Assessment of X-ray field congruence and beam perpendicularity testing for diagnostic equipment by medical physicists and radiographers in various hospitals in Albania

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Abstract. This study aimed at investigating the challenges facing the implementation of some quality control (QC) tests by medical physicists and radiographers for different diagnostic devices used in Albania. Light field-X-ray field congruence and beam perpendicularity tests results performed for 23 radiography and 10 fluoroscopic systems during a routine QC procedure are included in this study. Different measurement procedures are introduced using a collimator test tool, beam alignment - cylinder test tool, Leeds Test Objects′ FLUORO-4 phantom and coins. Analysis of the results showed that only 83 % of the radiography devices evaluated in this study were within acceptable criteria for the light and X-ray field misalignment test while 91 % for the perpendicularity test. All fluoroscopic systems were within acceptable criteria for both tests. Most of the radiology devices included in this study were not under a regular QC program by radiographers due to inadequate training and unavailable test tools. We addressed these specific needs to the hospital managers, recommending to them appropriate training and involvement of radiographers in implementing the QC program in their department as well as the use of the coin method for X-ray beam alignment testing as a very simple method with no cost.

1 Introduction

Maintaining consistent quality image after continuous use of radiology equipment is a major challenge for health care institutions so, application of a QC program is essential for each country to ensure that these devices operate optimally over time [1]. Before 2015 the proper function of X-ray medical modalities used in radiology departments in our country were checked only by service engineers during routine maintenance or any malfunction. Comparing to the last ten years, with the implementation of QC program in Albania other professionals such as medical physicist/physicist, became involved in checking X-ray equipment performance and now it is one of the main criteria that Radiation Protection Office in Albania requires when the healthcare institutions are processing for the license to operate. In this way not only is the maintenance of the X-ray equipment function reliable but also the

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assessment and optimization of the balance between patient dose and image quality. According to the International Atomic Energy Agency (IAEA) it is strongly recommended that QC process should be implemented by an experienced staff including not only a medical physicist but also a radiologist or a radiographer in their own department specifying the proper test and periodicity of any test performed by each of them [2]. Implementation of QC of diagnostic medical devices in Albania has started only during the last ten years and Institute of Applied Nuclear Physics (IANP) whose activities involve huge investments and efforts to improve radiation protection in our country owns the license of performing QC tests for radiology equipment according to Decision No.404 – "On basic rules of radiology installations in medicine" of the Albanian Ministry of Health. This decision specifies all the eligibility criteria of technical requirements needed for radiology equipment based on the IPEM 91 report emphasizing that all the radiology equipment used in Albania are obliged to pass in the periodical process of technical control not less than once in three years [3-5]. QC parameters tests assessed in this study are the light field-X-ray collimation and X ray beam perpendicularity. Collimators used in diagnostic radiology modalities are equipped with a white light source and a mirror to project a field of light over the patient which aims to precisely show where the primary X-ray radiation will be projected during exposure so that medical staff can determine the clinically relevant area that should be exposed to each patient [6, 7].
The purpose of this work was to evaluate the status of QC test performance for radiography and fluoroscopic systems in various healthcare institutions in different cities of Albania and to investigate how these tests are implemented by radiographers and medical physicists. A regular QC testing performed by medical physicists and radiographer operators is a critical aspect to provide optimal quality image with minimum necessary radiation dose to the patients.

2 Materials and Methods

Evaluation of the light field-X-ray congruence and beam perpendicularity tests for 23 radiography equipment and 10 fluoroscopic systems are presented in this study. Measurements are carried out by QC laboratory of X-ray medical devices part of IANP during the QC requests received from different healthcare institutions. Description of measurement procedures applied by medical physicist as well as the acceptability criteria specified in Decision Nr. 404 is presented in the following subsections. [2], [8-10].

