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Comparison of three different phantoms used for Winston-Lutz test with Artiscan software

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ABSTRACT

Background: One of the most important test in every quality assurances process of medical linear accelerators is the Winston-Lutz test, allowing an evaluation of the treatment isocentre in the light of uncertainty of the position of the collimator, the gantry and the couch.
Aim: The purpose of this work was analysis of the results of the Winston-Lutz test performed with three different phantoms for two different accelerators.
Materials and methods: Measurements were performed on two Varian machines: TrueBeam equipped with aS1200 EPID and TrueBeam equipped with aS1000 EPID. During the study three different phantoms dedicated for verification of the radiation isocentre were used: PTW Isoball, AQUILAB Isocentre Phantom and Varian Isocentre Cube. Analysis of the DICOM images was performed in Artiscan software.
Results: For TrueBeam with as1200 EPID, gantry MV isocentre was about 0.18 mm larger for Varian Isocentre Cube than for two other phantoms used in this study. The largest variability of this parameter was observed for the couch. The results differed to 1.16 mm. For TrueBeam with as1000 EPID, results for collimator isocentre with PTW Isoball phantom were about 0.10 mm larger than for two other phantoms. For the gantry, results obtained with Varian Isocentre Cube were 0.21 mm larger.
Conclusion: The obtained results for all three phantoms are within the accepted tolerance range. The largest differences were observed for treatment couch, which may be related to the phantom mobility during couch movement.

1. Introduction

In the last decade image-guided radiotherapy (IGRT) has become a widely used method of treatment, accepted by most of oncology centers and hospitals worldwide. This technique has many advantages and it is constantly improved.[1] IGRT allows a very precise patient positioning during the treatment, increasing the precision of the delivered dose and reducing dose of ionizing radiation in critical organs and healthy tissue. Obtained planar and volumetric images are used to analyze current patient position and immediate correction, directly on the treatment couch. An increase of dose delivery accuracy is achieved by verifying the position of the irradiation volume, which allows to reduce the PTV margin. Improved effects are also achieved by adapting treatment to changes identified during the process.[2]

Appropriate quality control of the linear accelerator and its imaging systems will ensure that treatment process is optimal and safe for the patient and allows to reduce the number of errors.[3,4] Preparation of proper procedures, QA protocols and tests is essential to detect any irregularities and errors in medical equipment which effect the quality of the treatment process.[5] One of the most important tests in the IGRT quality assurance process is the Winston-Lutz test, allowing to check the radiation isocentre.[6,7] Radiation isocentre is defined as a sphere in the space, where radiation beams intersect with each other, while gantry is rotating.[8] Gravitation can have a relevant influence on the mechanical parts of a medical linear accelerator, which can affect the beam direction. Radiation beams from many directions intersect in the very small volume (in most cases less than 2,00 mm of diameter), defined as a radiation isocentre.[9]

In the past, the Winston-Lutz test was performed with the use of a radiographic film. The radiographic film was irradiated from many directions, for various gantry positions. Radiation beams were running through the film and were visible as irradiated strips, in the

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Table 1
The sequence of images required to determinate radiation isocentre.

	Collimator position [°]	Gantry position [°]	Couch position [°]
Image 1	0	0	0
Image 2	90	0	0
Image 3	0	0	0
Image 4	270	0	0
Image 5	0	0	0
Image 6	0	90	0
Image 7	0	180	0
Image 8	0	270	0
Image 9	0	0	90
Image 10	0	0	0
Image 11	0	0	270

point where beams intersect. The circle which could fit inside all intersected beams is called the radiation isocentre.[10,11] However, this method of isocentre verification is no longer in use. The procedure is very time-consuming and difficult to complete, because it is not easy to position the film on the treatment couch in a proper way and with high precision.

Nowadays, radiation isocentre tests progressed to phantom EPID-based measurements, which are much easier and faster to perform.[12,13] The purpose of this work was to perform the Winston-Lutz test on the two linear accelerators, using three different phantoms and compare the obtained results with estimation of their variability. Additionally, it enabled the development of quality assurance protocols that were implemented in clinical practice.

2. Material and method

All measurements were performed on two Varian linear accelerators, installed at our hospital: TrueBeam equipped with High Definition 120 Leaf MLC (40 pairs of leaves 2,5 mm thick and 20 pairs of leaves 5 mm thick) with aS1200 EPID (1024 × 1024 pixels) and TrueBeam equipped with Millennium 120 Leaf MLC (40 pairs of leaves 5 mm thick and 20 pairs of leaves 10 mm thick) with aS1000 EPID (1024 × 768 pixels).[14] Both linear accelerators are able to perform advanced methods of treatment, like IMRT (Intensity-Modulated Radiotherapy), VMAT (Volumetric Intensity Modulated Arc Therapy), that can be supported by advanced image guided procedures. TrueBeam equipped with a HD collimator is also able to perform stereotactic radiotherapy.

