VMAT
Dosimetric characteristics and delivery

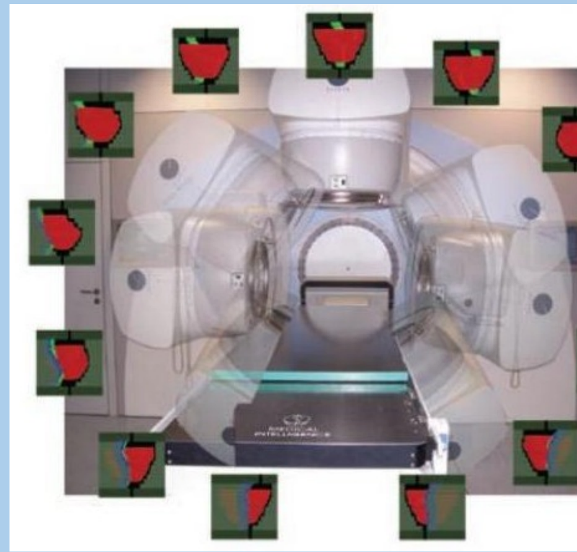
Marta Paiusco

Agenda

- IMAT Milestones
- Planning systems
- Commissioning

Milestone

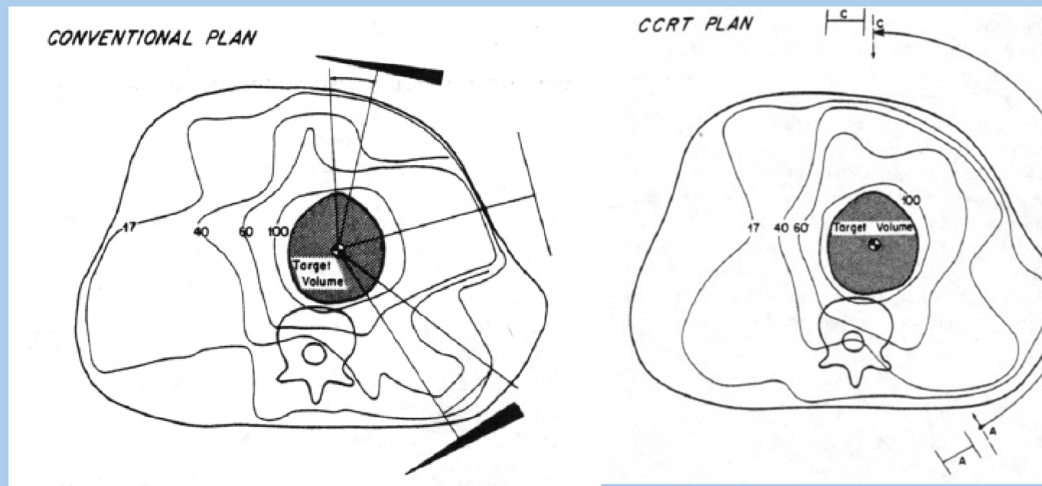
Arc Therapy is a very old concept



Dynamic Arc therapy ≡ Conformal arc therapy
beams aperture is dynamically shaped by the MLC to match the beam's eye view of the target

1983 **A theory by L.M.Chin**

gantry rotation (simulated by 72 static fields) +
collimator motion (conformed to the target) +
dose rate variation (different field's weight)
highly improve conformal dose distribution



Brahme 1988 : Fluence Intensties Modulation concept

Mackie 1993 : Tomotherapy

Cedric X Yu 1995 IMAT : an alternative to Tomotherapy

Tomotherapy vs IMAT

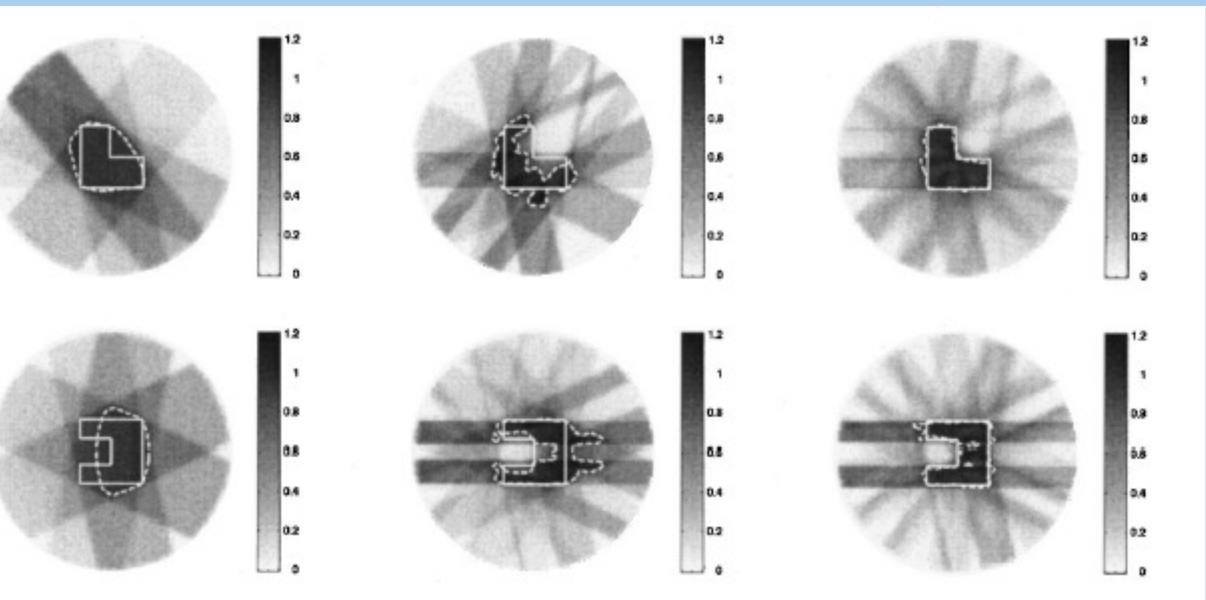
Tomotherapy	IMAT
continuous gantry rotation	continuous gantry rotation
fan beam	cone beam
binary collimator	standard MLC
couch translation	couch fixed

Shepard 1999: dosimetric advantages of rotational treatments

D.M. Shepard Med Phys 1999

Idea :through the summation of a series of adjacent beams, one can produce uniform broad beams.
A **segmented field** is produced and optimized in Aperture and Weight

3DCRT IMAT IMRT



Target complexity : C shape

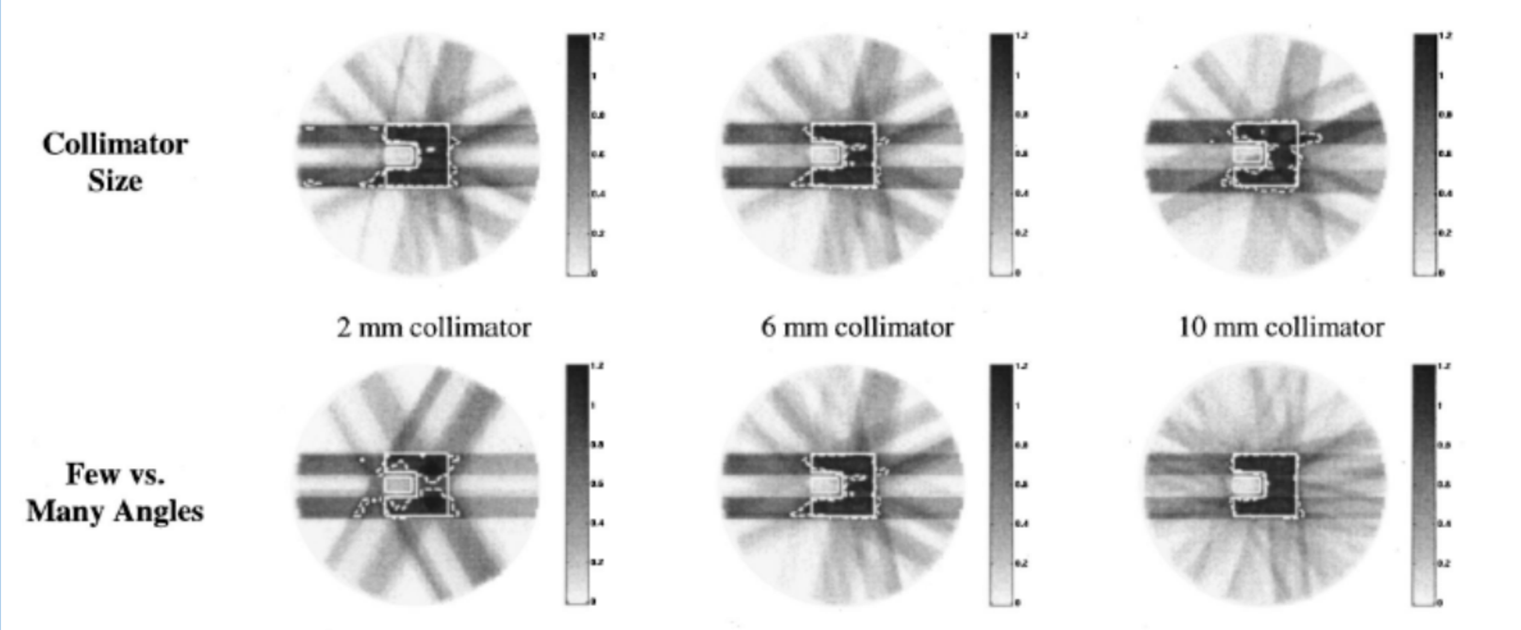
The benefits of IMRT are most apparent with the complex target shape. IMRT can provide both sparing of the regions at a risk and dose uniformity in the target

Segmented fields (IMAT) can provide a significant sparing of sensitive structures located in close proximity to the target,

but IMRT provides the ability to provide tight contours matching the tumor shape.

Planning parameters : collimator size and number of fields

IMAT



2 mm collimator   6 mm collimator   10 mm collimator

3 Angles   7 Angles   11 Angles

TABLE II. Dependence upon collimator size using diverging pencil bea

Collimator size (mm)	Standard deviation in dose over the target	Mean dose t region at ris
20	0.090	0.553
10	0.079	0.283
6	0.059	0.190
4	0.048	0.180
2	0.040	0.156

TABLE III. Dependence upon the number of angles.

Number of angles	Standard deviation in dose over target	Minimum target dose	Mean dose to RAR	To integ d
3	0.124	0.644	0.488	27
5	0.090	0.666	0.215	25
7	0.064	0.797	0.206	25
9	0.064	0.772	0.192	25
11	0.058	0.775	0.186	25
15	0.053	0.710	0.180	25
21	0.049	0.768	0.171	25
33	0.038	0.809	0.155	25

Cedric X Yu idea:

- IMRT : N fields with M Intensity level
- hp: Plan Quality PQ = f(NxM)
- Th : Increasing the number of gantry angle we can reduce the number of intensity level

The idea is to share the field modulation with several neighboring segments and regain the modulation through the superposition of these fields or arcs

S&S = IMRT 7 fields with 11 Intensity level $\Rightarrow$ 78 gantry angle should be enough for the same PQ without intensity modulation

A single arc with a sufficient number of aperture shape variations would be able to create optimal treatment plans

