Leibel Memorial Symposium
Advanced IMRT Planning and Delivery

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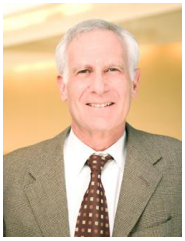
MASSACHUSETTS GENERAL HOSPITAL RADIATION ONCOLOGY

HARVARD MEDICAL SCHOOL

In memory of Steven Leibel

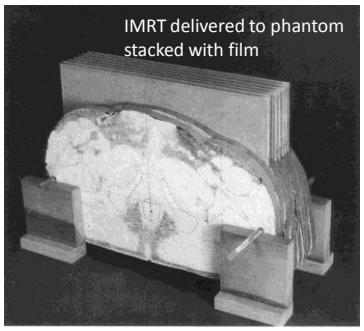


- Common roots?
  - The name Leibel originates from the area of Braunschweig, Germany
  - Leibel, Laib = Loaf –> Leibel = Baker

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*

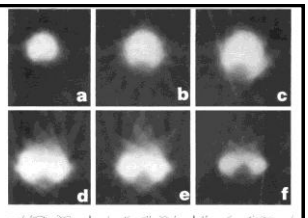
IMRT in 1993



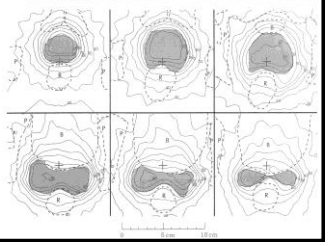
T. Bortfeld, A. Boyer, et al. 1993

IMRT in 1993

- 6 films in different slices showing concave dose distributions



- Overlay on anatomy



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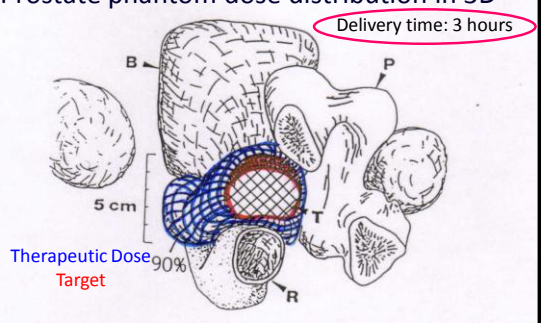
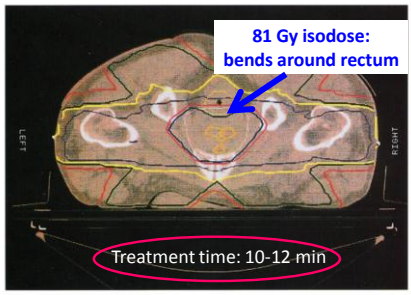
IMRT in 1993
Prostate phantom dose distribution in 3D



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

Translation into clinical use: 1995



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

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Radiotherapy and Oncology 55 (2000) 241±249

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

Michael J. Zelefsky[a*], Zvi Fuks[a], Laura Happersett[b], Henry J. Lee[a], C. Clifton Ling[b], Chandra M. Burman[b], Margie Hunt[b], Theresa Wolfe[a], E.S. Venkatraman[c], Andrew Jackson[b], Mark Skwarchuk[b], Steven A. Leibel[a]

- 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

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… 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,…"

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Advanced IMRT planning and delivery – Outline –

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

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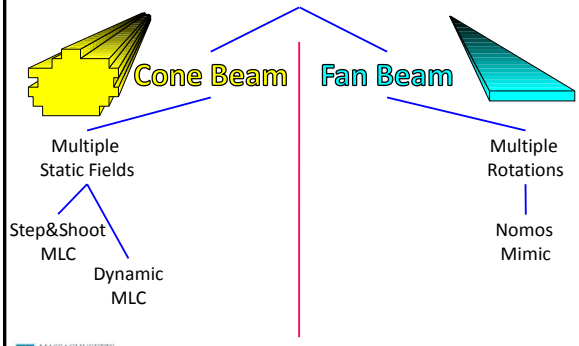
IMRT delivery technology 1990s



