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Radiology

HOW EFFICIENT ARE THE LEAD APRONS USED FOR RADIATION PROTECTION IN OUR HOSPITALS?

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ABSTRACT

Background of the study: X-rays are useful in medical care but careless uses of x-rays are harmful. One method of radiation protection is the use of structurally intact lead apron gowns.

Purpose of the study: This study aimed at evaluating the protective efficiency of the lead aprons used at the radiology department of a tertiary health institution in Anambra State of Nigeria.and correlate the transmittance, absorbed dose and transmission efficiency of the aprons with KVps.

Materials and Method: Nine (9) protective lead aprons of different type/make, lead equivalent and length of use were evaluated. Fluoroscopy and conventional x-rays were used. A pile of plastic foam was used to simulate a patient. Exposures were made using different KVp, mAs, focus Film distance settings. The lead apron being tested was hung close to the x-ray couch in a position that would be taken by a patient's relation aiding in the x-ray investigation. A dosimeter placed at a height above the x-ray couch (in front and back of the apron in turn) was used to measure the quantity of scattered radiation incident on the apron and the quantity transmitted through the aprons respectively. The efficiency of the aprons was calculated as the ratio of transmitted beam intensity to the incident beam intensity. Data was analyzed using the Statistical Package for Social Sciences (SPSS) version 20.0. Statistical significance was considered at $p < 0.05$.

Results: Physical examination showed that 7 (77.78%) of the aprons were good but qualitative assessment showed that only 4(44.4%) of the lead aprons were in good condition. The efficiency of lead aprons increases with the KVp and decreases with lead thickness

Conclusion: Physical examination and qualitative assessment are important for evaluation of lead aprons. Radiology departments should ensure that lead suitable are used.for KVp settings on their x-ray equipments.

KEYWORDS : Lead-aprons, radiation protection, transmission; efficiency.

INTRODUCTION

X-ray is the most widely and frequently used ionizing radiation for diagnostic imaging and plays a significant role in the effective health care delivery system both in developed and developing countries of the world(Okowookere et al.,2012). In fact the discovery of x-rays by William Conrad Roentgen of Wurtzburg University in November 8, 1895 laid the foundation of modern medicine(NCRP, 1989). Just as the use and importance of x-rays in medical care is well known. Also well known by users of x-rays is the harm that can occur if x-rays are not used carefully. Careless use of x-rays can result in a number of somatic and genetic diseases. The evidence for the occurrences of these radiation effects was seen on early radiation workers, including Roentgen and Becquerel. Sequel to this early radiation effects incidences and to subsequently prevent future occurrences (because the risks associated with radiation exposure cannot be totally eliminated but can only be restricted (Lopez et al. 2005) thus necessitating adequate radiation protection, prominent radiation protection committees such as the International Commission on Radiological Protection (ICRP), United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR), the Biological Effects of Ionizing Radiation (BEIR), the International Atomic Energy Agency (IAEA), etc. had been established to handle radiation protection issues (Lopez et al., 2005).

Radiation protection is the protection of people from the harmful effects of exposure to ionizing radiation. Fundamental to radiation protection is the reduction of dose and the measurement of human dose uptake (absorbed dose). For radiation protection and dosimetry assessment the ICRP and the International Commission on Radiation Units and Measurements (ICRU) have published recommendations and data which are used to calculate the biological effect on the human body, and set exposure limits. In diagnostic radiography, the two main sources of ionizing radiation exposure that require adequate protection are the primary radiation (from the x-ray beam that has not interacted after emerging from the x-ray tube) and the scattered radiation produced by interactions of the primary beam with the intercepting medium (such as the patient). These radiation exposures are controlled by one of the basic principles of radiation protection namely, optimization of dose following the ALARA (As Low As Reasonably Achievable) principles, namely, minimizing time spent in radiation area or with radionuclide materials and or areas proximal to the patient; applying the inverse square law and the use of lead shields at different levels of protection. Proper and careful observation of radiation protection measures and practices can mean little or no harm from the use of x-rays. One of the ways of effecting radiation protection is the use of lead apron gowns (composed of thin rubber material impregnated with lead) to protect the radiation worker, any other carerer (such as patients' relations) helping during the x-ray investigation and the patient (depending o the investigation being carried out). Radiation workers in diagnostic radiology wear lead aprons when standing in the vicinity of a patient being exposed to x-rays. Lead aprons protect the wearers' trunk against radiation scattered from the patient and/x-ray couch. Lead has been found to be the best shield for the protection against diagnostic x-rays, because it has the highest atomic number among all non-radioactive elements (Jefferson County's Radiological Safety Division, JCRSD).