The idea is a Multi-arc therapy with **NO** Modulation inside the field

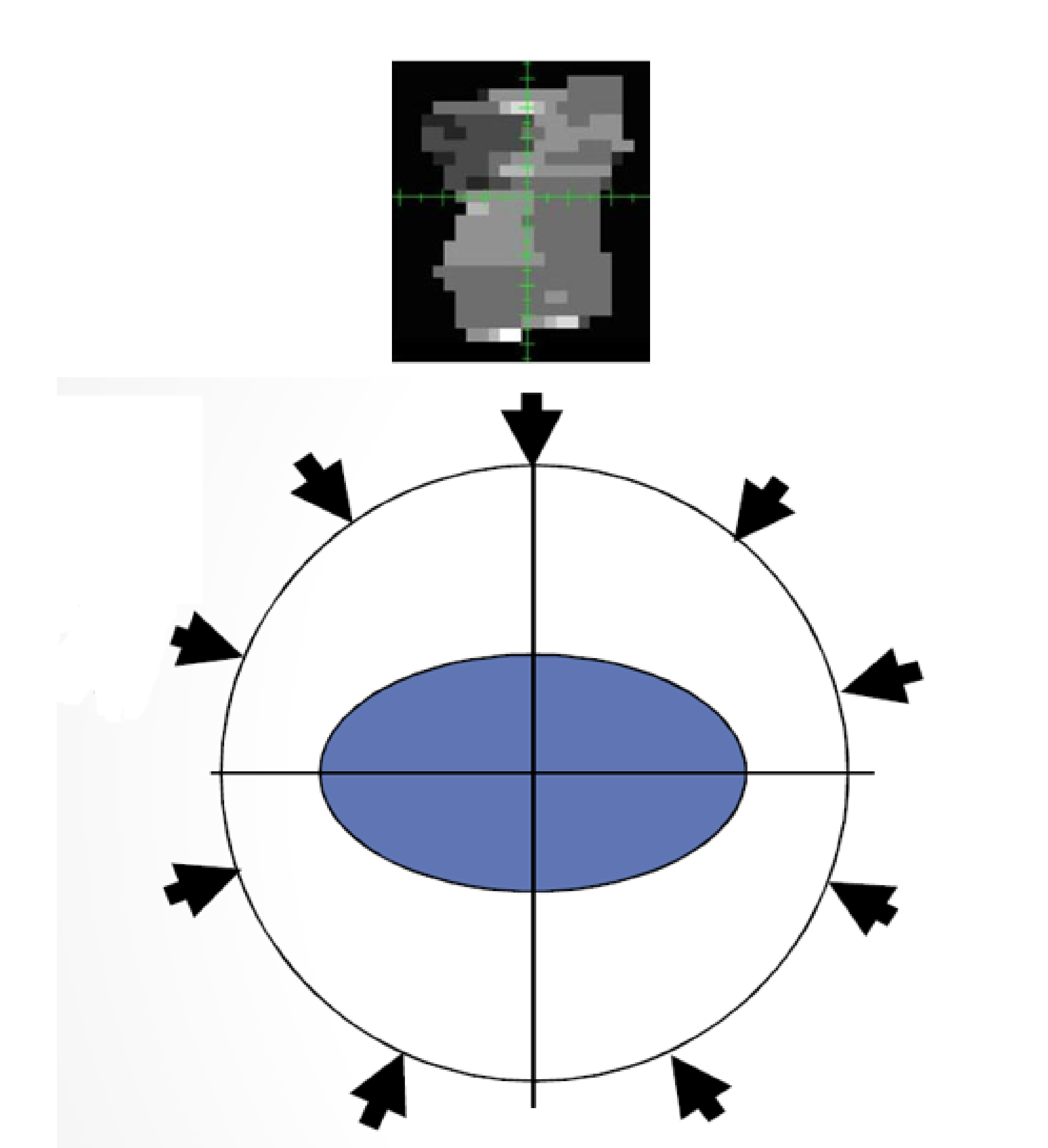
Intensity Modulated Arc Therapy

Arc therapy: depict the actual delivery method
(gantry moves continuously while the beam is on)

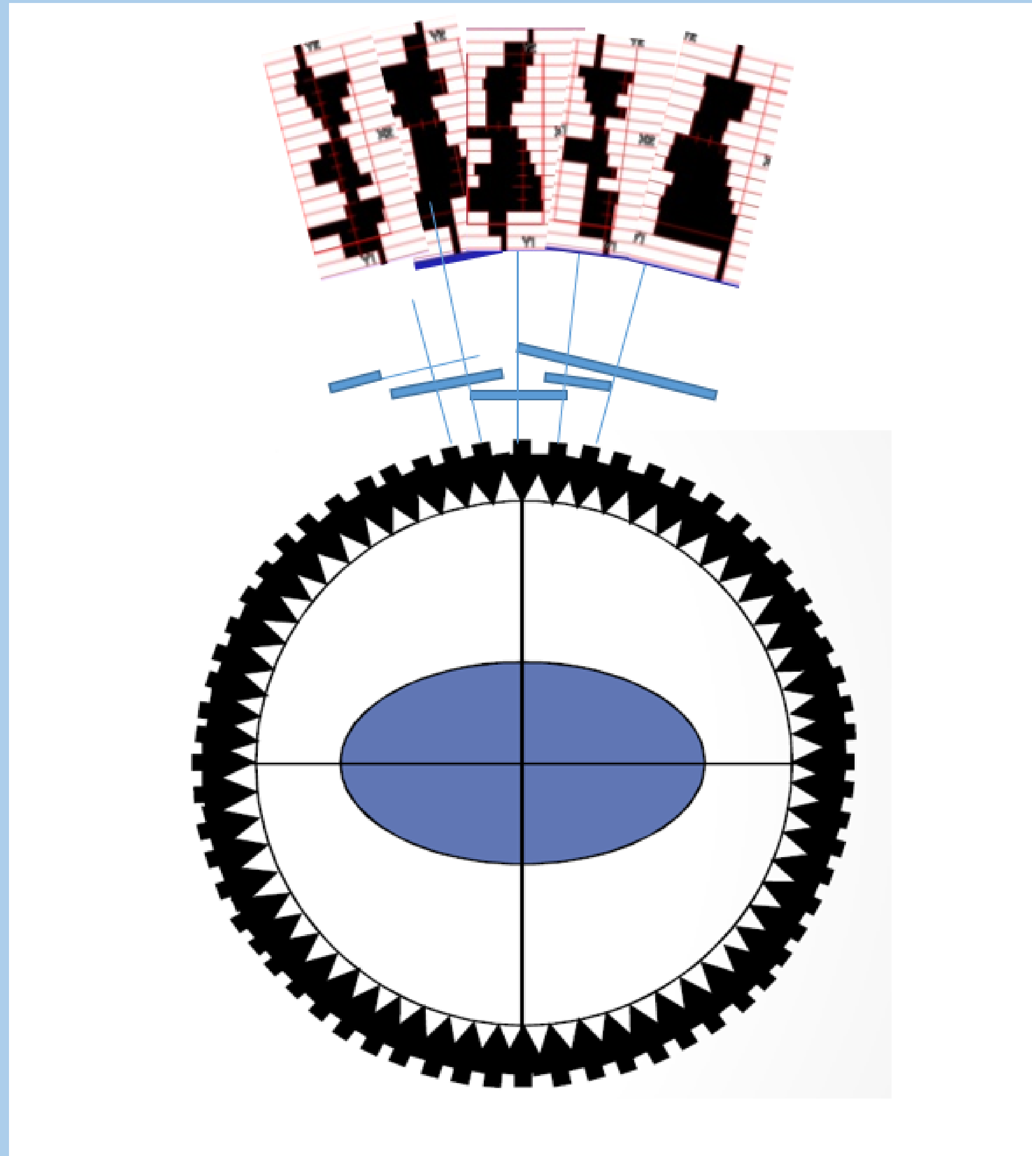
Intensity modulated : No intensity modulation is within each beam
The needed intensity variation at the target reagion is achieved with the aperture from the neighboring angles.

2008 Otto K. developed a single arc IMAT with variable dose rate

Volumetric Modulated Arc Therapy (Varian :RapidArc)™- Elekta VMAT ™



Static Gantry IMRT



VMAT

IMAT Planning- Inverse planning solutions

- Varian :Eclipse RapidArc
- Philips: Pinnacle SmartArc
- Elekta: Monaco VMAT & Oncentra MasterPlan VMAT
- Raysearch : VMAT module

IMAT Planning- Inverse planning solutions

Main problem :

Aperture connectivity

To make the plan deliverable MLC cannot travel long distance while the gantry rotates around the patient and the radiation beam is on. Geometric connectivity between adjacent beam angles must be satisfied.

Gantry rotation speed

cannot have frequent variations due to its weight so variations in aperture weights must be achived primarely by dose rate variations

IMAT Planning- Inverse planning solutions

- **Pinnacle, Masterplan and Raysearch system**
- Two step process based on Bzdusek approche

> **Development and evaluation of an efficient approach to volumetric arc therapy planning**
>
> Karl Bzdusek[a)]
> *Philips Healthcare, Fitchburg, Wisconsin 53711*
>
> Henrik Friberger, Kjell Eriksson, and Björn Hårdemark
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>
> (Received 29 November 2008; revised 3 March 2009; accepted for publication 20 April 2009; published 27 May 2009)

STEPS:

1. Set arc parmeters
2. Generate initial arc (fields per arc)
3. Optimize the fluence and aperture for all the beam used to approximating an arc without constraints related to the delivery.
4. Apertures are spaced over the angular arc range and e DAO algorithm is used to optimize weights and shapes taking into account MLC and converting the beam intensities and aperture into deliverable MLC segments

IMAT Planning- Inverse planning solutions

Volumetric modulated arc therapy: IMRT in a single gantry arc

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(Received 25 June 2007; revised 21 September 2007; accepted for publication 5 November 20
published 26 December 2007)

<u>Eclipse RapidArc</u>

<u>One step inverse planning algorithm</u>

<u>Based on Otto paper where Shepard *Direct Aperture Optimizazion* approach</u>

1. Based on more control points in a single arc (177)
2. Progressive sampling was used to improve the speed of the algorithm.
3. All the delivery constraints are included directly into the IMAT DAO optimization.
4. A simulated annealing algorithm is used to optimize the MLC leaf positions and aperture weights.
5. After each change in an MLC leaf position, the algorithm checks the delivery constraints

Direct aperture optimization: A turnkey solution for step-and-shoot IM

D. M. Shepard, M. A. Earl, X. A. Li, S. Naqvi, and C. Yu
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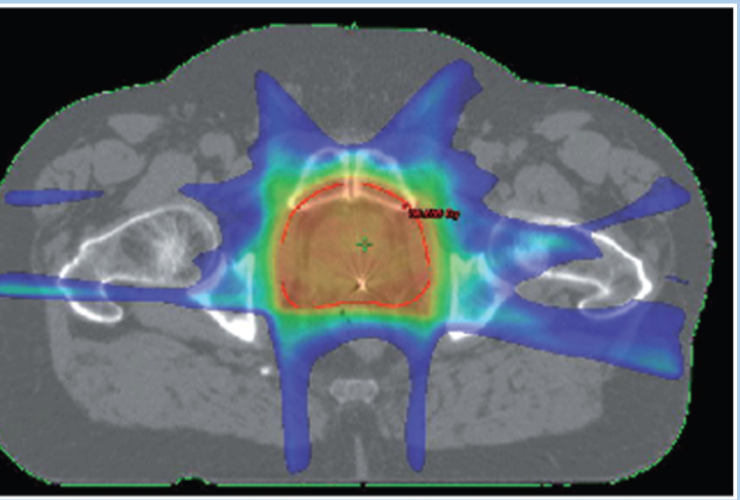
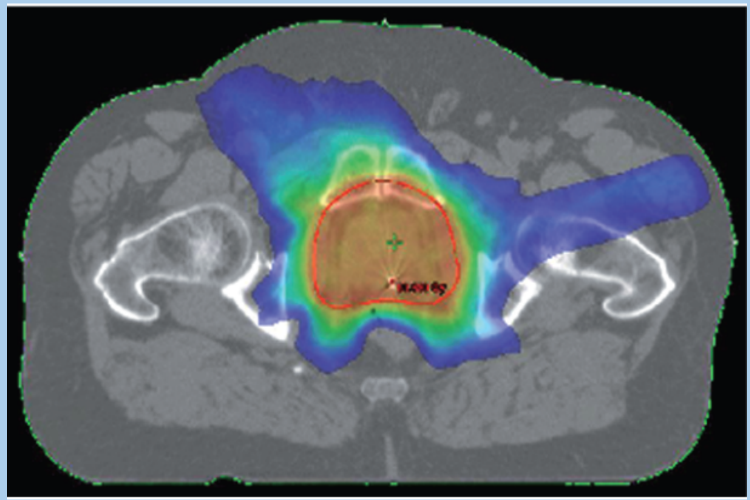
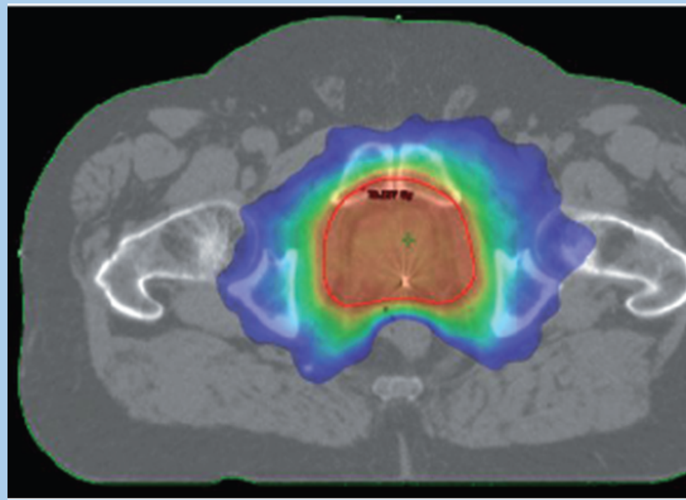
(Received 26 September 2001; accepted for publication 12 March 2002; published 13 May 2002)

