n:

$$D_{v,n} = \min\{D_{v,i} \,|\, r_{v,n} \geq r_{v,i} \text{ and } V_{95,i} \geq a\%\}$$

Condition, V95, >= a%, serves to confine the search results to the previous plans with a good planning target volume (PTV) coverage,where Vx represents the percentage of the PTV receiving x% of the prescription dose. The typical a value was 99 (V95 >= 99% for PTV coverage).

# 5. Method Used (4)

--Comparison Design and Criteria

- 15 Patients Were Selected;
- All For Head and Neck Therapy;
- Three sets of plans: Clinical Plans(CP), Optimization Plan 1(OP1), Optimization Plan 2 (OP 2);
- Planned Target Volume(PTV) dose should not be compromised between the three plans;
- Compare doses received for OAR between the plans;
- Compare number of optimization rounds between plans

# 6. Results (1)

## --PTV Dosage Comparison

Table 4. Summary of the dosimetric results for the PTVs in the three sets of plans.

| | CP | OP1 | OP2 | Wilcoxon $p$ test | | |
|---|---|---|---|---|---|---|
| Variable | Average | Average | Average | CP vs OP1 | CP vs OP2 | OP1 vs OP2 |
| $PTV^{58.1}$ | | | | | | |
| $V_{100}$ (%) | 94.1 | 94.3 | 94.5 | .56 | .23 | .85 |
| $V_{98}$ (%) | 97.1 | 97.9 | 98 | .3 | .24 | .6 |
| $V_{95}$ (%) | 98.9 | 99 | 99 | .8 | .71 | .6 |
| $D_5$–$D_{95}$ (Gy) | 16 | 13.9 | 13.7 | .2 | .24 | .85 |
| $CI^{58.1}$ | 1.2 | 1.2 | 1.2 | .55 | .76 | .95 |
| $PTV^{63}$ | | | | | | |
| $V_{100}$ (%) | 98.7 | 99.1 | 99 | .08 | .15 | .9 |
| $V_{98}$ (%) | 99.2 | 99.6 | 99.6 | .12 | .23 | .55 |
| $V_{95}$ (%) | 99.7 | 99.8 | 99.9 | .34 | .77 | .43 |
| $D_5$–$D_{95}$ (Gy) | 9 | 8 | 8.1 | .1 | .28 | .67 |
| $CT^{63}$ | 1.3 | 1.3 | 1.3 | .6 | .45 | .65 |
| $PTV^{70}$ | | | | | | |
| $V_{100}$(%) | 95.1 | 95.4 | 95.3 | .5 | .32 | .9 |
| $V_{98}$(%) | 98.6 | 98.8 | 99 | .4 | .21 | .9 |
| $V_{95}$(%) | 99.8 | 99.9 | 99.9 | .3 | .2 | .93 |
| $D_5$–$D_{95}$ (Gy) | 3.7 | 3 | 3.2 | .6 | .97 | .7 |
| $CI^{70}$ | 1.2 | 1.3 | 1.3 | .6 | .42 | .88 |

Abbreviations as in Tables 1 and 3.
No statistically significant differences were observed.

