

**VMAT vs. IMRT:  
Does the Choice Matter?**

---

Martha M. Matuszak, Ph.D., DABR

*Department of Radiation Oncology  
University of Michigan, Ann Arbor, Michigan*

MARCH 7-10, 2015  
St. Louis, MO

AAPM  
SPRING CLINICAL MEETING

THE HYATT REGENCY ST. LOUIS  
at the Arch

---

---

---


---

---

---

---

---



**Disclosure**

---

- Research Funding, Varian Medical Systems
- Associate Physicist, Michigan Radiation Oncology Quality Consortium (Funded by Blue Cross Blue Shield of Michigan)

---

---

---


---

---

---

---

---



**Outline**

---

- Brief Refresher of Intensity Modulated Techniques
- Evidence for choosing VMAT vs. IMRT
- Practical Pros and Cons and Considerations
- Take-Home Message

---

---

---

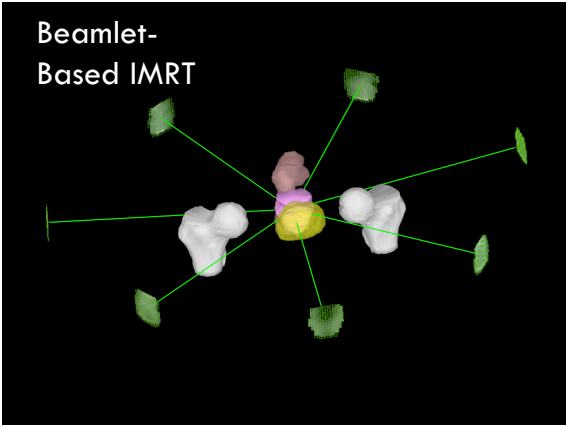
---

---

---

---

---



---

---

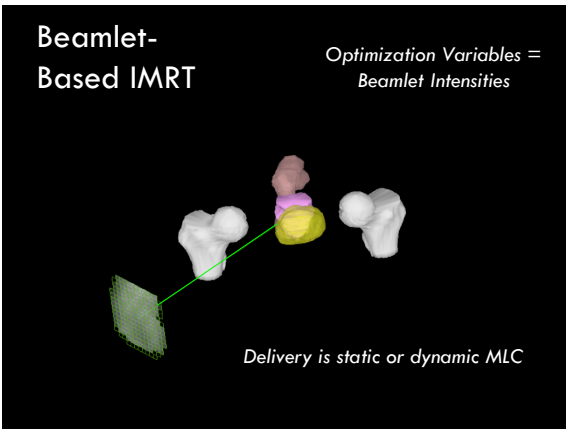
---

---

---

---

---



---

---

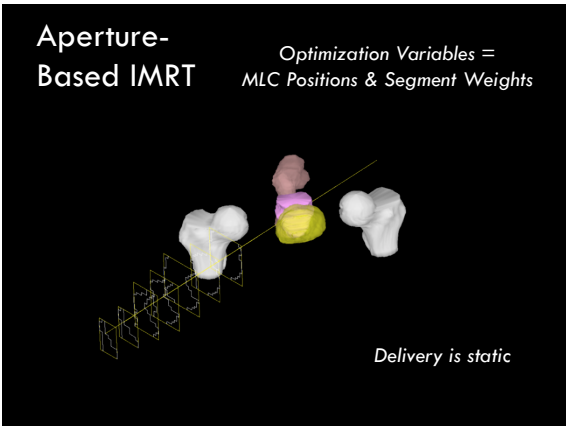
---

---

---

---

---



---

---

---

---

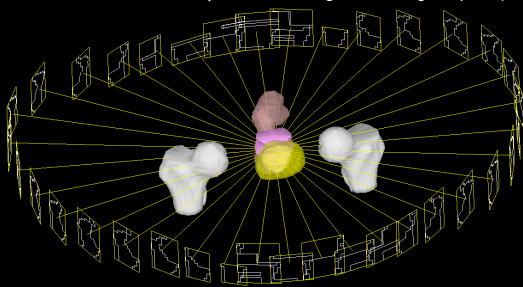
---

---

---

VMAT

Optimization Variables  
= MLC positions & segment weights (MUs)



Delivery is fully dynamic (gantry, MLC, collimator, but not table), moving linearly between MLC positions while the beam is on with variable dose rate and gantry speed

---

---

---


---

---

---

---

---

What does the literature say?

