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Effect of technical parameters on dose and image quality in a computed radiography system

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Aims and objectives

The discovery of X-rays was undoubtedly one of the greatest stimulus for improving the efficiency in the provision of healthcare services. The ability to view, non-invasively, inside the human body has greatly facilitated the work of professionals in diagnosis of diseases.

The exclusive focus on image quality (IQ), without understanding how they are obtained, affect negatively the efficiency in diagnostic radiology. The equilibrium between the benefits and the risks are often forgotten. It is necessary to adopt optimization strategies to maximize the benefits (image quality) and minimize risk (dose to the patient) in radiological facilities [1].

In radiology, the implementation of optimization strategies involves an understanding of images acquisition process. When a radiographer adopts a certain value of a parameter (tube potential [kVp], tube current-exposure time product [mAs] or additional filtration), it is essential to know its meaning and impact of their variation in dose and image quality. Without this, any optimization strategy will be a failure.

Worldwide, data show that use of x-rays has been increasingly frequent [2,3]. In Cabo Verde, we note an effort by healthcare institutions (e.g. Ministry of Health) in equipping radiological facilities and the recent installation of a telemedicine system requires purchase of new radiological equipment. In addition, the transition from screen-films to digital systems is characterized by a raise in patient exposure [4]. Given that this transition is slower in less developed countries, as is the case of Cabo Verde, the need to adopt optimization strategies becomes increasingly necessary. This study was conducted as an attempt to answer that need.

Although this work is about objective evaluation of image quality, and in medical practice the evaluation is usually subjective (visual evaluation of images by radiographer / radiologist), studies reported a correlation between these two types of evaluation (objective and subjective) [5-7] which accredits for conducting such studies.

The purpose of this study is to evaluate the effect of exposure parameters (kVp and mAs) when using additional Cooper (Cu) filtration in dose and image quality in a Computed Radiography system.

Methods and materials

For different exposure setting (combination of cooper filter thickness, kVp and mAs), air kerma and DAP (dose area product) were measured using an ionization chamber (IC) and a DAP meter, respectively. The additional filter thicknesses used was none, 0.1, 0.2

and 0.3 mm. The IC was placed at roughly 1 m from the focus. The schematic of the experimental setup using for air kerma measurement is shown in Fig. 1 on page 4.

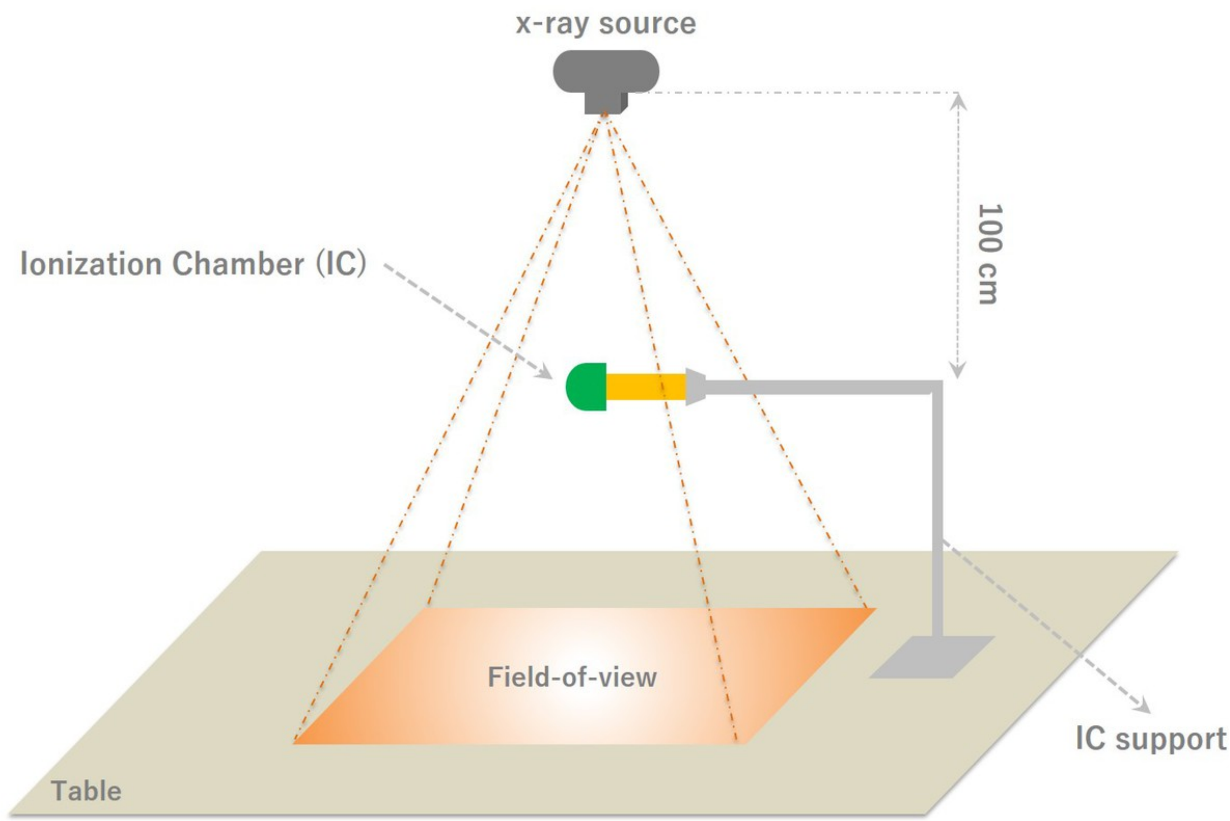

Fig. 1: Schematic of the experimental setup for air kerma measurement
References: Imagiology, Hospital Agostinho Neto - Praia/CV

As is known, DAP meter was incorporated at the exit of source, placed just beyond the x#ray collimators. For air kerma measurement, we opted for manual control of exposure, where mAs and kVp were selected manually. For DAP, the exposure control was semi-automatic (manual selection of kVp and automatic selection of mAs).

In image acquisition, we used a Computed Radiography (CR) system (Siemens Multix Pro generator, Agfa CR MD4.0 imaging plate) and a contrast-detail phantom (CDRAD 2.0, Artinis Medical Systems). In addition, 14 PMMA plates, 1 cm each, were placed before the phantom to simulate the dispersion of photons, as happen in patient exposure in diagnostic radiology. The source to detector distance was 180 cm (Fig. 2 on page 5). kVp was selected manually and mAs automatically by the equipment.