During this study we used three different phantoms dedicated for verification of the radiation isocentre: PTW Isoball, AQUILAB Isocentre Phantom and Varian Isocentre Cube (Fig. 1).

All phantoms are used to perform Winston-Lutz. Before the image acquisition, the phantom should be placed on the treatment couch, following the manufacturer's instructions. Precisely positioned phantom should not move, due to the influence on the final test result. Accuracy of each phantom is to 0.01 mm. To collect DICOM images, electronic imaging portal devices (EPID) were used.

Winston-Lutz test allows to determinate the diameter of the sphere containing the radiation isocentre. In Artiscan software, determining the size of the sphere required that 11 images be obtained, for various position of the collimator, gantry and couch.[15] The positions of the collimator, gantry and couch are presented in Table 1.

Analysis of the obtained DICOM images was performed with the Artiscan software. The software uses mathematical algorithms and tools to compute each parameter, which allows to reduce the number of errors by eliminating subjective estimation of the images. Software allows to implement tolerance levels. Tolerance levels allow to contact the service before the parameter reaches the unacceptable value. First tolerance level is activated when the parameter exceeds 80% of tolerance value, the second level is activated after exceeding a given tolerance.

During three months, six series of measurements were performed, for both linear accelerators. The measurement series required performing a Winston-Lutz test for each phantom. During each session the diameter of the sphere containing radiation isocentre was computed, based on 11 collected DICOM images.

The size of the sphere containing collimator radiation isocentre is defined as twice the largest distance between the collimator rotation center and the centers of irradiation fields. Gantry and couch isocentres are computed with the same method as the collimator isocentre. The equations used by the software are presented below.[15]

$$d = \sqrt{{X_C}^2 + {Y_C}^2} \quad (1)$$

With:

X_C — position of the collimator rotation center in relation to the isocentric reference in the X direction,

Y_C — position of the collimator rotation center in relation to the isocentric reference in the Y direction,

d — distance of the collimator rotation center in relation to the isocentre reference [mm].

$$d = \sqrt{{X_G}^2 + {Z_G}^2} \quad (2)$$

With:

X_G — position of the gantry rotation center in relation to the isocentric reference in the X direction,

Z_G — position of the gantry rotation center in relation to the isocentric reference in the Z direction,

d — distance of the gantry rotation center in the relation to the isocentre reference [mm].

$$d = \sqrt{{X_C}^2 + {Y_C}^2} \quad (3)$$

With:

X_C — position of the couch rotation center in relation to the isocentric reference in the X direction,

Y_C — position of the couch rotation center in relation to the isocentric reference in the Y direction,

d — distance of the couch rotation center in relation to the isocentre reference [mm].

3. Results and discussion

Based on the obtained DICOM images, diameter of the spheres containing radiation isocentre of the collimator, gantry and couch have been computed for both linear accelerators. Tables 2 and 3 present the parameter values collected over three months. The charts below present the variation of this parameter for each measurement series (Figs. 2 and 3).

Analyzing the diameter of the radiation isocentre of the collimator for TrueBeam accelerator, equipped with aS1200 EPID, it can be stated that the results obtained are very similar, regardless of the type of the phantom used. For the gantry, the results with PTW's and Aquilab's phantoms are similar to each other. We observed that the diameter of the radiation isocentre of the gantry was about 0.18 mm larger for Varian Isocentre Cube than for the two other phantoms used in this study. The largest variability of this parameter was observed for the treatment couch. The results differed to 1.16 mm, but they were still in the acceptable range which is 2.00 mm. For the second TrueBeam, equipped with aS1000 EPID, we observed that differences of the size of radiation isocentre sphere were slightly larger for the collimator and gantry. Results for the collimator isocentre sphere computed with PTW Isoball phantom were about 0.10 mm larger than for the two other phantoms. For the gantry, results obtained with Varian Isocentre Cube

