STUDY ON DIFFERENT TYPES OF CERVICAL COLLAR AND IMAGE QUALITY IN GENERAL RADIOGRAPHY

Ummi Syahirah Mohd Yusof[1], Fairuz Mohd Nasir[1]*
[1]Faculty of Health Sciences, Universiti Sultan Zainal Abidin, Terengganu, Malaysia
[*]Corresponding author: fairuznasir@unisza.edu.my

Abstract

Radiographic images of patients wearing cervical collars raise some issues regarding image quality and the use of cervical collars in routine trauma patients is questioned by researchers. Therefore, this study aims to investigate the effect of different types of cervical collars on image quality. Radiographic images of a phantom wearing four types of cervical collars (hard, soft, adjustable, and traction devices)were taken separately and evaluated in terms of signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), artefact, and spatial resolution using Image J software. Kyoto Kagaku PBU-50 body phantom was positioned in anteroposterior (AP) axial cervical projection and exposed using Siemens Multix Polydoros IT 55 X-ray Machine. Among of studied cervical collars, the hard cervical collar gives the best image quality in terms of SNR and spatial resolution compared to other cervical collars while the adjustable cervical collar gives the best value of CNR. The artifact is also seen in the images of hard, adjustable, and traction devices of the cervical collar. Apart from that, artifacts are also seen in hard, adjustable, and traction device images of the cervical collar, where the traction device shows the most artifacts. As a result, the

In conclusion, there is a difference in the image of the four types of cervical collars; hard cervical collars give the best image quality in SNR and spatial resolution compared to other cervical collars. The best image quality in CNR is an adjustable cervical collar. More artefact occurs in traction device compared to hard cervical collar and adjustable cervical collar. According to the result of this study, a radiographer can manipulate the exposure factor according to the type of cervical collar to obtain a quality radiographic image. However, further study should be carried out to estimate the entrance surface dose if the exposure factor change.

KEYWORDS: Cervical collar, Image quality, traction device, artefacts

Introduction

A cervical collar is one of the immobilization devices that is used to protect the patient's cervical spine when the patient has the worst injury to the cervical spine. Mostly, the trauma patient wears a cervical collar when getting the worst injury that involves the cervical spine. The use of a cervical collar is the first measure applied in a prehospital setting to prevent secondary injury to the spinal cord and it has been used for >30 years in prehospital trauma care (Bazaie, 2022). There are several types of cervical collars in the emergency room, ward, and among patients usually wear. Different types of cervical collars; adjustable, soft, hard, and traction devices are different in size, and function. Each cervical collar is made of different materials. The use of cervical collars depends on their availability and function. In the emergency department, the staff nurse usually uses an adjustable cervical collar, as shown in Figure 1, for trauma and emergency patient, which can wear to the patient and adjust the height easily. The adjustable neck collar is an indispensable product for ambulance medical equipment, which is dedicated to injured people and provides excellent convenience for healthcare personnel. The adjustable cervical collar is made of polypropylene plastic which is radiolucent material. However, using this type of cervical collar introduces artefacts to the image, appearing as straight lines near the region of interest, parallel to the cervical spine (Sayed, 2018).

Figure 1: An adjustable cervical collar

The soft cervical collar is usually made of materials such as felt, foam, or rubber. Soft cervical collars are used for temporary relief from moderate neck pain, not for serious neck injuries (Daniel et al, 2019). This type of cervical collar reduced movement by an average of just over 17 % and this was not enough to provide adequate immobilization to have clinical benefits (Daniel et al, 2019). However, the soft cervical collar helps relieve mild neck pain and stiffness and is ideal when providing rest and warmth to the cervical region. Hard collars are usually made from plexiglass or plastic. This type of cervical collar has a chin support but it restricts head rotation and side-to-side movement more than softer collars. Hard neck braces are often prescribed for severe neck pain, spinal fractures, and trauma injuries. Another type of cervical collar is a traction device, also called neck traction or cervical traction. The term traction refers to using a pulling force to treat joint, bone, or muscle problems (WebMD, 2023). A neck traction device is often used in physical therapy or orthopedics to treat long-lasting muscle spasms, dislocation, fractures, and deformities. The device is to help align the bones for proper healing. It is detachable and lightweight to be worn and carried around, whether used at home or on the go (WebMD, 2023).

Usually, the material of the immobilization device should be radiolucent and should not degrade the radiograph image quality. However, previous studies show there are changes in the signal-to-noise ratio (SNR) of the image and there are also artefacts present in the images (Sayed, 2018). In a previous study, the artefacts were found in 67% out of 275 Computed Tomography (CT) scans patients on spineboard devices, hampered diagnosis in 10 % of cases (Hemmes et al, 2016). Although the study used a spine board and head blocks rather than a cervical collar, both are immobilization devices that should be radiolucent where they allow X-rays to pass through.

