QUALITY CONTROL PROGRAM OF X-RAY EQUIPMENT IN ESTONIA

Vladimirov A, Kepler K
Training Centre of Medical Physics and Biomedical Engineering (BMTK), University of Tartu, Tartu, Estonia

1. INTRODUCTION

The Training Centre of Medical Physics and Biomedical Engineering (BMTK) of the University of Tartu has been established in 1996 to promote academic and continuing education in medical physics and biomedical engineering in Estonia. From 1997 to 2000 the BMTK carried out a medical (incl. radiological) equipment quality and safety assessment survey in Estonian health care institutions. During the survey and after that the Centre has provided technical expertise and disseminating knowledge of modern equipment maintenance principles, affordable quality control and constancy check, increasing quality awareness of users and introducing quality management practices and procedures in health care organizations. Requirements for radiation protection and quality assurance (QA) in X-ray examinations are defined in the Regulation 56 (1998) of the Ministry of Social Affairs, concerning requirements for using medical exposure, based on directive 97/43/Euratom. This regulation lists also acceptance criteria for basic parameters of X-ray units and refers to the priority of IEC standards.

2. MATERIAL AND METHODS

Currently BMTK provides a service of quality control (QC) measurements of diagnostic X-ray equipment to the majority of hospitals in Estonia. The BMTK maintains database of more than 150 X-ray units, incl. radiographic, fluoroscopic, dental, mobile, mammographic units and C-arms, of more than 60 health care institutions (hospitals, health centres, emergency stations etc). Many of units have been tested already two or three times.

The distribution of X-ray equipment by age is shown in figure 1.

![Figure 1. Age of the X-ray units: new - purchased after 1994 (incl.), old - purchased before 1994.](image)

X-ray equipment quality control procedures of the BMTK have been adopted from several international (incl. IEC and CEC) standards and guidelines (e.g.,[1, 2, 3, 4]) of good practice, and adapted for our conditions, instruments and test phantoms. A Keithley Model 10100A TRIAD Field Service Kit (Keithley Instruments, Cleveland, Ohio, USA), including Model 35050A dosimeter/ kV readout, 15 cc Model 96035B ion chamber, Model 35080A non-invasive kV divider with wide range 50-150 kV filter pack and Model 35035 mA/mAs meter are employed for the survey. A 3% NIST (National Institute of Standards and Technology, USA) traceable calibration is provided with dosimetric system and 2% with kV meter. The measurement system was interfaced with a computer to store waveforms and raw data of measurements. Different types of phantoms and test objects were produced and verified as...
most appropriate for our conditions (patient PMMA phantom, central beam pin test tool, multi-pinhole test tool, low contrast detectability test tool).

BMTK carries out the following QC test procedures (usually after the initial inventory of X-ray equipment and checking availability of accompanying documents):

1) **Mains supply tests** (line resistance, mains voltage fluctuations).

2) **Electrical safety tests** (protective earth resistance, leakage currents).

3) **High-voltage generator tests** (accuracy of X-ray tube voltage (incl. spotfilm device and fluoroscopic mode), reproducibility of X-ray tube voltage, constancy of X-ray tube current for various tube voltage settings, reproducibility of the exposure (air kerma), linearity of exposure over limited intervals of X-ray tube current, linearity of exposure over limited intervals of loading time, compensation of X-ray tube voltage for various tube current settings, accuracy of X-ray tube current (invasive measurements), constancy of X-ray tube current for various exposure time settings, constancy of exposure values for various focal spot dimensions, accuracy of loading time, reproducibility of loading time).

4) **Radiographic X-ray tube tests** (focal spot size, half-value layer (HVL), radiation output).

5) **Radiographic table tests** (X-ray central beam, light beam, X-ray/light field and Bucky tray alignment, light field/X-ray field congruence, accuracy of indication of light field indicator, light field illumination, X-ray image non-uniformity, Automatic Exposure Control (AEC): AEC homogeneity for various sensor elements, reproducibility of AEC, kV compensation, patient thickness compensation, calibration of density control, calibration of FSC control, calibration of FSC latitude control).

6) **Bucky wall stand tests** (X-ray central beam and Bucky alignment, accuracy of indication of light field indicator, X-ray image non-uniformity).

7) **Fluoroscopic tube tests** (focal spot size, half-value layer (HVL), radiation output).

8) **Fluoroscopic table tests** (X-ray central beam, X-ray field, spot film device and X-ray image intensifier (XRII) alignment, X-ray image non-uniformity (spot film device)).

9) **Patient entrance dose rate** (manual mode, reproducibility of patient entrance dose rate (fluoroscopic auto mode), patient entrance dose rate (zoom mode), patient entrance dose rate (II AERC mode), maximum patient entrance dose rate: in manual mode and in automatic mode, patient thickness compensation (AERC)).

10) **X-ray image intensifier input dose rate** (reproducibility of X-ray image intensifier input dose rate (fluoroscopic auto mode), X-ray image intensifier input dose rate (zoom mode), X-ray image intensifier input dose rate II AERC mode, patient thickness compensation (AERC)).

11) **X-ray image intensifier tests** (functional distortion (TV): integral distortion and radial distortion, line pair resolution, XRII entrance field size, XRII luminance non-uniformity, XRII conversion factor, XRII contrast ratio, low contrast object detectability).

3. RESULTS

Some statistical results of the QC measurements are presented in figures 2 to 5. IEC criteria of acceptability are shown with yellow lines. IEC criteria for KVp accuracy is ± 10 %. IEC stipulates the minimum HVL layer as 2.3 mm Al for the X-ray units at 80 kV. As we can see from the figure IEC criteria for MAS accuracy is ± 20 %. By IEC the patient maximum entrance dose rate should not exceed 100 mGy/min in AERC mode and 50 mGy/min in manual mode.
Figure 2. KVp accuracy of X-ray units.

Figure 3. HVL of radiographic and fluoroscopic X-ray @ 80 kV.

Figure 4. MA accuracy of X-ray units.
4. CONCLUSIONS

The quality control program reported in this study provides a necessary part of the quality assurance programs in Estonian health care institutions with X-ray department.

Some typical QA and QC issues that need more detailed discussion in future:

a) compatibility of methods - how to make the QC methods universal for each X-ray unit?

b) optimisation of the number of QC tests - how much tests is good enough?

c) estimation of uncertainty in each QC measurement.

5. REFERENCES


