EFFECTS OF CERVICAL COLLAR ON ENTRANCE SURFACE DOSE, EXIT SURFACE DOSE AND IMAGE QUALITY IN PLAIN RADIOGRAPHY: A PHANTOM STUDY

NADHRATUL WARDAH BINTI ADNAN
DEPARTMENT OF DIAGNOSTIC IMAGING AND RADIOTHERAPHY, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH, BANDAR INDERA MAHKOTA, 25200 KUANTAN, PAHANG, MALAYSIA
nadhratulwardah@gmail.com

SAYED INAYATULLAH SHAH (CORRESPONDING AUTHOR)
DEPARTMENT OF DIAGNOSTIC IMAGING AND RADIOTHERAPHY, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH, BANDER INDERA MAHKOTA, 25200 KUANTAN, PAHANG, MALAYSIA
inayatullah@iium.edu.my

ABSTRACT

Introduction: Trauma patients presented to emergency department usually come with spinal immobilization device as a precaution and initial pre-management care by emergency medical personnel. These types of patients are at higher risk for suspected cervical fractures and internal injuries. The use of cervical collar raises some issues on radiation dose to the patient and image quality. Therefore, the use of cervical collar in routine trauma patients is questioned by researchers. The purpose of this paper was to investigate the effect of cervical collar on entrance surface dose, exit surface dose and image quality. **Methods:** Siemens Multix Top CR System and Kyoto Kagaku PBU-50 Body Phantom was used. The phantom was positioned supine on the table couch and was exposed with and without cervical collar. An Anteroposterior (AP) Axial cervical projection was performed and the phantom was also exposed with and without Automatic Exposure Control (AEC) to study the effects on radiation dose and image quality. The dose reading was recorded in all exposures and compared. Images obtained were analyzed for Signal to Noise Ratio (SNR). **Results:** Lower entrance dose was recorded with cervical collar when the AEC was disabled during the exposure and the results were vice versa when the AEC was enabled. Higher exit dose was calculated when cervical collar was applied to the phantom. Greater signal to noise ratio (SNR) was observed with cervical collar. **Conclusions:** This study concluded that cervical collar adds to exit dose and without any impact on image quality. The entrance surface dose recorded with cervical collar and AEC disabled was lower compared to when it was removed. However, the entrance surface dose recorded with cervical collar and the AEC enabled was higher compared to when it was removed.

KEYWORDS: Cervical collar, Radiation Dose, Image Quality, Computed Radiography (CR).

INTRODUCTION

Trauma patient usually transported to radiology department with immobilization device such as cervical collar, splint and spine board. The device is removed once the injury such as spinal cord has been ruled out by the clinician, after the radiological workup has been done. Anteroposterior (AP) Axial Cervical x-ray was performed as most of the trauma patient come to the emergency department are suspected to have spinal cord injury. Immobilization device is used to reduce any deterioration of injury to the patient and patient movement. Berlin (2003), mentioned that the widespread use of spinal immobilization device for patient suspected with cervical spine trauma injury has been practiced by emergency medical service personnel at the accident scene. Immobilization devices are applied as initial preclinical trauma management. Bledsoe (2016), also explained that the practice of applying cervical collar in trauma patient was a time-consuming process. This is because the researchers do not have a consensus of this practice due to fears of worsening the injuries, missed diagnosis and legal conduct.

Hemmes *et a*l, (2016) reported that the x-ray radiation was attenuated in conventional radiography by the immobilization device that ranges 9% to 23%. This shows that it is important to have an immobilizer with lower attenuation properties. The use of Automatic Exposure Control (AEC) in certain practices may cause the (CR) system to automatically adjust the exposure to compensate the loss of x-ray beam penetration. Applying immobilizer when the exposure was made with AEC influences the radiation dose to patient. As stated by Rollins, (2016), patient with immobilization device such as backboard or spine board may require radiographic exposure factor compensation when making exposure. This is because of the concept of attenuation of x-ray beam as it passes through an object.

The use of cervical collar might affect the image quality and has adverse impact on the diagnosis due to the material, density and thickness. Therefore, this study aims to find out the effects of cervical collar on the dose received (entrance surface dose and exit surface dose) and image quality in plain radiography.

