Increasing the number of Arcs improves VMAT plan quality for complex shaped Pelvic targets.

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DISCLAIMER

• This presentation is not sponsored by any vendor nor is it endorsing any specific TPS or one delivery system over others.
• The material presented is based solely on my planning experience across multiple TPS, delivery systems.
• The intention of this talk is meant for educational purposes.
• The technique discussed should be evaluated on a case by case basis to see if it can apply to your clinical settings.
OBJECTIVES

• To provide an overview of Intensity modulated radiotherapy for Pelvic malignancies.
• To review existing literature for the efficacy in treatment of large pelvic fields.
• To review VMAT planning techniques and tools for creating optimal VMAT plans
• To examine the quality of plans that can be obtained using VMAT4.

OUTLINE

• XRT of the Pelvic area
• Literature Review
• Contouring
• Rings
• Beam setup-Use of Multiple Arcs/different collimator angles
• Field size limitations
• Role of VMAT in SIB scenario
• 2 arcs vs. 4 arcs Dosimetric plan evaluation
XRT of the Pelvis

• Large variation in the shape and sizes of the target
  • Cancer (Prostate or endometrial vs. Anorectal or Vulvar)
  • disease
  • progression/extent of disease

Common Sites:
• Prostate
• Bladder
• Rectum
• Anus
• Endometrial
• Cervical
XRT of the Pelvis

XRT of the Pelvis
XRT of the Pelvis

[Images of X-ray scans of the pelvis]

XRT of the Pelvis

[Images of X-ray scans of the pelvis]
XRT of the Pelvic area

Treatment planning challenges:
• Abutting dose sensitive OARs.
• Concurrent chemotherapy.
• Large Field size and machine limitations
XRT of the Pelvis

- RT+ Concurrent chemo → potential toxicities
  - Small bowel → diarrhea, malabsorption, SBO, enteritis
  - Rectum → diarrhea, rectal bleeding, proctitis
  - Bone Marrow → WBC, platelets, anemia
  - Pelvic Bones → Insufficiency fractures, necrosis
- Volume of normal tissues irradiated → risk of acute and chronic RT side effects.

Radiation Complications…

Credit: Dr. Vishwanathan et al. Complications of Pelvic Radiations in patients treated for Gynecological Malignancies.

Radiation Complications…

Courtesy: Dr. Vishwanathan et al. Complications of Pelvic Radiations in patients treated for Gynecological Malignancies.
Radiation Complications…

• 39% of human bone marrow is in field/around pelvic tx field + ~12% in lower lumbar spine

FLT/PET imaging showing loss of active bone marrow during chemo/RT
Intensity modulated radiation therapy (IMRT)

- Conformal dose distribution around an irregular shaped target volume.
- Delivers non-uniform beam intensities
- Exact patient positioning and motion management.
- Image guidance: ability to image patient daily at time of treatment.

Credit: Roeske – AAPM 2006  Role of IMRT in the Treatment of Gynecologic Malignancies
Better OAR sparing with intensity modulation,

Abstract

Purpose: To evaluate the ability of intensity-modulated radiation therapy (IMRT) to reduce the volume of small bowel irradiated in women with gynecologic malignancies receiving whole pelvic radiotherapy (WPRT).

Initial Clinical Experience with Intensity-Modulated Whole-Pelvis Radiation Therapy in Women with Gynecologic Malignancies

Abstract

Objective: Our goal in this article is to describe our initial experience with intensity-modulated whole-pelvis radiation therapy (IM-WPRT) in gynecologic malignancies.
Int J. Radiat Oncol Biol Phys. 2001 Sep 1;51(1):261-6

Abstract

Purpose

To evaluate intensity-modulated whole pelvis radiotherapy (IM-WPRT) (with bone marrow [BM] as a planning constraint) as a means to reduce the volume of pelvic BM irradiated.
Literature review.. IMRT and OAR Sparing