- Otto Med Phys 2008: "dose distributions equivalent or superior to static gantry IMRT"
- Bedford Med Phys 2009: "VMAT provides treatment plans which are higher in quality and/or faster to deliver than IMRT"
- Bzdusek Med Phys 2009: "In comparison to step-and-shoot IMRT, dosimetric plan quality was comparable or improved"
- Wu UROBP 2009: "Although VMAT provided comparable PTV coverage for spine SBRT, 1 arc showed significantly worse spinal cord sparing compared with IMRT, whereas 2 arc was comparable to IMRT"
- Rao Med Phys 2010: "VMAT and HT are capable of providing more uniform target doses and improved normal tissue sparing as compared with fixed field IMRT"
- Holt UROBP 2011: "Coplanar VMAT for SBRT for early-stage lung cancer achieved plan quality and skin dose levels comparable to those using noncoplanar IMRT and slightly better than those with coplanar IMRT"
- Popescu UROBP 2010: "VMAT achieved similar PTV coverage and sparing of organs at risk (for Breast + IMN). The healthy tissue volume percentages exceeding 5 Gy were significantly larger with VMAT (53.1% ± 2.1%) and IMRT (45.3% ± 3.1%) than with IMRT (19.4% ± 3.7%)"
- Shaffer UROBP 2010: "Compared with cIMRT, VMAT achieved equal or better PTV coverage and OAR sparing while using fewer monitor units and less time to treat high-grade gliomas."
- Clemente UROBP 2011: "VMAT-S target coverage was close to that achieved by IMRT, but inferior to HT. The conformity and homogeneity within the PTV were improved for HT over all strategies"
- Quan UROBP 2012: "IMRT plan quality only similar/superior with 12-24 beams in prostate"
- Myrehaug UROBP 2012: "Unable to conclude that VMAT provides a (dosimetric) benefit to IMRT (for Pelvic Nodal RT)"

---

---

---


---

---

---

---

---

What does the literature say?

- Otto Med Phys 2008: "dose distributions equivalent or superior to static gantry IMRT"
- Bedford Med Phys 2009: "VMAT provides treatment plans which are higher in quality and/or faster to deliver than IMRT"
- Bzdusek Med Phys 2009: "In comparison to step-and-shoot IMRT, dosimetric plan quality was comparable or improved"
- Wu UROBP 2009: "Although VMAT provided comparable PTV coverage for spine SBRT, 1 arc showed significantly worse spinal cord sparing compared with IMRT, whereas 2 arc was comparable to IMRT"
- Rao Med Phys 2010: "VMAT and HT are capable of providing more uniform target doses and improved normal tissue sparing as compared with fixed field IMRT"
- Holt UROBP 2011: "Coplanar VMAT for SBRT for early-stage lung cancer achieved plan quality and skin dose levels comparable to those using noncoplanar IMRT and slightly better than those with coplanar IMRT"
- Popescu UROBP 2010: "VMAT achieved similar PTV coverage and sparing of organs at risk (for Breast + IMN). The healthy tissue volume percentages exceeding 5 Gy were significantly larger with VMAT (53.1% ± 2.1%) and IMRT (45.3% ± 3.1%) than with IMRT (19.4% ± 3.7%)"
- Shaffer UROBP 2010: "Compared with cIMRT, VMAT achieved equal or better PTV coverage and OAR sparing while using fewer monitor units and less time to treat high-grade gliomas."
- Clemente UROBP 2011: "VMAT-S target coverage was close to that achieved by IMRT, but inferior to HT. The conformity and homogeneity within the PTV were improved for HT over all strategies"
- Quan UROBP 2012: "IMRT plan quality only similar/superior with 12-24 beams in prostate"
- Myrehaug UROBP 2012: "Unable to conclude that VMAT provides a (dosimetric) benefit to IMRT (for Pelvic Nodal RT)"

---

---

---

---

---

---

---

---



### SAM Question 1

1. The main advantage of VMAT compared to IMRT is:
  - a. Improved target coverage
  - b. Improved delivery efficiency
  - c. Reduced integral patient dose
  - d. Improved sparing of normal tissues
  - e. Faster dose calculations

---

---

---

---

---

---

---



### SAM Answer 1

- Answer: b

Otto K. Volumetric modulated arc therapy: IMRT in a single gantry arc. Med Phys 35 (2008)

---

---

---

---

---

---

---

### Prostate IMRT vs VMAT (Princess Margaret Hospital)

- Retrospective comparison of sequential cohorts
  - The last 146 prostate patients treated with IMRT
  - The first 147 prostate patients treated with VMAT
- Identical prescription doses, contouring, IGRT, QA