METHODS

Experimental Setup

Siemens Multix Top CR System was used and Kyoto Kagaaku PBU-50 Whole Body Phantom was positioned in supine on the table couch. Fifteen degree cephalad angulation of x-ray tube was used to obtain anteroposterior (AP) axial projection of the cervical. The superior collimation was included from the level of external acoustic meatus (EAM), lateral collimation to include both lateral soft tissues and inferior collimation was covered until (T1) Thoracic Vertebrae. The parameters were set to 100 cm of source to image distance (SID), 12:1 focused grid, and 1.3mm large focal spot size. A 10 x 12 inch sized imaging plate in lengthwise orientation was used. The size of collimation was set to 22 x 25 cm to cover the region of interest only. The phantom was exposed by using tube voltage of 68 kV and tube current of 8 mAs. The imaging parameters used for this study were fixed throughout the experiment. The EB-2B model extrication collar (Wanrooe Medical), an adjustable cervical collar made of radiolucent materials was used in this experiment to study the effects of the collar on dose and image quality.

Data Recording

A nanoDot optically stimulated luminescent dosimeter (OSLD) was placed on the anterior left side of the neck region between the cervical collar and the phantom to measure the entrance surface dose. Another nanoDot OSLD was placed at the center underneath the neck area of the phantom to measure the exit surface dose. The nanoDot OSLD position was fixed and three exposures were made to calculate the average dose reading. The Automatic Exposure Control (AEC) was switched off during the exposure. The steps and experimental setup was repeated and remained the same in all exposures. The phantom was exposed with the same imaging parameters and the AEC was enabled. The phantom was exposed with and without the cervical collar as shown in Figure 1 and 2. The data were plotted into simple bar chart and graph. The average reading of entrance surface and exit surface dose was compared. The experimental setups are summarized as in Table 1.

