Strahlentherapie und Onkologie

Supplementary material to:
“Technological quality requirements for stereotactic radiotherapy
Expert review group consensus from the DGMP Working Group for Physics and Technology in Stereotactic Radiotherapy”

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Reference (Year Published) (Sub-Reference, Year published)	**Mechanical Precision in End-To-End Test** (median/range or mean + standard deviation)	**Dosimetry Precision in End-To-End Test** (median/range or mean + standard deviation)	**Dosimetry Precision in Patient Specific Phantom Test** (median/range or mean + standard deviation)	**Report / Tested System**	**Measurement Tools**	**Volume Specific Recommendation**	**Comments**
IAEA Technical Reports Series 483 (2017) [4]	2mm	3–10%	5–10%	General Report	n.s.	n.s.	For EBRT only, SRS/SRT/ SBRT not specified
ESTRO / ACROP Guideline for Lung SBRT (2017) [20]	1.25mm (0.5–4 mm)	3% (2–5%)	No Consensus	Consensus Guideline	n.s.	n.s.	For lung SBRT only, small consensus, no procedural details
ICRU Report 91 (2017) [3]		n.s.	n.s.	Expert Guideline	n.s.	n.s.	References only, no recommendation for end-to-end accuracy
(Hacker, 2006)	≤ 1.5mm ± 0.7mm			ExacTrac			
(Jin, 2008)	0.56mm ± 0.7mm			ExacTrac			
(Verellen, 2003)	0.6mm ± 0.9mm			ExacTrac			
(Antypas, 2008)	0.56mm ± 0.7mm			CyberKnife			

(Desai, 2006)	0.8mm ± 0.05mm			CyberKnife			
(Kilby, 2010)	0.4mm ± 0.1mm 0.5mm ± 0.2mm 0.3mm ± 0.1mm			CyberKnife - 6D Skull - XSight Spine - Fiducial			
(Hyde, 2012)	< 1.4mm and < 0.7° (95% CI)			CBCT			
(Sharpe, 2006)	1–1.5mm (95% CI)			CBCT			
(Fenwick, 2004)	±1mm			TomoTherapy			
(Boswell, 2006)	1mm			TomoTherapy			
(Depuydt, 2011)	0.54mm ± 0.2mm			VERO			
AAPM-RSS Guideline 9.a (2017) [172]				Expert Guideline			To be performed annually/quarterly, no details provided
	1.0mm	5%	n.s.	C-Arm LINAC / TomoTherapy	n.s.	n.s.	
	1.0mm (static) 1.5mm (moving)	n.s.	n.s.	CyberKnife	n.s.	n.s.	
Dosimetry Audit in lung SBRT trials (2017) [206]			n.s.	Expert Report	Anthropomorphic lung phantom	n.s.	New and large data included, though no recommendation, Lung SBRT only
NRG LU002, BR001, BR002, LUSTRE OCOG (IROC, 2013)	n.s.	0.9% 1.8% 3.2% 3.8%		Acuros Monte Carlo Superposition AAA	TLD, Film		
SARON, CORE (UK, 2017)	3mm (-6–7mm) 100% 5mm (-10–19mm) 50% Isodose-to-Isodose	0.7% (-1.0–2.6%) 0.3% (-2.9–3.2%) 0.4 ± 1.4% 1.4 ± 3.4%		Conformal IMAT	Alanine Pellets, Film		

