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Quality control of radiotherapy simulators

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Summary

Introduction: A radiotherapy simulator makes it possible to verify a radiotherapy treatment plan before starting treatment. The aim of this work was to evaluate the parameters of radiotherapy simulators affecting the precision of simulation.
Material and methods: A test protocol has been prepared based on appropriate IEC norms and the methodology used by service engineers, as well as on previous work undertaken at the Medical Physics Department. Two radiotherapy simulators (Varian Ximatron and Oldelft Simulix) have been regularly tested for a period of over one year.
Results: Tests have shown that on both simulators, precision of laser centrators (light beams indicating the isocenter), field size and telemeter (light scale indicating the source-to-skin distance) varies over time, which in some situations could lead to significant inaccuracies in simulations. Inaccuracies observed during the tests were, in most cases, not noticed by the operators. Usually, appropriate adjustments can only be made by service engineers. Other parameters affecting the geometrical precision of simulations have proved to be stable. Evaluation of image quality and X-ray beam parameters did not reveal any significant changes over a one-year period.
Conclusions: Mechanical parameters of radiotherapy simulators need to be tested regularly, with precision of laser centrators, field size settings and telemeter readings requiring special attention.
Key words: quality control, radiotherapy simulators.

Kontrola jakości symulatorów stosowanych w radioterapii

Streszczenie

Wstęp: Symulator radioterapeutyczny umożliwia zweryfikowanie planu radioterapii przed jej rozpoczęciem. Celem pracy było przeprowadzenie oceny parametrów symulatora mających wpływ na dokładność symulacji.
Materiał i metody: Dwa symulatory radioterapeutyczne (Varian Ximatron i Oldelft Simulix) były regularnie kontrolowane przez okres ponad jednego roku zgodnie z protokołem opracowanym na podstawie stosownych norm IEC, metod używanych przez inżynierów serwisu obu aparatów oraz wcześniejszych prac wykonanych w Zakładzie Fizyki Medycznej Centrum Onkologii w Warszawie.
Wyniki: Wykazano, że na obu aparatach dokładności wskazań centratorów laserowych (świateł wskazujących położenie izocentrum), rozmiaru pola (wyznaczonego przez położenie drutów) oraz telemetru (świetlnej skali do odczytu odległości SSD, czyli od źródła promieniowania do powierzchni ciała pacjenta) podlegają zmianom w czasie, co może powodować niedokładności w procesie symulacji. W większości przypadków wykroczenia poza przyjęte granice tolerancji nie były zauważone przez techników obsługujących aparat. Usunięcie stwierdzonych niedokładności w większości przypadków wymagało interwencji pracowników serwisu danego aparatu. Wartości pozostałych parametrów mających wpływ na geometryczną poprawność symulacji nie wykazywały zmienności czasowej i mieściły się w przyjętych granicach tolerancji. Jakość obrazu i parametry wiązki rentgenowskiej nie uległy zmianie w analizowanym okresie jednego roku.
Wnioski: Symulator radioterapeutyczny musi być regularnie kontrolowany, szczególnej uwagi wymagają centratory, druty wyznaczające pole symulacji i telemetr.
Słowa kluczowe: kontrola jakości, symulator radioterapeutyczny.

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Introduction

A radiotherapy simulator is an X-ray machine whose design makes it possible to obtain X-ray images under geometrical conditions simulating a radiotherapy irradiation unit. Consequently, it makes it possible to verify of the size and position of the planned treatment radiation beams, relative to the surrounding anatomical structures. It also allows correction of beam sizes and directions, and the overall control of the treatment plan.

A radiotherapy simulator is a complex and bulky machine with heavy movable parts, similar to radiotherapy machines. Mechanical accuracy requirements for such machines are very high. Improper and inaccurate functioning of the simulator's elements may cause serious errors in the radiotherapy treatment process. Therefore, regular testing of simulator performance is an important step in the overall system of quality assurance in radiotherapy.

The aim of this study was to evaluate various parameters of simulators, which affect the accuracy of the process of radiotherapy simulations.

