UAB Department of Radiation Oncology

Volumetric modulated arc therapy

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Disclosures

- UAB has research agreements with Varian Medical Systems
- Speaking honoraria from Varian Medical Systems

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Outline

- Patient-specific QA
- SRS, SBRT, and flattening filter free VMAT
- Respiratory motion management
- Starting a VMAT program

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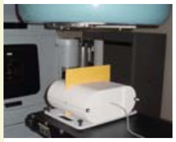
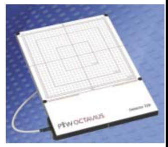
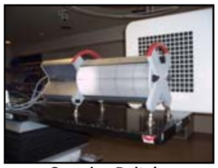
Patient Specific QA devices


IBA IMRT/VMAT phantom


Sun Nuclear ArcCheck

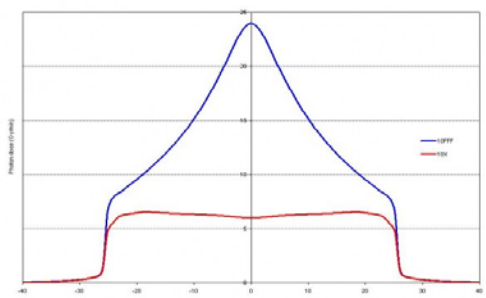

PTW Octavius


Scandos Delta[4]


IBA Matrixx Evolution

Slide courtesy Rajat Kudchadker, The University of Texas M.D. Anderson Cancer Center

Beam Profile – Flattening Filter

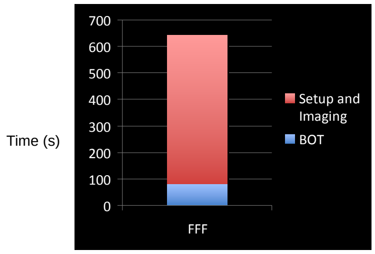


Common SBRT sites

- Spine
- Lung
- Liver and other abdominal targets

CNS Radiosurgery Efficiency

12-30 Gy in 1-5 fractions (n=27)

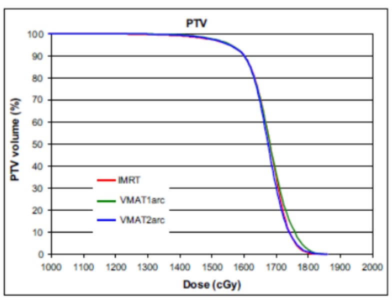


Beam on time = mean 81s

Clinical Dose Rate = 1840 MU/min

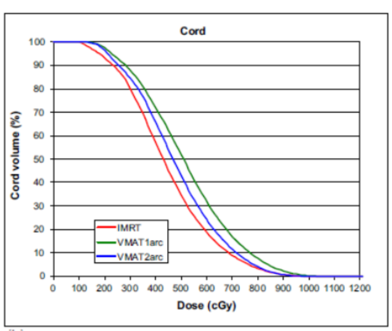
Prendergast BM et al. *Jour of Radiosurgery and BRT* 1, 117–122 (2011)

Spine



Q.J. Wu et al., *Int. J. Radiation Oncology Biol. Phys.*, **75**, 1596–1604 (2009)

Spine



Q.J. Wu et al., *Int. J. Radiation Oncology Biol. Phys.*, **75**, 1596–1604 (2009)

Spine

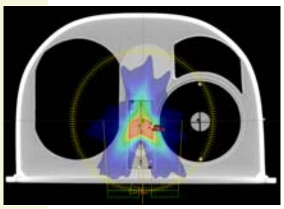
Table 4. Delivery differences

	IMRT (mean ± SD)	$VMAT_{1arc}$ (mean ± SD)	$VMAT_{2arc}$ (mean ± SD)
Total MU	8711 ± 1308	7730 ± 1843	6317 ± 1156
Total MLC segments	1131 ± 183	177	354
Beam-on time (min)	8.71 ± 1.31	7.81 ± 1.84	6.38 ± 1.16
Treatment time* (min)	15.86 ± 1.52	8.56 ± 1.84	7.88 ± 1.16
Integral dose ratio		1.13 ± 0.11	1.09 ± 0.09

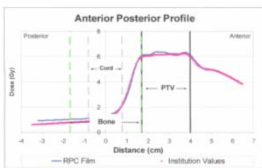
Abbreviations: MU = monitor unit; MLC = multi-leaf collimator.
* Treatment time defined as from start first beam to finish of last beam, excluding imaging guidance.

