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Modified Technique for the Visualization of C6/C7 in Lateral Cervical Spine Radiography

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ABSTRACT

Introduction: In the Swimmer's view, the C6 and C7 can be visualized as superimposed on the shoulders. This study aimed to explore the technique to demonstrate C1 to C7 in the lateral spine and improve the diagnostic value in that region.

Material and Methods: An experimental study was carried out using a RANDO phantom to obtain images of the lateral cervical spine. Twelve radiographs were taken using different kVps at different centering points. The image quality of the radiographs was evaluated by two radiographers using the modified image quality criteria score sheet adapted from the Commission of European Communities on image quality. A dose area product meter was utilized to estimate the entrance surface dose (ESD); however, CALDose_X5 Monte Carlo software was used to estimate the effective dose.

Results: The findings indicated that a higher centering point at 2 inches above the pinna of the ear can clearly visualize the lower cervical spine (C6/C7) and cervicothoracic junction (C7/T1). The results of the Kruskal-Wallis test revealed significant differences ($p<0.05$) in the image quality at different centering points. However, no significant differences were observed ($p>0.05$) in the ESD between different utilized centering points. The effective dose of the modified technique was reported to be lower, compared to that for the Swimmer's view.

Conclusion: The modified lateral technique can be used to replace the Swimmer's view to adequately demonstrate the lower cervical spine and cervicothoracic junction with a lower radiation dose while not harming the patient due to movement during positioning.

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Introduction

Cervical spine injuries can be considered rare in blunt trauma injury cases; however, the impact of the injuries is potentially devastating. The results of a retrospective study carried out on trauma patients within 3.5 years revealed that only 469 cases of cervical spine fractures and/or spinal cord injuries were admitted to the emergency department at Shiraz Shahid Rajaei Hospital, Shiraz, Iran. Although the rate of spinal cord injuries in the aforementioned study was only 3.62% in all cases but the mortality rate reported as 6.18% [1] is quite high.

A study conducted by Sekhon and Fehlings [2] reported that 55% of all spinal cord injuries originate from the cervical spine that makes it the most common site for spinal cord injuries. In the management of the patients with a cervical spine injury, a wise selection of imaging modality is crucial due to the great number of long-term or permanent neurological outcomes if any cervical spine fracture is missed [3].

Many studies, such as a study performed by Griffen et al. [4], recently have given ample evidence to consider computed tomography as a better imaging modality in the assessment of cervical trauma injury. However, plain radiography is still widely used as the standard imaging procedure because it is cheap, readily available, noninvasive and can be virtually performed on any patient [3, 5, 6].

The lateral cervical spine radiography is the preferred projection in determining the integrity of the cervical spine for initial evaluation during trauma imaging. Most cervical spine injuries can be assessed in the lateral projection because it can demonstrate most of the neck anatomy, including the cervical vertebral bodies, intervertebral joint spaces, and zygapophyseal joints. However, poor technique during the lateral cervical spine examination can reduce the quality of the cervical radiograph, particularly in demonstrating the C6 and C7 [5]. A supplementary view like the Swimmer's view may be required when the lateral cervical radiograph is inadequate to show the clearance of the cervical spine at the C6 and C7 areas [7].

The results of a study carried out by Goldberg et al. [8] indicated that C6 and C7 are the most commonly injured levels in the subaxial region.

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However, despite this high number of cervical spine injuries, the frequency of missed injuries on initial assessment varies from 4% to 30%. This could be due to an inadequate radiographic technique that causes a delay in diagnosis and consequently puts the patient at risk for neurologic deterioration and progressive instability [9].

Despite the fact that it is crucial for the radiographer to demonstrate adequate visualization of all cervical vertebrae bodies in the lateral cervical spine film, it is commonly very difficult to observe the spines at the subaxial region, especially the C6/C7 on the lateral radiograph [7]. The findings of a study carried out by Shrestha et al. [5] showed that the poor image quality of the lateral cervical radiograph was mostly due to the incompetence of radiographers.

Among 188 patients who underwent lateral cervical X-ray, a high percentage of the radiographs (76.6%) indicated improper positioning. A major fault (50.0%) is due to patient rotation, and other faults are due to unraised chin (46.3%), no collimation (33.5%), inadequate coverage (33.5%), and minor cause from artifacts (13.3%). These statistical results indicated that most radiographers have neglected their duty to provide good quality images to aid in the diagnosis of the underlying pathology or problem. Any incorrect technique can result in a repeated examination, which can cause the patient to receive unnecessary radiation dose [5].