Material and methods

A test protocol, based on an appropriate IEC norms [1,2] and on previous studies undertaken at the Medical Physics Department [3], has been prepared. Additionally, the methodology used by service engineers has been taken into account.

Two radiotherapy simulators (Oldelft Simulix and Varian Ximatron) installed at the Radiotherapy Department of the Centre of Oncology in Warsaw have been regularly tested by a medical physicist for a period of over one year.

Various types of measuring equipment have been used including an RMI isocentre test tool, RMI and PTW phantoms for ima-ge quality assessment, a Keithley TRIAD kit for X-ray beam measurements, and others.

All the parameters tested are listed in *Table 1*.

Table 1. Range of tests performed.

test or parameter	equipment	test frequency (initial)
	X-ray beam	
tube voltage dose (dependance on mAs) half-value layer focal spot size	dosimeter with an ionization chamber set of attenuation filters non-invasive kVp detector (kVp divider) star test pattern or slit camera films in light-proof envelopes	bi-annually
	image quality	
visibility of structures geometrical distortions resolution contrast	phantom for checking the visibility of structures that simulate veins with contrast agent, calcifications, tumours, masses etc. phantom with parallel grid lines, resolution pattern, step-wedge	monthly
	geometry of simulation	
collimator rotation gantry rotation isocentre (size, position) laser centrators SSD (source-to-skin distance) scale FAD (focus-to-axis distance) scale table movement image intensifier movement simulation field size radiation field vs. light field	level (preferably digital) graph paper films in light-proof envelopes isocenter test tool	weekly

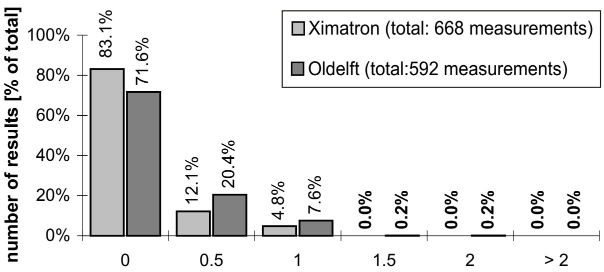

Figure 1a. Deviation of laser from isocentre [mm]. Note: lasers on Oldelft have been installed by a third-party company.

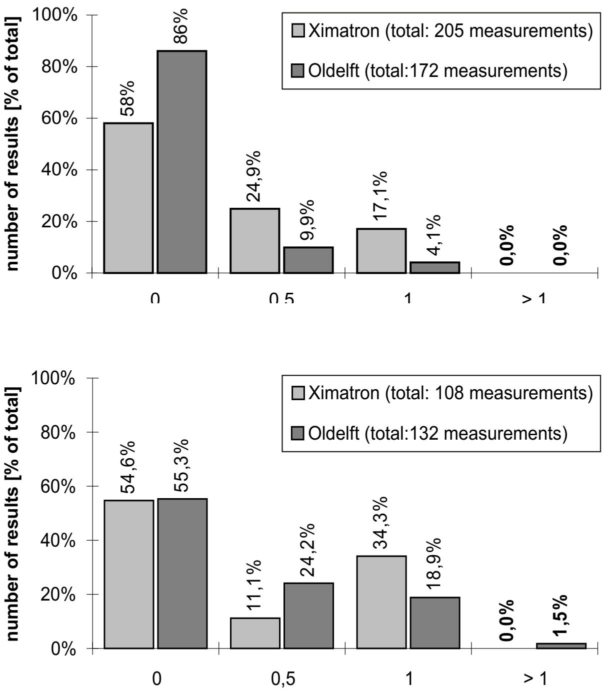

Figure 1b. Simulation field - difference between the set and measured position of the wires, set field size 6 cm x 6 cm (left) and 20 cm x 20 cm (right) [mm].

