Clinical Testing of Automated Planning Modules

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Disclosures

- Partial of the research was supported by Philips Radiation Oncology Systems.

- Co-inventor of a patent associated with the knowledge-based planning (KBP) approach utilizing overlap-volume histogram (OVH), which was licensed to Varian Medical Systems in 2015.

"Method and system for determining treatment Plans," US Patent 8,688,618, 4/1/2014

Challenges

KBP requires a **sufficient, large number of high quality plans** for predictive model build-up.

- Prior data collection (>100 plans for prostate library)
  - Target-organ anatomical variations
- Dosimetric & anatomical feature extraction
- Model review for removing dosimetric outliers
- Model testing

Sample size requirements for knowledge-based treatment planning. Med Phys 2016; 43: 1212–21

Effect of dosimetric outliers on the performance of a commercial knowledge-based planning solution. IJROBP 2015; 94: 469–77.

Aims

Aim 1: Cross-institutional plan library sharing in KBP

- **Significance**: allow centers to utilize an **estabilished** library from another center to generate their KBP plans, instead of building their own library and developing their own model
- **Hypothesis**: target coverage and organ sparing achieved at the established library would be obtainable to other centers
- **Focus**: IMRT/VMAT for oropharyngeal cancer

Aim 2: KBP and Pinnacle^3 Auto-Planning Engine (APE) performance comparison under cross-institutional implementations.

Cross-institutional KBP implementation and its performance comparison to Auto-Planning Engine (APE), Radiother Oncol 2017; 123: 57-62

Study design

Center 1: Radboud University Medical Center (RUMC), Netherlands

Center 2: Johns Hopkins University (JHU), Baltimore, MD,

Aim 1: Cross-institutional library sharing: utilizing an established library (179 H&N pt's plans) from JHU for KBP on RUMC's 35 pts

Aim 2: KBP and APE performance comparison: RUMC's APE plans are compared to the library-shared KBP plans

Fully automated SIB-IMRT treatment planning is feasible for Head-and-Neck cancer: a prospective clinical study, IJROBP 2012; 84: e647–653.

Automatic planning of head and neck treatment plans. JACMP 2016; 17:272-282.

Aim 1: Cross-institutional library sharing

Challenges: protocol discrepancy among centers

- Beam configuration: IMRT Vs. VMAT Vs. TomoTherapy
- Prescription: RUMC's 2-dose level Vs JHU's 3-dose level
  - e.g., (50.3 Gy and 68 Gy) Vs. (58.1 Gy, 63 Gy and 70Gy)
- Target–organ anatomical variations
- Planning guideline: sparing goals are different
  - RUMC: (Cord: $D_{0.1\ cc} \leq$ 50 Gy) Vs. JHU: (Cord4mm: $D_{0.1}$ cc $\leq$ 44 Gy)

Beam configuration discrepancy

As reported as the following references, plans generated by

- 7-beam/9 beam IMRT/2-arc VMAT/TomoTherapy

are comparable.

	RUMC	JHU (library)
IMRT angles	7	9
Maximal segments per plan	60	120
Minimal area per segment (cm^2):	10	4
Machine	Synergy	Infinity

The number of beams in IMRT—theoretical investigations and implications for single-arc IMRT. PMB 2010; 55:83 97.

Integrated multicriterial optimization of beam angles and intensity profiles for coplanar and noncoplanar head and neck IMRT and implications for VMAT. Med Phys 2012; 39:4858-4865.

SmartArc-based VMAT for oropharyngeal cancer: a dosimetric comparison with both IMRT and helical tomotherapy. IJROBP 2011; 80: 1248-1255

Using overlap volume histogram and IMRT plan data to guide and automate VMAT planning: A head-and-neck case study, Med Phys 2013, 40:021714

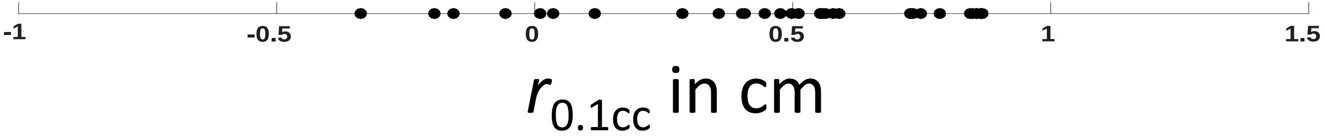
Prescription discrepancy

- RUMC: 50.3 Gy and 68 Gy
- JHU (library): 58.1 Gy, 63 Gy and 70G
- Assumption: organ doses depend only on low-level PTV
  - RUMC's 35 pts: D_{95} of PTV50.3 = 44.9 Gy
  - JHU's 179 pts: D_{95} of PTV58.1 = 57.3 Gy
- Dose scaling factor: 57.3/44.9 = 1.27
  - Predicted organ's dose from JHU library is scaled down by 1.27, and then applied to RUMC pts for KBP.