Cuthbert, Lindsay, Craig, Catton (PMH)




---

---

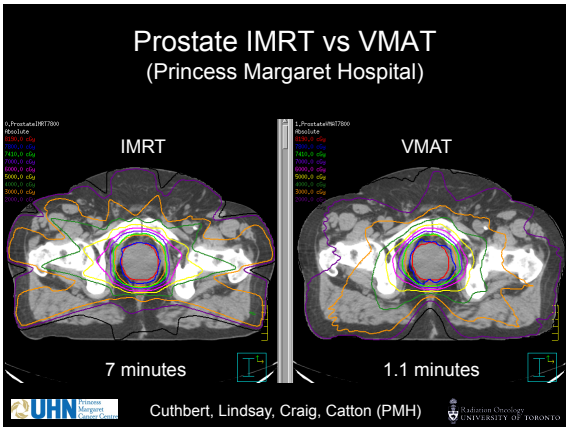
---

---

---

---

---



---

---

---

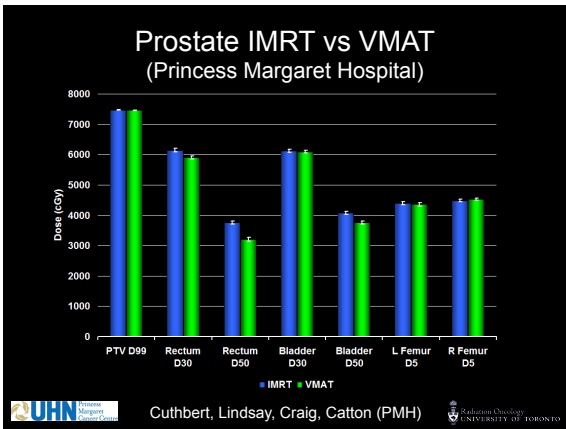
---

---

---

---

---



---

---

---

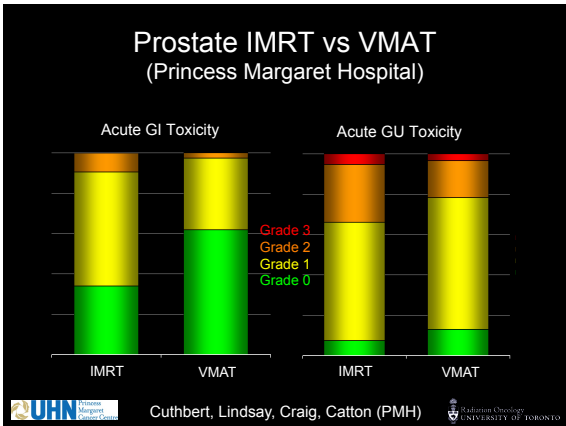
---

---

---

---

---



---

---

---

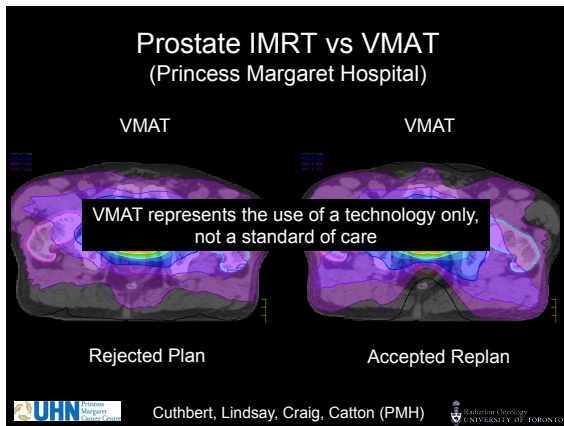
---

---

---

---

---




---

---

---

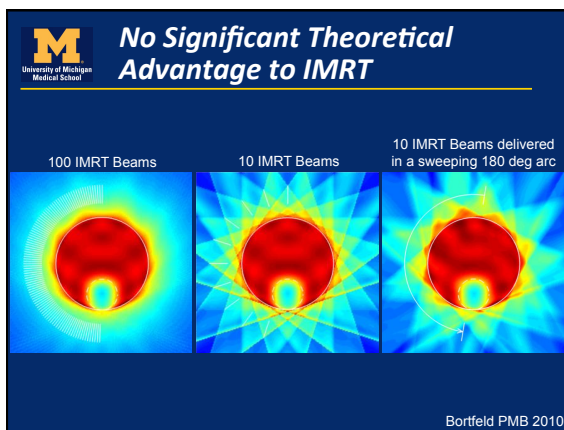
---

---

---

---

---




---

---

---

---

---

---

---

---

### Take Home Message from Literature

- Treatment planning comparisons between IMRT and VMAT are very dependent
  - Planning system
  - Planner experience
  - Comparison methods ( i.e. normalization)
- VMAT and IMRT are capable of producing similar dosimetric quality in most situations with major differences in
  - Delivery time
  - Planning time/iterations (including dose calcs)
  - Special geometric situations