Lead aprons contain lead and often other metals (e.g., tin, tungsten, antimony, barium). These metals are homogeneously mixed with synthetic rubber or polyvinyl chloride (PVC). Between two and five thin sheets of metal-impregnated rubber/PVC are placed between sheets of nylon fabric and coated with urethane on the side against the lead-impregnated rubber/vinyl. The materials are cut into a pattern and sewn together to form the protective garment. The manufacturers of lead aprons vary the number of sheets, the percentage of metal, the grade of rubber or PVC, and the mixture of metals to affect flexibility, durability, radiation absorption efficiency, and weight (ESRP, 2011). These factors equally affect the efficiency of the lead apron. The Australian and New Zealand standard specification for protective clothing and devices for the gonads states that "the required attenuation equivalent of light protective aprons should not be less than 0.25mm/Pb over the entire area, and for heavy protective aprons, it should be not less than 0.35mm/Pb for the front section and 0.25mm Pb for remaining parts. (AS/NZS 2000). For effective radiation protection, the lead aprons should not only be won, but they should also maintain their integrity. Otherwise wearing them is just 'cosmetics'. Hiroshige et al (2013) in a study showed that the effectiveness of lead apron depends on the thickness of the lead apron, the energy of the x-radiation used and the rate and angle of scatter radiation.

Because these aprons are made of composite materials, the 'lead equivalent' also vary with beam quality (e.g. kVp, HVL). (ARPANSA). It is recommended that both the design and 'lead equivalent' of an apron is suitable for its intended use. With usage over time, the efficiency of lead aprons decreases due to the presence of cracks, tears and holes found in the lead aprons and this should be checked periodically. It is also recommended that regular testing for defects in aprons be included as part of the quality assurance program for an X-ray department (JCRSD). The Department of Human Services of Victoria (Australia) advisory information, states that aprons should be tested for integrity on initial receipt and at 12-18 months intervals. Testing for imperfections in an apron can be achieved by visual test and x-ray test. X-ray test can be done via fluoroscopy on a floating top table or by radiography. Any cracks or holes found should be marked and recorded. To reduce costs, a lead apron may only have to be replaced if the defect is greater than 15mm² in areas close to critical organs and for areas at the back or along the seams, replacement is made only if the defect is greater than 670mm.(AS/NZS 4543.3:2000). Our aim in this study was to evaluate the effectiveness of lead aprons used in the radiology department of a tertiary health institution in Anambra State of Nigeria(i.e. evaluate how much protection do the lead aprons provide) and the main factors that determine the protection efficiency of the lead aprons.

MATERIALS AND METHODS

A combination of non-experimental and experimental research design was adopted for this research. Ethical approval was obtained from the Research Ethics Committee of the study health institution in Anambra State. Nine (9) lead aprons being in use in the radiology department of the institution were studied.. The study was conducted from 15th May to 15th June, 2016.

Visual Assessment of the lead aprons was made. The aprons were inspected, identified, sorted and recorded according to size, type, lead content or lead equivalent and length of usage(age). Each was assessed for the presence of tears, cracks and holes.

Qualitative Assessment was made by screening each lead apron using a fixed fluoroscopic unit to search for any defect. Areas on the lead aprons with holes, tears and cracks were exposed to radiation and radiographs of the aprons were obtained using a 35cm x 43cm size cassette.

Quantitative Assessment was also made by measuring the transmission of scattered radiation through each lead apron. The assessment was made using 50-120 kVp range at 10Kvp intervals.

