

HUMANITAS
GAVAZZENI



Sabato 21 MAGGIO 2011

Incontro AIRO - AIFM
Lombardia

EVOLUZIONE
DELLE TECNICHE
DI RADIOTERAPIA
IN IMRT:
LA PRATICA,
LE INCERTEZZE
E LE PROSPETTIVE

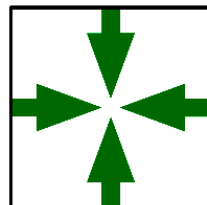
CASA DEL GIOVANE
Sala degli Angeli
Via M. Gavazzeni 13 - Bergamo

www.humanitasgavazzeni.it

Possibilità tecnologiche e tecniche di esecuzione nella radioterapia ad intensità modulata: il punto della situazione

Emanuele Pignoli

S. C. Fisica Sanitaria



Fondazione IRCCS

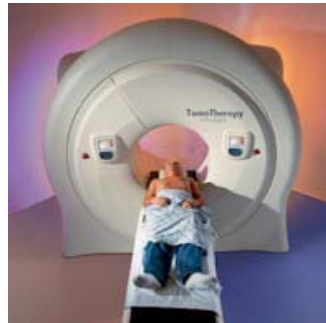
Istituto Nazionale dei Tumori

IMRT in Lombardia

IMRT con Linacs



IMRT con Tomo



IMRT con CyberKnife



Prossimamente IMRT con VERO



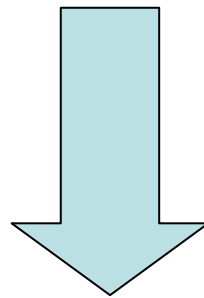
Numero centri di radioterapia (identificati)	28
Con IMRT	17
Senza IMRT	5
Non è dato a sapere	6

Cosa ci si aspettava dai trattamenti IMRT

ASPETTATIVE

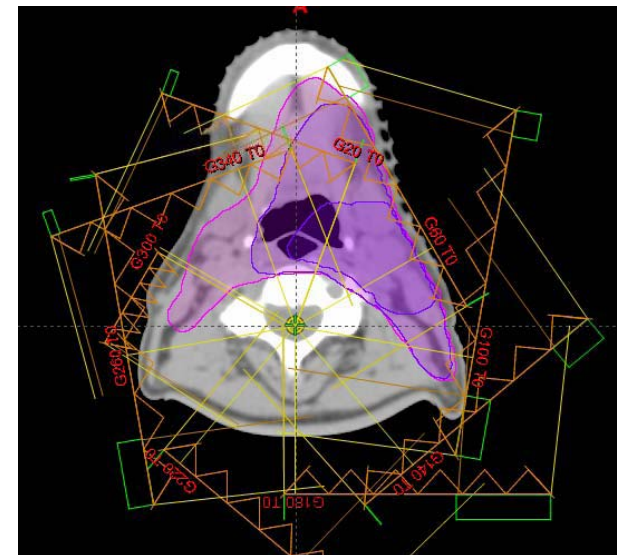
Alta conformazione della dose attorno al PTV

forte riduzione della dose agli OAR

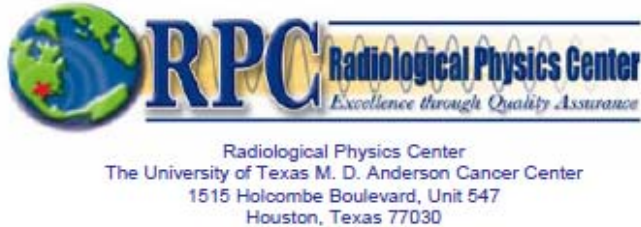


CONSEGUENZE

Aumento della complessità del trattamento



Conseguenze dei trattamenti IMRT



REPORT TO THE AAPM THERAPY PHYSICS COMMITTEE

Report No. 130

March 1, 2008 – July 1, 2008

Table 1

Successful Completion of RPC Credentialing Procedures

<u>Site</u>	<u>Technique</u>	<u>Irradiations</u>	<u>Number Passing</u>	
H&N	IMRT	558	425	76.1 %
Pelvis	IMRT	109	89	81.6 %
Lung	SBRT	55	42	76.4 %
Liver	SBRT	13	6	46.2 %
Benchmark*	IMRT	89	55	61.8 %

Criteria adottati da RPC

Dose-Agreement (DA): 7%

Distance-to-Agreement (DTA): 4 mm

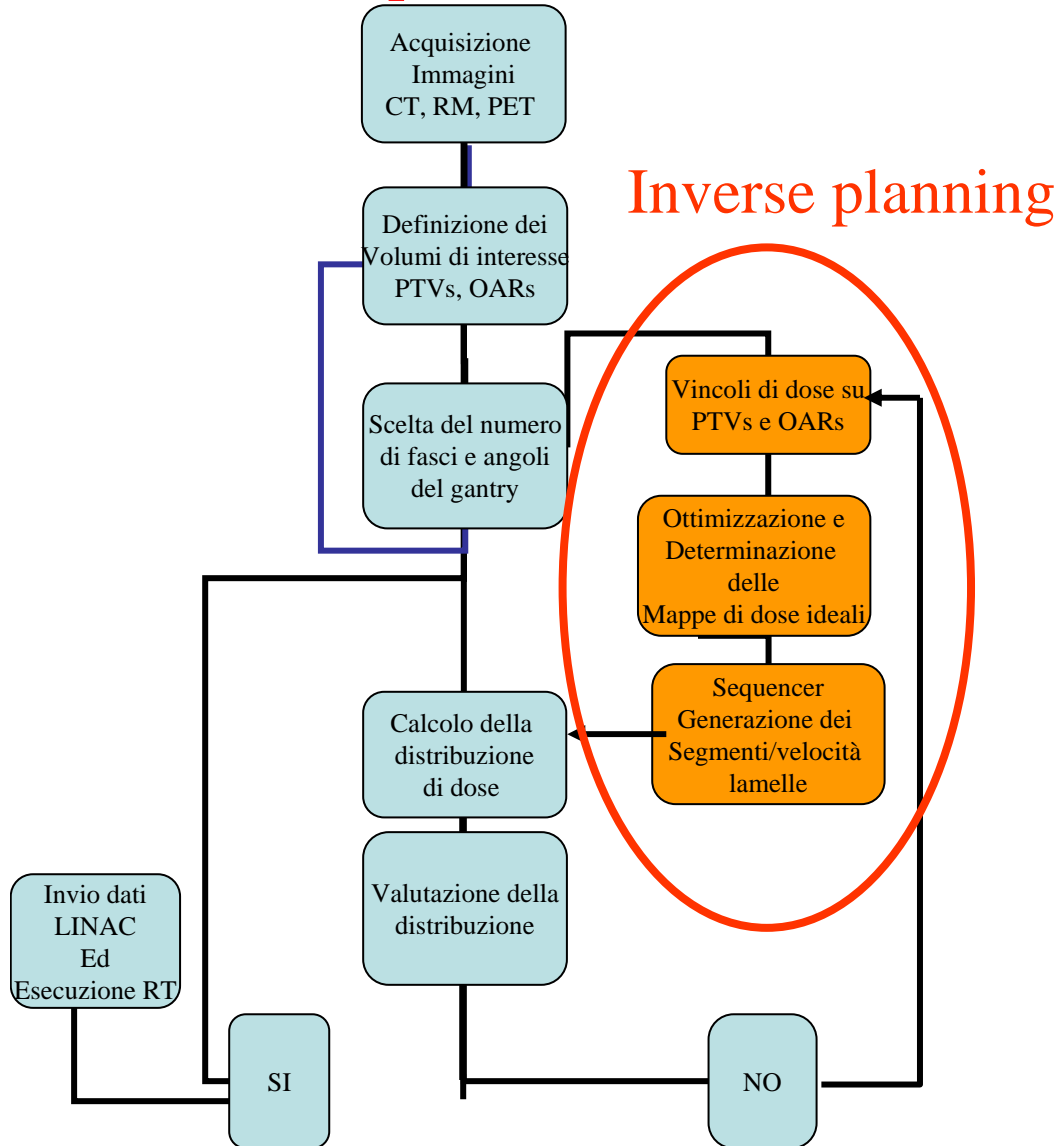
Criteria adottati in INT

Dose-Agreement (DA): 3 %

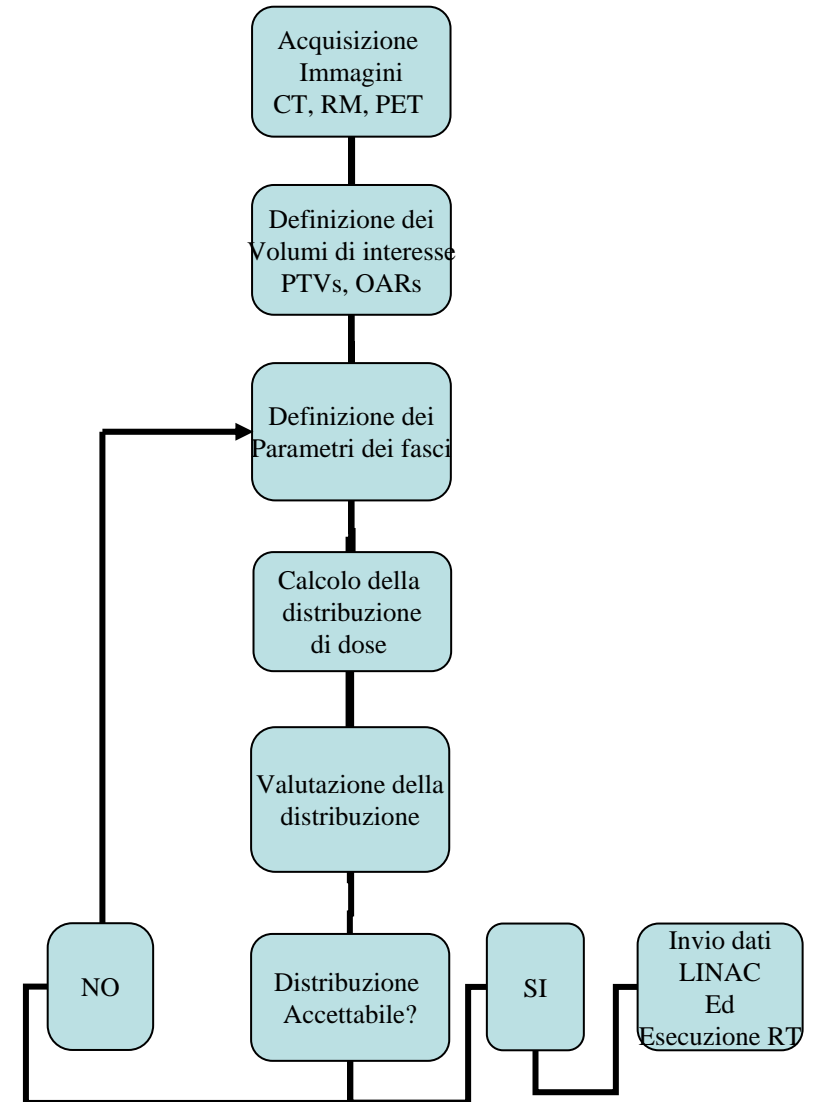
Distance-to-Agreement (DTA): 3 mm

*Includes reviews done by QARC.