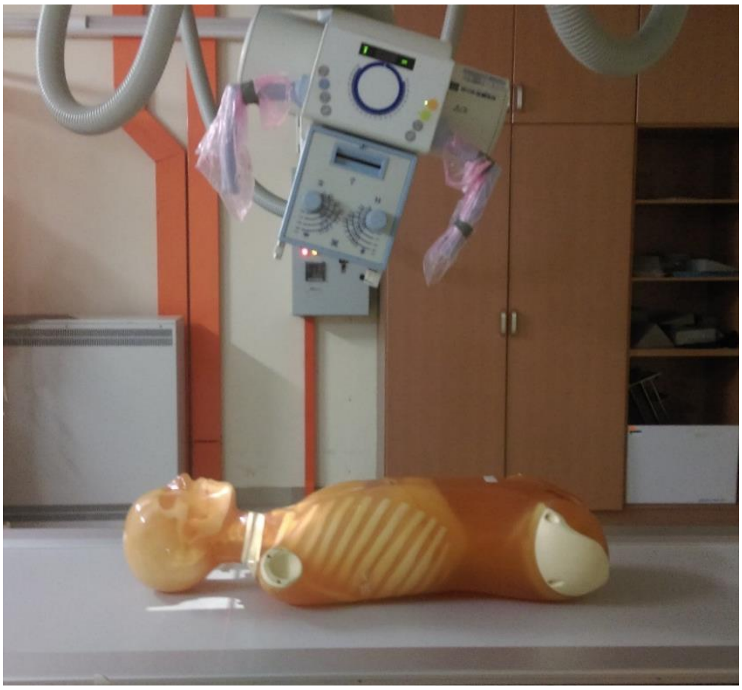

Figure 1 The phantom exposed without cervical collar

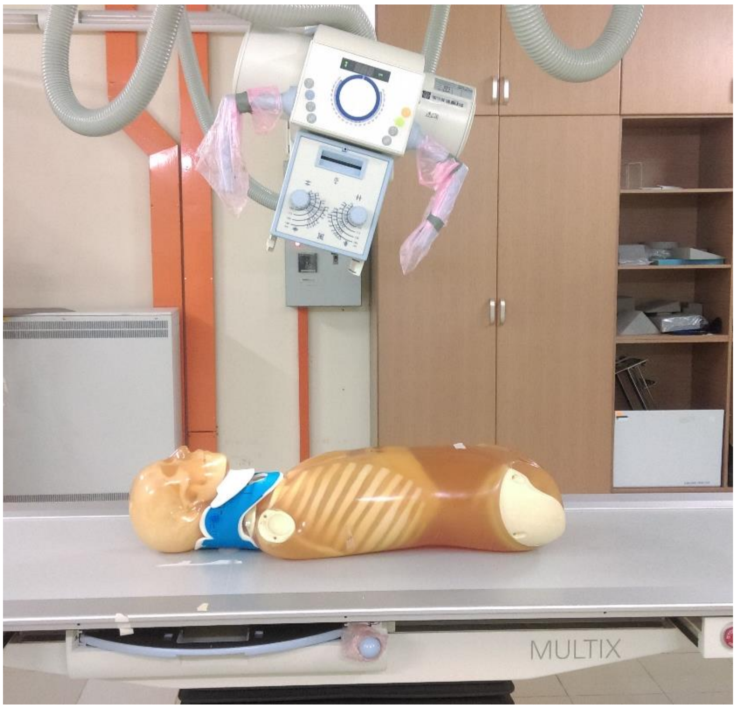

Figure 2 The phantom exposed with cervical collar

Table 1: Experimental Set Up used

Experimental Set Up	Cervical collar	AEC Enabled
A	No	No
B	Yes	No
C	No	Yes
D	Yes	Yes

Data analysis

The percentage difference was calculated to compare the dose value using the formula:

$$\text{Percentage difference } \left(\frac{\textit{Measured value with collar} - \textit{Measured value without collar}}{\left(\frac{\textit{Measured value without collar} + \textit{Measured value with collar}}{2}\right)}\right) \times 100\ \% \quad (1)$$

Images obtained from all exposures with and without cervical collar were saved in JPEG format and labelled. The images were analyzed by using computer software, namely, ImageJ 1.51j8. The images obtained from the procedure were analyzed in terms of SNR using the following formula:

$$\text{Signal to Noise Ratio (SNR)} = \mu \,/\, \sigma \quad (2)$$

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

RESULTS

Effects on entrance surface dose

The average entrance dose reading with cervical collar is lower which is 2.8754 mGy compared to average entrance surface dose calculated without cervical collar which is 2.9744 mGy. A slight decrease of 3.4% of entrance dose was recorded with the collar. As the AEC was enabled, the result obtained was vice versa. Higher averaged entrance dose was calculated with cervical collar compared to without cervical collar. Entrance dose of 1.1752 mGy was calculated with the collar whereas 1.0773 was recorded without the cervical collar. There is 9% increase in dose when the collar was applied. The relationship between the cervical collar, entrance surface dose and AEC were plotted and shown in Figure 3.

Effects on exit surface dose

From the findings, higher exit surface dose which is 0.3959 mGy was associated when the collar is fitted to the phantom compared to 0.3592 mGy when the collar was removed. Only 10.2% increase of exit dose was calculated with the collar. The results show that a higher average exit surface dose was also recorded with cervical collar when AEC was enabled which is 0.1543 mGy compared to 0.1137 mGy when the collar was removed. An increase of 35.7% in exit dose was recorded with the collar when the phantom was exposed with AEC. The relationship between the cervical collar, exit surface dose and AEC is shown in Figure 4.

