IMRT vs Tomoterapia - Le nuove sfide

Cinzia Iotti

Radioterapia Oncologica
Ospedale S. Maria Nuova - Reggio Emilia

Nov 2007

Varian claims that RapidArc delivers uncompromised treatments in "two minutes or less"

Mar 2008

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 a two-minute, single-rotation RapidArc delivery (Varian)"

IMRT delivery systems

Standard Linac based

- MiMIC / Peacock
- Metal compensators
- Step and Shoot MLC
- Dynamic MLC
- Arc therapy with standard Linac

Special linear accelerator

- HiArt (Tomotherapy)
- Robotic gantry (Cyberknife)

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Linac

Dynamic MLC affords fine-grained intensity modulation by continuous leaf movement, whereas static MLC creates the intensity profile by superposition of field segments

Tomotherapy

Helical tomotherapy (HT), is an alternative intensity modulation technique. Radiation is delivered in fans modulated by a binary collimator during continuous rotation of the source around the patient.

Volumetric imaging

LINAC

1. On board KV-CBCT: the KV imaging chain can be mounted orthogonal to or in-line with treatment beam. The 3 most common solutions share the principle that the KV imaging isocenter and the MV treatment isocenter are independent and might not necessarily coincide exactly
2. MV-CBCT: the Epid available on a conventional Linac is used to produce MV-CBCT image data. No additional hardware is required and there is a perfect alignment of target and treat beam

TOMOTHERAPY (MVCT)

2-in-1 concept of a linac with a helical CT scanners. High mechanical stability. Dose to the patient below 3cGy

With MV, contrast is poorer compared to diagnostic X ray quality, but high-Z artifacts are not present.

Linac-IMRT vs Tomoterapia

Radiother Oncol 2006

Significant improvement in normal tissue sparing and target coverage for head and neck cancer by means of helical tomotherapy

Fiorino C, Dell'Oca I, Pierelli A, Broggi S, De Martin E, Di Muzio N, Longobardi B, Fazio F, Calandrino R

CONCLUSIONS: Preliminary findings obtained in a sequential approach for HNC suggest that Tomotherapy has the potential to significantly improve the therapeutic ratio with respect to a conventional IMRT delivery method.

Strahlentherapie und Onkologie 2007

Simultaneous Integrated Boost (SIB) for Nasopharynx Cancer with Helical Tomotherapy

A Planning Study

Claudio Fiorino[1], Italo Dell'Oca[2], Alessio Pierelli[1], Sara Broggi[1], Giovanni Mauro Cattaneo[1], Anna Chiara[2], Elena De Martin[1], Nadia Di Muzio[2], Ferruccio Fazio[2,3], Riccardo Calandrino[1]

CONCLUSIONS: HT improves the homogeneity of dose distribution within PTV and PTV coverage together with a significantly greater sparing of OARs compared to linac five-field IMRT

Technol Cancer Res Treat 2009

Comparison of the helical tomotherapy and MLC-based IMRT radiation modalities in treating brain and cranio-spinal tumors

Mavroidis P, Ferreira BC, Shi C, Delichas MG, Lind BK, Papanikolaou N

In the **brain cancer**, the HT treatment gives slightly better results than the MLC-based IMRT in terms of optimum expected clinical outcome

In the **cranio-spinal axis cancer**, the HT plan is significantly better compared to the MLC-based IMRT plan over the clinically useful dose prescription range

In comparison to MLC based-IMRT, HT can better encompass the often large PTV while minimizing the volume of the OARs receiving high dose

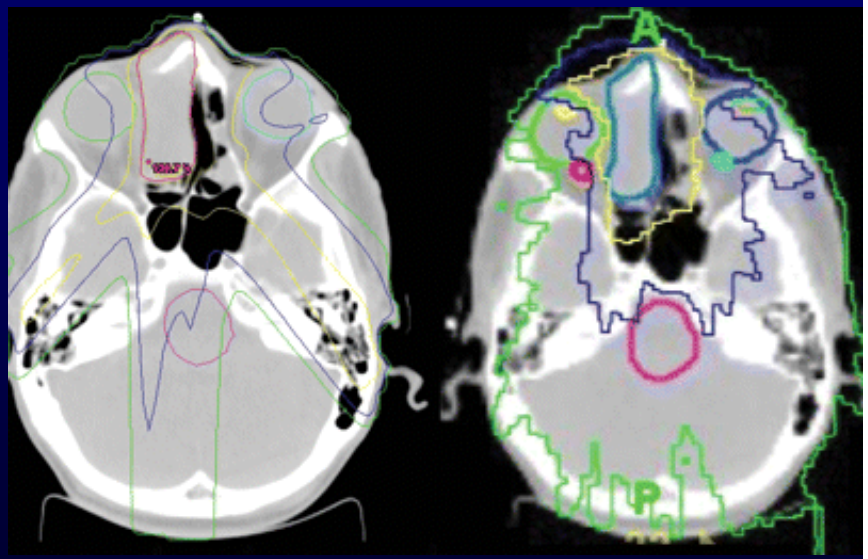
Br J Radiol 2008

A dosimetric comparison between two intensity-modulated radiotherapy techniques: tomotherapy *vs* dynamic linear accelerator

GL Whitelaw, I Blasiak-wal, K Cooke, C Usher, ND Macdougall, P N Plowman

3 cases: vertebral metastasis re-treatment, radical prostate therapy and an ethmoid sarcoma re-treatment

Subtle dosimetric differences between the two techniques but no marked advantage with either system. Therefore, other factors may need to be considered when making a decision between HT and Linac IMRT.



