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NATIONWIDE AUDIT OF SMALL FIELDS OUTPUT CALCULATIONS IN POLAND

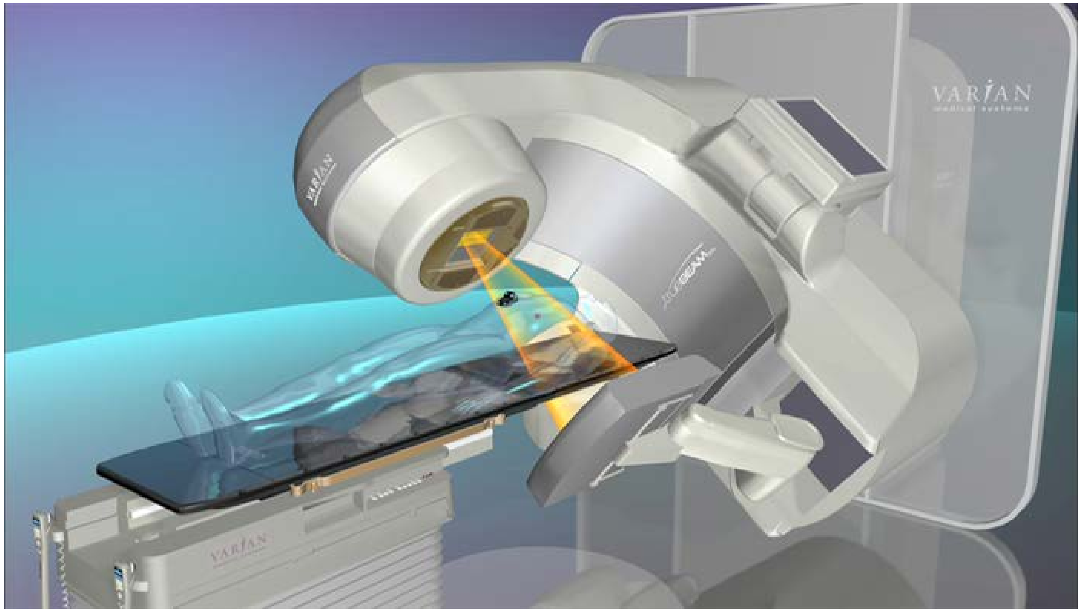
IAEA/WHO E2.40.18 Coordinated Research Programme (CRP)
"Development of Quality Audits for Advanced Technology in Radiotherapy Dose Delivery"