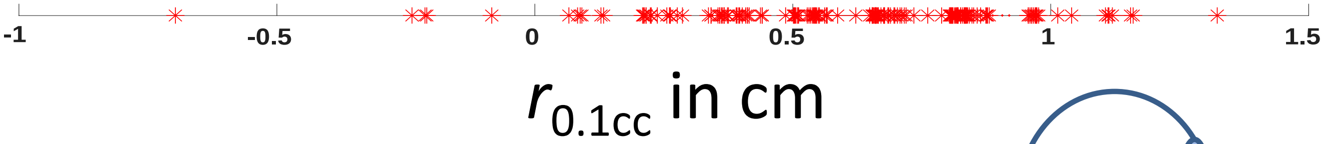
Target–organ anatomical variations

PTV-cord distance $r_{0.1cc}$ for predicting cord's $D_{0.1cc}$

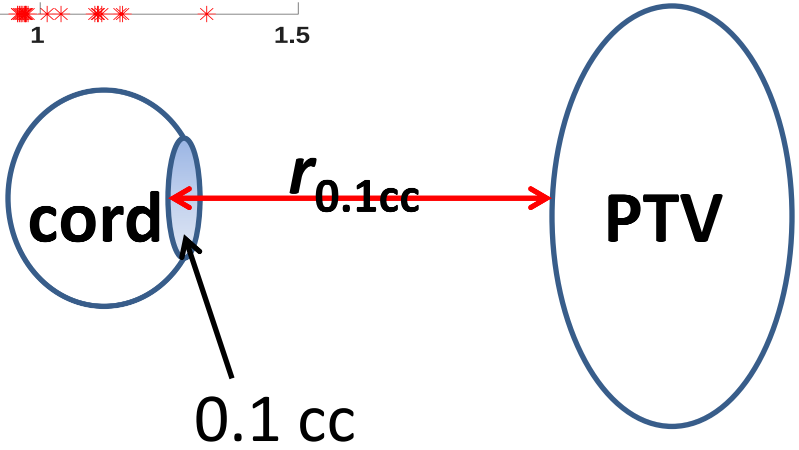
RUMC: PTV-cord distance from 35 pts



JHU (library): PTV-cord distance from 179 pts



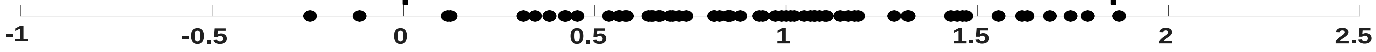
$r_{0.1cc}$: Shortest distance from the PTV surface to the cord for covering 0.1 cc of the cord.



Target–organ anatomical variations

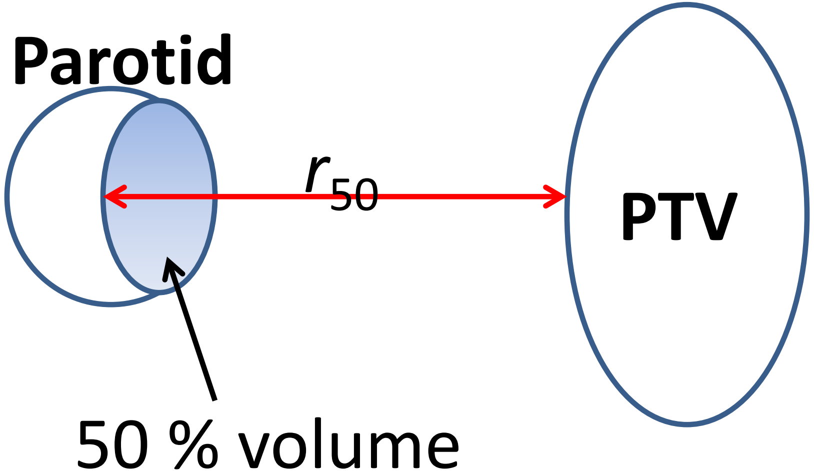
PTV-parotid distance r_{50} for predicting parotid's D_{50}

RUMC: PTV-parotid distance from 35 pts



JHU (library): PTV-parotid distance from 179 pts

r_{50}: Shortest distance from the PTV surface to the parotid for covering 50% volume of the parotid.