Med phys 2008

Comparison of fixed-beam IMRT, helical tomotherapy, and IMPT for selected cases

Muzik J, Soukup M, Alber M

Five cases were selected to offer each technique a chance to show its strengths:

I. a deep-seated prostate case for15 MV linac-based-IMRT,

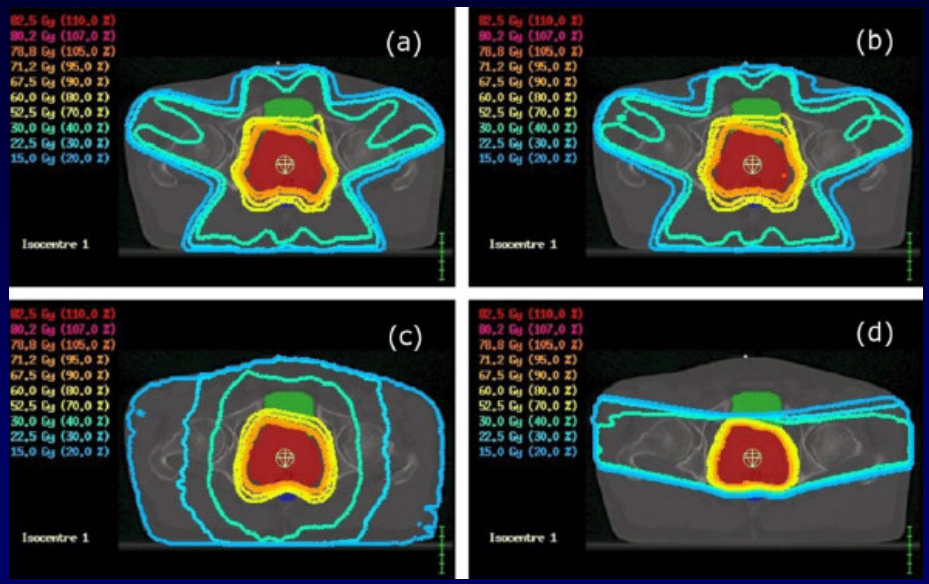
II. a pediatric case for IMPT,

III. an extensive head–and-neck case for HT,

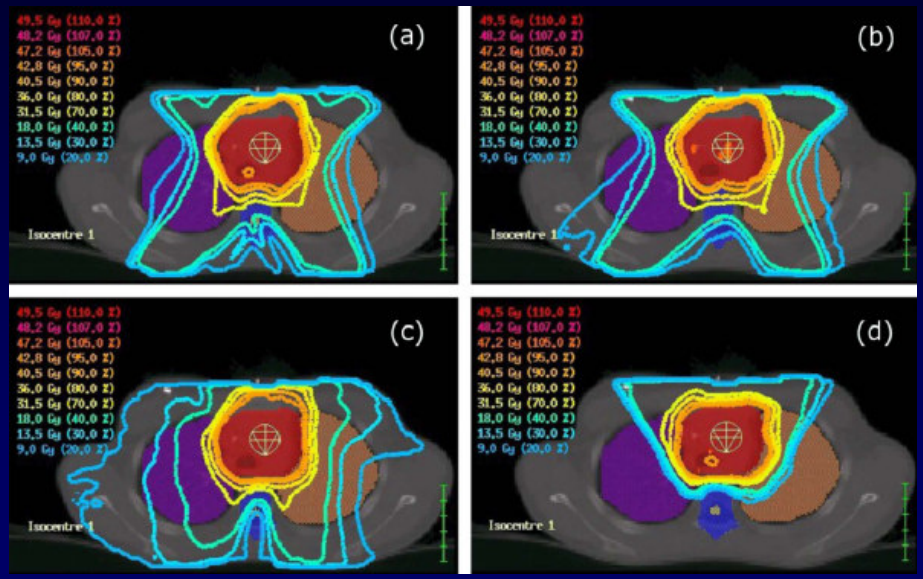