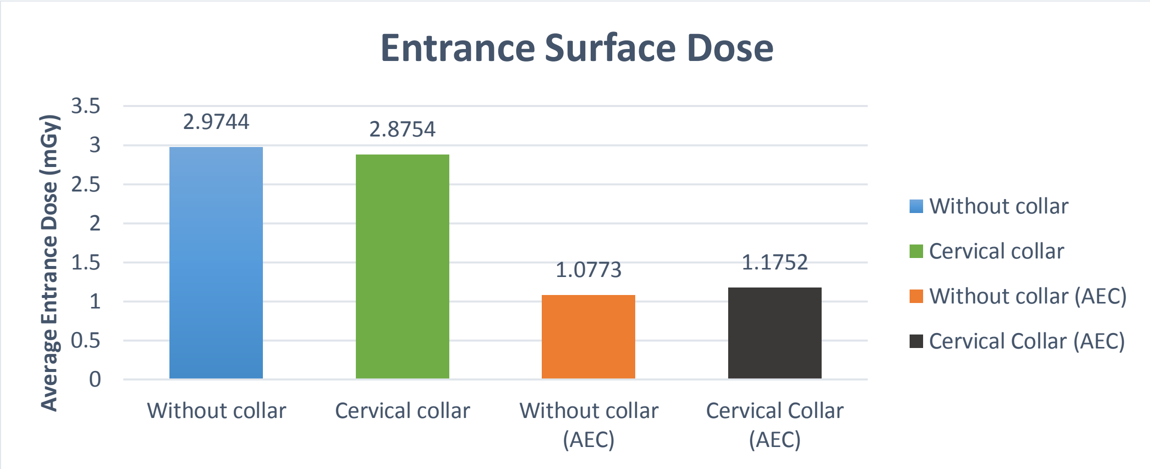

Figure 3 Comparison of the effect of cervical collar and (AEC) on entrance surface dose

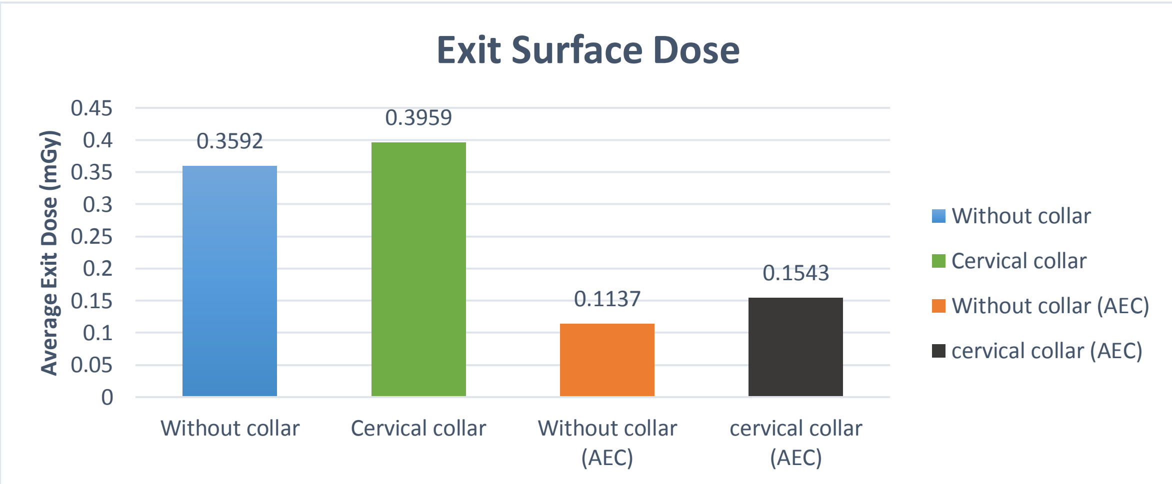

Figure 4 Comparison of the effect of cervical collar and automatic exposure control (AEC) on exit surface dose.

Effect on image quality

Higher SNR value was calculated when cervical collar was applied compared to when it was removed. The percentage difference increased to 7.8% when cervical collar was applied. A higher percentage difference was recorded with collar up to 15.5% when the AEC was enabled during the exposure.

The table below shows calculated SNR values.

Table 2 SNR values calculated in all images.

