ORIGINAL ARTICLE

ASSESSMENTOF PROTECTIVE APRON IN A MEDICAL FACILITY IN ASABA, DELTA STATE, NIGERIA

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ABSTRACT

BACKGROUND: Lead aprons and equivalent lead materials continue to be critical tools in imaging, with the main purpose of absorbing scatter radiation arising from radiological investigations. **OBJECTIVE:** The goal of the study is to use a digital X-ray source to look for cracks, tears, and other deformities that might render protective aprons unusable. The study also measured absorbance and transmission factors (TF) among the aprons and compared the results with relevant literature. **METHODS:** By placing the 4 lead equivalent aprons carefully on the machine's table bulky, a digital radiography (DR) X-ray unit was used to image the aprons each. The ionization chamber (IC) was positioned with care at a point in the air, just before the protective apron and behind it, at a source to image distance (SID) of 100 cm, covering a 43 by 43 cm^2 beam area at an exposure range of 80-100 kV. **RESULTS:** The weight and age of the aprons ranged from 4.8 (3-6) kg and 6.3 (3-11) years respectively. The mean absorbance and transmission factor (TF) for apron A-D were 97 and 3 % respectively, with apron B with back protection of 0.25 mm having the least absorbance (95%) and highest TF (5%). The protective aprons were found to be intact, although, broad lines were noticed for all the aprons. These are not considered as defects. **CONCLUSION:** The absorbance and TF were comparable to most studies and were found to be adequate. The study reaffirms that the aprons were in good condition to be clinically. Proper handling of protective apron before and after use should be taught among end users.

Keywords: Absorbance, Transmission Factor, Protective Apron, Digital Radiography, Magic Max Basic Unit

Introduction

To save guard persons working with radiation and caregivers during imaging, protective apron are often worn to minimize the risk arising from primary and secondary ionizing radiation. From the radiation protection point of view, it s critical to protect radiosensitive parts of the body that are not of interest during imaging and to reduce dose to occupationally exposed workers.[1-5]

To a greater extent, personal protective equipment, such as aprons, is worn by all interventional staff working in fluoroscopy inside the X-ray room.[6] These aprons usually contain the equivalent of 0.25, 0.35, or 0.5 mm of lead, and some designs have an overlap at the front to provide protection of 0.5 mm lead equivalence, with 0.25 mm lead equivalence else where (side and behind).[7] Transmission is typically between 0.5% and 5% in the range 70-100 kV[8] and other studies have reported higher TF between 20-35 % for 0.25 mm lead apron.[9,10] Although they shield the trunk against scattered radiation, parts of the

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body, including the head, arms, hands, and legs, are not protected by the apron and need to be considered in the radiological protection programme. Lead equivalence and attenuation by the apron should be sufficient for the staff doses to meet regulatory dose limits of 20 mSv in any calendar year and 1 mSv to the general public in a single year.[11]

Protective apron maintenance protocol is still a major problem and appropriate proper handling of the apron before and after use have great impact on their life expectancy. In many occasion, they are either kept of the bucky table or spread around a lead screen.[11,12]

Testing for defects in an apron can be achieved using fluoroscopy or radiography. The purpose is to spot tear, cracks, holes, or stretch marks.[13] International best practices recommend that those areas with a defect should be marked and recorded, and further evaluation test should be performed before a protective apron is replaced. To reduce costs, a protective apron may only have to be replaced if the defect is $\geq$15 mm^2 in areas close to critical organs, and for areas at the back or along the seams, a replacement can be made if the defect is $\geq$670 mm^2.[14,15]

The aim of this study is to check the integrity of the front/back protective area of four protective aprons with digital radiography and to determine the percentage absorbance and transmission factor (TF) of the apron. The study would also compare findings with similar studies.

Methods

This research was a prospective study, carried out in a medical facility in Delta State with a calibrated direct digital radiography (DDR)system (Carestream Health, Inc. Rochester, NY 14608 United States) (Tab.1). A total of four protective aprons were used denoted as A-D.

A Magic Max universal software and a multidetector XR (silicon photodiode) with energy range of 50-150 kV was used for quality checks of the DDRbefore the assessment of the protective aprons (Fig.1).

A calibrated DCT 10-MM Ionization Chamber (IC)with active length of 100 mm, energy range of 100-150 kV for computed tomography (CT) and 50-150 kV for conventional radiography, a dose range of 0.01mGy-15Gy, sensitivity of 1.42 nC/Gy, active volume of 4.9cm^3 and with uncertainty of < 5% (IBA Dosimetry, Germany). The unit has the capacity to measure dose quantities (Gy, mGy and Gy) and other quantities like the dose rate, exposure time, practical peak voltage (PPV), mA and mAs.

