Varian's Adaptive Planning Solution – Online or Offline

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Disclosures

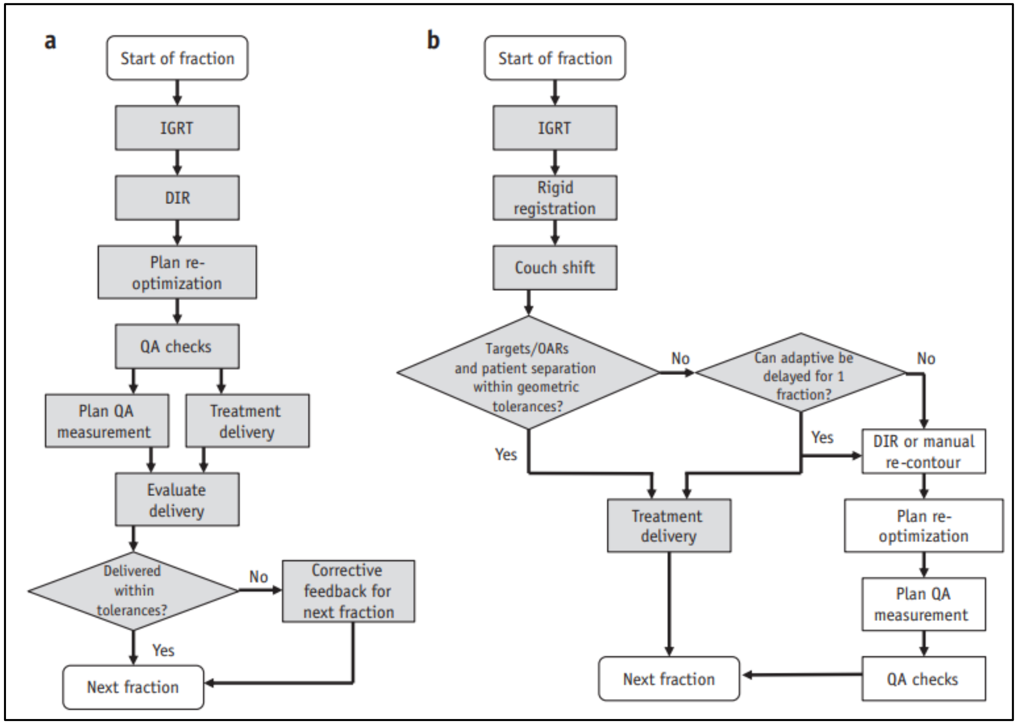
- Supported by Research Grants by Varian Medical Systems.

Adaptive Radiation Therapy (ART)

- Introduced over 20 years ago
  - ✓ Initially used for imaging (e.g. MV, KV, etc.) prior to each treatment fraction to monitor /correct daily patient setup errors – commonly referred as IGRT.
  - ✓ Now defined as a process for modifying patient treatment plan by systematic monitoring of daily anatomical changes in target and OARs during the course of radiotherapy.

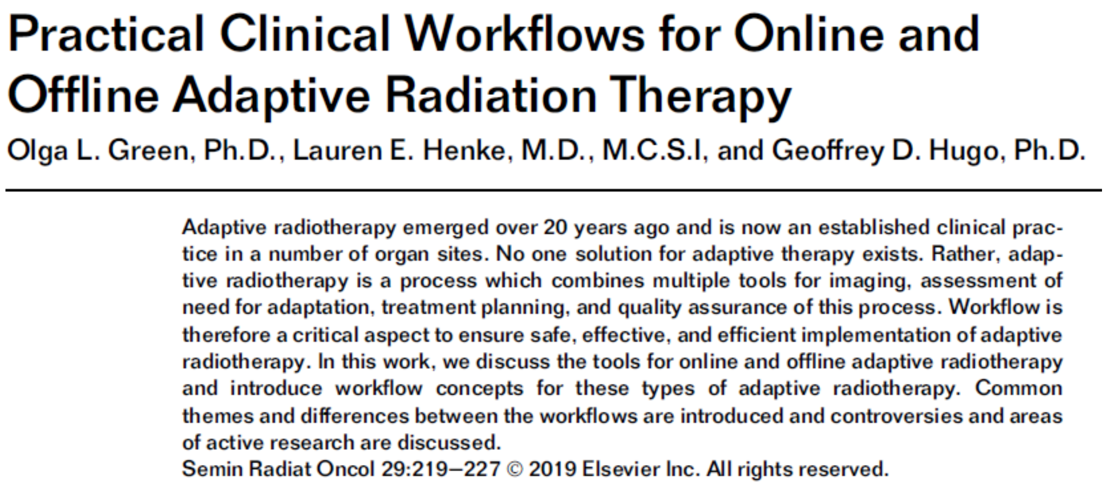
Adaptive Radiation Therapy (ART)

- can be implemented
  - ✓ Offline – new treatment plan between fractions – addresses systematic and progressive changes
  - ✓ Online – new treatment plan prior to a fraction while patient is on treatment couch – stochastic changes
  - ✓ Realtime – make changes during a fraction (e.g. gating, dynamic tracking)



S. Lim-Reinders et al., Int J Radiation Oncol Biol Phys, Vol. 99(4), pp. 994- 1003, 2017

ART Workflow and Tools


Practical Clinical Workflows for Online and Offline Adaptive Radiation Therapy

Olga L. Green, Ph.D., Lauren E. Henke, M.D., M.C.S.I, and Geoffrey D. Hugo, Ph.D.

Adaptive radiotherapy emerged over 20 years ago and is now an established clinical practice in a number of organ sites. No one solution for adaptive therapy exists. Rather, adaptive radiotherapy is a process which combines multiple tools for imaging, assessment of need for adaptation, treatment planning, and quality assurance of this process. Workflow is therefore a critical aspect to ensure safe, effective, and efficient implementation of adaptive radiotherapy. In this work, we discuss the tools for online and offline adaptive radiotherapy and introduce workflow concepts for these types of adaptive radiotherapy. Common themes and differences between the workflows are introduced and controversies and areas of active research are discussed.