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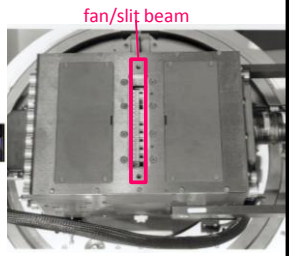
Cone beam IMRT vs. fan-beam IMRT 1990s

MLC based IMRT (Varian, Elekta, Siemens)

Nomos Mimic



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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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Shiao Y. Woo, M.D.
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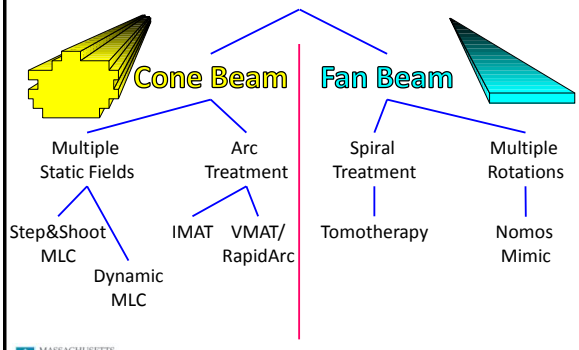
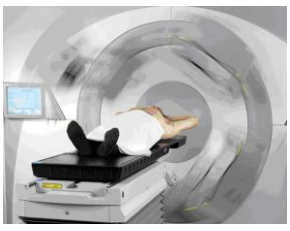
IMRT delivery technology today



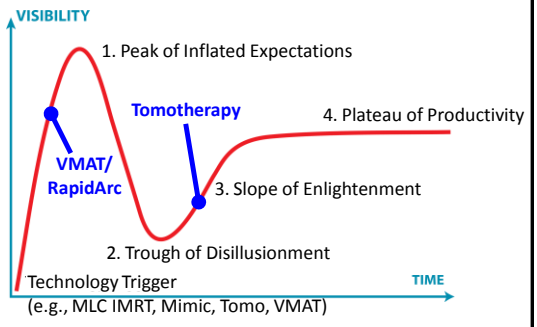
Cone beam IMRT vs. fan-beam IMRT Today

Cone-beam arc IMRT: VMAT/Rapidarc



Fan-beam arc IMRT: Tomotherapy

The hype cycle



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]

VMAT/RapidArc planning comparisons

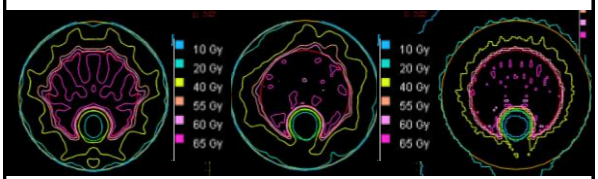
- IMRT: "RapidArc, however, is capable of producing better plans than IMRT for the test cases examined in this study." Oliver et al., J Appl Clin Med Phys. 2009
- Tomo: "VMAT was able to provide approximately a 40% reduction in treatment time while maintaining comparable plan quality to that of HT." 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., IJROBP 2010
- …
- VMAT always better – in one aspect or another
- Key advantage of VMAT: greater efficiency

Tomotherapy is still better in very complex cases

9-field IMRT
0/4 constraints met

2-arc RapidArc
0/4 constraints met

Tomotherapy
2/4 constraints met

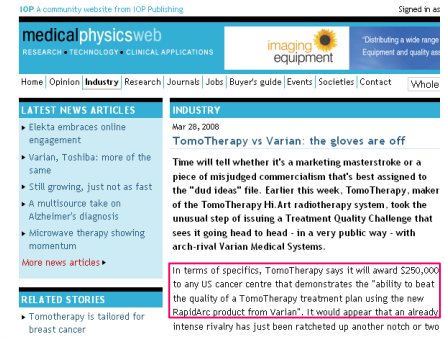


Oliver, Ansbacher, Beckham: JACMP 10(4): 117-131, 2009

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)

The $250,000 challenge



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INDUSTRY

Mar 28, 2008

TomoTherapy vs Varian: the gloves are off

Time will tell whether it's a marketing masterstroke or a piece of misjudged commercialism that's best assigned to the "dud ideas" file. Earlier this week, TomoTherapy, maker of the TomoTherapy Hi.Art radiotherapy system, took the unusual step of issuing a Treatment Quality Challenge that sees it going head to head - in a very public way - with arch-rival Varian Medical Systems.

