Computer-Assisted Laboratory Exercises for Quality Control of X-Ray Modalities

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Abstract: - The X-ray equipment used in medical imaging is bulky and costly. Therefore, setting up a laboratory exercise base on real machines requires significant amount of space and funds. Since the quality control procedures are based on produced images by such machines together with statistical evaluation of measured technical parameters, computers can be employed to describe these procedures using multimedia applications and provision of data and software for statistical analyses. Within this scope, a set of exercises is proposed in which the results of real-life quality control measurements are presented to students as the next best thing to a real, hands-on experience.

Key-Words: - X-Ray imaging modalities, Quality Control, Fluoroscopy, Mammography, Computer-based exercises

1 Introduction*

The imaging modalities of diagnostic radiology are playing a key role in early sickness diagnosis and therapy. Several of these modalities however utilize X-rays during the examination procedure. The latter associates each examination with a corresponding patient dose. In order of this dose to be minimal and at the same time keep an excellent image quality, X-ray modalities should function in their best performance, while the personnel dedicated to their service and maintenance should be fully aware of the modalities operational conditions and their effect in image quality and patient dose. The installation of X-ray modalities in universities for training purposes is costly. Under these circumstances the utilization of a computer based teaching tool, that employs quality control (QC) and image quality procedures of various X-ray imaging modalities is of value, yet not costly.

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2 Materials and Methods

Three computer based exercises have been designed regarding quality control procedures of radiographic, fluoroscopic and mammography X-ray systems. Each of these exercises consists of two parts: The first is a computer presentation of a quality control test. This presentation is comprised of small multimedia parts (videos) in which a quality control test for each parameter is performed while figures of the instruments used are displayed. In addition, raw data (the results of real-life measurements without any processing) of such quality control tests are given to the students. Each student is asked to evaluate the system performance and denote the parameters that are off limits set by the manufacturer or Greek legislation [1]. The second part of each exercise deals with image quality and how it is affected from the operational parameters of each system (i.e. kVp, mAs).

At the end of each exercise a questionnaire is given to the students. It is a two-folded test that consists of exercise parameters calculation (i.e. estimation of a parameter through a formula) and requires from them to comprehend the relation between theory and laboratory results.

3 Exercise Implementation

3.1 Exercise layout

The leaflet of each exercise is divided into 2 major

components: At first, a brief theory related to the associated imaging modality and the QC steps of the exercise are presented. The theory has all the data necessary for the student to understand the concept and aim of the exercise and answer all the questions asked.
Afterwards, the presentation of the exercise take place and the questions for the students are given. These questions may be either simple, requiring only evaluation of resulted data, or may need further knowledge of theory and synthetic reasoning. Moreover, an appendix will be provided in each exercise listing mathematical formulas necessary for the raw data evaluation. For all the mathematic and statistical calculations the students will use a spreadsheet software. Five written tests were created for the demonstration of QC procedures and image quality evaluation

3.2 Quality Control

The first exercise deals with quality control in a simple X-ray radiography system. In the first part a brief theory regarding physics and instrumentation along with some videos and photographs are presented to the students. The exercise scope is for the student to get familiar with the methodology and the instrumentation incorporated in acquiring quality control data, such as measuring the kVp, the timer, the X-ray output , the HVL etc [2]. Additionally the student may familiarize itself with the main components of X-ray radiographic equipment. For example in figure 1 the control panel of a simple X-ray unit is presented. In figure 2 an X-ray apparatus is also illustrated. With these figures the student gets an idea regarding the X-ray system setup and utilization.

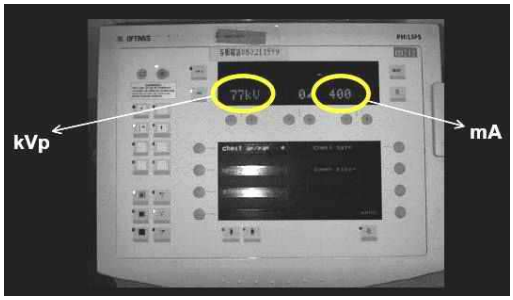

Fig. 1. X-ray control panel


Fig. 2. X-ray system

In the beginning, within the exercise a set of quality control procedures of parameters such as: X-ray output, Half Value Layer determination, X-ray generator timer and high voltage accuracy and concistency and beam alignment [2], are demonstrated (figure 3).

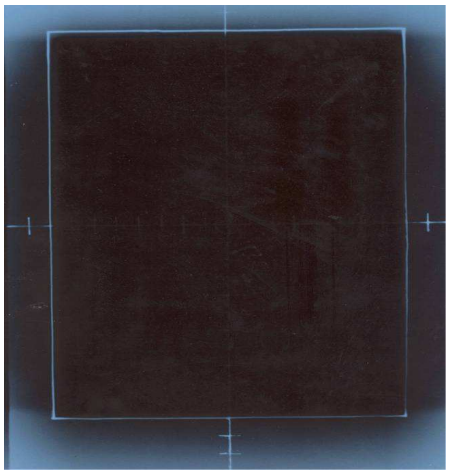
Fig. 3. X-ray beam alignment

The exercise continues with raw data of the aforementioned quality control checks. The students are asked to calculate the reproducibility and the accuracy of the X-ray generator timer and high voltage, to determine the X-ray output, its reproducibility and linearity (in regards with X-ray tube current) and finally the Half Value Layer of the X-ray tube [2].
Similar to the quality control of the simple X-ray unit, two exercises describing the quality control of a fluoroscopic unit (figure 4) and a mammographic unit have also been created. In both cases, figures or videos demonstrating the quality control procedure and instrumentation are shown.

