

10 kVp rule – an anthropomorphic pelvis phantom imaging study using a CR system: impact on image quality and effective dose using AEC and manual mode

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Background/rationale

- Pelvis and hip radiography are consistently found to be amongst the highest contributors to the collective effective dose (E) in all ten DOSE DATAMED countries in Europe, representing 2.8 to 9.4% of total collective dose (S) in the TOP 20 exams list¹

1. European Commission. Radiation Protection N° 154 European Guidance on Estimating Population Doses from Medical X-Ray Procedures [Internet]. 2008.

Available from: http://ddmed.eu/_media/background_of_ddm1:rp154.pdf

Background/rationale

- The level of image quality should provide all the diagnostic information in order not to jeopardise the diagnosis, but being able to provide the needed clinical information with the minimum dose²

2. Martin CJ. Management of patient dose in radiology in the UK. Radiat. Prot. Dosimetry [Internet]. 2011 Nov [cited 2012 Mar 26];147(3):355–72. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/22008582>

Background/rationale

- A recent study³ suggests further research to determine whether the “10 kVp rule” would have value for a range of examinations using Computed Radiography (CR) systems

3. Allen E, Hogg P, Ma WK, Szczepura K. Fact or fiction: An analysis of the 10 kVp “rule” in computed radiography. *Radiography* [Internet]. 2013 Aug [cited 2013 Nov 16];19(3):223–7.

Available from: <http://linkinghub.elsevier.com/retrieve/pii/S1078817413000497>

Background/rationale

- As a “rule of thumb” increasing the kVp by 10 whilst halving the mAs is suggested to give a similar perceptual image quality when compared to the original exposure factors

Aims

- In light of the 10kVp rule, this study aims to investigate the influence of tube potential (kVp) variation in relation to perceptual image quality and E for pelvis imaging using automatic exposure control (AEC) and non-AEC in a Computed Radiography (CR) system

Research questions

- Does the 10kVp rule works for the pelvis in relation to image quality in a CR system?
- Does the image quality differs when the AEC is used instead of manual mode using the 10kVp rule and how this impacts on E?

Method

- To determine the kVp variation using AEC and non-AEC - the 10 kVp rule - on perceptual image quality and E a series of X-ray images were produced
- This study used a similar methodology to previous studies in chest radiography^{3,4}

3. Allen E, Hogg P, Ma WK, Szczepura K. Fact or fiction: An analysis of the 10 kVp “rule” in computed radiography. *Radiography* [Internet]. 2013 Aug [cited 2013 Nov 16];19(3):223–7.

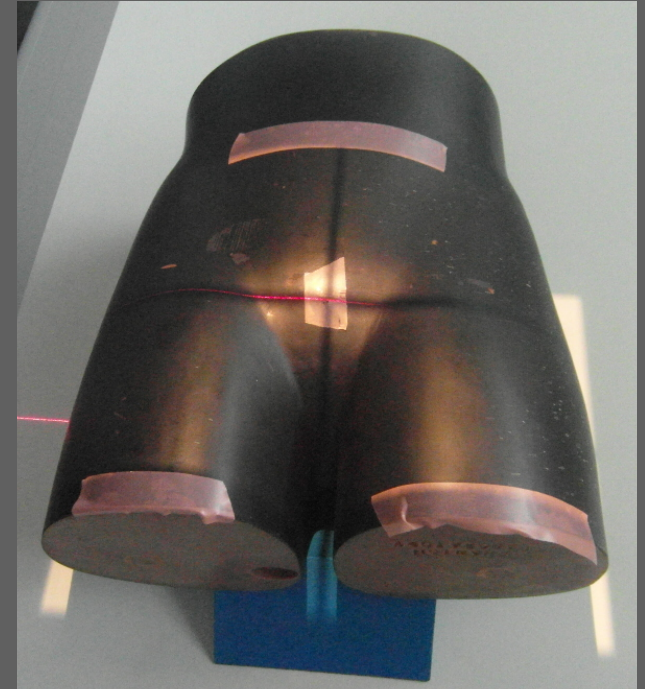
Available from: <http://linkinghub.elsevier.com/retrieve/pii/S1078817413000497>

4. Ma WK, Hogg P, Tootell a., Manning D, Thomas N, Kane T, et al. Anthropomorphic chest phantom imaging – The potential for dose creep in computed radiography. *Radiography* [Internet]. 2013 Aug [cited 2013 Nov 18];19(3):207–11.