ORIGINAL ARTICLE

The normal tissue sparing obtained with simultaneous treatment of pelvic, lymph nodes and bladder using intensity-modulated radiotherapy

YI QIANG1, YANHONG WANG2, KAI CHEN3, XINPING CAI3 and YIMING ZENG3

1Department of Radiotherapy, Sun Yat-Sen University Cancer Center, State Key Laboratory of Oncology in South China, Collaborative Innovation Center for Cancer Medicine, Guangzhou, Guangdong 510006; 2Department of Radiotherapy, Respiratory Department, The Second Affiliated Hospital of Fujian Medical University, Quanzhou, Fujian 362000, P.R. China

Received July 22, 2016; Accepted July 11, 2017

DOI: 10.3892/ol.2017.7077

Literature Review..SIB.

ONCOLOGY LETTERS 14: 2068-2076, 2017

Clinical outcome of extended-field irradiation vs. pelvic irradiation using intensity-modulated radiotherapy for cervical cancer

YI QIANG1, YANHONG WANG2, KAI CHEN3, XINPING CAI3 and YIMING ZENG3

1Department of Radiotherapy, Sun Yat-Sen University Cancer Center, State Key Laboratory of Oncology in South China, Collaborative Innovation Center for Cancer Medicine, Guangzhou, Guangdong 510006; 2Department of Radiotherapy, Respiratory Department, The Second Affiliated Hospital of Fujian Medical University, Quanzhou, Fujian 362000, P.R. China

Received July 22, 2016; Accepted July 11, 2017

DOI: 10.3892/ol.2017.7077
Volumetric-modulated arc therapy

VMAT: Volumetric modulated arc therapy
• IMRT with multiple beam angles
• Variable aperture shape, delivery dose rate, and gantry speed as the gantry rotates
• Shorter tx time compared to IMRT ⇒ Less intra-fraction movement
• Using Optimization similar to IMRT Optimization
• Tx delivered in a single 360 degree rotation or multiple arcs
• Dose highly conformal, than conventional IMRT

Contouring for IMRT…
• Contouring accuracy is very important
• Pay extra attention to overlapping structures for optimization
  – Critical structures from targets
  – Multiple targets with varying dose constraints (SIB)
Contouring OAR’s…

- Normal tissues delineated depends on the clinical case
- Small bowel, rectum, Colon, bladder, femoral heads.
- Patients receiving chemotherapy, include the bone marrow
- Kidneys and liver included if treating more comprehensive fields
Contouring- Female pelvis

https://www.rtog.org/LinkClick.aspx?fileticket=P5eAjYB90Ow%3d&tabid=355

Contouring- male pelvis

https://www.rtog.org/LinkClick.aspx?fileticket=054g99vNGps%3d&tabid=354
Literature review .. Simultaneous integrated boost (SIB)

Intensity Modulated Radiation Therapy (IMRT): A New Promising Technology in Radiation Oncology

BIN S. TEEH, SIBAO Y. WOO, E. BRIAN BUTLER
Department of Radiology/Radiation Oncology, Baylor College of Medicine, Houston, Texas, USA

Abstract

Intensity modulated radiation therapy (IMRT) is a new technology in radiation oncology that delivers radiation more precisely to the tumor while relatively sparing the surrounding normal tissues. It also introduces new concepts of inverse planning and computer-controlled radiation deposition and normal tissue avoidance in contrast to the conventional trial-and-error approach. IMRT has wide application in most aspects of radiation oncology because of its ability to create multiple targets and multiple avoidance structures, to treat different targets simultaneously in different doses as well as to weight targets and avoidance structures according to their importance. By delivering radiation with greater precision, IMRT has been shown to minimize acute treatment-related morbidity, making dose escalation feasible which may ultimately improve local tumor control. IMRT has also introduced a new accelerated fractionation scheme known as SMART (simultaneous modulated accelerated radiation therapy) boost. By shortening the overall treatment time, SMART boost has the potential of improving tumor control in addition to offering patient convenience and cost savings. *The Oncologist* 1995; 4:124-142
Literature review: Simultaneous integrated boost (SIB)