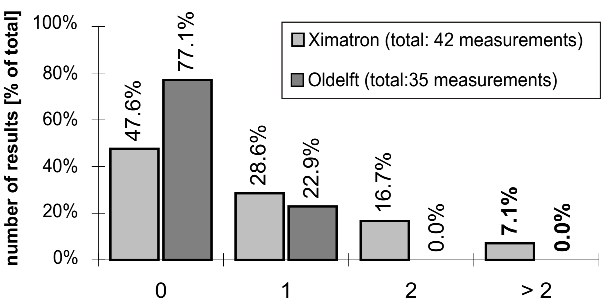

Figure 1c. Difference between the FAD and SSD readings [mm].

Figure 1. Histograms of some selected test results for both simulators.

Results

The tests performed on both simulators have shown that the precision of laser indicators (the light beams indicating the position of the isocentre), the field sizes (delineated by wires in the collimator), and the telemeter (light scale indicating the SSD – Source-to-Skin Distance) varies over time, which in some situations could lead to significant inaccuracies in simulations. Lasers are more precise on the Ximatron simulator *(Figure 1a),* while the SSD scale is better on the Oldelft simulator *(Figure 1c).* Precision of the simulation field depends on its size *(Figure 1b).* In some cases, large inaccuracies can be predicted as trends may be observed over long periods (*Figure 2a*) but sometimes they occur suddenly *(Figure 2b).* The analysis of results over a long period of time can help reveal situations, in which adjustments are needed *(Figure 3).*

Inaccuracies observed during the tests were in most cases, not noticed by simulator operators. Usually, appro-

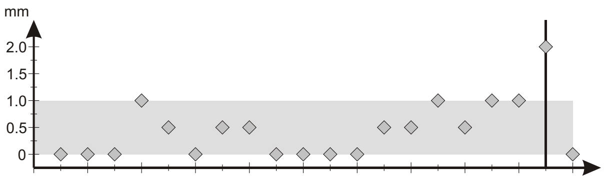

Figure 2a. Laser centrator: deviation between the laser beam position and the isocentre (Oldelft).

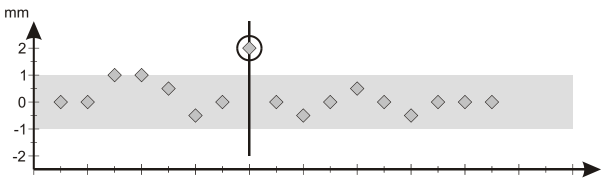

Figure 2b. Simulation field size: deviation between the set and measured positions for one of the wires delineating the simulation field set to 10 x 10 cm size (Oldelft).

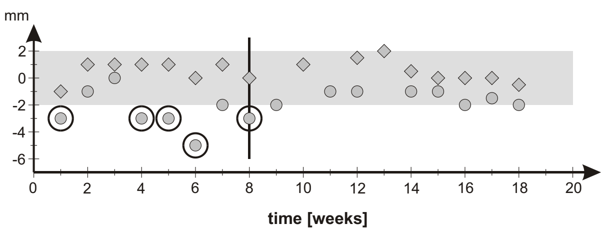

Figure 2c. SSD: deviation between source-to-skin distance indicated by the mecha-nical device (front pointer) and by the light scale (for 100 cm - circles, 80 cm - diamonds) (Ximatron).

Figure 2. Time dependence of some selected parameters (measured wee-kly). Shaded areas indicate tolerance limits; points falling outside the limits are marked with ellipses, corrective actions are marked with vertical lines.