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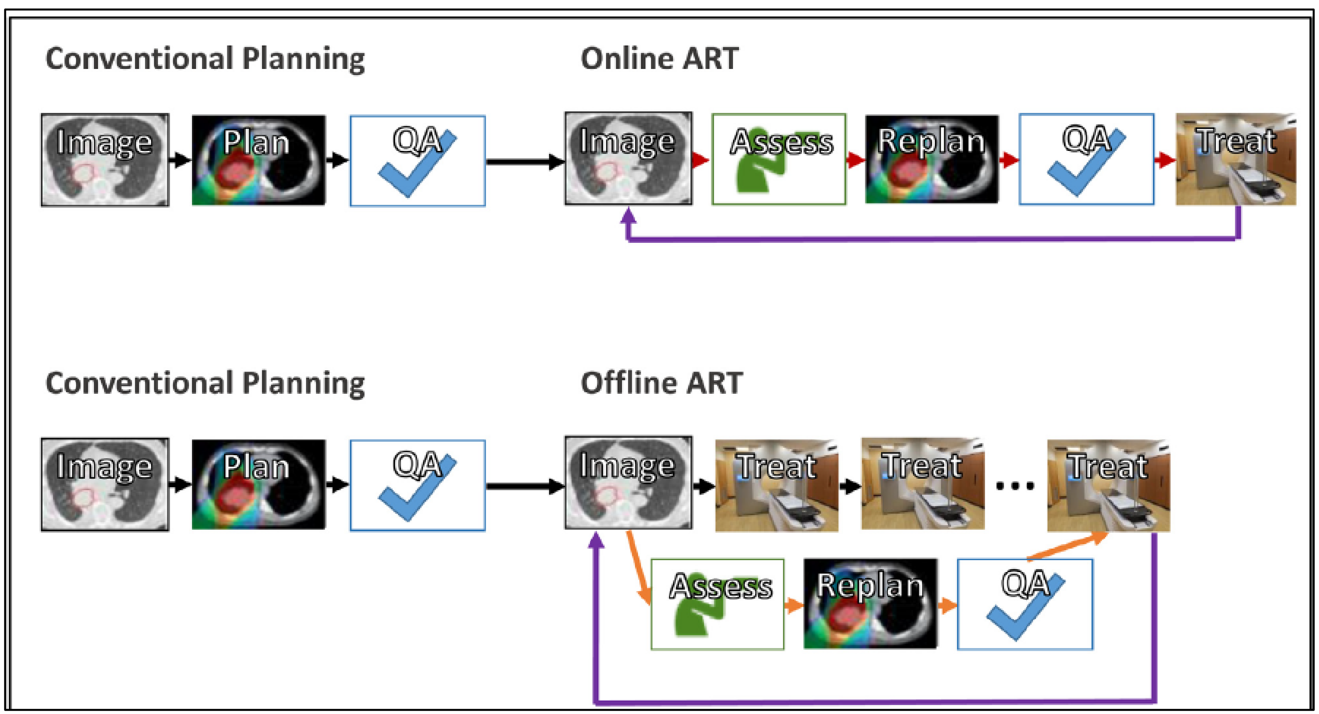
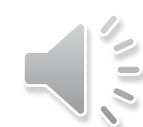


Green et al, Sem Rad Onc, 2019



Offline, Online and Real-Time ART Approaches

Physics Contribution

Adaptive Radiation Therapy (ART) Strategies and Technical Considerations: A State of the ART Review From NRG Oncology

Carri K. Glide-Hurst, PhD,[*] Percy Lee, MD,[†] Adam D. Yock, PhD,[‡] Jeffrey R. Olsen, MD,[§] Minsong Cao, PhD,[||] Farzan Siddiqui, MD, PhD,[¶] William Parker, MS,[#] Anthony Doemer, MS,[¶] Yi Rong, PhD,[**] Amar U. Kishan, MD,[||] Stanley H. Benedict, PhD,[**] X. Allen Li, PhD,[††] Beth A. Erickson, MD,[††] Jason W. Sohn, PhD,[‡‡] Ying Xiao, PhD,[§§] and Evan Wuthrick, MD[||||]

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C.K. Glide-Hurst et al., Int J Radiation Oncol Biol Phys, Vol. 109(4), pp. 1054- 1075, 2020

Tools for ART

- High Quality Imaging – CT, MRI, CBCT, PET/CT
- Deformable Image Registration (DIR)
  - ✓ Contour propagation for dose tracking and re-plan
  - ✓ Adaptive dose accumulation – accuracy depends on DIR algorithm and image quality
- Automated Re-Planning
- Patient Specific QA

Integrated ART Systems

- incorporates imaging, treatment planning and delivery for online ART:
  - ✓ MRI guided (ViewRay and Elekta)
  - ✓ Iterative CBCT (iCBCT) guided (Varian Ethos)
  - ✓ Biologically (PET) guided (RefleXion) – not FDA approved yet

- Many investigational studies using MR-Guided RT systems demonstrated improvements in target coverage and OAR sparing ART techniques.

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Assessment of online adaptive MR-guided stereotactic body radiotherapy of liver cancers

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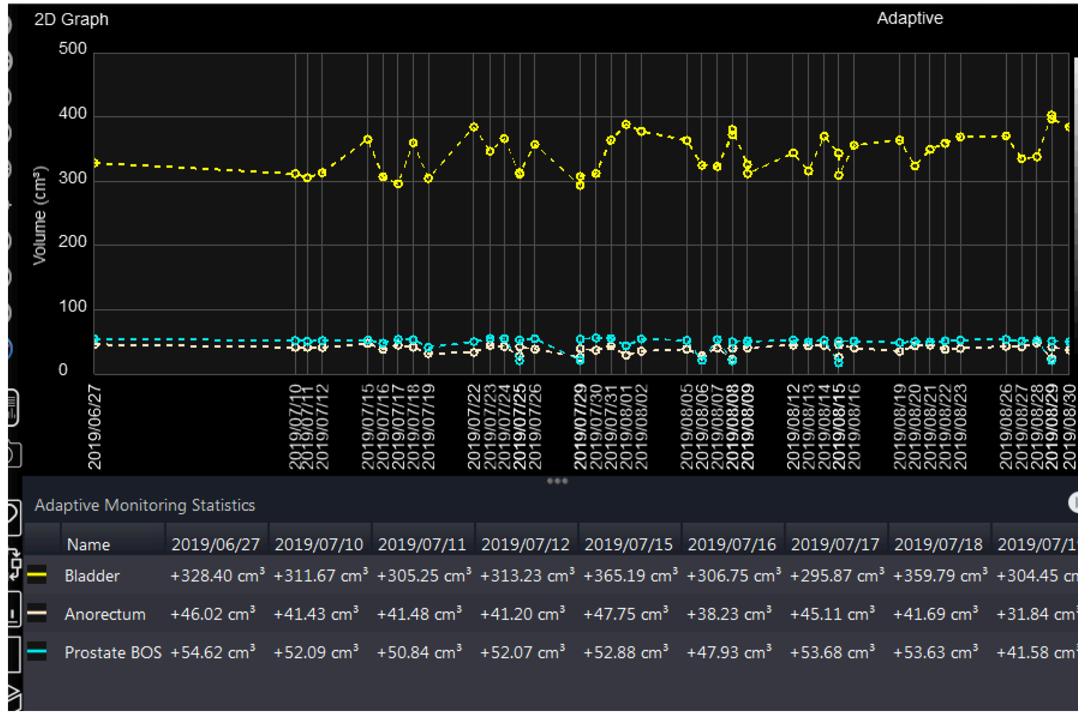
A B S T R A C T

Purpose/objective: Online Adaptive Radiotherapy (ART) with daily MR-imaging has the potential to improve dosimetric accuracy by accounting for inter-fractional anatomical changes. This study provides an assessment for the feasibility and potential benefits of online adaptive MRI-Guided Stereotactic Body Radiotherapy (SBRT) for treatment of liver cancer.
Materials/methods: Ten patients with liver cancer treated with MR-Guided SBRT were included. Prescription doses ranged between 27 and 50 Gy in 3–5 fx. All SBRT fractions employed daily MR-guided setup while utilizing cine-MR gating. Organs-at-risk (OARs) included duodenum, bowel, stomach, kidneys and spinal cord. Daily MRIs and contours were utilized to create each adapted plan. Adapted plans used the beam-parameters and optimization-objectives from the initial plan. Planning target volume (PTV) coverage and OAR constraints were used to compare non-adaptive and adaptive plans.
Results: PTV coverage for non-adapted treatment plans was below the prescribed coverage for 32/47 fractions (68%), with 11 fractions failing by more than 10%. All 47 adapted fractions met prescribed coverage. OAR constraint violations were also compared for several organs. The duodenum exceeded tolerance for 5/23 non-adapted and 0/23 for adapted fractions. The bowel exceeded tolerance for 5/34 non-adaptive and 1/34 adaptive fractions. The stomach exceeded tolerance for 4/19 non-adapted and 1/19 for adaptive fractions. Accumulated dose volume histograms were also generated for each patient.
Conclusion: Online adaptive MR-Guided SBRT of liver cancer using daily re-optimization resulted in better target conformality, coverage and OAR sparing compared with non-adaptive SBRT. Daily adaptive planning may allow for PTV dose escalation without compromising OAR sparing.

