Radiography 29 (2023) 870–877

Contents lists available at ScienceDirect

Radiography

journal homepage: www.elsevier.com/locate/radi

Optimisation of exposure parameters using a phantom for thoracic spine radiographs in antero-posterior and lateral views

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ARTICLE INFO

Article history:
Received 3 April 2023
Received in revised form
19 June 2023
Accepted 20 June 2023

Keywords:
Plain radiography
Source-to-detector distance
Beam energy
Beam intensity
Radiographers

ABSTRACT

Introduction: To investigate the exposure parameters for thoracic spine/(TS) radiography that allows the image acquisition at the lowest dose possible, while maintaining an adequate image quality/(IQ) to identify all relevant anatomical criteria.
Methods: An experimental phantom study was conducted, and 48 different radiographs of TS (24 AP/24 lateral) were acquired. The Automatic Exposure Control/(AEC) with the central sensor was used to select the beam intensity, while Source-to-Detector-Distance/(SDD) (AP:115/125 cm; Lateral:115/150 cm), tube potential (AP:70/81/90 kVp; Lateral: 81/90/102 kVp), use of grid/no grid and focal spot (fine/broad) were manipulated. IQ was assessed by observers with ViewDEX. Effective Dose (ED) was estimated using PCXMC2.0 software. Descriptive statistics paired with intraclass correlation coefficient (ICC) were applied to analyse data.
Results: The ED increased with a greater SDD for lateral-view, presenting a significant difference ($p = 0.038$), however IQ was not affected. For both AP and lateral, the use of grid had a significant effect on ED ($p < 0.001$). Despite the images acquired without grid had lower IQ scores, the observers considered the IQ adequate for clinical use. A 20% reduction in ED (0.042mSv–0.033 mSv) was observed when increasing the beam energy from 70 to 90 kVp for AP grid in. The observers ICC ranged from moderate to good (0.5–0.75) in lateral and good to excellent (0.75–0.9) for AP views.
Conclusions: The optimised parameters in this context were 115 cm SDD, 90 kVp with grid for the best IQ and lowest ED. Further studies in clinical setting are necessary to enlarge the context and cover different body habitus and equipment.
Implications for practice: The SDD impacts on dose for TS; Higher kVp and grid are necessary to better image quality.

Introduction

The thoracic spine is often affected by trauma, arthropathy, neoplasms, metabolic diseases and congenital deformities, which require medical imaging examinations to diagnose and to follow up these disorders.[1] The choice of the imaging modality depends on the clinical situation, available resources and treatment options.[2] Computed tomography (CT) and magnetic resonance imaging (MRI) are sensitive in assessing spinal disorders.[3] However, these imaging methods are not always available, MRI is expensive and requires longer acquisition times,[2,4] while CT involves typically higher radiation dose compared to plain radiography.[5,6] Plain

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https://doi.org/10.1016/j.radi.2023.06.009
1078-8174/

radiography is an advantageous modality for thoracic spine assessment due its accessibility, low cost and low dose required and it is useful in assessing skeletal alignment, trauma and arthropathies.[2,7] It is important to highlight that patients who requires thoracic spine radiography due to spinal arthropathy suspicion are typically older (60–70 years old),[7] while cases of spinal trauma usually affect the younger populations (20–50 years-old),[8,9] which is a concern because the younger population is more radiosensitive. Therefore, it is critical to optimise the image acquisition to ensure that patients receive the lowest possible radiation dose, while the relevant anatomical structures are still visible to detect the abnormalities.[10] Additionally, the thoracic spine is located near by the breast tissue, and this is one of the most radiosensitive anatomical structures, particularly in the female population. Furthermore, the images must be of adequate quality to allow the detection of fracture lines, particularly in the older population with less dense bones and less tissue contrast.[11] To achieve this balance between dose and image quality, patient positioning, beam energy and intensity, focal spot, use of a grid, collimation, source-to-detector distance (SDD) and additional filtration must be carefully selected and combined.[12]

The objective of this study was to identify the ideal exposure parameters (SDD, focal spot, use of grid, and beam energy) for thoracic spine radiography, while optimising the dose and the IQ balance.

Methodology

For this research, an experimental phantom study was conducted. The research was performed in 4 phases: 1. Image acquisition, 2. Effective dose estimation, 3. Perceptual image quality assessment and 4. Data analysis.

