



Mass General Brigham

Online Adaptive Radiotherapy - CBCT Workflows and Challenges for Clinical Implementation

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Outline

- Introduce CBCT online adaptive systems and workflows
- Discuss clinical implementation challenges

Disclosures

Co-investigator of Varian-sponsored clinical trial for adaptive lymphoma on Ethos

AAPM:

- AAPM Newsletter Editor
- Member of Task Group 395 on “X-Ray based Online Adaptive RT: Guidelines for quality assurance and clinical implementation”

ASTRO:

- Member of task force developing a Safety White Paper on Adaptive Radiation Therapy



CBCT online adaptive systems



CBCT-guided online ART systems

Theoretically, any linac with CBCT could be used for online ART

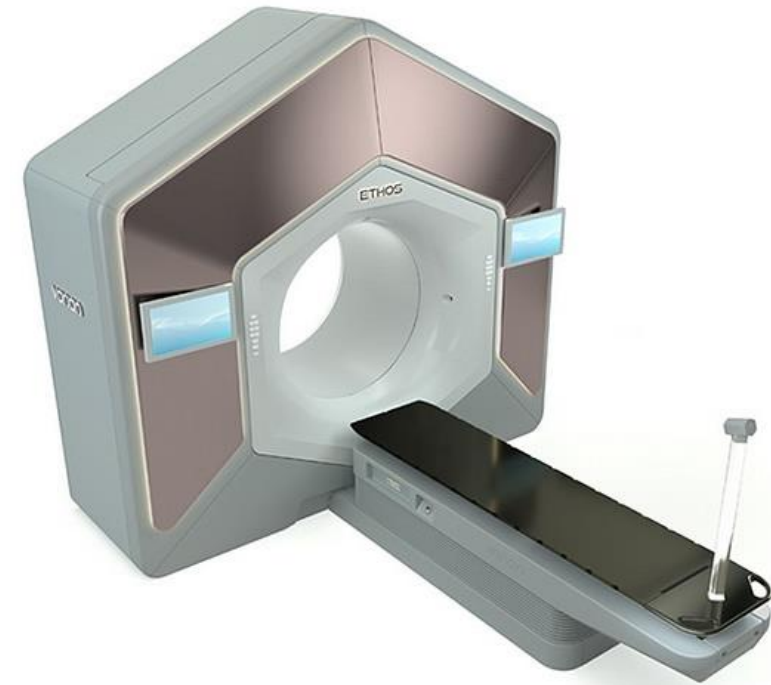
- Ethos from Varian is currently the only integrated solution

Ethos is a Halcyon linac with integrated online adaptive software

- Halcyon: 6 FFF, 28cm x 28cm field size, dual-layer MLCs
- Ethos: includes standalone TPS with fast, simple optimizer and R&V

Adaptive workflow relies on high-quality CBCT imaging and AI contouring

- HyperSight upgrade: 6-sec CBCT acquisition with sufficient HU accuracy to allow photon dose calculation directly on the CBCT
 - Ethos v1 still uses a deformed planning CT
- Varian-provided AI models assist with normal organ contours
 - Targets are either deformed or can be rigidly transferred