Available from: <http://linkinghub.elsevier.com/retrieve/pii/S1078817413000424>

Method

- A quantitative experiment was undertaken using a Rando® SK250 sectional lower torso anthropomorphic phantom
- Pilot study
 - test the x-ray tube performance and CR images output
 - explore the range of parameters for the each experiment from an objective and perceptual approach



Experiments

Images were acquired using 10kVp increments:

kVp	60	70	80	90	100	110	120
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Images were produced with fixed:

- Source image distance (110 cm SID),
- 35x43cm collimation,
- Anti-scatter grid and
- Broad focus spot

Experiments

To determine the effects of using AEC and non AEC with 10 kVp rule **two experiments** were conducted

First experiment:

Using the seven AEC combinations with each kVp value

49
Images

Second experiment:

The mean mAs from each kVp increment were used as a baseline. These had increments and decrements calculated using percentiles of 25% assessing the 10 kVp rule influence on perceptual image quality and effective dose (E)

35
Images

Reference image for the 2AFC

84 Images were produced

Pelvis Regions: left and right

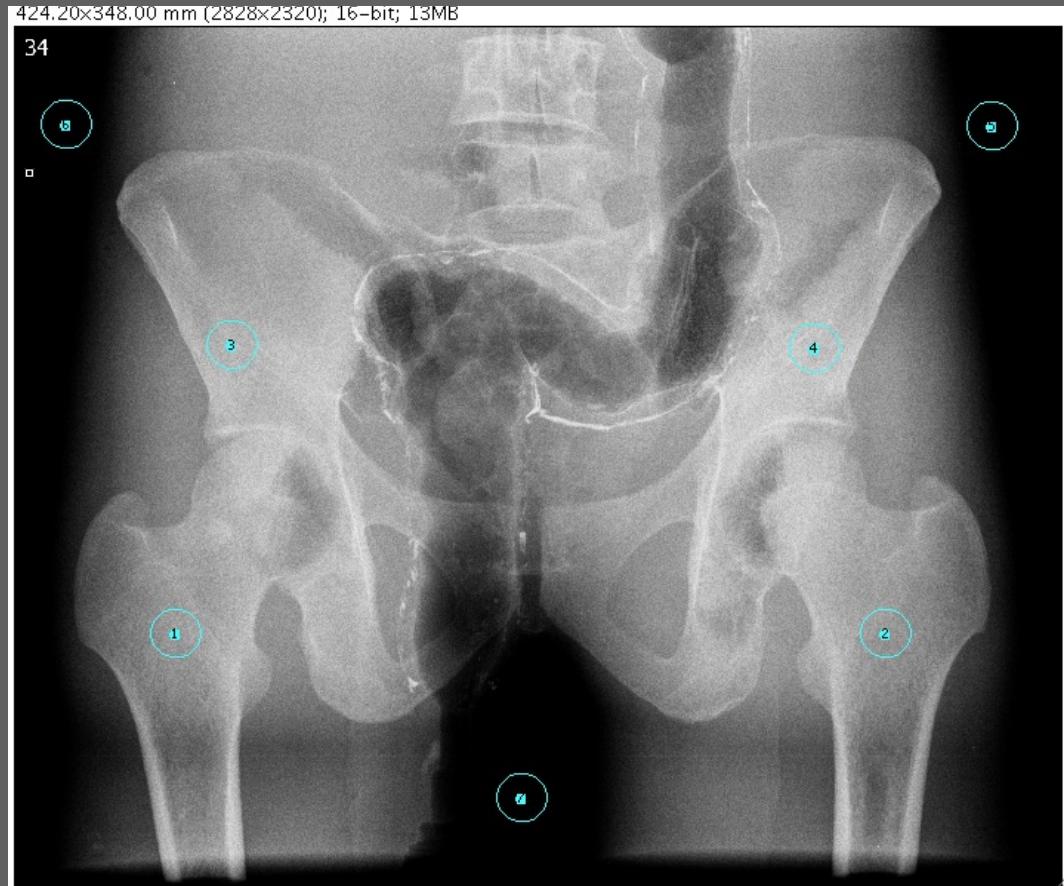
(ROI 1) : Iliac

(ROI 2) : Inter-trochanter

ROI 1 – ROI 2 = pixel value

> Reference Image

The identified reference image (#34) was performed using all AEC chambers, at 90 kVp and 11.2 mAs and an E of 0.104mSv