Processo di pianificazione per IMRT



Processo di pianificazione conformazionale



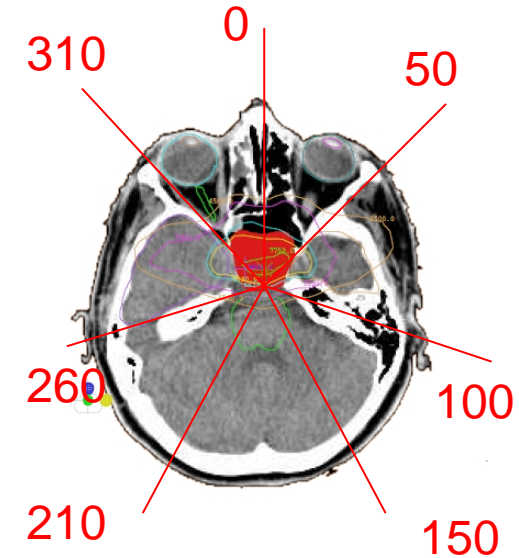
Cosa abbiamo imparato dalla IMRT

Organi e strutture precedentemente non coinvolte vengono irradiate a dosi non completamente trascurabili (+ campi di trattamento) \longrightarrow + dose integrale

Aumento delle MU da erogare (+ tempo):

i primi trattamenti per H&N e prostata in INT richiedevano da 40-45 minuti, oggi sono eseguiti in 15-20 minuti

Elevati gradienti di dose, maggiore criticità nel set up: necessità di integrare tecniche IGRT



Quanti campi dobbiamo utilizzare

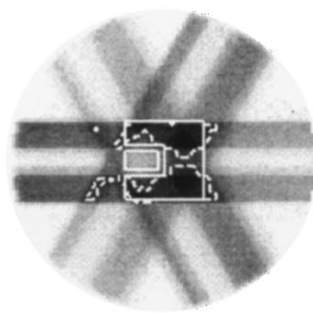
A simple model for examining issues in radiotherapy optimization

David M. Shepard,^{a)} Gustavo Olivera, Lisa Angelos, Otto Sauer, Paul Reckwerdt,
and T. Rockwell Mackie

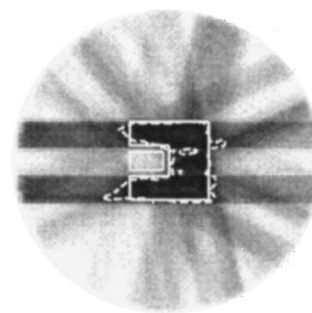
Department of Medical Physics, University of Wisconsin–Madison, Madison, Wisconsin 53706-1532

(Received 18 May 1998; accepted for publication 30 March 1999)

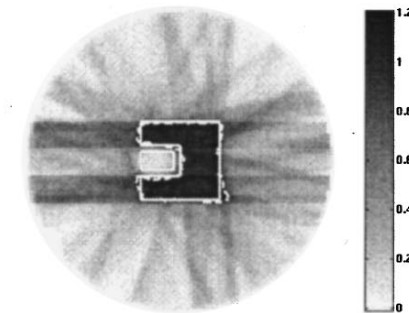
**Few vs.
Many Angles**



3 Angles

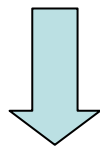


7 Angles



11 Angles

Incremento del numero di campi

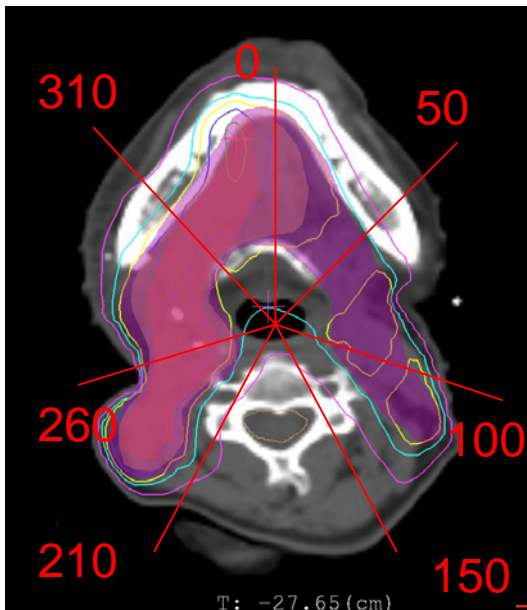


Aumento della conformazione e del
tempo globale di trattamento

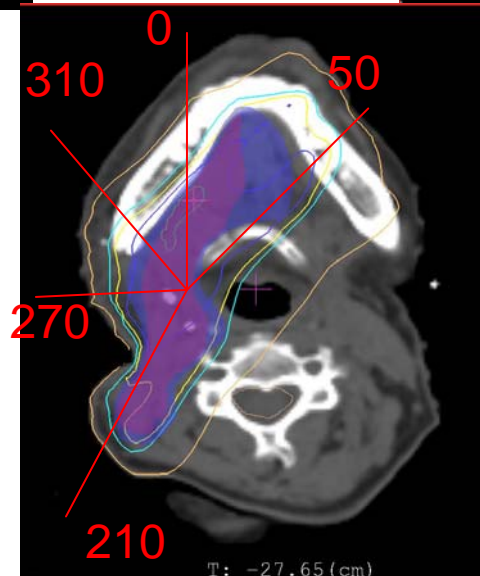
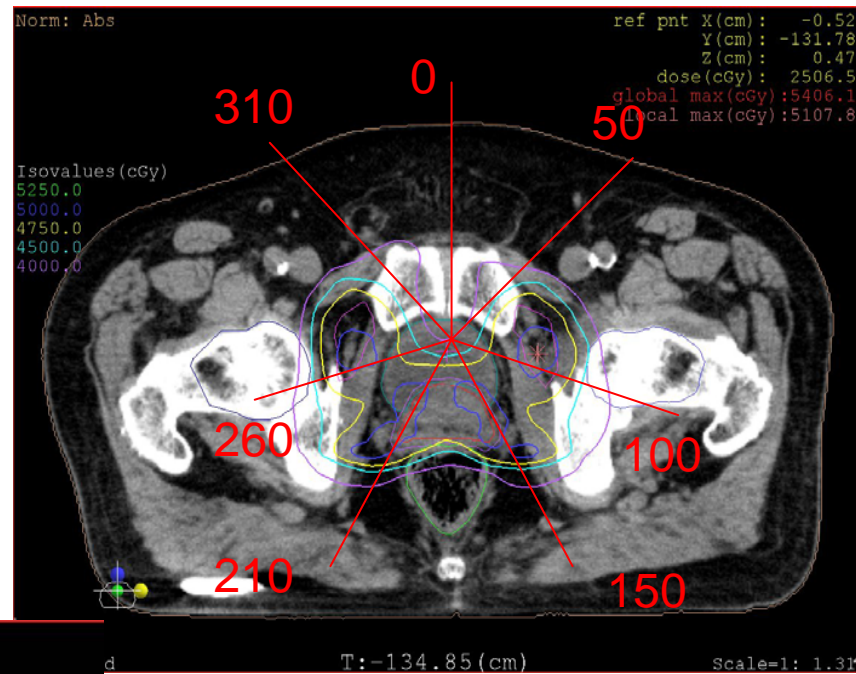
TABLE III. Dependence upon the number of angles.

Number of angles	Standard deviation in dose over target	Minimum target dose	Mean dose to RAR	Total integrated dose
3	0.124	0.644	0.488	2732.5
5	0.090	0.666	0.215	2563.3
7	0.064	0.797	0.206	2596.8
9	0.064	0.772	0.192	2598.3
11	0.058	0.775	0.186	2570.2
15	0.053	0.710	0.180	2542.9
21	0.049	0.768	0.171	2545.1
33	0.038	0.809	0.155	2543.5

Compromesso scelto in INT



7 campi



In alcuni casi 5 campi

Impatto del tempo di trattamento

Physics in Medicine and Biology > Volume 43 > Number 1

Cedric X Yu *et al* 1998 *Phys. Med. Biol.* **43** 91 doi: 10.1088/0031-9155/43/1/006

The effects of intra-fraction organ motion on the delivery of dynamic intensity modulation

Cedric X Yu, David A Jaffray and John W Wong

La variazione della dose in una singola frazione di trattamento può variare tra il 30 e il 50 % rispetto alla dose calcolata in assenza di movimento

INSTITUTE OF PHYSICS PUBLISHING

PHYSICS IN MEDICINE AND BIOLOGY

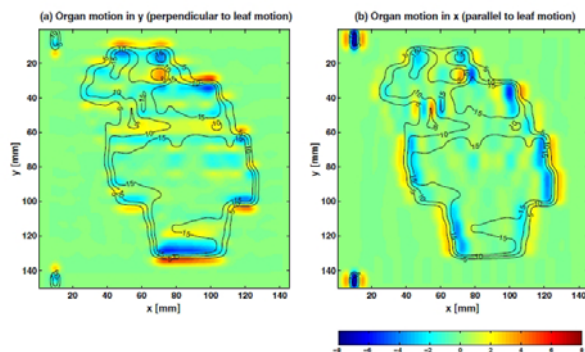
Phys. Med. Biol. 47 (2002) 1–19

PII: S0031-9155(02)34249-0

Effects of intra-fraction motion on IMRT dose delivery: statistical analysis and simulation

Thomas Bortfeld, Kimmo Jokivarsi, Michael Goitein, Jong Kung and Steve B Jiang

Department of Radiation Oncology, Massachusetts General Hospital and Harvard Medical School, Boston, MA 02114, USA



per un trattamento con IMRT di 30 frazioni, la variazione della dose totale può essere dell'ordine del 10 % rispetto alla dose calcolata in assenza di movimento

Impatto del tempo di trattamento sulla sopravvivenza cellulare

Radiobiological Investigation of Dose-Rate Effects in Intensity-Modulated Radiation Therapy

Florian Sterzing¹, Marc W. MÜNter¹, Mattias Schäfer¹, Peter Haering², Bernhard Rhein², Christoph Thilmann¹, Jürgen Debus¹

