Leibel Memorial Symposium
Advanced IMRT Planning and Delivery

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In memory of Steven Leibel

• Common roots?
  – The name Leibel originates from the area of Braunschweig, Germany
  – Leibel, Laib = Loaf → Leibel = Baker

IMRT in 1993 – presentation at Memorial Sloan Kettering in July of 1993
• IMRT delivery on Varian Clinac 2100C (MLC Mark0) – MD Anderson Cancer Center, Houston
• 9 equispaced IMRT beams delivered to prostate phantom, 20-30 segments each
• Inverse treatment planning with OPT3D program – DKFZ Heidelberg, Germany

IMRT in 1993
IMRT delivered to phantom stacked with film

T. Bortfeld, A. Boyer, et al. 1993
IMRT in 1993

• 6 films in different slices showing concave dose distributions

• Overlay on anatomy

Translation into clinical use: 1995

Ling et al., IJROBP 35(4): 721-730, 1996

81 Gy isodose: bends around rectum

Delivery time: 3 hours

Therapeutic Dose
Target

(c) A. Boyer, T. Bortfeld, 1993

Radiotherapy and Oncology 55 (2000) 241-249

Clinical experience with intensity modulated radiation therapy (IMRT) in prostate cancer

Michael J. Zelefsky a,*, Zvi Fuchs a, Laura Happesetti a, Henry J. Lee b, C. Clifton Ling c, Chandra M. Burman f, Margie Hunt f, Theresa Wolff f, E.S. Venkataraman f, Andrew Jackson b, Mark Skvorcuk e, Steven A. Leibel f

• Dose escalation 81 Gy
  -> reduced biochemical failure
  – 61 3DCRT patients
  – 171 IMRT patients

• Results
  ... The 2-year actuarial risk of grade 2 bleeding was 2% for IMRT and 10% for conventional 3D-CRT
... but where is the evidence that IMRT is indeed objectively better?

- Clinical results from randomized trials become available in Europe, e.g.:
  - Al Mamgani et al., Int J Radiat Oncol Biol Phys 2009: “...IMRT reduced the toxicity without compromising the outcome in patients with localized prostate cancer...”
  - Nutting et al., Lancet Oncol. 2011: “Sparing the parotid glands with IMRT significantly reduces the incidence of xerostomia and leads to recovery of saliva secretion and improvements in associated quality of life,...”

Advanced IMRT planning and delivery

-- Outline --

1. The IMRT story, clinical impact ✅
2. Advanced IMRT delivery
3. Developments in IMRT planning (at MGH)
CLINICAL REALIZATION OF 3D CONFORMAL INTENSITY MODULATED RADIOTHERAPY: REGARDING BORTFELD ET AL., IJROBP 30:899–908; 1994

If intensity modulated therapy does improve patient outcome, it is clear that the systems of the future will be different from these used today. Manufacturers may elect to make the sort of modifications suggested by Bortfeld and the co-authors or support a dedicated machine such as described by Mackie et al. (12). More likely, a system would evolve that is not linked to what is familiar to us all at this time. We believe that the clinical experience we gain today with this type of technology will enable radiotherapy community to obtain the most practical system.

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Shagy Y. Woo, M.D.
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Cone beam IMRT vs. fan-beam IMRT

Today

Cone-beam arc IMRT:
VMAT/RapidArc

Fan-beam arc IMRT:
Tomotherapy

IMRT delivery technology today

The hype cycle

1. Peak of Inflated Expectations
2. Trough of Disillusionment
3. Slope of Enlightenment
4. Plateau of Productivity

Technology Trigger
(e.g., MLC IMRT, Mimic, Tomo, VMAT)

J. Fenn, M. Raskino: Mastering the hype cycle, Harvard Business Press, 2008
VMAT/RapidArc publications

- 2007: 0
- 2008: 10
- 2009: 46
- 2010: 93
- 2011: 65 until July 20 – 120

*PubMed search: (vmat OR rapidarc) NOT vesicular NOT protein [All Fields] AND 20** [DP]

