Iranian Journal of Medical Physics

ijmp.mums.ac.ir

Image Quality and Entrance Surface Dose Evaluation of Lateral Cervical Spine: A Study Using Grid and Non-Grid Techniques

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ARTICLE INFO

Article type:
Original Article

Article history:
Received: Oct 23, 2017
Accepted: Feb 15, 2018

Keywords:
Cervical Vertebrae
Digital Radiography
Image Quality
Radiation Dosage

ABSTRACT

Introduction: The purpose of this study is to investigate the effects of grid and non-grid techniques in the lateral cervical spine radiography on image quality and entrance surface dose (ESD). Although image quality and radiation doses have been studied by researchers, there is still a dearth of information on image quality and patient dose with different techniques.

Material and Methods: The radiographs of the lateral cervical spine were acquired by positioning the RANDO phantom abutting the erect bucky while using the grid and non-grid techniques. This study benefited from using a 24 cm x 30 cm Fuji standard cassette type imaging plate. A Leeds TOR test tool was utilized for relative comparison of image quality. The ESD of each examination was determined by using the optically stimulated luminescence dosimeter.

Results: The increased kilovoltage (kVp) resulted in the reduction of ESD whether moving grid, stationary grid, or non-grid techniques were utilized. Significant differences in terms of contrast sensitivity and spatial resolution were indicated when comparing the grid technique to that of the non-grid technique (i.e., χ^2=8 and 5, respectively, $p < 0.05$). The results also indicated significant differences in ESD when using the moving grid, stationary grid, and non-grid techniques (i.e., χ^2=7.2, $p < 0.05$).

Conclusion: Significant differences in image quality and ESD were indicated when grid and non-grid techniques were used in the lateral cervical spine radiography. A non-grid with the highest appropriate kVp is recommended as the air gap acts as a grid, resulting in acceptable image quality with reduction in ESD.

► *Please cite this article as:*
Moey SF, Binti Mohd Ramlee NN. Image Quality and Entrance Surface Dose Evaluation of Lateral Cervical Spine: A Study Using Grid and Non-Grid Techniques. Iran J Med Phys 2019; 16: 166-170. 10.22038/ijmp.2018.33059.1400.

Introduction

Cervical spine X-ray examination is a common radiographic imaging examination employed for assessing the fracture of the cervical vertebrae in trauma and non-trauma cases. The two common radiographic projections of the cervical spine are anteroposterior (AP) and lateral projections. The lateral view of the cervical spine is considered as the most reliable projection in assessing the extent of traumatic injury to the head and neck. The reason for this is that it is a simple, readily available, and cost-effective radiographic projection [1, 2, 3]. Lateral cervical radiographs include images of the cervical vertebral bodies, intervertebral joint spaces, articular pillars, spinous process, and zygapophyseal joints.

The grid is a tool that is used to improve the contrast of the radiographic image by reducing scattered radiation penetration from the image receptor [4]. The utilization of a grid improves the image contrast with increasing patient dose. A grid is employed when the thickness of the imaging body part exceeds 10 cm and 60 kVp [4, 5, 6].

In cervical spine radiography, it has been a standard practice to use a grid in the AP cervical spine projection. However, the practice of using a grid for the lateral cervical spine radiography varies between diagnostic imaging departments and also amongst radiographers within the same department [7]. The utilization of a grid is optional due to the existence of the air-gap in the lateral cervical spine radiography. However, the practice to carry out the lateral cervical spine radiography using a grid is still widely used in some diagnostic imaging departments in Malaysia. When a grid is utilized, improvements in image quality must be balanced with the increased radiation dose. Therefore, this study aims to investigate the effects of moving grid, stationary grid and non-grid techniques in the lateral cervical spine radiography on image quality and entrance surface dose (ESD). The findings of the current study can help radiographers adopt appropriate techniques for the lateral cervical spine projection.