2.1 Measurement procedure using collimator test tools and beam alignment-cylinder

The collimator test tool used for the light field and X-ray beam congruence test is constructed of brass and has a 14 cm x 18 cm pattern engraved on its surface which can give a direct ruled dimension on the radiographic image obtained after exposure. Before starting the measurement procedure, it is placed in the centre of the couch at a source to image distance (SID) of 100 cm. After adjusting the collimator light according to the rectangular line on the plate surface we perform the exposure using parameters of 50-75 kV and 1.2-20mAs depending on radiography or fluoroscopic modality. According to our national radiation protection regulation, the sum of the misalignment of the visually defined field with the respective edge of the X-ray field in each of the principal directions ΔX, ΔY should not exceed 3% of the SID and the sum of the deviations in both perpendicular directions should not exceed 4% of SID. We have a good alignment in the acquired radiographic image if the X-ray field falls exactly within the rectangular frame image. The maximum misalignment allowed in each direction is 2% of SID. The beam alignment test tool used for perpendicularity test is constructed of a clear plastic cylinder with two steel balls located at each end directly above one another. For perpendicularity test, the beam alignment cylinder should be used together with the collimator alignment test tool as it is presented in figure 1a. The Leeds Test Objects′ FLUORO-4 phantom which is designed to check the image quality performance of fluoroscopic systems can also be used as a collimator test tool. It is an appropriate test object for testing the light field-X-ray beam congruence and can be used together with the beam alignment test tool as is presented in figure 1b.

(a)

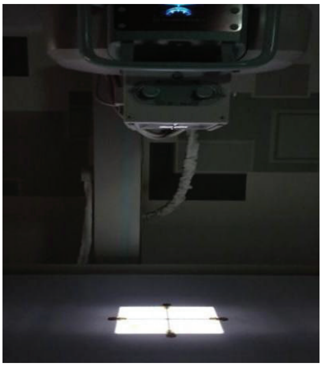
(b)

Fig. 1. collimator test tool and beam alignment tool (a); Leeds Test Objects′ FLUORO-4 phantom and beam alignment tool (b)

According to our national radiation protection regulation the angle between the central axis of the X-ray beam and the plane of the image receptor should be lower than 1.5^0.

2.2 Measurement procedure using coins

Coins method is introduced in this subsection as a method that was strongly recommended to the radiographers which operate the radiography devices included in this study. Coins method consists of placing 9 coins having a diameter of 2 cm in the image receptor on a flat surface. After setting the X-ray tube perpendicular to the image detector at SID of 100 cm we collimate the light beam to a known field (e.g. 15cm x 20 cm) on the image detector and place metal coins at every edge of the light field as is presented in figure 2a.



(a)

(b)

Fig. 2. Set up of coins before exposure (a); radiographic image obtained after exposure process (b)

After exposure as presented in figure 2b we measure the distance between the edges of the image and the coins ensuring that the deviation of the X-ray field from the light field does not exceed ±2 cm on any side. For conventional radiological systems a view box and a calibrated ruler is used to measure the distance while for computed and digital systems is used the ImageJ software.

3 Results

This study was carried out in some selected health facilities in the North and South regions of Albania. For reasons of identity protection radiology departments of different public and private healthcare institutions that were part of this study are marked with number 1-23 for radiography modalities in use and A-J for fluoroscopic systems.

3.1 QC tests results performed by medical physicist

The measurement results of light field and X-ray field congruence test for 23 radiography equipment are presented in table 1.