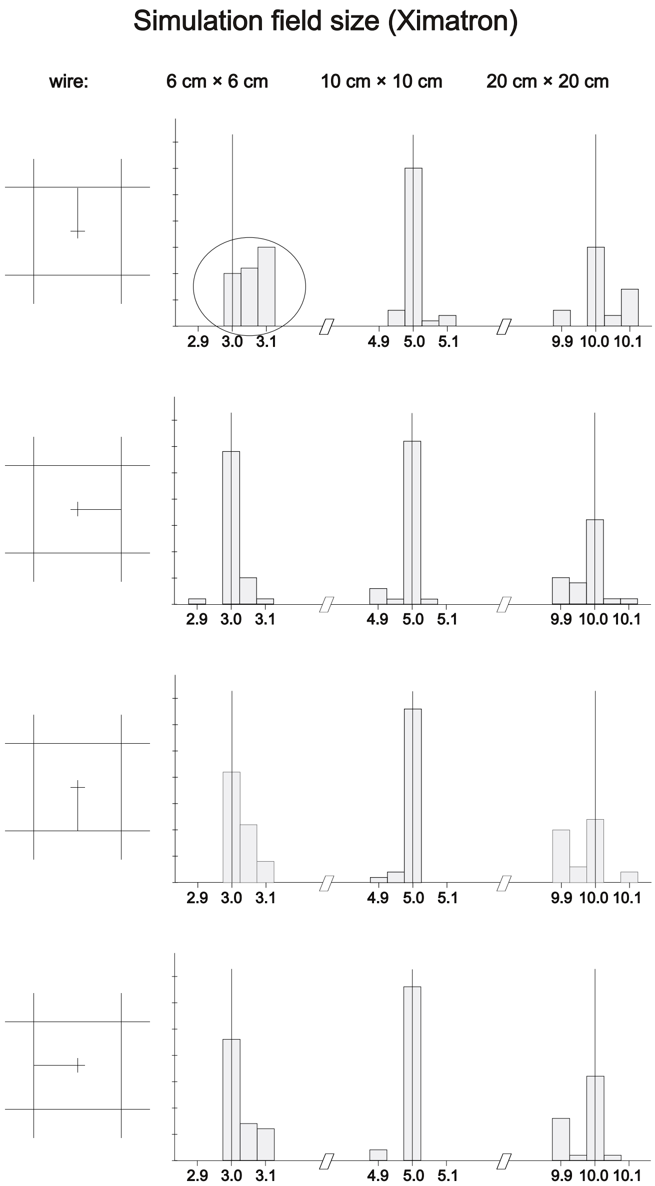

Figure 3. Simulation field size - histograms of measured values (set values indicated with vertical lines). The results are all within tolerance limits (±1 mm for each wire). However, some trends may be observed - for example for small field sizes (6 cm square field) one of the wires seems to be systematically misplaced (marked by an ellipse), which suggests the need or adjustment.

priate adjustments could only be made by service engineers. Only the position of laser indicators on one of the simulators could be corrected by the local staff.

Other tests, such as control of the gantry and collimator rotation angles, comparison of radiation and light fields, isocentre size, etc. have proven to be stable parameters on both simulators (*Table 2*). Nevertheless, the above mentioned tests should be carried out because they are not very time consuming, and the consequences of a possible inaccuracy could be very severe.

As expected, the evaluation of image quality and X-ray beam parameters of both simulators revealed no significant changes during a one year period. The measurements will be continued, but less frequently than during the initial period of testing. The results will be analyzed over longer periods of time. They would also serve as a reference point in real situations.

Conclusions

The mechanical parameters of a radiotherapy simulator need to be tested regularly; precision of laser centrators, field size settings and telemeter readings need special attention.

The analysis of results over a long period of time is a useful method for evaluation of both the simulator stability and the test protocol.

References

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2. International Electrotechnical Commission. IEC/TR2 61170: Radiotherapy simulators – Guidelines for functional performance characteristics. IEC; 1993.
3. Zygmuntowicz-Piętka A. Badanie parametrów symulatora radioterapeutycznego. MSc thesis prepared in Maria Skłodowska-Curie Memorial Cancer Centre and Institute of Oncology. Warszawa; 1995.

Table 2. Tolerance levels and typical test results for some selected geometrical parameters, which have proved to be stable over time.

parameter	tolerance level	typical result
collimator rotation angle	0.5°	0.3°
gantry rotation angle	0.5°	0.3°
isocentre size	1 mm	0.5 mm
radiation field vs. light field	1 mm for each wire	0.5 mm
table movement	1 mm	1.0 mm
image intensifier movement	1 mm	1.0 mm