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Table 1. Details of imaging parameters used for the lateral cervical spine projection

Imaging parameters	Details
Kilo-Voltage peak (kVp)	60, 66, 70, 75, 81
Imaging plate size (cm)	24 x 30, lengthwise
Central ray	Perpendicular to the center of IR, midsagittal plane at the level of C4
Source to image distance (cm)	150
Focal spot	Large focal spot (1.0 mm)
Grid (grid ratio)	Moving grid, 12:1; Stationary grid, 8:1; Non-grid
AEC	On (-3)
Chamber	Middle chamber

Materials and Methods

Images of the lateral cervical spine projection using moving grid, stationary grid, and non-grid techniques were acquired in a radiography laboratory at the Kulliyyah of the Allied Health Sciences, International Islamic University Malaysia (IIUM) Kuantan Campus. This experimental study was carried out using a standard X-ray unit, AXIOM Aristos (Siemens, Germany), and a 24 cm x 30 cm FCR standard cassette type CC imaging plate (Fujifilm, Japan). The images of the cervical spine using a moving grid were obtained by positioning the RANDO® phantom in the standard lateral cervical spine projection (Fig. 1). The imaging plate was placed in the X-ray erect bucky and the X-ray beam was properly collimated to include the region of interest. The X-ray source was positioned at a distance of 150 cm and the central ray was directed perpendicularly to the imaging plate at the level of C4. The Leeds TOR test tool (Fig. 2) was placed behind the phantom within the collimated field and the optically stimulated luminescence dosimeter (OSLD) was placed on the surface of the central cervical spine before the exposure.

Figure 1. Experimental setup of the phantom for the lateral cervical radiography

Figure 2. Leeds test Tool used for the relative comparison of image quality

The OSLDs used in this study were Landauer nanoDots [Al2O3: C] (Landauer, Japan) which were thin discs with a diameter of 4 mm and a thickness of 0.3 mm. The active dosimeter volume was enclosed in a plastic cassette of 10 × 10 × 2 mm (Fig. 3). All dosimeters were read using a single InLight MicroStar OSL reader (Landauer, Inc., Japan) which was operated in continuous wave mode for seven-second read time in the Radiography Laboratory, IIUM Kuantan. A strong LED beam (low dose) was also used for all readings in this study. For the image acquisition using the stationary grid, the imaging plate was placed on the erect bucky and the grid was placed in contact with the imaging surface of the imaging plate while the grid was removed for the non- grid technique.

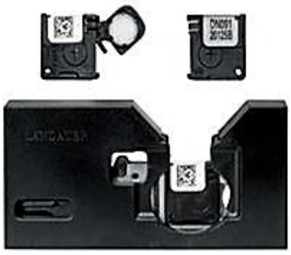

Figure 3. Illustration of a) OSLD nanoDot b) OSLD in situ in the inLight MicroStar Reader

Table 1 summarizes the technical parameters used in this study for the moving grid, stationary grid, and non-grid techniques. As it is shown, the quality of radiographs obtained in the configuration was evaluated in terms of high-contrast sensitivity, low-contrast sensitivity, and spatial resolution. The ESD was obtained by using OSLD for each projection using the technical parameters outlined in Table 1. Three readings for each projection were undertaken and the mean ESD obtained.

Statistical Analysis

The data was analysed using the IBM Statistical Package for Social Sciences (SPSS), version 20. The Kruskal-Wallis test was utilized to find the significant differences of image quality and the obtained ESD for the lateral cervical spine projections by employing the moving grid, stationary grid, and non-grid techniques. The technical parameters used were presented in Table 1.

Results

Table 2 shows the results of the image quality for the lateral cervical spine projection in terms of contrast sensitivity and spatial resolution using various kVp. The results obtained from the Kruskal-Wallis test indicated that there were significant differences in image quality when using the moving grid, stationary grid, and non-grid techniques while employing different tube potentials in the lateral cervical spine projection (Table 3) in terms of contrast sensitivity, and spatial resolution (i.e., χ^2= 8 and 5, respectively, $p < 0.05$). Figure 4 illustrates the images acquired in the current experimental study. Referring to Table 2, the ESD was higher when using a moving grid compared to a stationary grid. Furthermore, there was a significant reduction in ESD when using a non-grid technique in comparison with the grid technique. The study also reflected that as kVp was increased whether using a moving grid, stationary grid, or non-grid the ESD was decreased (Table 3). As can be seen in Table 4, there were also significant differences when using the moving grid, stationary grid, and non-grid techniques while utilizing different tube potential in the lateral cervical projection with regard to ESD (i.e., χ^2=7.200, $p < 0.05$).