IV. a lung tumor for HT,

V. an optical neurinoma for noncoplanar linac-based IMRT with a miniMLC.

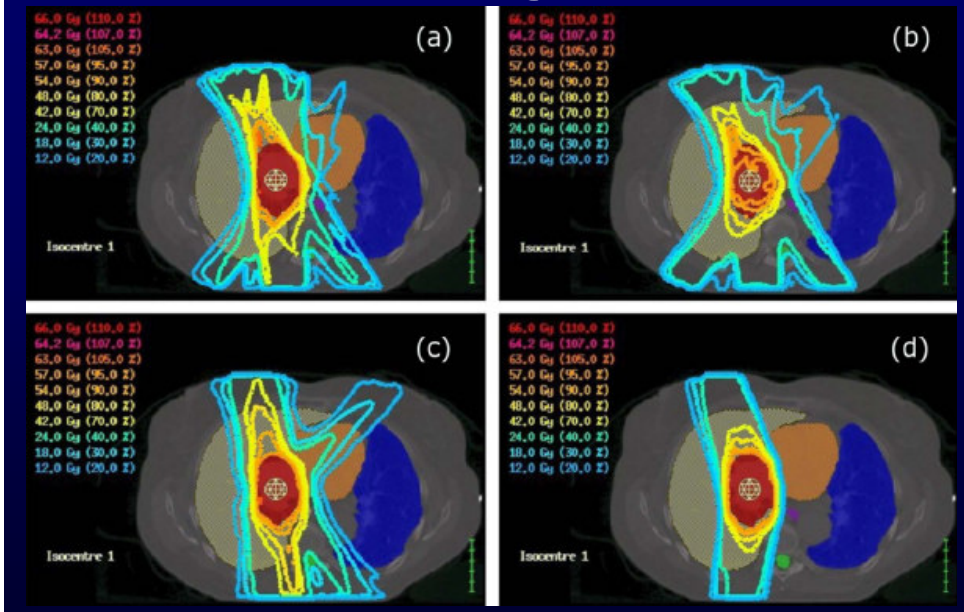
Prostate



Pediatric case

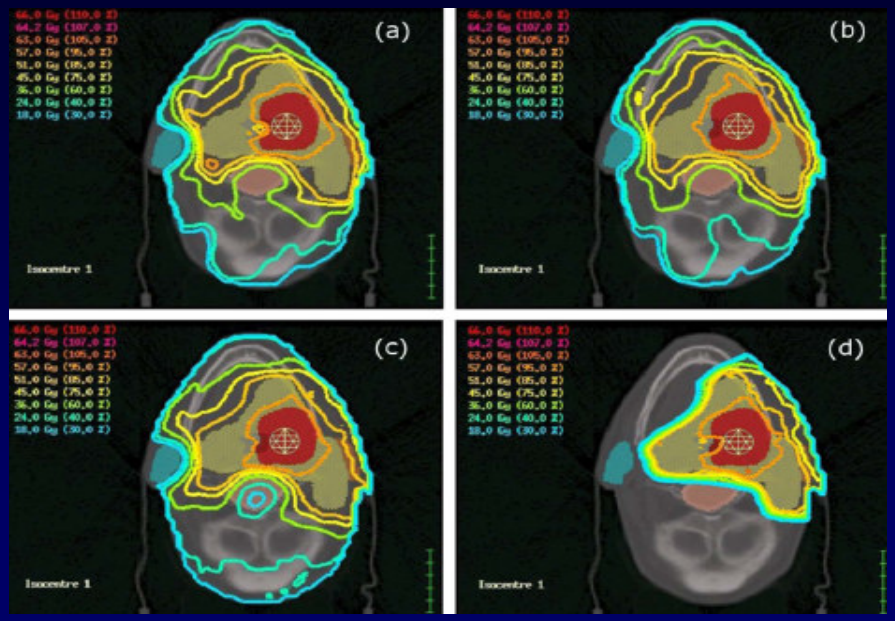


Lung

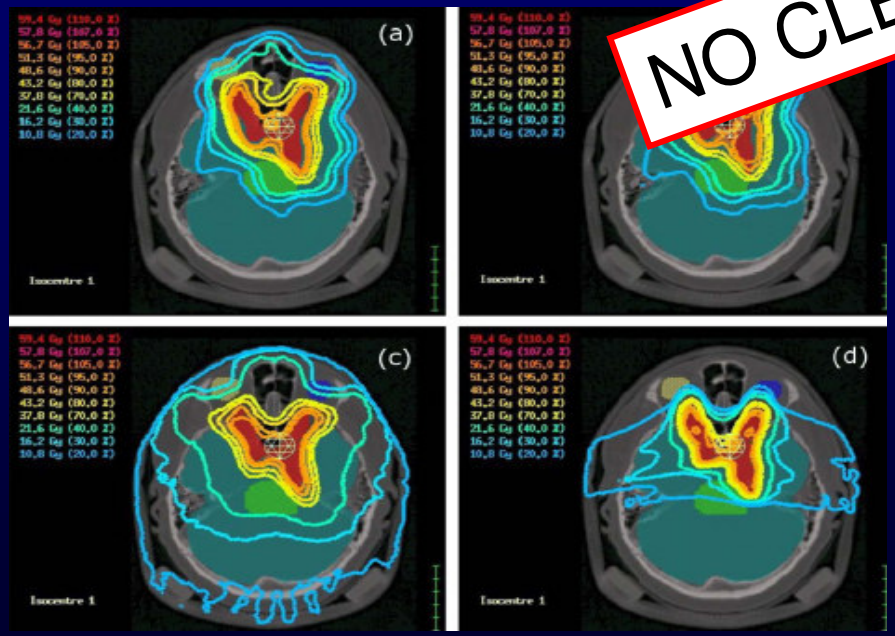


a. dMLC-IMRT
b. sMLC-IMRT
c. HT
d. IMPT

Head & Neck A



Head & Neck B



a.
IMRT
HT
d. IMPT

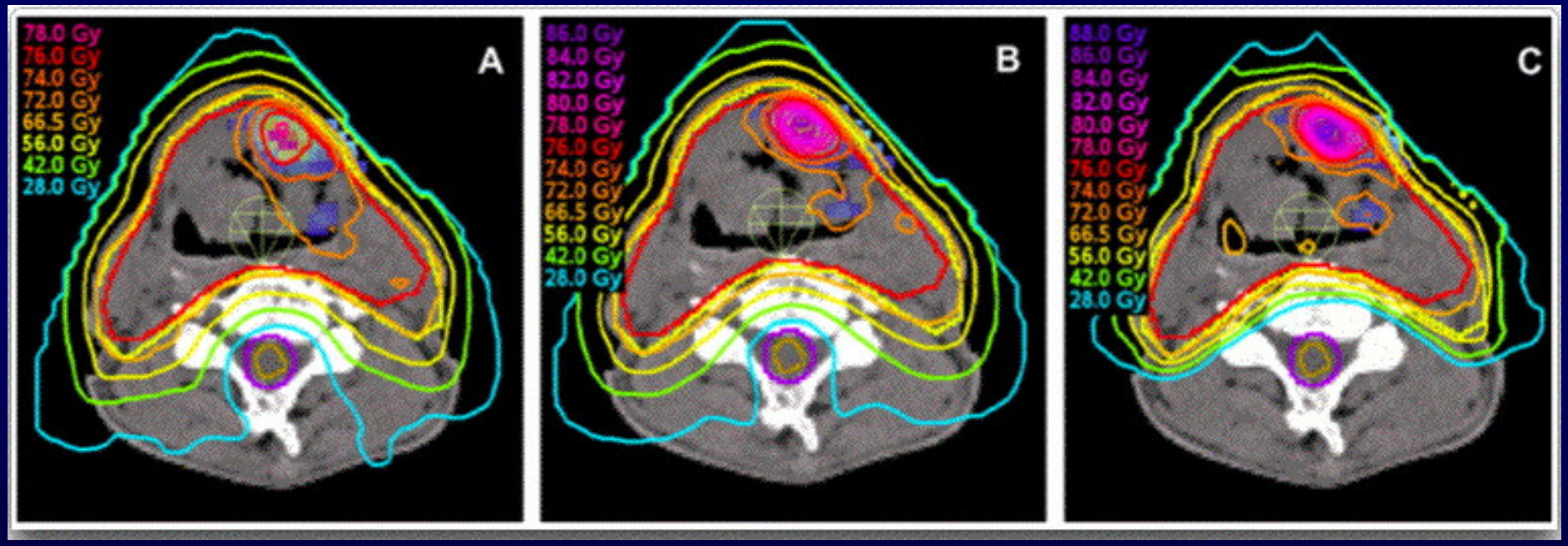
NO CLEAR WINNER WAS FOUND!