Assessing the feasibility of volumetric-modulated arc therapy using simultaneous integrated boost (SIB-VMAT): An analysis for complex head-neck, high-risk prostate and rectal cancer cases

Savino Cilla, Ph.D., Francesco Deodato, M.D., Cinzia Digesù, M.D., Gabriella Macchia, M.D., Vincenzo Picardi, M.D., Marica Ferro, M.D., Giuseppina Sallustio, M.D., Marco De Spatio, Ph.D., Angelo Piermattet, Ph.D., and Alessio G. Morganti, M.D.

Dosimetry Contribution:
Simultaneous integrated boost (SIB) for treatment of gynecologic carcinoma: Intensity-modulated radiation therapy (IMRT) vs volumetric-modulated arc therapy (VMAT) radiotherapy

Irina Vergalasova, Ph.D., Kim Light, C.M.D., Junzo Chino, M.D., and Oana Craciunescu, Ph.D.

*Department of Radiation Oncology, Rutgers The Cancer Institute of New Jersey, New Brunswick, NJ, USA; and †Department of Radiation Oncology, Duke University Medical Center, Durham, NC, USA
Literature Review..SIB.

ONCOLOGY LETTERS 16: 2966-2975, 2017

Clinical outcome of extended-field irradiation vs. pelvic irradiation using intensity-modulated radiotherapy for cervical cancer

YI OUYANG1*, YANHONG WANG2*, KAI CHEN2, XINPING CAO3 and YIMING ZENG3

1Department of Radiotherapy, Sun Yat-Sen University Cancer Center, State Key Laboratory of Oncology in South China, Collaborative Innovation Center for Cancer Medicine, Guangzhou, Guangdong 510060; 2Department of Radiotherapy, Respiratory Department, The Second Affiliated Hospital of Fujian Medical University, Quanzhou, Fujian 362000, P.R. China

Received July 22, 2016; Accepted July 11, 2017

DOI: 10.3892/ol.2017.7077

Simultaneous integrated boost (SIB).
Multiple targets with varying dose constraints (SIB)

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Multiple targets with varying dose constraints (SIB)

INOMA
Join the future of health.

40
Multiple targets with varying dose constraints (SIB)

41

Multiple targets with varying dose constraints (SIB)

42
A tale of two Rings…

• Ring – Pseudo structures around the target volume
• Helpful in dose optimization.
Rings…

Rings…
Rings in SIB scenario….

Rings….
- increase in the complexity of control points
- number of MUs, especially for complex-shaped target volumes.
- Heterogeneity in plan
Field size limitation:

- hardware restrictions for MLC movements
  1) inability of two separate MLC openings simultaneously in the direction of leaf movements at a specific gantry angle.
  2) restricted MLC velocity from one GA to another.

- physical limitations of the MLC geometry
  1) opening considerably wider than 15 cm in the direction of the MLC movements

Literature field size limitation:

A NEW APPROACH TO REDUCE NUMBER OF SPLIT FIELDS IN LARGE FIELD IMRT

Chen-Chao Lee, M.S., Andrew Wu, Ph.D., Madhur Garg, M.D., Subharak Mutyala, M.D., Shalom Kalnecki, M.D., Gary Sayed, Ph.D., and Dinani Mah, Ph.D.