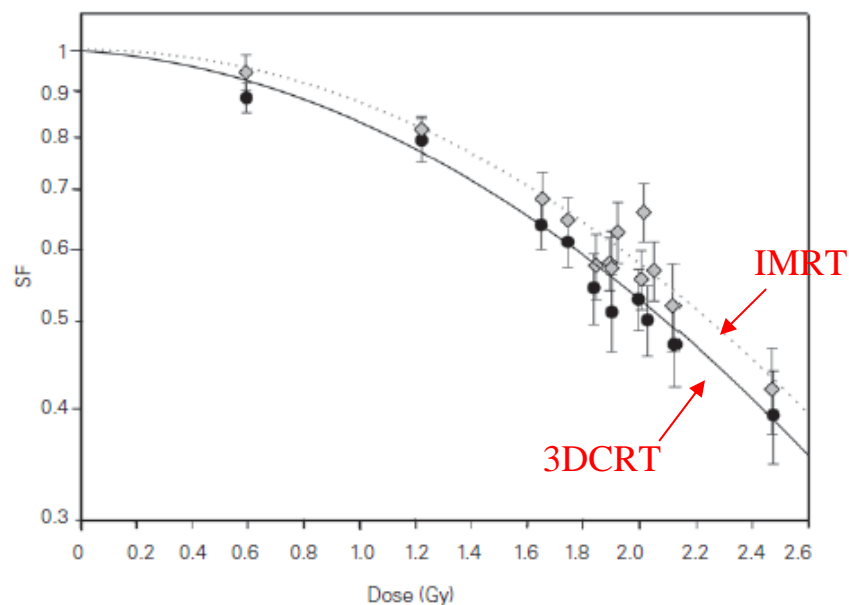


Figure 6. Survival curves of MeWo melanoma cells after irradiation with the four different IMRT plans (dotted line and diamonds) and after irradiation in the four-field box (black line and circles); mean values and standard deviations after ten repetitions.

Conclusion

The presented data show that an increase of fraction time of 15-30 min has a significant influence upon cell survival in cell culture. It seems to allow DNA damage repair during one fraction and lower the probability of lesion interaction. Hypersensitivity reactions after low-dose pulses could not be found in our experiments. The fraction time of 30 min seems to be too short to produce effects and differences in cell cycle progression during or after irradiation. For the first time this could be shown in real IMRT patient plans.

Due to the fact of the described influence of dose rate and dose protraction these parameters should be considered in future optimization of IMRT. Physical qualities such as target conformity or dose escalation are not the only determining factors of therapeutic effectiveness in IMRT.

Impatto del tempo di trattamento sulla sopravvivenza cellulare

Temporal characterization and *in vitro* comparison of cell survival following the delivery of 3D-conformal, intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT)

Conor K McGarry^{1,2}, Karl T Butterworth², Colman Trainor²,
Joe M O'Sullivan^{2,3}, Kevin M Prise² and Alan R Hounsell^{1,2}

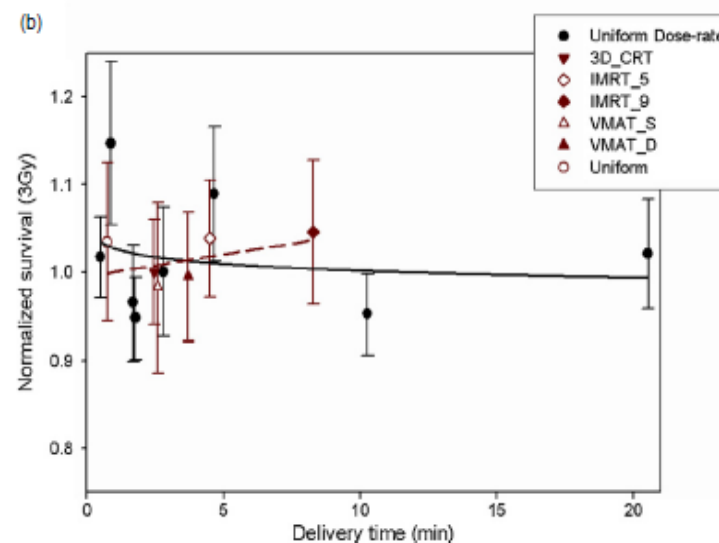
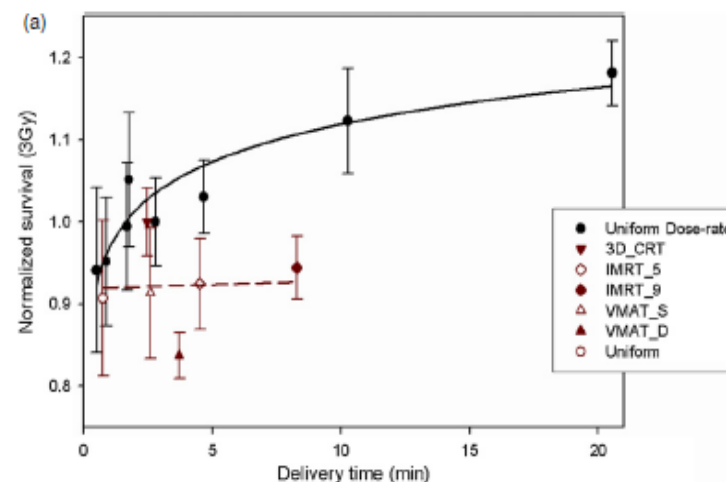
¹ Radiotherapy Physics, Northern Ireland Cancer Centre, Belfast Health and Social Care Trust, Belfast, UK

² Centre for Cancer Research and Cell Biology, Queen's University Belfast, Belfast, UK

³ Clinical Oncology, Northern Ireland Cancer Centre, Belfast Health and Social Care Trust, Belfast, UK

5. Conclusion

A phantom to study the delivery of radiotherapy plans *in vitro* was designed and validated. Single-beam, conformal, IMRT and VMAT plans were created for this phantom and the absorbed dose rates characterized using a 2D ionization chamber array. The delivery time and effective fraction time were found to vary widely between modalities. For uniform irradiations, a statistically significant trend towards increased survival with increased delivery time was observed for AGO-1522b cells, but not for more radioresistant DU-145 cells. No trend was observed in either cell line when survival was analysed against delivery time using the modulated clinical plans with widely differing absorbed dose rate histories. Differences in absorbed dose rate histories of techniques such as 3D-CRT, IMRT and VMAT may not allow direct interpolation of cell survival using data generated from uniform beam delivery over a range of treatment times.

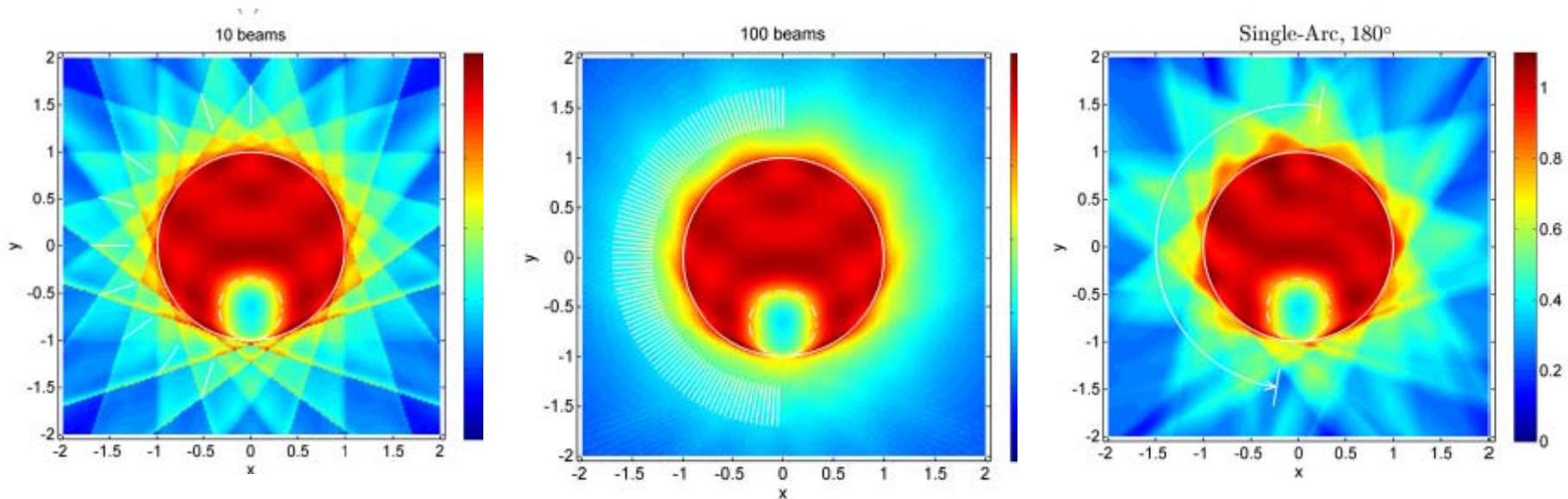


Dalla IMRT a campi fissi agli archi

The number of beams in IMRT—theoretical investigations and implications for single-arc IMRT *Phys Med Biol* 55 (2010) 83-97

Thomas Bortfeld

Massachusetts General Hospital and Harvard Medical School, Department of Radiation Oncology, 30 Fruit St, Boston, MA 02114, USA