The IC was carefully positioned with a retort stand at a point in air, just before the protective apron. This point was referred to as the incident Air Kerma (iAK), at a Source to Image Distance (SID) of 100cm, covering a beam area of 43 43 cm^2, this was necessary

Digital radiography equipment specifications	
Manufacturer	CARESREAMS
Type	Ceiling Mounted Unit (DR System)
Machine Model	18H1896
Serial Number	GQ50-18R-10022
Power Capacity	70kW
Maximum Tube Voltage	150kVp
Maximum X-ray Tube Current	1000 mAs
Total Filtration	3.3mmAl
Anode	Rotating Anode X-ray Tube Assembly
Electrical Circuit	High Voltage Generator
Line Voltage	115-240V
Phase/Frequency	3f, 50/60/150/180Hz
Target	Tungsten
Date of Manufacturer	July, 2018
Country of Make	China
Date of Installation	May, 2020

Table 1: Digital radiography specification

Figure 1: A calibrated ionization chamber (IC) (black) and a Magic Max basic unit (in green) for absorbance and transmission factor measurements

to ensure that the IC was fully within the beam area. Also, the IC was positioned in-between the protective apron, which is known as the Shielded Air Kerma (SAK). The distance from the source to this points were noted. Exposure was made at 100kV (Fig.2). This was to determine the transmission throughthe aprons and to determine the percentage absorbance for each apron. In addition, this study also determined if there were tear or cracks from X-ray images of the lead apron at 60-70kV on 10-20mAs. This energy was sufficient to visualize the aprons.

Figure 2: A picture of a digital ceiling mounted X-ray unit and a protective apron on the X-ray bucky

The broad-beam transmission equation from the National Council on Radiation Protection and Measurements (NCRP 147) and was later extrapolate from the transmission graphs to determine corres--ponding lead thicknesses. The broad-beam transmission equation is given by:[16]

$$B\,(x) = \frac{k\,(x)}{k\,(0)\,R} \qquad (1)$$

Where *B (x)* - Broad - beam transmission

k (x) = Shielded air kerma (SAK)

K (0) = Incident air kerma (iAK)

R = Square of the ratio of incident to shielded distances

The mathematical expression for the percentage (%) absorbance was:

$$\%\ \text{Absorbance} = \frac{\textit{Incident Air Kerma-Shielded Air Kerma}}{\textit{Incident Air Kerma}} \qquad (2)$$

The transmission factor (TF) is determined as:

$$\text{TF} = 100\% - \%\ \text{absorbance} \qquad (3)$$

Statistical analysis

The study used descriptive statistics (mean and standard deviation), a One Sample t-test, an inde-