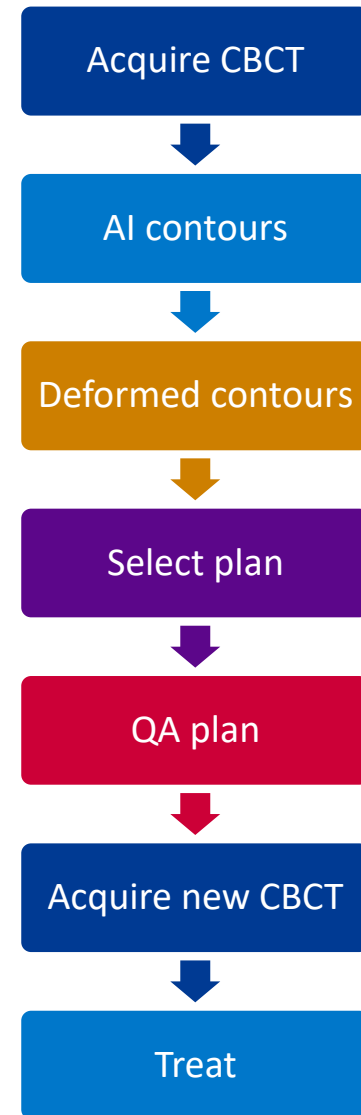


From Siemens-Healthineers.com



Ethos v1 online adaptive workflow

1. Review CBCT for artifacts and appropriate anatomy
 - Movement causes artifacts, more challenging to visualize anatomy
2. Review and edit AI-generated contours (Influencers)
 - Male pelvis model has bladder, rectum, bowel (loops), prostate, and SVs
3. Review and edit deformed contours
 - Physician called to review and edit targets
4. Compare scheduled vs adapted plan and decide which to use
 - If adapted, physician signs plan and may leave afterwards
5. Perform physics QA if using adapted plan
 - Compare changes in MU from scheduled plan, review isodoses
 - Mobius secondary dose calculation, review synthetic CT generated from CBCT
6. Repeat CBCT to check anatomy and patient alignment prior to treatment
 - As bladder fills, it pushes prostate INF and POST so usually have to shift to align



CBCT ART Advantages and Limitations

Advantages (compared to MR-guided ART):

- Familiar technology and less expensive
- CBCT-guidance results in a faster online ART workflow
- Can replace a conventional linac and carry a full IGRT patient load

Limitations:

- Soft tissue visualization
 - HyperSight approaches CT image quality but it's not MRI
 - Can incorporate multi-modality imaging to supplement CBCT
- Motion management/monitoring
 - Still see motion artifacts even with 6 second CBCT
 - Can't monitor target/OAR motion during adaptation or treatment
 - Use surface image guidance as a surrogate for internal motion
 - Monitor patient movement, perform gating/breath hold



HyperSight images of prostate and pancreas from MGH



Implementation challenges for CBCT online adaptive



Commissioning

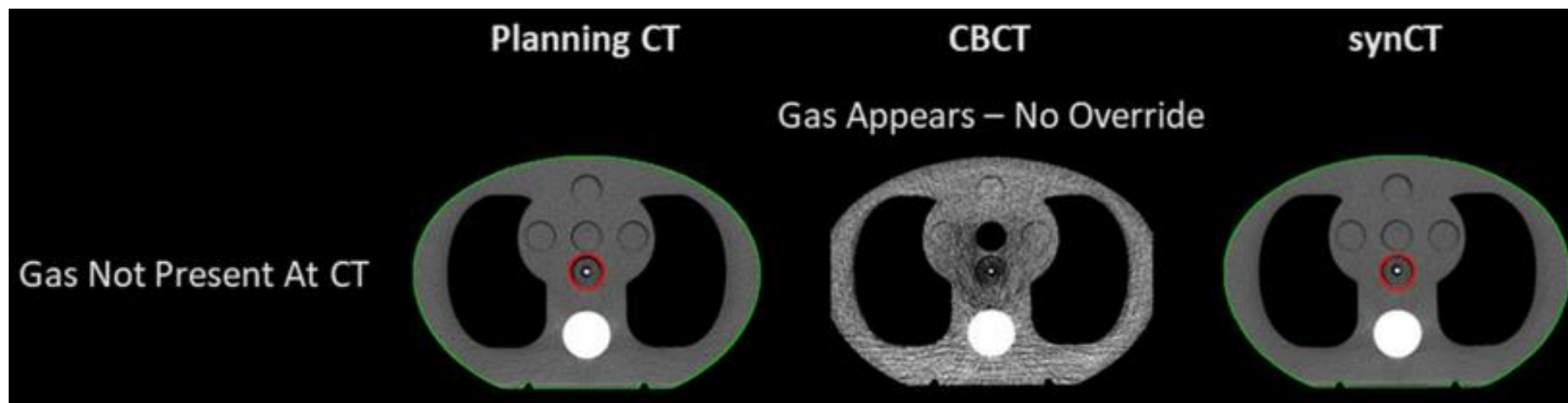
Commissioning a CBCT linac is pretty straightforward