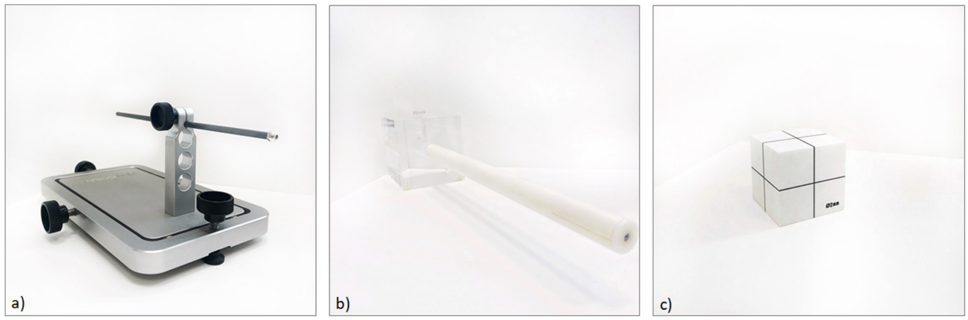

Fig. 1. Phantoms used for radiation isocentre verification: a) PTW Isoball, b) Aquilab Isocentre Phanton, c) Varian Isocentre Cube.

Table 2
Diameter of the computed radiation isocentre for each phantom for TrueBeam with aS1200 EPID.

Series number	Component	PTW Isoball	Aquilab Isocentre Phanton	Varian Isocentre Cube
1	Collimator	0.70	0.73	0.72
	Gantry	0.41	0.33	0.65
	Couch	0.72	0.70	1.92
2	Collimator	0.77	0.72	0.75
	Gantry	0.18	0.24	0.70
	Couch	1.10	0.41	1.47
3	Collimator	0.80	0.72	0.68
	Gantry	0.30	0.29	0.78
	Couch	1.60	1.25	1.14
4	Collimator	0.72	0.69	0.68
	Gantry	0.28	0.31	0.80
	Couch	0.70	0.82	0.69
5	Collimator	0.89	0.74	0.73
	Gantry	0.33	0.29	0.79
	Couch	0.38	0.67	1.14
6	Collimator	0.72	0.70	0.73
	Gantry	0.31	0.39	0.88
	Couch	0.39	1.32	0.81

Table 3
Diameter of the computed radiation isocentre for each phantom for TrueBeam with aS1000 EPID.

Series number	Component	PTW Isoball	Aquilab Isocentre Phanton	Varian Isocentre Cube
1	Collimator	0.90	0.98	1.03
	Gantry	0.12	0.11	0.30
	Couch	1.77	1.82	1.75
2	Collimator	0.91	1.01	1.00
	Gantry	0.12	0.17	0.32
	Couch	1.55	1.66	1.58
3	Collimator	0.93	0.99	0.97
	Gantry	0.15	0.18	0.44
	Couch	1.51	1.49	1.60
4	Collimator	0.91	0.99	1.01
	Gantry	0.13	0.16	0.36
	Couch	1.52	1.32	1.71
5	Collimator	0.92	0.95	1.03
	Gantry	0.16	0.13	0.31
	Couch	1.61	1.55	1.57
6	Collimator	0.91	1.00	0.99
	Gantry	0.10	0.18	0.29
	Couch	1.19	0.69	0.66