• Plans comparison







IMRT

VMAT 1 arc

VMAT 2 arcs

Table 1. Comparative planning studies in prostate cancer

Paper [ref] *VMAT commercial system*	Number of patients	Site and dose	Comparison	PTV	OAR	MU per fraction	Treatment time per fraction
Palma et al [51] *Predecessor to RapidArc*	10	Prostate alone 74 Gy in 37 fractions	3D-CRT *vs* IMRT(5F,SW) *vs* CDR-VMAT (SA) *vs* VDR-VMAT (SA)	IMRT and VMAT – similar PTV coverage and homogeneity (homogeneity inferior to 3D-CRT). Conformity best with IMRT and VDR-VMAT	VDR-VMAT best (compared with IMRT for sparing of rectum and femoral heads; compared with CDR-VMAT for sparing of bladder and rectum)	CDR-VMAT, 491.6; VDR-VMAT, 454.2; IMRT, 788.8; 3D-CRT, 295.5	
Zhang et al [52]	11	Prostate + prox imal SV 86.4 Gy	IMRT (5F,SS) *vs* VMAT (SA)	IMRT – slightly higher dose to PTV (V95%, D95%, mean dose and TCP) and better homogeneity compared with VMAT	VMAT better then IMRT (sparing of rectum, bladder, femoral heads)	VMAT, 290; IMRT, 642	VMAT, 1 min; IMRT, 5 min
Kjaer-Kristoffersen et al [53] *RapidArc*	8	Prostate + SV, 78 Gy (5 pts); 74 Gy (1 pt) Prostate bed, 66 Gy (2 pts)	IMRT (5F,SW) *vs* VMAT (partial SA)	IMRT – slightly better PTV coverage (V95%) but VMAT better in PTV minus rectum coverage. Hotspots higher in VMAT plans.	VMAT better than IMRT (sparing of bladder, rectum). Integral dose to body similar. Low dose bath (V5 Gy) to body larger for VMAT	VMAT, 529; IMRT, 647	
Hardcastle et al [54] *SmartArc*	10	Prostate 78 Gy in 39 fractions	IMRT (7F,SS) *vs* VMAT (SA)	IMRT and VMAT – similar PTV coverage (except D95% where VMAT had lower values).	VMAT better than IMRT at rectal sparing at doses <50 Gy. VMAT – higher doses to femoral heads. No significant difference in bladder doses.	VMAT, 417; IMRT, 526	VMAT, 1.3 min; IMRT, 4.5 min
Ost et al [55]	12	Prostate + SV (76 Gy) and IPL boost (82 Gy). Additional IPL dose level >85 Gy	IMRT (3F,5F,7F,SS) *vs* VMAT (SA)	IMRT (5F,7F) and VMAT – similar PTV coverage and all better than IMRT 3F. Dose escalation up to 95 Gy to IPL with VMAT	VMAT better at rectal sparing (significant at rectal volumes receiving 20–50 Gy). No difference in integral dose to body.	For 6 MV: VMAT, 447; IMRT (3F), 362; IMRT (5F), 407; IMRT (7F), 434	VMAT, 1.95 min; IMRT (5F), 3.85 min; IMRT (7F), 4.82 min
Weber et al [56] *RapidArc*	7	Recurrent prostate carci noma 56 Gy in 14 fractions	IMRT (5F,SW) *vs* IMPT *vs* VMAT (SA)	IMPT best for PTV coverage, VMAT better than IMRT for GTV and PTV coverage. VMAT (high definition MLC) – best for homogeneity. IMRT, VMAT better than IMPT for conformity	IMPT and RA better than IMRT (sparing of rectum, urethra, bladder). Integral doses to body lowest with IMPT. IMPT best at sparing penile bulb		
Kopp et al [57] *RapidArc*	292	Prostate 77.4 Gy in 43 fraction	IMRT (7F,SW) *vs* VMAT (SA)	VMAT and IMRT similar PTV coverage (VMAT less homogeneous). VMAT – slightly higher D2%	VMAT better than IMRT (sparing of rectum at high doses, bladder, femoral heads, penile bulb)		
Yoo et al [58] *RapidArc*	10	Prostate, SV and LN (primary) 46.8 Gy; prostate and SV (boost) 28.8 Gy (1.8 Gy per fraction)	IMRT (9F,7F) *vs* VMAT (SA) *vs* VMAT (DA)	Primary plans – IMRT better than VMAT (PTV coverage, conformity). Boost plans – similar PTV coverage, homogeneity; IMRT had worse conformity compared to VMAT	Primary plans-IMRT better than VMAT (sparing of bladder, rectum, small bowel). Boost plans – IMRT and DA VMAT better than SA VMAT. Higher integral doses to body with VMAT	Primary plans: VMAT (SA), 429; (DA), 444; IMRT, 1300. Boost plans: VMAT (SA), 443; VMAT (DA), 484; IMRT, 777	Primary plans: VMAT (SA), 1.5 min; VMAT (DA), 3.1 min; IMRT, 8.1 min. Boost plans: VMAT (SA), 1.5 min; VMAT (DA), 3.1 min; IMRT, 4.9 min.

ble 3. Comparative planning studies in head and neck cancer

er [ref] *AT* *nmercial* *tem*	Number of patients	Primary tumour site	Comparison	PTV	OAR	MU per fraction	Treatment time per fraction
rbakel et al [91] *RapidArc*	12	Nasopharynx, oropharynx and hypopharynx	IMRT (7F,SW) *vs* VMAT (SA) *vs* VMAT (DA)	Similar PTV coverage. DA VMAT better than SA VMAT and IMRT for homogeneity	No significant difference. Parotid dose lower with DA VMAT (by average 2Gy) compared with SA VMAT and IMRT	VMAT (SA), 439; VMAT (DA), 459; IMRT, 1108	
netti et al [92] *RapidArc*	29	Oropharynx, hypopharynx and larynx	IMRT (7–9F,SW) *vs* VMAT (SA) *vs* VMAT (DA)	Similar PTV coverage and conformity. DA VMAT better than SA VMAT and IMRT for homogeneity (SA VMAT slightly inferior to IMRT)	VMAT better than IMRT at sparing spinal cord (D2%, mean dose), brainstem (D2%, mean dose) and parotid glands (mean dose). DA VMAT better than SA VMAT. VMAT – lower integral doses to body	VMAT (SA), 463; VMAT (DA), 584; IMRT, 1126	VMAT (SA), 1.2–1.5 min; VMAT (DA), 3 min; IMRT, 15 min
nnston et al [93] *RapidArc*	10	Nasopharynx and oropharynx	IMRT (9F,SW) *vs* VMAT (DA)	Similar PTV coverage IMRT slightly better than VMAT for conformity and homogeneity	No significant differences for spinal cord, brainstem doses. VMAT better than IMRT for contralateral parotid gland sparing	VMAT, 529; IMRT, 1628	
ckenberger et al [94] *SmartArc*	15 (of 20)	Post-operative pharynx/ larynx, primary pharynx, paranasal sinus	IMRT (9F,SS) *vs* VMAT (1–3 arcs)	For PTV coverage and homogeneity: (post-operative pharynx/larynx) SA VMAT inferior to IMRT, DA VMAT = IMRT TA VMAT better than IMRT; (primary pharynx) SA and DA VMAT inferior to IMRT TA VMAT= IMRT; (paranasal sinus) All VMAT plans inferior to IMRT; (decreased coverage between orbits)	(Post-operative pharynx/larynx, primary pharynx) No significant difference (SA VMAT inferior to DA VMAT; TA VMAT and IMRT) (paranasal sinus) All VMAT plans inferior to IMRT for lens sparing	IMRT, 430–688; VMAT (SA), 358–440; VMAT (DA), 460–519; VMAT (TA), 506–560	IMRT, 9.55–12.25 min; VMAT (SA), 1.85–2 min; VMAT (DA), 3.83–3.98 min; VMAT (TA), 4.42–4.58 min
rtelsen et al [95] *Smartarc*	25	Oropharynx and hypopharynx	IMRT (5–7F,SS) *vs* VMAT (SA)	Similar PTV coverage and homogeneity. VMAT better than IMRT for elective PTV coverage and conformity	VMAT better than IMRT at sparing spinal cord, parotid glands, submandibular glands at high dose levels. VMAT – lower volumes of normal tissue (outside PTV) irradiated to higher doses	VMAT, 460; IMRT, 503	VMAT, 4.02 min; IMRT, 6.2 min
varez-Moret 96] *Oncentra Masterplan*	4	Oral cavity, hypopharynx, nasal cavity	IMRT (7–9F,SS) *vs* VMAT (SA) *vs* VMAT (DA)	IMRT and DA VMAT similar PTV coverage, homogeneity (SA VMAT inferior to IMRT and DA VMAT)	IMRT and DA VMAT largely similar OAR sparing (SA VMAT inferior to IMRT and DA VMAT)	VMAT (SA), 491.3; VMAT (DA), 596.4; IMRT, 575.4	VMAT (SA), 1.86 min; VMAT (DA), 3.64 min; IMRT, 11.7 min

VMAT vs other tecniques

It is important to note that there are many other issues in addition to plan quality that are associated with different delivery techniques. These include the efficiency of planning, delivery, quality assurance (QA), the complexity and reliability of delivery, and the total Mus required to deliver the prescribed doses and the total leakage radiation received by the patient outside the target region.

CX YU

VMAT Commissioning

Marta Paiusco

- Guidelines for commissioning
- TG 142
- TG 119

Basic requirements:

calculate doses must match the delivered ones

delivery must be stable and reproducible

We need to verify the reliability and accuracy of the whole chain from planning to delivery.

VMAT delivery requires more advanced linac control capabilities than IMRT

- Variable dose rate
- Variable gantry speed
- Dynamic MLC movement

Like IMRT for a TPS

- Geometric caracteristics of the linac must be put into the planning system
- Geometrical errors in MLC positioning can have dose impact
- Tongue and groove modeling can have dosimetric impact

Dose calculation model from the fixed beams may not accurately reflect rotational delivery due to the lack of adeguate sampling .

Commissioning and QA Program **is closely related to the IMAT solution** : Delivery and TPS

Commissioning by C C Ling : Linac capabilities

1. Accuracy of the DMLC during RapidArc : picket fence test

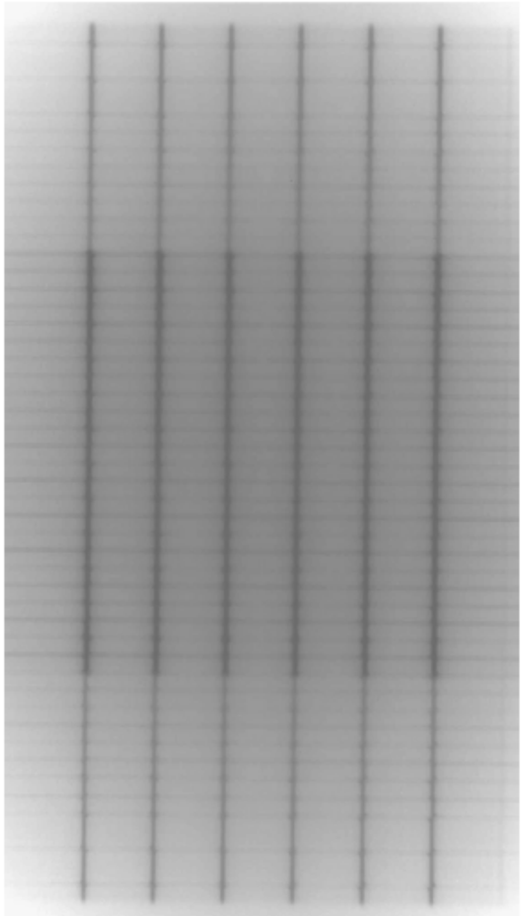
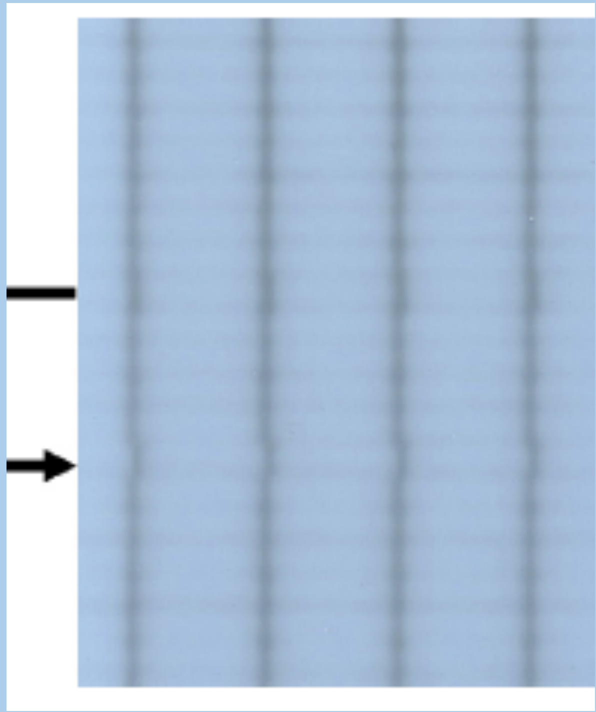


Fig. 3. Image of a film that was exposed twice to the 1-mm-wide picket fence pattern, once at stationary gantry angle and a second time in RapidArc mode.



