

A Method for the Daily Quality Assurance of a Six-Degree-Of-Freedom Treatment Table

O Dona¹, Y Wang¹, A Xu¹, C Wu¹
¹ Columbia University Irving Medical Center, New York

INTRODUCTION

Phantom localization and repositioning with couch shift is one of the daily quality control tests recommended for CT-based IGRT systems by AAPM TG-179 and AAPM TG-142 [1,2]. The Penta-Guide phantom is commonly used to tests 3 translational degrees-of-freedom as it contains a secondary point of alignment. However, end-to-end testing of rotational degrees-of-freedom with this phantom adds complexity and time to the daily workflow at the clinic.

AIM

To establish a simplified workflow for the daily QA of a 6-degrees-of-freedom (6DOF) treatment table by applying a known transformation matrix on a straight-aligned CT image of the Daily QA phantom.

METHOD

A Quasar Penta-Guide phantom was CT scanned with 0° rotations (yaw, pitch, roll) using the CT scanner laser alignment. Before loading the images into the treatment planning system, a transformation matrix with 1.5° of roll, pitch and yaw was digitally applied to the image matrix. All image preprocessing steps were done in the 3D Slicer platform. The transformed image was used to create a daily QA plan containing 3 set-up fields: CBCT and orthogonal KVs. The Penta-Guide phantom was then acquired using CBCT with a known translation shift, and registered to the transformed planning image to obtain the measured translation, roll, pitch and yaw estimates. The pre- and post-alignment orthogonal KV images were used to verify that the planned iso-center was within 2mm of the machine iso-center after the alignment.

RESULTS

A digitally rotated image was created in 3DSlicer from a Penta-Guide phantom scanned with 0o rotations (yaw, pitch, roll) as shown in Figure 1.a,b. The transformation matrix to rotate 1.5o in each direction is shown in Equation 1. The digitally rotated image is imported into the TPS to create a daily QA plan with set up fields (Figure 1c). Alignment errors shown in Table 1 were below 2mm and 0.2o. Our proposed method is capable of accurately assessing the functioning of the 6DOF treatment table on a daily basis without the need for additional phantoms or therapist time.

Alignment was performed on the Varian TrueBeam OBI software using automated registration between the planning CT and CBCT to minimize user dependent registration errors. The preset values for translation and rotation were: vertical 1.2 cm, lateral 1.0 cm, longitudinal -1.4 cm, roll 1.5°, pitch 1.5° and yaw 1.5°. After the alignment, the overall uncertainty of the measured translational and rotational values were below 1mm and 0.1o and the iso-center was within 1mm of the original positioning.

Yaw, pitch and roll are the counterclockwise rotations of a, b and g about the z, y and x axis respectively. The rotation matrix for 1.5° yaw, 1.5° pitch and 1.5° roll is given by:

$$R_{(\alpha,\beta,\gamma)} = \begin{bmatrix} \cos\alpha\cos\beta & \cos\alpha\sin\beta\sin\gamma - \sin\alpha\cos\gamma & \cos\alpha\sin\beta\cos\gamma + \sin\alpha\sin\gamma \\ \sin\alpha\cos\beta & \sin\alpha\sin\beta\sin\gamma + \cos\alpha\cos\gamma & \sin\alpha\sin\beta\cos\gamma - \cos\alpha\sin\gamma \\ -\sin\beta & \cos\beta\sin\gamma & \cos\beta\cos\gamma \end{bmatrix}$$
$$= \begin{bmatrix} 0.50 & -0.15 & 0.85 \\ 0.53 & 0.83 & -0.16 \\ -0.69 & 0.53 & 0.49 \end{bmatrix}$$