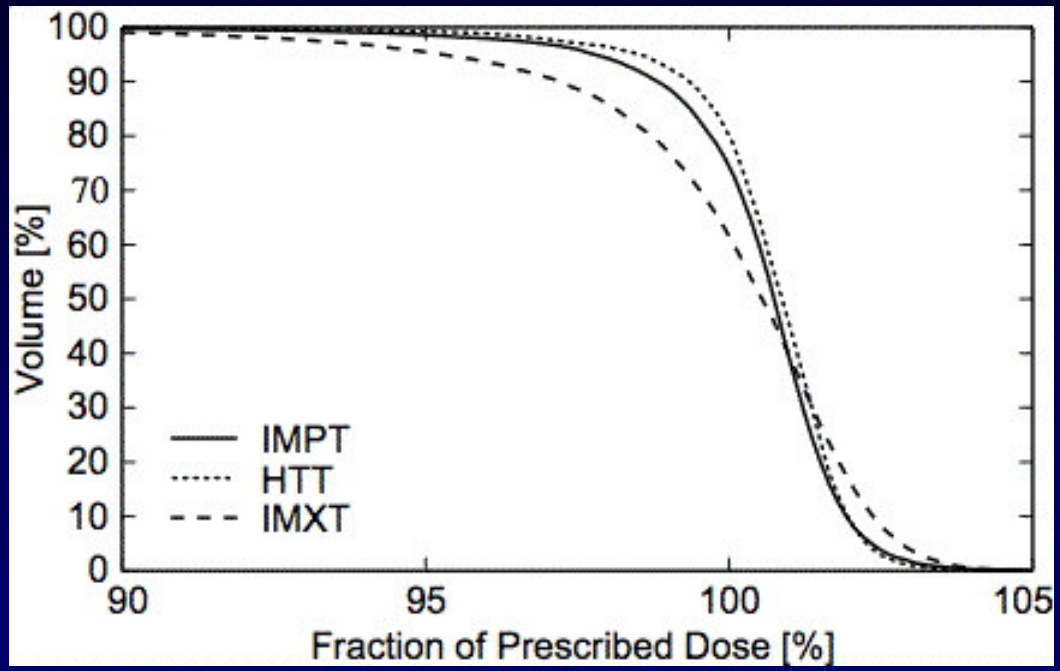
Radiother Oncol 2008

Dose painting with IMPT, helical tomotherapy and IMXT: A dosimetric comparison

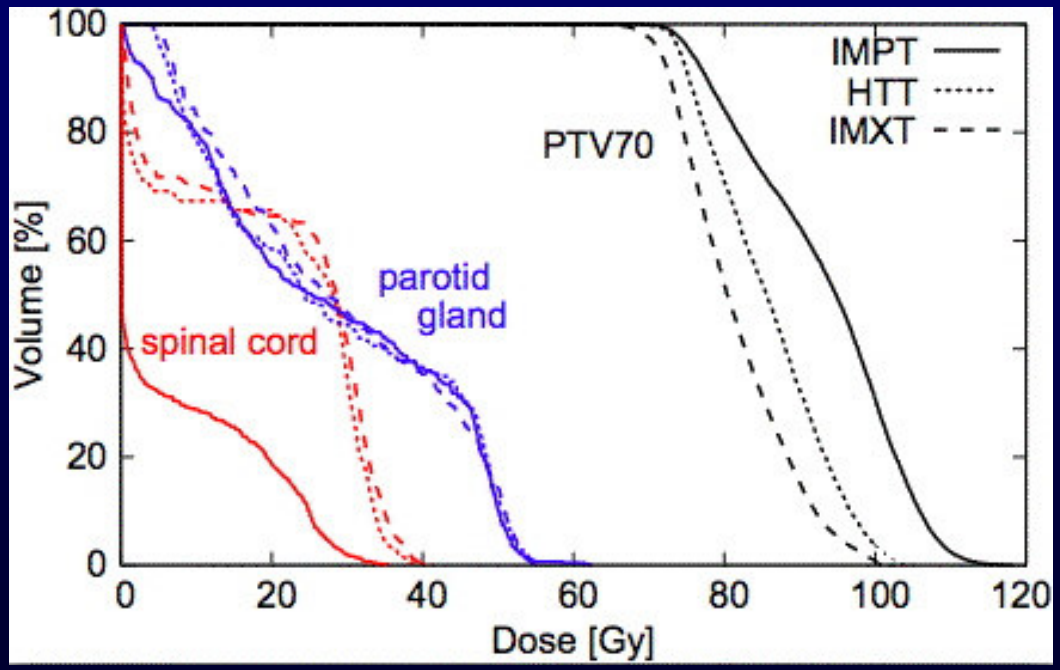
Daniela Thorwarth*, Martin Soukup, Markus Alber

IMXT HT IMPT

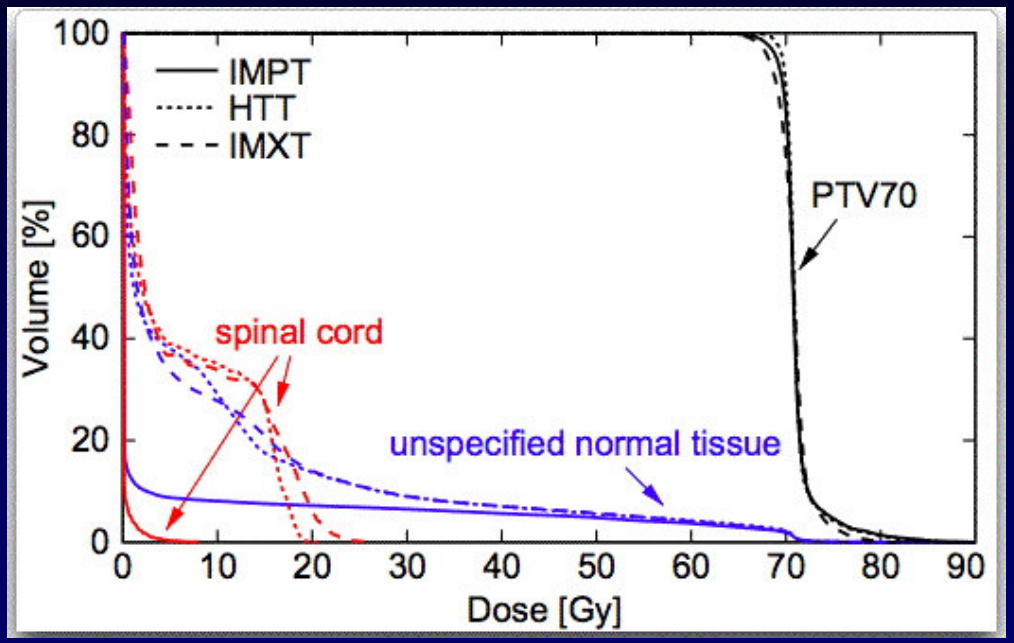




Effective target DVH



Max dose escalation under iso-toxicity constraints



- The quality of plan is comparable in the case of inhomogeneous dose prescriptions.