2. Ability to vary dose rate and grantry speed

the 7sQA plan, which delivered the same dose to the seven strips with different combinations of ΔMU/Δt, Δθ, and Δθ/Δt: 111 MU/min, 90° and 5.54°/s; 222 MU/min, 45° and 5.54°/s; 332 MU/min, 30° and 5.54°/s; 443 MU/min, 22.5° and 5.54°/s; 554 MU/min, 18° and 5.54°/s; 600 MU/min, 15° and 5°/s; 600 MU/min, 12.9° and 4.3°/s.

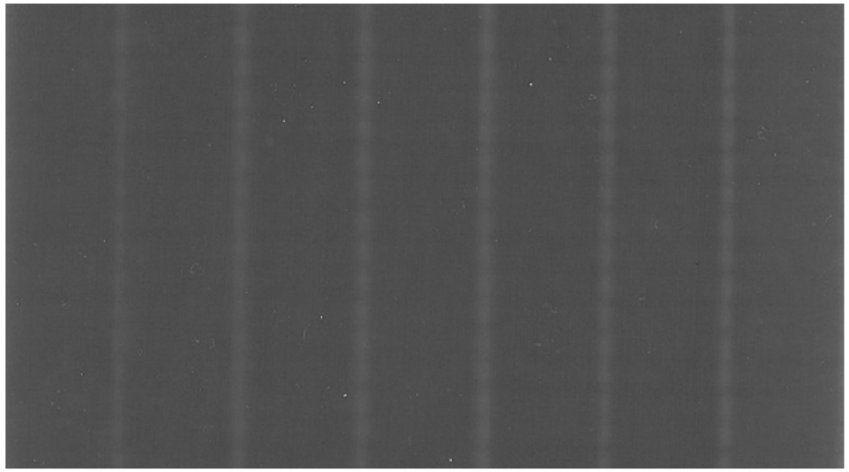
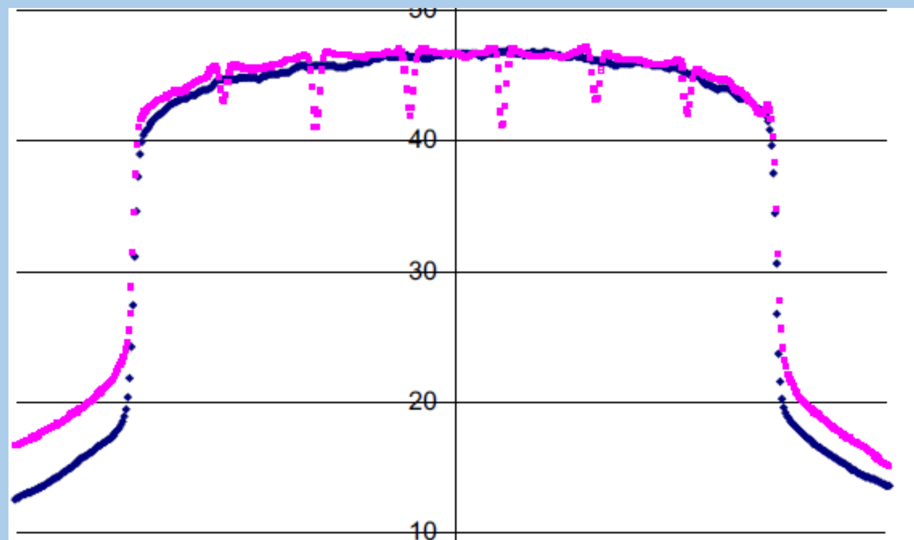


Fig. 5. Film exposed to a RapidArc QA plan, combining different dose-rates, gantry ranges, and gantry speeds, to give the same monitor unit (MU) to the different parts of the field.

3. Ability to accurately vary MLC leaf speed

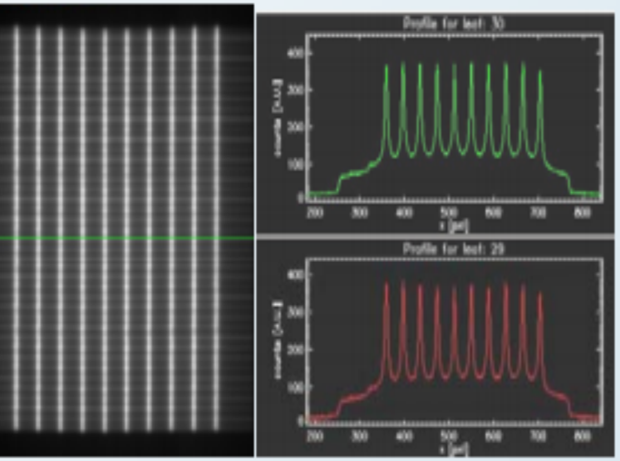
four different parts were exposed to the same dose with the four sliding windows at leaf speeds of 0.46, 0.92, 1.84, and 2.76 cm/s. When the LSQA radiation profile was normalized to and superimposed on the profile of the corresponding open MLC field, the two profiles were closely matched.



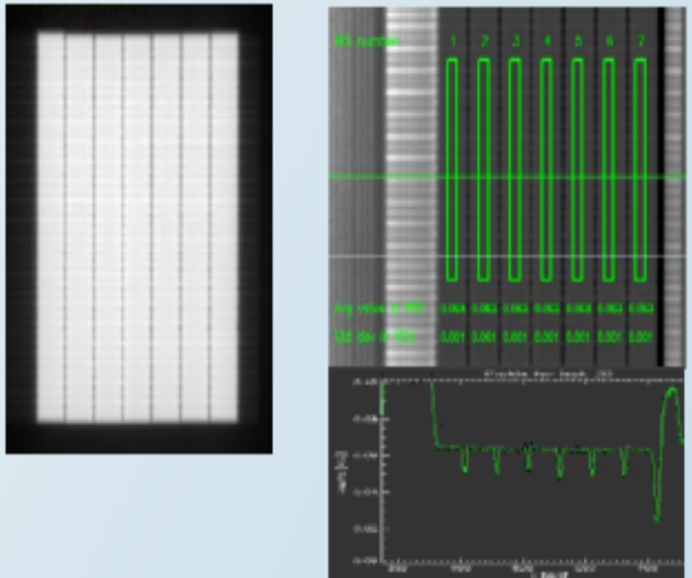
RapidArc commissioning QA with Epiqa

Three tests (recommended by Ling et al [2] and adopted by Varian) were performed during the commissioning phase, and then repeated at least once a month for a total of acquisitions. Analysis was performed with Epiqa. Results presented a very good stability of RapidArc delivery as dose rate variation, gantry speed and leaf speed.

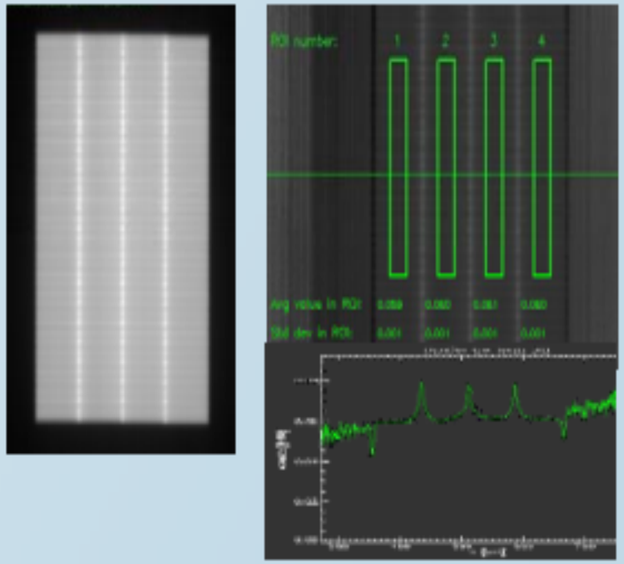
T1: Picket Fence Test during RapidArc



T2: Control of Dose Rate and Gantry Speed during RapidArc



T3: Control of Leaf Speed during RapidArc

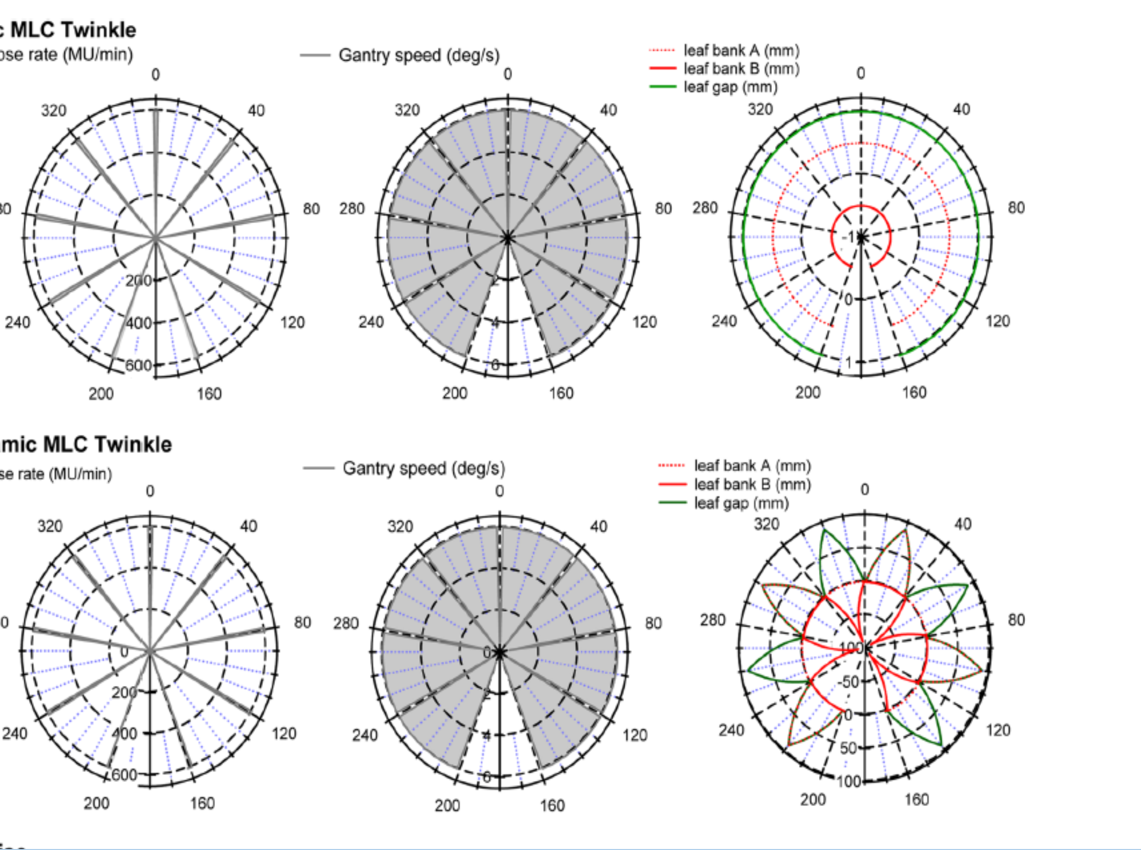


A. Van Esch :Additional commissioning and QA are required

Systematic method

A. Linac commissioning and QA
B. TPS validation
C. Patient QA

Linac Performances



Test 1: Dose is deliverd only for a narrow angular s

Static MLC :