---

---

---

---

---

---

---

---



### Commissioning of New Planning Techniques is Critical

- Due to the differences encountered in VMAT and IMRT planning, the transition to VMAT for certain body sites should be properly commissioned
  - Planner training and hands-on practice
  - Physician review of plan quality including differences noted in low dose and DVH shape changes
  - Physicist review of plan quality, monitor units, and quality assurance needs

---

---

---

---

---

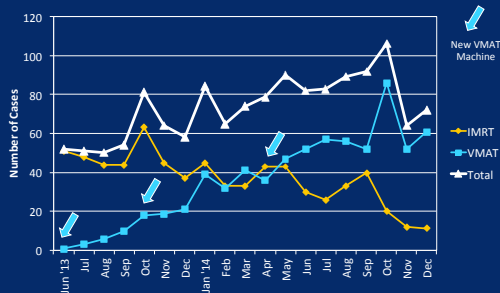
---

---

---



### VMAT and IMRT Trends at UM




---

---

---

---

---

---

---

---



### Pros and Cons of VMAT vs. IMRT at Michigan

#### PROS

- Significantly faster delivery
- Reduced MU (30-40% in many cases)
- Typically fewer normal tissue hotspots and easier planning for complex cases
- Improved optimization tools in planning system

#### CONS

- Only 3/6 machines are VMAT capable
- Flash is very difficult to add for tangential VMAT arcs
- Arc clearance challenging for some geometries (prone, extremities, tilt-board)
- Iterative planning required to reduce V5 when a concern (i.e. lung)

---

---

---

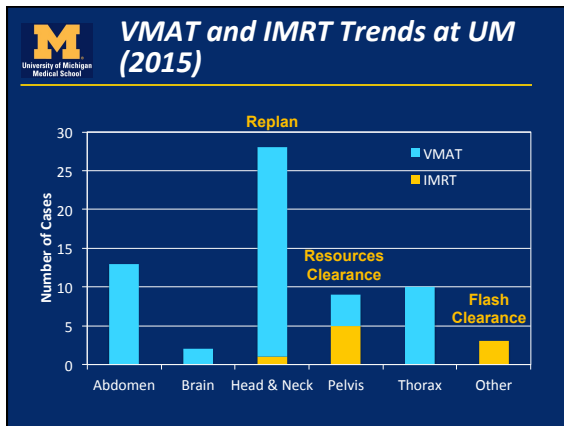
---

---

---

---

---




---

---

---

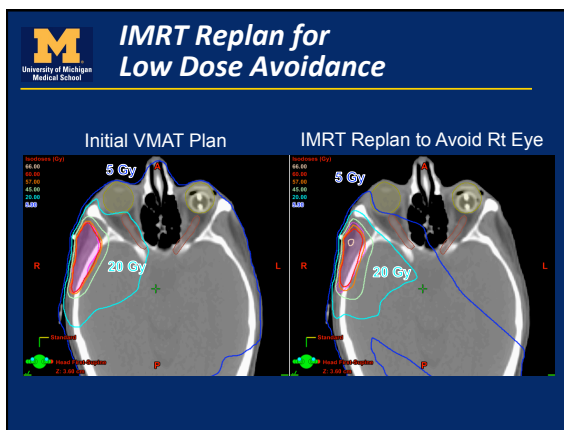
---

---

---

---

---




---

---

---

---

---

---

---

---

**IMRT for Cases Requiring Flash**

- Flash is difficult to add for VMAT
  - Methods include adding fake bolus for optimization
  - Breast planning studies may ignore flash due this issue [Tsai JACMP 2012]
- Most planning systems have fluence or segment editing capabilities to add flash for IMRT

---

---

---

---

---

---

---

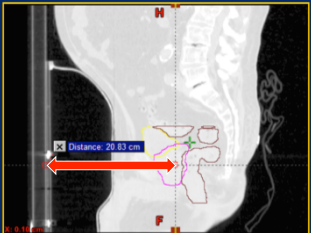
---



**M**  
University of Michigan  
Medical School

### Iso Placement & Clearance

- In order to safely rotate around the patient, the lateral + vertical distance from table to isocenter must accommodate clearance of the head and imaging devices



The diagram shows a sagittal cross-section of a patient lying on a treatment table. A red double-headed arrow indicates the distance from the table surface to the isocenter, labeled as 20.63 cm. The isocenter is marked with a green dot. The patient's head and shoulders are visible, and the diagram illustrates the clearance required for the treatment head and imaging devices to rotate around the patient.