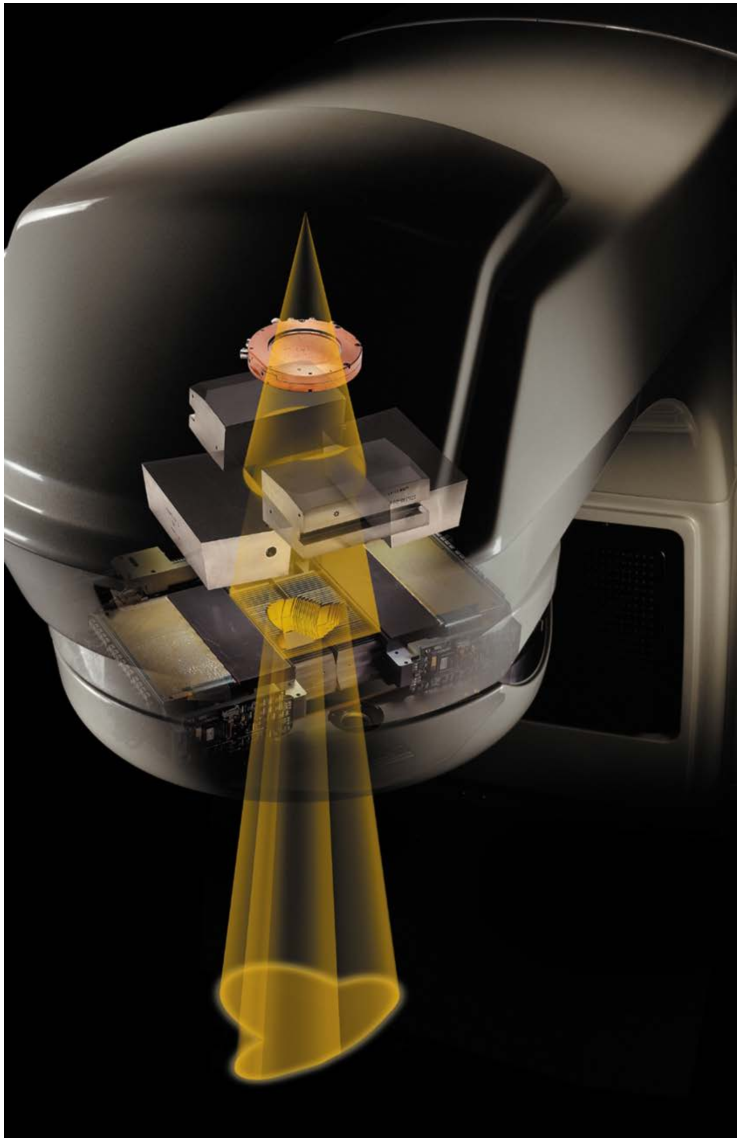
CENTRUM ONKOLOGII – INSTYTUT
IM. MARII SKŁODOWSKIEJ-CURIE

Purpose

- Modern radiotherapy routinely involves the use of small radiation fields, either for the delivery of stereotactic treatments, or as components of intensity-modulated radiation therapy (IMRT).
- The purpose of the small field dose rate dependence audit is to check dosimetric data in the treatment planning system (TPS), as used for patient Intensity Modulated Radiation Therapy (IMRT) treatments, related to a radiotherapy treatment unit equipped with an multileaf collimators (MLC).

Introduction





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Methods

- The methodology worked out in the framework of the IAEA Coordinated Research Project E2.40.18 was used.
- The audit participants were asked to calculate the number of MUs for 5 MLC-shaped field sizes (10×10 cm^2, 6×6 cm^2, 4×4 cm^2, 3×3 cm^2 and 2×2 cm^2) to deliver 10 Gy on axis at 10 cm depth, 100 cm SSD in water, using their treatment planning system.
- These calculations had to be repeated for each photon beam energy used for IMRT treatments. Eventually, they had to calculate the dose rate (Gy/MU) for each of the five MLC defined field sizes and normalize each value to the 10×10 cm^2 value.
- These results were compared with the benchmark data from the publication: "The Radiological Physics Center's standard dataset for small field size output factors" (Followill *et al.*, Journal of Applied Clinical Medical Physics, 2012) [2-3].
- Since this dataset did not provide data for certain beam qualities the interpolation /extrapolation was performed fitting the second degree polynomials to the RPC measured values.

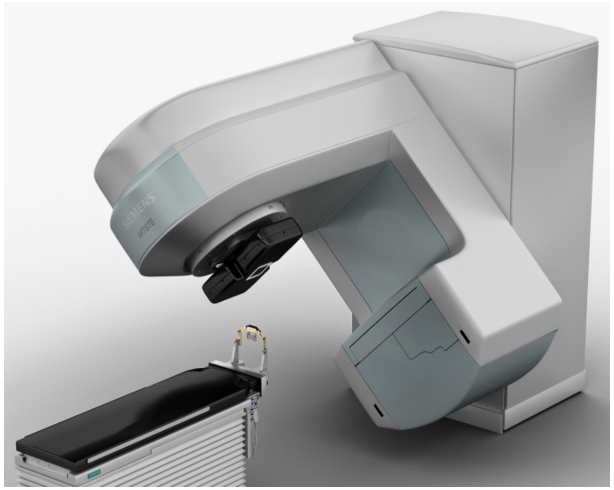
[1] Tomsej M, Followill D, Georg D, Izewska J, Kry S, Tenhunen M, et al. Development of external dosimetry audits for advanced technology in radiotherapy dose delivery: An IAEA coordinated research project. Physica Medica 2015;31, Supplement 2:e29 .
[2] Followill D, Kry S, Qin L, Lowenstein J, Molineu A, Alvarez P, et al. The Radiological Physics Center's standard dataset for small field size output factors. Journal of Applied Clinical Medical Physics 2012;13(5).
[3] Followill D. Erratum: The Radiological Physics Center's standard dataset for small field size output factors. Journal of Applied Clinical Medical Physics 2014;15(2).

Materials

- The audit was performed in all of 32 Polish radiotherapy centres for different linacs, TPS, MLC types and beam energies.
- The beam qualities ranged from 4 MV to 20 MV. In total, 65 beams were checked (Varian 30, Elekta 20, and Siemens 15).

- Varian #30

- Elekta #20



- Siemens #15

Materials

A number of treatment planning systems (TPS) were examined during the audit. The participants were obliged to use the clinically used TPS together with an approved beam model for the calculations.