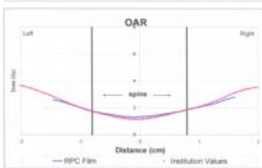
Q.J. Wu et al., *Int. J. Radiation Oncology Biol. Phys.*, **75**, 1596–1604 (2009)

RPC VMAT Spine



Location	Institution Reported Doses (cGy)	TLD Dose (cGy)	Measured/Institution
PTV_TLD_sup_ant	612	618	1.01
PTV_TLD_inf_ant	614	619	1.01
PTV_TLD_sup_post	616	619	1.00
PTV_TLD_inf_post	620	627	1.01
HEART_TLD	134	135	1.01





For spine SBRT, the technique with the fastest delivery time is:

20%	1. 8-12 field DMLC IMRT
19%	2. 1 arc VMAT
19%	3. 2 arc VMAT
23%	4. Depends on prescription dose
20%	5. Depends on target volume

For spine SBRT, the technique with the fastest delivery time is:

1.
2.
3. 2 arc VMAT
4.
5.

Reference:

Q.J. Wu, S. Yoo, J.P. Kirkpatrick, D. Thongphiew, and F. Yin. "Volumetric arc intensity–modulated therapy for spine body radiotherapy: comparison with static intensity-modulated treatment", *Int. J. Radiation Oncology Biol. Phys.*, **75**, 1596-1604 (2009).

Treatment Efficiency for FFF Lung SBRT

Ten Lung SBRT clinical cases on a modified Clinac 21EX:

- Similar plan quality for FFF vs non-flat
- 6MV beam time reduced by 2.3 (1400 MU/600 MU)

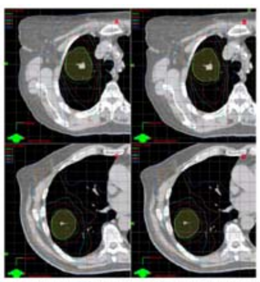


FIG.2. Planning CT images with isodose lines for two patients. Images A and B are from patient 1, C and D from patient 2. Images A and C show plans with flattened 6 MV beams while B and D show plans with unflattened 6 MV beams. Isodose lines represent planned doses of 50 Gy (green), 40 Gy (red), 30 Gy (cyan), 20 Gy (orange), 10 Gy (blue). The maximum dose in these plans is less than 60 Gy. The PTV is shown in yellow.

Journal of Applied Clinical Medical Physics, Vol. 10, No. 1, Winter 2009

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Lung

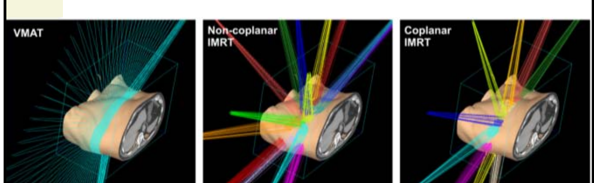

Fig. 1. Beam setups for three different treatment techniques for a representative example case.

A. Holt et al., "Volumetric-modulated arc therapy for stereotactic body radiotherapy of lung tumors: a comparison with intensity-modulated radiotherapy techniques," *Int. J. Radiation Oncology Biol. Phys.* (in press)

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Lung

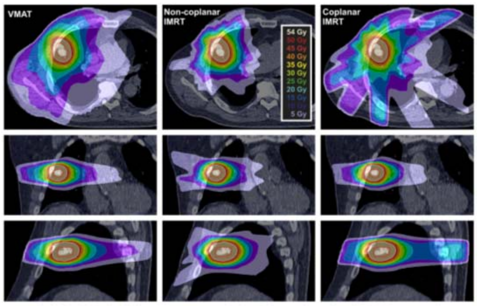

Fig. 2. Dose distributions for three different treatment techniques for the example case shown in Fig. 1. Gross tumor volume depicted by thin solid red line.