---

---

---

---

---

---

---

**M**  
University of Michigan  
Medical School

### SAM Question 2

- Flash is most easily added to
  - Static beam IMRT treatment plans
  - Tomotherapy treatment plans
  - Single arc VMAT treatment plans
  - Dual arc VMAT treatment plans
  - 3DCRT treatment plans

---

---

---

---

---

---

---

**M**  
University of Michigan  
Medical School

### SAM Answer 2

- Answer: e

Tsai P-F et al. The feasibility study of using multiple partial volumetric-modulated arcs therapy in early stage left-sided breast cancer patients. JACMP 13 (2012)

---

---


---

---

---

---

---



## An Informal Poll

Institution	Use of VMAT vs. IMRT
1	Moving toward VMAT for all sites except breast; Only use IMRT in sites where a VMAT procedure hasn't been commissioned yet; Issues that delay implementation: dose calculation time constraints and low dose splash
2	Moving toward VMAT for all sites but may still choose IMRT on short timelines when planner is more comfortable
3	Majority VMAT except for larger thorax/abdomen cases (worry about low dose); Avoid modulation in cases with >1-1.5 cm motion
4	VMAT unless there isn't sufficient time (takes longer to plan than IMRT); Don't use VMAT or IMRT for breast
5	85% VMAT; 15% IMRT; Many prostate and brain cases still IMRT due to only 3/6 machines having VMAT; Avoid VMAT for breast, cases with flash, clearance issues

---

---


---

---

---

---

---



## Unique Considerations

- VMAT delivery efficiency is extremely beneficial for larger tumors but leads to:
  - Field size concerns
  - Low dose spread concerns

---

---


---

---

---

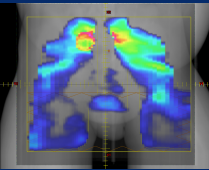
---

---

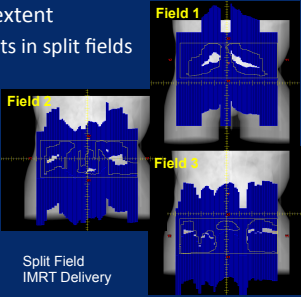


## Large Field Concerns

- Some MLCs cannot travel all the way across the jaw extent
  - For IMRT, this results in split fields



Optimized Fluence Pattern



Split Field IMRT Delivery

---

---

---

---

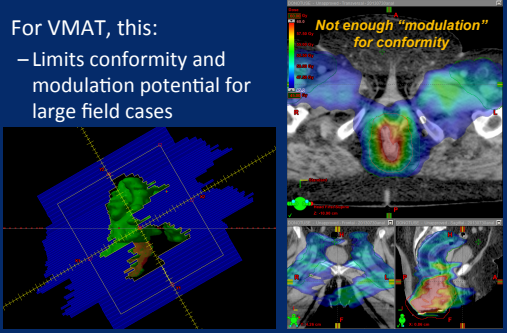
---

---

---

**Large Field VMAT**

- For VMAT, this:
  - Limits conformity and modulation potential for large field cases




---

---

---

---

---

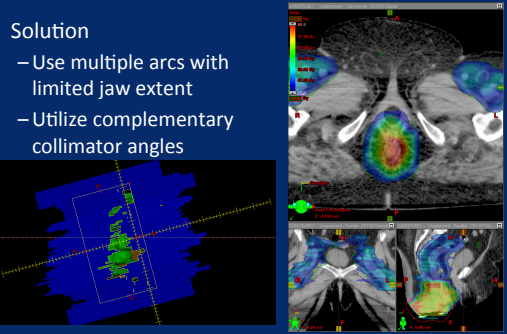
---

---

---

**Large Field VMAT**

- Solution
  - Use multiple arcs with limited jaw extent
  - Utilize complementary collimator angles