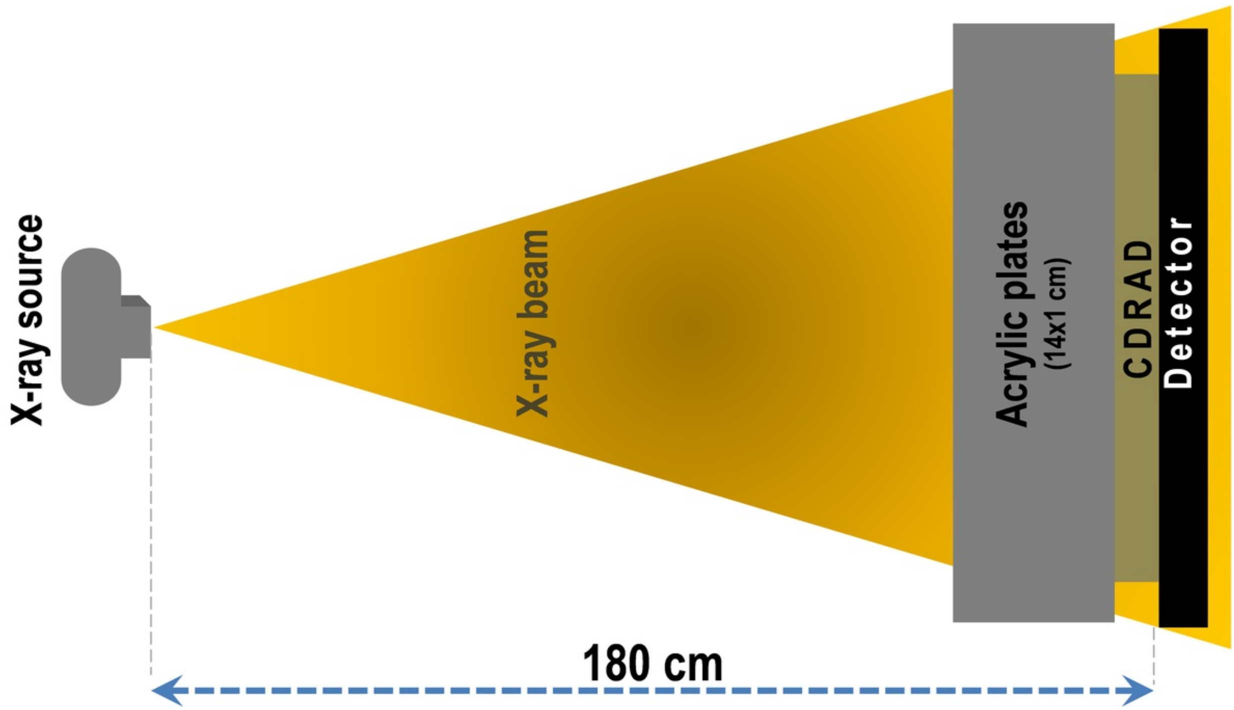

Fig. 2: Schematic of the experimental setup used in image acquisition
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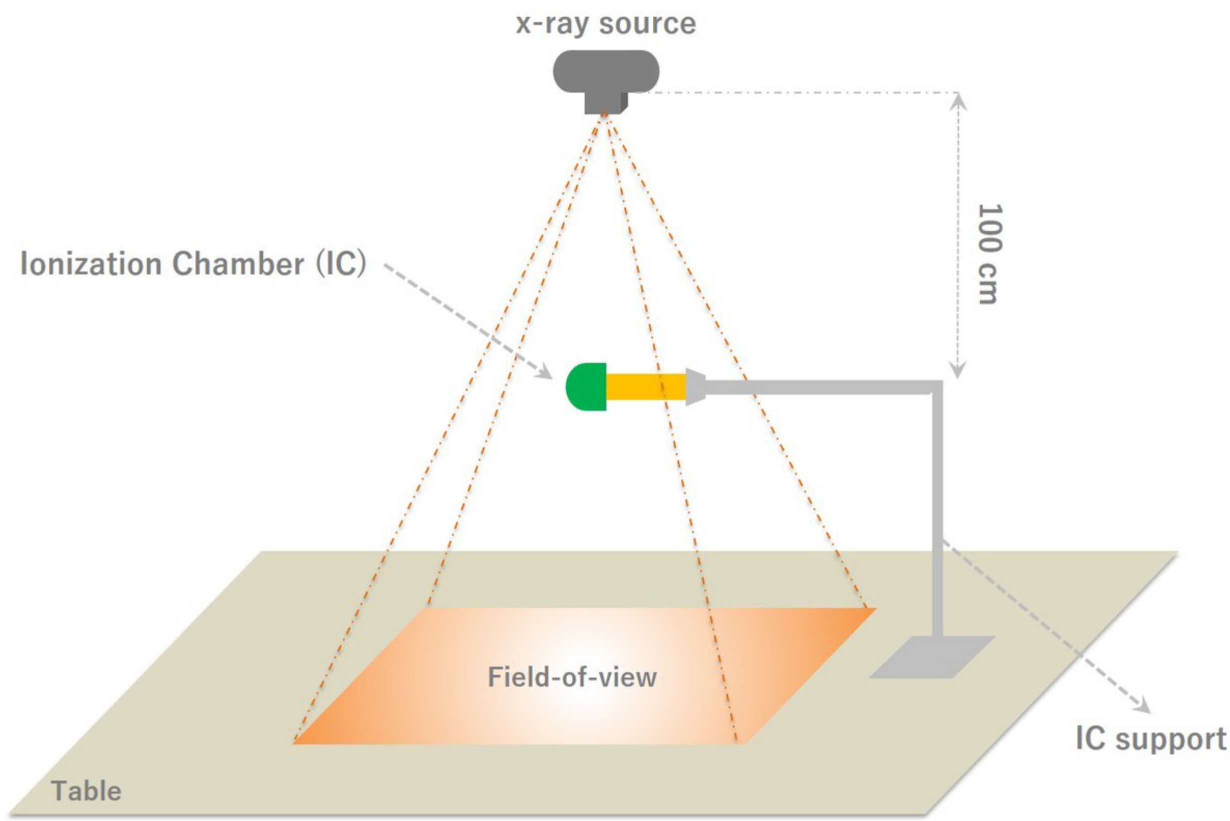
Image quality were evaluated automatically by inverse Image Quality Figure (IQFinv) with CDRAD Analyser (Artinis Medical Systems). After the upload of obtained images (phantom radiography) in CDRAD Analyser, the software output provides value and curve of IQFinv and the detected details (holes). Higher IQFinv means better image quality and more details detected.

Images for this section:



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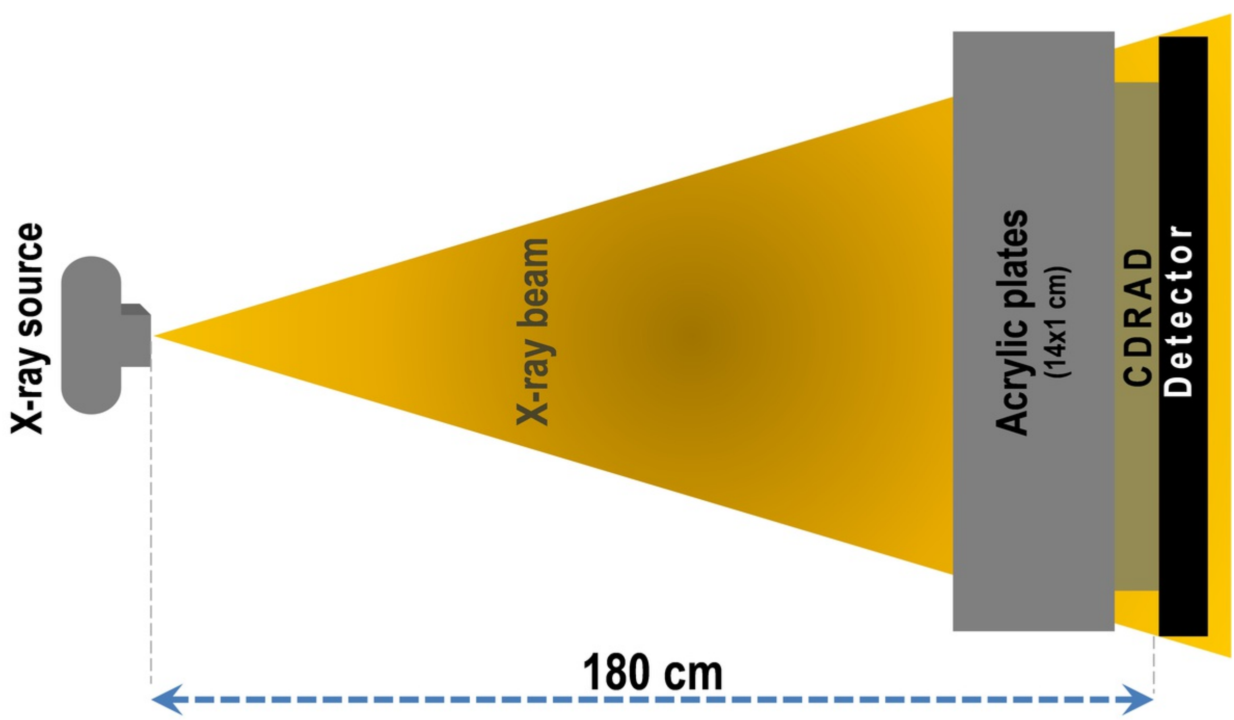