K. Padgett. et al., Phys Med, Vol. 77, pp. 54-63, 2020

Varian's Offline ART Tools

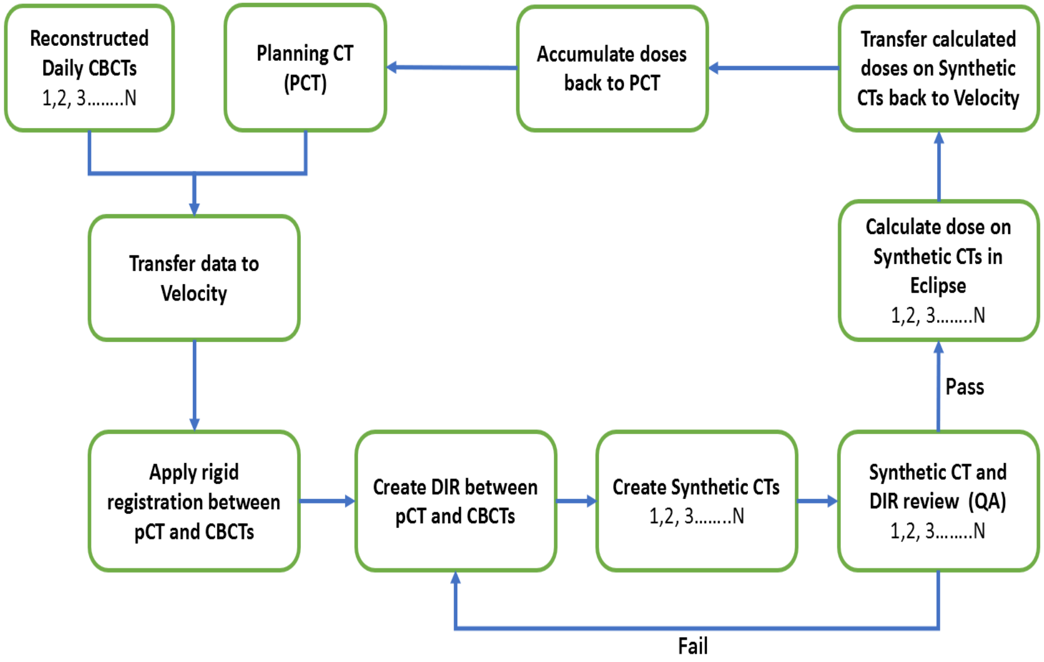
- Adaptive Monitoring in Velocity (ver. 4.1) is a tool which provides assistance when a re-plan is needed.
  - ✓ Structures from planning CT are propagated to the daily setup images (e.g. CBCT).
  - ✓ Changes in structure volumes and COM and DVH during the course of treatment.



	Name	2019/06/27	2019/07/10	2019/07/11	2019/07/12	2019/07/15	2019/07/16	2019/07/17	2019/07/18	2019/07/19
	Bladder	+328.40 cm³	+311.67 cm³	+305.25 cm³	+313.23 cm³	+365.19 cm³	+306.75 cm³	+295.87 cm³	+359.79 cm³	+304.45 cm³
	Anorectum	+46.02 cm³	+41.43 cm³	+41.48 cm³	+41.20 cm³	+47.75 cm³	+38.23 cm³	+45.11 cm³	+41.69 cm³	+31.84 cm³
	Prostate BOS	+54.62 cm³	+52.09 cm³	+50.84 cm³	+52.07 cm³	+52.88 cm³	+47.93 cm³	+53.68 cm³	+53.63 cm³	+41.58 cm³

Automated Dose Accumulation Workflow for Offline ART

- Velocity Adaptive Dose Accumulation Workflow
  - ✓ DIR, dose monitoring (daily, weekly, etc.) and dose accumulation
  - ✓ DIR documentation



Velocity 4.1, Varian Medical Systems, Offline Adaptive Workflow

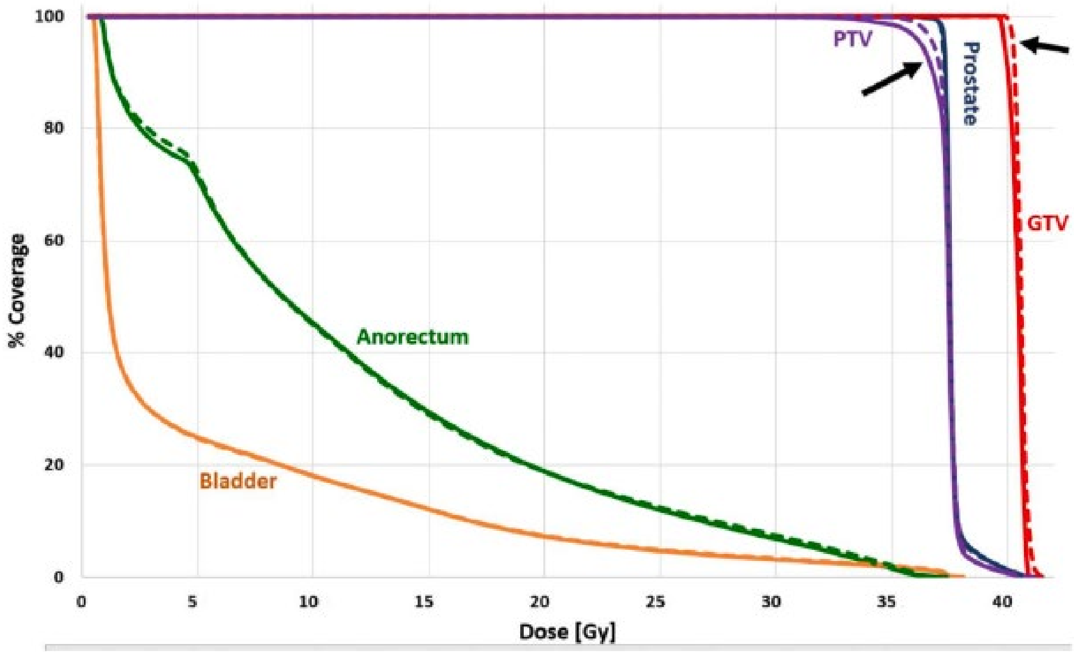
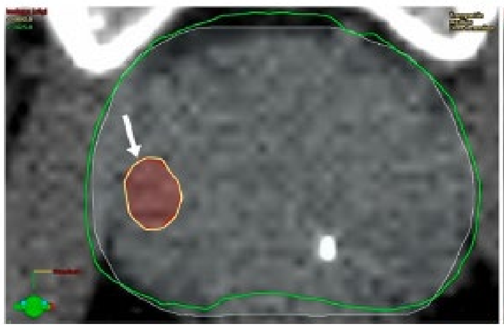
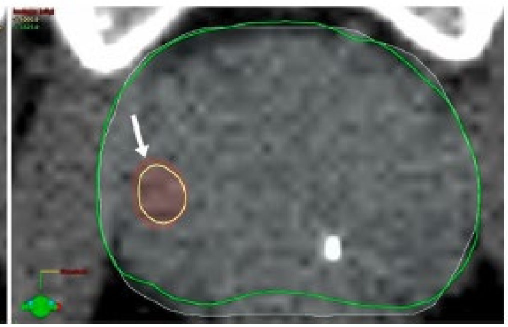