- HT and IMPT allow a better target coverage

- Approximately equivalent levels of sparing OARs and UNT with IMXT and HHT

Thorwarth D, Radiother Oncol 2008

Second cancers

- IMRT probably worse than 3D
- HT (expected to be worse due to the helical delivery) is at least comparable to IMRT (good design of head and shielding)

ASTRO 2008

Second cancers

AbstractID: 6924 Title: Risk of Secondary Fatal Malignancies from Hi-Art Tomotherapy IMRT

Purpose: This work compares out-of-field secondary doses and associated risk of a fatal secondary malignancy from a Hi-Art Tomotherapy machine and a conventional gantry based accelerator for an adult IMRT prostate and a pediatric cranio-spinal treatment.

Method and Materials: A conventional 3D and tomotherapy IMRT cranio-spinal treatment plan were developed to deliver the same prescription to a pediatric anthropomorphic Rando phantom using a Philips Pinnacle and Hi-Art Tomotherapy planning system, respectively. Similarly, an adult IMRT prostate treatment plan, using the Pinnacle and tomotherapy planning systems was developed to deliver the same prescription with the same constraints to an adult Rando phantom. The target and organs at risk (OAR) were contoured. TLD were located within each of the OARs selected. Each phantom was irradiated three times per plan. The out-of-field organ TLD doses for the gantry based delivery and tomotherapy treatments were compared. For each organ site, an average dose was determined and organ weighted linear non-threshold dose response model risk factors were used to estimate the risk of a secondary fatal malignancy for each treatment.

Results: Doses calculated from the adult TLD data were lower for all organs when treated with the Tomotherapy plan and the overall risk was lower. The pediatric TLD dose findings were mixed between the 3D and tomotherapy treatment, however because of the higher integral dose with the Tomotherapy, the overall risk is higher for the Tomotherapy treatment.

Conclusion: The risk of a secondary fatal cancer was lower for the Hi-Art Tomotherapy adult prostate treatment than the gantry based IMRT treatment due to due to the lower integral out-of-field secondary radiation doses. The risk for the pediatric case appears higher for the Hi-Art Tomotherapy treatment than the 3D conformal cranio-spinal treatment.

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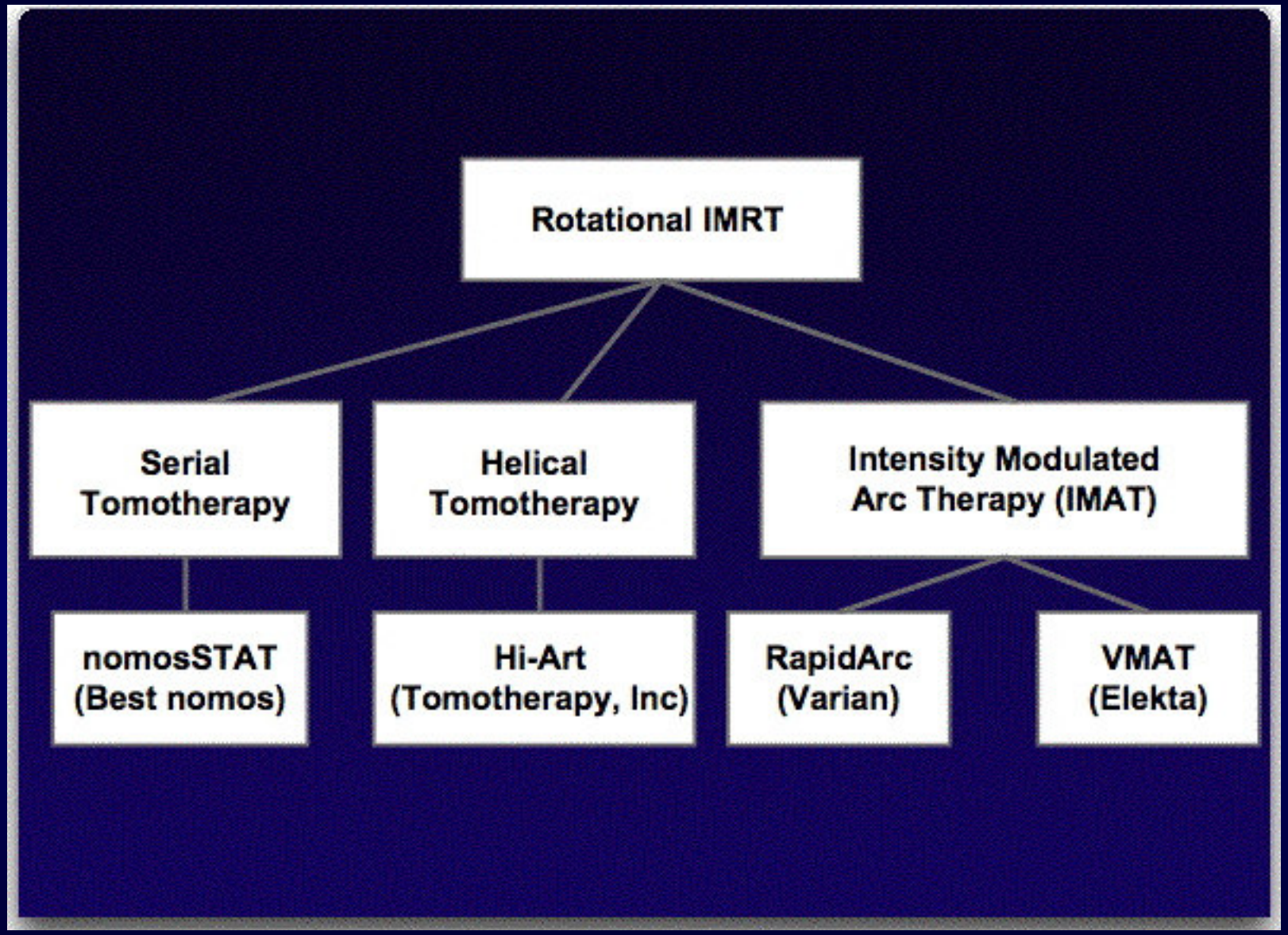