In the Swimmer's projection, occasionally the C6 and C7 can be visualized as superimposed on the thick anatomy of the shoulders. However, some considerations are needed before performing this view on the patient with a cervical spine injury. Many studies have shown that the Swimmer's view remarkably demonstrated a higher patient radiation dose than other plain radiographic projections. Furthermore, it is unsafe to move patients with suspected neck injuries. This raises concerns among the radiographers over the usefulness of the Swimmer's view to make the diagnosis [7].

Accordingly, to overcome the problem related to the visualization of C6 and C7 in the lateral cervical spine, this study aimed to use a modified technique in the replacement of the Swimmer's view for better visualization of this region of interest. The present study can also provide the radiographers with a new technique in producing an image of diagnostic quality with reduced radiation dose in line with the principle of As Low as Reasonably Achievable.

Materials and Methods

The X-ray unit used in this study was a ceiling-mounted X-ray tube, Siemens AXIOM ARISTOS (Siemens, Germany). The set-up of the experimental study is shown in Figure 1. The images of the cervical spine were obtained by positioning the RANDO phantom (Radiology Support Devices Inc., CA, USA) in the lateral cervical spine projection and abutting the erect bucky. A dose area product (DAP) meter (Kerma X_Plus, IBA, Germany) was placed below the X-ray tube collimator and zeroed before each exposure. A total of 12 images were acquired using the imaging parameters in Table 1.

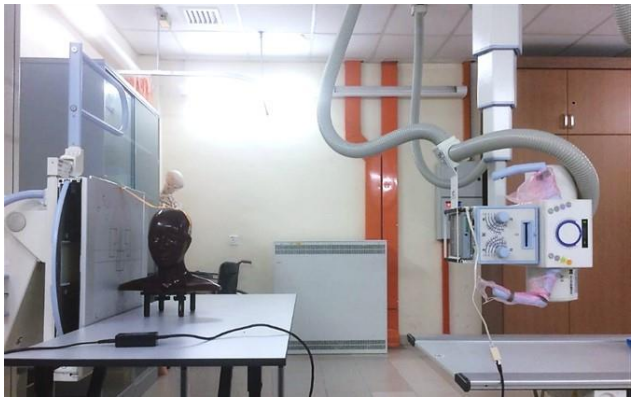

Figure 1. Set-up of experimental study

A 10×12 inches imaging plate was placed in the X-ray erect bucky. The X-ray beam was properly collimated to only include the region of interest. The DAP reading was displayed on the DAP meter after each exposure. The image processing parameters, including GA and GS values, were set at 0.9 and 0.55, respectively, before the images were printed using the Fuji Medical Dry Laser DRYPIX Plus (Model 4000, Fuji, Japan) . Then, the obtained images were scored for image quality by two radiographers using the modified image quality criteria adopted from the Commission of European Communities (CEC) in 1996.

Image Quality

The modified image quality criteria score sheet on image quality derived from the CEC (1996) was utilized to evaluate the image quality of the obtained images. The score sheet was given to two radiographers who were blinded to assess the image quality based on the subjective visibility of specific anatomical structures for the lateral cervical spine radiographs. The anatomical structure visibility was assessed using a score of 0 or 1 for each criterion. Accordingly, the total score for image quality for the lateral cervical spine could be within the range of 4 to 9. Depending on the number of scored criteria, the higher score indicated better image quality in this graded system. Table 2 tabulates the summary of the criteria used in this graded system.

Table 1. Imaging parameters used for the modified technique for lateral cervical spine radiography

Imaging parameter	Details
Central beam point	At the pinna of the ear, 1 inch above the pinna of the ear, 2 inches above the pinna of the ear
Tube voltage (kVp)	70, 75, 81, 85
Imaging plate point	Centre perpendicularly to the level of C4
Source to image distance (cm)	150
Imaging plate size (cm)	24 x 30, lengthwise
Focal spot size	Fine focal spot (1.0 mm)
Grid (grid ratio)	Moving grid, 12:1
Filtration	No filter
Automatic Exposure Control (AEC)	On
Chamber	Middle chamber

Table 2. Image quality criteria for the evaluation of lateral cervical spine radiographs

Image quality criteria
Visually sharp reproduction of the vertebral body and posterior arch of C1; vertebral body and spinous process of C2 without any superimposition
Visually sharp reproduction of vertebral body and spinous process of C6 and C7 without any superimposition
Reproduction of zygapophyseal joint
Reproduction of articular pillar
Reproduction of intervertebral joints
Reproduction of all spinous processes from C1-C7
Reproduction of cortex and trabecular structures
Reproduction of adjacent soft tissues, particularly air-filled trachea
Full superimposition of posterior vertebral edges