(a) (b) (c)

Figure 4. Image acquires from the current experimental study: a) 60kVp, 10.1 mAs 12:1 for the moving grid; b) 60kVp, 6.30 mAs 8:1 for the stationary grid; c) 60kVp, 2.5 mAs for the non-grid technique

Table 2. Technical parameters, ESD value, and image quality used for the lateral cervical spine projection

Imaging Parameters			Dose	Image Quality			
Grid Status/ Grid Ratio	kVp	mAs	Mean ESD (mGy)	SD (mGy)	High Contrast	Low Contrast	Spatial Resolution
Moving Grid/12:1	60	10.1	0.2377	0.0255	6	3	11
	66	7.26	0.2293	0.0195	5	3	11
	70	6.86	0.2141	0.0244	5	2	10
	75	5.43	0.1960	0.0325	5	1	9
	81	4.19	0.1754	0.0250	4	0	8
Stationary Grid/8:1	60	6.30	0.1750	0.0135	5	3	11
	66	3.20	0.1124	0.0105	5	2	10
	70	2.50	0.0953	0.0072	5	2	10
	75	1.40	0.0646	0.0089	4	1	9
	81	0.71	0.0377	0.0050	3	1	9
Non-Grid	60	2.50	0.0717	0.0026	4	4	12
	66	0.80	0.0290	0.0065	4	3	11
	70	0.63	0.0255	0.0018	3	3	11
	75	0.50	0.0246	0.0015	3	2	10

Table 3. Kruskal-Wallis test results regarding the effects of different kVp on high-contrast sensitivity, low-contrast sensitivity, and spatial resolution

kVp	Grid Status	High Contrast	Low Contrast	Spatial Resolution
		Chi-Square/df Asymp. Sig. *p*	Chi-Square/df Asymp. Sig. *p*	Chi-Square/df Asymp. Sig. *p*
60	Moving Grid/Stationary Grid/Non-grid	8.000/2 0.018*	8.000/2 0.018*	8.000/2 0.018*
66	Moving Grid/Stationary Grid/Non-grid	8.000/2 0.018*	8.000/2 0.018*	8.000/2 0.018*
70	Moving Grid/Stationary Grid/Non-grid	8.000/2 0.018*	8.000/2 0.018*	8.000/2 0.018*
75	Moving Grid/Stationary Grid/Non-grid	8.000/2 0.018*	8.000/2 0.018*	8.000/2 2 0.018*
81	Moving Grid/Stationary Grid	5.000/1 0.025*	5.000/1 0.025*	5.000/1 0.025*

**Statistically significant difference (P<0.05)

Discussion

Based on the findings in this study, high-contrast sensitivity was higher when utilizing the moving and stationary grid techniques compared to the non-grid technique. This was due to the absorption of scattered radiation (i.e., a form of "noise" by the lead strips of the grid). In contrast, the quantity of scattered radiation reaching a receptor can be reduced by separating the receptor surface (except for the naturally occurring air gap) which resulted in a radiograph of low-contrast sensitivity. This phenomenon was reflected in the findings of the current study in which high-contrast sensitivity was higher when grid techniques were employed.

In addition, the findings of the study indicated that the spatial resolution was higher for the non-grid technique compared to grid technique (Table 2). Theoretically, the utilization of a grid does not affect the spatial resolution. However, with regard to image acquisition by the non-grid technique, the obtained spatial resolution appeared to be better because discerning the bars and spaces in a low-contrast sensitivity environment is easier for humans. This means that visualization is enhanced in such environments [8, 9]. The grid ratio also determines the maximum angle the scattered radiation could pass through the grid which affects the amount of scattered radiation reaching the image receptor (Table 2). In short, a high grid ratio is more effective in reducing the amount of scattered-radiation penetration due to the small grid angulation [4]. In this study, the utilization of a moving grid with high grid ratio improves the image contrast by the "clean up" scattered radiation from reaching the image receptor.