Fig. 2: Schematic of the experimental setup used in image acquisition

Additional filtration (mm Cu)	Exposure parameters kVp	mAs	air kerma (μGy)	DAP (μGy.m²)
No filtration	81	10	557.4	76.8
		20	1112.0	153.8
		40	2211.0	307.8
	90	20	1352.0	184.0
	99		1606.0	214.8
	109		1901.0	248.6
	121		2270.0	289.2
0.1	81	20	567.0	82.1
	90		734.2	102.7
	99		921.1	124.5
	109		1144.0	149.0
	121		1437.0	179.6
0.2	81	20	374.1	54.0
	90		506.6	70.2
	99		658.4	87.4
	109		845.7	107.3
	121		1095.0	132.4
0.3	81	20	265.4	38.0
	90		374.2	50.8
	99		501.9	65.0
	109		662.3	81.3
	121		880.2	102.2

Table 1: Exposure parameters and dose values measured

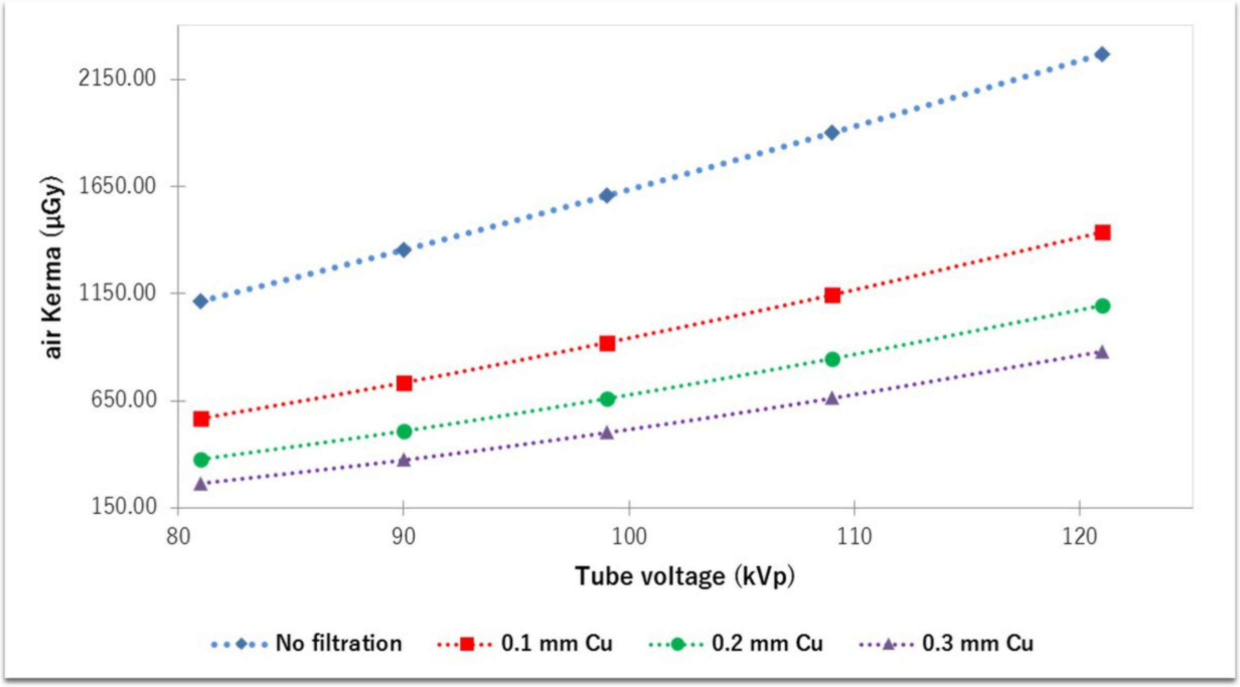

Fig. 3: Influence of kVp and additional filtration in air kerma

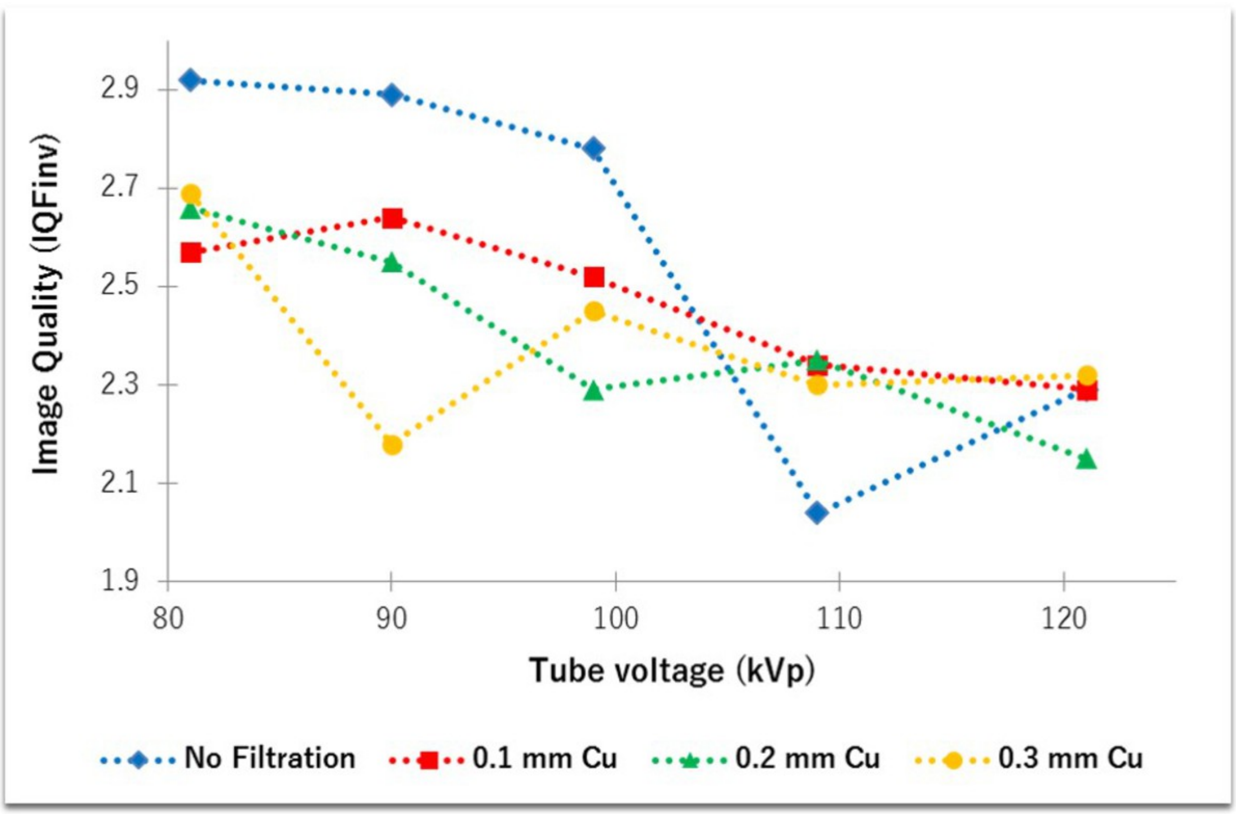

Fig. 4: Influence of kVp and additional filtration in image quality

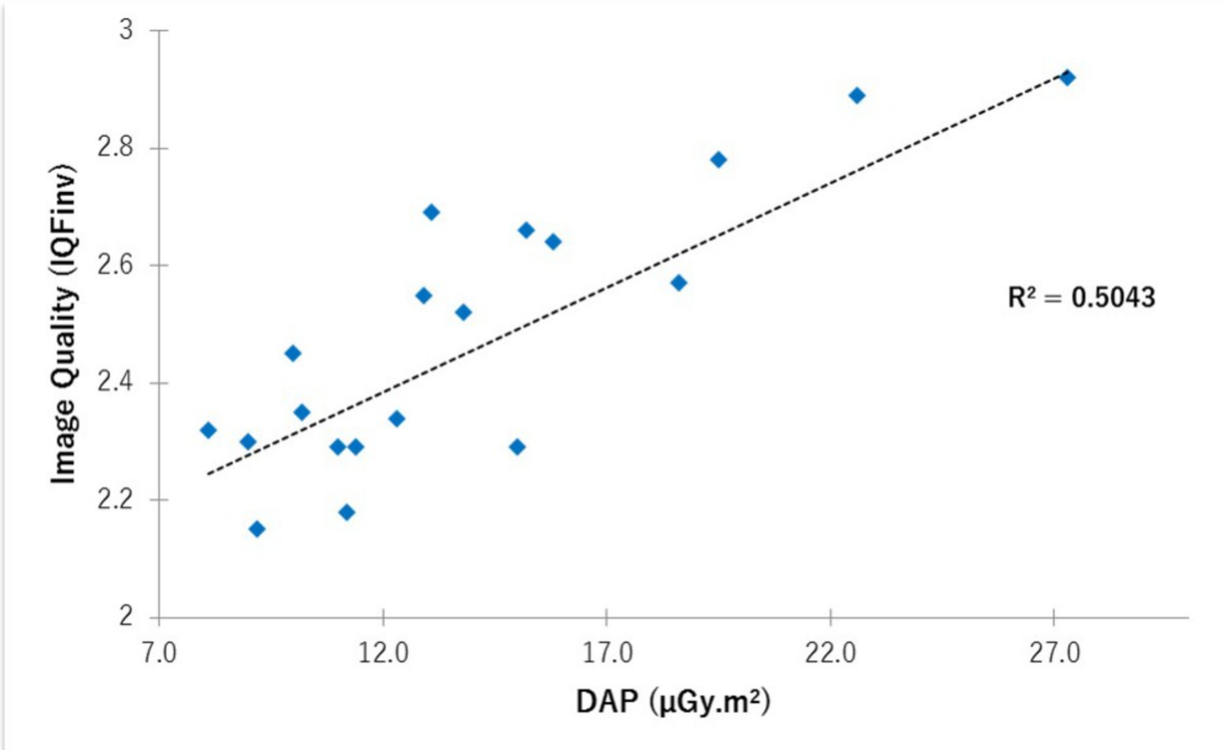

Fig. 5: Dose (DAP) and its influence on image quality (IQFinv)

