1 Background

2 Methods

Need to speak about of the period of time of the gamma measurements

3 Results (result and control charts)

Table 1: Averages, standard deviation, lower control limits, upper control limits and action limits of γ 3%, 3 mm, γ 3%, 2 mm and percentage of difference of dose

Test	Area	Average (%)	Standard deviation (%)	LCL (%)	UCL (%)	AL (%)
3% 3 mm Local	Abdominal	96.99	0.07	89.07	–	87.85
	Breast	85.53	0.47	64.36	–	51.98
	Head & Neck	95.69	0.07	88.82	–	84.84
	Prostate	96.78	0.08	90.20	–	87.16
3% 2 mm Global	Abdominal	98.95	0.04	94.98	–	93.17
	Breast	96.02	0.22	82.66	–	81.65
	Head & Neck	99.64	0.04×10^-3	97.82	–	97.73
	Prostate	97.58	0.07	90.17	–	89.17
Dose difference test	Abdominal	-0.15	0.01	-1.79	1.48	±2.12
	Breast	0.29	0.06	-4.96	5.54	±7.47
	Head & Neck	-0.08	0.02	-4.01	3.85	±4.19
	Prostate	0.02	0.01	-3.41	3.45	±3.61

4 Comparison

4.1 Gamma (table comparison with the literature)

Table 2: Criteria γ 3% 3mm Local normalization compare to literature result (10% threshold dose)

Anatomical sites	Author - year	Reported γ passing rates (%)	Local γ passing rate (%)
Abdominal	Rajasekaran(41), 2014	85.33 ± 3.26	87.85 ± 0.07
Breast + SVC	−−	−−	51.98 ± 0.47
Head & Neck	Song JH(35), 2015	98.65 ± 0.43	84.84 ± 0.07
Prostate	Song JH(35), 2015	97.70 ± 1.21	87.16 ± 0.08

Table 3: Criteria γ 3% 2mm Global normalization compare to literature result (10% threshold dose)

Anatomical sites	Author - year	Reported γ passing rates (%)	Local γ passing rate (%)
Abdominal	$--$	$--$	93.17 ± 0.04
Breast + SVC	Kaneko (44), 2019	85.90 ± 2.30	81.65 ± 0.22
Head & Neck	$--$	$--$	$97.73 \pm 0.04 \times 10^{-3}$
Prostate	Tomori (45), 2018	94.15 ± 1.28	89.17 ± 0.07

5　Stability of the test verifications in the time

- results of the comparison in the time of the process and graph of that results (box plots)

- Differences doses

Table 4: Comparison table

Test	Area	Period of time	
		First Evaluation (%)	Second Second (%)
3% 3 mm Local	Abdominal	88.43 ± 0.06	87.85 ± 0.07
	Breast+SVC	77.38 ± 0.13	51.98 ± 0.47
	Head & Neck	90.29 ± 0.03	84.84 ± 0.07
	Prostate	89.10 ± 0.06	87.16 ± 0.08
3% 2 mm Global	Abdominal	94.86 ± 0.02	93.17 ± 0.04
	Breast+SVC	88.30 ± 0.10	81.65 ± 0.22
	Head & Neck	81.09 ± 0.30	97.73 ± 0.04
	Prostate	91.86 ± 0.04	89.17 ± 0.07
Difference of dose	Abdominal	4.27 ± 0.02	2.12 ± 0.01
	Breast+SVC	6.34 ± 0.04	7.47 ± 0.06
	Head & Neck	3.08 ± 0.01	4.19 ± 0.02
	Prostate	5.57 ± 0.03	3.61 ± 0.01

References

[1] Mai, Y., Kong, F., Yang, Y. et al. *Voxel-based automatic multi-criteria optimization for intensity modulated radiation therapy.* Radiat Oncol 13, 241 (2018). https://doi.org/10.1186/s13014-018-1179-7

[2] Vieillevigne, Laure; Molinier, Jeremy; Brun, Thomas; Ferrand, Regis. *Gamma index comparison of three VMAT QA systems and evalua-*

tion of their sensitivity to delivery errors. Physica Medica, (2015). https://doi.org/10.1016/j.ejmp.2015.05.016