Ethical approval was not required by the University of Ljubljana to carry out this study as it was conducted with a phantom in a controlled environment and not in a clinical setting with real patients. For the third phase (perceptual image assessment), all participants signed an informed consent form prior to taking part in the assessment. All responses were anonymous, and submissions were in compliance with the General Data Protection Regulation (GDPR).

Image acquisition

An anthropomorphic phantom PBU 60 (Kyotokagaku Co., Ltd, Japan), which represents a human of 160 cm in height and 50 kg in weight, was used to produce anteroposterior (AP) and lateral thoracic spine radiographs (Fig. 1). The images were acquired on a Siemens Multix/Vertix (Siemens, Germany) unit. Prior to the study, quality control (QC) tests of tube voltage accuracy, reproducibility, half-value layer, current time product linearity, tube output, total filtration and the dose area-product (DAP) were performed. In the study, a fine focal spot of 0.6 mm and a broad focal spot of 1.0 mm were used. Total filtration of the beam was 2.5 mm of Aluminium. Images were obtained using two different grids, one focused for SDD 115 cm, with a ratio of 12:1, 40 lines per centimetre and one focused for SDD 150 cm with a ratio 13:1 and 70 lines per centimetre. The digital detector was composed by Amorphous Silicon with a thin-film transistor (TFT) array and a pixel matrix of 2560 × 3072 with pitch of 140 μm. A constant collimation for the AP projection (43.0 × 13.9 cm) was applied. Due to the diverging X-ray beam, the collimation had to be adjusted for the lateral projection, using 17.1 × 43cm with 115 cm SDD and 16.8 × 41.7 cm with 150 cm SDD. By manipulating different parameters (SDD, kVp, focal spot size, use of grid), 48 different radiographs of thoracic spine (24 AP and 24 lateral) were acquired, and each exposure was repeated three times

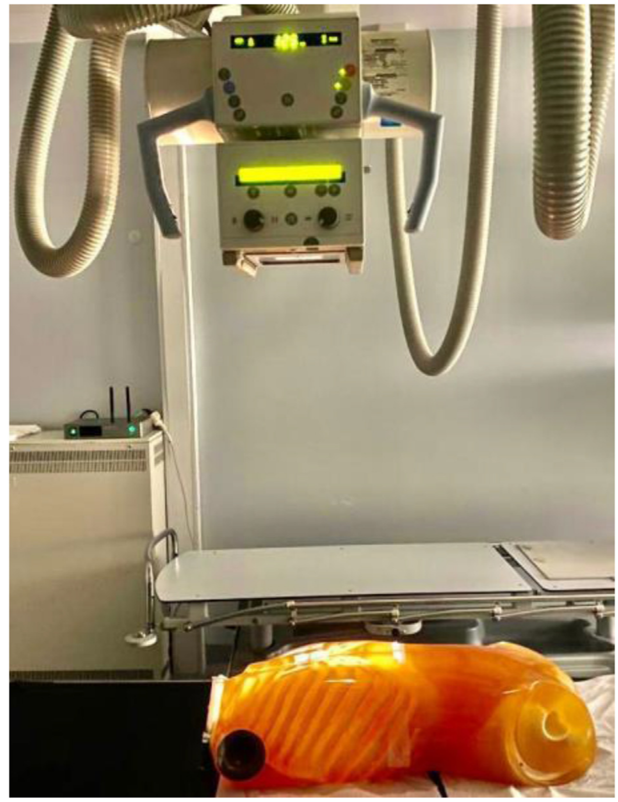

Figure 1. Phantom positioning during image acquisition for antero-posterior projection at Source-to-Detector Distance of 125 cm.

to observe the consistency of the system. The central sensor of the Automatic Exposure Control (AEC) was used for the acquisition of all radiographs (Table 1; Fig. 1). The exposure parameters were selected according to the published literature,[13–15] namely for the selection of beam energy range (see Fig. 2).