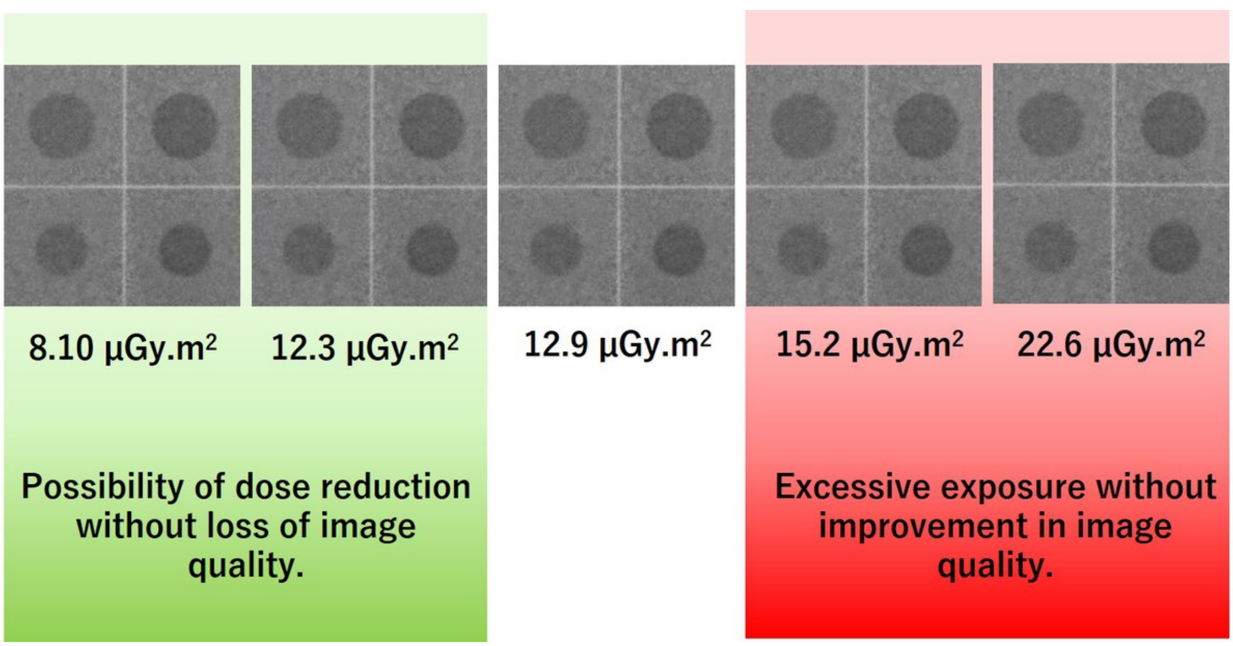

Fig. 6: Series of images obtained at different dose (DAP) values

Results

With tube current-exposure time product fixed at 20 mAs and tube potential ranging between 81 and 121 kVp, air kerma varies between 1120.00 and 2270.00 µGy. For 81 kVp, using 10, 20 and 40 mAs, air kerma were 557.00, 1120.00 and 2210.00 µGy, respectively (Table 1 on page 12).

Additional filtration (mm Cu)	Exposure parameters kVp	mAs	air kerma (µGy)	DAP (µGy.m²)
No filtration	81	10	557.4	76.8
		20	1112.0	153.8
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Table 1: Exposure parameters and dose values measured
References: Imagiology, Hospital Agostinho Neto - Praia/CV

The air kerma is directly dependant on the exposure parameters (mAs and kVp) with high correlation (R^2>0.99) and dose reduction is achieved increasing of filter cooper thickness (Table 1 on page 12 and Fig. 3 on page 13).