The radiographer should never remove any immobilization device without a physician's orders and should provide proper immobilization to minimize the risk of motion (Rollins, 2016). Primarily in image radiographs, the radiographer will try to avoid artefacts to get the correct diagnosis. False treatment may be given to the patients when poor image quality affects the diagnosis. Since cervical collars are made of different materials, each type may have a different effect on the quality of the resulting radiographic image. There are limited studies done on the impact of the cervical collar on radiographs and previous studies only reviewed the SNR and artefact in the image when the cervical collar is applied. Therefore, this study was carried out to evaluate the SNR, CNR, spatial resolution, and artefact of different types of cervical collars.

Methodology

Setup procedures

This study was carried out in the X-ray laboratory of Universiti Sultan Zainal Abidin (UniSZA) Medical Campus. In this study, four radiographic images of phantom wearing four types of cervical collars and one without cervical collars were taken separately. The phantom used in this study was Kyoto Kagaku body phantom while the X-ray machine used was Siemens Multix Polydoros IT 55. The phantom was positioned supine on the table couch and the angulation cephalad of the X-ray was 15^o to get an anteroposterior (AP) axial projection of the cervical as shown in the illustration in Figure 2. The level of the external acoustic meatus (EAM) is the collimation of the superior with includes both lateral soft tissues for lateral collimation, the inferior collimation is covered until (T1) of thoracic vertebrae. The source-to-image distance (SID) was set up to 100 cm with a 12:1 focus grid and a large focal spot size of 1.3 mm.

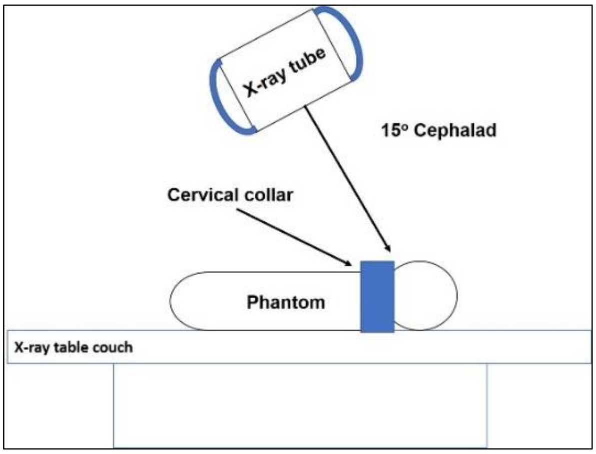

Figure 2: Illustration of the experimental setup; phantom wearing cervical collar positioned supine on the table couch

Cervical collars

There are four types of cervical collars used in this study; soft, hard, adjustable and traction device of a cervical collar. Figures 3a, 3b, 3c, and 3d show the setup of the phantom wearing soft, hard, adjustable, and traction device cervical collars respectively.

Table 1 summarized the brand, materials, and specifications for each type of cervical collar used in this study.

Exposure parameters

The parameter setting is summarized in Table 1. Since each cervical collar is made of a different material, the image quality was also compared between using AEC and not using AEC. The tube voltage was set at 68 kV for all exposure made. Without AEC, the tube current setting was 8 mAs, while with AEC utilized, the tube current changed for each type of cervical collar as in Table 2.