Dose less segmente gantry speed =max

Dose segmente gantry spped= min

To test acceleration and deceleration effects, inert

overly smoothened

Errors introduced 1° 2° 3°

Dynamic MLC : MLC sweping motion at maximum

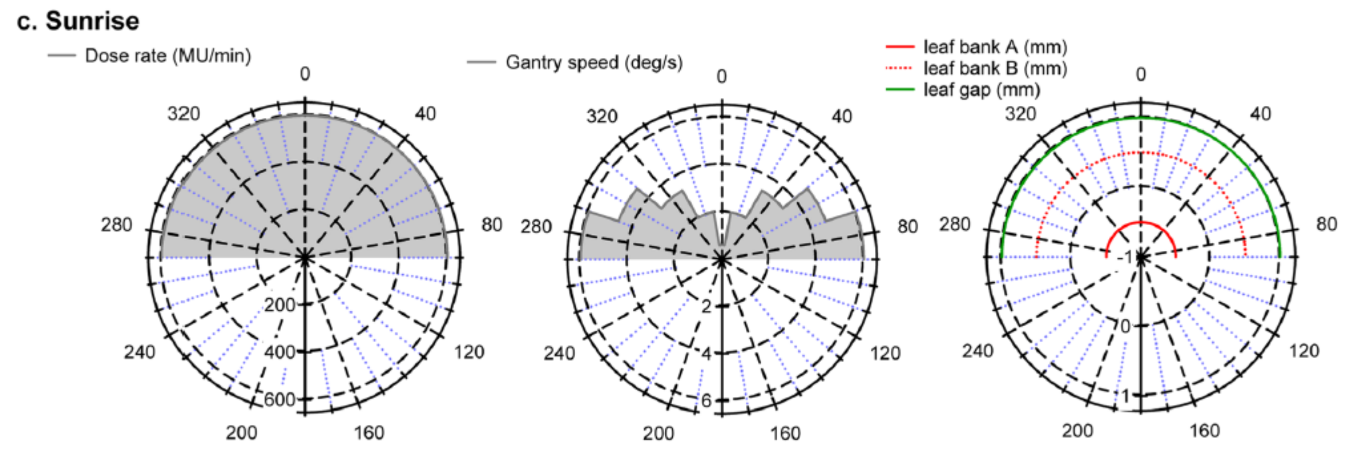
speed .at the start of narrow sector delivery leaves

be in a central positions

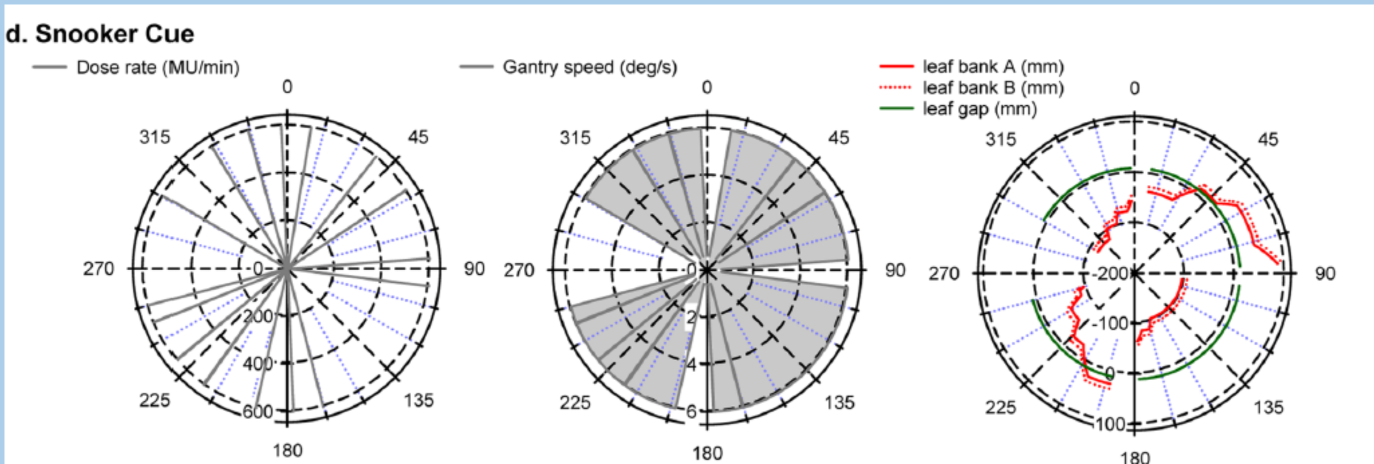
To test Syncronization from MLC and gantry

Errors introduces 0,2-0,5-1 mm

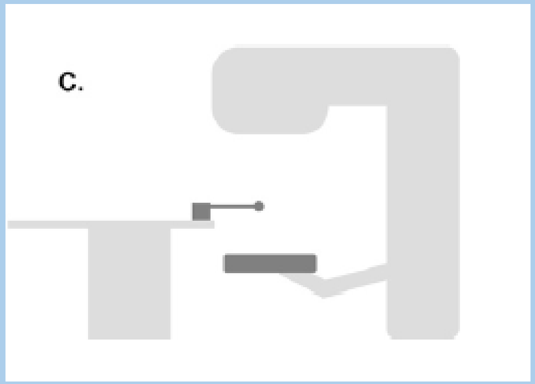
Introduced erros of 1° do not distort the measurements



To test the impact of gantry speed ,gravity and inertia.
High MU
Dose rate at maximum
minimum gantry speed at 0°
dose maximum at 0°
like a double stairs
if a parameter affects the test we will see a broadening in a transition from one sector to another



Interplay between gantry angle, MLC position and dose delivered
MLC gap of 1 cm
A narrow angular sector is deliverd
The metal road with a sferical tip should be precisely in the centre of the gap.
.



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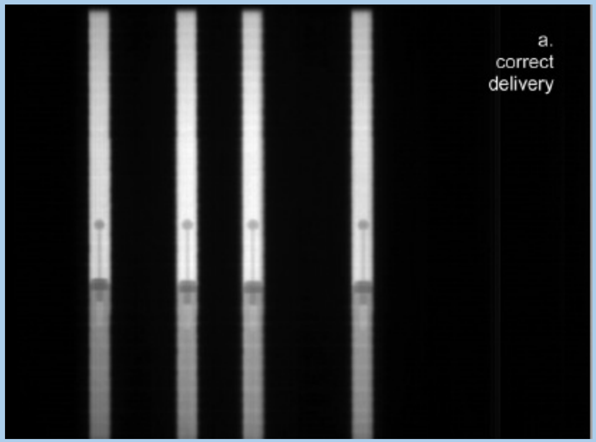
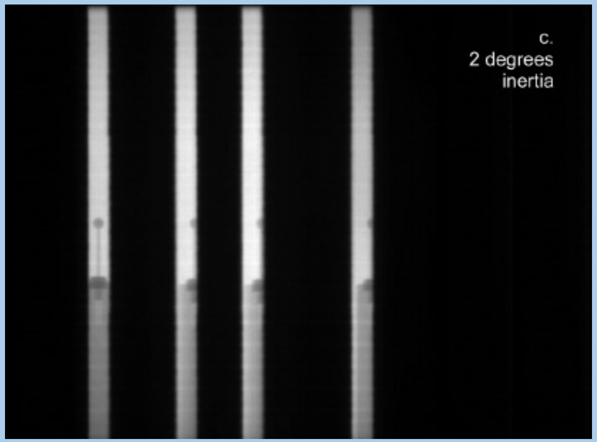
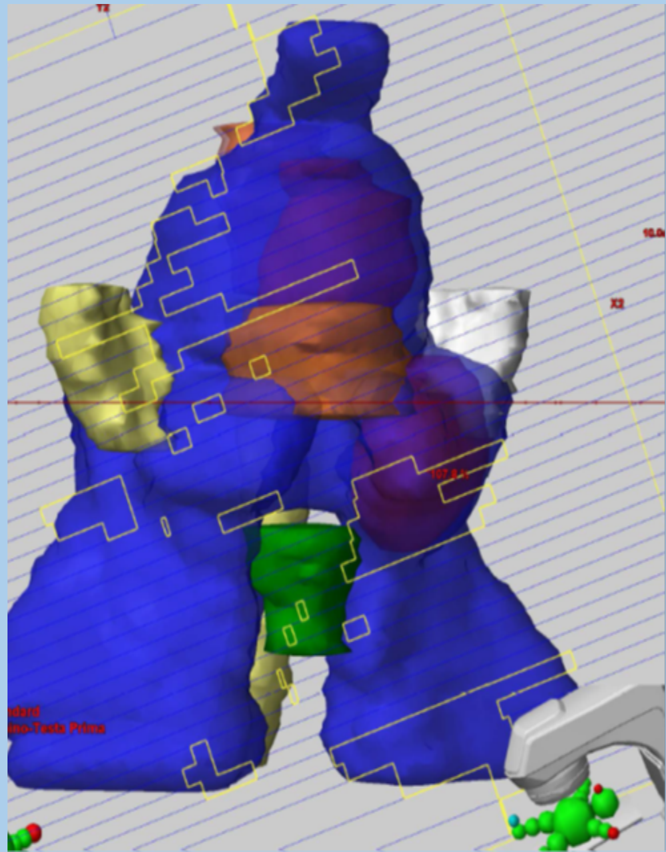




Errors of 1° in a gantry position are now detectable

TPS



Is the calculation done with the validated algorithm?

YES

Is the calculation performed like in a validated delivery tecnique?

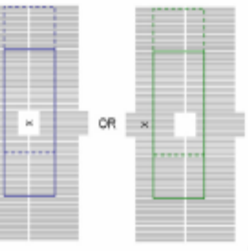
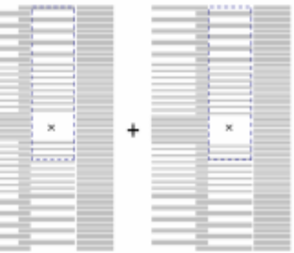
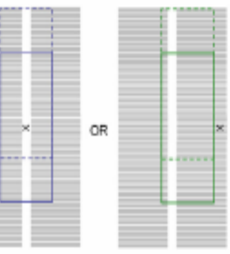
Dose calculation differs from the static ones as it make use of an interpolazione between two control points

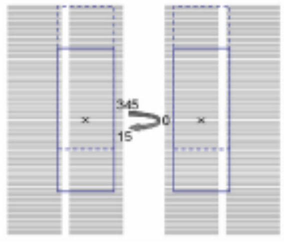
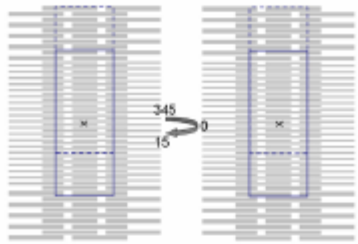
Is the standard calibration methods proper?

Arc vs static field

Are the standard validation package rappresentative of the tipical VMAT configuration?