The following TPS and related calculation algorithms were examined:

TPS	Algorithm
Monaco	Monte Carlo (MC)
XiO	Convolution (CV), Superposition (SP)
Oncentra MasterPlan	Pencil Beam Convolution (PBC), Collapsed Cone Convolution (CCC)
Pinnacle	Collapsed Cone Convolution (CCC)
Prowess Panther	Collapsed Cone Convolution (CCC)
Eclipse	Pencil Beam Convolution (PBC), Analytical Anisotropic Algorithm (AAA), Acuros XB (AXB)

No.	MV	Linac	year	MLC type, no. of leafs	TPS	Algorithm
1	6	2300 C/D	2008	Millennium 120	Eclipse 8.6	AAA
2	6	2300 C/D	2010	Millennium 120	Eclipse 11.0	AAA
3	6	2300 C/D-S	2005	Millennium 120	Eclipse 11.0	PBC
4	6	2300 C/D-S	2007	Millennium 120	Eclipse 13.0	AAA
5[a]	6	2300 C/D-S	2003	Millennium 120	Eclipse 13.0	AXB
6[a]	6	2300 C/D-S	2003	Millennium 120	Eclipse 13.0	AAA
7	6	2300 C/D-S	2011	Millennium 120	Eclipse 11.0	AAA
8	6	2300 C/D-S	2003	Millennium 120	Eclipse 10.0	AAA
9	6	23EX	2002	Millennium 120	Eclipse 10.0	AAA
10	6	iX	2013	Millennium 120	Eclipse 10.0	AAA
11	6	iX	2012	Millennium 120	Eclipse 11.0	AAA
12	6	TrueBeam	2013	HD 120	Eclipse 11.0	AAA
13	6	TrueBeam	2012	HD 120	Eclipse 10.0	AAA
14	6	TrueBeam	2012	HD 120	Eclipse 11.0	AAA
15	6	TrueBeam	2014	Millennium120	Eclipse 13.0	AAA
16	6	TrueBeam	2013	HD 120	Eclipse 13.6	AAA
17	10	TrueBeam	2012	HD 120	Eclipse 11.0	AAA
18	15	2300 C/D	2008	Millennium 120	Eclipse 8.6	AAA
19	15	2300 C/D-S	2007	Millennium 120	Eclipse 13.0	AAA
20b	15	2300 C/D-S	2003	Millennium 120	Eclipse 13.0	AXB
21b	15	2300 C/D-S	2003	Millennium 120	Eclipse 13.0	AAA
22	15	2300 C/D-S	2011	Millennium 120	Eclipse 11.0	AAA
23	15	2300 C/D-S	2009	Millennium 120	Eclipse 10.0	AAA
24	15	iX	2013	Millennium 120	Eclipse 10.0	AAA
25	15	iX	2012	Millennium 120	Eclipse 11.0	AAA
26	15	TrueBeam	2012	HD 120	Eclipse 10.0	AAA
27	15	TrueBeam	2012	HD 120	Eclipse 11.0	AAA
28	15	TrueBeam	2014	Millennium 120	Eclipse 13.0	AAA
29	18	2300 C/D	2010	Millennium 120	Eclipse 11.0	AAA
30	20	2300 C/D-S	2003	Millennium 120	Eclipse 10.0	AAA
31	20	23EX	2002	Millennium 120	Eclipse 10.0	AAA
32	20	TrueBeam	2012	HD 120	Eclipse 10.0	AAA

a,b same beam

Varian

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No.	MV	Linac	year	MLC type, no. of leafs	TPS	Algorithm
1	4	Synergy	2012	Agility 160	Monaco 3.2	MC
2[a]	6	Synergy	2009	MLCi 80	XiO 4.7	SP
3[a]	6	Synergy	2009	MLCi 80	Oncentra 4.3	CCC
4[a]	6	Synergy	2009	MLCi 80	Monaco 3.2	MC
5	6	Synergy	2010	MLCi2 80	Oncentra 4.3	CCC
6	6	Synergy	2013	Agility 160	Pinnacle 9.8	CCC
7[b]	6	Synergy	2009	MLCi2 80	XiO 4.6	SP
8[b]	6	Synergy	2009	MLCi2 80	Oncentra 4.3	CCC
9	6	Synergy	2013	Agility 160	Monaco 5.0	MC
10	6	Synergy	2009	MLCi2 80	Monaco 3.3	MC
11	6	Synergy	2012	Agility 160	Monaco 5.0	MC
12	6	Synergy	2013	Agility 160	Monaco 5.0	MC
13	6	Synergy	2012	Agility 160	Monaco 3.2	MC
14	6	Synergy	2005	MLCi 80	Monaco 3.2	MC
15	6	Synergy	2011	MLCi2 80	Monaco 3.3	MC
16	6	Synergy	2013	Agility 160	Monaco 5.0	MC
17	6	Synergy	2013	Agility 160	XiO 5.0	SP
18	6	VersaHD	2013	Agility 160	Monaco 3.3	MC
19	10	Synergy	2013	Agility 160	Monaco 5.0	MC
20	15	Synergy	2010	MLCi2 80	Oncentra 4.3	CCC
21	15	Synergy	2013	Agility 160	Monaco 5.0	MC
22	15	Synergy	2013	Agility 160	Monaco 5.0	MC
23	18	Synergy	2012	Agility 160	Monaco 3.2	MC