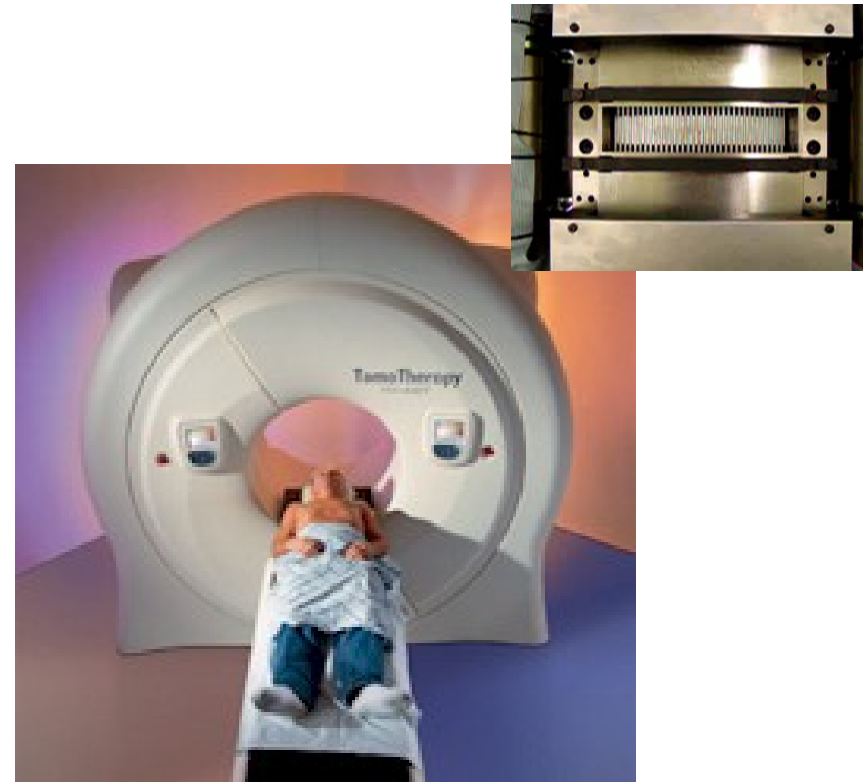
Tecniche IMRT rotazionali

MIMIC Collimator



Tomoterapia seriale

TOMOTHERAPY

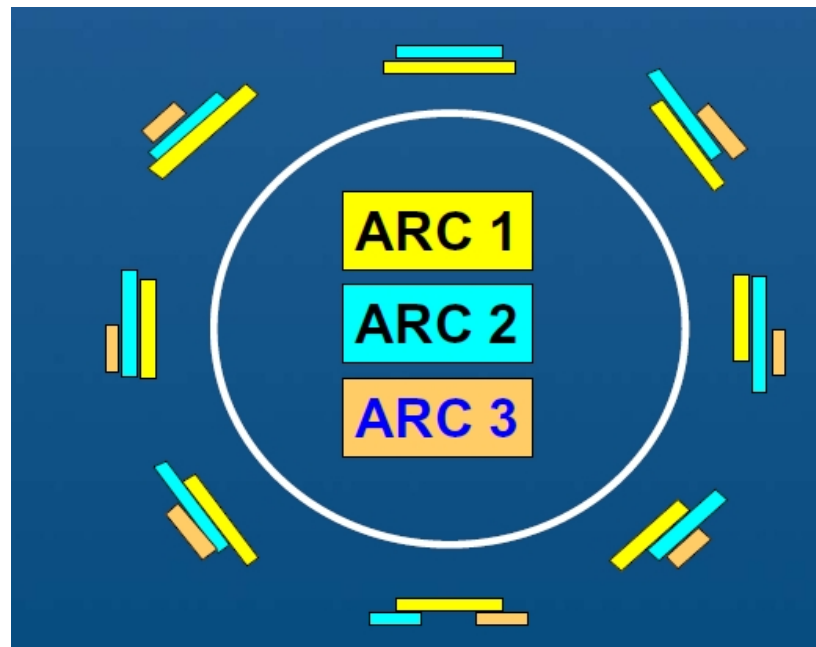


Tomoterapia elicoidale

Intensity-Modulated Arc Therapy IMAT

Intensity-modulated arc therapy with dynamic multileaf collimation:
an alternative to tomotherapy

C X Yu 1995 *Phys. Med. Biol.* **40** 1435-1449 doi:10.1088/0031-9155/40/9/004



Volumetric-Modulated Arc Therapy VMAT/RapidArc

Volumetric modulated arc therapy: IMRT in a single gantry arc

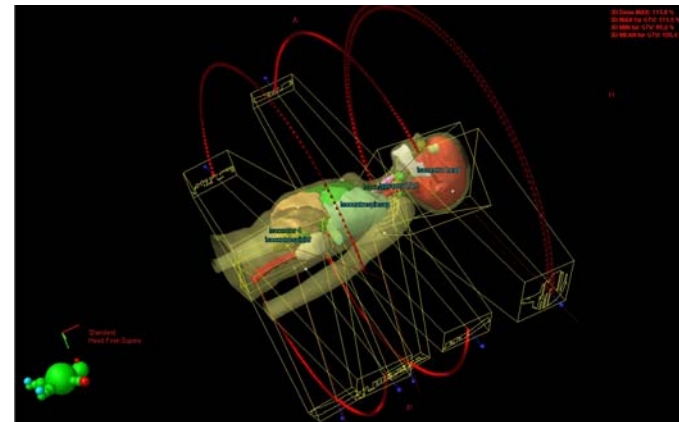
Karl Otto^{a)}

Vancouver Cancer Centre, BC Cancer Agency, Vancouver, British Columbia V5Z 4E6, Canada

(Received 25 June 2007; revised 21 September 2007; accepted for publication 5 November 2007;
published 26 December 2007)

Durante l'arco viene modificato dinamicamente:

- Velocità del gantry
- Dose rate
- Forma del campo



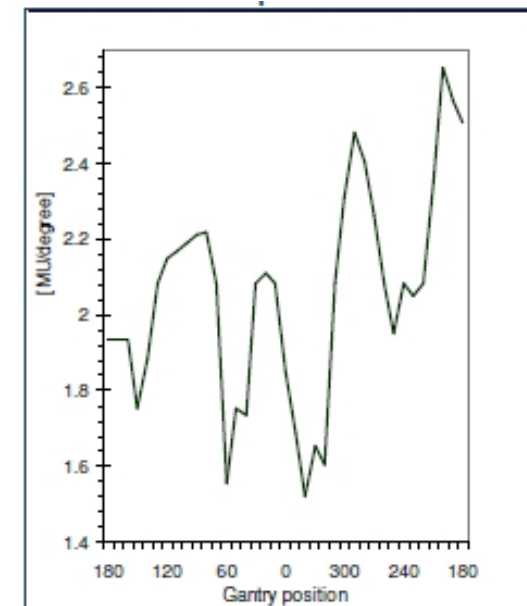
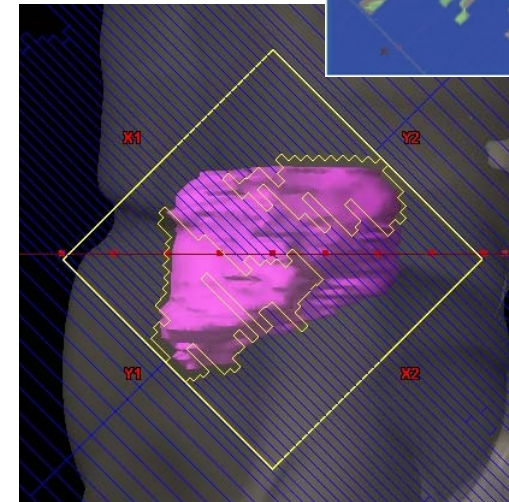
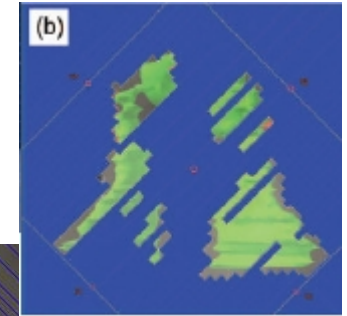
VMAT/RapidArc

E' consigliabile utilizzare un angolo di collimatore diverso da zero

- ✓ Riduzione dell'effetto Tongue-Groove e della trasmissione tra lamelle affiancate
- ✓ Permette di generare la modulazione in corrispondenza di una sezione assiale con più coppie di lamelle
- ✓ L'interdigitazione delle lamelle permette di creare aree di irraggiamento separate per ogni posizione del gantry

Vantaggi legati ad una variazione continua della velocità di rotazione del gantry e del dose rate

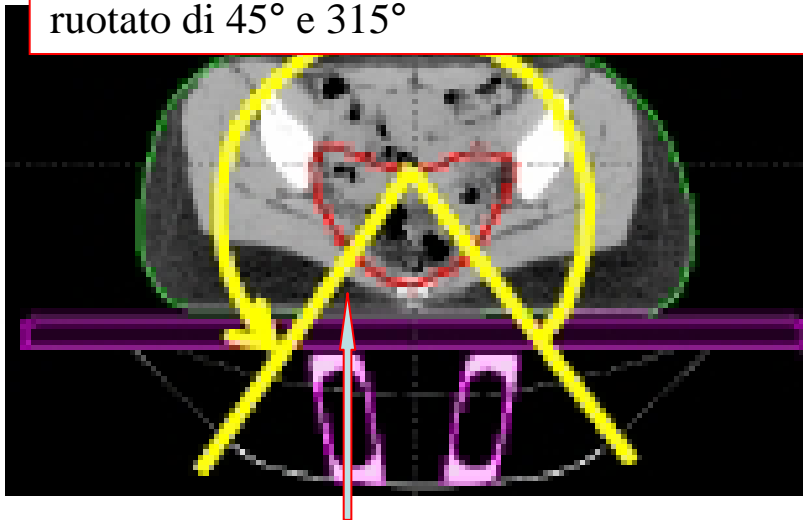
- ✓ Permette di incrementare o ridurre la dose impartita per grado