Perceptual image quality assessment and scoring

- To score the images, the observers used 2AFC software allowing the images being displayed on a dual monitor system, mimicking a reporting station
- The images were displayed on two LCD monitors with a 1.8 megapixel resolution calibrated to DICOM GSDF (luminance of >170 cd/m²) and a low level lighting was used in the viewing area

Image quality evaluation

- 5 experienced observers
- 2AFC software was used to score the images

	Categories	Item #
Anatomic region	Right hip 5 items	<p>2. The right lesser trochanter is visualised adequately</p> <p>3. The right hip joint is adequately visualised</p> <p>5. The right iliac crest is visualised adequately</p> <p>6. The right greater trochanter is visualised adequately</p> <p>11. The right femoral neck is visualized adequately</p>
	Left hip 5 items	<p>1. The left hip joint is adequately visualized</p> <p>4 The left greater trochanter is visualised adequately</p> <p>7. The left iliac crest is visualised adequately</p> <p>8. The left lesser trochanter is visualised adequately</p> <p>9. The left femoral neck is visualised adequately</p>
Noise	Noise perception 1 item	10. There is a significant amount of noise in this image

Table 1: Image Quality Scoring
Criteria

Image quality evaluation

- Perceptual image quality was evaluated using 2AFC method using a psychometric scale⁵

1	2	3	4	5
much worse than	slightly worse than	equal to	better than	much better than

5. Mraity H, Hogg P. Development and Validation of a Psychometric Scale for Assessing Pelvis Image Quality. University of Salford; 2013.

Effective dose (E) estimation

- Monte Carlo simulation software (PCXMC) was used to calculate the E from the dose area product (DAP) and the acquisition parameters.
- Effective dose (E) data were analysed in the two experiments to statistically describe the effect of independent variables such as kVp and mAs in effective dose at the different kVp settings.

Statistical analysis

- SPSS software (version 21.0)
 - Descriptive statistics (e.g. average) were used to provide a quantitative measure of image quality
 - A one-way between groups analysis of variance (ANOVA) at a 5% level was conducted to any significant difference between tube potentials concerning image quality score and E

Image quality score (%)

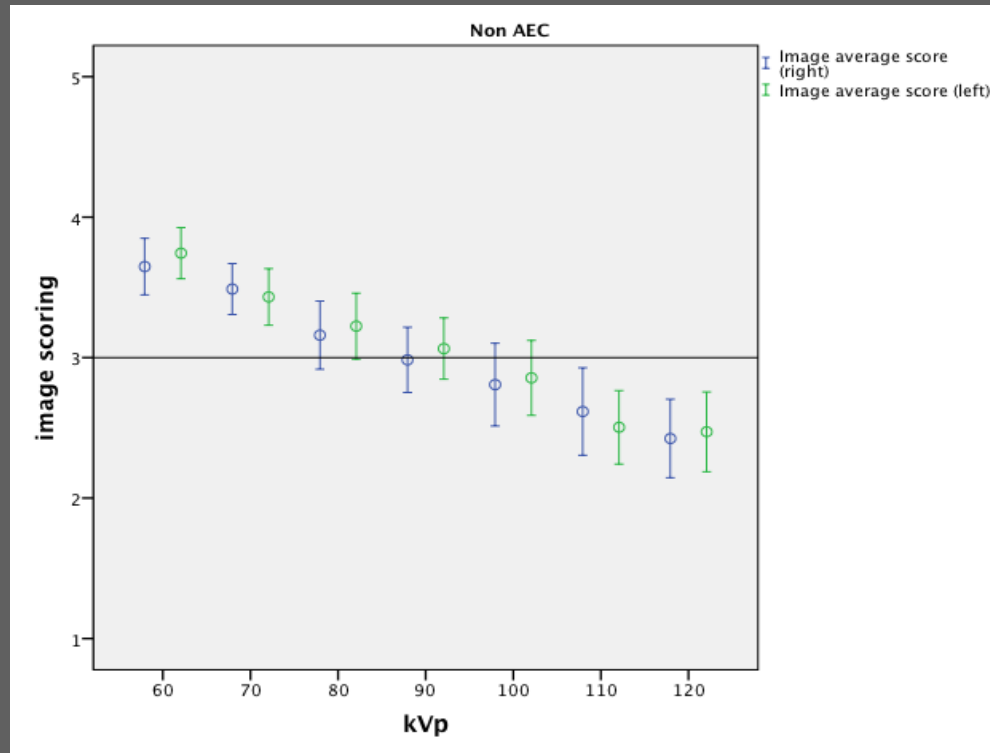
		kVp						
		60	70	80	90	100	110	120
Max image quality global score %	Non AEC	94	84	92	80	80	80	80
	All	78	84	76	R	80	58	60
	Right	96	82	80	80	60	60	60
	Left	100	84	76	76	60	62	56
	Centre	80	78	80	60	60	60	54
	Right/Centre	82	78	74	68	62	62	60
	Left/centre	90	80	66	60	60	60	56
	Upper	90	78	68	62	76	62	60