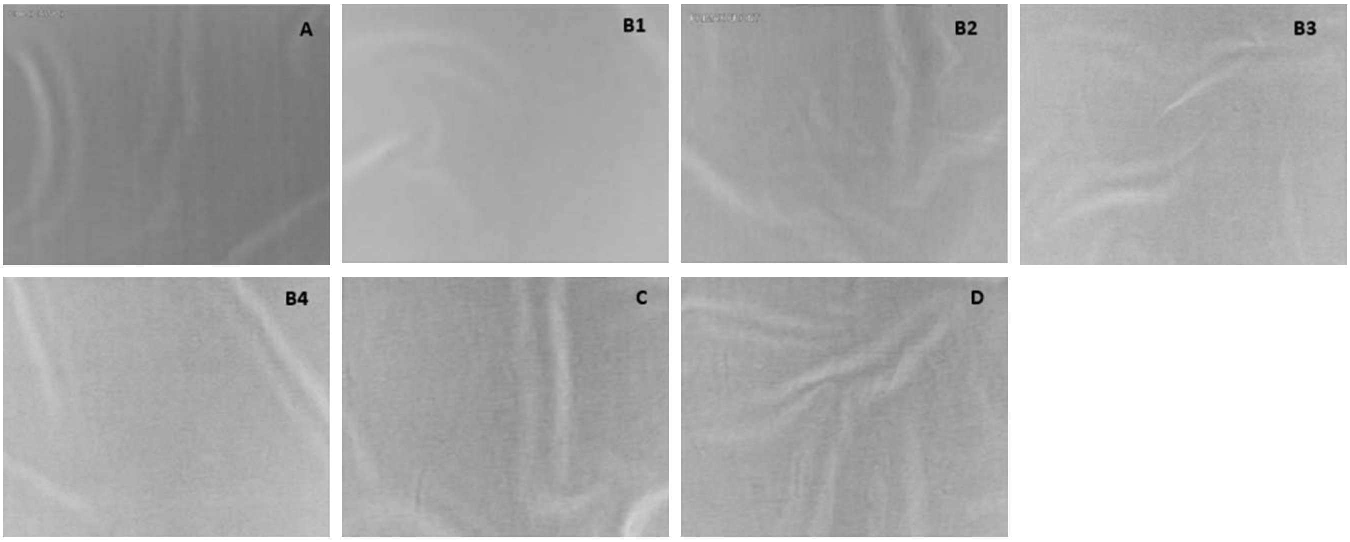

Figure 3: Front side of apron A **(A)**, apron B (front upper and lower side **(B1 and B2)**), back upper and lower side **(B3 and B4)**, front side of apron **C** and front side of apron **D**

pendent sample t-test was used to determine if the mean between the protective aprons were statistically significant. Similarly, the study used a one way ANOVA to test if the mean for thickness, weight and age of the aprons were statistically significant. In addition, Pearson correlation was used to determine the association among thickness, weight and age. P< 0.05 shall be considered to be statistically significant and vice versa.

Results

A total of 4 protective aprons were used. 3 out of 4 of the aprons were 0.35 mm lead equivalent. All of the aprons were manufactured in Germany. Apron B had front and back protection with 0.35 mm and 0.25 mm. Apron C was 0.5 mm and apparently the thickest. These measurements were computed into a spread sheet by checking the labels of the aprons individually (Tab.2).

Specifications	Apron A	Apron B	Apron C	Apron D
Type	CAWO	PRIMAX	KIRAN	KIRAN
Model	-	EN 61331-3	X1113732	X1103232
Size in cm	-	MM	L	L
Batch number	20040202	-	690LL11102	1201165132
Front	0.35 mm Pb	0.35 mm Pb	0.5 mm Pb	0.35 mm Pb
Back	-	0.25 mm Pb	0.25 mm Pb	-
Manufacture year	05/2018	07/2018	11/2010	05/2013
Country of make	Germany	Germany	Germany	Germany

Table 2: Specification of the protective apron used

Quality checks were performed for the DDR unit. The kVp, mAs, exposure and mA accuracy passed the test, while other parameters like the radiation output at 80Kv, tube leakage and half-value layer (HVL) similarly passed the test (Tab.3)

The mean incident air kerma (iAK) of the aprons ranged from 1.026-1.033 mGy for 0.25-0.5 mm of equivalent lead. A One-Sample T test shows that there was statistically significant difference in the iAk (P < 0.001).

Similarly, the shielded air kerma (SAK) measurements ranged from 0.0125-0.0569 mGy. A student T test shows that there was statistically significant difference between iAk and SAK (P < 0.001). The range of the absorbance and TF was 95-99 % and 1-5 % respectively. There was correlation between the SAK and % TF(P = 0.004). Radiographic images of the aprons are shown (Fig.3).

Apron	No of sides	Mean iAK (mGy)	Mean SAK (mGy)	% Absorbance	% TF
A (0.35)	Front	1.033	0.0447	96	4
B (0.35)	Front	1.026	0.0261	97	3
B (0.25)	Back	1.031	0.0569	95	5
C (0.50)	Front	1.027	0.0125	99	1
D (0.35)	Front	1.032	0.0175	98	2

Table 3: Percentage absorbance and transmission factor of apron A-D

Apron	No of sides	Weight (kg)	Age (years)
A	Front	5	3
B	Front /back	5.05	3
C	Front	6	11
D	Front	3	8

Table 4: Weight and age of the 4 aprons used

The weight of the aprons ranged from 3-6 kg, with a mean weight of 4.8 kg. Apron C (11 years) was the heaviest (6 kg), while apron D (8 years) was the lightest.2 out of the 4 were 3 years each. There was association between weight of the aprons and % absorbance (P = 0.035) (Tab.4).