VMAT/RapidArc in INT

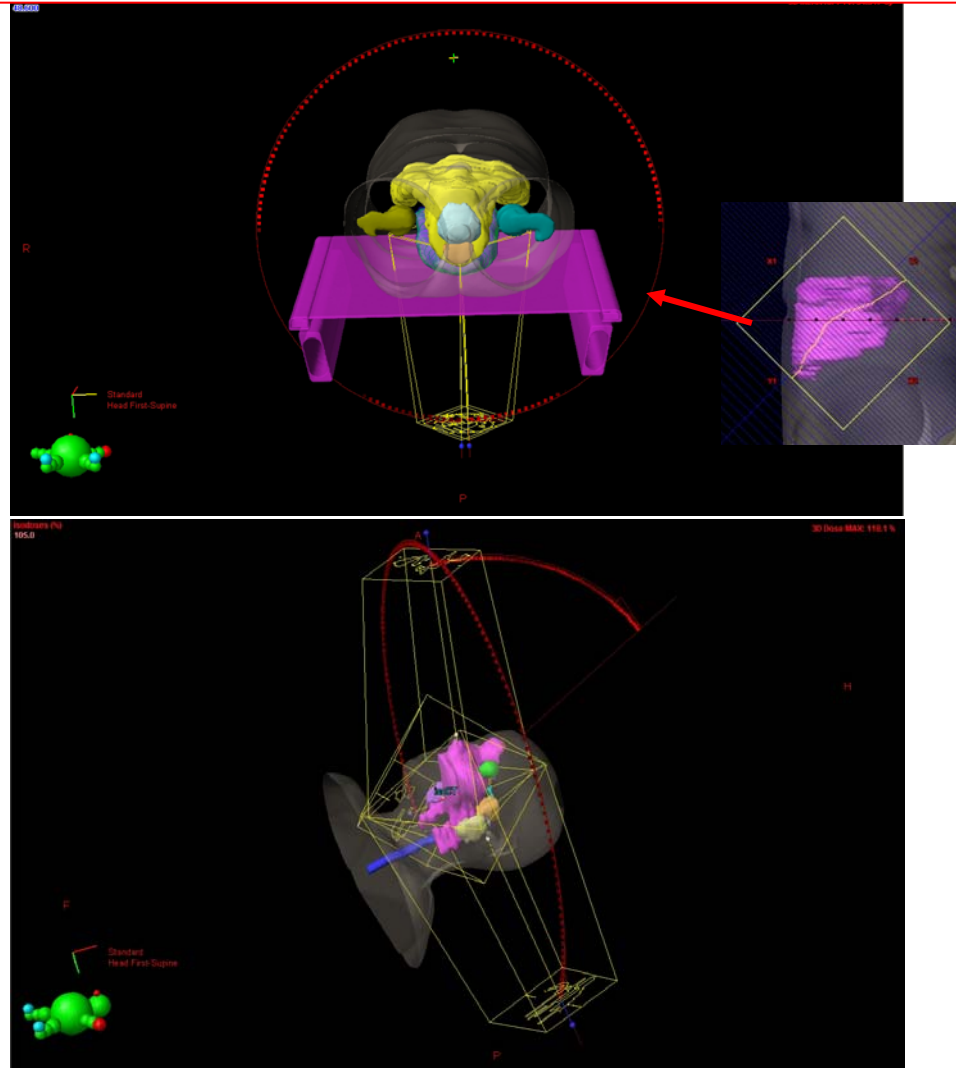
Arco singolo vs Archi multipli

2 archi da 240 a 120° con collimatore ruotato di 45° e 315°



Attenuazione 4-5%

2 archi da 360° con collimatore ruotato di 45° e 315°

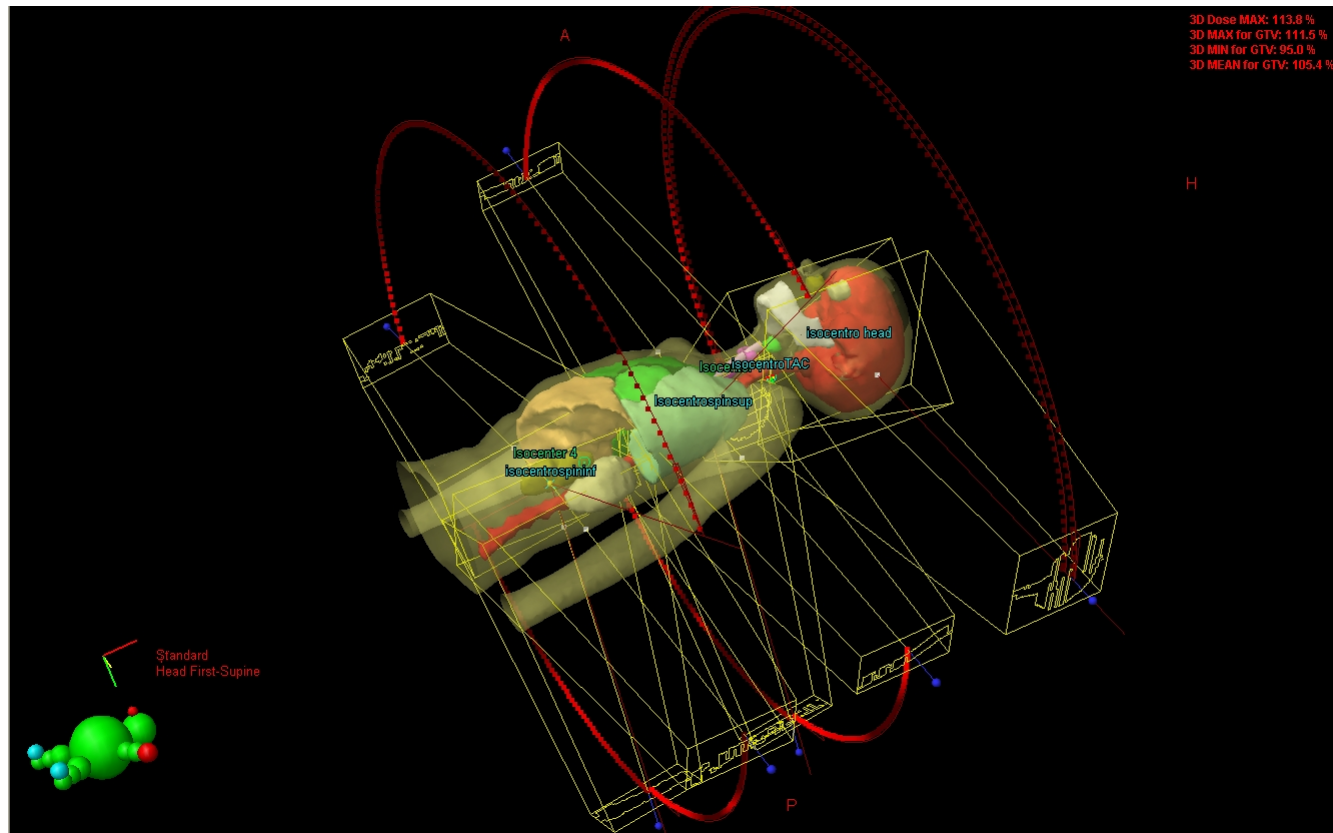


Archi non coplanari

VMAT/RapidArc

Archi multipli ed isocentri multipli

Studio di fattibilità del trattamento del Sistema Nervoso Centrale con tecnica RapidArc

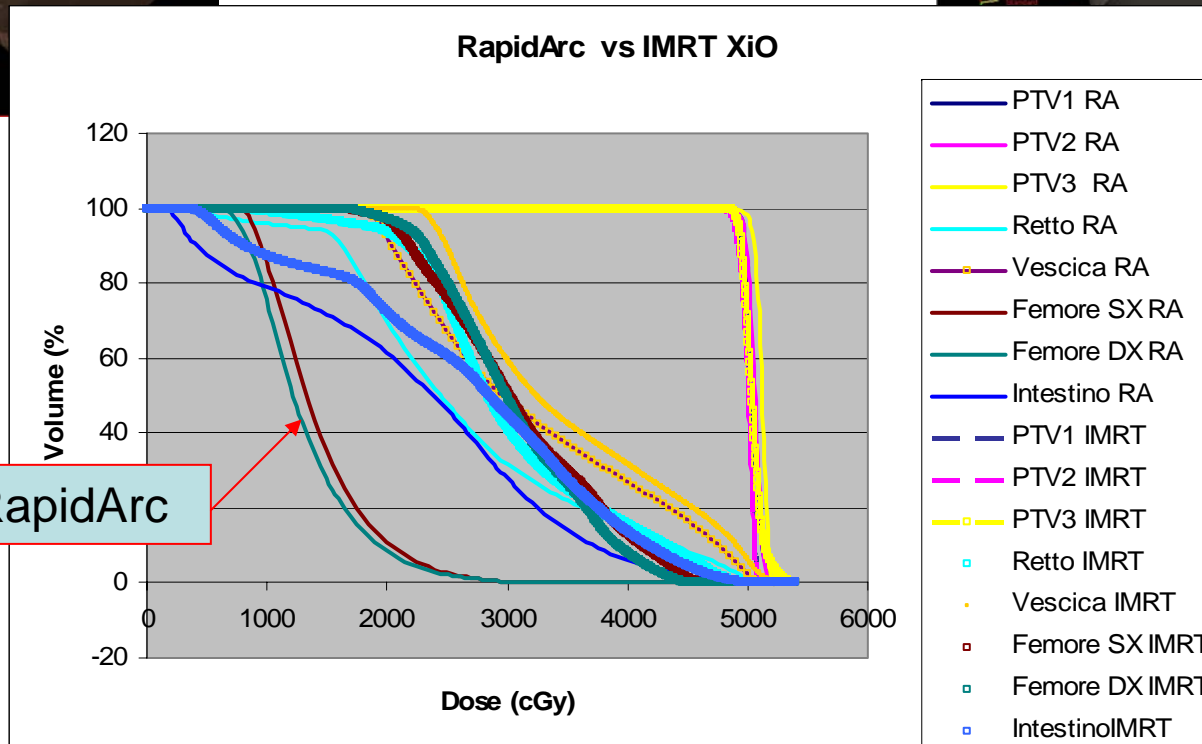
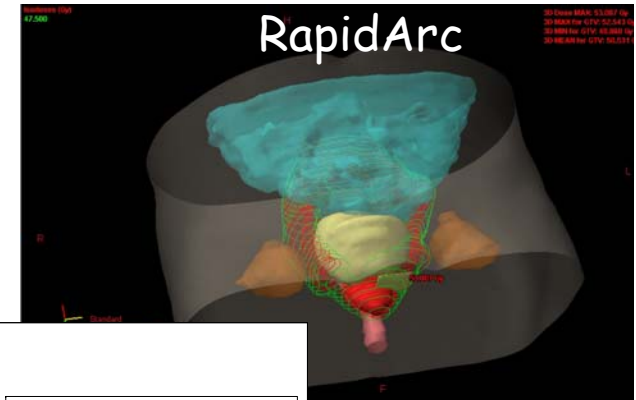


Prostata e linfonodi



Dose prescritta 50 Gy

Targets: prostata (PTV1)
vescicole (PTV2)
linfonodi (PTV3)