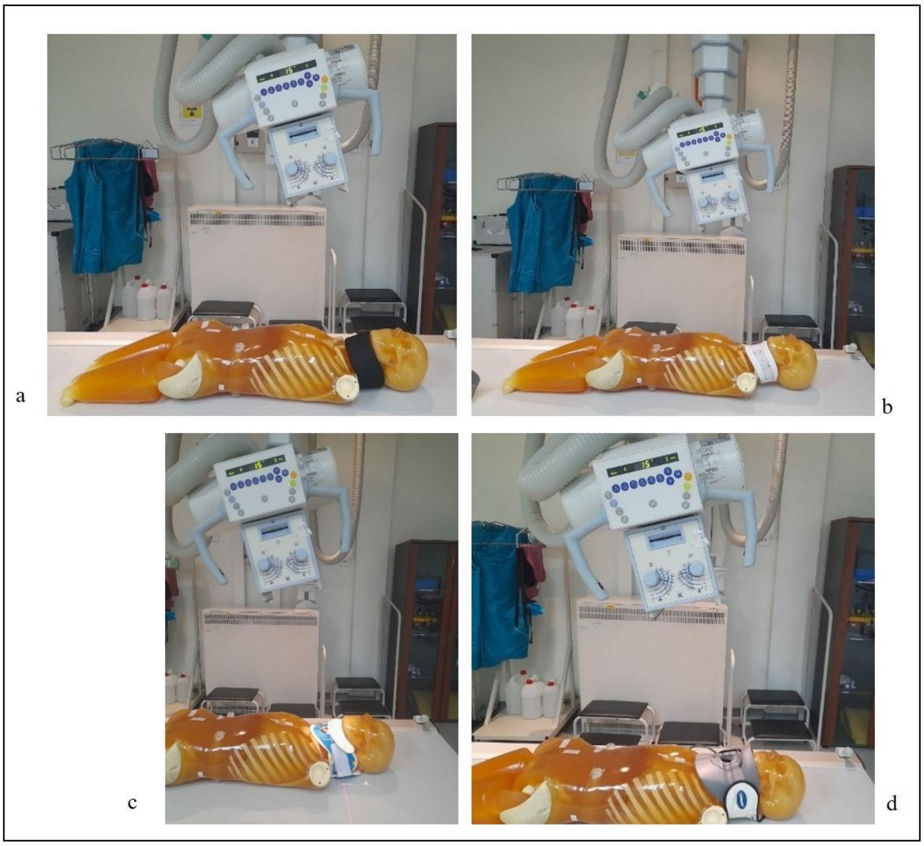

Figure 3: Phantom setup wearing different types of cervical collar used in this study, a) soft cervical collar, b) hard cervical collar, c) adjustable cervical collar, and d) traction device of the cervical collar.

Table 1: The type, brand, materials, and specification of cervical collar used in this study

Types	Brand	Materials	Specification/size
Soft	AMC	High-density polyurethane	Length: 34 cm – 38 cm Density: 0.97 g/cm3
Hard	ESCO	Low-density polyurethane	Length: 40 cm – 45 cm Height: 10 cm Density: 0.91 g/cm3
Adjustable	VitalFour	Polypropylene plastic	Length: 55 cm – 59 cm Height: 12.5 cm - 17.5 cm Weight: 0.13kg Density: 0.92 g/cm^3
Traction device	LEAMAI	Air sac: Thermoplastic Polyurethane (TPU) Support bel: Polyurethane	Traction Height：20cm Air charging mode: pump Weight: 0.68kg Density of TPU:1.21 g/cm3

Table 2: Parameter setting used in this study

Type of cervical collar	kVp	mAs	
		AEC off	AEC on
Non	68	8	6.63
Hard			7.25
Soft			6.77
Adjustable			6.12
Traction Device			6.97

Image quality analysis

The image quality of all images taken is assessed quantitatively in terms of SNR, CNR, and spatial resolution using ImageJ Software. This software is a Java-based image processing program developed at the National Institutes of Health (NIH). It is free public domain image processing software and allows researchers to display, annotate, edit, calibrate, measure, analyze, process, print, and save raster image data (Lee & You, 2016). This method of image assessment was also demonstrated in a previous study by Sayed (2018). All images are saved in JPEG format and analyzed by the software. Using the software, the SNR and CNR were calculated. SNR is the measurement of the image signal to a certain region of the background while CNR refers to the measurement of image contrast between the region of interest and the background. The size of the region of interest (ROI) was kept as small as possible to obtain the most accurate data. Equation 1 and Equation 2 are the formula to calculate SNR and CNR respectively:

$$SNR = {}^{\mu}/_{\sigma} \tag{1}$$

Where μ is the mean value of the image pixels that represent the expected signal and σ is the standard deviation of the pixel value that represents the estimated noise.

$$CNR = \frac{(Avg.Signal\ ROI - Avg.Background\ ROI)}{(Std.Background\ ROI)} \tag{2}$$

All images have also observed the presence of the artefact. The presence of artefacts was observed manually, especially in the ROI area.

Result and Discussion

SNR, CNR and Spatial Resolution

The SNR, CNR and Spatial Resolution were obtained and calculated using ImageJ software. All the values were calculated based and categorized according to AEC utilization. The result is summarized in Table 3. The higher SNR value was calculated when applying a cervical collar for both AEC and non-AEC settings, except for the traction device which is lower compared to not applying a cervical collar. Greater SNR values indicate more significant signals and lower noise. This result is aligned with a study where a higher SNR value was recorded when applying an adjustable cervical collar due to the presence of an air gap between the neck and the image receptor because of the cervical collar (Sayed, 2018). For both AEC and non-AEC settings, the highest SNR is when using the hard cervical collar, followed by the adjustable cervical collar soft and traction device cervical collar. This difference is due to the density of the material for each type of cervical collar. The traction device is made of Thermoplastic Polyurethane (TPU) and the density is higher compared to a soft, hard and adjustable cervical collar. The density of traction device, soft, adjustable, and hard cervical collars is 1.21, 0.97, 0.92, and 0.91 g/cm^3 respectively. Higher density gives a lower SNR value and shows less signal reaches the image detector which indicates higher noise. Greater noise was observed when using spinal immobilization due to the denser material used since it allows higher X-rays to attenuate (absorbed and scattered) within the device (Hemmes et al, 2016).

