MRI-Guided On-line Adaptive Radiotherapy – The UCLA Physics Experience

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Disclosures

· Consulting fees from ViewRay for machine testing

• "Adaptive radiation therapy is a closed-loop radiation treatment process where the treatment plan can be modified using a <u>systematic feedback of</u> <u>measurements</u>." Yan, Di, et al. "Adaptive radiation therapy." *Physics in* medicine and biolog/42.1 (1997): 123.

- On-line adaptive: measure something about the patient while he/she is on the table and modify the delivery.
 - Change the treatment plan
 - Select plan of the day from a plan library, based on best match to the current daily anatomy

On-line plan change: re-optimization





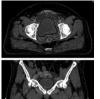


Planned

ed Fx1 V35 Gy(bowel)=0.02 cc V35 Gy(bowel)=1.12 cc

ed Fx1 V35 Gy(bowel)=0.05 cc

On-line plan of the day selection



Murthy, Vedang, et al. Radiotherapy and Oncology 99.1 (2011): 55-60.

 Studied for bladder [1], prostate [2], and cervical cancer [3].

· Established clinical use in bladder cancer.

Burridge, Nichola, et al. International Journal of Radiation Oncology: Biology: Physics 66.3 (2006); 882-897.
 Cj Gili, Suki, et al. Radiotherapy and Oncology 107.2 (2013): 165-170.
 Heijkop, Sabrina T., et al. International Journal of Radiation Oncology: Biology: Physics 503 (2014); 67-3678.

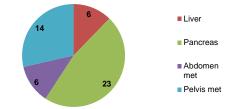
MRI Guided Plan of the Day Selection - UCLA



Challenges:

- Who decides which plan matches the daily anatomy best?How easily can you change plans with the system?

On-line Adaptive Fractions Treated on UCLA ViewRay 2015-2016 (N=45)

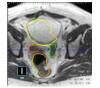


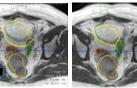
Since April 2016, all our abdominal and pelvic SBRT on ViewRay are evaluated for adaptive on a per-fraction basis.

Quality considerations

- · Keep the time under control
- · Get the best dosimetry possible
- · Avoid (or catch and correct) human error made more likely by time pressure

- Deformable contour propagation: saves time but editing still needed.
- · Review of edited contours by second expert is mandatory.

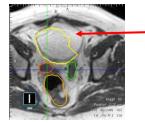




Treatment plan (Fx1) Fx2 - rigidly propagated Fx2 - deformed

Contouring: Don't waste time on useless

precision



Time to room pt. and acquire image Image to room pt. and acquire image to room pt.

Things that make the time blow up

- Physician or physicist didn't respond promptly to pages.
- Physicist or physician unfamiliar with tools.
- · Contoured more anatomy than needed.
- Made a mistake in contouring, noticed it in plan evaluation, and had to go back and correct.
- · Needed to make in depth plan modification.

How to plan like your plan will be adapted

- · Avoid derived optimization structures if possible.
- · Use the conformality constraint.
- Put optimization weights on all structures coplanar with the target, even if far away.

How to plan like your plan will be adapted



Initial plan: kidney far away and not getting much dose, so not included in optimization.



Re-optimized plan: still far away, but not weighted and optimizer happens to puts a beam through it.



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Edited optimization:
Fixed the problem but
added time and
complexity.
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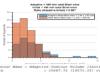
QA Tools: What do we need to check?

- · Will the delivered dose match the planned dose?
- · For off-line planning we do IMRT QA
- For on-line adaptive planning: recalculate plan using an independent Monte Carlo dose calculation engine (provided by ViewRay)
- Did we make a mistake in planning due to the time pressure?
 - · Contour and dosimetry consistency checks

On-line Adaptive – WUSTL QA Tools



On-line Adaptive - UCLA QA Tools



Project lead at UCLA: David Thomas, PhD

Acknowledgements:
 Zeus MC support: Tony Apicella / ViewRay
 3D Gamma code: Mark Geurts / UW

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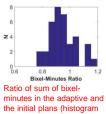
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3	200	44.1490	56.5718
4	72	69.2655	114.3012
5	192	19.5921	25.1045
	312	121.1390	155.2227
7	96	22.3055	28.6814
8	216	2.0753	2.6592
9	336	67.9028	87.0079
10	358	112.2362	143.0150
11	264	57.6528	74.1303
12	24	165.6028	212.1968

UCLA Consistency checks - Bixel-Minutes Example

MLC segment

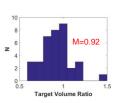


17 1x1 cm² elements X 18 seconds 5.1 bixel-minutes



of 40 adapted fractions)

Consistency checks



 Adapted target volume relative to initial volume.