Rotational IMRT
Serial Tomotherapy
Helical Tomotherapy
Intensity Modulated Arc Therapy (IMAT)
nomosSTAT (Best nomos)
Hi-Art (Tomotherapy, Inc)
RapidArc (Varian)
VMAT (Elekta)

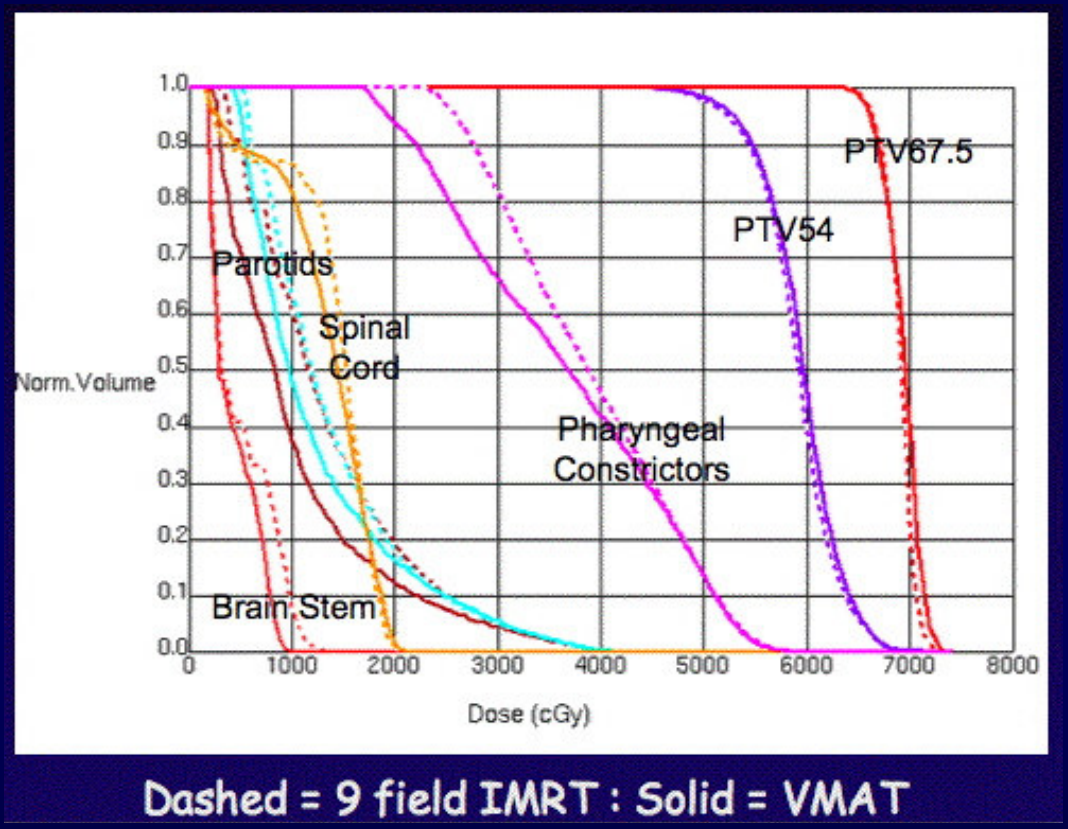
Teminology: IMAT vs VMAT

IMAT (2000): the use of multiple superimposing arcs of radiation to achieve the desired intensity modulation

VolumetricMAT (2007): rotational IMRT delivered in single arc

(for same cases multiple arcs can be used to improve the plan quality or provide adequate coverage of large targets)

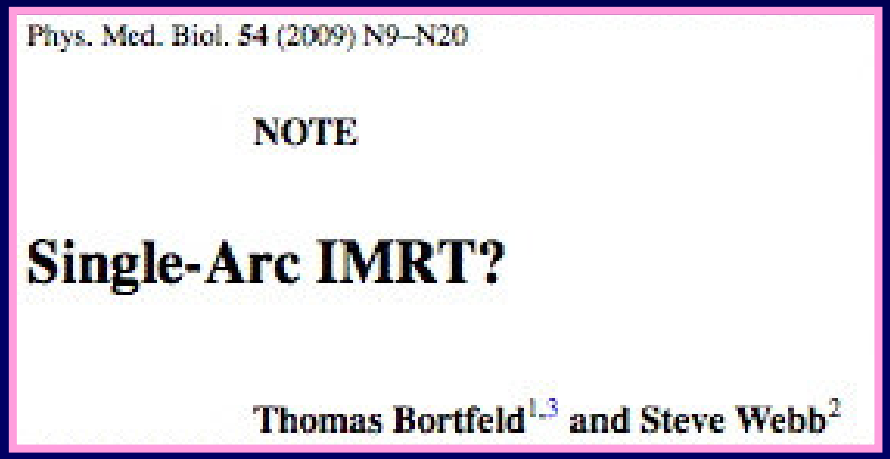
H&N plan and delivery comparison: 5 cases study



Dashed = 9 field IMRT : Solid = VMAT

	9 field IMRT	VMAT
Delivery time	**12'50"**	**4'58"**
MUs	858	608

Shepard-SanFrancisco Conference 2009



Phys. Med. Biol. 54 (2009) N9–N20

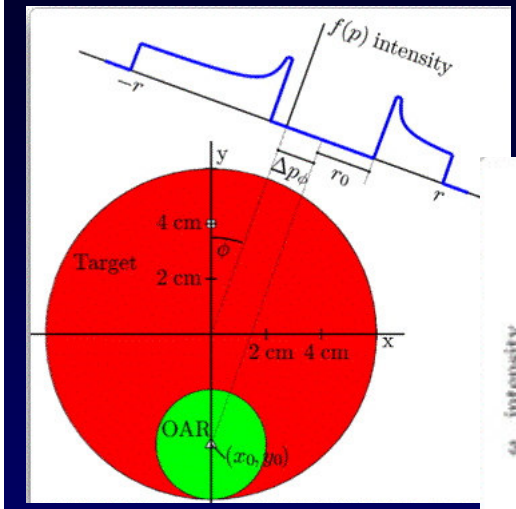
NOTE

Single-Arc IMRT?