AAPM TG 101 Report (2010) [2]		n.s.	n.s.	Report with Guideline		n.s.	References only, no recommendation
(Ryu, 2001)	1.0–1.2mm (RMS)			Stereo X-Ray	Hidden target		
(Verellen, 2003)	0.41 ± 0.92 mm			Stereo X-Ray	Hidden target		
(Verellen, 2003)	0.28 ± 0.36 mm			Stereo X-Ray	Fiducials		
(Yu, 2004)	0.68 ± 0.29 mm			Stereo X-Ray	Fiducials		
(Solberg, 2008)	1.10 ± 0.42 mm			Stereo X-Ray	Anthropomorphic phantom		
COMP Report Gamma Knife (2018) [209]	n.s.	1–5%/0.5 mm (Gamma, no specifics)	n.s.	Report with Guideline / Gamma Knife	Appropriate (1% with Ion-Chamber, 5% with Film	n.s.	No specific procedural details given
COMP Report CyberKnife (2018) [189]	0.75mm (static) 1mm (moving)	n.s.	Gamma with absolute dose and 90% pass rate: 5%/2mm (static) 5%/3mm (moving)	CyberKnife	Appropriate (≤10 mm collimator with Film)	≤10mm collimator split for measurement tools	For mechanical accuracy stricter (newer systems), but for DQA weaker recommendations as AAPM TG 135
COMP Report CBCT (2018) [202]	±1mm	n.s.	n.s.	CBCT	n.s.	n.s.	No specific procedural details given
AAPM TG 135 Report (2011) [188]	<0.9mm (static) <1.5mm (moving)	n.s.	Gamma with absolute dose and 90% pass rate: 2%/2mm (static) 3%/3mm (moving)	CyberKnife	n.s.	n.s.	No specific DQA procedural details given, for old systems only
Wen et al. (2018) [204]	1.0 ± 0.1 mm	n.s.	1.64 ± 1.90% (-3.50–0.79%) Gamma (no details) 96.87% (3%/1mm)	MR-Linac	Film	n.s.	Monocentric, prototype phantoms
Pantelis et al. (2018) [212]	Gel <0.66 mm 0.4 ± 0.18mm 0.55 ± 0.20 mm 0.40 ± 0.19mm	n.s.	n.s.	CyberKnife - 6D Skull - XSight Spine - Fiducial	Gel Film	n.s.	Monocentric, but comprehensive

Kron et al. (2018) [201]	< 3 mm (stationary)	0-2.6% difference between moving and stationary measurement	n.s.	CBCT	Film with motion platform	n.s.	Multicenter, lung only, limited evaluation quality
Kurosu et al. (2017) [217]	n.s.	n.s.	1.0 ± 0.9% (isocentric) 0.5 ± 1.4% (conformal, homogeneous dose) 4.1 ± 2.8% (conformal, inhomogeneous dose)	CyberKnife	Ion-Chamber	n.s.	Monocentric, point dose measurement error analysis based on dose gradient
Bellec et al. (2017) [218]	n.s.	n.s.	Gamma 3% relative dose and 1.5mm DTA >88% for error detection	CyberKnife	Film Process-Control-Statistics	n.s.	Monocentric, large data set, process control
Calvo Ortega et al. (2017) [199]	1.4 ± 0.2mm 1.8mm (95% CI)	n.s.	n.s.	CBCT	Head Phantom Film	n.s.	Monocentric, SRS only
Colodro et al. (2017) [216]	n.s.	n.s.	Gamma 3%/1.5mm (absolute dose) 98.8% (95.8–100.0%) 99.3% (97.9–99.9%) (relative dose) 80.7% (65.2–92.9%) 92.7% (87.5–97.3%)	CBCT	Ion-Chamber Array Film	6.8-79.4ccm	Monocentric, lung SBRT only, gamma pass rate analysis
Dimitriadis et al. (2016) [200]	0.8mm (0.1-2.0mm)	n.s.	n.s.	All	n.s.	n.s.	Questionnaire, SRS only
Fürweger et al. (2016) [195]	0.38 ± 0.05mm	n.s.	n.s.	CyberKnife	Film	n.s.	Monocentric, small series
Calvo Ortega et al. (2016) [203]	-0.4 ± 0.6 mm LR -0.1 ± 0.4 mm AP 0.2 ± 0.4 mm SI	n.s.	n.s.	CBCT	Head Phantom	n.s.	Monocentric, SRS only
Wen et al. (2016) [211]	0.44–0.64mm (beam positioning) 0.27–0.61mm (gantry rotation)	n.s.	n.s.	Edge	Film	n.s.	Monocentric, prototype phantom, SRS/SRT only