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VMAT/RapidArc planning comparisons

- IMRT: “RapidArc, however, is capable of producing better plans than IMRT for the test cases examined in this study.” Oliver et al., J Appl Clin Med Phys. 2009
- Tomo: “VMAT was able to provide approximately a 40% reduction in treatment time while maintaining comparable plan quality to that of HT.” Rao et al., Med Phys 2010
- SBRT: “VMAT is preferable because of significantly shorter treatment delivery times.” Brock et al., Clin.Onc. 2011
- Radiosurgery: “VMAT radiosurgery will likely replace multi-isocenter techniques…” Clark et al., IROBP 2010
- ...  
- VMAT always better – in one aspect or another  
- Key advantage of VMAT: greater efficiency

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Tomotherapy is still better in very complex cases

<table>
<thead>
<tr>
<th>9-field IMRT</th>
<th>2-arc RapidArc</th>
<th>Tomotherapy</th>
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<tr>
<td>0/4 constraints met</td>
<td>0/4 constraints met</td>
<td>2/4 constraints met</td>
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Tomotherapy is still better in very complex cases

“The overall treatment plan quality using Tomo seems to be better than the other TPS technology combinations.” Wiezorek et al. Rad Onc 6/20, 2011 (multi-institutional planning study, head&neck)
Advanced IMRT planning and delivery

Outline:

1. The IMRT story, clinical impact ✓
2. Advanced IMRT delivery ✓
3. Developments in IMRT planning (at MGH)

- Tomotherapy plan is a gold standard.
- VMAT is usually the most time efficient method
➢ Can we get the best of both worlds?

MCO – Multi-Criteria Optimization
Pareto optimization – “cannot make one better off without making the other worse off”

3D prostate Pareto surface (“frontier”)
VMAT/RapidArc planning is more time consuming than fixed-field IMRT

- Planning for VMAT/RapidArc is a more challenging problem than for IMRT
- Calculation times for VMAT planning can be longer (factor of 6 reported):

  MCO benefit could be even bigger for VMAT planning

MCO for VMAT

- Fast MCO for “gold standard” solution (“many” fixed beams)
- Determine acceptable deviation from that plan
- Arc sequencer that guarantees to stay within that deviation and allows for efficient delivery

David Craft talk: Tuesday, 8 am, Ballroom B
Overall summary

1. IMRT clinical success has been proven
2. Developments in cone beam IMRT (e.g., VMAT) and fan beam IMRT (tomotherapy) have led to higher treatment efficiency or better dose plans.
3. VMAT/Rapidarc can yield both, to some degree.
   - Planning often more time consuming
   - No clear sense of tradeoff: quality vs. efficiency
4. Developments in VMAT treatment planning are needed for greater efficiency of planning, to guarantee uncompromised dosimetric quality, and high delivery efficiency. MCO promises to accomplish all of that.

MCO for VMAT

- Substantially reduced planning time (minutes), even more relevant for VMAT than for fixed field IMRT
- Guaranteed uncompromised plan quality, practically indistinguishable from gold standard (tomotherapy)
- Highly efficient delivery with VMAT
  ➢ Best of all worlds!

Special thanks

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- Helen Shih
- Ted Hong
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- Alexander Scherrer
- Phil Süss
- R01-CA103904
Treatment planning comparison study (2010): Standard IMRT planning (XiO) versus MCO (RayStation)

Study Design:
- 5 glioblastoma cases (brain)
- 5 pancreas cases
- Patients chosen for this treatment planning study by the physicians at the time of contouring.
- All patients planned with standard IMRT and treated as in normal workflow.
- Planning time logged by treatment planners.
- In parallel, MCO databases were generated for patients. This process also logged.

MCO 2011 study results (cont’d):
- For all cases, the physicians preferred the MCO plan to the Standard plan in a blind review weeks after initial assessments.

D. Craft et al., IJROBP, published online 2/7/2011