Control System of Digital X-ray Systems by Quality Parameters

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***Abstract* — The paper proposed a control system of X-ray digital equipment on quality indicators. Two basic parameters were determined: image quality and patients` radiation load. A method for monitoring these indicators is proposed. The criterion of equipment suitability is to obtain control digital X-ray images of diagnostically acceptable quality at a fixed low entrance dose in the plane of the digital detector. It is shown that the control system of X-ray digital equipment based on indicators of quality is the most appropriate in situations of deficit of financial resources, since minimizing the costs for the purchase and running of control systems, does not require highly skilled technical personnel, and reduces the duration of the equipment inspection.**

***Index Terms* — control system, X-ray digital equipment, quality indicators, the entrance dose, the test object, a clinical dosimeter.**

I. INTRODUCTION

Technical condition of X-ray equipment is an important constituent of X-ray diagnostic process [1-4]. The main task of a system control of X-ray equipment is timely discovery of its inoperative state and non-admission of using defective devices. High cost of measuring and control equipment and its metrological support make it difficult to widely implement of control methods used in developed countries. Periodic multi-parameter control is expensive and inefficient.

The objective of the paper is to substantiate a structure of a control system of digital X-ray systems, which would exist under conditions of lack of funds to service medical devices, and to develop a methodology to monitor their technical condition.

II. MATERIALS AND METHODS

The data on operation of over 600 X-ray systems, materials on the results of monitoring their technical condition during periodic maintenance and audits were used.

In September 2009, within the framework of a joint Ukrainian-Swedish project of radiation safety and quality assurance in medical radiology, 9 digital X-ray systems were checked in the course of joint audits by Ukrainian and Swedish experts in various cities of Ukraine in order to compare Swedish methods of control their technical condition and methods developed during this work. Opinion regarding the equipment fitness for work based on the results of both audits was the same, so the suggested
methodology of quality evaluation of digital X-ray systems may be applied in practice.

III. RESULTS

2 main quality parameters were determined, characterizing the intended purpose of X-ray equipment – image quality and radiation exposure on the patient. Thereat, a criterion of the device fitness for operation is an obtaining a control image, suitable for diagnostics, for a fixed, sufficiently low entrance dose in the digital detector plane. For standard X-ray examinations, control images of the test object, suitable for diagnostics, should be received at patient doses not exceeding control values, and where they are absent – maximum admissible values.

Several parameters are used to evaluate image quality:

- coincidence of radiation and light fields;
- presence of artifacts;
- image uniformity at the detector's operating field;
- the limit of spatial resolution (high contrast resolution);
- dynamic range;
- threshold contrast (low contrast resolution);
- presence of artifacts on the display.

All of these parameters may be actually checked at a time using a special test object with an aluminum step wedge (figure 1).

In order to evaluate radiation exposure for the patient entrance dose measurement in the detector plane a clinical dose meter is used (figure 2). Entrance dose is most commonly measured without backscatter.

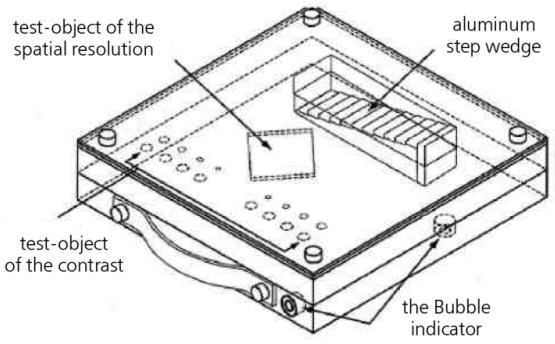


Fig. 1 Special test-object to check image quality of X-ray systems

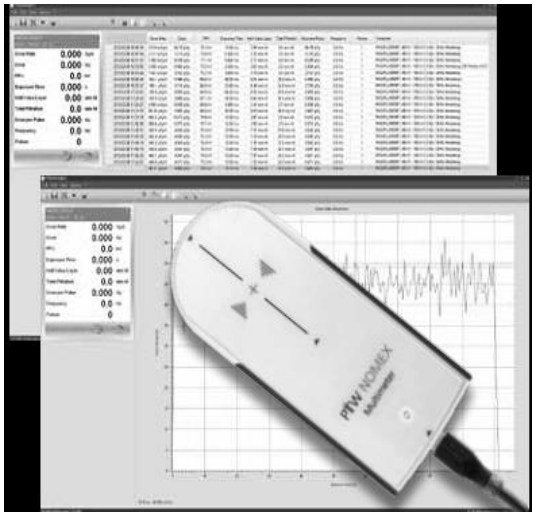


Fig. 2 Clinical dose meter (multimeter)

