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SURVEY ON PERFORMANCE ASSESSMENT OF CARDIAC ANGIOGRAPHY SYSTEMS

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Advances in imaging technology have facilitated the development of increasingly complex interventional cardiac equipment. Consequently, there is a need for definitive equipment requirements. The aim of the study is to assess the performances of different cardiac angiographic systems. A questionnaire was sent to centres participating in SENTINEL Project to collect dosimetry data (typical entrance dose rate in fluoroscopy and imaging mode), image quality evaluations (low and high contrast resolutions) and KAP calibration factors. Results from this survey could contribute to the explanation of patient dose variability in angiographic cardiac procedures and to derive reference levels for cardiac angiographic equipment performance parameters.

INTRODUCTION

The number of fluoroscopically guided interventional cardiology procedures increased more and more rapidly in the last 10 y together with their complexity. The main reason is that, with interventional cardiology, even more patients can often be cured without the use of surgery and their stay in hospital is limited.

Advances in imaging technology have facilitated the development of increasingly complex radiological IC equipment[1,2]. Consequently, there is a need for definitive equipment requirements[3,4,5,6].

The aim of this study is to assess the performances of different cardiac angiographic systems and reference levels for relevant performance parameters. This study was performed in cardiac centres participating in European SENTINEL Project collecting dosimetry data, image quality evaluations and KAP calibration factors.

MATERIALS AND METHODS

A questionnaire was sent to SENTINEL centres to collect dosimetry data (typical entrance air kerma rate in fluoroscopy and imaging mode), image quality evaluations (low and high contrast resolutions) and KAP calibration factors. The questionnaire included instructions on the agreed methodology to be followed for measurements.

The list of angiographic units included in the survey is reported in Table 1 and comprises six systems with flat panel imaging detectors (FPDs) and six with image intensifier-TV chains (II). The table reports also the year of installation.

Tests included measurement of air kerma dose rates in fluoroscopy and digital acquisition modes and a subjective assessment of image quality using the Leeds test object TOR 18FG. Dose rates were measured under automatic exposure control in fluoroscopy and digital acquisition modes by measuring the entrance surface air kerma rate when a phantom of 20 cm PMMA thickness simulates a patient attenuation, and the field of view (FOV) on the detector has been set at 22 cm or nearest with a focus-entrance phantom distance of ~65 cm and the image detector positioned at 5 cm from the exit phantom surface.

With the purpose to use the KAPmeter calibration factor to correct collected patient KAP values, the calibration procedure is performed taking into account the attenuation determined by the patient table and mattress. The calibration has been performed at 60–80–100 kV X-ray qualities with an ion chamber on the axis of the X-ray beam placed at minimum 10 cm away from the patient table and the

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Table 1. Cardiac angiographic systems included in the SENTINEL survey.

Unit no.	Manufacturer	Model	Imaging detector	Year of installation
1	Siemens	Axiom Artis dBc	FPD	2005
2	Siemens	Axiom Artis dBc	FPD	2005
3	Siemens	Bicor Top	II	1995
4	Siemens	Multistar T.O.P.	II	1995
5	Philips	Allura F9	FPD	2002
6	Philips	Allura 9	II	2002
7	Philips	Integris 5000H	II	1998
8	GE	Innova 2000	FPD	2002
9	Philips	Integris 3000	II	1994
10	Siemens	Axiom Artis	FPD	2003
11	Philips	Integris CV9	II	2003
12	Siemens	Axiom Artis	FPD	2004
13	Philips	Integris 5000H	II	2002

image detector to avoid scatter. The different X-ray qualities are reached inserting in the X-ray beam, between the ion chamber and the image detector, attenuating material (copper and/or aluminium) simulating the patient attenuation and driving both kilo volt and added filtration to typical clinical conditions. Surface area is calculated from field dimensions measured with a radio-opaque ruler or an equivalent method. KAP calibration factor is assumed as the mean value of the calibration factor measured for the three X-ray qualities.

RESULTS

Entrance surface air kerma rates

The majority of the tested systems have a wide range of user selectable dose options, including a range of pulsed fluoroscopy modes, digital acquisition frame rates and automatic insertion of spectral filters. The pulsed fluoroscopy mode most frequently used on the equipment tested is 12.5 or 15 pulses per second (pps) and the acquisition modality 12.5 or 15 images per second.

Figure 1 shows entrance surface air kerma rate for different fluoroscopy modes available in each system. The air kerma entrance rates range from 3.6 to 26.5 mGy min^{-1} in low fluoroscopy mode, from 8.8 to 48 mGy min^{-1} in medium fluoroscopy mode and from 10.7 to 77.7 mGy min^{-1} in high fluoroscopy mode. Air kerma entrance rate does not seem to be strictly manufacturer dependent. For the majority of the systems tested, the patient entrance dose rate varies between 5 and 20 mGy min^{-1} for low and medium modes. The two systems presenting the highest dose rates are installed in the same centre.