Communication is critical: Templated document

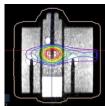
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For covering planner: optimization structures and booleans

End-to-End Tests for QA and Training



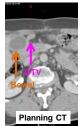
Motion phantom: move the plunger and adapt.

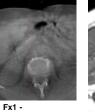


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On-line imaging is the foundation of on-line adaptive

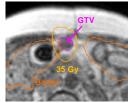






Fx 2 On-line MRI

On-line re-optimization



Predicted V35 Gy(bowel)=0.73 cc



Adapted V35 Gy(bowel)=0.05 cc

Physicist's wish list and future directions

- Fast and user friendly interface to choose "Plan of the Day"
- Adaptive optimizer that runs multiple plans in parallel with a range of critical structure weights, lets the user choose which one he/she likes best.
- Decision support tool for physicians to evaluate a full adaptive course.

Summary

- · On-line adaptive is a new paradigm; analogous to surgery
- · QA of technical factors still important
- · QA of human factors and workflow increasing in importance
- Further development of workflow and tools needed to bring the benefits of on-line adaptive to more patients.



Thank you!

On-line adaptive clinical workflow Planning Treatment Planning MR Sim CT Sim Plan QA ŕ 3D MRI Couch Dose Adaptive Delivery planning Scan shift Predication Cine MRI motion Treatment Delivery evaluation Gating or Monitoring David Geffen RADIATION CONCOLOGY

Outline

- Introduction to the ViewRay system
- UCLA adaptive case statistics
- Adaptive case studies
- QA tools
- Timing
- Adaptive commissioning
- · Physicist's wish list and other final thoughts

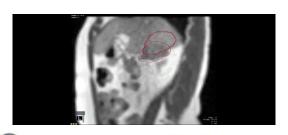
Motion Management

- · free-breathing with monitoring
- free-breathing with gating
- breath-hold treatment
 - Inhale
 - Exhale

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Introduction to the ViewRay system

MRI components:

- Split superconductor MRI (0.345 T)
- 50cm FOV with 70cm bore size
- · Imaging isocenter coincident with RT system isocenter
- · High resolution 3D MRI images in 25s-172s
- · Real time cine MRI image (4 frames/s)



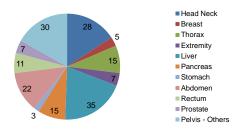
UCLA ViewRay Project Timeline

- June 2014
- Acceptance tests July – October 2014 Commissioning
- October 27th, 2014
- May 14th, 2015
- August 7th, 2015
- First patient treated First gated treatment
- First adaptive treatment

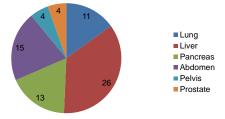


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Patients treated on UCLA ViewRay 2014-2016 (N=181)



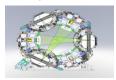
SBRT Patients Treated on UCLA ViewRay 2014-2016 (N=75)



Introduction to the ViewRay system

RT components:

- 3 headed cobalt system, each 15,000Ci, dose rate around 500cGy/min at 105cm SAD
- 3 independent MLC systems (1cm leaf width, double focus, field size 27.3cm x 27.3cm)





Summary

- Commercially available on-line adaptive has arrived with commercially available MRI-guided RT.
 - · Other systems likely to follow suit.
- Attention must be paid to QA and process in order to maintain quality and safety.
- Further development of workflow and tools needed to bring the benefits of on-line adaptive to more patients.

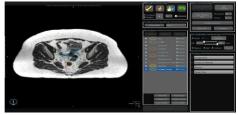
Re-optimize the new plan



Volumetric setup image - initial assessment for adaptive



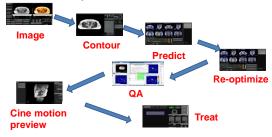
Auto-contouring and manual adjustment



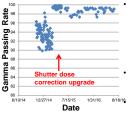
"Predict" - Calculate dose on new anatomy



Online Adaptive Treatment Flow



The value of phantom-based IMRT QA



Failures with phantom based IMRT QA are associated with:
known limitations of dose calculation (DLG)
Reproducible machine performance problema.

- problems.

Not likely to be caught with Monte Carlo based QA.

Partly addressed by periodic phantom QA of a standard plan

Off-line Patient Specific QA

• MR-safe/MR-compatible equipment



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