Colvill et al. (2016) [89]	n.s.	n.s.	Gamma 2% absolute dose and 2mm DTA Motion Compensation 98.4% (lung) 98.6% (prostate) No Compensation 84.8% (lung) 82.7% (prostate)	C-Arm with - MLC Tracking - Couch Tracking CyberKnife Vero	Diode or Ion-Chamber Array or Film with motion platform and multiple given motion traces	7.2cc (lung) 55.3cc (prostate)	Multicenter benchmark for motion compensation systems, large variety in measurement systems, SBRT only
Sothmann et al. (2016) [205]	-1.0–0.7mm (LR) -0.6–0.1mm (SI) -0.8–0.2mm (LR) -0.8–0.4mm (SI)	n.s.	1–2% (regular motion) 2–4% (complex motion) 1–2% (regular motion) 2–3% (complex motion)	CyberKnife Vero	Ion-Chamber Array with motion platform and patient motion	30-180ccm (liver)	Benchmark and error classification for motion changes, SBRT only
Blanck et al. (2016) [197]	0.15mm (end-to-end) 0.97 (0.1–1.8mm) (patient specific QA)	n.s.	Gamma 3% relative dose and 1mm DTA 95.8% (90.5–100%)	CyberKnife	Ion-Chamber Array	n.s.	Multicenter, geometric errors attributed to array
Sarkar et al. (2016) [208]	n.s.	-1.4–1%	Gamma 2% absolute dose and 2mm DTA 83.4%–98.0%	Frame CBCT Stereo X-Ray	Ion-Chamber Film	n.s.	Phantom / technique comparison, small study, monocentric
Blanck et al. (2015) [196]	0.55mm (end-to-end) 0.45mm (0.2–0.9mm) (patient specific QA)	n.s.	Gamma 3% relative dose and 1mm DTA 95.45% (81.3–100%)	CyberKnife	Film	n.s.	Multicenter, dosimetric errors attributed to film
Gallo et al. (2015) [207]	n.s.	1.5% (1.4-3.1%) Gamma with absolute dose and 90% pass rate: 96.1–100% (3%/3mm) 93.3–100% (2%/2mm) 49.8–95.4% (1%/1mm)	n.s.	CBCT Tomotherapie CyberKnife Vero	Ion-Chamber Film Dedicated Spine Phantom	n.s.	Multicenter, comprehensive, Spine SBRT only
Seravalli et al. (2015) [190]	Σ 0.49mm σ 0.53mm	n.s.	n.s.	CBCT	Film	n.s.	Monocentric, but comprehensive, SRS only
Wen et al. (2015) [191]	0.66 ± 0.18mm (drift over 3 months)	1.3 ± 0.9%	Gamma (no details) 99.4 ± 0.8% (3%/3mm) 93.0 ± 6.0% (3%/1mm)	Edge	Film Ion-Chamber	n.s.	Monocentric, small test series

Swamy et al. (2015) [213]	n.s	n.s.	-2.5% (-4.6–-1.2%) -1.6% (-5.1–3.0%) -0.01% (-2.6–2.9%)	CBCT	CC13 Ion-Chamber A14 Ion-Chamber W1 Ion-Chamber	>10cc	Monocentric, small test series
Solberg et al. (2014) [194]	0.27mm LR 0.34mm AP 0.27 mm SI	n.s.	n.s.	Vero	Film	n.s.	Monocentric, commissioning only
Ma et al. (2014) [192]	0.03 ± 0.2 mm (2σ)	n.s.	n.s.	Gamma Knife	Film	n.s.	Monocentric, but large data, SRS only
Novotny et al. (2014) [193]	<0.2mm	n.s.	n.s.	Gamma Knife	Film Diodes	n.s.	Monocentric, but long time data, SRS only
Mamalui-Hunter et al. (2013) [210]	n.s.	n.s.	2.3% (-5.7–4.9%)	Gamma Knife	Independent Dose Calculation	n.s.	Monocentric, no measurement, SRS only
Thomas et al. (2013) [214]	n.s.	n.s.	3D Gamma (no details) 99.9% (5%/3mm) 98.0% (3%/2mm)	Stereo X-Ray	Gel	>5cc	Monocentric, single plan, SRS only
Weyh et al. (2013) [215]	n.s.	n.s.	Gamma 3% absolute dose and 3mm DTA 92.9–100.0%	CBCT TomoTherapy	Ion-Chamber Array	n.s.	Monocentric, small cases, no motion compensation

Supplementary table 1: Guidelines and publications for mechanical and dosimetric accuracy for stereotactic radiotherapy. References in parentheses are part of the respective report in the row above. n.s.: not specified.