- A decrease in perceptual image quality as the kVp increases was observed both in non-AEC and AEC experiments
- No significant statistical differences ($p > 0.05$) were found

Image quality score (%)

		kVp						
		60	70	80	90	100	110	120
Average image quality global score % (sd)	Non AEC	73,9 (8,8)	69,2 (8,9)	63,8 (11,3)	60,5 (10,3)	56,6 (13,4)	51,2 (13,6)	49,0 (13,3)
	All	71,6 (7,9)	70,8 (11,4)	65,6 (7,1)	R	60,8 (14,2)	53,2 (4,6)	48,8 (6,4)
	Right	77,2 (12,5)	70,0 (12,2)	71,6 (8,9)	68,4 (13,2)	56,4 (2,6)	56,8 (3,0)	53,6 (6,2)
	Left	77,2 (17,8)	70,0 (11,7)	62,4 (9,9)	60,4 (10,6)	56,4 (3,3)	50,2 (8,0)	48,0 (6,3)
	Centre	73,2 (8,4)	67,2 (6,9)	67,2 (7,6)	58 (2,0)	55,6 (3,8)	46,8 (9,7)	48,0 (5,8)
	Right/Centre	72,8 (10,5)	71,2 (8,3)	66,4 (6,5)	62 (7,1)	56,8 (4,6)	51,6 (8,6)	49,2 (7,4)
	Left/centre	75,2 (11,4)	67,2 (8,4)	61,6 (4,3)	56,8 (5,0)	57,6 (1,7)	51,2 (6,7)	46,0 (7,6)
	Upper	72,8 (14,0)	68,8 (8,9)	64,8 (2,3)	58 (5,8)	59,2 (10,3)	54,8 (6,4)	47,6 (8,9)

Image quality score – against reference image



- Image quality scores from all observers at 10 kVp increments for all mAs values using non-AEC mode demonstrates a better score up to 90kVp