Fig. 4. Fluoroscopy X-ray unit

In figure 5 the results of high and low contrast resolution test in a radiographic film are shown. In this figure the student may observe the bar pattern areas in order to determine high contrast spatial resolution and the grey level scale, which shows the low contrast spatial resolution of the system.

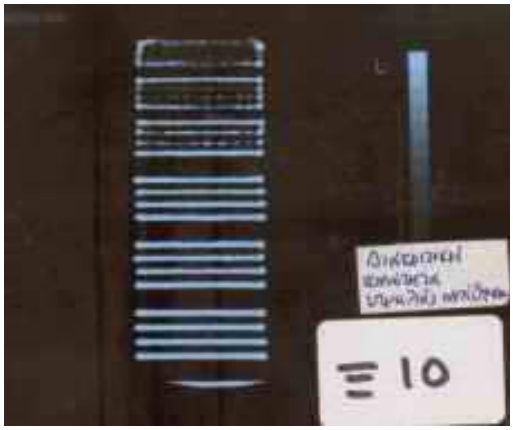

Fig. 5. spatial resolution test

Additionally in fluoroscopy the students are required to determine the HVL of the X-ray tube in fluoroscopy and the entrance surface dose rate at the patient.

The presented set of exercises treats mammography as a dedicated X-ray system. Therefore the students are requested to calculate mammographic generator accuracy and reproducibility similarly to the simple X-ray system [2], with stricter acceptance limits. An example of the raw data of the quality control of a an X-ray tube for mammography is given in figure 6.

Σύστημα 2

kVp	mAs	μετρούμενα kVp	μετρούμενος χρόνος	kerma εισόδου (mGy)
22	100	23.1	1005	1.95
28	63	29.2	560	5.2
35	28	34.6	220	4.6
28	63	29.6	556	5.3
28	63	29.5	564	5.2
28	63	29.7	558	5.4
28	63	29.4	560	5.3
28	63	29.6	553	5.1
28	16	29.5	140	1.3
28	20	29.7	198	1.4
28	20	29.9	197	1.4
25	48	26.2	423	2.9

filter (28kVp)		Απόσταση 60 εκατοστά
mGy	mm Al	mGy
360	0	5.1
300	0.1	4.9
250	0.2	4.2
200	0.3	3.5
170	0.4	2.9

Fig. 6. Mammography raw data

3.3 Image Quality

The aspects of image quality in X-ray imaging (i.e contrast, noise and signal) and their relation to the parameters of the system such as the generator voltage (KVp), timer (ms) and current (mA) are presented in the theoretical part of the exercises. A phantom image (comprised from several areas of different radiographic opacity - figure 7) irradiated in two different exposure conditions is presented in order for the students to comprehend the above relations.

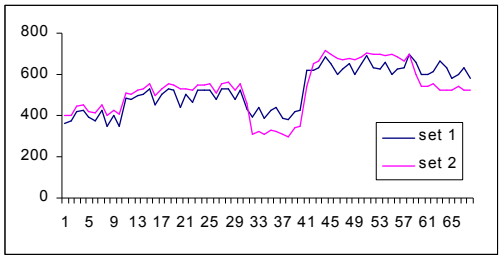

Fig. 7. Data profiles from several areas with different exposure

For each profile the students are asked to calculate the signal-to-noise ratio of each visible area and the contrast between neighbouring areas. Then they are asked to estimate the relation of image quality parameters with the used kVp and mAs, as well as with the effect of these parameters in patient dose. Moreover, students must evaluate the low and high contrast spatial resolution of images obtained during fluoroscopy (figure 8).

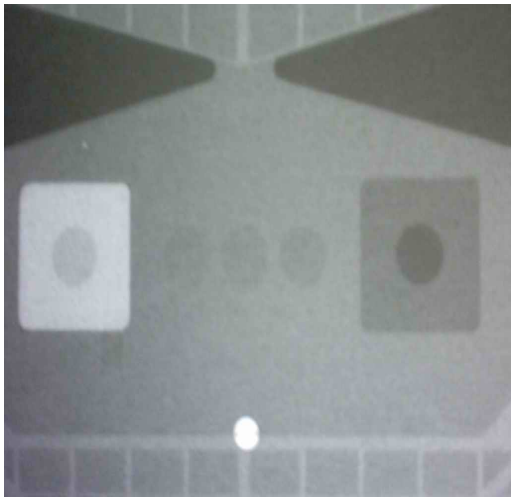

Fig. 8. Contrast check

4 Educational Benefits

After completing these exercises all students should:

- Understand the procedures in a quality control protocol of X-ray equipment.
- Understand the limits, according to the Greek and the European Legislation, of the acceptable deviations of the X-ray system operational parameters (i.e. KVp, timer, light and X-ray field coincidence, patient entrance surface dose etc).
- Process the raw data of the quality control and evaluate the results.
- Understand the effect of high voltage generator voltage (kVp) in contrast and noise.
- Understand the effect of X-ray output and patient dose in contrast and noise

5 Teacher notes

For every exercise a special leaflet is created for the teacher. This leaflet addresses the questions asked to the students. For the questions requiring a subjective evaluation of images from the student the teacher is provided with theory hints so as to evaluate the answer of the student. For the questions requiring evaluation of data through calculations with formulas the correct numerical answer is provided. For the questions requiring synthetic reasoning a brief discussion is performed.

6 Acknowledgments

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7 References

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