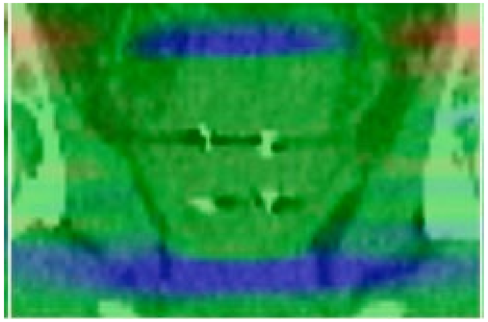
Fig. 2. DVH for Patient 4. Solid lines represent the accumulated plan and dashed are the original. The arrows show where the coverage is decreased for the PTV and GTV.



Planned Dose



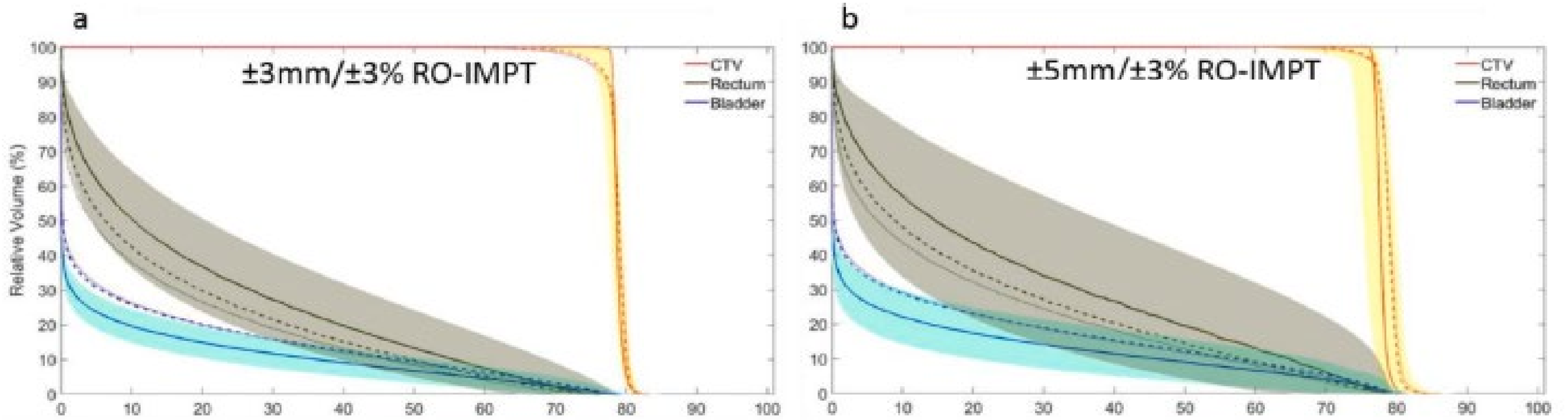
Accumulated Dose



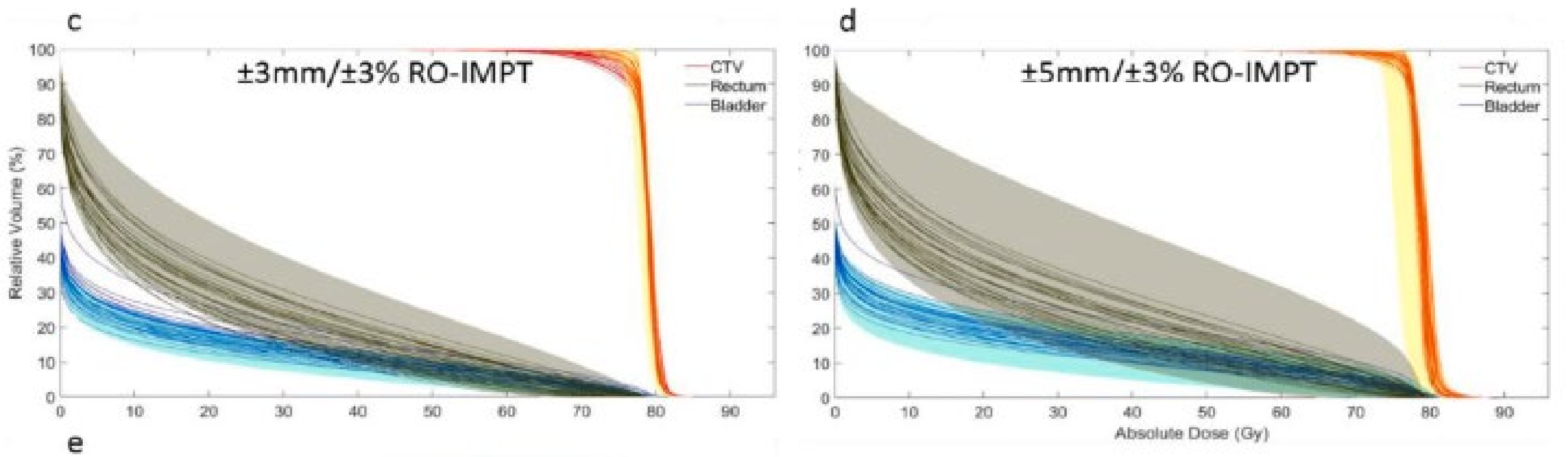
Dose Diffference

M. Studenski et al., Physica Medica, Vol. 77, pp. 154- 159, 2016

Daily vs. Weekly Dose Accumulation



Planned dose
Daily dose accumulation
Weekly dose accumulation
Daily fluctuations in DVH