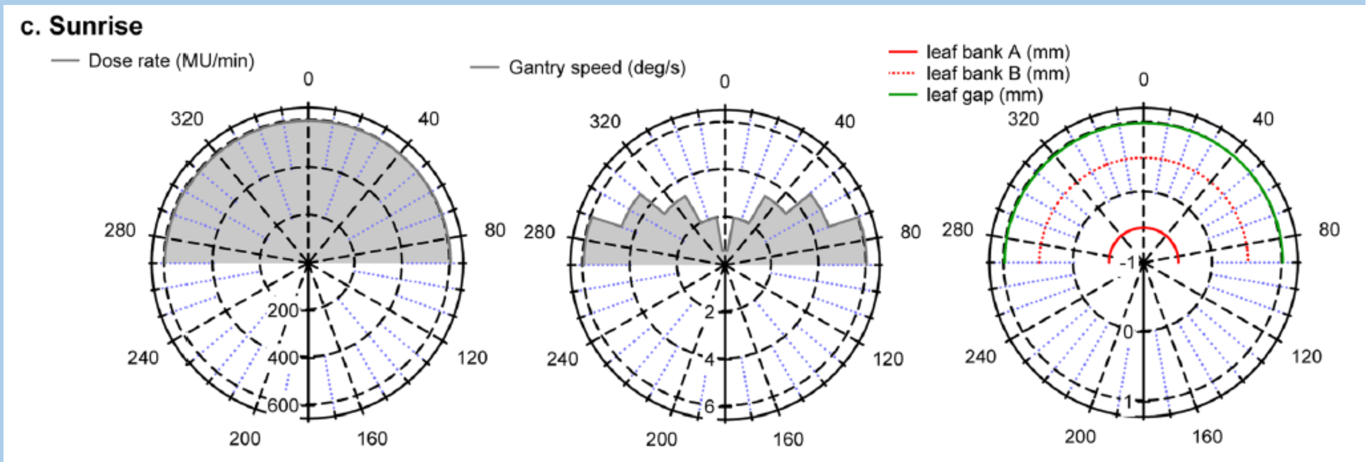
Small field in a large collimator opening
Small field off axis
MLC tips nearly closed

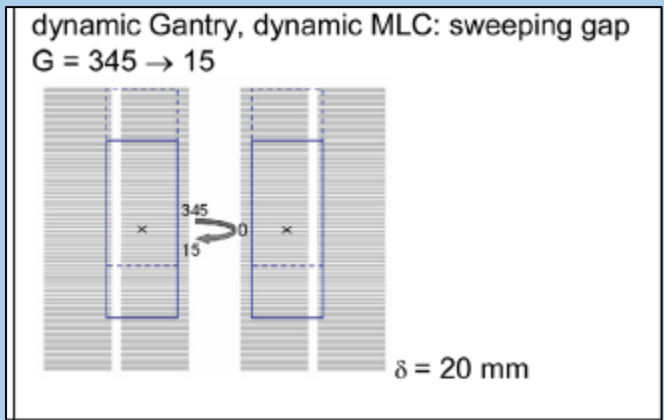
...ntry and MLC	Collimator settings (cm)	
	Millenium120 MLC	HD MLC
...ic gantry, DLG and OF ... 0  δ =1,3 & 5 mm	DLG *central :* X=14,Y=24 (—) X=14,Y1=4,Y2=20 (---) *off-axis :* X1=-2,X2=16,Y=24 (—) X1=-2,X2=16,Y1=4,Y2=20 (---)	DLG *central :* X=14,Y=20 *off-axis :* X1=-2,X2=16,Y=20
	OF *central :* X=4…24, Y=4…40 *off-axis :* X1=-2,X2=16,Y1=4,Y2=4…20	OF *central :* X=4…24, Y=4…40 *off-axis :* X1=-2,X2=16,Y=4…20
...ic gantry, TnG ... 0  δ =14 mm	*central :* X=14,Y1=4,Y2=20 (---)	*central :* X=14,Y=20
...amic Gantry, static MLC ...= 345 → 15  δ = 20 mm ...atic Twinkle G = 200 → 160 ...unrise G = 200 → 160	*central :* X=14,Y=24 (—) X=14,Y1=4,Y2=20 (---) *off-axis :* X1=-2,X2=16,Y=24 (—) X1=-2,X2=16,Y1=4,Y2=20 (---)	*central :* X=14,Y=20 *off-axis :* X1=-2,X2=16,Y=20

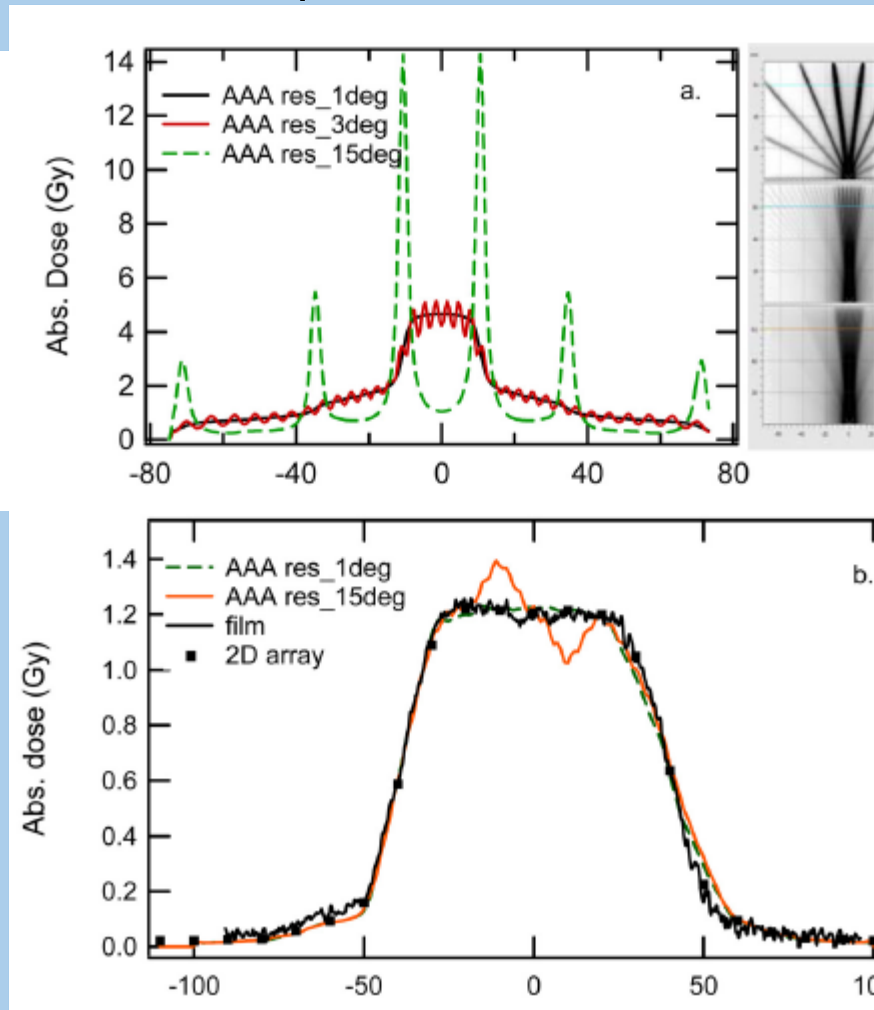
d.	dynamic Gantry, dynamic MLC: sweeping gap G = 345 → 15  δ = 20 mm	*central :* X=14,Y=24 (—) X=14,Y1=4,Y2=20 (---)	*central :* X=14,Y=20
e.	dynamic Gantry, dynamic MLC: TnG G = 345 → 15  δ =20 mm	*central :* X=14,Y=24 (—) X=14,Y1=4,Y2=20 (---)	*central :* X=14,Y=20

Commissionig of TPS to check the impact of different parameters

Control point resolution = interpolation between two control point

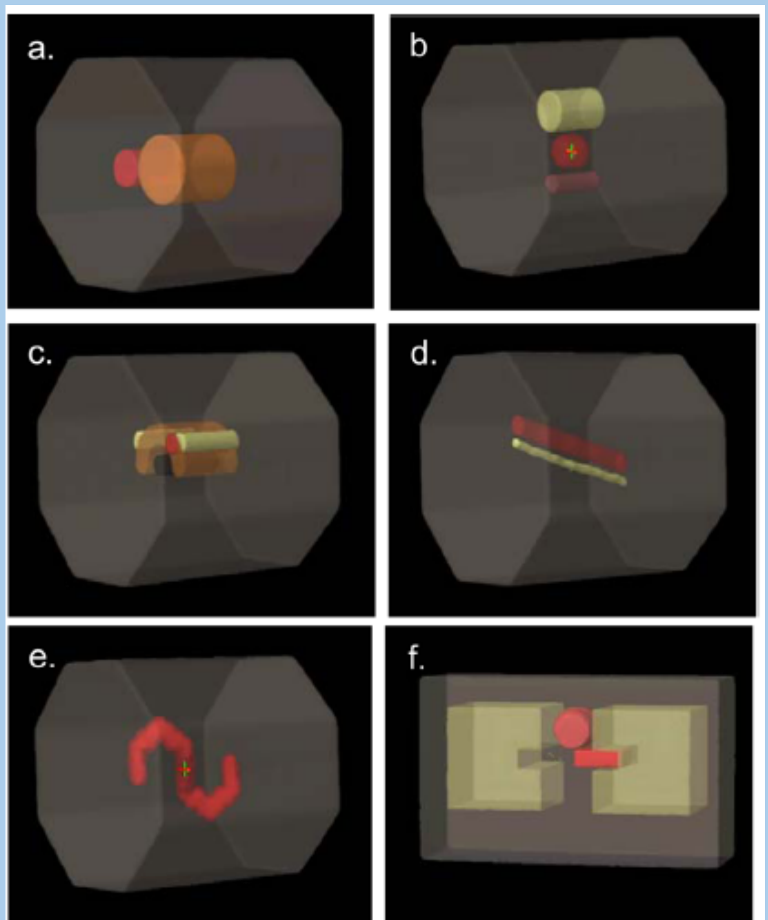


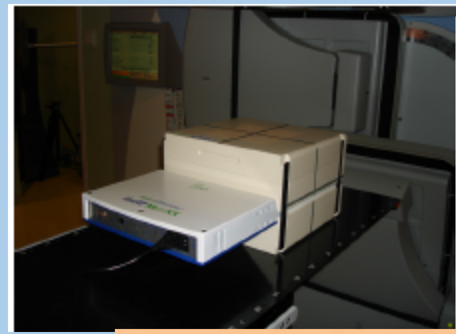


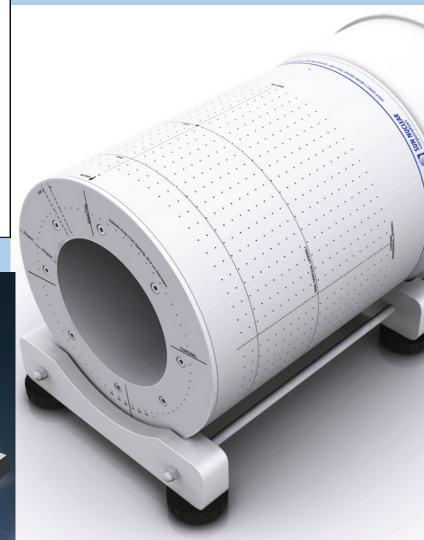


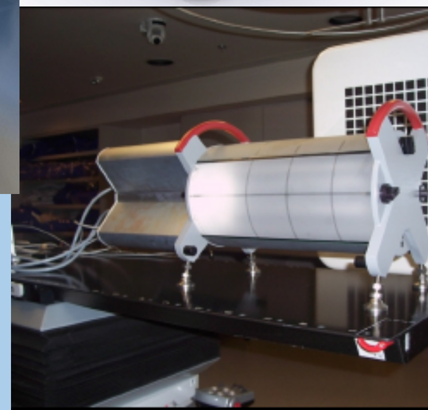
AAPM TG-119 IMRT commissioning like

Test plans verification







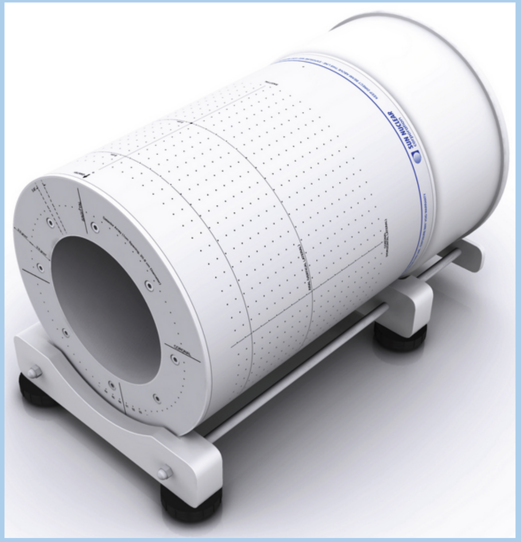


Dosimeter must be tested, validated and its sensitivity must be known

The AAPM TG-142 report recommended that the tolerance of laser localization was 1.5 mm for IMRT.[32] For both ArcCHECK and Delta^4 systems, 1° rotational error could cause an approximate error of 2 mm on the surface of the phantoms. Therefore, the cumulative effect of

We break down QA dosimeter validation into a logical process of three distinct phases (I-III).