Femori con RapidArc

15 MV

IMRT	RapidArc
1229 MU	294x2 = 588 MU
~ 4 min	< 2 min

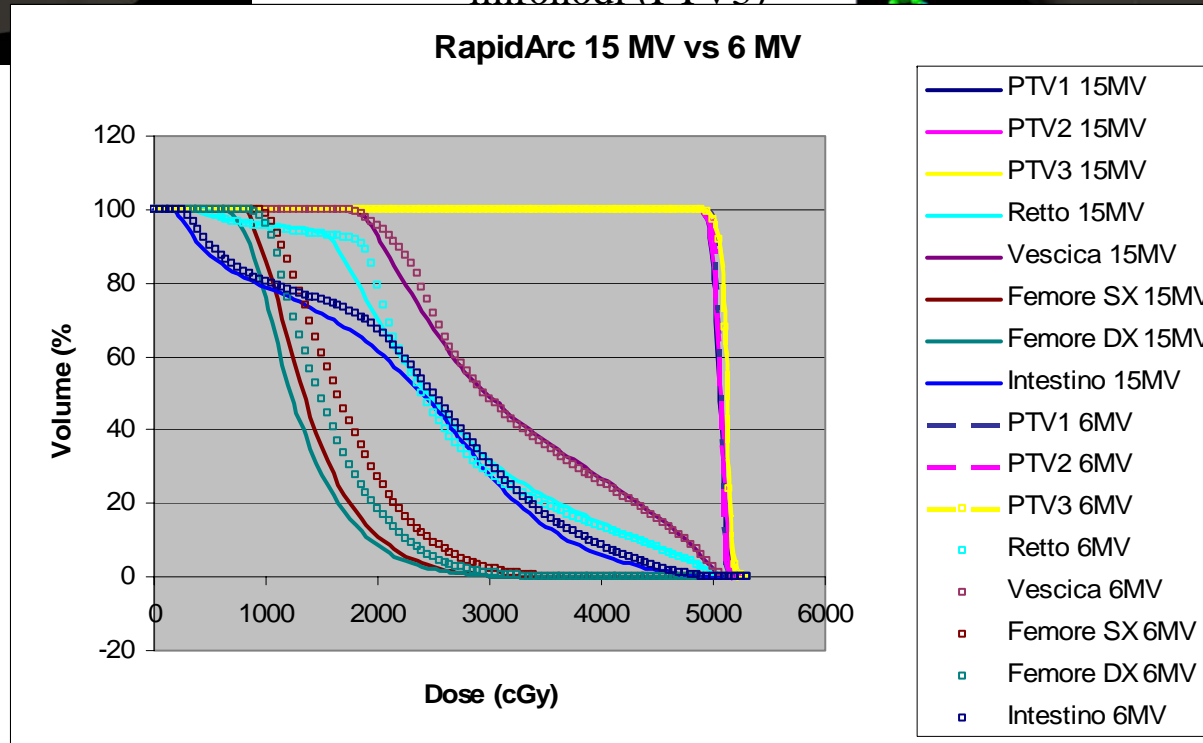
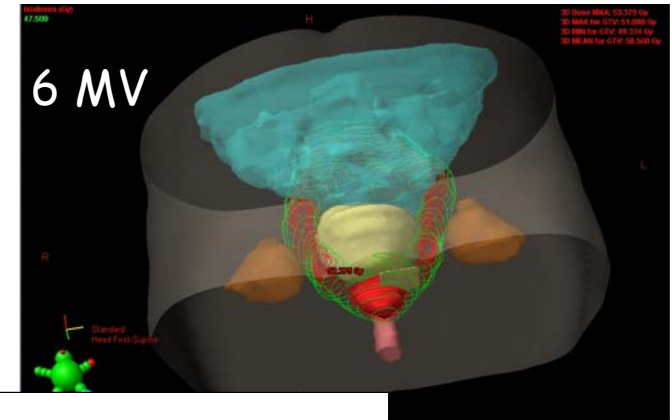
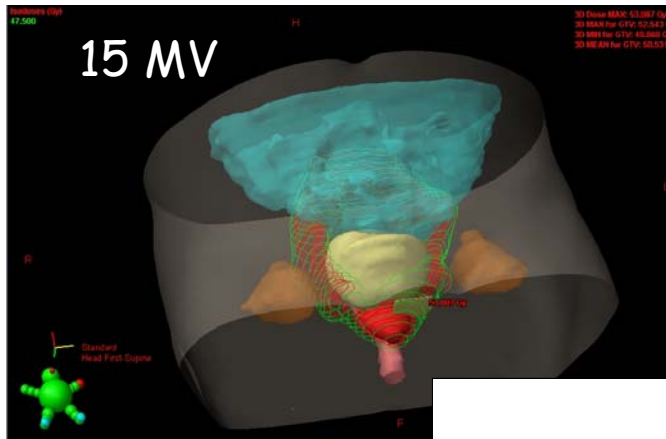
N.B. Tempo di erogazione raggi

Prostata e linfonodi 15 MV vs 6 MV

RapidArc

Dose prescritta 50 Gy

Targets: prostata (PTV1)
vescicole (PTV2)
linfonodi (PTV3)



RapidArc 15 MV	RapidArc 6 MV
294x2 = 588 MU	355+349 = 704 MU
< 2 min	~ 2 min

N.B. Tempo di erogazione raggi

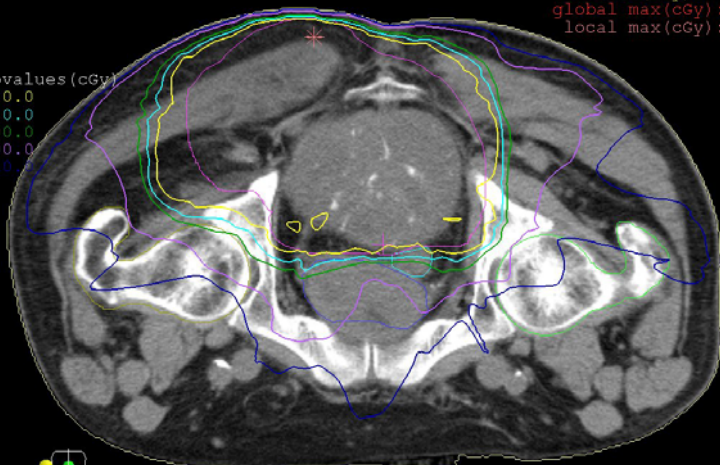
Cordoma 6 MV

IMRT XiO

RapidArc

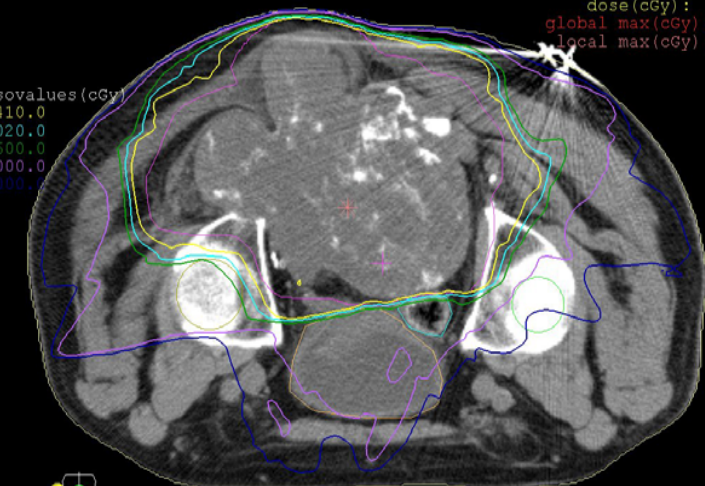
Norm: Abs
ref pnt X(cm): -2.87
Y(cm): -136.60
Z(cm): 11.70
dose(cGy): 6656.2
global max(cGy): 8511.2
local max(cGy): 8168.1

Isovalues (cGy)
7410.0
7020.0
6600.0
5000.0
4000.0



Norm: Abs
ref pnt X(cm): -2.87
Y(cm):
Z(cm):
dose(cGy):
global max(cGy):
local max(cGy):

Isovalues (cGy)
7410.0
7020.0
6600.0
5000.0
4000.0



Maximized

T: -138.10 (cm)

Scale=

Standard

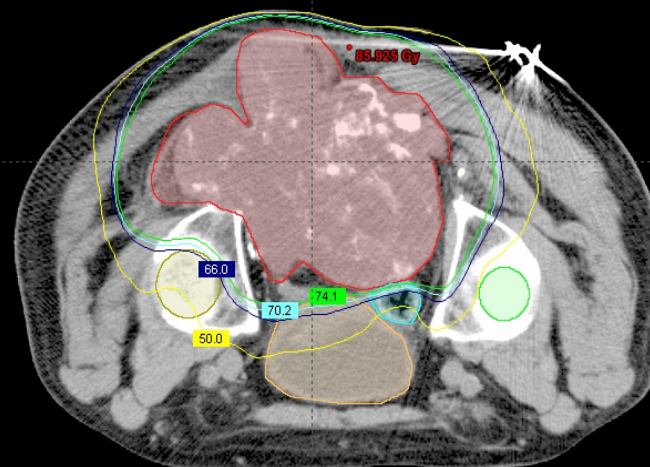
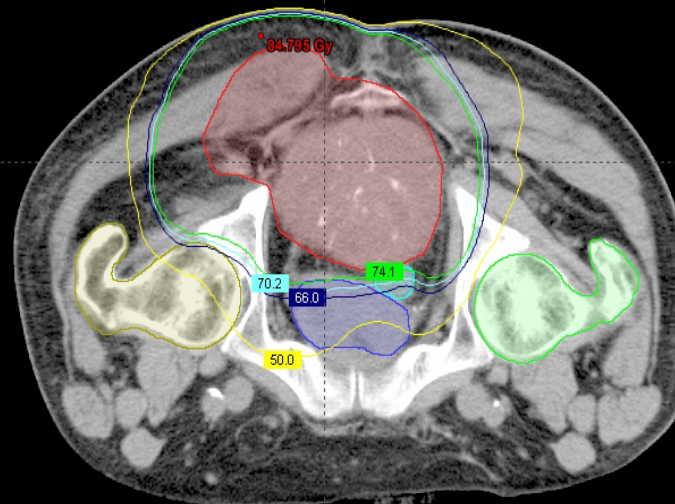
L