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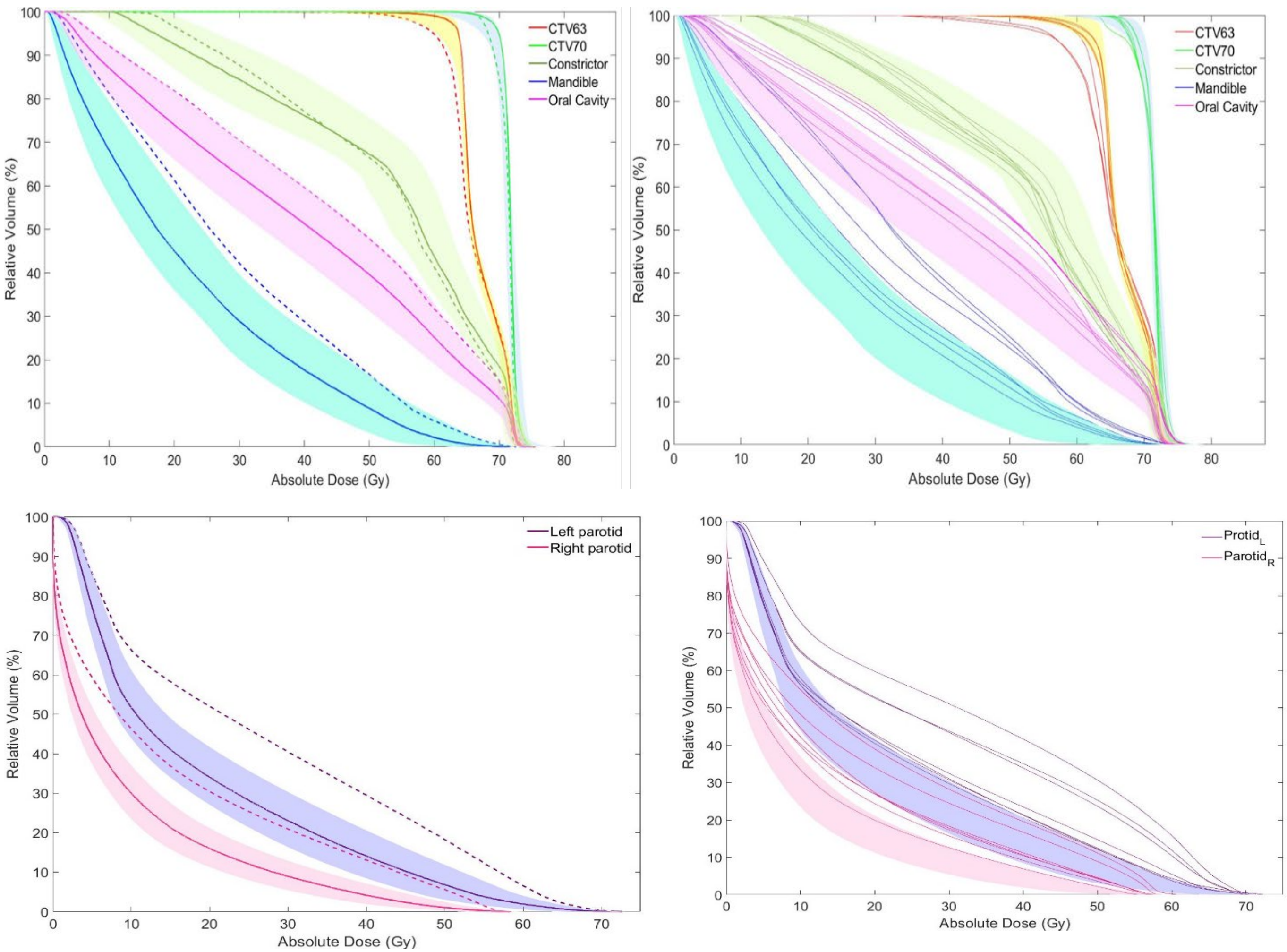
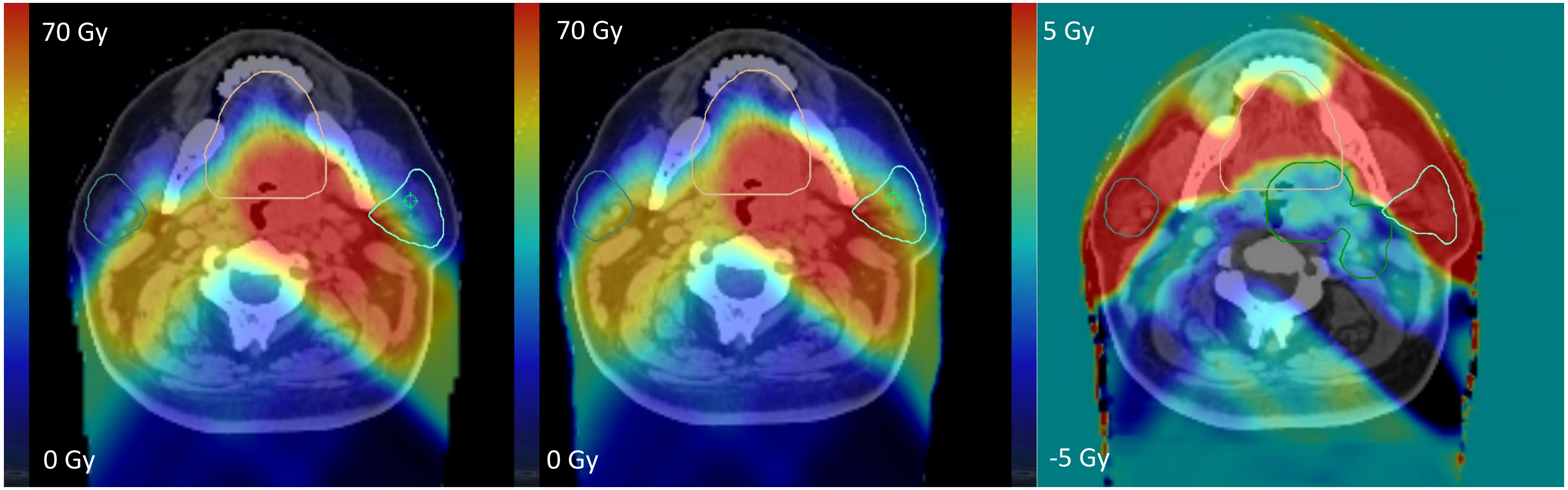
Y. Xu et al., Physica Medica, Vol. 81, pp. 77- 85, 2021

DVH comparisons of CTVs, constrictor, mandible, oral cavity, left and right parotid for a patient with significant weight loss. The planned dose (solid line) and accumulated dose (dashed line) are shown on the left graph of each panel and the shaded region represent the original plan range of uncertainty scenarios. The graphs on the right show the weekly dose fluctuations along with the best- and worst-case uncertainly bands.



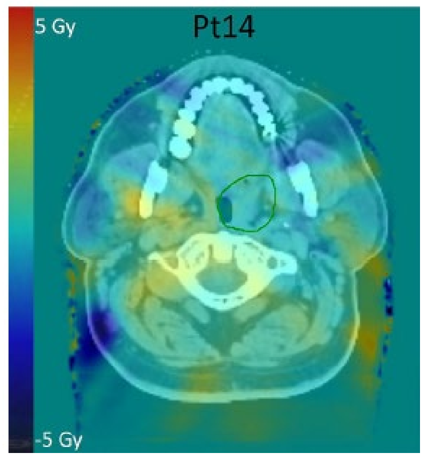
M. De Ornelas, et al., IJPT, Vol. 74, pp. 29- 41, 2021



a. Nominal Planned Dose

b. Accumulated Dose

c. Dose Difference between a and b



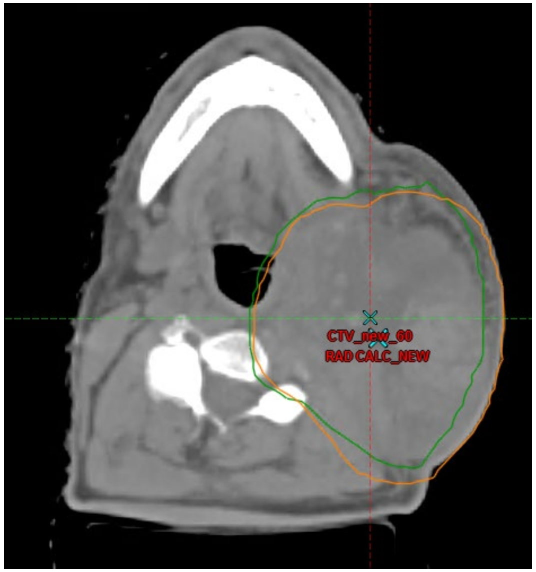
d. differences in daily and weekly dose accumulation