In Phase I testing, the ArcCHECK exhibited robust response uniformity between the diodes. Measurement accuracy for the fields exceeding approximately 15 cm in width is compromised by the diodes' angular response dependence. This is being addressed by the manufacturer. ArcCHECK exhibits stronger field size response dependence compared to its predecessor, MapCHECK, which should be corrected in the software.



A comparison of the gamma index analysis in various commercial IMRT/VMAT QA systems

Mohammad Hussein [a,b,*], Pejman Rowshanfarzad [c], Martin A. Ebert [c,d], Andrew Nisbet [a,b], Catharine H. Clark [a,e]

Table 1
Summary of the mean and minimum measured gamma index passing criteria for each system. The concordance correlation coefficient, ρ_c, is also given assessing agreement with independent gamma index. The softwares are listed in the same order as the associated measurement system.

System	% Detectors/pixels passing with $\gamma < 1$ and ρ_c								
	3%/3 mm			3%/2 mm			2%/2 mm		
	Mean	Min	ρ_c	Mean	Min	ρ_c	Mean	Min	ρ_c
Software predicted									
Verisoft v5	99.0	89.9	0.97	98.4	83.9	0.95	97.2	75.4	0.95
SNC Patient v6	98.7	84.5	0.97	98.0	78.5	0.99	96.4	70.0	0.96
Delta4 software	98.8	89.4	0.96	98.3	84.9	0.93	97.3	77.3	0.93
OmniPro I'MRT v7	98.7	82.6	0.95	97.9	73.8	0.97	96.2	57.1	0.92
Portal Dosimetry v10	98.7	84.7	0.97	98.0	73.6	0.96	97.5	68.2	0.92
Independent predicted	98.8	87.0	–	97.9	78.0	–	96.4	58.1	–
Measured									
PTW 2D-Array	98.0	86.3	0.87	96.2	79.3	0.86	90.7	70.9	0.61
ArcCHECK	98.4	87.2	0.96	97.2	81.6	0.95	93.9	74.1	0.83
Delta4	96.2	86.6	0.53	93.4	78.5	0.58	85.5	68.8	0.33
Gafchromic	98.1	88.2	0.81	94.6	76.5	0.62	91.2	70.1	0.54
EPID	97.7	77.4	0.82	96.2	66.3	0.84	93.6	59.1	0.82

Open problems

Gamma Passing rate criteria is dosimeter independent?

3%3mm criteria is suggested by TG119 : insensitive to most of the errors! 2%2mm and local normalization should be better.

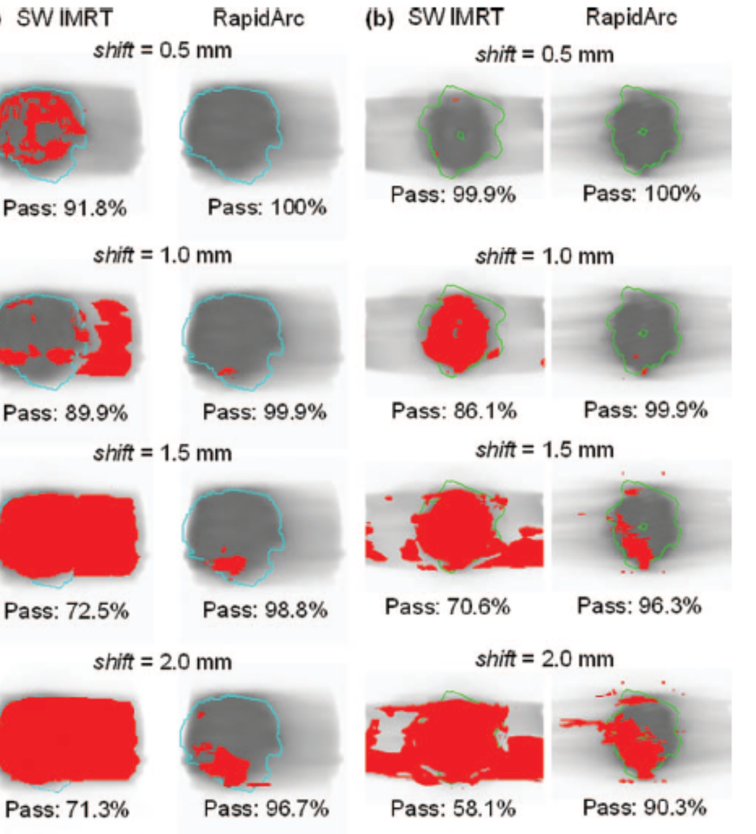
90% -95% mode than 95% ??? The best threshold

> The AAPM TG-142 report recommended that the tolerance of laser localization was 1.5 mm for IMRT.[32] For both ArcCHECK and Delta^4 systems, 1° rotational error could cause an approximate error of 2 mm on the surface of the phantoms. Therefore, the cumulative effect of

Patient Specific Metric (DVH) must be better than Gamma passing rate function

RapidArc more susceptible to delivery uncertainties than dynamic IMRT?

Gregory T. Betzel and Byong Yong Yi
Department of Radiation Oncology, University of Maryland School of Medicine, Baltimore, Maryland 21201



G. 4. Dose distribution comparisons using 2%-2 mm Gamma analysis cri-ion illustrating pass rates for MLC leaf bank shifts of 0.5, 1.0, 1.5, and 0 mm for (a) one HN case and (b) one prostate case. PTV contours are own. Points that failed are indicated in red.

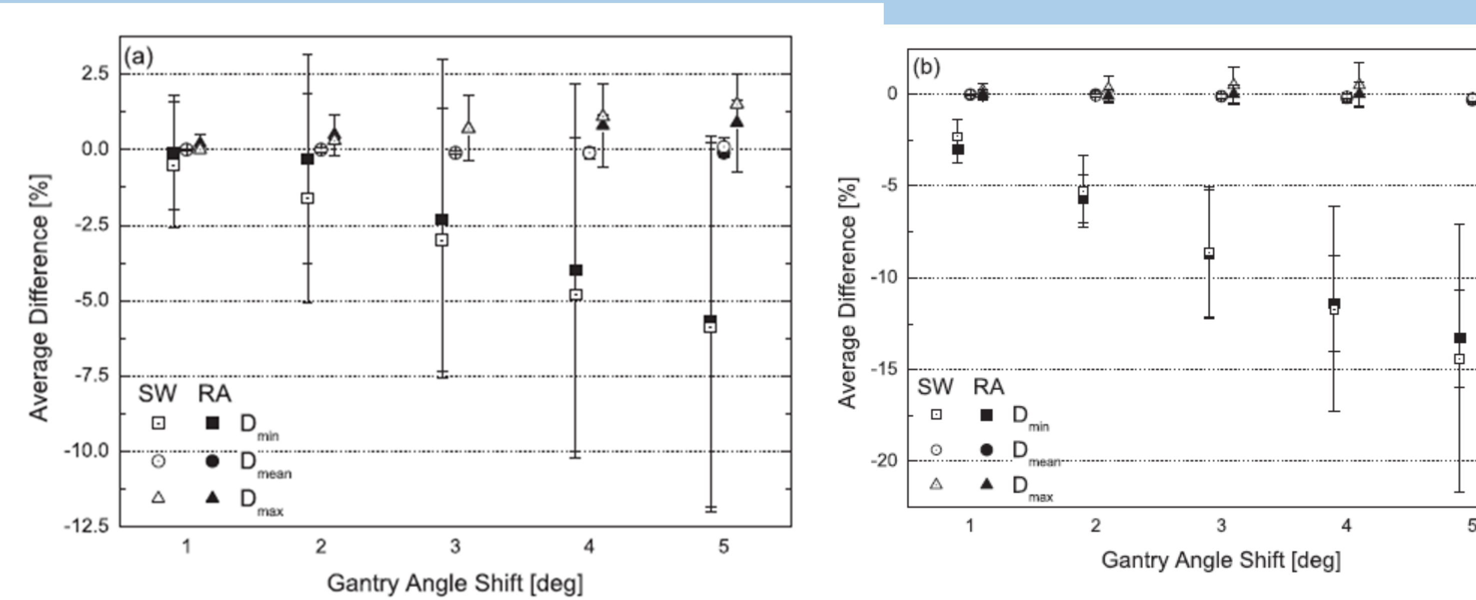
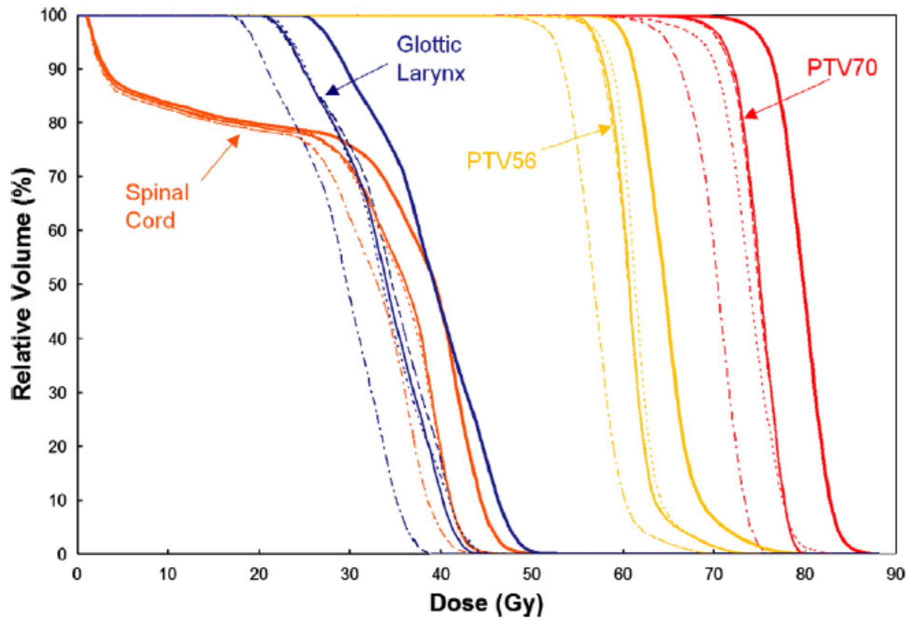


FIG. 5. Comparison of average PTV minimum, maximum and mea values for (a) head-and-neck and (b) prostate cases planned using eith ing window (SW) IMRT or RapidArc (RA) cases with systematic gan gle variations.

y assurance

cal significance of multi-leaf collimator positional errors for volumetric ulated arc therapy

Oliver *, Isabelle Gagne, Karl Bush, Sergei Zavgorodni, Will Ansbacher, Wayne Beckham



n example DVH of 2 mm errors included into a sample treatment plan for baseline (solid), Type 1: random (dash), Type 2: systematic shift (dotted), Type 3a: ic close (dash dot) and Type 3b: systematic open (solid thick). Note that the DVH lines for the parotids are not included.

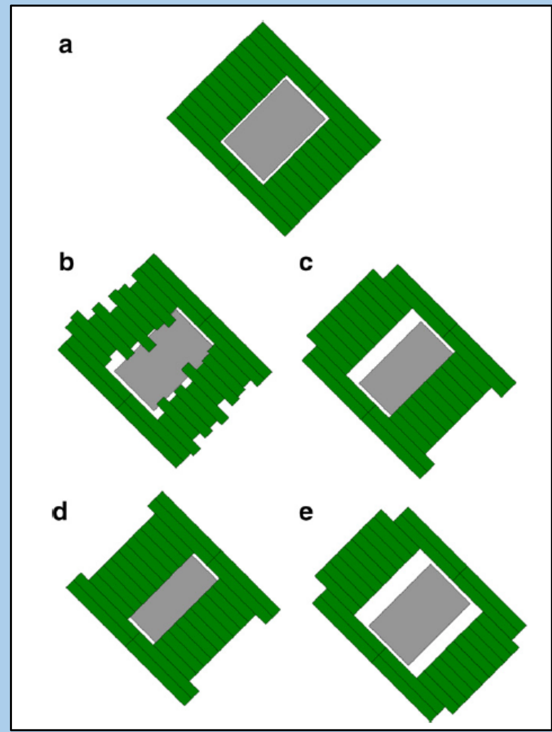


Fig. 1. An example MLC shape which conforms to the PTV (grey) for on point of the RapidArc plan for (a) baseline plan which is then modified random MLC positional errors, (c) a systematic MLC shift, (d) a systematic the MLC positions and (e) a systematic opening of the MLC positions.