Department of Radiation Oncology, Montefiore Medical Center and Albert Einstein College of Medicine, Bronx, NY; and Department of Radiologic Sciences, Thomas Jefferson University, Philadelphia, PA

(Received 12 March 2009; accepted 7 October 2009)

Abstract—Intensity-modulated radiation therapy (IMRT) has been applied for treatments of primary head with neck nodes, lung with supravacular nodes, and high-risk prostate cancer with pelvic wall nodes, all of which require large fields. However, the design of the Varian multileaf collimator requires fields >14 cm in width to be split into 2 or more carriage movements. With the split-field technique, both the number of monitor units (MUs) and total treatment time are significantly increased. Although many different approaches have been investigated to reduce the MUs, including introducing new leaf segmentation algorithms, none have resulted in widespread success. In addition, for most clinics, writing such algorithms is not a feasible solution, particularly with commercial treatment planning systems. We introduce a new approach that can minimize the number of split fields and reduce the total MUs, thereby reducing treatment time. The technique is demonstrated on the Eclipse planning system V7.3, but could be generalized to any other system. © 2011 American Association of Medical Dosimetrists.
Reducing split fields in large-field IMRT • C.-C. Li et al.

DOSEMETRIC COMPARISON OF SPLIT FIELD AND FIXED JAW TECHNIQUES FOR LARGE IMRT TARGET VOLUMES IN THE HEAD AND NECK

SHIV P. SRIVASTAVA, M.S., INDERA J. DAS, PH.D., F.A.C.R., ARVIND KUMAR, PH.D., M.D., and PETER A. S. JOHNSTONE, M.D., F.A.C.R.

Department of Radiation Oncology, Reid Hospital and Health Care Services Richmond, IN; and Department of Radiation Oncology, Indiana University School of Medicine, Indianapolis, IN.

(Received 19 December 2006; accepted 8 October 2009)

Abstract—Some treatment planning systems (TPSs), when used for large-field (>14 cm) intensity-modulated radiation therapy (IMRT), create split fields that produce excessive multiple-leaf collimator segments, mismatch, dose inhomogeneity, and higher treatment times than non-split fields. A new method using a fixed-jaw technique (FJT) forces the jaw to stay at a fixed position during optimization and is proposed to reduce problems associated with split fields. Dosimetric comparisons between split-field techniques (SFT) and FJT used for IMRT treatment is presented. Five patients with head and neck malignancies and regional target volumes were studied and compared with both techniques. Treatment planning was performed on an Eclipse TPS using beam data.
A novel arc geometry setting for pelvic radiotherapy with extensive nodal involvement

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Received 27 August, 2015; accepted 18 February, 2016
Field size limitation.
Field size limitation

![Field size limitation image](image_url)

**Literature review**

**IOP Publishing**  
doi:10.1088/0031-9155/54/1/N02

**NOTE**

**Single-Arc IMRT?**

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\textsuperscript{2} Joint Department of Physics, Institute of Cancer Research and Royal Marsden NHS Foundation Trust, Downs Road, Sutton, Surrey, SM2 5PT, UK

Received 19 August 2008, in final form 16 November 2008  
Published 10 December 2008

Online at stacks.iop.org/PMB/54/N9
Multiple Arcs..

IMRT
Is a single arc sufficient in volumetric-modulated arc therapy (VMAT) for complex-shaped target volumes?
Matthias Guckenberger *, Anne Richter, Thomas Krieger, Juergen Wilbert, Kurt Baier, Michael Flentje
Department of Radiation Oncology, University of Würzburg, Würzburg, Germany

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Keywords:
Step-and-shoot intensity-modulated radiotherapy (s-IMRT) with volumetric-modulated arc therapy (VMAT) for complex-shaped target volumes with a simultaneous integrated boost (SIB).

ABSTRACT
Purpose: To compare step-and-shoot intensity-modulated radiotherapy (s-IMRT) with volumetric-modulated arc therapy (VMAT) for complex-shaped target volumes with a simultaneous integrated boost (SIB).
Methods and methods: This retrospective planning study was based on 20 patients composed of prostate cancer (n = 5), postoperative (n = 5) or primary (n = 5) radiotherapy for pharyngeal cancer and for cancer of the paranasal sinuses (n = 5). A SIB with two or three dose levels was planned in all patients. For each patient, one s-IMRT plan with direct-machine-parameter optimization (DIMP) and VMAT plans with one to three arcs (SMARTArc technique) were generated in the Pinnacle planning system.

