Statistical Process Control in Tomotherapy pre-treatment QA

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Background and Objective

Patient-specific pretreatment QA is essential in highly modulated RT techniques to detect eventual problems in dose delivery before treatment. The objective of this research is to monitor over time the performance of the pretreatment QA for TomoTherapy™ (Accuray) treatments in different anatomical sites using the statistical process control (SPC) method proposed in the AAPM TG218[1] report .

Methods

SPC defines action limits (AL) and control limits (CL). AL give the minimum level of process performance that can be accepted; CL give the range within which the QA process is considered to be unchanging; if a QA measurement is outside the CL but within AL there is a warning that the process might be changing and causes should be investigated.

Historically, it has been observed that dose distribution complexity varies according to anatomical site, and, also, that QA results may vary within institutions. So, acceptance criteria must be adapted at the institution's local level and for the different sites of treatment (here we considered abdominal , breast + SVC, head & neck and prostate) starting from measurement results.

Given a set of n QA results, AL are defined as the QA target value (T) ± ΔA/2, where $\Delta A = \beta\sqrt{\sigma^2 + (\bar{x} - T)^2}$, σ is the process variance, $\bar{x}$ the process mean and β is usually set to 6.

Upper (UCL) and lower (LCL) control limits are defined as "center line± 2.660 ·mR" where center line is the average of QA results and mR the moving range.

We evaluated AL and CL for the following parameters measured in pre - treatment QA :

- γ-index passing rate with 3%, 3 mm , local normalization (γ33L) and 3%, 2 mm, global normalization (γ32G). Here T=1 and only lower AL and LCL are defined.
- Dose difference

QA was performed using ArcCheck™ (Sun Nuclear) phantom, with an ionization chamber (A1SL) placed in the center of the phantom for absolute dose measurement. The calculation of the patient plan on ArcCheck™ was carried out with Tomotherapy "Delivery Quality Assurance" software available in the planning station.

Results and Discussion

In Fig. (1) and Fig. (2) measured data for diverse anatomical sites and consequent center line (CentL) , AL and LCL can be seen for γ33L and γ32G, respectively.

The highest indices belong to the Head & Neck (LCL = 90.96% AL =87.25%) and Prostate (LCL = 88.40%, AL = 82.45%) for the γ33L criterion. While the lowest indices correspond to Breast + SVC (LCL = 75.35%, AL = 60.29%) and Abdomen (LCL = 76.85%, AL = 72.87%).

The evaluation of the γ32G criterion showed that the highest indices belong to the Abdominal area (LCL = 96.12%, AL = 92.36%) and the Prostate (LCL = 93.21%, AL = 90.19%); On the other hand, the lowest indices were for Breast + SVC (LCL = 90.04%, AL = 84.50%) and Head & Neck (LCL = 89.99%, AL = 84.44%).

These results indicate that the most stable process is the prostate treatment while the process with the greatest variations is the Breast + SVC, this is because these treatments generally involve large volumes, and it can be difficult to place the ArcCheck to efficiently sample the dose distribution with the diodes while preserving the proper position of the central ionization chamber in a region of low full dose gradient.

Results for dose difference are shown in Table 1: the smallest values were for head & neck (average difference 0.76%) and prostate (average difference 0.93%). The high variability and control levels for breast + SVC are due to the fact that ArcCheck positioning in these cases often results in the ionization chamber placed in a low dose and/or high gradient region.

Conclusions

- Tolerance and action limits were successfully established for the verification metrics.
- The tolerant limits found are within the action limits, which indicates that the process is within control, this means that the process only needs to continue to be monitored over time Fig.(1).
- The results of the "historical" parameter γ33L were compared with the γ32G proposed in the AAPM TG 218, and the gamma passing rate are definitively better with this latter, denoting the importance of knowing how the behaviour is changing from one focus to the other.

Figure 1: Measured γ33L, center line, lower control limits and action limits of γ33L.

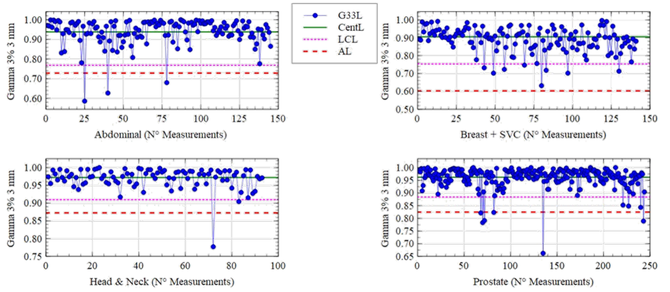

Figure 2: Average γ32G, center line, lower control limits and action limits of γ32G.

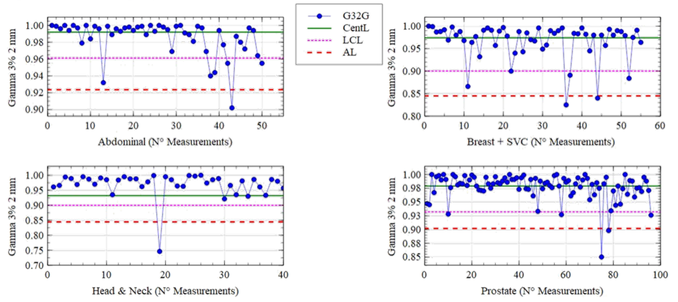

Table 1: Results for dose difference QA

Test	Area	Average (%)	Standard deviation (%)	LCL (%)	UCL (%)	AL (%)
Dose difference test	Abdominal	0.94	0.03	-2.95	5.02	5.56
	Breast + SVC	1.06	0.89	-22.04	26.09	28.52
	Head & Neck	0.76	0.01	-1.83	4.00	4.27
	Prostate	0.93	0.03	-2.27	4.73	5.53

References

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