Half value layer and AEC receptor dose compliance survey in Estonia

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Introduction

- CEC Radiation Protection 91 (1997) *Criteria of acceptability of radiological (including radiotherapy) and nuclear medicine installations*

- CEC Radiation Protection 162 *Radiation criteria for acceptability of medical radiological equipment used in diagnostic radiology, nuclear medicine and radiotherapy*
  - Suspension levels (type A, B, C and D) – quantitative indicators of performance which must be met
  - Draft for public consultation – 2009
  - Final draft - Dublin workshop, Sept. 2011
  
http://www.neyhqarc.nhs.uk/rp162/
Introduction

• During the last decade practically all radiology departments of Estonia have successfully moved from film-screen based technology to filmless digital technology - computed radiography (CR) and digital radiography (DR). Now the majority (about 90%) of the radiographic systems are CR systems, but the number of DR systems is increasing. In the same time many AEC systems of the radiographic equipment have remained adjusted as for film-screen systems sensitivity and energy response. The question is, if the AEC needs readjustment for being used with CR system.

• One of the significant modifications in the new draft of Radiation Protection 162 (RP162) includes specification of acceptable half value layer (HVL) values for diagnostic X-ray equipment at different tube potentials. The new criteria are based on the international standard IEC 60601-1-3:2008. In the previous Radiation Protection 91 (RP91) only criteria for total filtration (>2.5 mm Al), was given. In practice, total filtration is not directly measurable as HVL.
Minimum permissible HVL in X-ray equipment by IEC 60601-1-3

<table>
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<th>X-ray tube voltage, kV</th>
<th>IEC (1994) HVL, mm Al</th>
<th>IEC (2008) HVL, mm Al</th>
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Materials and methods

• Half value layer (HVL) was estimated by Barracuda MPD detector (RTI, Sweden) using narrow beam geometry with aluminium filter thicknesses of 1, 2, 2.5, 3 and 4 mm
  – for 226 general radiographic X-ray tube assemblies at 80 kVp and
  – for 53 dental X-ray tube assemblies at 70 kVp.

• Receptor entrance dose set by AEC was estimated for 54 AEC systems in routine QC tests during last two years in order to get distribution of AEC setup curves at different tube potentials.
  – The indicated tube current - exposure time product value (mAs) was used to calculate receptor entrance dose taking into account the measured tube output, HVL and estimated scattering for 15 cm PMMA phantom.
  – The selection included CR systems manufactured by Agfa (31), Fujifilm (19) and Kodak (1) and DR systems manufactured by Trixell, GE and DRTech.
Measurement geometries for receptor dose by IPEM

• Only one unit of the tested 226 X-ray tube assemblies evaluated by the IEC 60601-1-3:1994 (HVL>2.3 mm Al at 80 kV) was subject to readjustment.
• 14% of the tested X-ray tube assemblies evaluated by the IEC 60601-1-3:2008 and draft RP162 criteria (HVL>2.9 mm Al at 80 kV) were subject to readjustment.
Results: HVL in dental radiography

- Only one unit of the tested 53 dental X-ray tube assemblies evaluated by the IEC 60601-1-3:1994 and RP91 criteria (HVL>2.1 mm Al at 70 kV or total filtration >1.5 mm Al) was subject to readjustment.
- IEC 60601-1-3:2008 sets the minimum HVL at 70 kV to 2.5 mm Al which have made necessary to troubleshoot 59% of the tested dental X-ray tube assemblies.
- Draft RP162 does not state any criteria for HVL in dental radiography.
Results: AEC & receptor entrance dose

- In studies of 54 AEC units the estimated receptor entrance dose varied, depending on AEC calibration:
  - at 60 kV from about 3 to 16 μGy, third quartile 6.4 μGy
  - at 80 kV from about 2 to 9 μGy, third quartile 4.5 μGy
- It is obvious that AEC of some CR systems have remained calibrated by film-screen sensitivity at lower energies (60 kV) – some receptor doses are located at about 10-12 μGy.
Results: AEC & receptor entrance dose

- In studies of 54 AEC units the estimated receptor entrance dose varied, depending on AEC calibration:
  - at 100 kV from about 2 to 7 μGy, third quartile 4.2 μGy
  - at 125 kV from about 2 to 7 μGy, third quartile 3.8 μGy
• Average receptor dose for CR systems is given with standard deviation (vertical) bars compared with the receptor dose for three DR systems from different manufacturers and pre-adjustments.
Conclusions

- About every seventh of the tested radiographic X-ray tube assemblies and more than half of the tested dental X-ray tube assemblies need some filtration to be added in order to comply with the new IEC standard and RP162 requirements.
- The results correspond well with the draft RP162 recommended type C criteria for receptor entrance dose: maximum allowed dose of 10 μGy per plate while using grid.
- In practice some AEC used in CR systems may need adjustment at lower tube potentials. Apparently the AEC system has remained with the same adjustment as it was for screen-film systems using higher receptor doses at low potentials.
- Average receptor dose of the CR systems was about twice as high as for the best optimised DR systems.
- The draft RP162 specifies radiation criteria for the radiological equipment useful for radiation protection purposes and carrying out routine tests. Clinically optimal setup of AEC system is still an open question and depends on the examination and the detector features. Evaluation of AEC curves and distribution of receptor entrance doses enables to establish baseline for the future dose vs digital image quality optimisation methods.
Additional remarks

- It is not probably justified to differ suspension levels for X-ray equipment depending on the year of manufacture because of absence of such references (no on year 2006 nor 2012). EN 60601-1-3:2008 states: “This European Standard supersedes EN 60601-1-3:1994. However, EN 60601-1-3:1994 remains valid until all the Parts 2 that are used in conjunction with it have been withdrawn”. The older particular standards (Part 2 standards) for radiography and fluoroscopy, CT and mammo have been withdrawn already. For dental radiography the particular standards are not published yet (draft 2011) but the following statement from EN 60601-1-3:2008 applies for them: “when Part 1-3 is used for appliances not covered by a Part 2, EN 60601-1-3:1994 is not to be used after 2009-09-12”. Radiation quality criterion (expressed as minimum HVL) is a general radiation protection requirement and should be applicable to all X-ray diagnostic equipment in clinical use, independent on the year of manufacture. In the same time it is quite easy to add filtration, if needed, even for older types of X-ray equipment.
References

- EC (European Commission) (1997) *Criteria for acceptability of radiological (including radiotherapy) and nuclear medicine installations*. Radiation Protection 91. EC, Luxembourg.
Thank you!