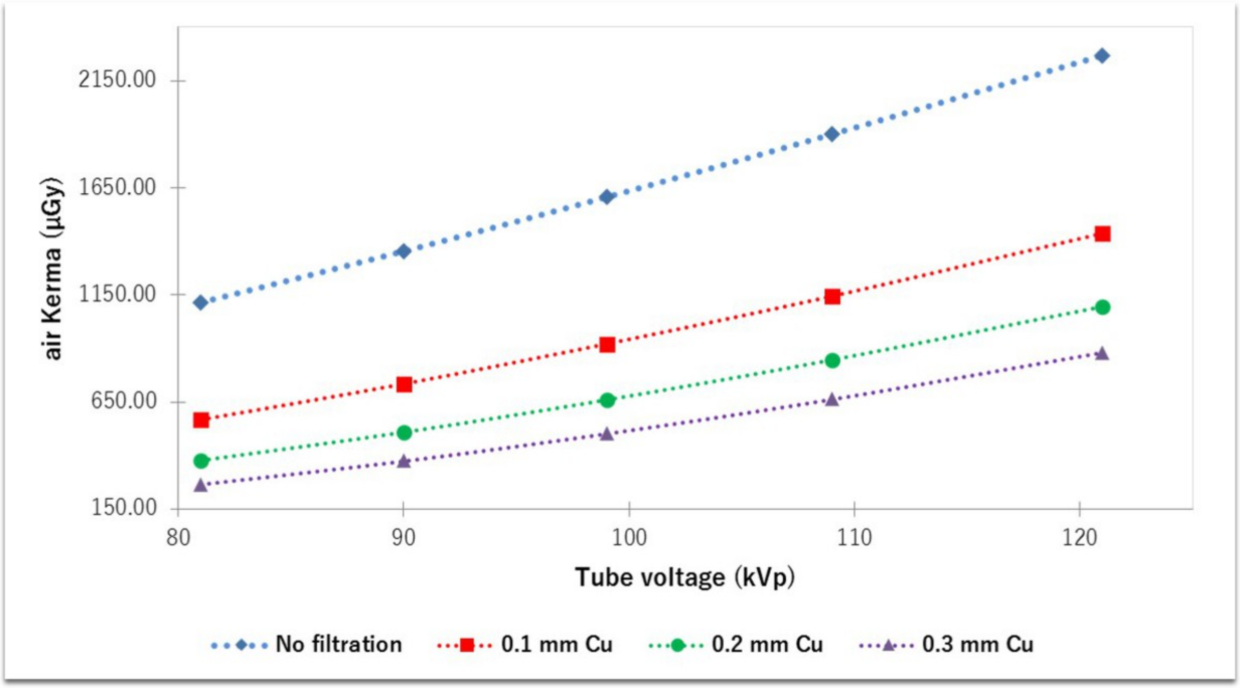

Fig. 3: Influence of kVp and additional filtration in air kerma
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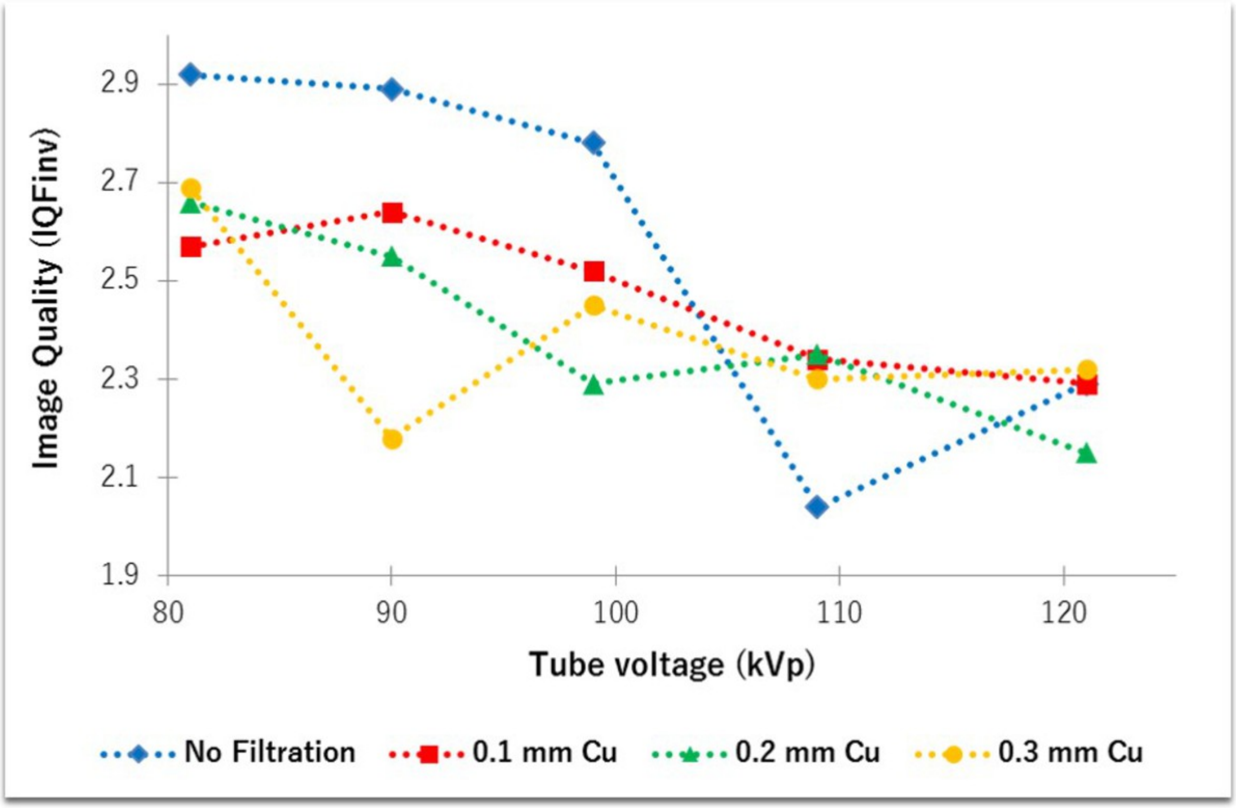
In the absence of additional filtration, for 81 kVp and 20 mAs, air kerma was 1112.0 µGy. Increasing filter thickness to 0.1 mm, air kerma decrease to 567.0 µGy (50% less dose) and for 0.2 mm dose reduction is about 70% (Fig. 3 on page 13).

Regarding the image quality, there is a tendency to be degraded (lower IQFinv) when kVp is increased. For example, using 0.1 mm Cu, for 90, 99, 109 and 121 kVp, IQFinv were 2.64, 2.52, 2.35 and 2.28, respectively. At fixed kVp, the same trend occurs at increased filter thickness. At 89 kVp and in absence of additional filtration, IQFinv was 2.89. Using 0.1, 0.2 and 0.3 mm, IQFinv were 2.64, 2.55 and 2.18, respectively (Fig. 4 on page 14).



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As stated above, in images acquisition, we opted for the semi-automatic exposure mode, where manual selection of kVp is accompanied by automatic mAs selection, resulting in a dose value, DAP in this case. The evaluation of the image quality will be based on these dose values, as illustrated in Fig. 5 on page 14.