The CNR is higher when an adjustable cervical collar is applied for both AEC and non-AEC settings. For the AEC setting, the CNR of the adjustable cervical collar image is 5.4% higher than the non-cervical collar, while for the non-AEC setting, the percentage difference is 4.7% higher. The lowest CNR is recorded when applying a traction device. For the AEC setting, the CNR of the traction device cervical collar image is 6.3% lower than the non-cervical collar, while for the non-AEC setting the percentage difference is 5.3% lower. The CNR is calculated as the average contrast divided by the noise, therefore it evaluates the contrast between the object of interest and its background. As the CNR increases, the object will be more easily visualized in the background, which is why CNR increases the ability to distinguish between two areas of clinical interest.

In the spatial resolution evaluation, without AEC, the highest value is the non-cervical collar compared to the lowest value is an adjustable cervical collar, but a hard cervical collar is recorded as the highest value when AEC is applied. The difference decreased when four different types of cervical collars is applied; a hard, soft, traction device, and an adjustable is 1.036, 4.923,4 and 11.251, respectively. The highest difference is recorded with hard cervical collars up to 12.975 when AEC is enabled during exposure. High spatial resolution means more detailed and smaller grid cell size because the spatial resolution is the detail in pixels of an image and reveals more minor features. However, as the area becomes small, the contrast increases the object automatically with similar visibility or detectability as the noise increase. (Brian, 2020).

Table 3: The value of SNR, CNR, and spatial resolution for each type of cervical collar

Types of Cervical Collar	Non - AEC				AEC			
	mAs	SNR	CNR	Spatial Resolution	mAs	SNR	CNR	Spatial Resolution
Non	8	1.341	3.979	108.512	6.63	1.356	3.939	100.361
Hard		1.540	3.901	107.476	7.25	1.564	3.832	113.336
Soft		1.352	3.926	103.589	6.77	1.375	3.956	105.301
Adjustable		1.429	4.201	97.261	6.12	1.401	4.128	95.133
Traction Device		1.301	3.736	104.512	6.97	1.314	3.736	100.387

Artefact evaluation

The artefact of each radiograph was observed and recorded. The artefact presence in the adjustable, hard and traction device of the cervical collar image as in Figure 4a, 4b and 4c respectively. No artefact was seen in the soft cervical collar as in Figure 4d. The usage of a cervical collar also introduces artefacts to the image. Many artefacts were seen with a traction device of cervical collar compared to the hard cervical collar and an adjustable cervical collar. In the image of the adjustable cervical collar, the artefacts appeared as straight lines near the ROI, parallel to the cervical spine as in Figure 4a. A study done by Sayed (2018) also shows the same artefact seen in the image with an adjustable cervical collar. However, the artefact does not obscure the ROI and the anatomy demonstrated. For the hard cervical collar, the presence of an artefact was seen that got inside the ROI at the level of the first rib (T1) surrounding the neck as in Figure 4b. The artefact is obscured by the region of interest and the anatomy demonstrated. The presence of the artefacts in the traction device is significantly seen in the image as in Figure 4c. The metals besides the cervical spine and inside the tissue automatically inside the region of interest make the image evaluation more complex and harder to interpret. The metals besides the cervical spine will not obscure the region of interest. The anatomy demonstrated but not both metals inside the region of interest will make the anatomy demonstrated. Therefore, artefacts should be kept to a minimum level.