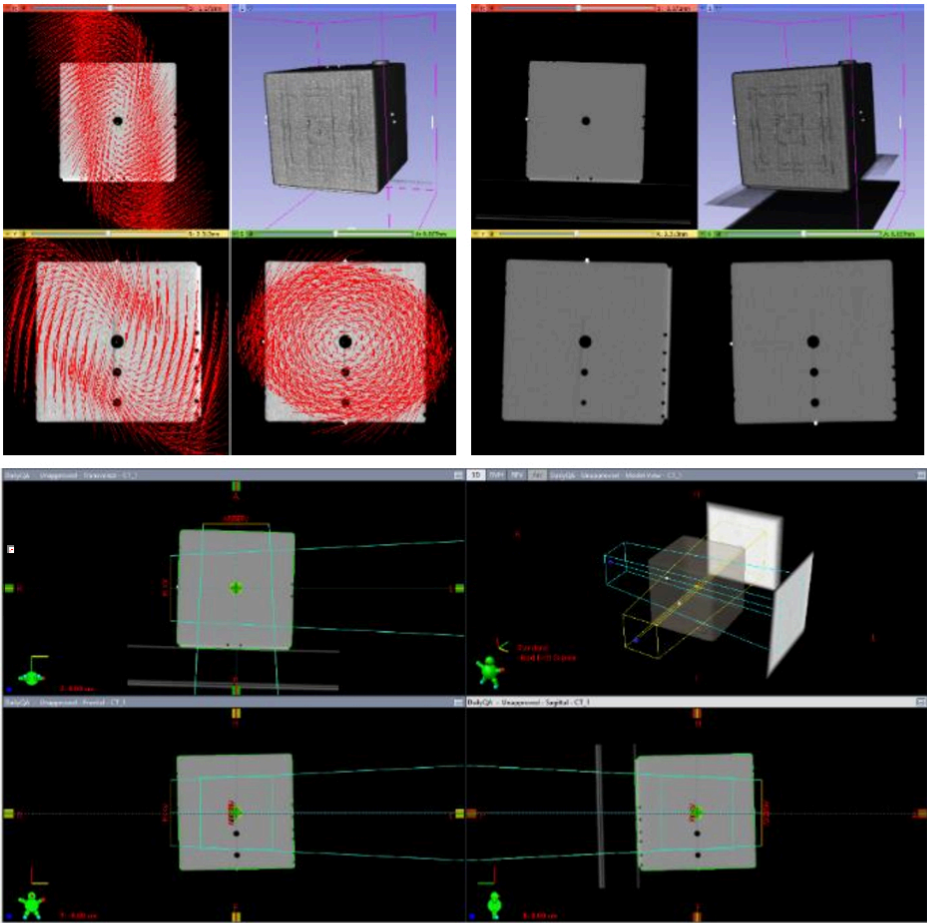


Figure 1. a) Penta-Guide phantom CT scanned in a straight orientation showing the transformation matrix in red. b) Rotated and resampled image [3D slicer]. c) TPS showing set-up fields and DRR on the digitally rotated phantom.

Table1. Registration values for alignment with the 6DOF treatment table and OBI.

6DOF	Expected (cm/degrees)	Measured (cm/degrees)	Error (%)	Error (mm/degrees)
Vertical	-1.2	-1.17±0.03	-2.92	0.4
Lateral	-1.0	-1.02±0.00	2.00	-0.2
Longitudinal	+1.4	1.47±0.22	4.64	0.7
Pitch	-1.5°	-1.45±0.05	-3.33	0.1
Roll	-1.5°	-1.53±0.08	1.67	-0.0
Yaw	+1.5°	1.55±0.09	3.33	0.1

CONCLUSIONS

Our proposed simplified workflow is capable of accurately assessing the rotational estimates of the 6DOF treatment table on a daily basis without the need for additional devices. Implementing this method will not increase the time to perform daily QA, as the registration of the transformed phantom will provide the verification of the 6DOF in a single acquisition.

REFERENCES

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CONTACT INFORMATION

Olga M. Dona Lemus, PhD
Department of Radiation Oncology
Columbia University Medical Center
CHONY North Bsmt Room 11
622 West 168th Street
New York, NY 10032
Tel: 646-317-0179
Email: od2233@cumc.columbia.edu