In Figure 2, the entrance surface air kerma per image is shown for all imaging acquisition modes available and for the same geometry and FOV used for fluoroscopy measurements. The entrance surface

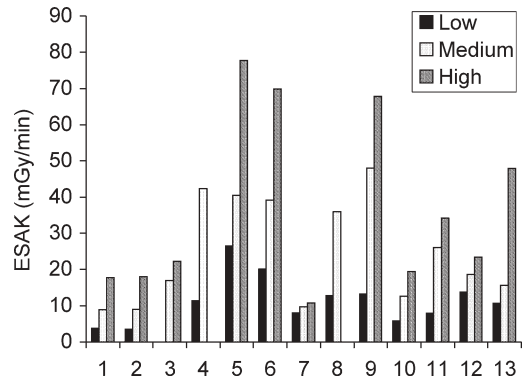

Figure 1. Entrance surface air kerma rate in fluoroscopy at the entrance surface of a phantom of 20 cm of PMMA and a FOV of about 22 cm for 13 cardiac angiographic systems.

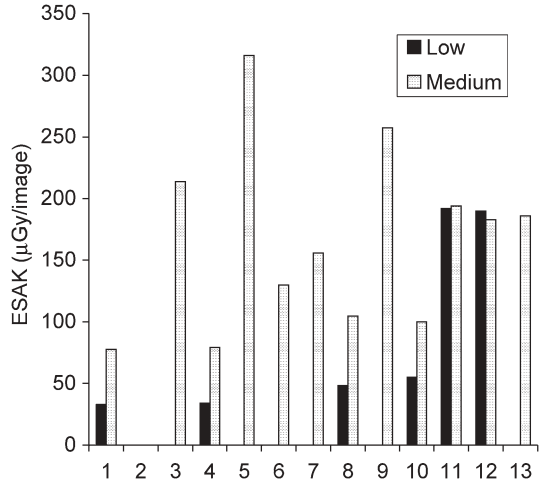

Figure 2. Entrance surface air kerma in image acquisition modes (cine modes) at the entrance surface of a phantom of 20 cm of PMMA and a FOV of about 22 cm.

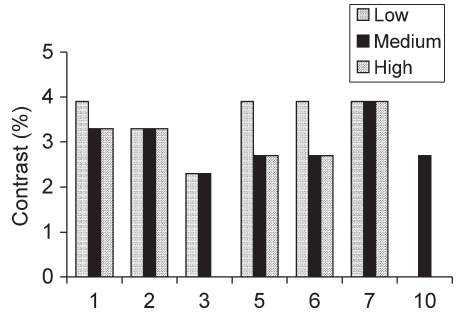

Figure 3. Threshold contrast in fluoroscopy for the Leeds TOR 18FG test phantom inserted in the central plane of the 20 cm PMMA phantom, FOV of about 22 cm.

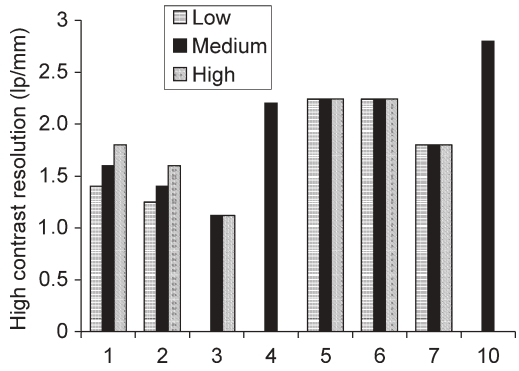

Figure 4. Limiting spatial resolution in fluoroscopy for the Leeds 18FG test phantom inserted in the central plane of the 20 cm PMMA phantom, FOV of about 22 cm.

air kerma per image ranges from 32.9 to 192 μGy per image in the low cine mode and from 77.8 to 316 μGy per image in the normal acquisition mode.

Image quality

Image quality was assessed by imaging the Leeds test objects TOR 18FG. Threshold contrast for fluoroscopy modes is shown in Figure 3. For all the systems, the threshold contrast varies between 2.5 and 4%. Only unit no. 3 has a threshold contrast quite lower (2.3%).

In general, an improvement in image quality is not apparent for the systems operating at higher dose levels: this is particularly important for systems exhibiting the highest entrance doses. Results on the evaluation of limiting spatial resolution of high contrast details of FG18 test phantom are shown in Figure 4. All analysed systems have limiting spatial resolution >1.25 lp mm^{-1}. Only system 3 has a resolution lower than 1.25 lp mm^{-1}.

Table 2. KAP calibration factors for the angiographic units included in the survey.

Unit	KAP calibration factor
1	0.880
3	0.890
4	0.714
5	0.841
8	0.789
10	0.683
12	1.049
13	0.844

Table 3. Reference levels proposed for interventional cardiology equipment.

Imaging mode	Entrance surface air kerma rate
Fluoroscopy low	13 mGy min^{-1}
Image acquisition	100 μGy per frame

Kerma area product meter calibration

The calibration factors evaluated in the survey are reported in Table 2. A large variation, $KAP_{real}/KAP_{dispalyed}$ from 0.68 to 1.05, in KAPmeter calibration and/or in the attenuation properties of patient tables and mattresses is recognised and cannot be neglected when patient doses are reported or compared between centres.

CONCLUSION

The survey on the cardiac angiographic units in a sample of European centres demonstrates a large variability in entrance dose rates for both, fluoroscopy and image acquisition modes, image quality performance and KAP calibration.

As an outcome of this study, a preliminary set of reference levels for the ESAK quantity is proposed in Table 3. It can be adopted by centres and maintenance engineers to set up cardiac equipment at an acceptable dose performance level and by standardisation bodies as an input to introduce proper standards. SENTINEL consortium is finally recommending a European action directed to harmonise the level of performances of angiographic systems used in the daily cardiac practice.

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