Literature..Increasing # arcs....
Medical Physics Contribution:

Modeling the target dose fall-off in IMRT and VMAT planning techniques for cervical SBRT


*Department of Radiation Oncology, School of Medicine, Cancer Therapy & Research Center, The University of Texas Health Science Center San Antonio, San Antonio, TX 78229, USA, and †Department of Radiation Oncology, Miami Cancer Institute, 8000 North Kendall Drive, Miami, FL 33179, USA

<table>
<thead>
<tr>
<th>IMRT6 MV</th>
<th>IMRT 10 MV</th>
<th>VMAT2-ac 4 MV</th>
<th>VMAT2-ac 10 MV</th>
<th>VMAT3-ac 6 MV</th>
<th>VMAT3-ac 10 MV</th>
</tr>
</thead>
<tbody>
<tr>
<td>60.9%</td>
<td>59.9%</td>
<td>60.4%</td>
<td>56.6%</td>
<td>58.8%</td>
<td>55.2%</td>
</tr>
<tr>
<td>47.3%</td>
<td>45.1%</td>
<td>42.1%</td>
<td>38.4%</td>
<td>37.2%</td>
<td>35.5%</td>
</tr>
<tr>
<td>39.6%</td>
<td>39.3%</td>
<td>35.1%</td>
<td>32.4%</td>
<td>32.0%</td>
<td>28.4%</td>
</tr>
<tr>
<td>36.4%</td>
<td>37.2%</td>
<td>31.8%</td>
<td>29.4%</td>
<td>27.4%</td>
<td>26.5%</td>
</tr>
</tbody>
</table>

Table 5: Table shows the model calculated percent dose fall-off relative to the PTV edge at 1 cm, 2 cm, 3 cm, and 4 cm away for each treatment planning technique for different PTV size categories.
"I think you should be more explicit here in step two."
Current Study 4Arcs vs. 2 Arcs

Does increasing the number of arcs improve VMAT plan quality for complex shaped Pelvic targets?

Mathews, Thomas C.M.D, Majithia, Loniya M.D, Sun, Jason M.D
Dwight and Martha Schor Cancer Institute, Inova Alexandria Hospital, VA USA

- to evaluate the dosimetric and practical differences between VMAT2 and VMAT4 arcs in the irradiation of complex shaped targets volumes in pelvic radiation (+ SIB).
- n=15 with complex target shapes of pelvic disease sites ranging from Uterus (n=5), Cervix (n=5) and Anal (n=5).

Set up Gantry/collimator angles
- Tongue and groove effect
- 2 full arcs –complimentary collimator angles
  - 10° / 350°
  - 30° / 330°
  - 45° / 315°
Current Study..

- 4 Arcs
  - 2 full arcs – complimentary angles
    - $10^\circ$ / $350^\circ$
    - $30^\circ$ / $330^\circ$
    - $45^\circ$ / $315^\circ$
  - 2 full arcs – complimentary angles
    - $85^\circ$ / $105^\circ$
    - $80^\circ$ / $100^\circ$
    - $70^\circ$ / $110^\circ$

<table>
<thead>
<tr>
<th>Fields</th>
<th>Dose Prescription</th>
<th>Field Alignments</th>
<th>Plan Objectives</th>
<th>Optimization Objectives</th>
<th>Dose Statistics</th>
<th>Calculation Models</th>
<th>Plan Status</th>
<th>Cell Kill [%]</th>
<th>Efficiency [%]</th>
<th>Dose [%]</th>
<th>VMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4 Coll Arcs</td>
<td>ARC-1</td>
<td>Varian 2100C</td>
<td>VMAT</td>
<td>0.500</td>
<td>Varian 2100C</td>
<td>91.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Plan Evaluation Criteria

- dose constraints
- coverage objectives
- optimization parameters
- Optimization priorities