# 6. Results (2)

## --OAR Sparing Comparison

Table 6. Summary of dosimetric results for OARs in three sets of plans

| OAR | Endpoint | CP | OP1 | OP2 | Wilcoxon *p* | | |
|---|---|---|---|---|---|---|---|
| | | Average | Average | Average | CP vs OP1 | CP vs OP2 | OP1 vs OP2 |
| Cord + 4 mm | $D_{0.1cc}$ | 45.6 | 39.5 | 38.7 | <.0001* | <.0001* | .7 |
| Mandible | $D_{0.1cc}$ | 67.4 | 67.3 | 67.8 | .79 | 1 | .91 |
| Brainstem | $D_{0.1cc}$ | 47.7 | 40.4 | 40 | <.005* | <.005* | .85 |
| Brain | $D_{1cc}$ | 50.8 | 50 | 49.6 | .5 | .38 | .88 |
| Ipsilateral parotid | $V$(30 Gy) | 65 | 57 | 58.5 | .21 | .3 | .8 |
| Contralateral parotid | $V$(30 Gy) | 52 | 45 | 43.3 | <.0001* | <.0001* | .56 |
| Larynx | $V$(50 Gy) | 55.4 | 53.3 | 50.1 | .66 | .57 | .91 |
| Esophagus | $D_{1cc}$ | 53.9 | 54.1 | 54 | 1 | .9 | .95 |
| Ipsilateral brachial plexus | $D_{0.1cc}$ | 62.2 | 62.7 | 62 | .97 | .93 | .9 |
| Contralateral brachial plexus | $D_{0.1cc}$ | 58.4 | 59.44 | 59.53 | .79 | .84 | .86 |
| Oral mucosa | $V_{cc}$(66.5 Gy) | 37.6 | 39.5 | 40 | .6 | .74 | .93 |
| Ipsilateral inner ear | $D_{mean}$ | 31 | 25.7 | 26 | .32 | .47 | 1 |
| Contralateral inner ear | $D_{mean}$ | 25 | 19.5 | 21 | .2 | .43 | 1 |

Abbreviations as in Tables 1 and 3.
* Statistically significant.

# 6. Results (3)

## --Number of Clicks

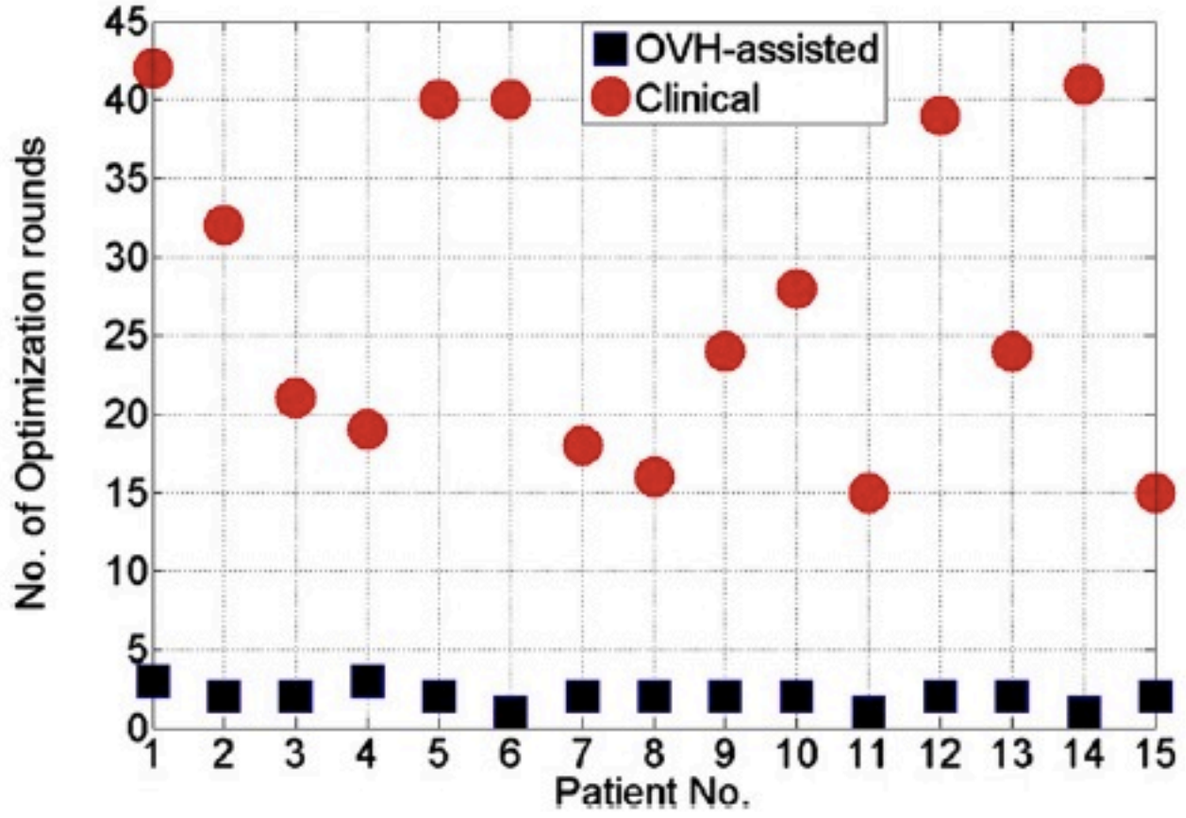



Fig. 1. Distribution of number of optimization rounds required for complete plan. OVH = overlap volume histogram.