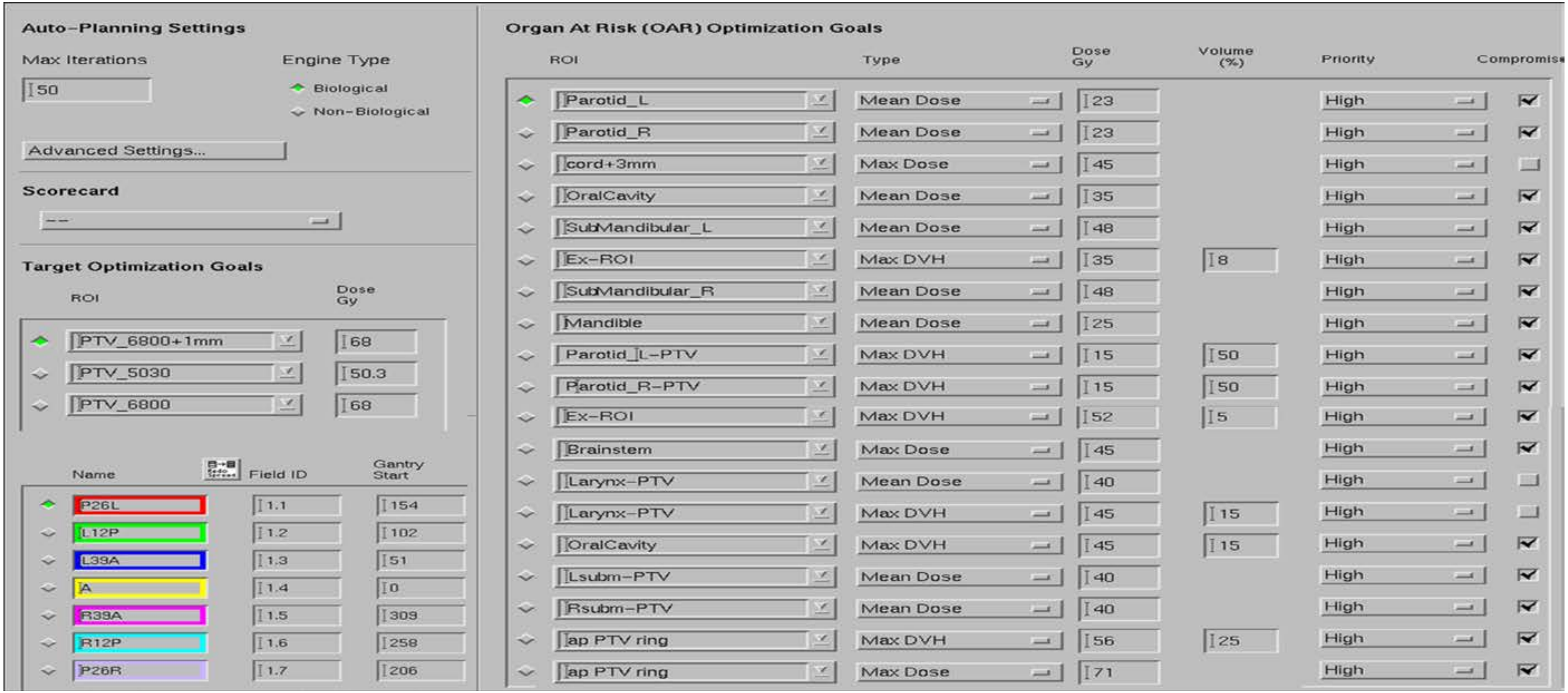
Planning guideline discrepancy

RUMC	JHU (library)
Cord: $D_{0.1\ cc} \leq 50$ Gy	Cord4mm: $D_{0.1}$ cc ≤ 44 Gy
Brainstem: $D_{0.1\ cc} \leq 54$ Gy	Brainstem: $D_{0.1}$ cc ≤ 54 Gy
Brain: N/A	Brain: $D_{1\ cc} \leq 60$ Gy
Mandible: N/A	Mandible: $D_{0.1\ cc} \leq 73.5$ Gy
Parotids: $D_{mean} \leq 20$ Gy	Parotids: V (30 Gy) ≤ 50%
Larynx: $D_{mean} \leq 30$ Gy	Larynx: V (50 Gy) ≤ 25%
Oral cavity: $D_{mean} \leq 20$ Gy	Oral cavity: V_{cc} (66.5 Gy) ≤ 64 cc
Esophagus: N/A	Esophagus: $D_{1\ cc} \leq 45$ Gy
Brachial plexuses: N/A	Brachial plexuses: $D_{0.1\ cc} \leq 60$ Gy
Inner ears: N/A	Inner ears: $D_{mean} \leq 50$ Gy
Submandibular: $D_{mean} \leq 40$ Gy	Submandibular: N/A