Effective dose estimation

The effective dose (ED) was estimated using the PCXMC 2.0 software, a Monte Carlo based program, and the tissue weighting factors were based on the International Commission on Radiological Protection (ICRP) 103.[15–18] The estimation was performed considering the different parameters that were manipulated during the acquisition as explained in the above section. These include beam energy (kVp), average beam intensity (average mAs), focal-skin distance, beam size (collimation field), beam placement and inherent filtration (1.5 mm Al + 1 mm in the collimator), different positioning (AP and Lateral), SDD and "adult" setting.[15] All these variables were established using mathematical probabilities of the interactions between photons and the phantom's body, such as the photoelectric effect, coherent scattering and incoherent scattering.[17] For the simulations, a maximum energy of 150 keV and 20,000 photons were used.

Image quality assessment

Perceptual IQ assessment was performed using the software "Viewer for digital evaluation of X-ray images" (ViewDEX).[19–21] ViewDEX is an image viewer that can be used for different image evaluation tasks and, in this study, it was used for Visual Grading Analysis (VGA).[19,20] The program was developed to support studies for protocol's optimisation. ViewDEX supports

Figure 2. Example of radiography used for image quality assessment (acquired in lateral position at 115 cm SDD, broad focus, 81 kVp beam energy, with grid in).

DICOM images, this is another reason to choose this program for this research.[19,20] Before the assessment, the program was set up with the images and the criteria used to analyse them (Table 2). The criteria were based on previous studies[15,17,22] and a 4-Likert scale was selected to score the images, which was adapted to the four groups of details analysed (anatomy, noise, overall image quality and contrast). Finally, a close-ended question was used to let

Table 1
Protocols used for image acquisition (positioning, beam energy and intensity, focus, grid in/out).

Projection (AP/lateral)	SDD (cm)	kVp	Focus	mAs (AEC)	Grid
AP	115	70	fine	11.7	In
				3.13	Out
			broad	11.9	In
				3.14	Out
		81	fine	6.12	In
				1.72	Out
			broad	6.25	In
				1.7	Out
		90	fine	4.26	In
				1.27	Out
			broad	4.34	In
				1.24	Out
	125	70	fine	14.7	In
				3.76	Out
			broad	1.5	In
				3.78	Out
		81	fine	7.65	In
				2.03	Out
			broad	7.82	In
				2.04	Out
		90	fine	5.33	In
				1.48	Out
			broad	5.45	In
				1.47	Out
Lateral	115	81	fine	4.14	In
				1.57	Out
			broad	4.13	In
				1.52	Out
		90	fine	3.31	In
				1.16	Out
			broad	3.34	In
				1.1	Out
				1.24	Out
		102	fine	2.17	In
				0.87	Out
			broad	2.18	In
				0.8	Out
	150	81	fine	6.27	In
				2.56	Out
			broad	7.39	In
				2.56	Out
		90	fine	5.03	In
				1.82	Out
			broad	4.31	In
				1.81	Out
		102	fine	3.22	In
				1.25	Out
			broad	3.25	In
				1.23	Out

observers decide if the evaluated image was clinically acceptable (Table 2). Criteria used for VGA are developed based on the assumption that the capacity to reproduce normal anatomical structures is correlated with the possibility of clinically detecting a lesion in radiography, which is normally evaluated with the Receiver Operating Characteristics (ROC) study.[23] However, VGA represents a much easier and faster method to evaluate IQ.

Three experienced radiographers and three radiography students were recruited as observers for the image assessment. These observers were chosen instead of other medical professionals as in a clinical setting, the radiographer is the professional responsible for deciding if an image is diagnostically acceptable by ensuring the clinical question posed in the request can be answered. This is done by assessing overall image quality and the visibility of all relevant anatomical structures.[15]

Before starting the task, the observers were asked about their eye's health and their experience in radiography. They were also informed and coached about how the assessment would be carried out, the assessment method and the functionalities of ViewDEX program. Participants were asked to focus on the middle region of the thoracic spine during the assessment because that was where IQ was homogeneous to ensured consistency across the observers with regard to the area of assessment. All participants were required to sign a consent form to inform them about the study objective, the rules and asking their permission to use the data for research purposes. During the assessment, four computers with the same diagnostic monitor model (DELL P2414H) were used. Both ambient lighting (10 lux)[24] and resolution (1920 × 1080 pixels) conditions were kept constant to simulate clinical conditions and to ensure consistency between observers. Participants were not able to zoom in or out of the images and they were not able to change the window level or width to prevent variability in the study.