Key: **Score 1: Yes; 0: No; Maximum total score=9

Entrance Surface Dose and Effective Dose

The radiation dose was obtained using the DAP meter Kerma X-plus. The DAP data was used for the estimation of the entrance surface dose (ESD) using equations 1 and 2 and effective dose (ED). CALDose_X Monte Carlo software (version 5.0) (Department of Nuclear Energy, Federal University of Pernambuco, Recife, Brazil) was utilized to obtain the backscatter factor (BSF) and organ/tissue absorbed dose.

$$ESD_{DAP} = \frac{DAP}{Area\ at\ (FSD)} \times BSF \quad (1)$$

$$Area\ (FSD) = Area\ at\ (FFD) \times \left(\frac{FSD}{FFD}\right)^2 \quad (2)$$

Where ESD: entrance surface dose, FSD: focus to skin distance, FFD: focus to film distance and BSF: back scatter factor

Statistical analysis

The collected data were analyzed using SPSS software (version 25.0). The nonparametric technique was used as the data violated the distribution assumptions of parametric tests. The Kruskal-Wallis test was utilized to assess significant differences between the image quality and ESD at different centering points (at the pinna of the ear, 1 inch above pinna of the ear, and 2 inches above pinna of the ear).

Results

Image Quality

Comparison of Image Quality Using Different Centering Points

The scores of the image quality of the lateral cervical spine were obtained based on the modified image quality criteria scoring lists derived from the CEC in 1996. The total scores of 1 to 3, 4 to 6, and 7 to 9 indicate poor, moderate, and good image qualities, respectively. Based on the collected scores, the centering point, which is 2 inches above the pinna of the ear, shows the highest mean score for the visibility of anatomical structures for lateral cervical spine radiographs depicted in Figure 2.

Among the criteria listed in the image quality scoring as shown previously in Table 2, one important criterion that is the visualization of sharp reproduction of the vertebral body and spinous process of C6 and C7 without any superimposition should be fulfilled to achieve the objectives of this study. This important criterion will distinguish the image quality between the different centering points in terms of the visualization of the lower cervical spine.

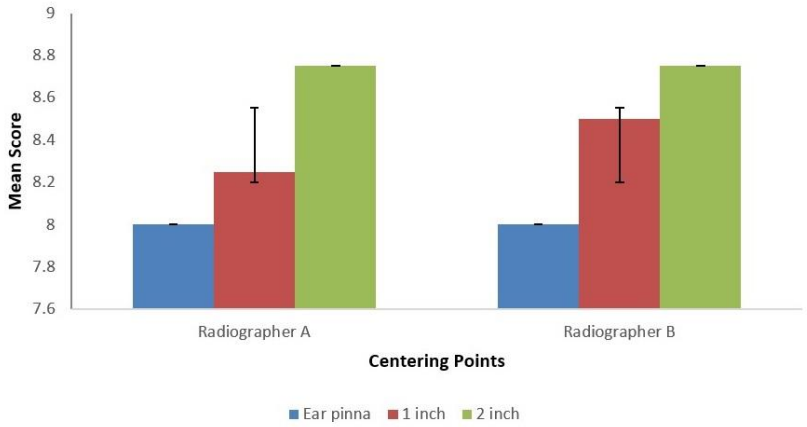

Figure 2. Comparison of image quality score for the modified lateral cervical spine radiographs between radiographers

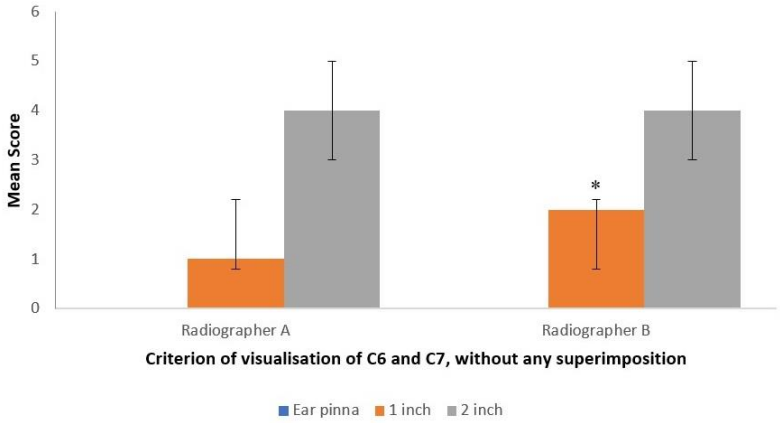

Figure 3. Comparison of specific image criterion score for modified lateral cervical spine radiographs between radiographers