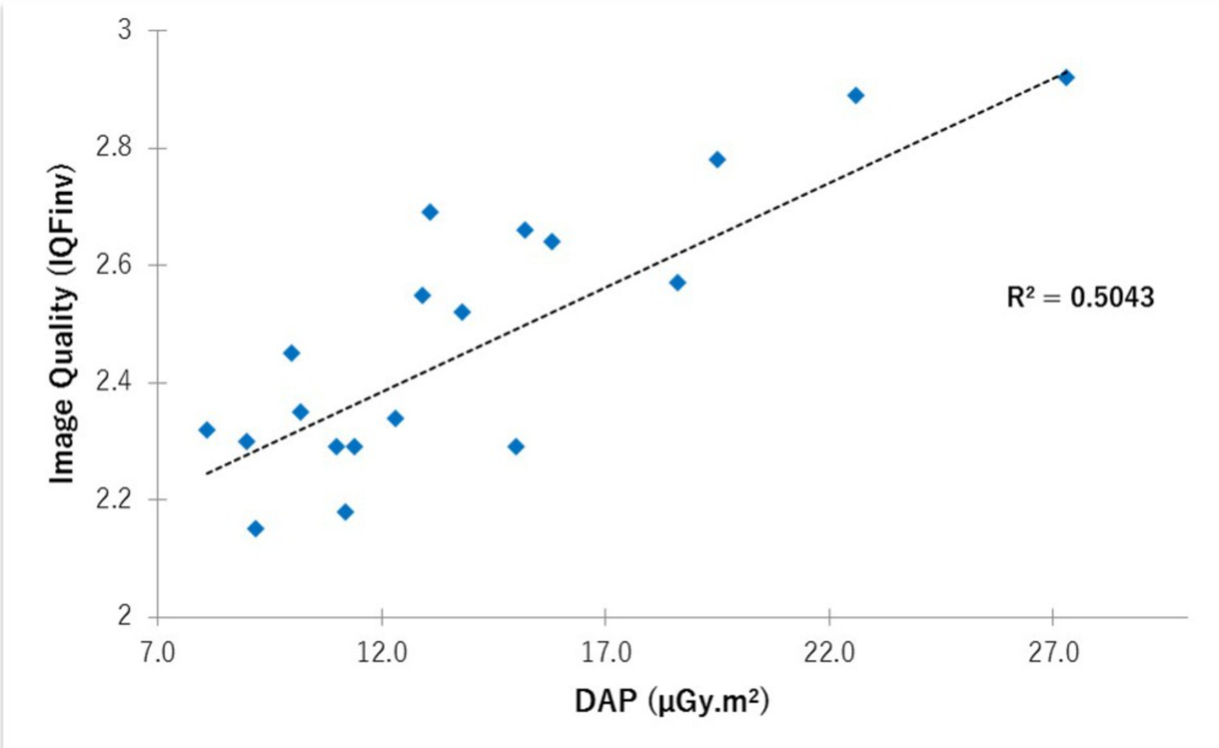

Fig. 5: Dose (DAP) and its influence on image quality (IQFinv)
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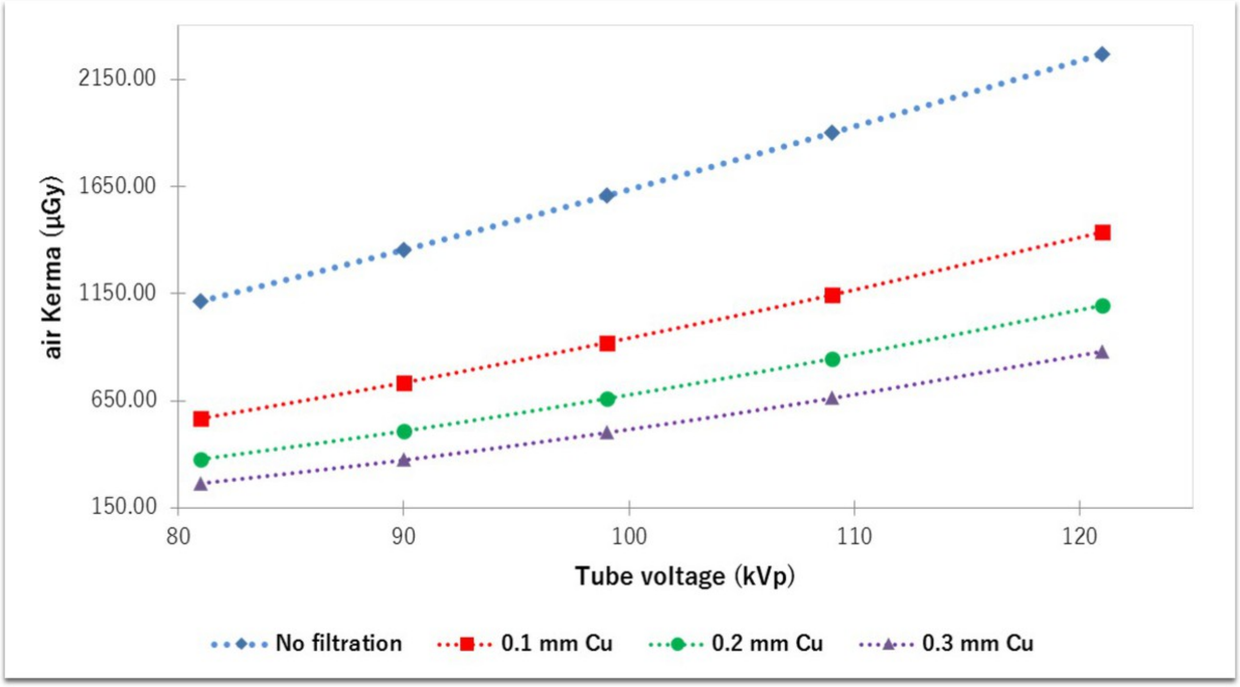

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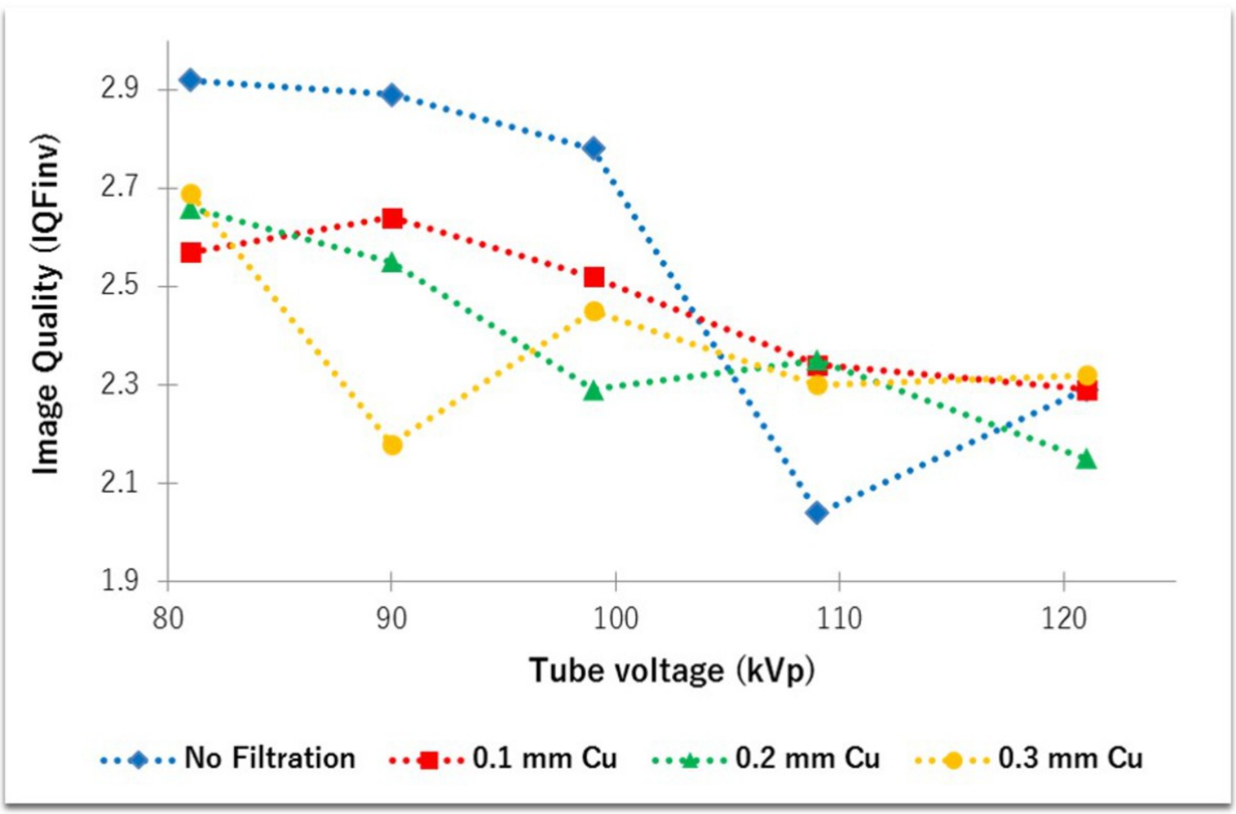

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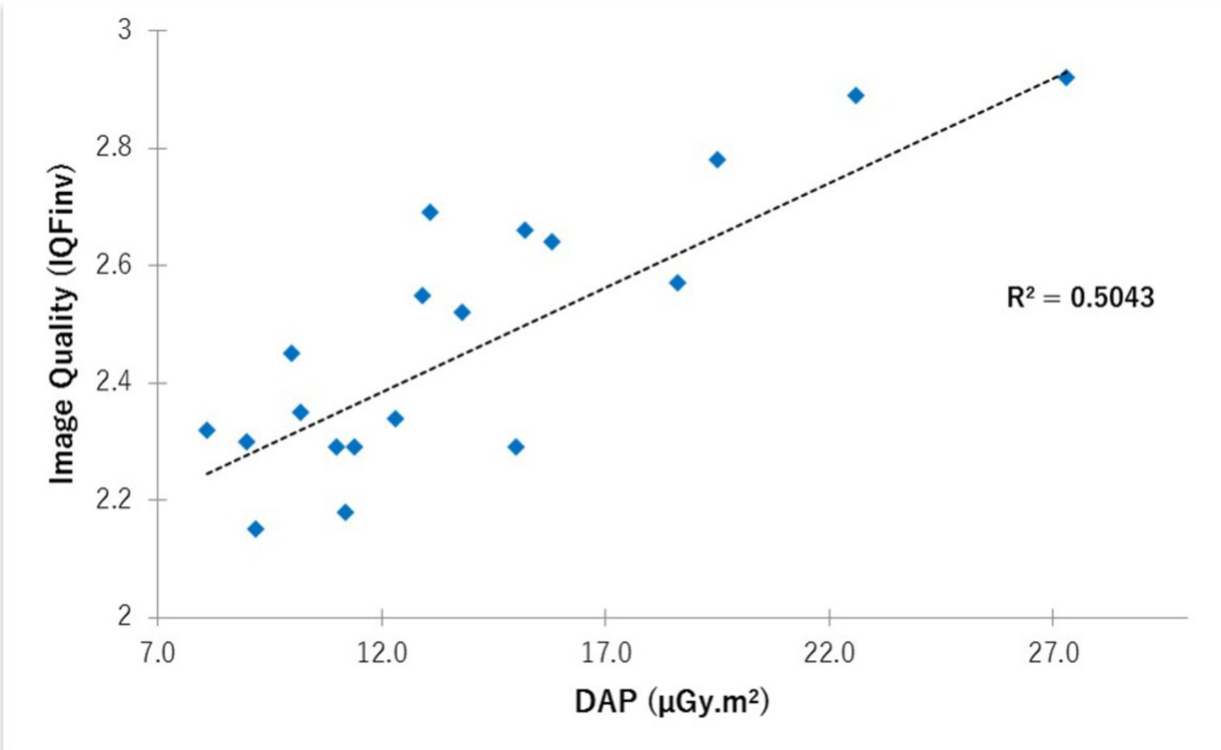