- 100% of the PTV > 95% coverage of the Rx dose.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Dose or volume objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV55Gy</td>
<td>Dmax ≤ 110% (55Gy)</td>
</tr>
<tr>
<td></td>
<td>D100% = 100% Rx (55Gy)</td>
</tr>
<tr>
<td></td>
<td>D105% = 5%</td>
</tr>
<tr>
<td>PTV45Gy (PTV55Gy)</td>
<td>Dmax ≤ 100% (55Gy)</td>
</tr>
<tr>
<td></td>
<td>D100% = 100% Rx (45Gy)</td>
</tr>
<tr>
<td></td>
<td>D105% = 10%</td>
</tr>
<tr>
<td>Rectum</td>
<td>Dmax ≤ 108% (59.4Gy)</td>
</tr>
<tr>
<td></td>
<td>V40% = 80%</td>
</tr>
<tr>
<td></td>
<td>Dmax ≤ 105% (58Gy)</td>
</tr>
<tr>
<td></td>
<td>V40% &lt; 40%</td>
</tr>
<tr>
<td>Bladder</td>
<td>Dmax ≤ 108% (59.4Gy)</td>
</tr>
<tr>
<td></td>
<td>V45Gy &lt; 45%</td>
</tr>
<tr>
<td></td>
<td>D2cc &lt; 70Gy</td>
</tr>
<tr>
<td>Colon</td>
<td>Dmax ≤ 108% (59.4Gy)</td>
</tr>
<tr>
<td></td>
<td>V45Gy &lt; 45%</td>
</tr>
<tr>
<td></td>
<td>Dmax ≤ 105% (58Gy)</td>
</tr>
<tr>
<td></td>
<td>V45Gy &lt; 195cc</td>
</tr>
<tr>
<td>Small Bowel</td>
<td>Dmax ≤ 108% (59.4Gy)</td>
</tr>
<tr>
<td></td>
<td>V45Gy &lt; 195cc</td>
</tr>
<tr>
<td>Femurs (Rt+Lt Femurs)</td>
<td>Dmax ≤ 110% (36.4Gy)</td>
</tr>
<tr>
<td></td>
<td>D100% = 100%</td>
</tr>
<tr>
<td>Bone Marrow (Iliac Crest, Scarum, Lower Lum Vert Body)</td>
<td>V10Gy &lt; 90%</td>
</tr>
<tr>
<td></td>
<td>V25Gy &lt; 90%</td>
</tr>
</tbody>
</table>

* Secondary constraint if primary cannot be achieved.
Metrics and evaluation methods

OAR Evaluation metrics:
- **D 0.03cc**—measure of the maximum dose quantified to a specific volume of 0.03cc of the structure;
- **Dmean**—mean dose to the structure; and
- **Dmax**—maximum point dose to the structure.
- For the organs at risk (OARs), **D2cc, V30, V40, V45, and V50**, were evaluated for the bladder, bowel bag, femoral heads, Rectum, Bone Marrow and sigmoid.

Plan Evaluation

PTV Evaluation metrics:
- Conformity index (CI),
- Homogeneity index (HI),
- **Dmean** and **Dmax** for both the PTV volumes.
- PTV coverage: **D98, D2, Dmean, V95%, and V107%** (the volume receiving 95% or 107% of the prescribed dose, respectively).
Conformity index (CI)

- Conformity index = \( \frac{TV_{PIV}^2}{TV \times PIV} \)

- The lower the score is, the less conformity the plan has.
- The index assigns under-treatment as being equally as bad as overtreatment.
- An overtreatment of 10% gives a score of 0.9, and a 10% under treatment also gives a score of 0.9.
- The ideal value for the conformity index is equal to 1 where the 100% isodose is exactly equal to the PTV in shape, volume and position.