It was required that all participants sit in front of the monitor approximately 1 m away.[25] The observers assessed 50 images (each radiograph once and one image repeated three times, to observe the consistency of the observer). They were informed that they could take a break when they reached 30 min to help reduce the influence of fatigue on their evaluation. A pilot was conducted prior to the real assessment to ensure the software setup worked and the questions were clear and understandable, while also answering the objective of the study. The feedback and suggestions to improve the assessment were integrated. During the real assessment, the observers were supported by two members of the research team if necessary. Once the study was completed, the results were saved in a log file and used for the statistical analysis, respecting the data security.[20]

Table 2
Observer study assessment criteria for thoracic spine with a 4 points Likert-scale.

Anatomical details			
1. Superior endplates of thoracic vertebrae are:			
1. Not defined	2. Slightly defined	3. Defined	4. Clearly defined
2. Inferior endplates of thoracic vertebrae are:			
1. Not defined	2. Slightly defined	3. Defined	4. Clearly defined
3. Spinous process of thoracic vertebrae are:			
1. Not defined	2. Slightly defined	3. Defined	4. Clearly defined
4. Pedicles of thoracic vertebrae are:			
1. Not defined	2.Slightly defined	3. Defined	4. Clearly defined
5. Intervertebral disc spaces are:			
1. Not defined	2. Slightly defined	3. Defined	4. Clearly defined
Noise			
6. How would you estimate the noise on this radiograph in general?			
A. Excessive noise	B. Prominent image noise	C. Some image noise	D. Limited perceptual image noise
Overall image quality			
7. How would you estimate the image quality in general?			
a. Very poor	b. Poor	c. Adequate	d. Very good
Contrast			
8. How would you estimate the contrast in general?			
a. Very poor	b. Poor	c. Adequate	d. Very good
Clinical acceptance			
9. Would you accept the radiograph?			
Yes		No	

Data analysis

Descriptive statistics analysis was performed using MS Excel program for dose estimation. IBM SPSS statistics version 28.0.1.0 was used to calculate the mean and standard deviation. The p-values for the distance, grid in/out and focus were calculated using the Mann–Whitney U test in SPSS. The p-value for the different energies was calculated using Kruskal–Wallis in SPSS. IBM SPSS was used to calculate the IQ assessment score from the ViewDEX program. The Intraclass Correlation Coefficient (ICC) was calculated to verify the performance of the observers[26] (Table 3).

Visual Grading Characteristics (VGC) analysis were also performed to compare the answers given by the observers for each image acquired with a different protocol, to identify which one was the best regarding quality, being considered a non-parametric rank-invariant statistical method.[28,29] With the VGC Analyser software,[30–33] data was analysed and VGC curves were created. These curves show the comparison of the IQ rating for two different parameters manipulated. In this study, the curves compared the images acquired at a SDD of 115 and 125 cm for the AP views and 115 and 150 cm for the lateral views. Additionally, the curves compare the two distances using Area Under the VGC Curve (AUC). If the AUC_{VGC} 95% Interval Confidence (IC) contains 0.5, it means that the two distances are showing similar outcomes regarding IQ. When the 95% IC AUC_{VGC} does not include 0.5, then the distances are statistically different. In this test, an AUC below 0.5 suggests preference for SDD of 115 cm.[34]

Results

The results chapter will be divided into two different sections - effective dose and image quality assessment.

Table 3
ICC score interpretation applied in this study.[27]

< 0.5	Poor reliability
0.5–0.75	Moderate reliability
0.75–0.9	Good reliability
>0.9	Excellent reliability

Effective dose (ED)

Regarding the impact of SDD on ED for AP views, it was observed that the average dose was 0.023 for a SDD 115 cm and 0.024 mSv for a SDD 125 cm, which is not statistically significant different ($p = 0.453$), while for lateral views the difference was significant ($p = 0.038$), with an increased ED from 0.007 (SDD 115 cm) to 0.009 mSv (SDD 150 cm).