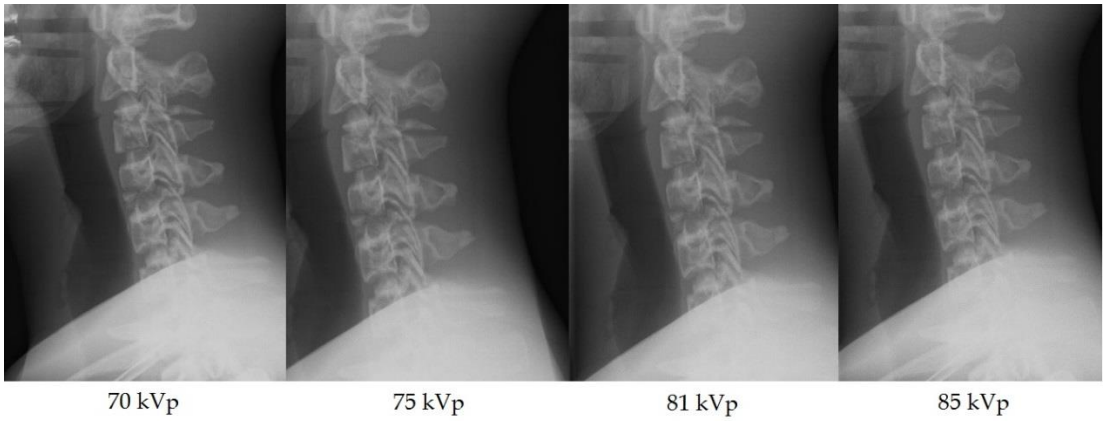

Figure 4. Images obtained at centering point 2 inches above pinna of the ear

Based on the obtained results, both radiographers agreed that all radiographs of the lateral cervical spine at the centering point of 2 inches above the pinna of the ear can visualize a sharp reproduction of the vertebral body and spinous process of C6 and C7 without any superimposition as shown in Figure 3. The obtained radiographs are depicted in Figure 4.

The results obtained from the Kruskal-Wallis test also revealed that there was a statistically significant difference in the image quality at different centering points, $x2(2)= 8.190$, $p=0.017$.

Table 3. Obtained entrance surface dose and image quality scores utilizing different centering points and imaging parameters

Imaging parameter			Dose	Image quality
Centering point	kVp	mAs	Entrance surface dose (µGy)	Mean score
At pinna of the ear	70	13.1	3.11	8
	75	9.61	2.81	8
	81	6.79	2.30	8
	85	5.74	2.20	8
1 inch above pinna of the ear	70	14.0	3.45	8
	75	10.2	2.83	8
	81	7.45	2.55	8.5
	85	6.29	2.42	9
2 inches above pinna of the ear	70	15.1	3.94	9
	75	10.9	3.15	9
	81	8.27	3.11	9
	85	6.96	3.01	9

Table 4. Estimated effective dose and cancer risk for projections in cervical spine radiography

Projection	Estimated effective dose (mSv)	Approximate risk of cancer
Lateral view	0.02	1 in 1,000,000
Swimmer's view	0.20	1 in 100,000
Modified view	0.03	1 in 1,000,000

Interobserver Agreement

Cohen's Kappa statistics showed a high inter-rater kappa coefficient of 0.83, which indicated a good rater agreement between the evaluators.

Entrance Surface Dose

The ESD for the centering point at the pinna of the ear was the lowest, compared to the centering points at 1 and 2 inches above the pinna of the ear. However, the difference in the ESDs between different centering points was small and negligible. For all the modified lateral cervical spine projections, the ESD decreased when the kVp increased and vice versa. The results of the Kruskal-Wallis test showed that there was no statistically significant difference in the ESD at different centering points, $x2(2)= 4.371$, $p = 0.112$. Table 3 shows the obtained ESD and image quality scores using different centering points and imaging parameters.

Effective Dose

The estimated EDs for the standard lateral view, Swimmer's view, and modified lateral view of cervical spine radiographs are shown in Table 4. The EDs for the standard lateral and Swimmer's view are derived from a study performed by Fell [7]; however, the ED for the modified lateral view is manually calculated.

Discussion

Image Quality

Based on the findings of this study, the image quality of all the obtained radiographs using the three centering points was reported as good (score 8 to 9). Most of the listed image quality criteria can be achieved even while using three different centering points. However, the present study required the visualization of the sharp reproduction of the vertebral body and spinous process of C6 and C7 without any superimposition. This is unlike the obtained radiographs using the lateral cervical spine technique, by which the C6/C7 and cervicothoracic junction cannot be visualized.