The average number of optimization rounds per OP was 1.9 (SD 0.6); that number for the CP was 27.6 (SD 10.4; p <.00001). Three OPs were completed in a single optimization round.

# 7. Conclusion

- Offers Prediction of Dosage Received
- Heralds Automated Planning
- Method Efficient
- Method Effective

# 8. How It Is Related

- The method generated in this paper is the fundamental method the python package for head and neck is going to use;
- The results of this paper provides proof for further optimization of this method(can be regarded as a pioneer study);
- Can be regarded as the prototype for the project;
- Still needs further and thorough assessment of the planning process, especially in new package.

# 9. Pros and Cons

| Pros | Cons |
| --- | --- |
| 1. Novel method in initiating IMRT planning | 1. Sample size too small (n=15) |
| 2. The model is straight forward enough for decision making, the new element introduced (OVH) is easy to compute | 2. Proved efficiency, claims to prove effectiveness by retrospective data search, but effectiveness yet to be evaluated |
| 3. A thorough comparison was made, efficiency of the new method was evaluated | 3. Optimized sparing of OAR != best outcome for patients |
| 4. Some new concepts of data reuse and information retrieval decision making is introduced | 4. New concepts of information and knowledge maintenance cycle is introduced, but not deeply discussed in the discussion part |

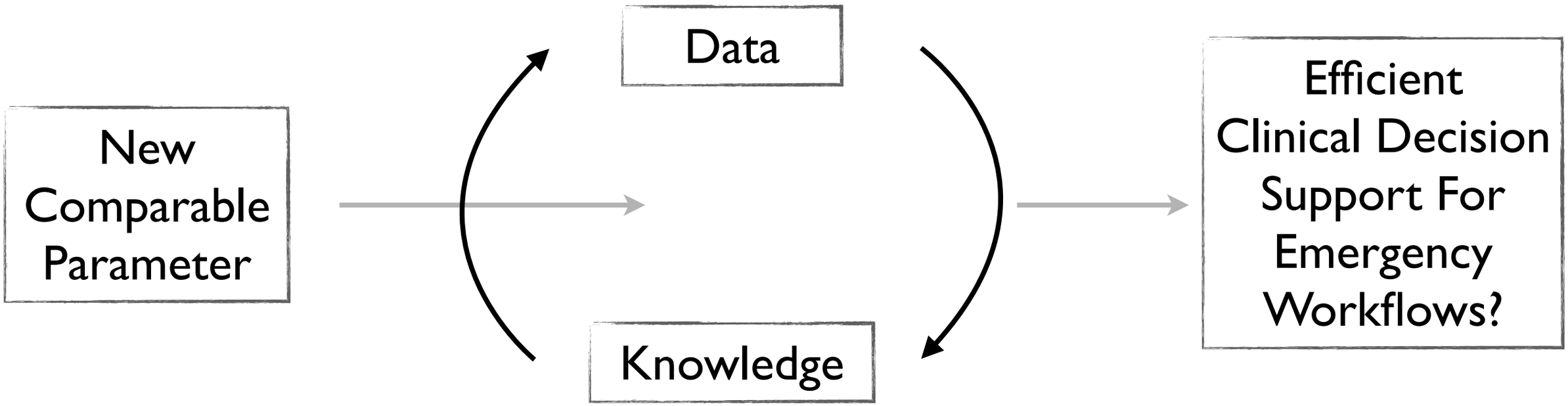
# 10. Further Discussions (1)

-- Outcome Measures

- The sparing of OAR proved Efficacy of the method, which means that the method "works" to answer the research question -- whether the new planning is more optimized to spare OAR and at the same time assure PTV dose. However, to prove the effectiveness, clinical questions must be answered, outcome measures of the patients have to be evaluated so that radiation therapy planners and patients "prefer" the new plan because it indeed reduce adverse effects of radiation therapy.

# 10. Further Discussions (2)

-- Informatics Stuff




# Thank You !