AEC SYSTEM	SNR VALUE (WITHOUT COLLAR)	SNR VALUE (WITH COLLAR)
AEC DISABLED	1.692	1.824
AEC ENABLED	1.513	1.748

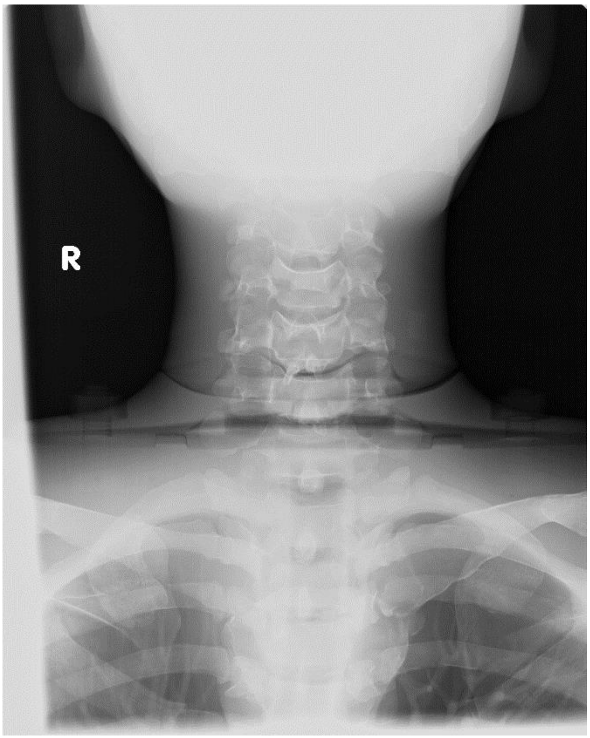

Figure 5 Image of phantom without cervical collar

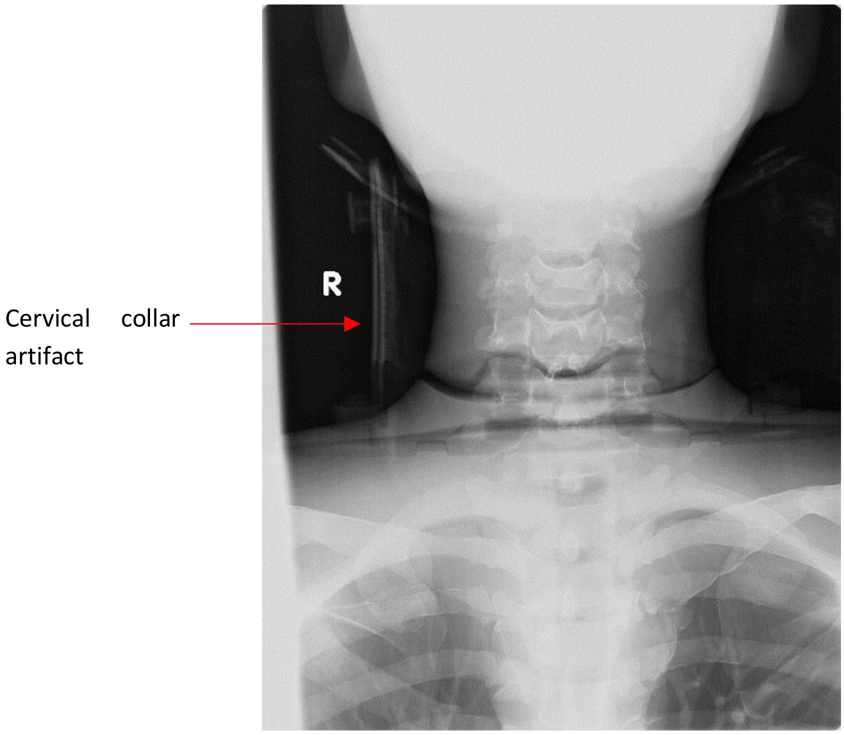

Figure 6 Image of phantom with cervical collar

DISCUSSIONS

The use of cervical collar resulted in lower entrance dose compared to when the collar was removed. This could be due to the concept of attenuation of x- ray beam. As mentioned by Naji, Jaafar, Ali & Al-Ani (2016), attenuation of x- ray beam can be influenced by several factors and this include exposure parameters used (kVp), type of materials and the thickness. Different type of materials have different attenuation properties and give different outcome after x-ray beam interaction. The penetration of x-ray beam through the material also depends on the thickness as thicker material used will result in fewer x- ray photon. Hemmes et al, (2017) wrote that manufacturers should consider the radiological properties of the immobilization devices in their design and this include higher rate of radiation transmission. In this study, the cervical collar was wrapped around the phantom's neck, therefore the quantity of photon was reduced and attenuated after the beam interaction with the material. Hence, lower entrance surface dose reading was measured.

