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Statistical process control and process capability analysis for non-normal volumetric modulated arc therapy pre-treatment delivery quality assurance processes

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INTRODUCTION

Statistical process control (SPC) and process capability analysis (PCA) have been useful tools to improve the intensity-modulated radiotherapy (IMRT) / volumetric modulated arc therapy (VMAT) pre-treatment delivery quality assurance (DQA) (1–8). The American Association of Physicists in Medicine (AAPM) Task Group 218 (TG-218) report(7) and previous studies(1–6,8) on SPC in IMRT/VMAT pre-treatment DQA have primarily adopted the conventional Shewhart control charts under the assumption of normality. However, non-normality will affect the performance of conventional control charts(9,10), resulting in the misestimation of process capability by conventional PCA methods, and lead to wrong decisions.

PURPOSE

The main purpose is to find accurate and reliable SPC and PCA methods for non-normal VMAT pre-treatment DQA processes by comprehensively comparing the performance differences between normal and non-normal SPC and PCA methods in VMAT DQA processes.

METHOD

1119 VMAT DQAs were performed on three beam-matched linear accelerators, using gamma analysis.

- The distributions of three DQA processes were tested for normality using Anderson-Darling statistic.
- The control charts for each VMAT DQA process were obtained using three non-normal-based methods (the Johnson transformation method(9), the Box-Cox power transformation method(11), and the skewness correction method(10)) and compared with that using the conventional Shewhart method.
- The ability of each DQA process to meet the specification limit was measured using the C_{pk} index; in this study, the C_{pk} values were calculated using the two transformation methods and compared with that calculated using the conventional normal method.

RESULTS

*All three DQA processes were non-normal (p-values < 0.005). For each linear accelerator, the lower control limit (LCL) of the DQA process obtained by the conventional Shewhart control chart was much higher than those obtained by other three non-normal methods (**Fig 1**). And the LCLs obtained by the three non-normal methods were very close, with a maximum difference of 0.9%. The false alarm rates of the three DQA process from the conventional Shewhart control chart were 0.83%, 3.77%, and 4.95%, respectively (**Tab 1**). For the three linear accelerators, the C_{pk} values calculated directly from the conventional normal method were much greater than those from the two transformation methods, with minimum differences of 0.59, 0.87, and 1.49, respectively. The C_{pk} values obtained by the two transformation methods were roughly similar, with a maximum difference of 0.11. From the C_{pk} values obtained by the normal method, the process capabilities of the three linear accelerators are excellent. However, through the non-normal methods, the process capabilities of the three beam-matched linear accelerators were at different levels.*