A. Holt et al., "Volumetric-modulated arc therapy for stereotactic body radiotherapy of lung tumors: a comparison with intensity-modulated radiotherapy techniques," *Int. J. Radiation Oncology Biol. Phys.* (in press)

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Lung

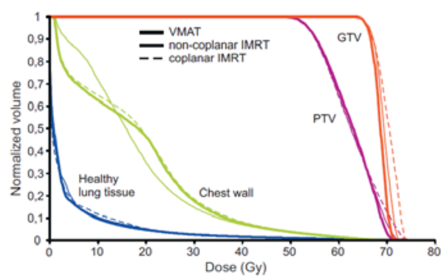

Fig. 3. Dose–volume histograms for example case shown in Fig. 2.

A. Holt et al., "Volumetric-modulated arc therapy for stereotactic body radiotherapy of lung tumors: a comparison with intensity-modulated radiotherapy techniques," *Int. J. Radiation Oncology Biol. Phys.* (in press)

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Lung

Table 5. Measured maximal skin dose for total treatment of 3×18 Gy

Tumor location	Coplanar VMAT	Noncoplanar IMRT	Coplanar IMRT
	Absolute skin dose at 70 μm (Gy)*		
Ventral	3.1	3.4	4.1
Dorsal	10.9	10.4	11.3

Table 3. Summary of plan parameters

Variable	Dose type	Coplanar VMAT	Noncoplanar IMRT	Coplanar IMRT
Delivery time (min)	NA	6.5 (4.8–9.9)*	23.7 (16.5–39.8)*	17 (12–26)*

A. Holt et al., "Volumetric-modulated arc therapy for stereotactic body radiotherapy of lung tumors: a comparison with intensity-modulated radiotherapy techniques," *Int. J. Radiation Oncology Biol. Phys.* (in press)

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For lung SBRT, the technique that minimizes skin dose is:

21%	1. IMRT using coplanar beams
19%	2. IMRT using non-coplanar beams
20%	3. VMAT using a coplanar arc
20%	4. Both 1 and 3
21%	5. Both 2 and 3

For lung SBRT, the technique that minimizes skin dose is:

1.
2.
3.
4.
5. Both 2 and 3

Reference:

A. Holt, C. van Vliet-Vroegindeweij, A. Mans, J.S. Belderbos, and E.M.F. Damen. "Volumetric-modulated arc therapy for stereotactic body radiotherapy of lung tumors: a comparison with intensity modulated radiotherapy techniques", *Int. J. Radiation Oncology Biol. Phys.*, **81**, 1560-1567 (2011).

What is your clinic's preferred technique to manage respiratory motion?

22%	1. Internal target volume (ITV)
20%	2. Abdominal compression
20%	3. Breath hold/Active breathing control (ABC)
20%	4. Gating
18%	5. About equal split between two or more of the techniques above

Gating - Varian

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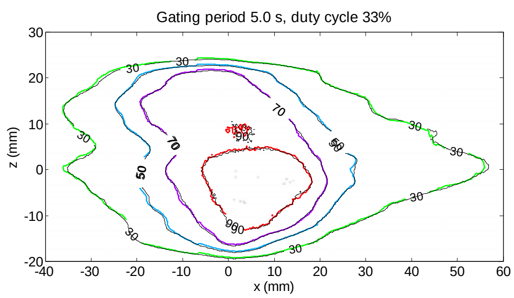
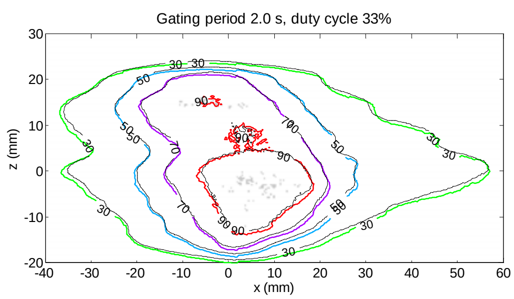