R



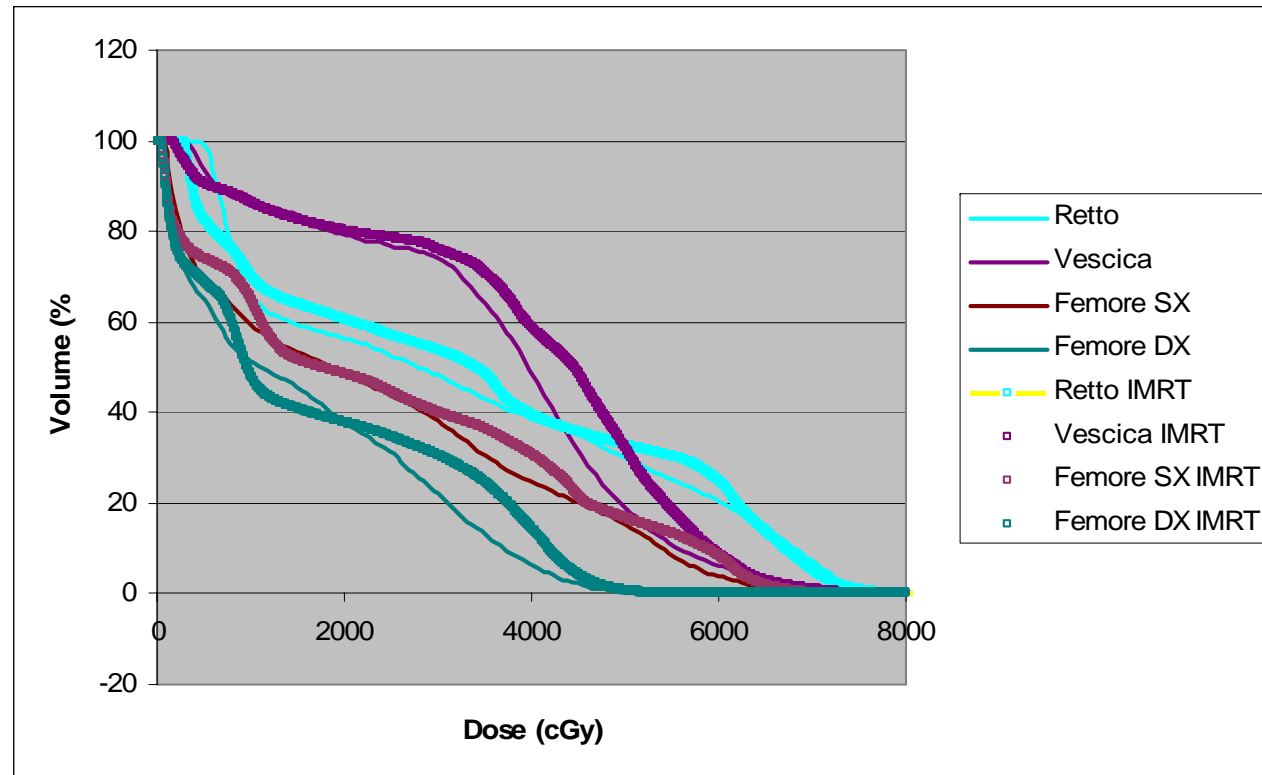
Head First-Prone

A



Cordoma 6 MV

Dose Prescritta
77 Gy al PTV

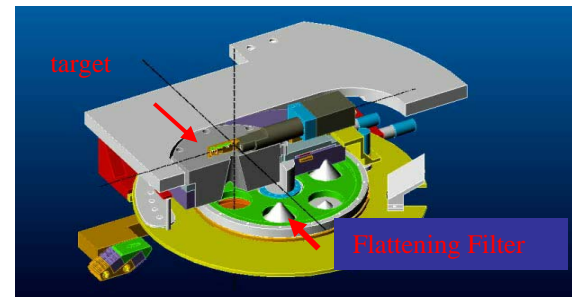
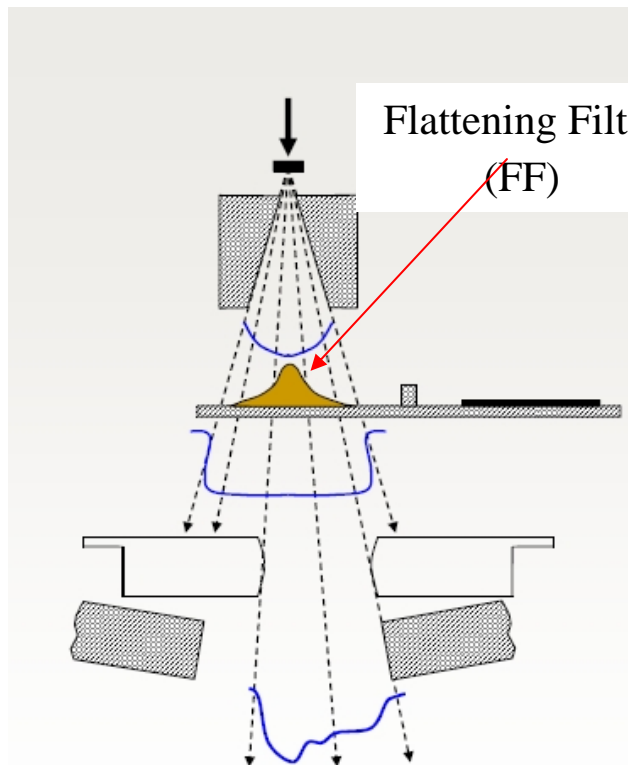


IMRT	RapidArc
1466 MU	228+201 = 429 MU
~ 5 min	~ 2 min

N.B. Tempo di erogazione raggi

Quale evoluzione ci aspetta nella tecnica IMRT/VMAT

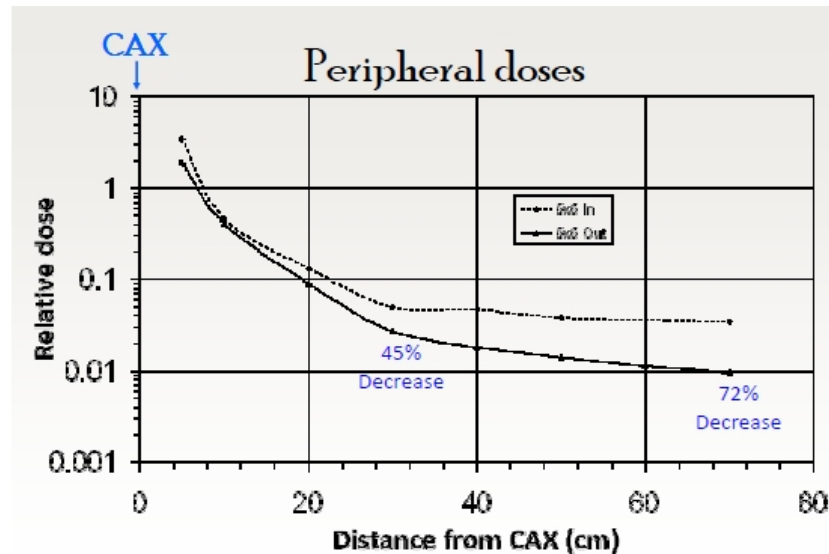
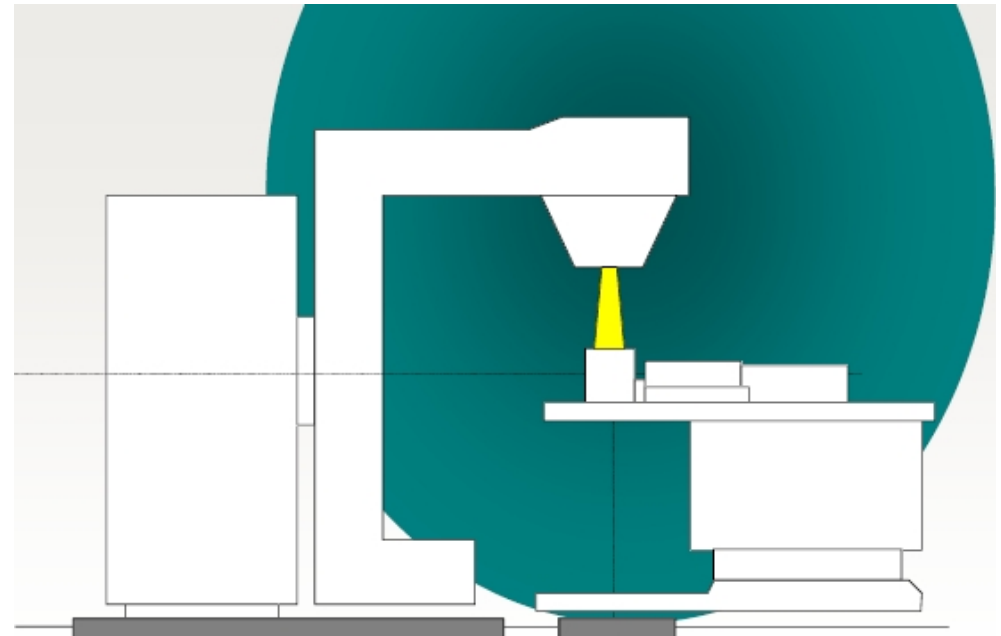
Flattening Filter Free (FFF)



SCOPO DEL FF
produrre un fascio piatto ed omogeneo (a 10 cm
di profondità in acqua)

Conseguenze dovute alla rimozione del Flattening Filter

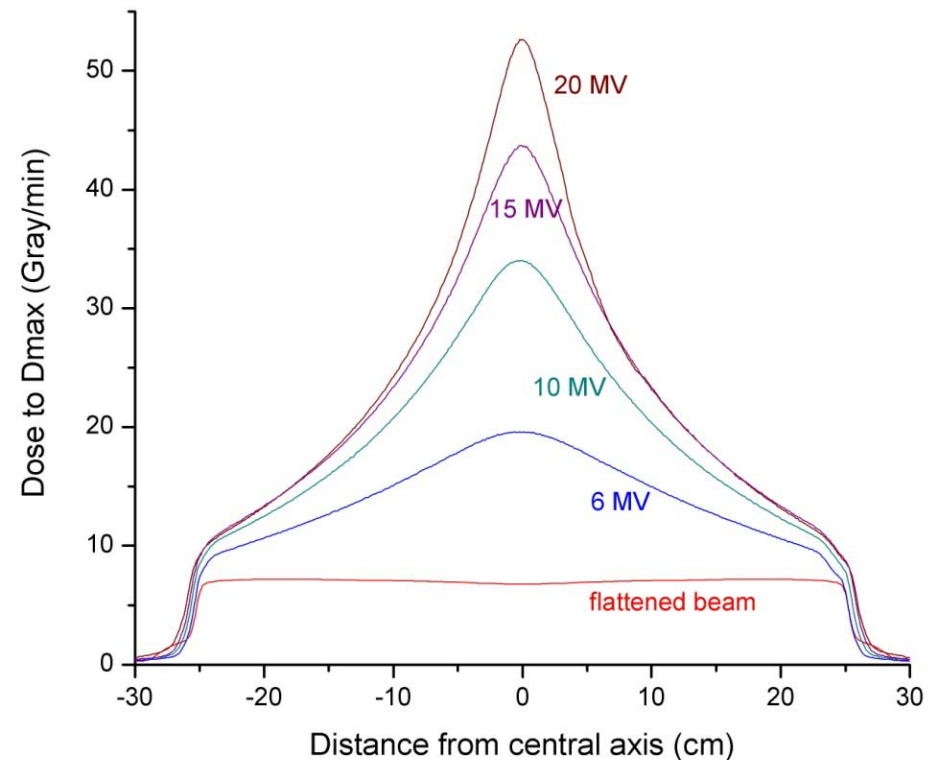
FF è la sorgente principale di radiazione diffusa nella testa:
riduzione della radiazione di fuga (riduzione tumori secondari)



Conseguenze dovute alla rimozione del Flattening Filter

FF attenua l'intensità fascio
(50% sull'asse a 6MV):