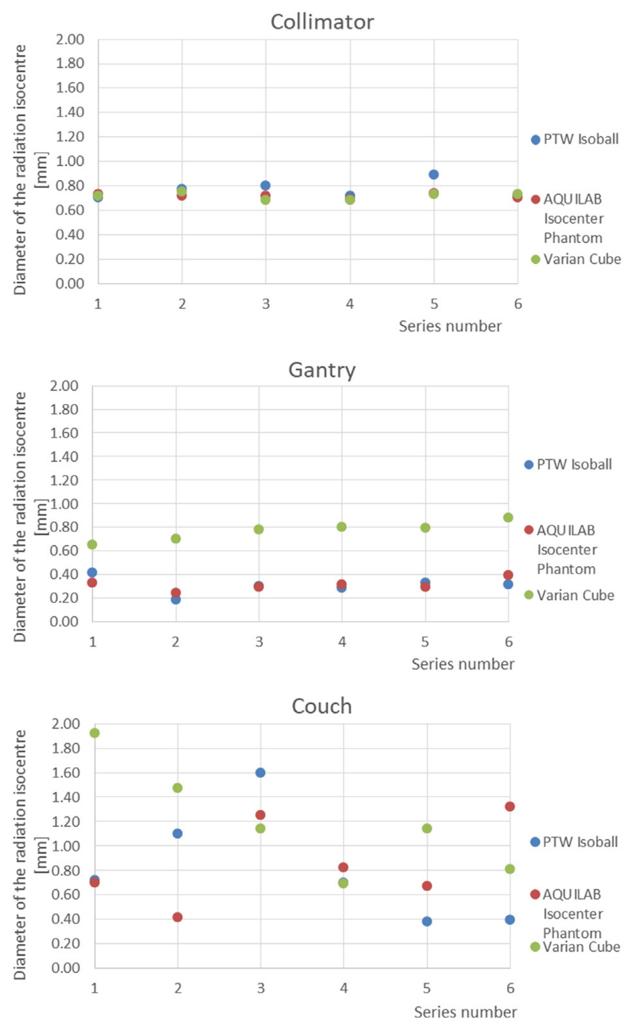

Fig. 2. Diameter of the radiation isocentre for TrueBeam with aS1200 EPID, for: a) collimator, b) gantry, c) couch.

were 0.21 mm larger, during the evaluation of the gantry radiation isocentre. For the couch isocentre, the results are more similar, the biggest difference during all measurements session was 0.39 mm.

We noticed that the results obtained are repeatable for both linear accelerators. For TrueBeam equipped with aS1200 EPID the largest differences between each measurement were observed for the couch radiation isocentre. For the second TruBeam with aS1000 EPID, the differences were smaller.

It is difficult to find literature data for similar studies, so we decided to use data from reports. We used recommendations mostly from Reports of the AAPM Task Group 40 and 142. While performing the Winston-Lutz test, it is very important to precisely position the phantom. Small inaccuracy can result in an error in calculating the size of the radiation isocentre. Regardless of the type of the phantom, linear accelerator or electronic portal imaging device, all obtained results were in the acceptable tolerance value of 2.00 mm, or smaller.

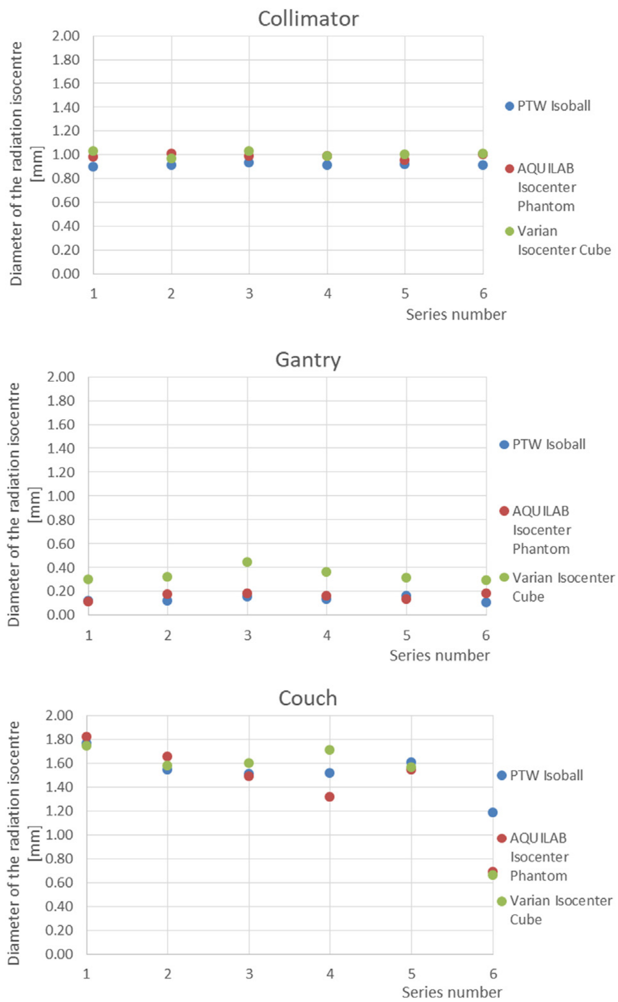

Fig. 3. Diameter of the radiation isocentre for TrueBeam with aS1000 EPID, for: a) collimator, b) gantry, c) couch.

4. Conclusions

Controlling the size of the sphere containing radiation MV isocentre became a very important process of every quality assurance program in radiotherapy. It guarantees that the whole treatment process will be accomplished in a correct and optimal way, with the minimization of systematical errors. Results obtained for all the three phantoms were within the accepted tolerance range. The largest differences were observed for the treatment couch, which may be related to the phantom mobility during couch movement. The results obtained from automatic image computing coincide with the values referred to in the AAPM TG-40 and TG-142 reports and acceptance tests of the Varian TrueBeam linear accelerator.

Conflict of interest

None declared.

Financial disclosure

None declared.

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