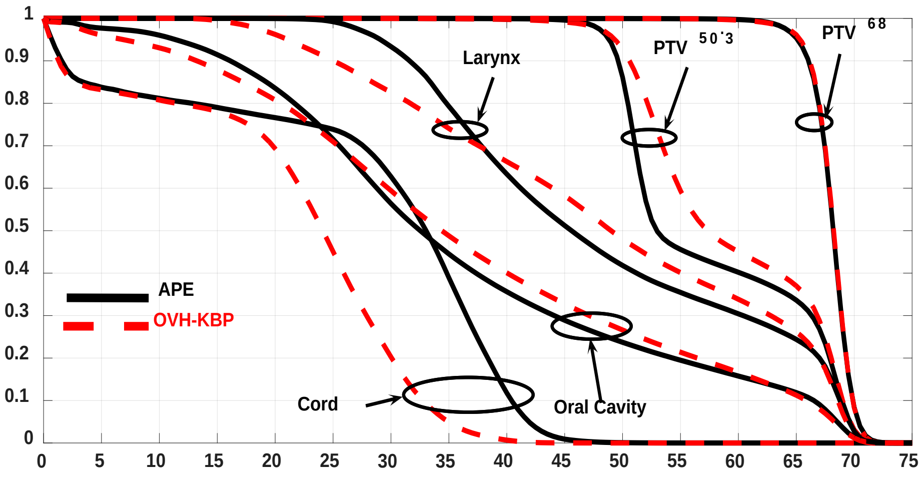
RUMC KBP: Brain, mandible, esophagus, brachial plexuses and inner ears are disregarded; fixed goals are applied to submandibular.

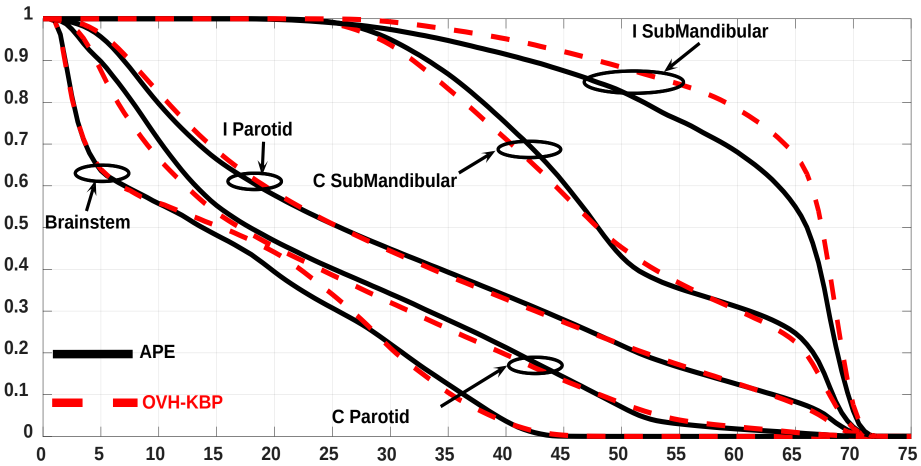
Pinnacle^3 Auto-Planning Engine (APE)

Optimization algorithm iteratively adjusts users' pre-set DVH objectives to meet or exceed sparing goals.



APE Vs. KBP: average DVH of RUMC 25 pts





RUMC's physician opinion for 25 pt's plans:

- All APE and KBP plans are clinically-acceptable

Cord sparing $D_{0.1\ cc}$ in KBP is significantly better: 5.1 Gy lower.

Final thoughts

- DVH objectives estimated from KBP model are patient geometric specific.
  - Performance depends on quality of play library
- APE employs a user’s pre-set of generic coverage/sparing goals, which are protocol-specific.
  - Performance depends on the pre-set goals and robustness of the “iterative algorithm”
- Hybrid solution integrating KBP and APE
  - KBP provides individualized optimization goals to APE’s optimizer
  - APE’s iterative algorithm is used to further refine them