For the AP projection with SDD 115 cm and grid in, the ED lied between 0.033 and 0.042 mSv with an average dose of 0.037 mSv. Similarly, the ED for a SDD 125 cm and grid in lied between 0.043 and 0.034 mSv. Without grid at 115 cm SDD, the average ED was 0.010 mSv varying between 0.010 and 0.009 mSv. For AP with SDD 125 cm without a grid, the ED ranged from 0.011 to 0.009 mSv. For AP grid in and grid out there was a significant difference ($p < 0.001$). The grid removal for image acquisition promoted a decrease of 74% in ED (Fig. 3). For the lateral projection with SDD 115 cm and a grid in, the ED varied between 0.011 and 0.010 mSv; while for a SDD of 150 cm, the ED ranged between 0.013 and 0.012 mSv. Without a grid at 115 cm SDD and 150 cm SDD, the ED was constant (0.004 mSv and 0.005 mSv, respectively). The ED increased with the distance but decreased by 61% when the grid was removed (Table 4). For the lateral grid in and grid out there was also a significant difference ($p < 0.001$).

Increasing the beam energy while keeping the same distance, reduced the ED. The ED for the AP view, with grid in and SDD 115 cm decreased from 0.042 mSv to 0.033 mSv (20% reduction) when the beam energy was increased from 70 to 90 kVp; but the ED difference for the AP view, was not significant ($p = 0.145$). For the lateral view, with the SDD 115 cm and grid in, the ED increased from 0.010 to 0.011 mSv when manipulating the kVp. Although, with grid out, the ED remained constant (0.004 mSv). For SDD 150 cm and grid in, the ED decreased from 0.013 mSv to 0.012 mSv when the energy was manipulated from 81 to 102 kVp. For lateral views, there was not observed a significant difference when beam energy was changed ($p = 0.983$).

Regarding the impact of focal spot-on ED, for the AP and Lateral projections, no significant difference was observed when comparing broad with fine focal spot ($p = 0.977$ and $p = 0.954$, respectively).

Image quality assessment

The image assessment was completed by the six observers (Table 5). The experience of the observers ranged from 1.5 years up to 30 years. The participant observers have previously had their eyes tested, being capable of evaluating the images.

The AP and Lateral projections anatomical criterion analysis by the VGC showed that AUC_{VGC} were approximately 0.5 for the AP and 0.51, which means that they are similar and neither SSD overrides the other. In addition, AUC_{VGC} 95% confidence interval ([0.400856, 0.546690] for the AP and [0.449097, 0.589907] for the lateral) of the two views includes the 0.5 value, which means that they are not statistically different (Fig. 3). The p-value was estimated as 0.478 for the AP and 0.910 for the Lateral views which is statistically no significant. In a similar way, for the IQ criterion of the AP and Lateral views, the results of the AUC_{VGC} curves were estimated at 0.523704 (AP) and 0.467222 (LAT), near to 0.5. As for the anatomical criteria, the IQ criteria values are inside the 95% confidence interval ([0.347802, 0.593452] for the AP [0.443890, 0.652503] for the Lateral). The two results are similar. The p-value corresponds to 0.593 for the AP and 0.337 for the Lateral one, which means that the result is statistically no significant due to the value being above 0.05 for a 95% confidence interval (Fig. 4).

The ICC values ranged from poor (0.151) to excellent ICC (0.906) (Table 6), with higher values observed to the AP view, while for Lateral views the ICC was always inferior, being worst for the criteria 1 and 2 (see Table 7).

The observers ranked IQ from 3.490 to 3.504 for AP views acquired with the grid and 2.587 to 2.729 when the grid was removed. For the Lateral views, the scores were lower and ranged from 3.462 to 3.569 when the grid was in and between 3.073 and 3.087 when the grid was removed (see Table 7).

Most of the observers accepted most of the images acquired (40 out of 48 images) for clinical purposes (Fig. 5).

Discussion

The objective of this study was to find a set of exposure parameters (SDD, focus, use of grid and beam energy) for thoracic spine radiography that allows the acquisition of images with the lowest dose possible, while keeping an IQ that shows all relevant information to facilitate an adequate diagnosis and/or follow up.