Table 1. measurement results of light field and X-ray field congruence for 23 radiography systems

Radiology Department	ΔX<3%	ΔY<3%	ΔX+ΔY<4%	Pass/Fail
1	0.6	1.0	1.6	Pass
2	0.4	0.6	1.0	Pass
3	0.4	1.2	1.6	Pass
4	0.7	0.3	1.0	Pass
5	0.9	0.9	1.8	Pass
6	1.3	0.3	1.6	Pass
7	0.7	0.4	1.1	Pass
8	1.0	0.5	1.5	Pass
9	0.7	0.3	1.0	Pass
10	0.5	0.0	0.5	Pass
11	3.0	3.1	6.1	Fail
12	0.1	0.3	0.4	Pass
13	0.7	0.6	1.3	Pass
14	1.3	0.5	1.8	Pass
15	0.3	3.2	3.5	Fail
16	1.2	0.5	1.7	Pass
17	0.8	1.6	2.4	Pass
18	2.9	1.7	4.6	Fail
19	0.1	1.4	1.5	Pass
20	6.0	3.2	9.2	Fail
21	0.2	0.5	0.7	Pass
22	1.5	0.8	2.3	Pass
23	1.5	0.3	1.8	Pass

Table 1 shows that four hospitals (Nr. 11, 15, 18, 20) failed to pass the light and X-ray field congruence test being greater than the acceptable criteria determined in Albanian radiation protection regulation.
According to radiographers, these devices were relatively old with a high workload especially during the coronavirus pandemic crisis. In figure 3 are presented the measurements results of perpendicularity test for 23 radiography devices.

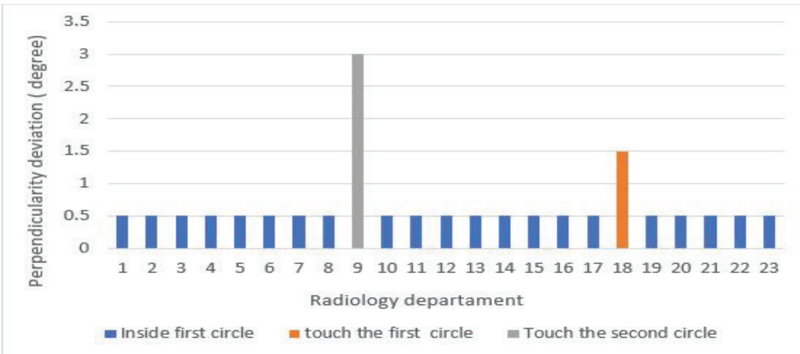
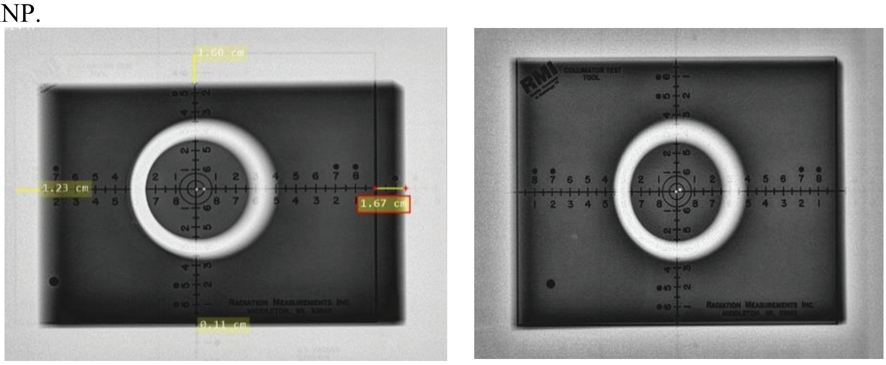


Fig. 3. measurement results of perpendicularity test for 23 radiography devices

The X-ray beam perpendicularity test results presented in figure 3 show a deviation of 3° for hospital Nr.9 that means this device exceeds the acceptance criteria determined in our national radiation protection regulation and 1.5^0 for hospital Nr.18 that means it is close to the upper specified limit. For hospitals that failed to pass the tests or with results very close to the set tolerances we recommended contacting the service engineers to regulate the collimator and repeat the QC tests measurements by IANP, ensuring that after repair the equipment keeps its original characteristics. In figure 4a is presented the radiographic image obtained during routine QC tests for hospital Nr.18 showing that there is a misalignment of light field and X-ray beam. It can be clearly seen that the top ball intercepts the first circle which means that the X-ray beam perpendicularity is about 1.5°. In figure 4b is presented the image obtained after repairing the device by service engineers and repeating QC tests by IANP.