[3] Mohammad Hussein, Pejman Rowshanfarzad, Martin A.Ebert, Andrew Nisbet, Catharine H.Clark. *A comparison of the gamma index analysis in various commercial IMRT/VMAT QA systems* Radiotherapy and Oncology, Volume 109, Issue 3, December 2013, Pages 370-376. https://doi.org/10.1016/j.radonc.2013.08.048

[4] Moyed Miften, Arthur Olch, Dimitris Mihailidis, Jean Moran, Todd Pawlicki, Andrea Molineu, Harold Li, Krishni Wijesooriya, Jie Shi, Ping Xia, Nikos Papanikolaou, Daniel A. Low *Report No. 218 - Tolerance Limits and Methodologies for IMRT Measurement-Based Verification QA: Recommendations of AAPM Task Group No. 218* Medical Physics, (2018),https://dx.doi.org/10.1002/mp.12810

[5] Low DA, Harms WB, Mutic S, Purdy JA. *A technique for the quantitative evaluation of dose distributions.* Med Phys. 1998 May;25(5):656-61. doi: 10.1118/1.598248. PMID: 9608475.

[6] Mackie TR. *History of Tomotherapy.* Phys Med Biol. 2006 Jul 7;51(13):R427-53. doi: 10.1088/0031-9155/51/13/R24. Epub 2006 Jun 20. PMID: 16790916.

[7] J.F.MacGregorT.Kourti *Statistical process control of multivariate processes* Control Engineering Practice, Volume 3, Issue 3, March 1995, Pages 403-414

[8] Palta JR, Kim S, Li J, Liu C. *Tolerance limits and action levels for planning and delivery of IMRT* Intensity- Modulated Radiation Therapy: The State of Art. Madison: Medical Physics Publishing; 2003:593–612.

[9] Hawbir Omer Ghafour, Serenella Russo, *Statistical process control analysis for patient-specific pre-treatment VMAT QA with PTW Octavius 4D system: setting tolerance limit and action threshold for different anatomical sites* MEDICAL PHYSICS INTERNATIONAL Journal, vol.7, 2019, 11.

[10] Fenoglietto P, Lalibert B, Aill eres N, Riou O, Dubois JB, Azria D. *Eight Years of IMRT quality assurance with ionization chambers and film dosimetry: experience of the montpellier comprehensive cancer center.* Radiat Oncol. 2011;6:85.

[11] Tom Depuydt, Ann Van Esch, dominique Pierre Huyskens *A quantitative evaluation of IMRT dose distribution: refinement and clinical assessment of the gamma evaluation.* Elsevier, radiotherapy and oncology 62 (2002) 309 -319.

[12] Van Dyk J, Barnett RB, Cygler JE, Shragge PC. *Commissioning and quality assurance of treatment planning computers* Int J Radiat Oncol Biol Phys 1993;26:261–273

[13] Riley, C., Yang, Y., Li, T., Zhang, Y., Heron, D.E. and Huq, M.S. (2014),*Dosimetric evaluation of the interplay effect in respiratory-gated RapidArc radiation therapy.* Med. Phys., 41: 011715. doi:10.1118/1.4855956

[14] Duan J, Shen S, Fiveash JB, Brezovich IA, Popple RA, Pareek PN. *Dosimetric effect of respiration-gated beam on IMRT delivery.* Med Phys. 2003;30:2241–2252.

[15] Song, Ji-Hye et al. *Gamma analysis dependence on specified low-dose thresholds for VMAT QA.* Journal of applied clinical medical physics vol. 16,6 263-272. 8 Nov. 2015, doi:10.1120/jacmp.v16i6.5696

[16] M. Hussein, C.H. Clark, *A. Nisbet Challenges in calculation of the gamma index in radiotherapy – Towards good practice,*Volume 36, P1-11, April 01, 2017, DOI:https://doi.org/10.1016/j.ejmp.2017.03.001

[17] S. Bresciani, A. Di Dia, A. Maggio, C. Cutaia, A. Miranti, E. Infusino, M. Stasi *Tomotherapy treatment plan quality assurance: The impact of applied criteria on passing rate in gamma index method,* 12 November 2013 Medical physics. https://doi.org/10.1118/1.4829515

[18] Tomotherapy Accuray customer documentation ETT.700500.A *VoLO™ Technology and Planning,* n.d.