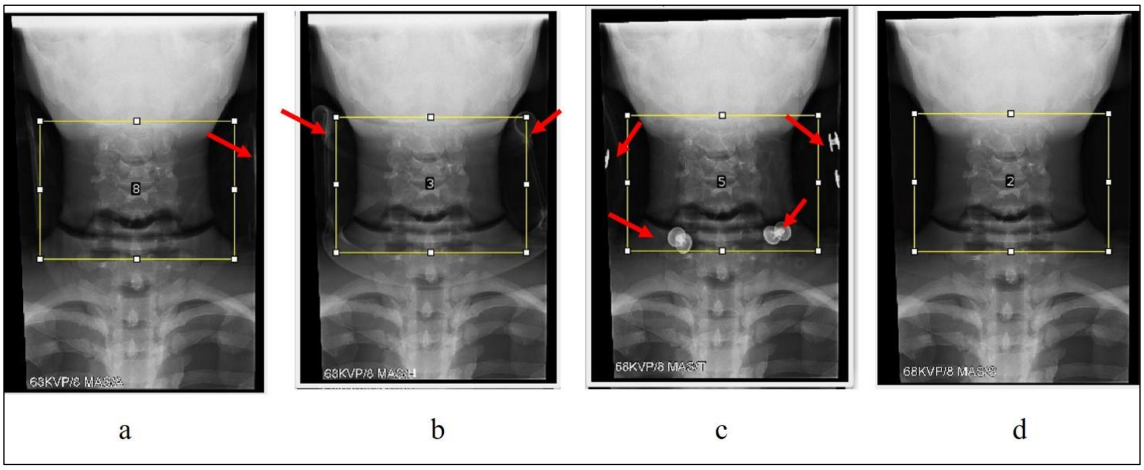

Figure 4: The artefact in the image of different cervical collars; a) adjustable cervical collar, b) hard cervical collar, c) traction device cervical collar, and d) soft cervical collar

In this study, however, the presence of artefacts in the image cannot determine whether they can influence the diagnosis made. It cannot be proven that the artefact present will result in misdiagnosis and missed diagnosis. Nevertheless, efforts to reduce the presence of artefacts in the image should be encouraged among healthcare personnel. Hemmes et al. (2016) suggest removing the spinal immobilization device before the imaging procedure and enhancing the device's radiology properties to reduce the artefacts. A radiographer is responsible for producing quality radiographic images regardless of the patient's condition, especially for patients who are restricted in movement. Radiographic image quality is very important to diagnose pathology or visualize any abnormalities in the patient so that doctors or radiologists can give proper diagnosis and give the best treatment to the patient.

Conclusion

In conclusion, there is a difference in the image of the four types of cervical collars; hard cervical collar give the best image quality in SNR and spatial resolution compared to other cervical collars. The best image quality in CNR is an adjustable cervical collar. More artefact occurs in traction device compared to hard cervical collar and adjustable cervical collar. According to the result of this study, a radiographer can manipulate the exposure factor according to the type of cervical collar to obtain a quality radiographic image. However, further study should be carried out to estimate the entrance surface dose if the exposure factor change.

References

Bazaie, N., Alghamdi, I., Alqurashi, N., Ahmed, Z., 2022. The Impact of a Cervical Collar on Intracranial Pressure in Traumatic Brain Injury Patients: A Systematic Review and Meta-Analysis. *Trauma Care*. 2(1):1-10.

Sayed, I. S., 2018. Effects Of Cervical Collar on Entrance Surface Dose, Exit Surface Dose and Image Quality in Plain Radiography: A Phantom Study. *International Journal Of Allied Health Sciences*. *2*(2), 383–391.

Daniel, Y., Claire, B., Tim, G., Siobhan, D. (2019). 'What Is a Cervical Collar Used For and Are There Side Effects?' *Healthline.* Available at https://www.healthline.com/health/cervical-collar (Accessed on 2 June 2023)

WebMD (2023). 'What to Know about Neck Traction?' *Pain Management Guide.* Available at https://www.webmd.com/pain-management/what-to-know-about-neck-traction (Accessed on 2 June 2023)

Hemmes, B., Jeukens, C. R., Al-Haidari, A., Hofman, P. A., Vd Linden, E. S., Brink, P. R., Poeze, M., 2016. Effect of spineboard and headblocks on the image quality of head CT scans. *Emerg Radiol*. 23(3):263-8.

Hemmes, B., Jeukens, C. R., Kemerink, G. J., Brink, P. R., Poeze, M., 2016. Effect of spinal immobilisation devices on radiation exposure in conventional radiography and computed tomography. *Emergency radiology*. 23(2), 147–153.

Rollins, J.H, (2016). 'Trauma Radiography'. *Radiology Key.* Available at https://radiologykey.com/trauma-radiography/#cesec3 (Accessed on 24 May 2023)

Lee, J. J., You, J. H., (2016). Movement Measurement Validity And Reliability Of The Image J Program For Kinematic Analysis. *Journal of Mechanics in Medicine and Biology*. 16(8), 1640028 (8 pages)

Brian Nett, PhD. (2020). X-ray Contrast To Noise (CNR) Illustrated Examples Of Image Noise (SNR, Quantum Mottle) For Radiologic Technologists. *How Radiology*

Works. Available at https://howradiologyworks.com/x-ray-cnr/ (Accessed on 24 May 2023)