Additionally, Yanch et al (2009) indicated there was a significant difference in image contrast and acceptability with regard to moving or stationary grids compared to a non-grid technique for AP projection of the cervical spine [10]. Therefore, the findings of the present study were in line with the previous studies in which the use of a grid improved the image quality, particularly the contrast of the radiographic image. However, image quality obtained by using the stationary grid was lower compared to the images from a moving grid due to the "marring" effect of the grid lines. In the non-grid technique, the air-gap naturally acted as a grid in removing the scattered radiation from the image receptor (Table 3). In the air-gap technique, the energy of the scattered photons declines due to the divergence of the X-ray beam [11]. In general, the use of the grid in radiology is named "radiographer dependent". The radiographers decide under which situation a grid is required by considering the thickness of the imaging part as well as kVp usage.

The obtained ESD values indicated that the dose was higher when using a moving grid compared to the stationary grid. This was because the moving mechanism of the moving grid, which was backward and forward during the exposure, removed more primary beam compared to the stationary grid. Therefore, when an automatic exposure control was used, radiation exposure was prolonged; accordingly, the ESD increases (Table 2). Another reason for the increase of ESD when using the moving grid in this study was probably due to the differences in the grid ratio between the moving and stationary grid techniques (Table 2).

A high grid ratio requires higher exposure factors, which increases the radiation dose to the patient, as well [7]. The outcomes of this study also showed there was a significant reduction of ESD in non-grid technique compared to the grid technique due to the requirements of increased exposure factors to produce an image of diagnostic acceptability (Table 4). The findings were consistent with Keating and Grange (2011), who indicated that there was an increase in radiation dose to the patients in a grid technique, which required an increased number of photons when it "blocks" the scattered photons from reaching the imaging receptor [12].

An increase in kVp degraded the image quality because more scattered radiation could reach the imaging receptor (Table 2). The findings were in line with Sherer et al (2012), Moey, Shazli and Sayed (2017) and Mitchell and Furey (2011) who revealed that an increase in kVp increased forward scattering which decreased the image contrast [13-15]. A grid technique was introduced to counterbalance the undesirable effect of the scatter in order to produce an image with acceptable radiological information; however, it may lead to the increase in the radiation dose to the patient. A high kVp with concurrent low mAs reduced the ESD (Table 2) when moving grid, stationary grid, and non-grid techniques were used. This is because the usage of high kVp and low mAs resulted in higher X-ray energy with increased penetration which reduced the patient's absorbed dose and led to a low patient radiation dose [14, 16, 17].

Table 4. Kruskal-Wallis test results regarding the effects of different kVp on ESD when using a moving grid, stationary grid, and non-grid in the lateral cervical spine projection

kVp	Grid Status	ESD Chi-Square /df Asymp. Sig. *p*
60	Moving Grid/Stationary Grid/Non-grid	7.200/2 0.027*
66	Moving Grid/Stationary Grid/Non-grid	7.200/2 0.027*
70	Moving Grid/Stationary Grid/Non-grid	7.200/2 0.027*
75	Moving Grid/Stationary Grid/Non-grid	7.200/2 0.027*
81	Moving Grid/Stationary Grid	3.857/1 0.050*

**Statistically significant difference ($P<0.05$)

Conclusion

This study indicated that there were significant differences in image quality and ESD when moving, stationary and non-grid techniques were used in the lateral cervical spine projection. The image quality of high-contrast sensitivity and ESD was significantly reduced when the non-grid technique was utilized compared to the time when the moving grid or stationary grid techniques were employed. The utilization of a grid in an examination improves the image quality, particularly the image contrast. However, an increased exposure factor can result in increasing the patient radiation dose. An increase in kVp degraded the image quality as a result of the decrease in the image contrast because of more forward scatter reaching the imaging receptor. Accordingly, a grid technique is utilized when using high kVp technique to absorb the undesirable effect of the scatter radiation, especially for the extremely large size patient. Furthermore, the findings of this study reflected that non-grid lateral cervical spine radiography using appropriate kVp should be used, as the existed air gap acts as a grid, resulting in acceptable image quality particularly resolution being "visually" improved with a reduction in ESD. This is in accordance with the lower a reasonably_achievable principle in keeping the radiation dose, the lower reasonably achievable yet maintaining the diagnostic quality of the radiograph.

Acknowledgment

The researchers would like to thank all lecturers and staff of the Department of Diagnostic Imaging and Radiotherapy, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia (IIUM) for helping to conduct this study.

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