Image quality score – against reference image

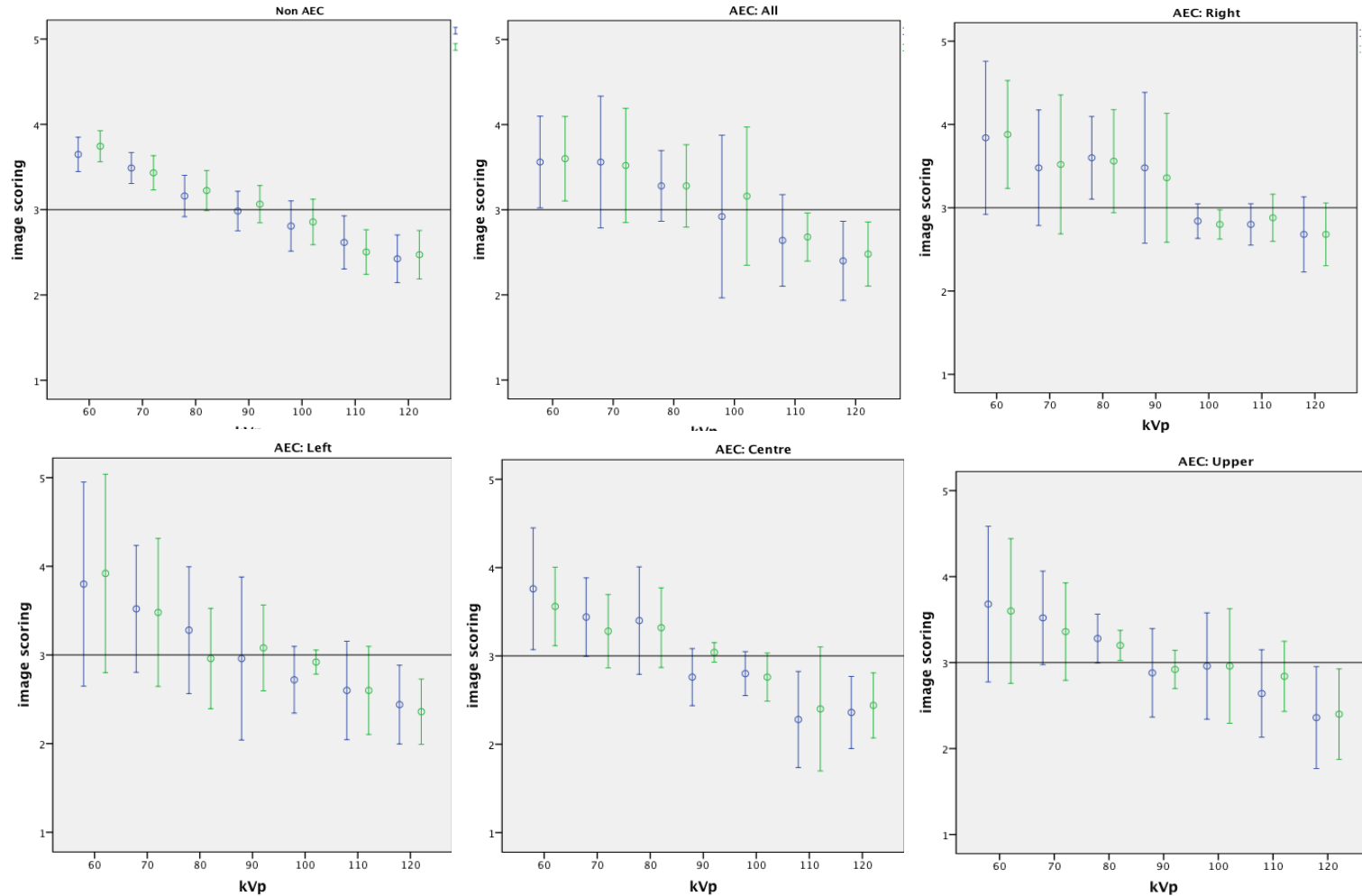


Image Noise

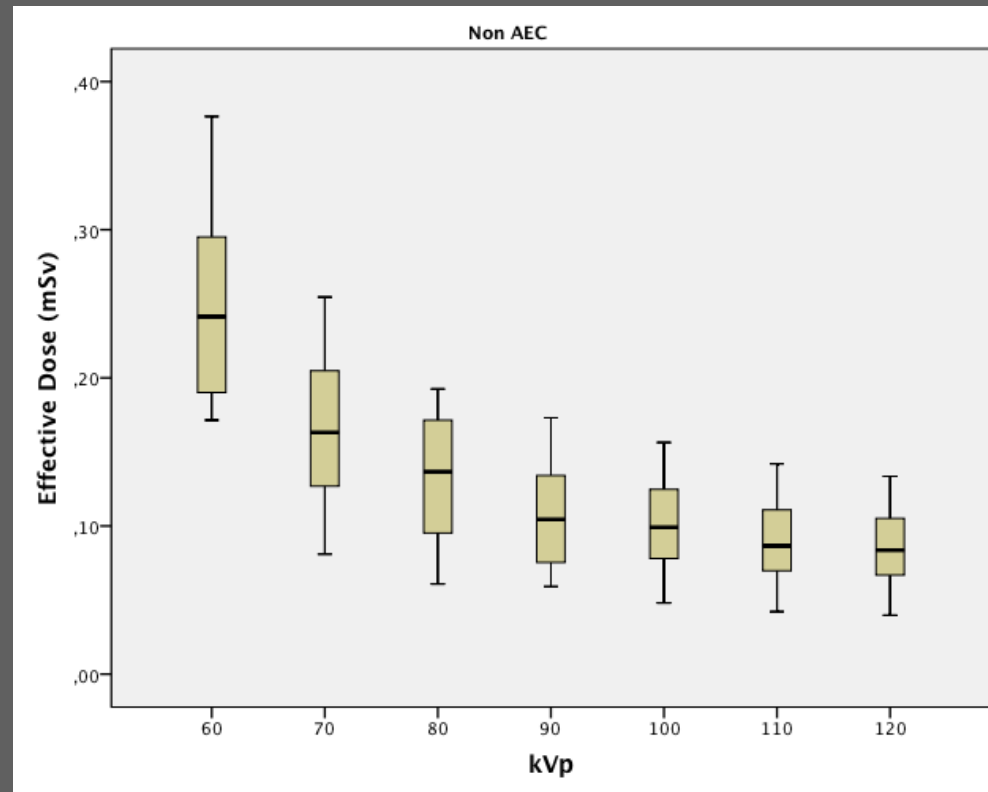
- Observers answered to the item number 10: “There is a significant amount of noise in this image”
 - The mean value ranges from 2.8 to 3.2 in a 5 point scale
 - The noise was perceived by 5 observers in all assessed images as very similar and with no important variations from the reference image

Image Quality

- In regard of image quality scores, no statistically significant differences were observed in manual mode and in five possible AEC combinations ($p \geq 0.05$)
- Using all AEC chambers combinations and also the left chamber a statistical significant difference was found ($p < 0.05$) for image quality differences between tube potentials

Effective dose

- A decrease on the 75th quartile effective dose from 0.37 mSv at 60 kVp to 0.13 mSv at 120kVp is observed
- A decrease is also observed in all AEC combinations from 60 kVp to 120 kVp
- The higher E at 60 kVp is found while using the right chamber (0.30 mSv) and the lower using the left (center combination) (0.22 mSv)
- At 120 kVp the values are substantially lower ranging from 0.08 mSv (right chamber) to 0.07 mSv (central chamber)



Effective Dose

- Concerning E, statistically significant differences ($p=0.000$) were observed at all tube potential variation in non-AEC mode and in three AEC mode combinations: left; centre; and left/centre

Discussion

- A decrease in perceptual image quality as the kVp increases was observed both in non-AEC and AEC experiments