Paddick CI=

\[ \frac{TV_{PIV}^2}{TV \times PIV} \]

where

- \( TV_{PIV} \) = Target volume covered by Rx isodose volume.
- \( TV \) = Target Volume
- \( PIV \) = Prescription Isodose Volume

Homogeneity index (HI)

- The dose homogeneity index (HI) was determined as follows:
  \[ HI = \frac{D2\% - D98\%}{D50\%} \]

  where
  - D2\% is the maximum dose received by 2\% of PTV,
  - D98\% is the minimum dose received by 98\% of PTV,
  - and D50\% is the dose received by 50\% of PTV.

  [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5330172/](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5330172/)
Plan Comparison:

VMAT4 vs. VMAT2. Dose conformality in simple SIB GYN targets

Dose spill in higher target volume seen in VMAT2

VMAT4 vs. VMAT2. Dose conformality in complex SIB targets
Plan comparison……

VMAT4 plan showing better OAR sparing in the rectum/colon region in Gyn case

Plan comparison……

VMAT4 plan showing better OAR sparing in the bowel/Bladder region anal case
MU comparison…

- Higher MUs in VMAT4 plans.
- A mean MUs difference of approximately 9.7% when compared to the VMAT2.
- The MU’s on average were 579.82 for VMAT4 and 523.38 for VMAT2.
- MU differences were not as significant as quoted in many other literatures.

Limitations…

- A limitation of the study was the diversity of the treatment volume size and shape.
- Delgado et al. compared the sizes of target volumes and their effect on the dose fall-off and concluded that OAR sparing and dose fall-off beyond the PTV is dependent on target volume size.
Dosimetric effects of photon energy on the plan quality

10-MV photons –
- statistically significantly lower relative integral dose,
- skin Dmax, volume 105%
- monitor units,
- OAR V30 than plans using 6-MV photons.
- no difference in rectal dose, high-dose-region bladder dose, PTV coverage, or conformity index.
- more pronounced for thicker patients (AP separation > 21 cm)

Discussion…
- Limiting dose spill to the overlapping tissues directly adjacent to the PTV’s is critical and at the same time challenging to achieve without losing coverage.
- by taking advantage of the VMAT4 capability of greater modulation to conform dose tighter to the PTV, better OAR sparing can be achieved.
Results

- improved capability of VMAT4 plans in obtaining a high level of modulation in SIB scenario over dual arc VMAT at cost of increased delivery times, increased MU’s and increased spread of low doses.
- very effective treatment technique for complex SIB treatment sites, such as head-neck, high-risk prostate, and pelvic cancers, that combines the advantages of dynamic IMRT with its highly conformal dose distribution, OARs sparing, and SIB approach
- The complexity of the target volume determined whether single arc VMAT was equivalent to multiple arcs.

Conclusion…

- Increasing the number of arcs has an advantage for complex shaped SIB targets but the technique of choice should be dependent on the patient’s target volume complexity, on departmental patient load and should be considered on a case-case situation.
- Simply slight increase in the treatment time or MU’s delivered shouldn’t be the deciding factor in picking one technique over another.
To the horror of the bystanders, "The Amazing Jimmy" miscalculates as he attempts to juggle a pin, a bowling ball and an elephant......

Practice of IMRT with SIB requires a high level of confidence in the accuracy of the entire treatment delivery process....

Conclusion...

- High confidence in precision of tumor delineation, identification and dose delivery, even with moving targets.
  - Dose errors will be more dramatic.
  - High Doses are very potent and biologically damaging, both to tumor and normal tissue.
  - Highly conformal
  - Sharp gradients from high to low dose areas.
Acknowledgments

- Dr. Lonika Majithia
- Dr. Jason Sun
- Dr. Brian Butler; Dr. Bin S. Teh; Dr. Arnold Paulino

Questions::
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• Is a single arc sufficient in volumetric-modulated arc therapy (VMAT) for complex-shaped target volumes? M. Guckenberger  Radiotherapy and Oncology Volume 93, Issue 2, 259-265