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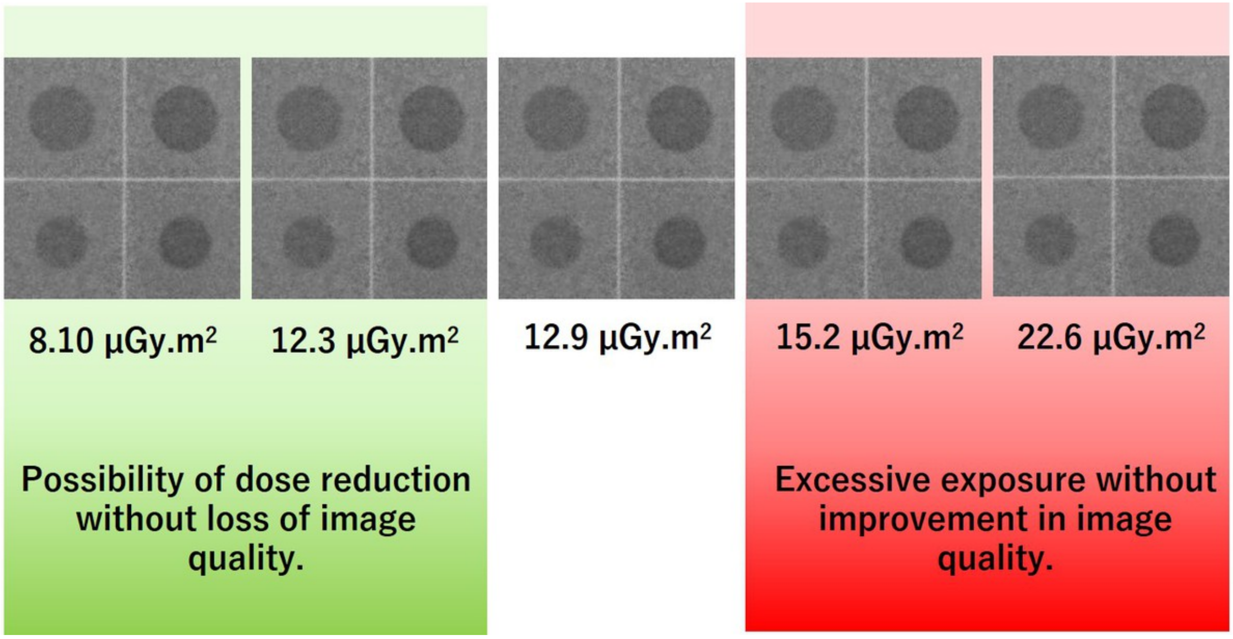
Conclusion

The results show direct variation between exposure parameters (kVp and mAs) and radiation dose (air kerma) (Table 1 on page 17 and Fig. 3 on page 17). These results support the statement that air kerma is the sum of initial kinetic energy of charged particles (e.g. electrons) released from air mass. Increasing kVp, electrons leave air mass most rapidly (more velocity) because "expulsion power" of beam is higher. With increase in mAs, the number of photons with that "expulsion power" increase and therefore more charged particles will be ejected from air mass. Studies related consistent results with those achieved in this work and support the adoption of low exposure parameters in diagnostic radiology [10, 11].

Additional filtration reduce significantly radiation dose (for a confidence interval [CI] of 95%). Additional filtration cause beam hardening by removing low energy photons from the beam and only the most energetic photons will across the filter material. Other studies achieved identical results [5, 13-15], what encourage the use of additional filtration for radiation protection in diagnostic radiology.

Regarding image quality, the results show the tendency for image quality degradation when tube potential or cooper filter thickness increases (Fig. 4 on page 18). This can be explained with decrease in differential attenuation (in this case between details [holes] and adjacent areas in CDRAD) or increase of secondary photons count that result in contrast reduction of obtained images. At low contrast, the difficult in identifying details in CDRAD is higher, thus IQFinv will be lower. Consistent results were achieved by others authors [12, 16, 17]. However, image quality degradation caused by additional filtration is statistically insignificant for a significance level of 5%.

Results shown in Fig. 5 on page 19 lead us to assumption that image quality is improved at higher dose values. These results are in concordance with those found in other studies with CDRAD phantom [16, 17]. However, visual evaluation of images obtained from CDRAD phantom, in this study, do not show significant difference in quality, as illustrated in Fig. 6 on page 19 This find can be explained by the wide dynamic range of digital system.



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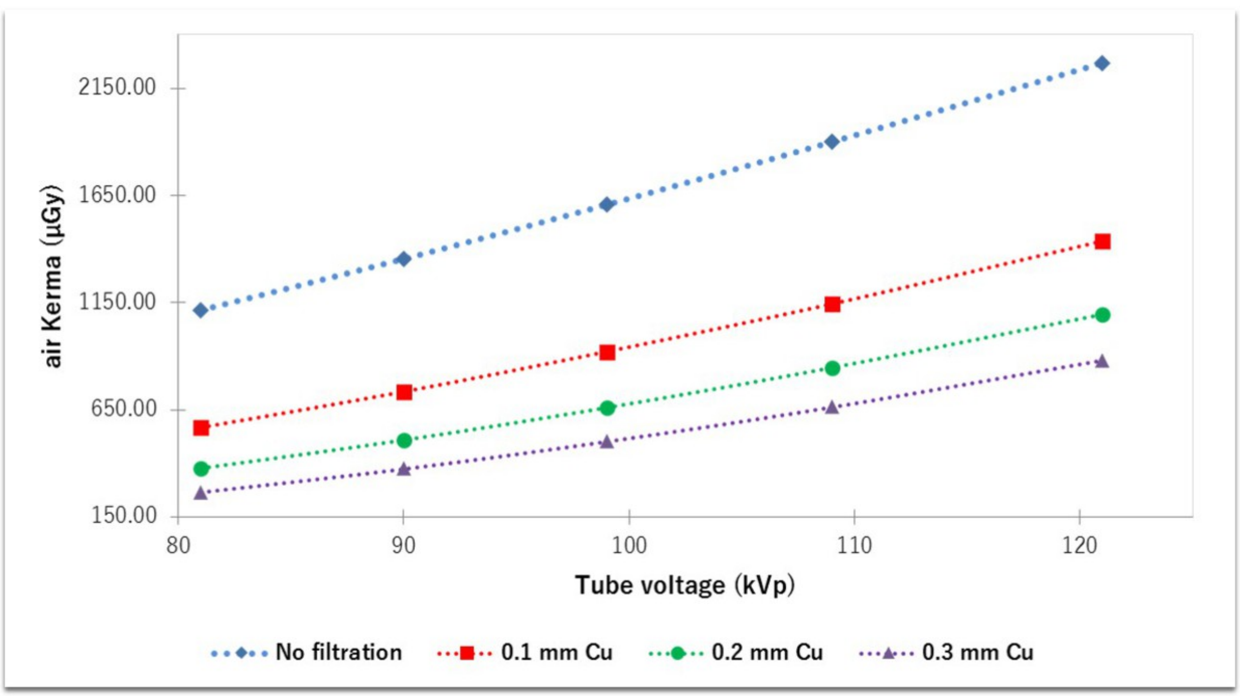