The results of this study showed that for AP projection, the ED remained almost the same (increase of 0.001 mSv) when increasing the SDD to 125 cm, presenting no significant difference ($p = 0.453$), which is expectable considering that SDD did not largely varied (115 cm–125 cm). For the Lateral projection, the difference between the two SDD was larger, 115 and 150 cm, conducting to a significant difference ($p = 0.038$) of ED. The ED increased from 0.010 mSv (at 115 cm SDD) to 0.013 mSv (at 150 cm SDD) when the

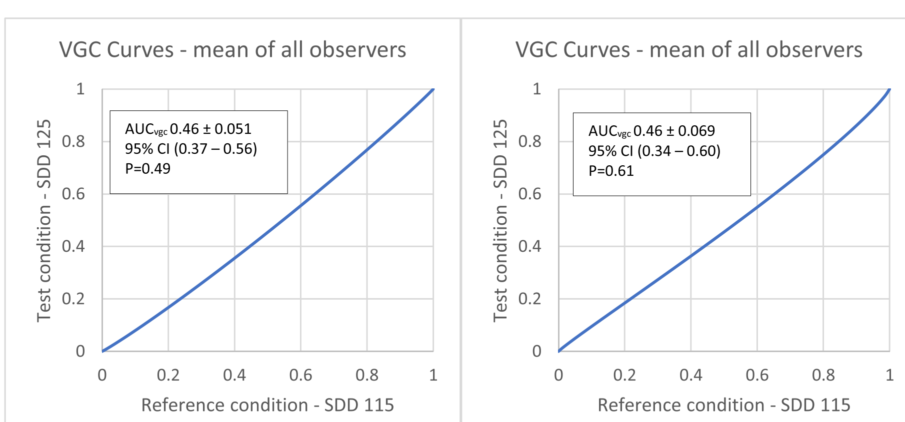

Figure 3. AUC_{VGC} curves comparing a reference condition (SDD 115 cm) to a test condition (SDD125cm) for AP projections.

Table 4
Estimated effective dose (mSv) for all parameters.

Grid	Energy (kVp)	Focus	Antero-Posterior			Lateral		
			SDD 115 cm	SDD 125 cm	Average (mSv)	SDD 115 cm	SDD 150 cm	Average (mSv)
In	**Average**	**IN**	**0.037**	**0.038**	**0.037**	**0.010**	**0.013**	**0.012**
	70	**Average**	0.042	0.043	0.042	–	–	–
		BF	0.041	0.043	0.042	–	–	–
		SF	0.042	0.043	0.042	–	–	–
	81	**Average**	0.035	0.036	0.035	0.010	0.013	0.012
		BF	0.035	0.036	0.035	0.010	0.012	0.011
		SF	0.035	0.036	0.036	0.010	0.014	0.012
	90	**Average**	0.033	0.035	0.034	0.011	0.013	0.012
		BF	0.033	0.034	0.034	0.011	0.013	0.012
		SF	0.034	0.035	0.034	0.011	0.013	0.012
	102	**Average**	–	–	–	0.010	0.012	0.011
		BF	–	–	–	0.010	0.012	0.011
		SF	–	–	–	0.010	0.013	0.011
Out	**Average**	**OUT**	**0.010**	**0.010**	**0.010**	**0.004**	**0.005**	**0.004**
	70	**Average**	0.010	0.011	0.011	–	–	–
		BF	0.010	0.011	0.010	–	–	–
		SF	0.011	0.011	0.011	–	–	–
	81	**Average**	0.009	0.009	0.009	0.004	0.005	0.004
		BF	0.009	0.009	0.009	0.004	0.005	0.004
		SF	0.009	0.009	0.009	0.004	0.005	0.004
	90	**Average**	0.009	0.009	0.009	0.004	0.005	0.004
		BF	0.010	0.010	0.010	0.004	0.005	0.004
		SF	0.009	0.009	0.009	0.004	0.005	0.004
	102	**Average**	–	–	–	0.004	0.005	0.005
		BF	–	–	–	0.004	0.005	0.005
		SF	–	–	–	0.004	0.005	0.004
	Total Average		**0.023**	**0.024**	**0.023**	**0.007**	**0.009**	**0.008**

Table 5
Observer questionnaire results.

Type of observer	How many years of experience in the field of radiography do you have (since beginning your studies)? (years)	Have you ever had your eyes checked?
Radiographers	18	Yes
	30	Yes
	25	Yes
Radiography Students	2	Yes
	1.5	Yes
	2	Yes