Results: There is a linear correlation of MLC errors with gEUD for all error types. The gEUD dose sensitivities with MLC error for the PTV70 were −0.2, −0.9, −2.8 and 1.9 Gy/mm for random, systematic shift, systematic close and systematic open MLC errors, respectively. The sensitivity of VMAT plans to MLC positional errors was similar to those of IMRT plans with less than 50 segments but much less than those created for a step and shoot with more than 50 segments or sliding-window delivery technique. To maintain the PTV70 to within 2% would require that MLC open/close errors be within 0.6 mm.

A. Rangel and P. Dunscombe: MCL position accuracy for dynamic delivery of IMRT

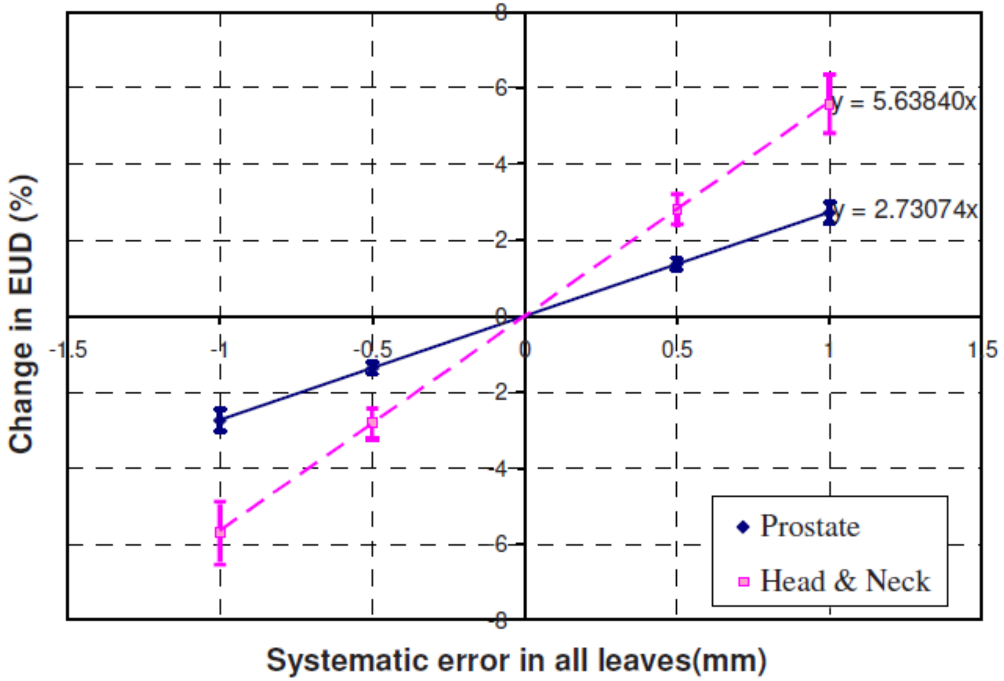


FIG. 2. Sensitivity of the EUDs of the structures of interest to systematic errors in all leaves. Every 1 mm error leads to average changes of 2.7% of the prostate CTV EUD and 5.6% of the H&N CTV EUD.

Physical and dosimetric aspects of a multileaf collimation system used in the dynamic mode for implementing intensity modulated radiotherapy

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(Received 19 May 1997; accepted for publication 3 August 1998)

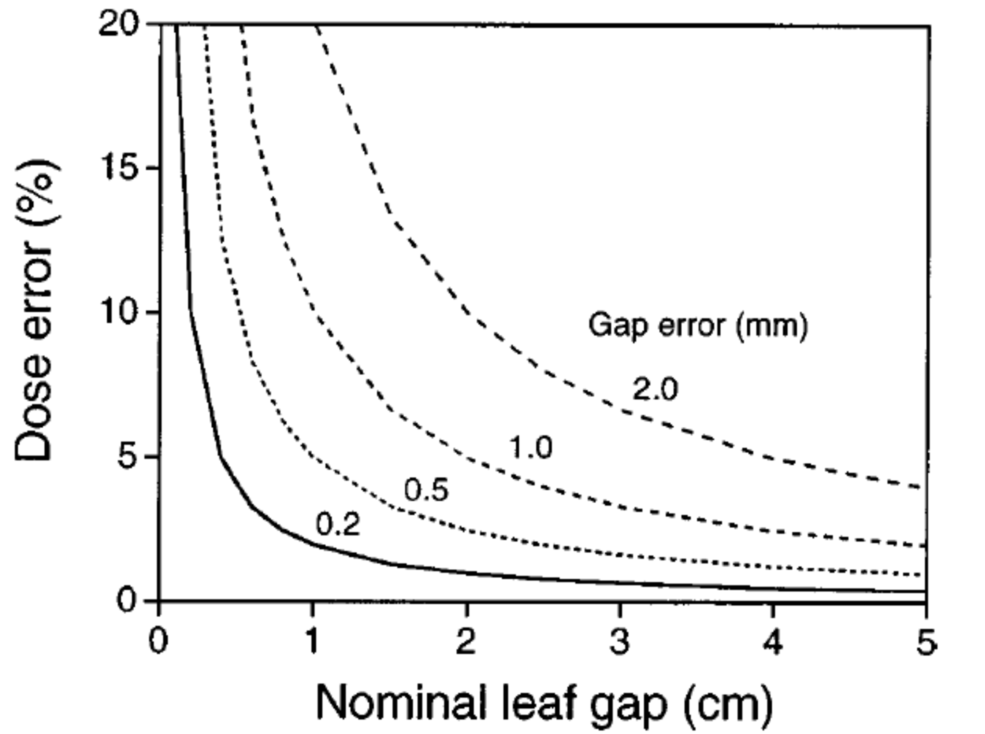
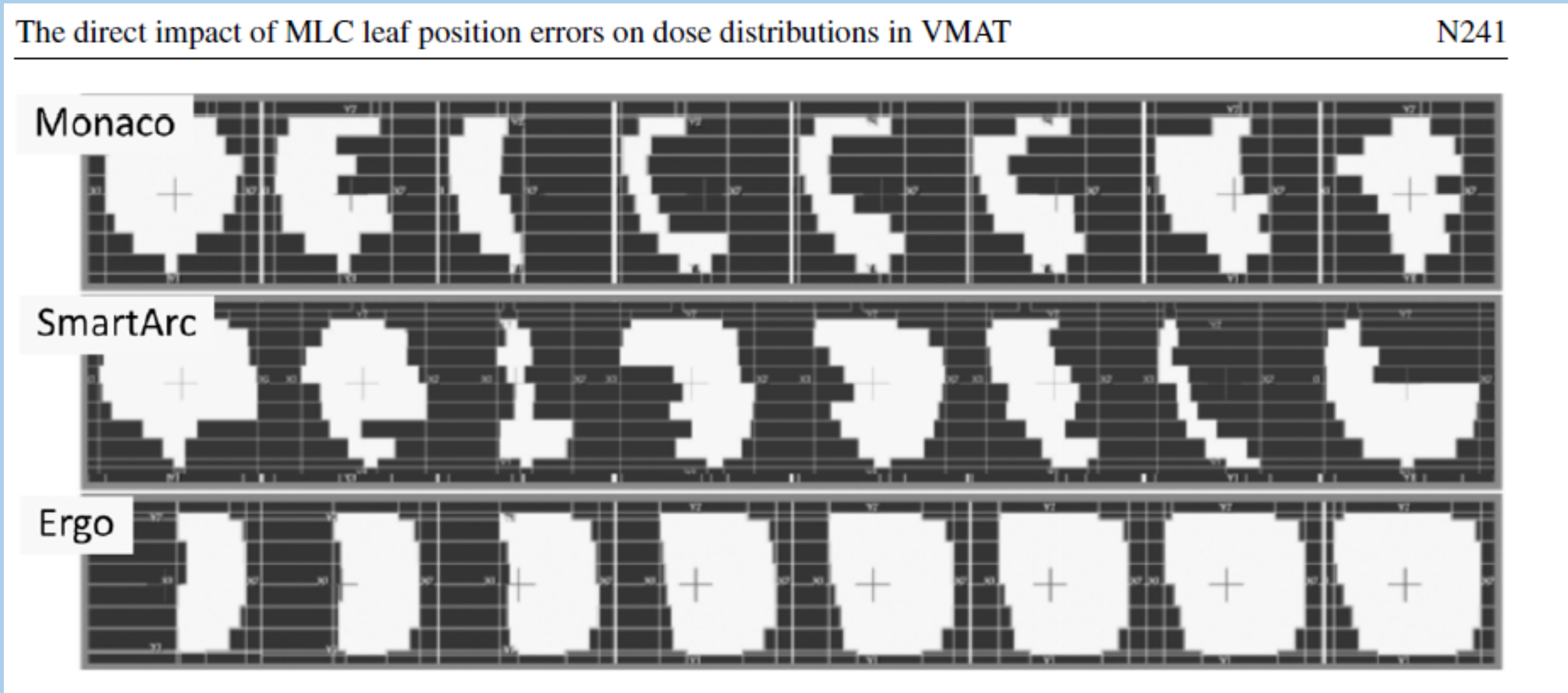
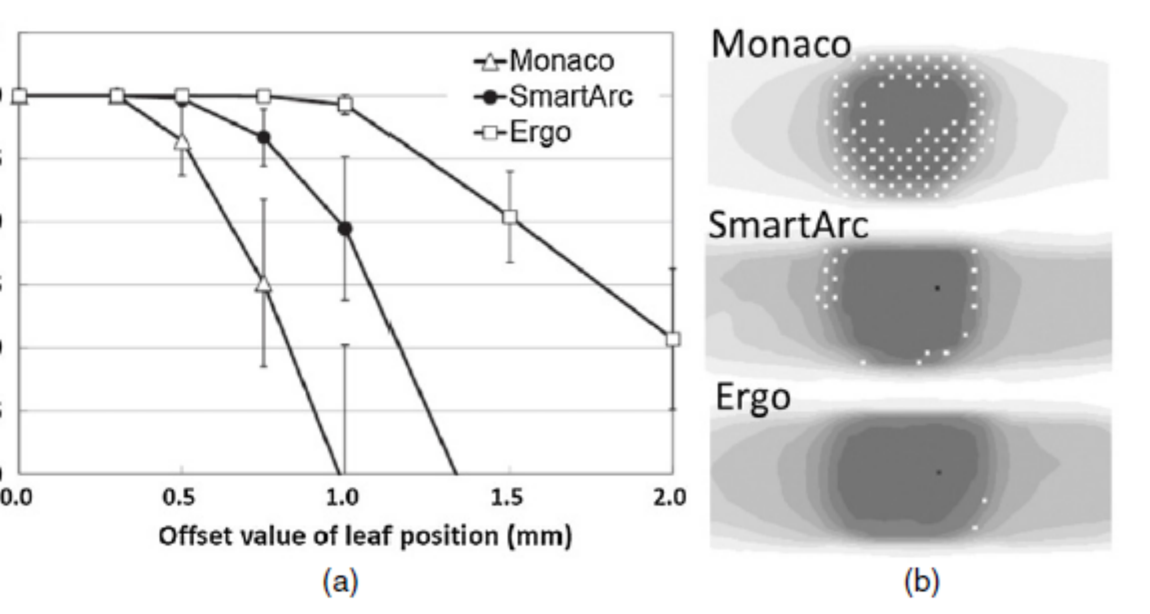


FIG. 8. Calculated results relating the error in the dose delivered to the error in the gap for a range of gap widths.





Tatsumi (2011) used 3 different TPS to create VMAT plans for 5 prostate cases and tested the pass rate when systematic MLC errors is introduced.

The impact of leaf position errors on dose distributio

depend upon the final optimization results

In agreeemtn with the correlation between dose erro

and average leaf gap.

Conclusions

- An extensive and comprehensive **commissioning** program is necessary for VMAT and IMRT to understand the chain of the system
- To be aware about limits and capabilities of the system allows us to set parameters for a robust treatment plan
- To be aware about accuracy of the dosimetry system allows us to define a tolerance limits for dosimetric comparisons
- Linac delivery seems to be reliable
- TPS commissiong is the most important
- Patient specific QA cannot replace a comprehensive QA program