The result obtained was slightly different when the AEC was activated where a higher dose was calculated with cervical collar. A slight increase of 9% in entrance dose was recorded with the collar suggestive that the use of AEC influences the radiation dose. The function of AEC is to terminate radiation exposure once the amount of radiation is adequate. According to International Atomic Energy Agency (IAEA), AEC has different type of working principles. Some AEC automatically adjust the exposure time and tube current, while other adjust the tube voltage (kVp). The AEC functioning principles are different depending on the vendors' preference. In this study, the results show that higher entrance dose was associated when AEC was enabled with cervical collar. Presence of cervical collar in x- ray beam pathway reduces the number of photons that can penetrate through the collar and cause the system to automatically adjust the exposure time. The AEC systems detect a smaller number of photons reaching the ionizing chamber and compensate the loss of tube current by increasing the exposure time. Longer exposure time gives higher radiation dose and increase the risk of cancer (Hemmes *et al*, 2016).

Next, higher exit surface dose was observed when the collar was fitted to the phantom. The same results were obtained when the phantom with collar was exposed with AEC. Factors that can influence the results are backscatter and beam energy. Backscatter formation is due to the interaction of x- ray beam between the soft and hard materials of the cervical collar. Backscatter can be defined as radiation that is reflected from objects in the immediate area. According to Schaue (2011), backscatter radiation can be detected near the surface of the skin. Interaction of x-ray beam with cervical collar, soft tissues, the vertebrae and other organs can contribute to higher exit surface dose.

In terms of image quality, higher SNR was calculated when cervical collar was applied (Table 2). Greater SNR value indicate greater signal and lower noise. The result obtained however contradict to what has been reported by Hemmes et al, (2016) where higher noise was associated when spinal immobilization was used. They also reported that more noise was produced when spinal immobilization used is made up from denser materials. Higher SNR value calculated in this study may indicate that adequate tube voltage was set before the exposure was made. Therefore, the x-ray beam has adequate number of photons reaching the ionizing chamber and more signal is produced.

Higher SNR value recorded suggest that applying cervical collar can remove some scatter radiation from reaching the ionizing chamber. Less scatter radiation reaching the ionizing chamber might attenuate some noise from being recorded thus leaving more signal to produce the image. Another factors that contribute to greater SNR value with cervical collar is the air gap technique. Applying cervical collar to the phantom increase the distance between the posterior neck of the phantom and the table couch. The phantom's neck is lifted upward due to the hard material of the collar creating little space or gap. The gap caused by the collar removes some scatter radiation. Air gap techniques is one of the methods to reduce scatter radiation other than reducing the size of collimation and the use of grids. This technique is crucial in reducing the low energy photon reaching the imaging plate. Hence, greater SNR value was recorded with the cervical collar.

Presence of artifact was seen with cervical collar and it should not be present on the image. Artifact due to the cervical collar appeared as straight lines nearby the region of interest, parallel to the cervical spine consequently making image interpretation more difficult and challenging (Figure 5). The artifact seen however does not obscure the region of interest and the anatomy demonstrated. As mentioned by Tien *et al*, (2007) diagnostic imaging plays a vital role in providing an initial evaluation of the patient. Therefore, artifact should be kept to minimum level.

In this study, the presence of artifact in the image cannot be determined whether it can influence the diagnosis made. This is because the images were not evaluated by radiologists subjectively. It cannot be proven that the artifact present will result in misdiagnosis and missed diagnosis. Nevertheless, effort to reduce the presence of artifact in the image should be encouraged between healthcare personnel. Hemmes *et al*, (2016) suggested that removing of spinal immobilization device prior to imaging procedure or enhancing radiological properties of the device as an effort to reduce artifacts.