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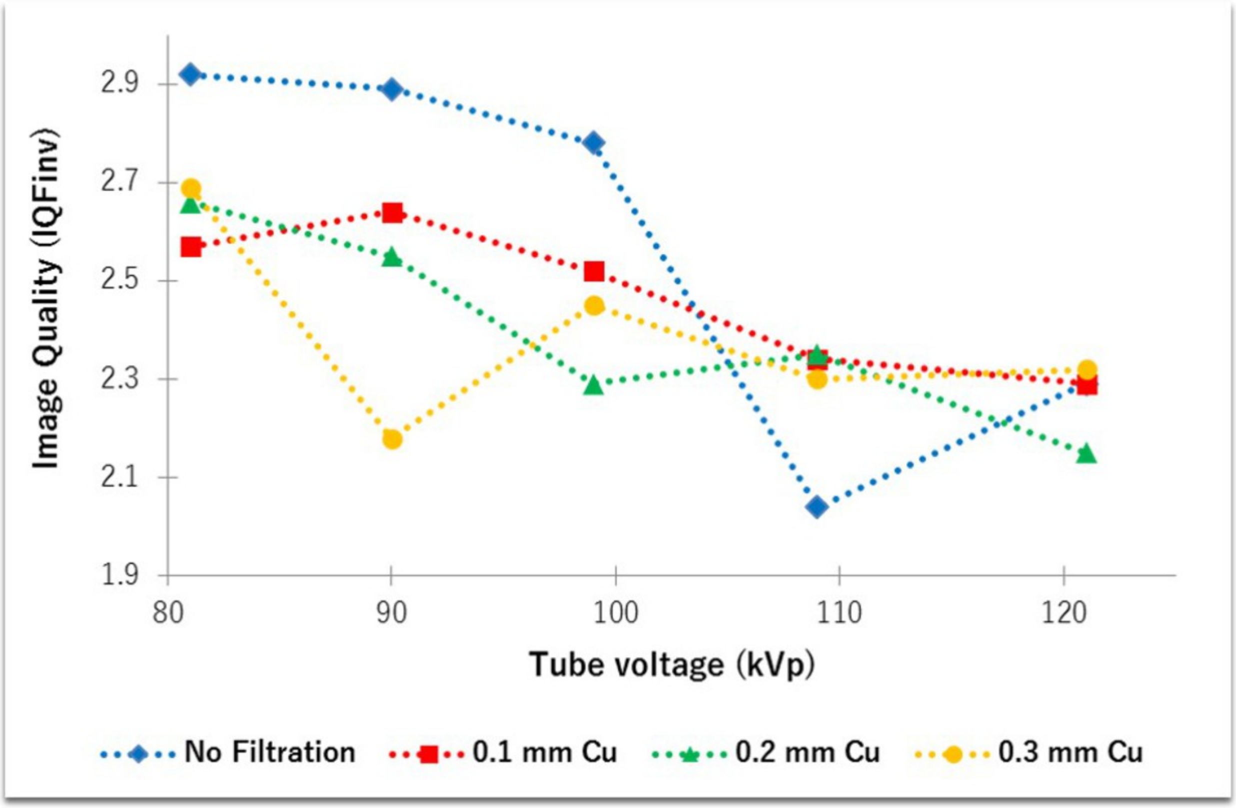

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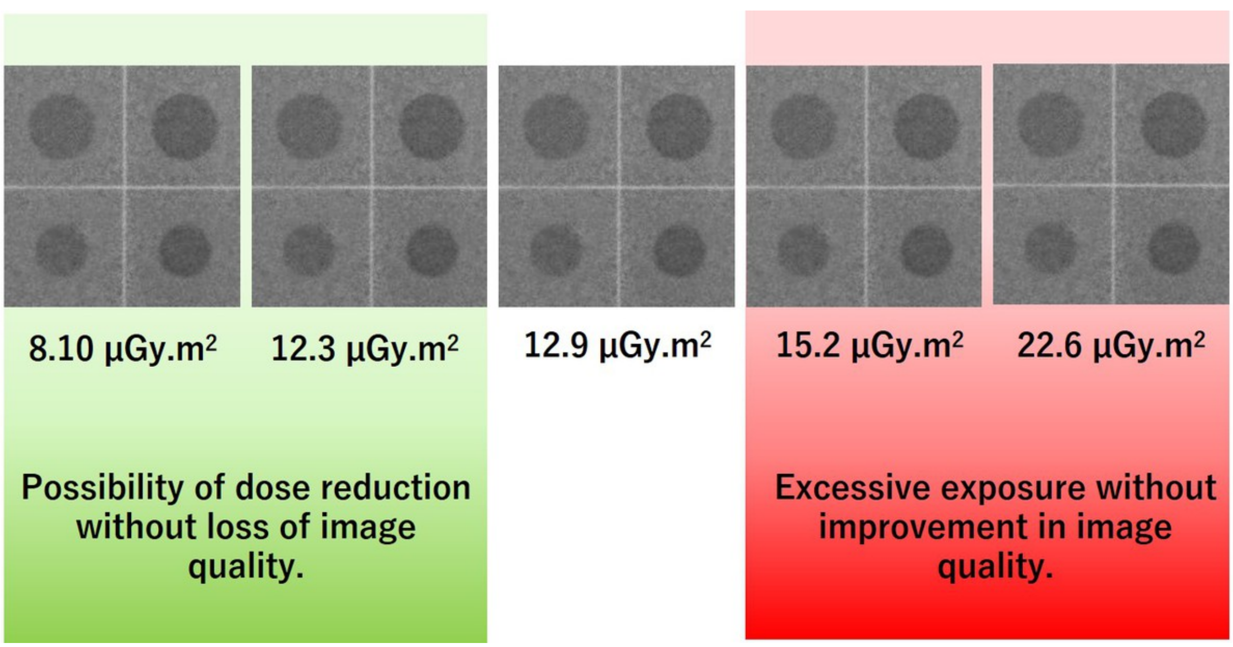

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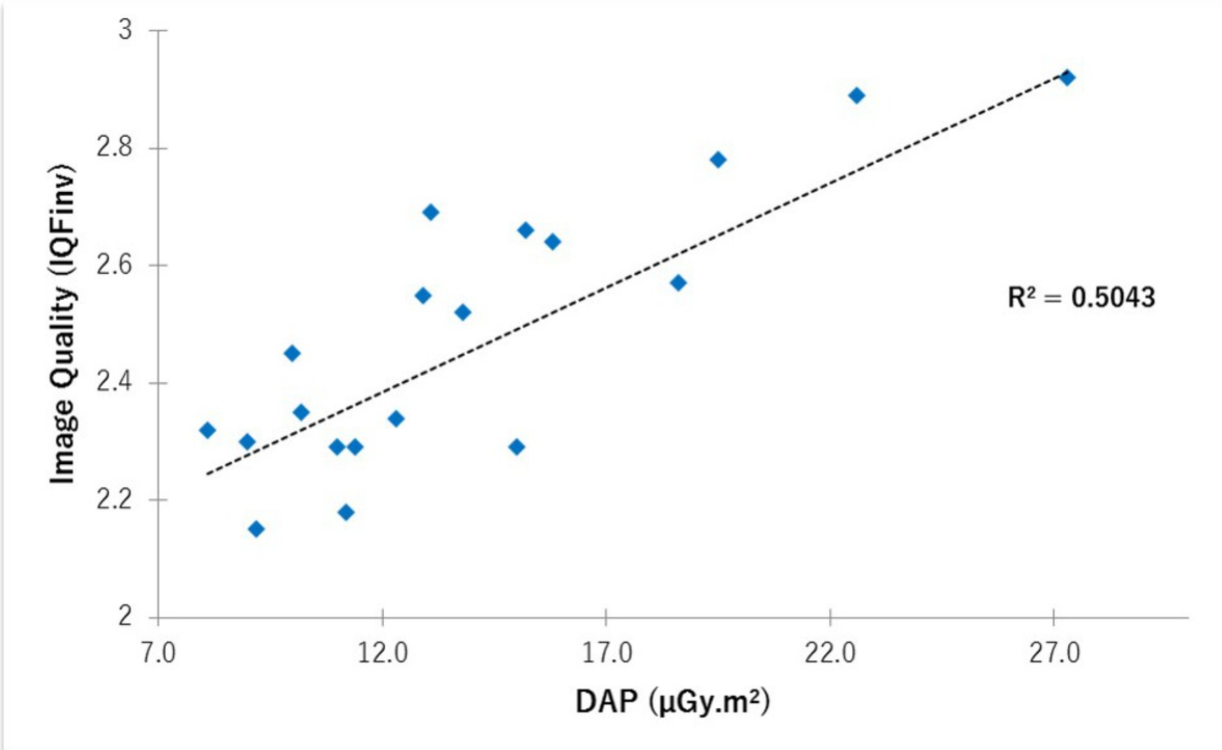

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Personal information

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