(a) (b)

Fig. 4. Image obtained during routine QC test (a); Image obtained after equipment repairing (b)

Figure 4b shows a very good alignment in the obtained radiographic image after repairing as the X-ray field falls exactly within the rectangular frame and the top steel ball falls inside the first circle that means the central ray is perpendicular to within 0.5°. In figure 5 are presented the measurement results for collimation field and perpendicularity test for 10 fluoroscopic systems included in this study.

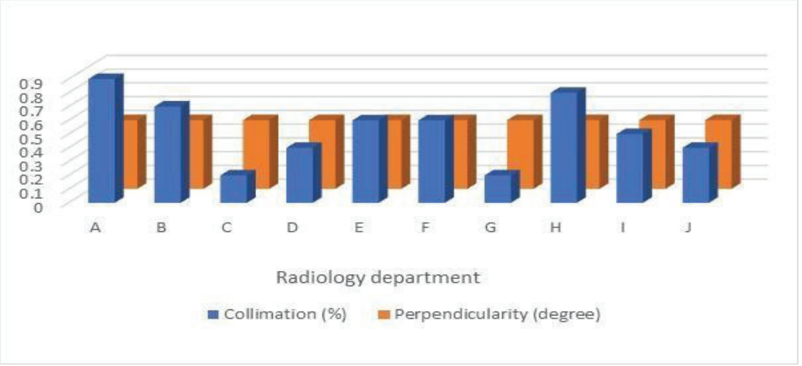


Fig. 5. collimation and perpendicularity tests results for fluoroscopic systems

As shown in figure 5 both collimation and perpendicularity tests results for all fluoroscopic systems included in this study are in a very good agreement with the acceptable criteria specified in Albanian radiation protection regulation.

3.2 QC tests performed by radiographers

During the performance of routine technical control tests of these diagnostic devices by IANP it was noticed that most radiographers did not perform any QC test on their equipment. The major challenges in conducting QC tests by radiographers in our country were the lack of test tools needed, proper knowledge and training in this field. Addressing all these factors that influence the implementation of QC test by radiographers to the hospital managers, we recommended establishing training in the field of QC of diagnostic devices for radiographers in collaboration with IANP. We explained and suggested to each radiographer the application of the coin's method for X-ray field congruence test as a very simple method with no cost. It was recommended to the hospitals management teams that all radiology devices in use should have periodical performance supervision by radiographers emphasizing also that regular QC practices are not only regulatory requirements.

4 Discussion

This study includes X-ray field congruence and beam perpendicularity tests assessment for 23 X-ray radiography devices and 10 fluoroscopic systems used in various radiology departments in Albania. Collimator test tools and beam alignment-cylinder were used for the measurement procedures. Among the studied radiography systems four of them failed to pass the light-X-ray field congruence test and two failed to pass the perpendicularity test. It was recommended to these hospitals to contact the service engineers to repair the equipment and after repairing the QC testing was repeated by IANP ensuring the proper functioning. All fluoroscopic systems were within acceptable criteria for both tests. Based on this survey, it was noticed that a significant number of X-ray systems used in radiology departments were not part of a regular QC program by radiographers due to the lack of test tools needed, proper knowledge and training. Consequently, this survey highlighted the need for our National Regulatory Authority and responsible healthcare institutions to establish a training program and support for radiographers in the field of QC for X-ray imaging modalities. This can be well established in collaboration with the IANP in our country, which offers various services in the field of radiation protection. It was suggested to the radiographers to use the coin`s method for X-ray beam testing due to the simplicity of this method and no cost. It was also proposed to the hospital managers that QC tests should be part of radiographer's routine work so they can detect at an earlier time any possible defect in the operation of the radiology equipment. QC practices are commitment to patient safety, diagnostic accuracy, and the reliability of X-ray diagnostic procedures performed in our country.

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