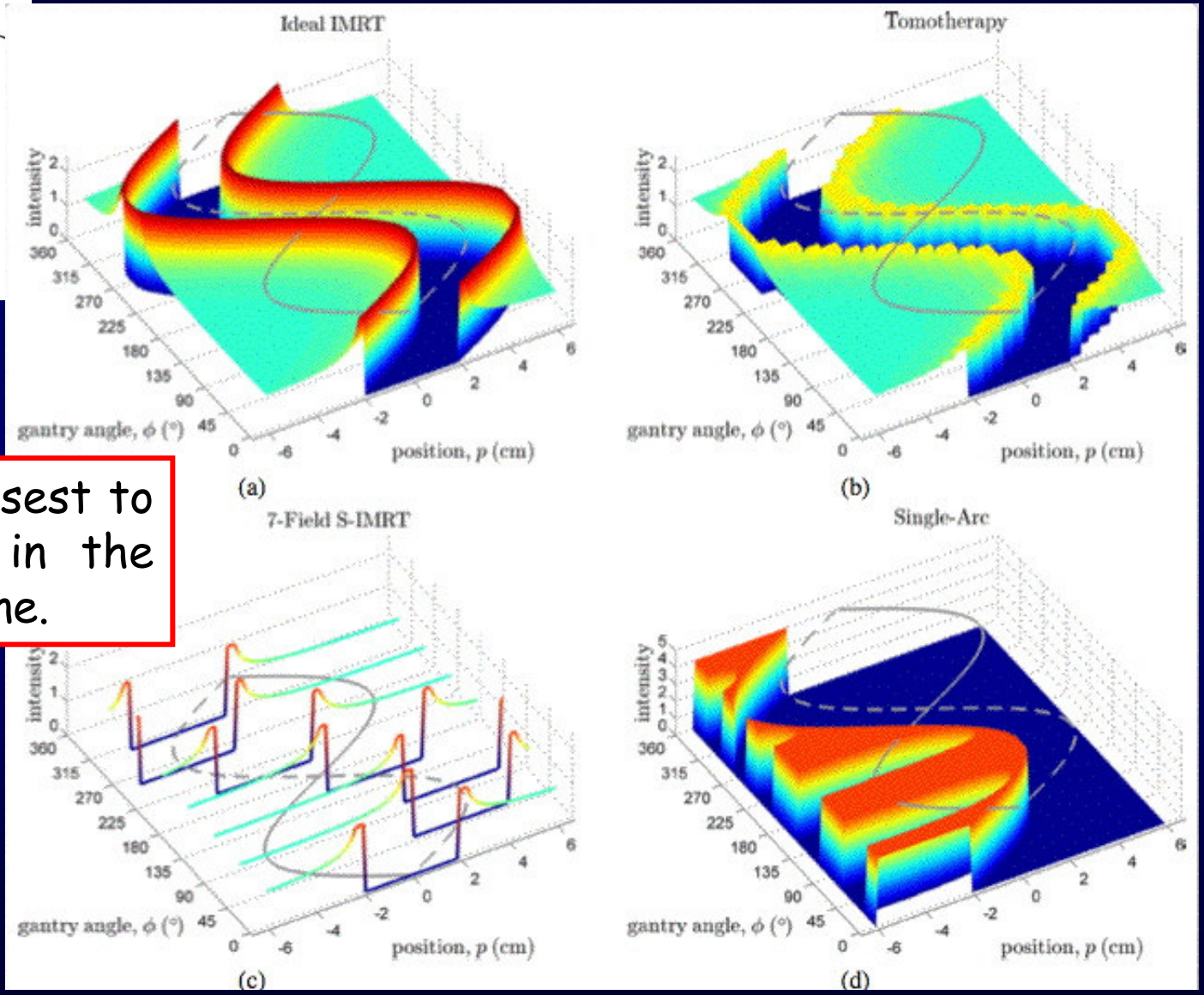
Thomas Bortfeld[1,3] and Steve Webb[2]

The paper goes on to consider the all-important trade-off between quality and efficiency.

Bortfeld, Webb 2009



Tomo came closest to "true" IMRT in the transverse plane.



Bortfeld, Webb 2009

Tomotherapy should almost always yield better dose distributions **in the transverse plane**. This is practically limited by the 6 mm resolution of its collimator

In the longitudinal direction, the resolution is determined by the field width, which is user adjustable (0-5 cm).

The choice between S-IMRT and Single-Arc is, to a large degree, one between distributing low doses uniformly within large volumes of normal tissues away from the target and delivering more dose to some normal tissues and sparing others completely

Bortfeld, Webb 2009

Efficiency vs Quality

If the geometry of the target volume is not too complex, then rapid radiation treatment during just one gantry rotation may be a better choice for both the patient and the clinic, but for extremely complicated cases, tomotherapy probably has the advantage

Bortfeld, Webb 2009

Optimization of volumetric IMRT is a difficult optimization problem.

The optimization of static-IMRT and tomotherapy is a much easier problem. These systems may not find the true optimum, but there is no risk that they will end up far way form the optimum. However the optimization of beam angles in S-IMRT is also a very difficult optimization problem

Comparisons of competing IMRT technologies should go beyond dosimetry The studies should consider more "clinically meaningful measures", such as the chance of destroying the tumor and the likelihood of complications in normal tissue.