Control system includes 3 main procedures:

1. determination of the base technical condition of the equipment by parameters «image quality - dose» at the state of its putting into operation;
2. current control of base condition stability;
3. periodic control of states «image quality – dose» for basic X-ray examinations: skull – lungs – abdominal cavity – spine, - as well as base condition stability using a clinical dose meter.

Determination of the base condition of X-ray equipment should be performed with participation of the X-ray office staff, representatives of the equipment supplier, a company that will provide its maintenance, X-ray department and sanitary-epidemiologic service. X-ray image of the test object, conforming to the base technical condition of the monitored equipment, as well as information about it, control means applied, and actually determined entrance dose value are entered in the electronic archive of the digital X-ray system for further comparison.

Current control of the base technical condition stability is performed by the X-ray office staff using a test object. In absence of a clinical dose meter, the necessary exposure parameters are be calculated by table method [5].

Periodic control is performed by specialists of the company providing maintenance, and representatives of the X-ray department subject to compulsory use of a calibrated clinical dose meter. At this stage, retrospective analysis of test object X-ray images recorded in the electronic archive, obtained during current control, is provided, if necessary.

Records of all work performed with the equipment should also be made in a technical monitoring log.

Below is a methodology to control parameters that a used to evaluate image quality and radiation exposure for the patient.

Let us review the methodology of quality control of a digital X-ray image using a pehamed DIGRAD phantom (test-object) and aluminum step wedge. Utilization of this phantom allows evaluating this following parameters of digital X-ray system (DXRS):

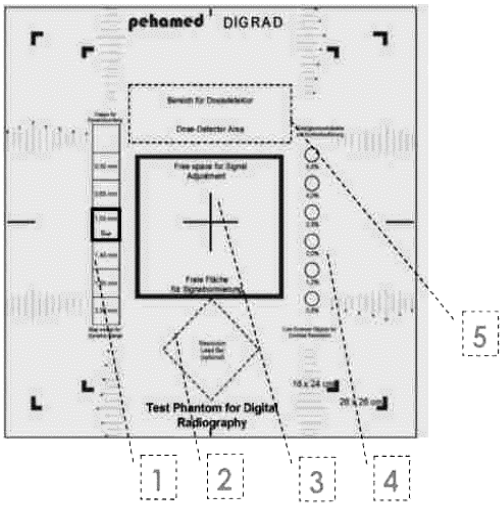
- coincidence of radiation and light fields
- presence of artifacts;
- image uniformity at the detector's operating field;
- thelimit of spatial resolution (high contrast resolution);
- dynamic range;
- threshold contrast(low contrast resolution);.

Equipment is controlled at anode voltage 70 kV. If a clinical dose meter is available, it is placed behind the phantom and set the quantity of electricity (mAs) that corresponds to the input dose of 10.0 μGy. In the absence of the dose meter value of electricity can be found with an error of less than 20% by using the table below.