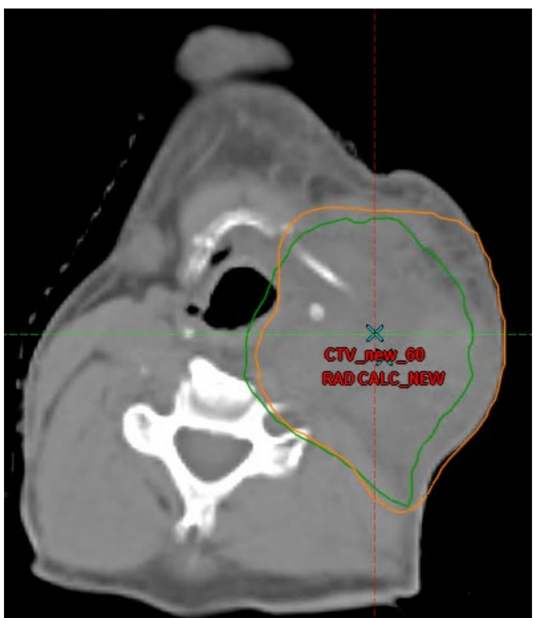
Dose difference map (c) between the nominal planning dose (a) and the weekly accumulated dose (b) for Pt14 who had significant weight loss. In panel (c), areas of positive dose represent accumulated doses greater than the nominal plan, and vice-versa, and (d) differences in daily weekly dose accumulation.