S Shen, R Popple, J Duan, X Wu, I Brezovich, "Dosimetric Evaluation of Beam-Hold Interruption in Respiratory Gated RapidArc Delivery," AAPM 2011 meeting SU-E-T-517



S Shen, R Popple, J Duan, X Wu, I Brezovich, "Dosimetric Evaluation of Beam-Hold Interruption in Respiratory Gated RapidArc Delivery," AAPM 2011 meeting SU-E-T-517

Measurement summary

- Chamber difference < 0.5%
- Gamma index for gated film relative to ungated
  - >99.9% pass for 3%/3mm
  - >99.5% pass for 2%/2mm

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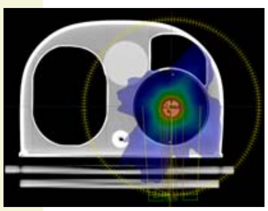
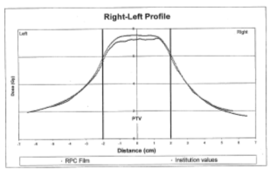
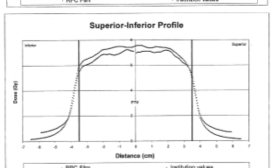
RPC Gated VMAT Lung







Summary of TLD and film results:

Location	RPC vs. Inst.	Criteria	Acceptable
PTV_TLD_sup	0.96	0.92 – 1.02	Yes
PTV_TLD_inf	0.96	0.92 – 1.02	Yes

Film Plane	Gamma Index*	Criteria	Acceptable
Axial	100	≥ 80%	Yes
Coronal	99	≥ 80%	Yes
Sagittal	98	≥ 80%	Yes
Average over 3 planes	99	≥ 85%	Yes

*Percentage of points meeting gamma-index criteria of 5% and 5 mm

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Respiratory motion management for Elekta VMAT

- Respiratory motion management for Elekta VMAT is a work in progress
- Elekta's motion management solution has been forced breath-hold based gating (Active Breathing Coordinator – ABC)
- Beam latency time on Elekta linacs has been a barrier to gated beam delivery. Recent latency time reductions have mitigated the clinical significance of beam latency.

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Slide courtesy of David Shepard, Swedish Cancer Institute

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Respiratory input: Surface imaging and spirometry

- C-Rad Catalyst
  - Surface mapping solution
  - Monitors the surface motion as a surrogate for respiration.

- Elekta ABC system
  - Turbine spirometer measures airflow
  - Research version provides gating interface.

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Gating test – Experiment setup

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Latest Gating Results

Pt	Gating window	Delivery time (min)	Ideal time (min)	Beam-on latency (s)
1	100%	5.15 (5.65)		
	77%	7.08 (9.97)	6.69	**0.22 (1.06)**
	66%	**8.13** (14.22)	**7.80**	**0.16 (1.59)**
2	100%	4.80 (5.32)		
	77%	6.40 (9.20)	6.23	**0.10 (1.00)**
	66%	**7.47** (13.80)	**7.27**	**0.11 (1.66)**
3	100%	4.12 (4.58)		
	77%	5.52 (8.13)	5.35	**0.12 (1.07)**
	66%	**6.40** (12.13)	**6.24**	**0.10 (1.71)**

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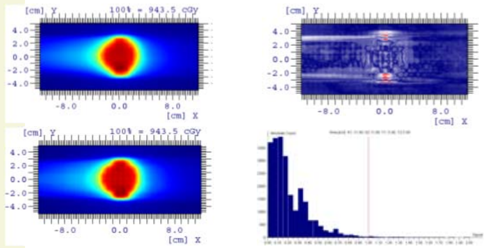
Dosimetric Accuracy



- Gamma passing rates are all > 99.0% for measured vs. planned dose distributions.
- Gamma passing rates are all = 100% (3mm/3%) for gated vs. un-gated deliveries, difference can only be observed with 1mm/1% gamma index passing criteria.