---

---

---

---

---

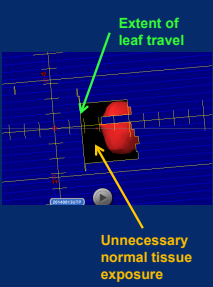
---

---

---

**Disadvantages of off-axis VMAT**

- For VMAT, this:
  - Limits conformity and modulation potential for large field cases
  - Causes unnecessary irradiation of normal tissue for off-axis isocenters




---

---

---


---

---

---

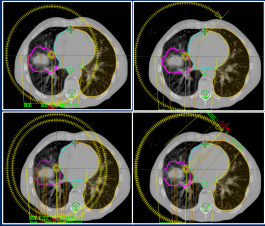
---

---



### Low Dose Concerns

- Low dose, such as V5 Gy for lung, is a concern with unrestricted full arcs
- Partial Arcs can be created by explicitly defining a start and end range or by using an avoidance sector



**Full Arc****Partial Arc**

Tong Zhu

---

---

---


---

---

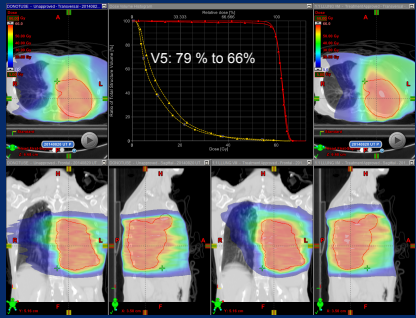
---

---

---



### Partial Arcs/Avoidance Sectors



---

---

---


---

---

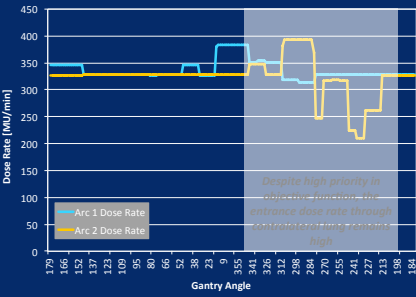
---

---

---



### Partial Arcs/Avoidance Sectors



---

---

---

---

---

---

---

---

**University of Michigan Medical School**

### Another Option: Hybrid 3D + IMRT/VMAT Techniques

AP/PA 3DCRT w/ segments + Single Arc VMAT  
(Optimized on top of 3D plan)

Charles Mayo

---

---

---

---

---

---

---

---

**University of Michigan Medical School**

### Another Option: Hybrid 3D + IMRT/VMAT Techniques

Composite Hybrid Lung Plan

Charles Mayo

---

---

---

---

---

---

---

---

**University of Michigan Medical School**

### SAM Question 3

- The volume of normal tissue receiving low dose (i.e. about 10% Rx Dose) to the contralateral side of the body is likely highest with
  - A 7 field IMRT plan
  - A 5 field IMRT plan
  - A full arc VMAT plan
  - A partial arc VMAT plan
  - A 3 field 3DCRT plan

---

---

---

---

---

---

---

---



### SAM Answer 3

- Answer: c

Popescu CC et al. Volumetric modulated arc therapy improves dosimetry and reduces treatment time compared to conventional intensity-modulated radiotherapy for locoregional radiotherapy of left-sided breast cancer and internal mammary nodes. *Int J Radiat Oncol Biol Phys.* 76 (2010)

Jiang X et. al. Planning analysis for locally advanced lung cancer: dosimetric and efficiency comparisons between intensity-modulated radiotherapy (IMRT), single-arc/partial-arc volumetric modulated arc therapy (SA/PA-VMAT). *Radiat Oncol.* 140 (2011)

---

---

---

---

---

---

---

---



### Take Home Message

- VMAT and IMRT are both capable of providing high quality dosimetric plans
- Commissioning a procedure for any new technique is critical
  - Inverse plan quality is highly dependent on planner experience
  - VMAT and IMRT have different unique issues that should be investigated during commissioning of a body site – not “on the fly”
- The increase in efficiency with VMAT makes it the the modulated technique of choice in many clinics with exceptions in cases where there are concerns regarding resource utilization, planner experience, flash/clearance, and low dose spread

---

---

---

---

---

---

---

---



### Acknowledgements

- |                |   |
|----------------|---|
| • Don Roberts  | • Tim Craig,<br>Princess Margaret<br>Hospital |
| • Jean Moran   |   |
| • Kelly Younge | • Rebecca Howell,<br>MD Anderson              |
| • Choonik Lee  |   |
| • Pam Burger   | • Indrin Chetty,<br>Henry Ford                |
| • Janell Dow   |   |
| • UM Rad Onc   | • Chuck Mayo,<br>Mayo Clinic                  |

---

---

---

---

---

---

---

---