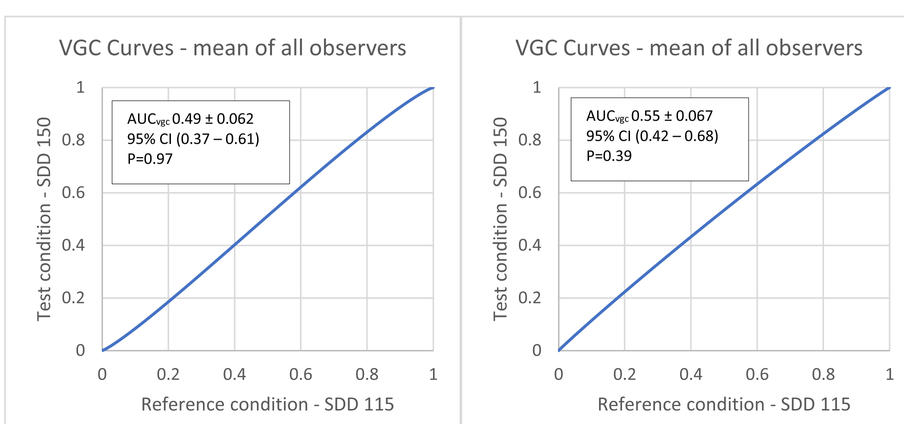

Figure 4. AUC$_{VGC}$ curves comparing a reference condition (SDD 115 cm) to a test condition (SDD 150 cm) for Lateral projections.

distance increased. No previous studies were done, considering the ideal SDD for thoracic spine radiography, only for lumbar spine radiography,[15] but considering the results for ED, the shorter SDD (115 cm) seems more adequate for radioprotection than a higher SDD. The increasing ED is probably due to a small collimation variation which could explain these results. The increasing ED is not expected considering the inverse square law,[12,35] even if the AEC system must adjust the exposure parameters to keep the same signal level on the detector.[36]

Scatter radiation is a known contributor to reducing contrast which impacts the detection of low contrast lesions such as fractures in elderly populations and a grid should be used to improve

Table 6
ICC values for each criterion assessed during image quality evaluation.[27]

Criteria	View	ICC	Confidence interval		ICC Meaning
Question 1	AP view	0.894	0.815	0.946	good to excellent
	LAT view	0.466	0.050	0.739	poor to moderate
Question 2	AP view	0.885	0.800	0.942	good to excellent
	LAT view	0.407	0.056	0.710	poor to moderate
Question 3	AP view	0.906	0.836	0.952	good to excellent
	LAT view	0.742	0.540	0.874	moderate to good
Question 4	AP view	0.872	0.777	0.935	good to excellent
	LAT view	0.673	0.417	0.840	poor to good
Question 5	AP view	0.857	0.751	0.928	good to excellent
	LAT view	0.504	0.118	0.757	poor to good
Question 6	AP view	0.894	0.815	0.946	good to excellent
	LAT view	0.588	0.267	0.799	poor to good
Question 7	AP view	0.846	0.732	0.922	moderate to excellent
	LAT view	0.676	0.423	0.841	poor to good
Question 8	AP view	0.682	0.446	0.839	poor to good
	LAT view	0.610	0.307	0.809	poor to good

Table 7
Observer study - mean scores for questions 1–8 (anatomy, overall IQ, noise, contrast).

	SDD (cm)	Grid In		Grid Out	
		IQ score mean ± STD	ED (mSv)	IQ score mean ± STD	ED (mSv)
AP	115	3.504 ± 0.666	0.037	2.729 ± 0.571	0.010
	125	3.490 ± 0.678	0.038	2.587 ± 0.667	0.010
Lateral	115	3.462 ± 0.672	0.010	3.087 ± 0.748	0.005
	150	3.569 ± 0.598	0.013	3.073 ± 0.692	0.005

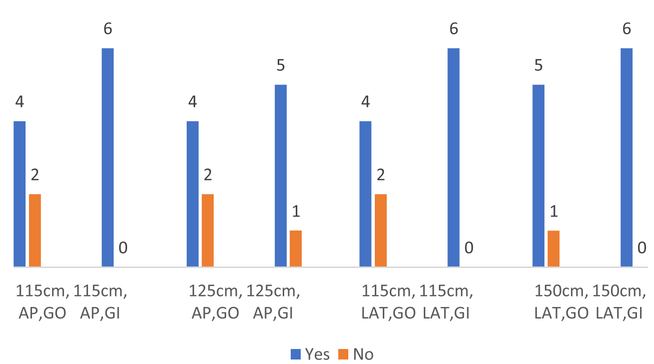

Figure 5. Answers provided by the observers when asked if they accept the image for clinical purposes. GO corresponds to Grid Out and GI to Grid In; AP – Antero-Posterior and LAT – Lateral Views.