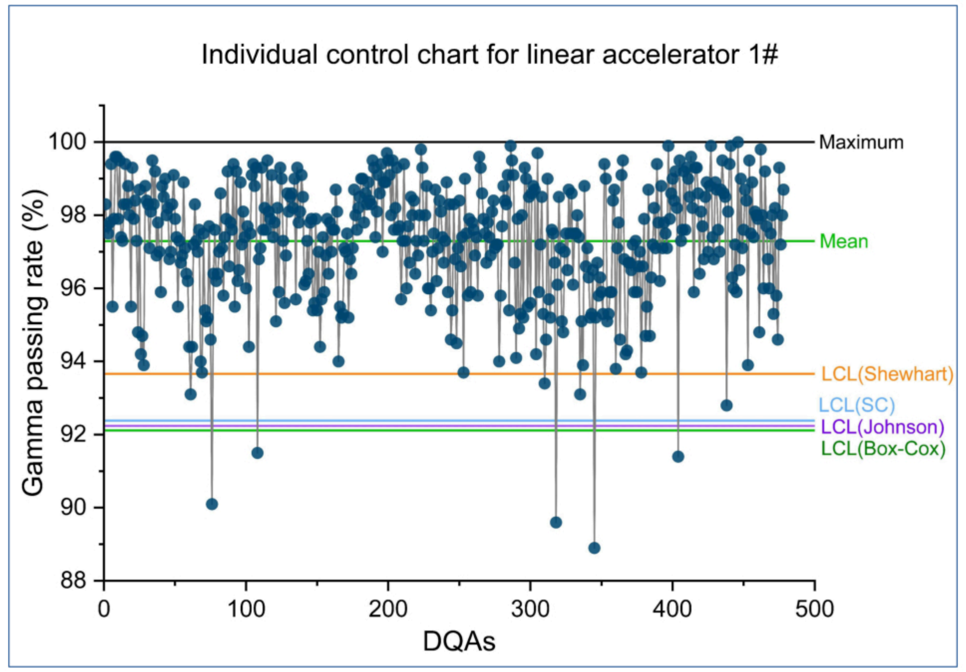

***Fig 1**. The comparison of four different LCLs of individual control chart for linear accelerator 1#.*

Linear accelerator	Methods	DQAs	$\bar{X} \pm S$ (γ%)	AD-test (p-value)	LCL (%)	DQAs below LCL (percentage)	C_{pk}
1 #	Conventional method	478	97.29±1.66	0.001	93.66	9 (1.88%)	1.98
	Skewness correction				92.38	5 (1.05%)	—
	Johnson transformation				92.24	5 (1.05%)	1.39
	Box-Cox transformation				92.11	5 (1.05%)	1.28
2 #	Conventional method	318	97.41±1.82	0.001	93.65	14 (4.40%)	1.91
	Skewness correction				90.57	2 (0.63%)	—
	Johnson transformation				90.40	2 (0.63%)	1.04
	Box-Cox transformation				90.09	2 (0.63%)	1.01
3 #	Conventional method	323	98.01±1.55	0.001	95.59	22 (6.81%)	3.06
	Skewness correction				93.48	6 (1.86%)	—
	Johnson transformation				92.58	5 (1.55%)	1.57
	Box-Cox transformation				93.12	6 (1.86%)	1.47

***Tab 1.** The results of statistical process control and process capability analysis of the VMAT DQA processes for the three beam-matched linear accelerators.*

CONCLUSIONS

SPC and PCA are useful tools for improving the VMAT DQA processes. Applying the conventional Shewhart control charts to non-normal VMAT pre-treatment DQA process will results in a high false alarm rate. The C_{pk} index calculated using the conventional normal method will overestimates the process capability of non-normal VMAT pre-treatment DQA process. For non-normal VMAT DQA processes, it is more appropriate to use the non-normal SPC and PCA methods.

REFERENCES

1. **Pawlicki T et al**. Moving from IMRT QA measurements toward independent computer calculations using control charts. *Radiother Oncol 2008; 89(3):330–7.*
2. **Breen SL et al**. Statistical process control for IMRT dosimetric verification. *Med Phys 2008; 35(10):4417–25*
3. **Gérard K et al**. A comprehensive analysis of the IMRT dose delivery process using statistical process control (SPC). *Med Phys 2009; 36(4):1275–85*
4. **Palaniswaamy G et al**. A statistical approach to IMRT patient-specific QA. *Med Phys 2012; 39(12):7560–70*
5. **Nordström F et al**. Control chart analysis of data from a multicenter monitor unit verification study. *Radiother Oncol 2012; 102(3):364–70*
6. **Gagneur JD et al**. An improvement in IMRT QA results and beam matching in linacs using statistical process control. *J Appl Clin Med Phys 2014; 15(5):4927*
7. **Miften Mb et al**. Tolerance limits and methodologies for IMRT measurement-based verification QA: Recommendations of AAPM Task Group No. 218. *Med Phys 2018; 45(4):e53-e83*
8. **Sanghangthum T et al**. A method of setting limits for the purpose of quality assurance. *Phys Med Biol 2013; 58(19):7025–37*
9. **Chou Y-M et al**. Transforming Non-Normal Data to Normality in Statistical Process Control. *Journal of Quality Technology 1998; 30(2):133–41*
10. **Chan LK et al**. Skewness correction and R charts for skewed distributions. *Naval Research Logistics 2003; 50(6):555–73*
11. **Box GEP et al**. An Analysis of Transformations. *Journal of the Royal Statistical Society. Series B (Methodological) 1964; 26(2):211–52*

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