Both radiographers agreed that the obtained radiographs of the lateral cervical spine at centering point 2 inches above the pinna of the ear can meet the above-mentioned criterion. This is because the higher centering position enabled the divergent X-ray beam to project the shoulder further down, providing the visualization of the lower cervical spine C6 to C7 and cervicothoracic junction (C7/T1) without being superimposed by the shoulder.

In comparison with the Swimmer's view, this modified technique can demonstrate a sharp visualization of all the cervical vertebral bodies from C1 to C7 and cervicothoracic junction (C7/T1) without any superimposition of the shoulder or head of the humerus. Furthermore, clear visualization, especially at the C6 to C7 and cervicothoracic junction was attained due to the absence of streaking artifacts different from that observed in the Swimmer's view.

In addition, no movement of the arm is required using the modified technique. Accordingly, this modified technique can be a useful technique to apply, especially for trauma patients with a suspected cervical spine fracture. Moreover, poor exposure technique, unclear soft tissue shadow visualization, and overlapping bones further marred the image quality of the Swimmer's view radiographs [10].

The image quality of the radiographs obtained using the modified technique was also better due to the distance between the cervical spine and image receptor. The arm nearest the image receptor was raised in the Swimmer's view. Then, it creates an additional distance between the cervical spine and image receptor, which decreases the resolution, especially at the lower cervical spine and cervicothoracic junction. In the light of these findings, the utilization of a higher centering point 2

inches above the pinna of the ear can produce a lateral cervical spine radiograph of good quality that can also visualize the entire cervical spine and cervicothoracic junction (C7/T1).

Entrance Surface Dose

Based on the results of the present study, the ESD obtained using the centering point at the pinna of the ear had the lowest value, compared to that using the centering point at 1 and 2 inches above the pinna of the ear. This is because the irradiated area was smaller when using the centering point at the pinna of the ear. According to the equation recommended by Meade et al. [11], the ESD can be determined by the calculation of the surface dose with the irradiated area and BSF. The lower centering point at the pinna of the ear had a smaller irradiated area (5.48 m^2) because the distance from the pinna of the ear to the upper border of the shoulder is shorter, compared to that when using higher centering points. Therefore, the lower centering point produced lower ESD because the irradiated area was smaller.

The BSF also plays an important role in the determination of the ESD as it considers the number of X-rays that are backscattered at their first interaction in the tissue and consequently can undergo multiple interactions contributing to increase the ESD [12]. As the BSF depends on the changes in X-ray beam quality and X-ray field size, any increase in the kVp or X-ray field size will also increase the BSF. This is because the usage of high kVp results in the production of more Compton scattered X-ray photons. On the other hand, a higher mAs value will lead to a higher ESD [13]. Accordingly, the usage of the centering point 2 inches above pinna of the ear resulted in a higher ESD due to the increase in the BSF although the findings of the Kruskal-Wallis test showed that the differences in the ESD using different centering points were not significant.

Effective Dose

The ED for the modified lateral projection at 0.03 mSv is near to the ED of the standard lateral cervical projection at 0.02 mSv. The reason is that the modified technique used exposure parameters similar to those applied in the standard lateral cervical spine projection. However, the ED for the Swimmer's view at 0.2 mSv was approximately ten times higher, compared to that reported for the modified lateral projection. This is because the utilized exposure parameters in the Swimmer's view use higher exposure factors, such as more than 80 kVp and 120 mAs.

These higher exposure factors are required for better X-ray beam penetration at the thick region of interest due to the superimposition of the shoulder and arm [14]. Accordingly, the higher ED produced by the Swimmer's view can increase the patient radiation dose. In light of the results obtained from this study, the modified lateral cervical projection was the preferred projection as it resulted in a lower radiation dose, compared to the Swimmer's view.

Conclusion

The centering point 2 inches above the pinna of the ear was the preferred centering point for the modified lateral cervical spine projection to visualize the lower cervical spines (C6 and C7) and cervicothoracic junction (C7/T1) free of the superimposition of the surrounding bony structures and streaking artifacts. In addition, the highest acceptable kVp should be utilized in this modified lateral cervical projection as it can reduce the dose to the patient without compromising the image quality. The modified lateral view is a projection that can replace the Swimmer's view as it can adequately demonstrate the lower cervical spine (C6 and C7), as well as the cervicothoracic junction, with a lower radiation dose while not harming the injured patient due to movement during positioning.

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