Limitation of the study

The limitation of this study was the absence of exposure chart for this Computed Radiography (CR) system. This might influence and affect the result obtained as the optimum exposure for cervical projection in this x-ray system was not known. Optimum exposure is required to ensure accurate diagnosis is made (Ching, Robinson & McEntee, 2014). According to AmehOgenyi *et al*, (2016) exposure chart is a part of quality assurance program and therefore it must not be disregard in radiology department. The study was not done on human and the specifications of radiolucent materials used in the cervical collar were not mentioned exactly by the manufacturer.

CONCLUSION(S)

It is concluded that, applying cervical collar adds to exit surface dose and have no impact on image quality. Wearing cervical collar give lower entrance surface dose and the use of Automatic Exposure Control (AEC) system with cervical collar result in higher entrance dose. The use of cervical collar in trauma patient should be used when deemed necessary. It is expected that this study can provide an idea on application of spinal immobilizer on patients in radiological settings. Future research should be done to study the effects of different designs and materials of spinal immobilizers available in the market.

ACKNOWLEDGEMENT(S)

The authors would like to acknowledge the Department of Diagnostic Imaging and Radiotherapy, International Islamic University Malaysia (IIUM) for providing the facilities and equipment to carry out the study. This research is supported by the International Islamic University Malaysia under the Research Initiative Grant Scheme, RIGS #16-302-0466.

REFERENCES

Berlin. L. (2003). Malpractice Issues in Radiology. CT Versus Radiography for Initial Evaluation of Cervical Spine Trauma: What Is the Standard of Care? *American Journal of Roentgenology.* 180(4), 911-915. doi: 10.2214/ajr.180.4.1800911

Bledsoe, B. (2015). Why EMS Should Limit the Use of Rigid Cervical Collars. Making the case for soft collars & alternative methods of spinal stabilization. *Journal of Emergency Medical Services*. 40(2) Retrieved from http://www.jems.com/articles/print/volume-40/issue-2/patient-care/why-ems-should-limit-use-rigid-cervical.html?c=1

Hemmes, B., Jeukens, C.R.L.P.N., Kemerink, G.J., Brink, P.R.G. and Poeze, M. (2016). Effect of spinal immobilisation devices on radiation exposure in conventional radiography and computed tomography. *Emergency Radiology*. 23(2), 147–153. doi: 10.1007/s10140-015-1371-0

Hemmes, B., Jeukens, C.R.L.P.N., Al-Haidari, A., Hofman, P.A.M., Vd Linden, E.S., Brink, P.R.G. and Poeze, M. (2016). Effect of spineboard and headblocks on the image quality of head CT scans. *Emergency Radiology*. 23(3), 263–268. doi: 10.1007/s10140-016-1396-z

Ching, W., Robinson, J. & McEntee, M. (2014). Patient-based radiographic exposure factor selection: a systematic review. *Journal of Medical Radiation Sciences*. 61(3), 176–190: https://onlinelibrary.wiley.com/doi/pdf/10.1002/jmrs.66 (Accessed on 10-05- 2018)

AmehOgenyi, P., O England, A., Geofery, L. & Maikudi, D. (2016). Radiology: Developing an Exposure Chart for A Minxray Hf120/60hppwv/Powerplustm (Mobile X-Ray Machine). *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS).* 15(5), 76-83. doi: 10.9790/0853-1505037683.

Naji, T., Jaafar, M.S., Ali, E.A. & Al-Ani, S.K.J. (2016). X-ray Attenuation and Reduction of Backscattered Radiation. *Applied Physics Research.* 8(4), 92-102.

Schauer, D. A. (2011). Does Security Screening with Backscatter X-Rays Do More Good than Harm?. *Radiology*. 259(1), 12-16. doi: 10.1148/radiol.11102376

Rollins. J.H, (2016). Trauma Radiography. Accessed on September 17, 2017 from https://radiologykey.com/trauma-radiography/

Tien, H.C., Tremblay, L.N., Rizoli, S. B., Gelberg, J., Spencer, F., Caldwell, C & Brenneman, F. D. (2007). Radiation Exposure From Diagnostic Imaging in Severely Injured Trauma Patients. *The Journal of Trauma Injury, Infection, and Critical Care.* 62(1). doi: 10.1097/TA.0b013e31802d9700