 - No significant statistical differences ($p > 0.05$) were found except in two chamber combinations
- Image quality scores from all observers at 10 kVp increments for all mAs values using non-AEC mode demonstrates a better score up to 90kVp

Discussion

- E results show a statistical significant decrease ($p=0.000$) on the 75th quartile when applying the 10 kVp rule
- Although no relationship between image quality and E was tested in this study, maximum image quality global score ranges are similar at 60kVp and 120kVp as data identifies the same perceptual differences while a marked reduction in effective dose is observed while applying the 10 kVp rule

Discussion

- The data was acquired using Agfa CR system
- It cannot be used to generalize to other manufacturers or equipments
- Further research should be performed using equipment from different manufacturers and also different technologies such as DR (digital radiology) systems

Conclusions & take-home messages

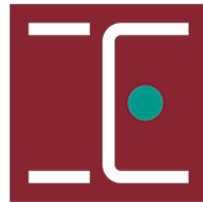
- Anthropomorphic pelvis phantom images with the non-AEC combinations demonstrated that the 10 kVp rule improves image quality when using Agfa CR image receptor
- AEC combinations also demonstrate an improvement in image quality with increments of 10kVp up to a threshold of 90kVp
- No significant reduction in perceptual image quality is observed when increasing kVp whilst a marked and significant effective dose reduction is observed

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