[19] Breen SL, Moseley DJ, Zhang B, Sharpe MB.*Statistical process control for IMRT dosimetric verification.* Med Phys. 2008 Oct;35(10):4417-25. doi: 10.1118/1.2975144. PMID: 18975688.

[20] Gérard K, Grandhaye JP, Marchesi V, Kafrouni H, Husson F, Aletti P. *A comprehensive analysis of the IMRT dose delivery process using statistical process control (SPC).* Med Phys. 2009 Apr;36(4):1275-85. doi: 10.1118/1.3089793. PMID: 19472636.

[21] Pawlicki T, Whitaker M, Boyer AL. *Statistical process control for radiotherapy quality assurance.* Med Phys. 2005 Sep;32(9):2777-86. doi: 10.1118/1.2001209. PMID: 16266091.

[22] Blau, N.; Hoffmann, G.F.; Leonard, J.; Clarke, J.T.R. (Eds.),*Physician's Guide to the Treatment and Follow-Up of Metabolic Diseases* 2006, XVIII, 415 p. 12 illus. With CD-ROM., Hardcover ISBN: 978-3-540-22954-4

[23] Mackie, T.A Bielajew, et al. *Generation of phton energy deposition kernel using the EGS Monte Carlo code.* Phys.Med.Bio 33(1):1-20 (1988)

[24] Mohan,T. R, Scrimger, et al *A convolution method of calculatin g dose fron 15 MeV x-ray* Med.Phy 12:188-196 (1985)

[25] Papanikolaou, N., T. R. Mackie, et al *Investigation of the convolution method for polyenergetic spectra* Medical Physics 20 (5): 1327 - 36 (1993).

[26] Nearlandse Commissie Voor Stralingsdosimetrie *Quality assurance for Tomotherapy systems, Report 27* Netherlands Comission on Radiation Dosymetry, March 2017

[27] Tomotherapy Accuray customer documentation 1049311-ITA A *QA dell' emissione radiante*, n.d.(2015)

[28] Sun nuclear corporation *Characteristics of Arccheck device* http://www.scienty-med.com/sunnuclear/arccheck-english.pdf

[29] Montgomery DC.*Introduction to Statistical Process Control*, 6th edn. Hoboken: Wiley, 2009.

[30] A. Nisbeta, I. Beangea, H. Vollmara, C. Irvineb, A. Morganb, I. Thwaitesc, *Dosimetric verification of a commercial collapsed cone algorithm in simulated clinical situations*,Radiotherapy and Oncology 73 (2004) 79–88

[31] Daniel A. Lowa, Jean M. Moran, James F. Dempsey, Lei Dong, Mark Oldham,*Dosimetry tools and techniques for IMRT* Medical Physics 38, 1313 (2011); doi: 10.1118/1.3514120.

[32] Tamer Dawod, *Evaluation of collapsed cone convolution superposition (CCCS) algorithms in prowess treatment planning system for calculating symmetric and asymmetric field size*, International Journal of Cancer Therapy and Oncology (2015).

[33] Emiliano Spezi, D. Geraint Lewis, *Gamma histograms for radiotherapy plan evaluation*, Radiotherapy and Oncology 79 (2006) 224–230.

[34] Heilemann G, Poppe B, Laub W. *On the sensitivity of common gamma-index evaluation methods to MLC misalignments in Rapidarc quality assurance.* Med Phys. 2013 Mar;40(3):031702. doi: 10.1118/1.4789580. PMID: 23464297.

[35] Song JH, Kim MJ, Park SH, Lee SR, Lee MY, Lee DS, Suh TS. *Gamma analysis dependence on specified low-dose thresholds for VMAT QA.* J Appl Clin Med Phys. 2015 Nov 8;16(6):263-272. doi: 10.1120/jacmp.v16i6.5696. PMID: 26699582; PMCID: PMC5691030.

[36] Aristophanous M, Suh Y, Chi PC, Whittlesey LJ, LaNeave S, Martel MK. *Initial clinical experience with ArcCHECK for IMRT/VMAT QA.* J Appl Clin Med Phys. 2016 Sep 8;17(5):20-33. doi: 10.1120/jacmp.v17i5.6118. PMID: 27685107; PMCID: PMC5874100.