- If dose is calculated on the CBCT, must commission for HU accuracy like a CT

Commissioning the adaptive TPS and online workflow require new considerations

- If using a deformed planning CT for dose calculation, understand how it works
- Understand how plan optimization works, how to create a robust daily optimization
- Learn how to use all the contouring tools including AI

Because the system is essentially a black box, find the limits with intelligent end-to-end tests



Kisling et al., JACMP
2022;23:e13801

Staff training

FIRST: Clearly define expectations and roles for each staff member/group

- Online ART requires staff to go beyond traditional duties
- Who will be present during adaptive treatments and when?
- Who will perform each step and who will check it?
 - Develop a process map and review it with each role group

Next, develop appropriate training programs for each role group

- Training in the adaptive system: know all the tools and buttons to click
- Training in contouring and anatomy identification
 - Recognize dosimetrically significant anatomical changes
- Training on how to work as a team: define safety checkpoints

Define credentialing requirements for onboarding new staff

- Determine if workflow updates require re-training or if periodic training review is helpful



Resource scheduling

Online ART takes longer than IGRT and requires more resources

- May require physician, dosimetrist or other contouring specialist, and physicist
 - ASTRO consensus: a physician must approve a new treatment plan
- As the number of adaptive cases per day increases, scheduling becomes more difficult
 - Consider schedule disruptions: machine downtime, falling behind schedule, patient delayed, anatomy changes so adaptation must be repeated, etc.
 - What if a physician isn't available? Don't treat, or treat with original plan only?

Decide how to handle adaptive scheduling and coverage

- At MGH, decided on 3 morning (9-10:30am) and 3 afternoon (2-3:30pm) adaptive timeslots
- One dosimetrist and two physicists (morning and afternoon) assigned to daily adaptive coverage
- Therapists work with physician admins to schedule physician coverage for each case



Quality management

During the adaptive process, team members work together to check each step

- Ultimately expect physician to verify clinical accuracy and physicist to verify technical accuracy
- But due to time pressures or human error, something could be missed
- Some decisions are a judgement call and different staff could make different calls

Quality management (QM) program should include offline review of each adaptive treatment

- Consider reviewing before the next fraction, so feedback can be implemented immediately
- Attending physician reviews the contours and plan chosen for treatment
 - If any constraints were violated, should adjustments be made to reduce organ dose?
- Physicist reviews the technical parameters and checks for QA issues
 - At MGH, afternoon physicist reviews morning cases and vice versa so it's an independent check
- Goal is to minimize variability so that treatments are performed consistently

Consider any other QM program additions that increase confidence in the accuracy of online ART



Summary

CBCT online adaptive is here, and its use is growing

- Ethos is currently the only FDA-approved integrated system, but others are on the horizon

Workflows are determined by technology and institutional practice

- Ethos has a streamlined workflow, but the user decides how to implement it in their clinic

Implementation challenges range from technical to institutional

- Technical: commissioning the adaptive parts, designing a quality management program
- Institutional: deciding who participates in adaptive treatments and training them, scheduling resources, how to handle disruptions

It's essential to share information between institutions so we can all learn and improve together!





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Average treatment times by modality

References:

1. Munshi et al., J Can Res Ther 2021; 17:523-9
 - Average IGRT time: 15.1 ± 10.9 mins
2. Stanley et al., JACMP 2023; 24(7), e13961
 - Average CBCT-adp time: 34.5 ± 11.4 mins
 - Average contouring time: 9.5 ± 8.4 mins
3. Gungor et al., PRO 2021; 11, e11-e21
 - Average MRI-adp time: 48.5 ± 13.5 mins
 - Average contouring time: 10.1 ± 6.0 mins