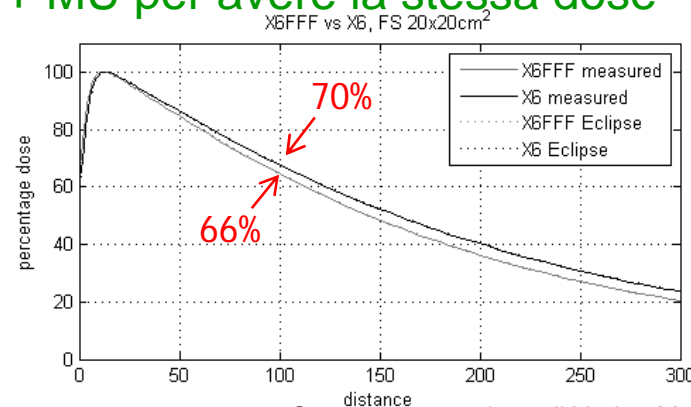
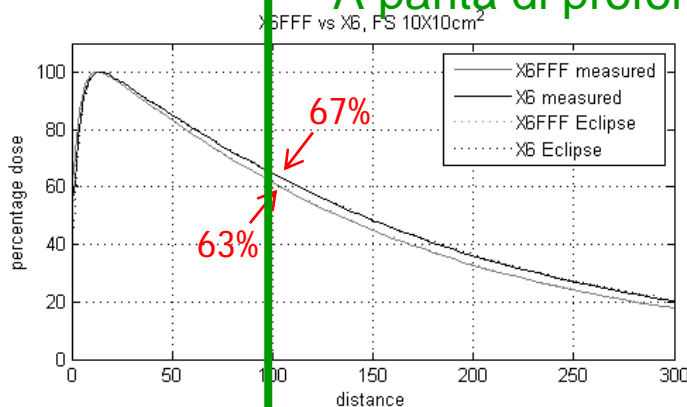
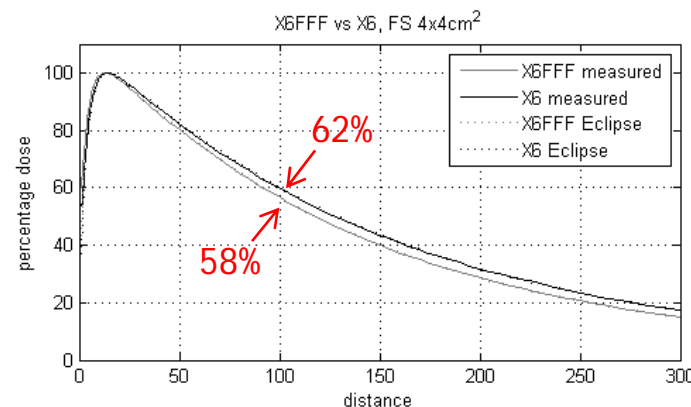
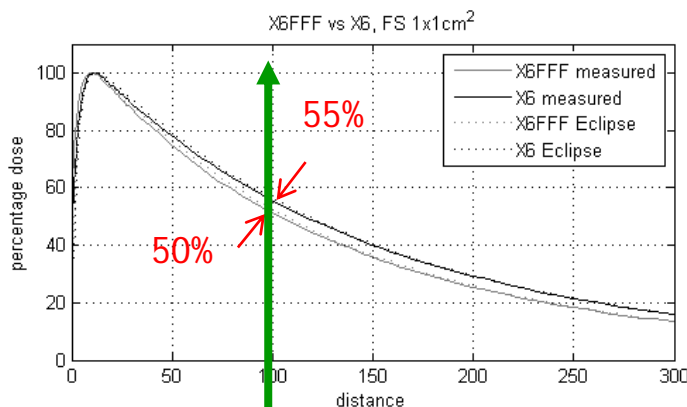
incremento dell'intensità del
fascio (aumento del dose-rate
1400-2400 MU/min)



Conseguenze dovute alla rimozione del Flattening Filter

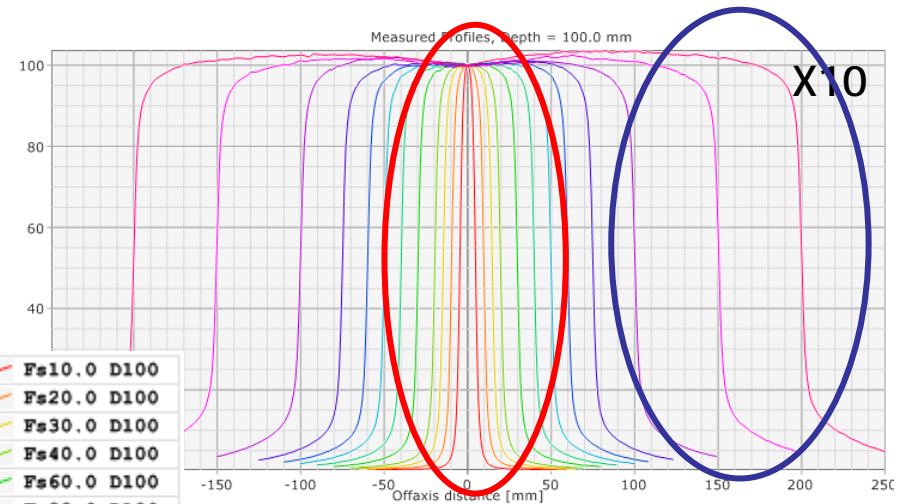
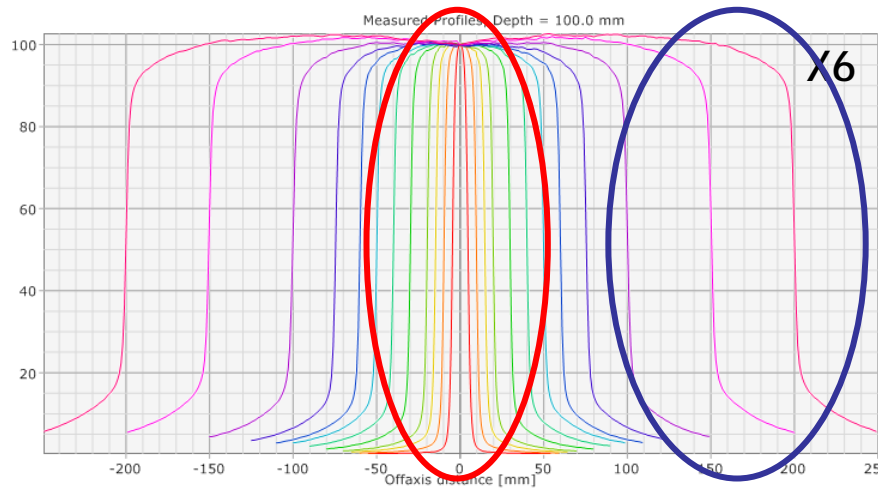
Riduzione dell'energia media del fascio: X6 MV FF \rightarrow \sim X4MV FFF

- Campi piccoli: aumento della dose superficiale (maggiore componente molle della radiazione)
- Campi grandi: riduzione della dose superficiale (riduzione della contaminazione elettronica)

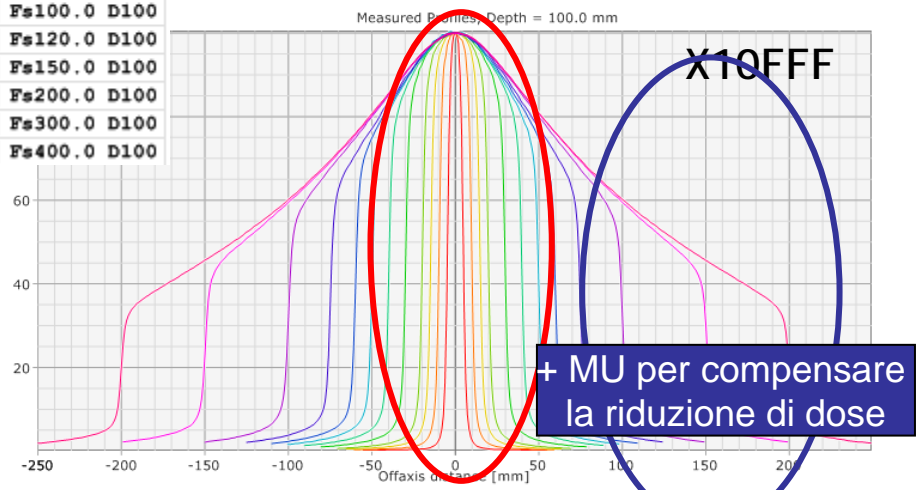
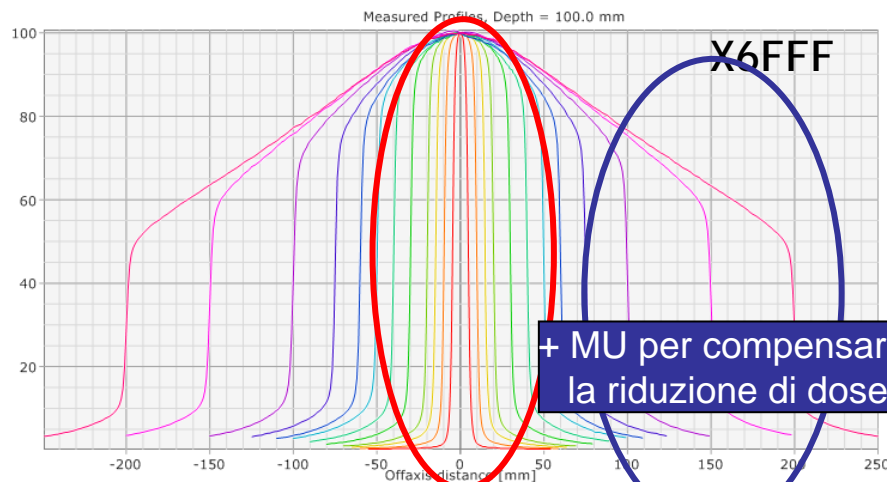


A parità di profondità + MU per avere la stessa dose

Conseguenze dovute alla rimozione del Flattening Filter



- Fs10.0 D100
- Fs20.0 D100
- Fs30.0 D100
- Fs40.0 D100
- Fs60.0 D100
- Fs80.0 D100
- Fs100.0 D100
- Fs120.0 D100
- Fs150.0 D100
- Fs200.0 D100
- Fs300.0 D100
- Fs400.0 D100



Conclusioni

□ VMAT/RapidArc può essere considerata una evoluzione tecnologica della IMRT

□ VMAT/RapidArc effettuata con 2 archi può essere un ottimo compromesso tra livello di conformazione e durata del trattamento

□ La riduzione del tempo di trattamento rispetto alla IMRT può:

- ridurre gli errori dovuti al movimento intra-fraction.

- Creare più tempo for IGRT

➤ I trattamenti di piccoli tumori possono beneficiare maggiormente dall'uso della tecnica FFF, in particolare con tecniche 3DCRT e SRT/SBRT

➤ La qualità dei trattamenti IMRT con tecnica FFF è comparabile a quella con filtro, ma per targets più grandi e forme più complicate un numero maggiore di MU sono necessarie (circa +25% per H&N). Possibilità di perdere alcuni dei vantaggi legati alla rimozione del FF.



La tecnologia cambia rapidamente, ma noi ci stiamo preparando

Grazie per l'attenzione