Comparison of the absorbance and TF was made with other studies at 70 and 100Kv for 0.25, 0.35 and 0.5 mm of equivalent lead apron. (Tab.5)

Author	Absorbance (%)			Transmission factor (%)			Energy (kV)
	0.25mm	0.35mm	0.5mm	0.25mm	0.35mm	0.5mm	
This study	95	97	99	5	3	1	100
Omojola et al [13]	78	94	95	20-23	5-7	4-6	100
Simon et al [18]	-	-	-	3-8	-	0.4-2	100
Livingstone et al [24]	90	-	97	-	-	-	100
Oyar et al [25]	-	-	99	-	-	-	100
Christodoulou et al [27]	-	-	-	5.4/7.1^a	-	0.9/1a	70
	-	-		15/16.8^a	-	5/4.9a	100

^{a}Lead-free apron

Table 5: Comparison of this study with similar work

Discussion

Radiological assessments of 4 aprons have been determined using a digital X-ray unit, to ascertain if there are cracks or tear among the aprons. The study discovered that all the aprons were still intact, as there was no crack or tear that was noticeable among them, although broad lines were noticed (A-D). A study by Lambert et al, have suggested that a protective apron be replaced if defect is seen to be ≥15 mm^2 for areas close to critical organs and for areas at the back or along the seams, a replacement can be made if the defect is ≥670 mm^2.[17] However, pressure marks was noticed among the aprons. This may be due to poor handling and storage after use. In most cases these marks may deteriorate over time and may affect the integrity of the apron. From the studied facility, there was only one apron stand for hanging them, which is insufficient.

The study also determined the percentage absorbance and transmission factors (TF) among the aprons. The mean % absorbance for apron A-D was 97%. The apron with the highest absorbance was apron C, which happens to be the oldest (11 years). Similarly it was also having the best TF (1%), while apron D had the second highest absorbance (98%) and a TF of 2%. Apron B with back protection had the least absorbance (95%), however, the front protection was 2% higher compared to the back side. Apron A and B had a TF of 4 and 3% respectively, indicating that apron C and D had better absorbance. A major reason could be the shielding components used in making the aprons. Also, the TF was comparable to Simon et al, where the TF ranged from 2.9-7.6 % for 0.25 mm apron and 0.4-2.2 % for 0.5 mm apron[18] and comparable to Yaffe et al.[19] Variation in TF could be associated to the type of measuring device used and selected technical factors. Protective aprons are often used to intercept or absorb scatter radiation during radiographic examinations. In most cases, it used as protection in special investigations by the radiologist like Hysterosalpingogram (HSG),[20] Intravenous pyelogram (IVU), Micturating Cystourethrogram (MCU) and Barium studies among others.[21-23] The use of protective apron has also gained grounds in interventional procedures in orthopedic surgery, cardiology and many others.

A study by Livingstone et al, who assessed the lead equivalent of different aprons in India, shows that at 0.5 mm Pb, a mean radiation attenuation of 97% was achieved at 100kV.[24] This was similar to Oyar et al, where it was 99%.[25] This result was similar to our study where 99% was achieved from a 0.5mm Pb apron at same X-ray potential.

The mean weight from Livingstone et al, was 4.2kg, while this study was 6kg. The differences observed were from the different materials used in manufacturing the aprons.[24] The use of several different lead free materials with less weight compared to the conventional use of lead has been discussed in literatures.[26]

A similar study to determine TF by Christodoulou et al, shows that 0.508 mm Pb at 70 kV was 0.9%, while those with lead equivalent (0.5 mm Pb) ranged from 0.6-1.6%. The above results was similar to what we obtained at 100 kV for 0.5 mm Pb, which had a TF of 1% but the TF results from Christodoulou et al, study at 100 kV was higher compared to our study, where at 0.5 mm Pb, TF was 5% and with lead equivalent (0.5 mm Pb), it was 3.5-6.7 mm Pb. Some factors that may affect both results could be from the kind of detector used and milliamphere (mAs) used.[27]

Transmission factor (TF) from a study by Omojola et al, 2019, shows that TF for 0.35 mm Pb ranged from 5.3-6.9%, while TF from this study ranged from 2-5%. Similarly TF for 0.5 mm Pb ranged from 3.7-6.3%, while TF from this study was 1%. The differen-ces observed can be explained based on the different detectors used. This study used an ionization chamber while Omojola et al, used an electronic dosimeter for measurements. The accuracy from both devicesvaries, and this may have affected the results that were compared.[13] The mean age of the apron used in this study was 6.3 years, which was higher compared to Finnerty et al[28] and Cohen et al[20] with mean age of 2 and 4.3 years respectively.

Broad lines may be seen on the protective aprons, indicating that there were no flaws. These lines are visible because the radiation path's length is larger through the slope's hypotenuse than it is perpendicular to the sheet. When the apron is pressed flat, they vanish.[29]

Conclusion

The study has determined the % absorbance and transmission factor for the 4 protective aprons. No tears and cracks were observed. The results from this study using an ionization chamber to determine the absorbance (attenuation) yielded good results as recommended from most literatures. Assessment of protective devices should be carried out from time to time to validate their continuous use.

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