M. De Ornelas, et al., IJPT, Vol. 74, pp. 29- 41, 2021

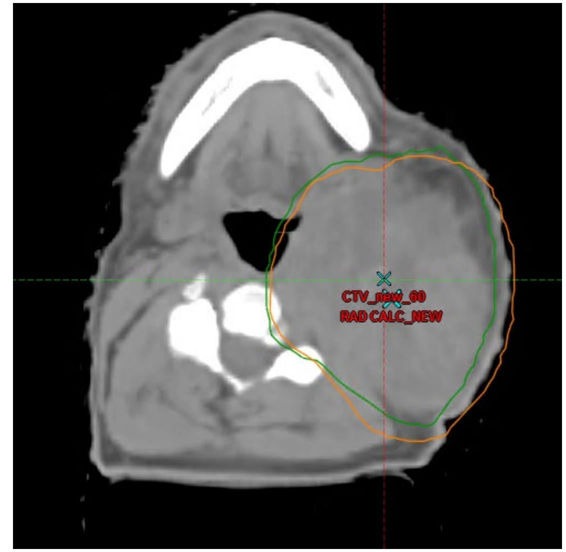
Patient with Tumor Growth

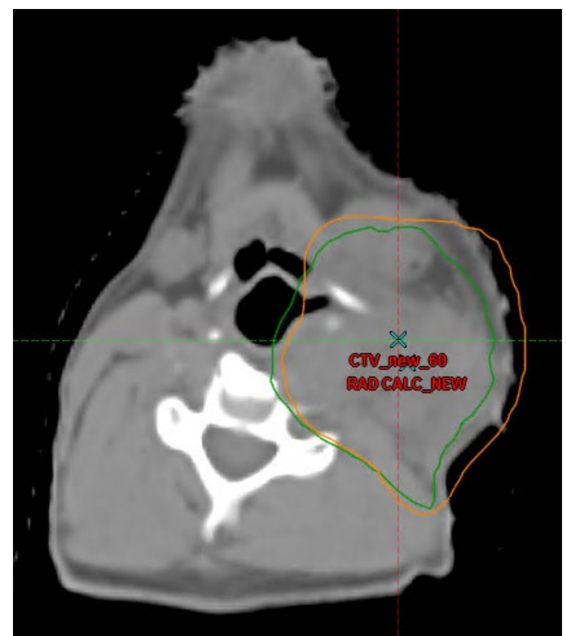
Repeat CT – 4th week



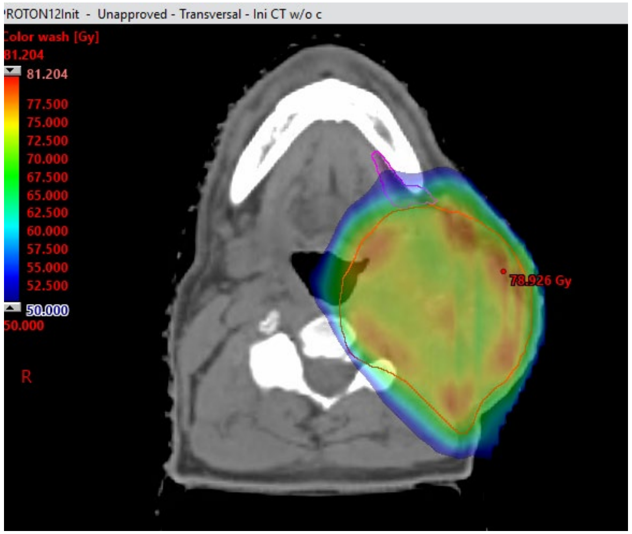


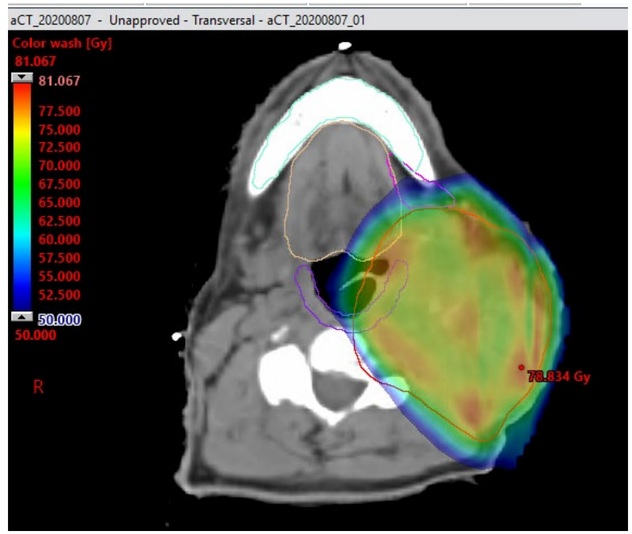
Synthetic CT – 4th week

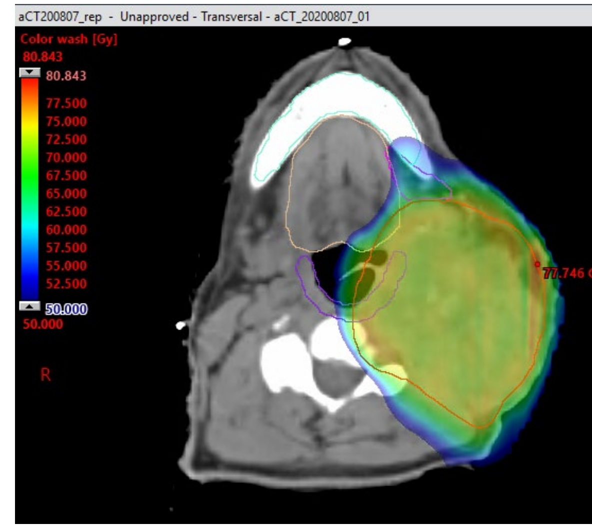


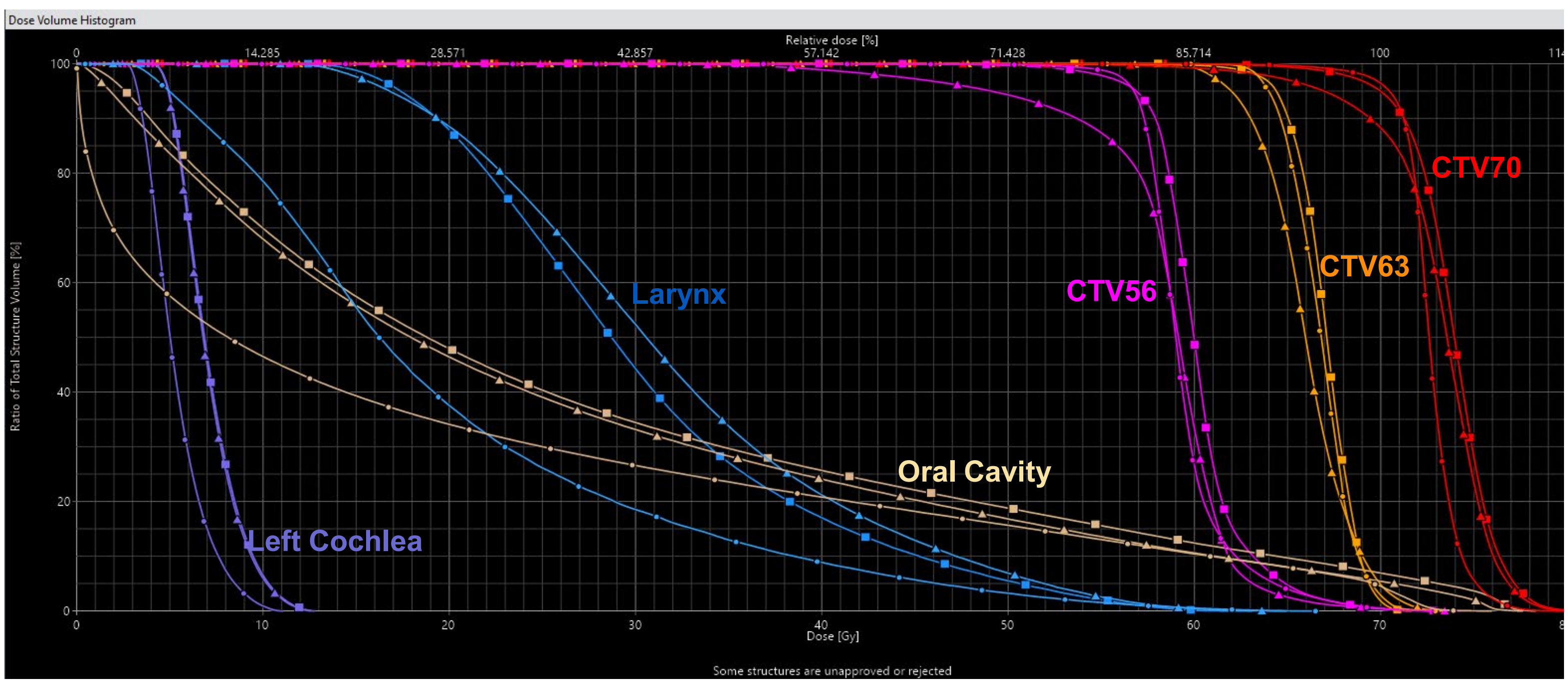


pCT | 1st week synthetic CT – recalc | 1st week synthetic CT- re-plan with RP PT









■ pCT

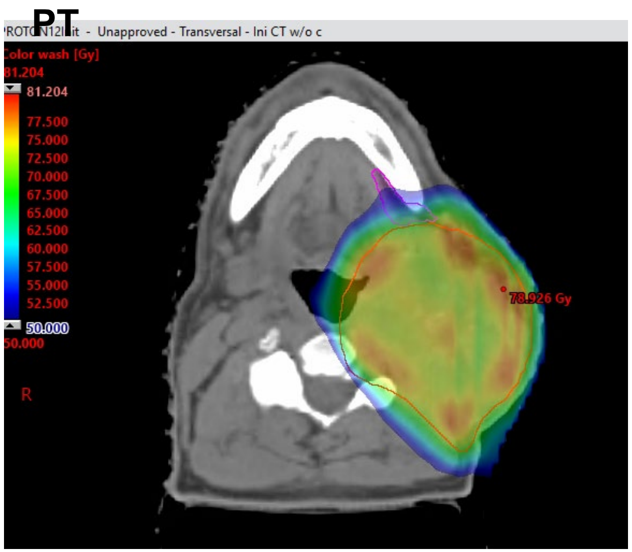
▲ aCT – recalc

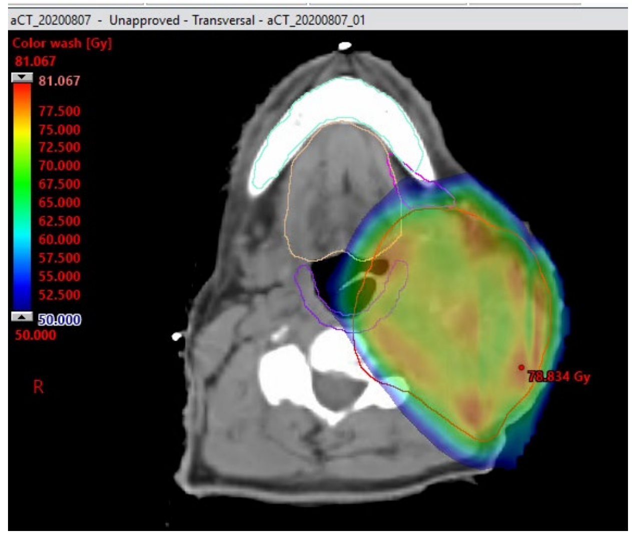
■ aCT-RapidPlan

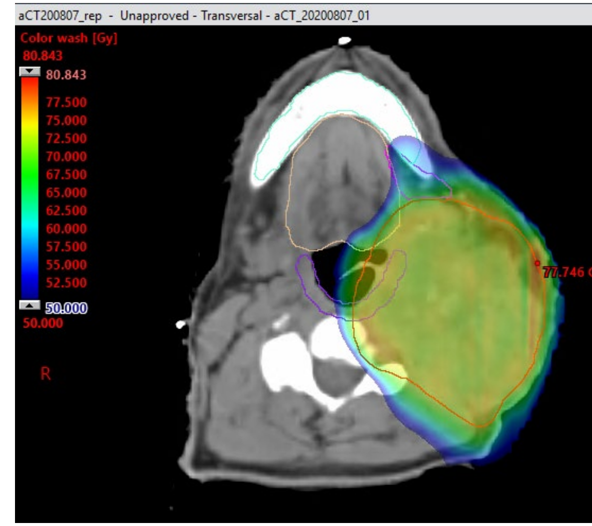
pCT

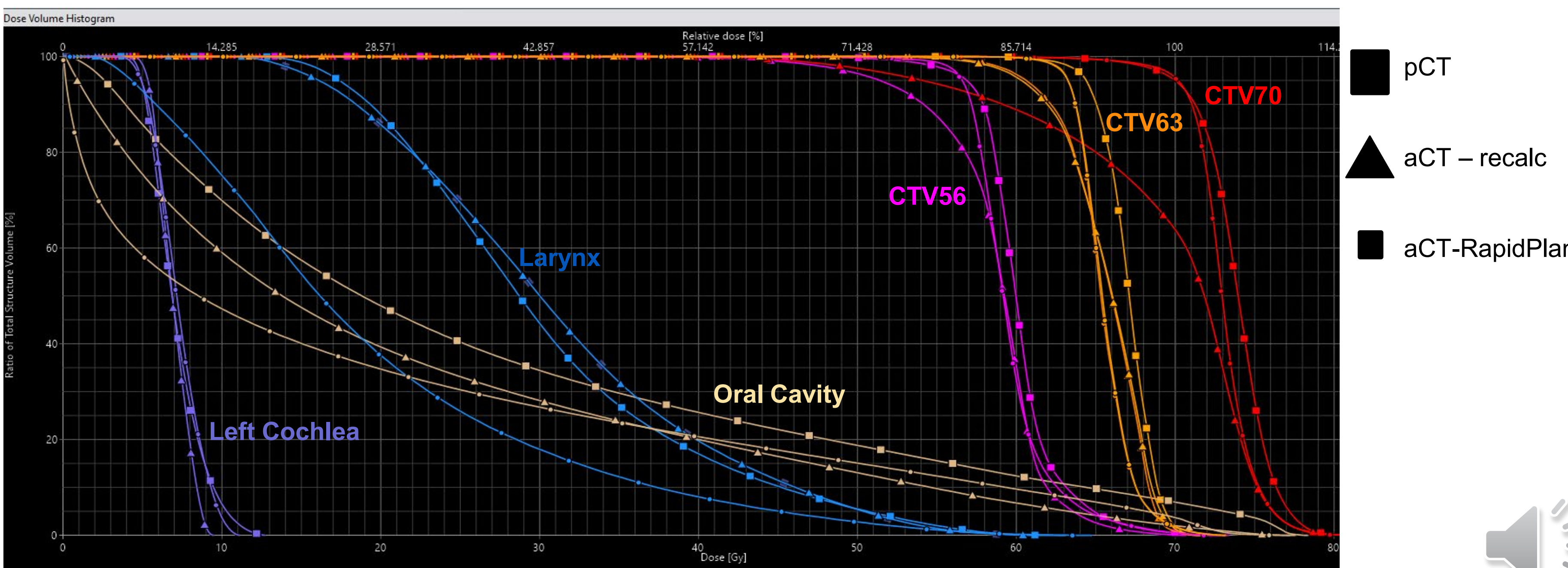
4th week synthetic CT – recalc

4th week synthetic CT- re-plan with RP







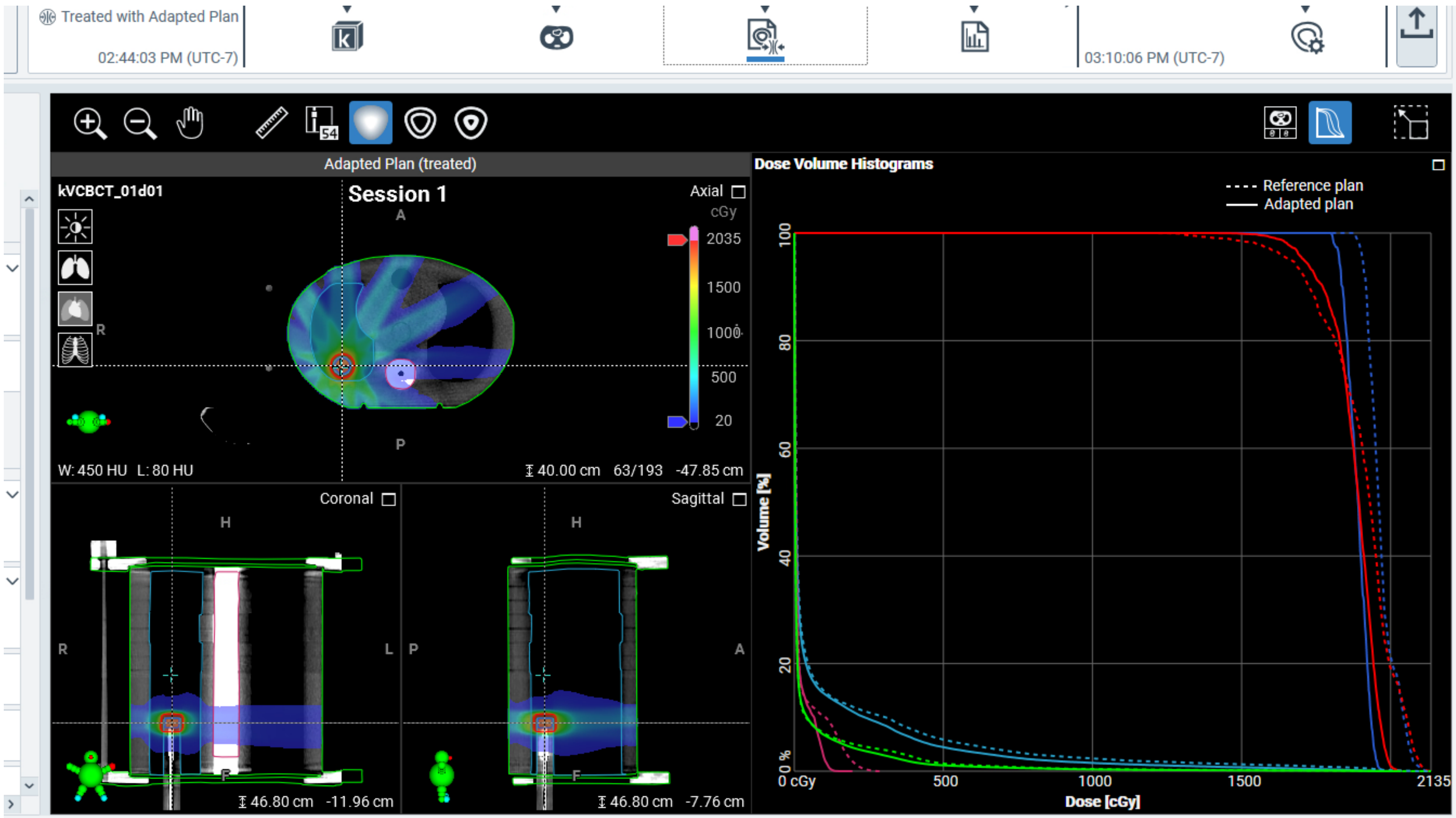


Varian Ethos online ART

- Ethos which is a standalone integrated ART platform using iterative kV CBCT imaging coupled with a linac:
  - ✓ Improved quality of kV CBCT images – artifact correction and statistical construction algorithm and high-speed GPU
  - ✓ Enables online adaptation – real time re-planning
  - ✓ Integrates automated contouring, treatment planning and treatment monitoring tools.
  - ✓ DVH assessment (reference plan vs adapted plan)
  - ✓ Patient Specific QA – Integrated Mobius 3D system for online adaptive QA – log-file based analysis.

Ethos System at U of Miami

Varian Ethos online ART



Courtesy of Dylan O'Connell, PhD, UCLA

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Summary

- ART has a great promise for both photon and proton patient treatments.
- Efficient workflows, Integration and automation are integral part of the ART process.
- Varian's ART solutions are very useful for managing patients requiring both offline and online ART.

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- Yihang Xu
- Ryder Schmidt
- Jonathan Cyriac
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Thank You!!!!