[37] Xu S, Xie C, Ju Z, Dai X, Gong H, Wang L, Yang J. *Dose verification of helical Tomotherapy intensity modulated radiation therapy planning using 2D-array ion chambers.* Biomed Imaging Interv J. 2010 Apr-Jun;6(2):e24. doi: 10.2349/biij.6.2.e24. Epub 2010 Apr 1. PMID: 21611040; PMCID: PMC3097769.

[38] Sanghangthum T, Suriyapee S, Kim GY, Pawlicki T. *A method of setting limits for the purpose of quality assurance.* Phys Med Biol. 2013 Oct 7;58(19):7025-37. doi: 10.1088/0031-9155/58/19/7025. Epub 2013 Sep 17. PMID: 24043363.

[39] Bresciani S, Di Dia A, Maggio A, Cutaia C, Miranti A, Infusino E, Stasi M. *Tomotherapy treatment plan quality assurance: the impact of applied criteria on passing rate in gamma index method.* Med Phys. 2013 Dec;40(12):121711. doi: 10.1118/1.4829515. PMID: 24320497.

[40] Sanghangthum T, Suriyapee S, Srisatit S, Pawlicki T.*Statistical process control analysis for patient-specific IMRT and VMAT QA.* J Radiat Res. 2013 May;54(3):546-52. doi: 10.1093/jrr/rrs112. Epub 2012 Dec 7. PMID: 23220776; PMCID: PMC3650738.

[41] Rajasekaran D, Jeevanandam P, Sukumar P, Ranganathan A, Johnjothi S, Nagarajan V. *A study on the correlation between plan complexity and gamma index analysis in patient specific quality assurance of volumetric modulated arc therapy.* Rep Pract Oncol Radiother. 2014 Sep 6;20(1):57-65. doi: 10.1016/j.rpor.2014.08.006. PMID: 25535586; PMCID: PMC4268596.

[42] Stasi M, Bresciani S, Miranti A, Maggio A, Sapino V, Gabriele P. *Pretreatment patient-specific IMRT quality assurance: a correlation study between gamma index and patient clinical dose volume histogram.* Med Phys. 2012 Dec;39(12):7626-34. doi: 10.1118/1.4767763. PMID: 23231310.

[43] Zhang D, Wang B, Zhang G, Ma C, Deng X. *Comparison of 3D and 2D gamma passing rate criteria for detection sensitivity to IMRT delivery errors.* J Appl Clin Med Phys. 2018 Jul;19(4):230-238. doi: 10.1002/acm2.12389. Epub 2018 Jun 15. PMID: 29905004; PMCID: PMC6036388.

[44] Kaneko, Akari Sumida, Iori Mizuno, Hirokazu Isohashi, Fumiaki Suzuki, Osamu Seo, Yuji Otani, Keisuke Tamari, Keisuke Ogawa, Kazuhiko. (2019).´ it Comparison of gamma index based on dosimetric error and clinically relevant dose–volume index based on three-dimensional dose prediction in breast intensity-modulated radiation therapy. Radiation Oncology. 14. 10.1186/s13014-019-1233-0.

[45] Tomori, S., Kadoya, N., Takayama, Y., Kajikawa, T., Shima, K., Narazaki, K. and Jingu, K. (2018), *A deep learning-based prediction model for gamma evaluation in patient-specific quality assurance.* Med. Phys., 45: 4055-4065. https://doi.org/10.1002/mp.13112

[46] Langen KM, Papanikolaou N, Balog J, Crilly R, Followill D, Goddu SM, Grant W 3rd, Olivera G, Ramsey CR, Shi C; *AAPM Task Group 148. QA for helical Tomotherapy: report of the AAPM Task Group 148.* Med Phys. 2010 Sep;37(9):4817-53. doi: 10.1118/1.3462971. PMID: 20964201.

[47] Chan, Lai K., Smiley W. Cheng, and Frederick A. Spiring. *A new measure of process capability: Cpm.* Journal of Quality Technology 20.3 (1988): 162-175