In terms of specifics, TomoTherapy says it will award $250,000 to any US cancer centre that demonstrates the "ability to beat the quality of a TomoTherapy treatment plan using the new RapidArc product from Varian". It would appear that an already intense rivalry has just been ratcheted up another notch or two

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- Tomotherapy plan is a gold standard.
- VMAT is usually the most time efficient method

➢Can we get the best of both worlds?

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Advanced IMRT planning and delivery – Outline –

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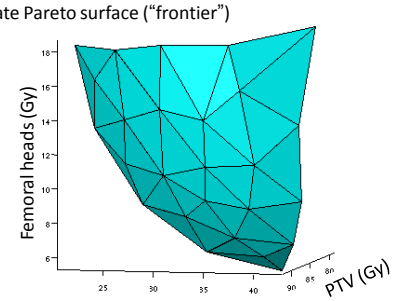
MCO – **M**ulti-**C**riteria **O**ptimization

Pareto optimization – "cannot make one better off without making the other worse off"

3D prostate Pareto surface ("frontier")



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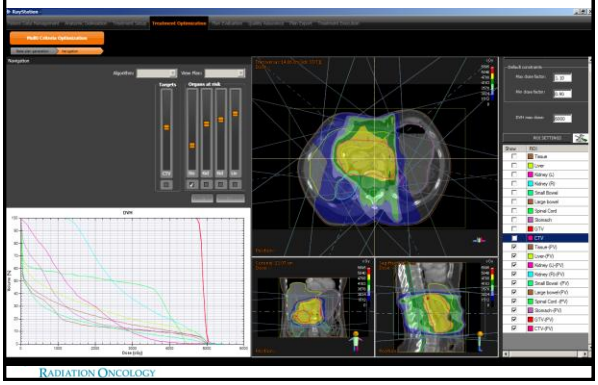
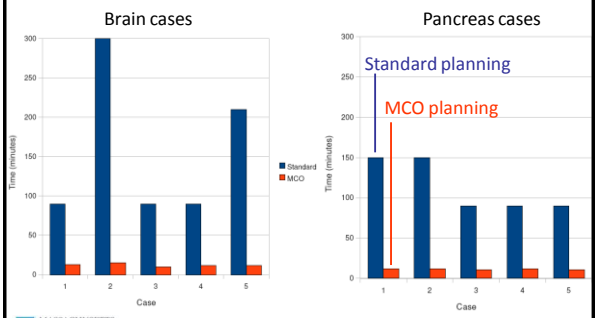
MCO 2011 commercial solution: RayStation



MCO planning efficiency
Comparison of IMRT treatment planning times



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

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):
  - Oliver, Ansbacher, Beckham: JACMP 10(4): 117-131, 2009

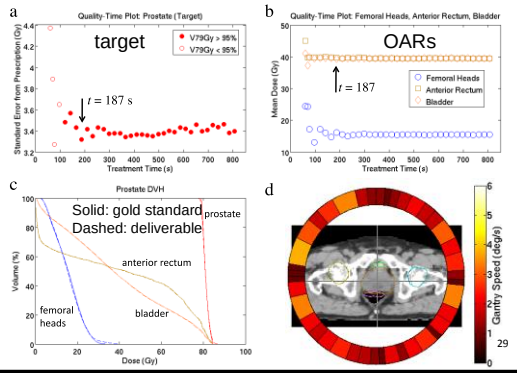
➢ MCO benefit could be even bigger for VMAT planning

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

MCO for VMAT: Prostate



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!

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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.

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Special thanks

MASSACHUSETTS GENERAL HOSPITAL RADIATION ONCOLOGY
- David Craft
- Jan Unkelbach
- Dualta McQuaid
- Jeremiah Wala
- Alexei Trofimov
- Wei Chen
- Helen Shih
- Ted Hong

Fraunhofer ITWM
- Karl-Heinz Küfer
- Alexander Scherrer
- Phil Süss

NATIONAL CANCER INSTITUTE
- R01-CA103904

RaySearch

PHILIPS

… and many others

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.

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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

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MCO for VMAT: Pancreas