Nahum A, 2008

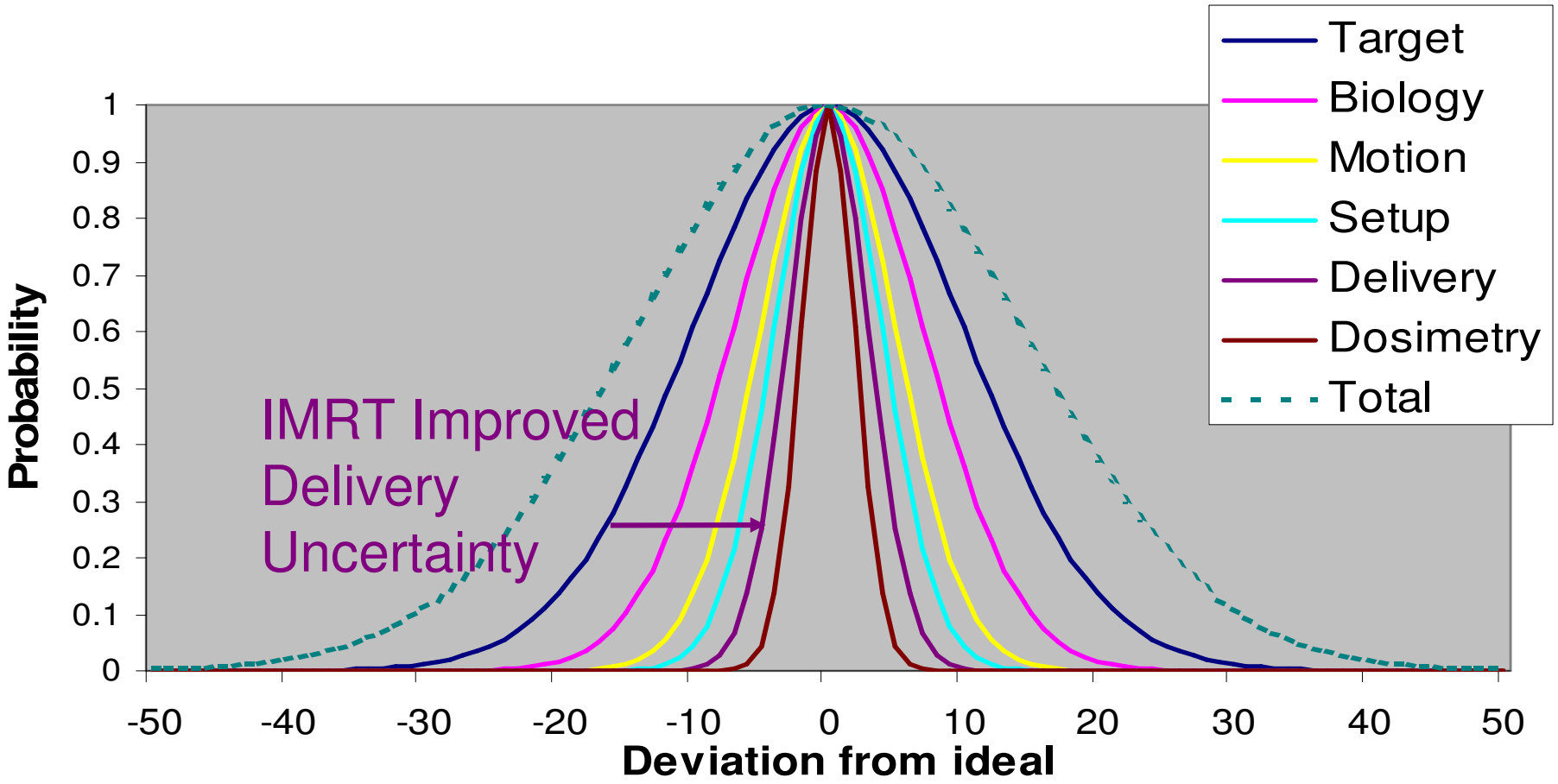
Radiother Oncol 2008

Dose-volume and biological-model based comparison between helical tomotherapy and (inverse-planned) IMAT for prostate tumours.

Mauro Iori[a,*], Giovanni Mauro Cattaneo[c], Elisabetta Cagni[a], Claudio Fiorino[b], Gianni Borasi[a], Calandrino Riccardo[c], Cinzia Iotti[c], Ferruccio Fazio[d], Alan Efraim Nahum[c].

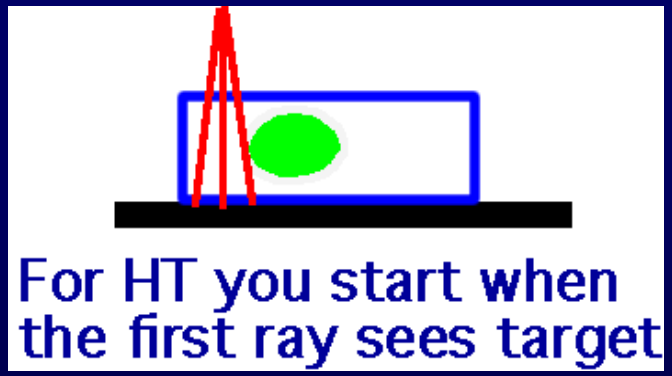
The mean dose delivered to the target tumor turned out to be similar for the tomotherapy and IMAT plans. However, when translating the data into radiobiological terms, tomotherapy surpassed IMAT in terms of tumor control.

Treatment Uncertainties



Does the Linac-IMRT experience help or hurt?

- A voxel can be only one tissue type for planning
- Targets are "sacred" and always have priority over structures
- Helical startup and end. Put a "cap structures" to keep dose driven toward target during ramp up and ramp down



(for HT it means you'll you have extra dose at both ends)

- The planning system does not allow sum plan
- The planning system does not allow plan comparison
- Tomoplan is basically a "one thing at a time" system. During beamlet calculations you can't be working on anything else
- It is possible to investigate various slice width & pitch combinations and develop new planning templates. But it take a lot of time. Consider when you will have time to validate things or you can just assume they are ok

HT treatment times are typically faster than IMRT delivery on conventional linacs

The treatment is being completed continuously and so the time between the beginning and end of treatment for any location is typically a minute or two and so the radiobiological repair is identical to non-IMRT radiotherapy

Conclusions - 1

The observable differences in the dosimetric studies appear small. Differences in the quality of plans produced are likely to reflect the area of expertise of the groups carrying out the work as well as intrinsic differences between the systems

The ultimate clinical significance of these dose distribution refinements remains ill defined

….. mainly in the light of the geometrical and biological uncertainties of such a treatment in practice…

Conclusions - 2

Considered that any IMRT approach showed a clinically meaningful superiority

- practical differences should be taken into account when deciding which modality to use. These factors could include the reliability of equipment, capital and running costs, time constraints, and the availability of trained staff.

- IMRT has approached its limits in the quality of treatment plans that can be physically achieved with current planning/delivery systems

The new challenges in radiation therapy

* Integrating biological and technical gains

* Estimate the risk of normal issue damage based on the individual patient using genomics, plasma biomarkers, and functional and metabolic imaging with adjustments during treatment

* Continued technical advances, but in broader context

....and use the technical gains to be aggressive at least as other players in the same game ...

MDRT
Money Driven Radiotherapy

Grant III, McGary