[a,b] same beam

Elekta

No.	MV	Linac	year	MLC type, no. of leafs	TPS	Algorithm
1	6	Oncor	2006	OPTIFOCUS 82	Oncentra 4.3	CCC
2	6	Oncor	2011	160 MLC	Prowess 5.01	CCC
3[a]	6	Artiste	2009	160 MLC	Prowess 5.10	CCC
4[a]	6	Artiste	2009	160 MLC	Oncentra 4.3	CCC
5[a]	6	Artiste	2009	160 MLC	Oncentra 4.3	PBC
6[b]	6	Artiste	2009	160 MLC	Prowess 5.10	CCC
7[b]	6	Artiste	2009	160 MLC	Oncentra 4.3	CCC
8[b]	6	Artiste	2009	160 MLC	Oncentra 4.3	PBC
9	6	Artiste	2013	160 MLC	Pinnacle 9.4	CCC
10	6	Artiste	2011	160 MLC	Prowess 5.15	CCC
11	6	Artiste	2011	160 MLC	Prowess 5.20	CCC
12	6	Artiste	2009	160 MLC	Prowess 4.07	CCC
13	6	Artiste	2008	160 MLC	Prowess 5.10	CCC
14	6	Artiste	2012	160 MLC	Prowess 5.10	CCC
15[c]	15	Artiste	2009	160 MLC	Prowess 5.10	CCC
16[c]	15	Artiste	2009	160 MLC	Oncentra 4.3	CCC
17[c]	15	Artiste	2009	160 MLC	Oncentra 4.3	PBC
18	15	Artiste	2011	160 MLC	Prowess 5.15	CCC
19	15	Artiste	2009	160 MLC	Prowess 4.07	CCC
20	15	Artiste	2008	160 MLC	Prowess 5.10	CCC
21	15	Artiste	2012	160 MLC	Prowess 5.10	CCC

Siemens

[a,b,c] same beam

Interpolation

Since this dataset did not provide data for certain beam qualities the interpolation /extrapolation was performed fitting the second degree polynomials to the RPC measured values of output factors (OF).

$$OF = a(f) \cdot E^2 + b(f) \cdot E + c(f)$$

Where:

f – field size; Q – beam quality; a(f), b(f), c(f) – coefficients

Interpolation for Varian

Field size f	*a(f)* *[MV^{-2}]*	*b(f)* *[MV^{-1}]*	*c(f)*
6×6 cm^2	-23×10^{-5}	80×10^{-4}	0.900
4×4 cm^2	-44×10^{-5}	140×10^{-4}	0.818
3×3 cm^2	-58×10^{-5}	166×10^{-4}	0.772
2×2 cm^2	-61×10^{-5}	150×10^{-4}	0.763

Interpolation for Elekta

Field size f	*a(f)* *[MV^{-2}]*	*b(f)* *[MV^{-1}]*	*c(f)*
6×6 cm^2	-6×10^{-5}	27×10^{-4}	0.916
4×4 cm^2	-14×10^{-5}	52×10^{-4}	0.852
3×3 cm^2	-27×10^{-5}	81×10^{-4}	0.803
2×2 cm^2	-23×10^{-5}	52×10^{-4}	0.767

Interpolation for Siemens

Field size f	*a(f)* *[MV^{-2}]*	*b(f)* *[MV^{-1}]*	*c(f)*
6×6 cm^2	-13×10^{-5}	54×10^{-4}	0.886
4×4 cm^2	-31×10^{-5}	105×10^{-4}	0.803
3×3 cm^2	-35×10^{-5}	109×10^{-4}	0.767
2×2 cm^2	-8×10^{-5}	46×10^{-4}	0.740

Results

- For Elekta accelerators, all the calculation results show a deviation from the reference values lower than 3%.
- For Siemens and Varian accelerators, the resulting calculations for fields larger than 2×2 cm^2 differ less than 4%.
- For 2×2 cm^2 large fields formed by Siemens and Varian MLC, the differences between the calculated and measured output factors often exceed 5%, but still are below 10%.

Varian 6-10 MV

Varian 15-20 MV

Elekta

Siemens

Observations and conclusions

- The set of measured small field output factors provided by the RPC is a very good tool for QA of the treatment planning systems.
- A comparison of particular institution's data with the RPC data is very helpful in quality assurance of IMRT treatments. Such quality control should be performed before the IMRT is used in clinical practice.
- In Poland, the results of the audit were found very useful for the participants who should carefully investigate any detected discrepancies between the standard dataset and calculated values, with attention to the specific beam model.