Slide courtesy of David Shepard, Swedish Cancer Institute

Elekta Gating Summary

- Elekta has not offered a free-breathing solution for beam gating.
- Elekta's latest solutions make it possible to deliver gated treatments including gated VMAT with reasonable beam latencies.
- Tests have included using both the C-RAD Catalyst (surface mapping) and ABC (turbine) as the tool for providing the gating signal.

Slide courtesy of David Shepard, Swedish Cancer Institute

Do you use VMAT in your clinic?

26%	1. Don't have VMAT, no plans to start VMAT
24%	2. Planning to start a VMAT program
26%	3. Just started
25%	4. Our VMAT program is well established

Starting an IMAT program

- Time and resource allocation
- Training
- Case selection

Time and resource allocation

- Form an implementation team
  - Physicists
  - Dosimetrists
  - Therapists
  - Physicians
- Develop an implementation plan
  - Establish a timeline
  - Develop written procedures
  - Evaluate training needs

Physicist tasks

- Acceptance
- Commissioning
  - Delivery system
  - Treatment planning
- Development of planning protocols (joint with dosimetrists)
- Development of QA procedures
  - Patient specific
  - Machine
- Development of treatment protocol (joint with therapists)

Dosimetrist tasks

- Development o planning protocols (joint with physicists)

RapidArc planning procedure

- Energy 6X
- Dose Rate 600
- Tolerance PHOTONS

3. On the Geometry tab of the field properties, enter
   - Technique ARC
   - Setup Isocentric
   - Gantry RTN 1
   - Stop Angle 359
   - Collimator Angle 135
   - Direction CCW
   - Isocenter Enter the coordinates noted in 5.
4. Enter prescription parameters.

Therapist tasks

- Development of treatment protocol (joint with physicists)

RapidArc treatment delivery procedure

3 Procedure

1. Open the patient from the treatment queue.
2. There should be a single plan named *SITE*.
3. There should be setup fields and a single field named *NN-ARC*.
4. Perform standard image guided patient setup.
5. On the first treatment, confirm that captured couch positions have been applied to all fields.

Physician tasks

- Identify cases appropriate for initial patient cohort

Timeline

- Developed in coordination with vendor(s)
- List of all milestones, including training
- Example excerpt from UAB plan:
  - Therapist RapidArc training
  - Develop dry-run plan
  - Perform QA on dry run plan
  - Have therapists deliver dry run plan, including CBCT (with chambers & film).
- Make reasonable time estimates
- Have a contingency plan!

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Training

- Vendor training
  - Delivery
  - Planning
  - Physics
- Implementation team to develop internal training
  - Planning procedures
  - Treatment procedures
  - QA
- Implementation team should also develop a post-implementation training plan

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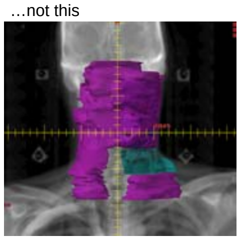
Case selection

- Simple targets
  - < 12 cm diameter
  - Spherical or cylindrical – no bifurcations

Start with this…

…not this



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Case selection

- Suggestions
  - Prostate – low or intermediate risk
  - High-risk prostate boost
  - Brain
  - Head and neck boost

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Initial cohort – standard plans

- For initial cohort of cases, develop “standard” plans
  - Use as reference for comparison with IMAT plans
  - Available as contingency treatment plan

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Post-implementation

- Initial implementation period is preclinical to completion of the initial patient cohort
  - Initial patient cohort typically 5 to 20 cases
- Implementation team should develop a training plan for the general clinic
- Implementation is an ongoing process that will last significantly beyond the first patient cohort
- Implementation team should continue to monitor process

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Thank you

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