IQ. This scatter radiation adds to the patient's dose but does not contribute to the signal to form the radiographic image. The higher the energy used, the higher the amount of radiation that scatters. Therefore, it was expected that the use of a grid had a significant impact on IQ ($P < 0.001$ for AP and lateral). In the AP projection, the dose decreased by 74% when there was no grid being used, while for the lateral projection, the decrease was 61%.

In this study, when the kVp was increased, while maintaining the same distance and grid in, there was no significant difference ($p = 0.145$ for AP and $p = 0.983$ for Lateral) in the effective dose, which means that to select the ideal parameters IQ assessment is critical, being necessary to choose the images with higher contrast to be able to detect fractures. Concerning the IQ data analysis with VGC analyser, it was shown that there were no significant differences when the distances were changed in lateral ($p = 0.593$) and in AP ($p = 0.337$).

The ICC values showed mostly good to excellent reliability (0.75–0.9) in the AP images, but in the lateral images the reliability of the observers was mostly poor to moderate (0.5–0.75). This may be caused by the difficulty in clear visualization of structures on the lateral images, as they overlap,[37] making it difficult for observers to assess the image quality or the difference reference point used to evaluate the images.[38] Another reason for the moderate reliability among observers could be the differences in clinical experience and knowledge amongst the recruited participants in this study.[39]

The AP and Lateral projection AUC_{vgc} curve values were 0.523704 and 0.467222 respectively, meaning that the images are similar in quality even if the distance has been changed. These results are similar to other studies in literature.[40] Their study found that the increased SDD from 100 to 130 cm reduced the radiation dose significantly with no significant effect on image quality. Tugwell and co-workers (2014)[41] demonstrated in their study of AP pelvis imaging that there is no significant difference between IQ when increasing source to image distance (SID) from 110 to 140 cm.

Regarding the impact of the grid, the average score of IQ without the grid was lower (2.73) than the score given for the images with the grid (3.50). However, the result of question 9 (do you accept the image for clinical purpose?) showed that in the case of the radiographs without the grid, most of the images (40/48) were accepted by the observers even if the quality was not as good as the one with the grid. This result shows that, according to the observers, even if the image is scored lower, it could still be used for clinical practice.[42]

This study faced several limitations. Firstly, the use of an anthropomorphic phantom restricted the simulation of diverse body types, such as individuals with higher Body Mass Index or paediatric patients. The simulation solely focused on the radiation absorption properties and scatter production of a standard adult body habitus. Consequently, the impact of these factors on image quality could not be accurately assessed. Furthermore, the anthropomorphic phantom did not incorporate any pathological features and in the majority of contexts, not only the anatomy is assessed but also the low contrast lesions that can be present on the images. To address these limitations, it is recommended to include real patient images featuring different types of lesions (low contrast details). Additionally, conducting receiver operating characteristic analysis can help determine the system's capabilities and limitations in detecting major pathologies.

The X-ray equipment utilised in the study was not "ceiling mounted," which limited the ability to manipulate different SDDs. Only two focused grids (115 cm and 150 cm) were available for use, preventing the evaluation of the influence of different grid properties (such as type, grid frequency, interspace materials, and grid ratio). Another constraint is the observers' study, as it was conducted in a controlled "reading lab" environment. This setting is not fully representative of the working conditions in a real radiography department.

Conclusion

The objective of this study was to investigate the ideal exposure parameters for thoracic spine radiography for optimal image quality and dose, with a focus on the SDD. It was shown that dose increases when the SDD increases, however, image quality does not degrade when the SDD increased. It can therefore be concluded that the preferable SDD for thoracic spine radiography is 115 cm as the image quality is the same and the patient dose is lower than with an SDD of 125 cm or 150 cm.

Future research should consider analysing real patient data, including different body habitus mainly obese, different pathologies, and applying real clinical conditions for a more realistic assessment.

Acknowledgements

The authors would like to thank the support from all students and tutors that participated in our study, namely to the observers, to Prof. Nejs Mekis for his availability during the Optimax summer school and to the University of Ljubljana for making this summer school possible.

Conflict of interest statement

None of the authors has a conflict of interest.
Cláudia Sá dos Reis (on behalf of all the authors).

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