Table 1. Quantity of electricity correspondent to an entrance dose of 10.0 μGy for anode voltage 70 kV and different general filtration of X-ray radiation

o	General filter, Al, mm	Quantityofelectricity, mAs
	2,0	6,3
	3,0	7,4
	4,0	8,0
	5,0	9,8
	6,0	11,3

Therefore, image quality control is performed at anode voltage 70 kV, entrance dose in the digital detector plane of 10.0 μGy, and the distance from the focal spot to the detector of 1.0 m,



1. Step wedge to measure dynamic range
2. Test object to measure spatial resolution
3. Phantom center
4. Six low contrast circles
5. Dose-detector area to measure entrance dose to the x-ray detector

Fig. 3 Test-object for quality control of digital X-ray systems

Let us shoot the test object and check the following parameters using the obtained digital X-ray image:

1. Coincidence of radiation and light fields

According to this parameter, image quality is considered fit for diagnostics if deviation of the radiation field from the light field does not exceed 2%, i.e. the following requirements are met:

$$|a| + |b| \leq 0{,}02 \cdot r \cdot V$$
$$|c| + |d| \leq 0{,}02 \cdot r \cdot V$$

where – r – the distance from the focal spot to the detector;

V – image magnification ratio;

a, b, c, d – relevant deviations of the radiation and light fields shown on figure 4.

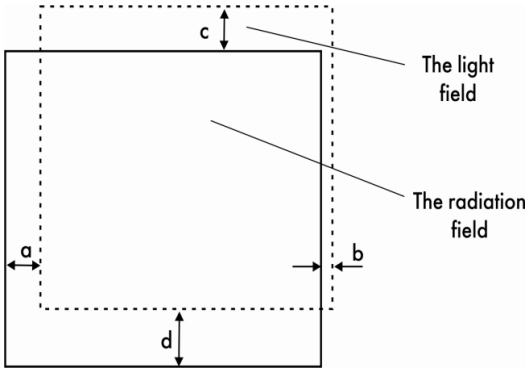


Fig. 4. Check of the coincidence of radiation and light fields: the integral line limits the radiation field; dash line – the light field.

Standard program tools are used to measure values of a,b,c,d deviations in digital X-ray systems.

2. Threshold contrast (low contrast resolution).

A step wedge and a set of low-contrast circles, placed on the phantom, are used to determine contrast differentiation.

Step wedge to check dynamic range and the low contrast objects to check low contrast resolution

A DXRS suitable for operation should provide visibility of not less than 4 circles. However, it should be mentioned that if 6 circles were visible in determining the base condition, their number on images should be the same during the following checks. For example, prior to repair the image showed 6 circles (i.e. 0,8% contrast), and after - four (i.e. 2%) – so the system should be rejected according to this parameter.

All 7 steps should be visible on the step wedge.

3. The limit of the spatial resolution

Spatial resolution is measured on a special test-object placed on the phantom (see figure 1).

For the specified dose of 10.0 μGy the spatial resolution value should be not less than 2 pl/mm. Lines on a measure should be different and the intervals between them on 75% of the line length. Measurements should be performed with deactivated programs for additional image processing. The receiver should be set to obtain maximum refinement on the image, if such function is present.

4. Field uniformity on the image.

The obtained image should contain no non-uniformities. When searching for them, attention should be paid to visibility of all 7 steps on the step wedge to measure dynamic range.

Non-uniformity should be not worse than during previous system quality control.

5. Presence of artifacts.

The phantom should be checked for artifacts – they should be absent.

Presence of spots or scratches preventing correct diagnosis should be monitored. Image integrity regarding absence of displacement or straight line discontinuity on the phantom should be monitored.

6. Dose value stability check

Dose value stability control should be evaluated by two or several pictures. In the center of the phantom, deviations in the measured value of darkening density should not exceed 10 percent. Besides, stability of parameters measured according to paragraph 2 should be controlled. Standard built-in program tools were used for measurements.

IV. CONCLUSION

The suggested system to control digital X-ray systems by quality parameters is the most acceptable under conditions of financial deficit, as it minimizes expenses for procurement and operation of control devices, does not require highly qualified engineering and technical staff, and reduces duration of equipment checks.

Control of the technical condition of digital X-ray equipment using phantoms (test objects) establishes a number of simple criteria by which the staff of X-ray offices using it may make a justified decision regarding possibility or impossibility of its use..

APPENDIX A

Appendices, if present, must be marked A, B, C, and placed before Acknowledgment.

ACKNOWLEDGMENTS

Place your acknowledgments before References. Do not mention the sponsors and/or financial support obtained in this section. These specifications are to be included in an unnumbered footnote on the first page of the paper.

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