The x-ray machine was CTL classed Medical Equipment, a product of GE Hualun Medical System Co Limited. It was manufactured in 2008 and installed 2009. It has KVp range of 45-150 and mAs range of 3-80, a manual collimator and inherent filtration of 1.5mmAl at 100KVp.

A pile of plastic foams placed on the x-ray couch was used to simulate a patient for making the exposures. The lead apron to be tested was hung by the edge of the table. The dosimeter for measuring the scatter radiation was placed on a long stool in front of the lead apron. Then using the x-ray machine, exposures are made at set kVp, mAs and focus-film distance (FFD) and the readings on the dosimeter were recorded. The same process was carried out for all the aprons and the dosimeter readings were recorded. The same procedure was repeated with the dosimeter placed behind each apron in turn. Defects such as racks, holes and tears on the lead apron were checked by palpation and radiographs of the portion/portions of the apron where the defects were observed were obtained using a screen-film cassette. The film was the processed to evaluate the defect. Data capture sheet was used to record the information obtained such as the serial number, thickness of lead apron, defects and their sizes, readings from the dosimeter, and state of the aprons i.e. whether very clean, slightly clean, very dirty or dirty etc.

DATA ANALYSIS

Data analysis was done using Statistical package for social sciences (SPSS) Version 20.0(Chicago Illinois). Statistical significance was taken at 0.05% (i.e. $p<0.05$). Results were presented using statistical tools such as tables, pie-charts and graphs and described using descriptive statistics of frequency and percentages.

RESULTS

All the lead aprons are of the same size and of the same thickness except for C. Four of them are from 10-12 years old, one is 8 years, two are 5 years and one is 3years (Table 1). The mean transmittance through the lead aprons is highest with a value of 6.80 at 120KVp followed by 06.40 at 110KVp, and least (0.03) at 50KVp (.From Table 2). There is a negative correlation between KVp and the beam transmittance through the lead aprons. The correlation was strong but non-significant at 70KVp(r = - 0.601; P = 0.087) and very strong and significant at 80KVp(r = - 0.769; P = 0.015) as shown in Table 3.

TABLE 1: General features of the lead aprons evaluated

	Type of apron	Size of apron	Thickness of apron(mmpb)	Age of apron(years)
A	Ward ray promise	Medium	0.35	12
B	Ward ray promise	Medium	0.35	12
C	Mediphot(4400001082)	Medium	0.25	10
D	Mediphot(4447001082)	Medium	0.35	5
E	Ward ray promise	Medium	0.35	10
F	Mediphot(4447001082)	Medium	0.35	3
G	Ward ray promise	Medium	0.35	8
H	Mediphot(4447001082)	Medium	0.35	5
I	Mediphot(4447001082)	Medium	0.35	5

Table 2 Transmittance Through The Lead Aprons

KVp/Aprons	A 0.35	B 0.35	C 0.25	D 0.35	E 0.35	F 0.35	G 0.35	H 0.35	I 0.35	Mean trans	STD
50	0.05	0.00	0.03	0.01	0.12	0.01	0.02	0.00	0.01	**0.03**	**0.01**
60	0.28	0.06	0.61	0.20	0.70	0.06	0.11	0.13	0.06	**0.24**	**0.08**
70	0.66	0.56	1.06	0.37	0.95	0.31	0.40	0.31	0.21	**0.53**	**0.10**
80	3.27	3.06	3.77	0.42	1.00	0.44	0.72	0.63	0.85	**1.57**	**0.46**
90	5.03	4.64	5.55	1.27	4.62	1.09	4.72	3.97	3.39	**3.81**	**0.54**
100	6.38	6.82	6.56	5.22	5.30	3.32	5.80	5.30	5.95	**5.63**	**0.35**
110	6.84	6.86	6.68	6.45	6.57	4.18	6.88	6.55	6.67	**6.40**	**0.28**
120	7.15	7.05	7.38	6.53	6.90	5.30	7.17	6.80	6.92	**6.80**	**0.20**

Table 3. Correlation of KVp with beam transmittance and absorbed dose

KVp	Beam Transmittance		Absorbed dose	
	Correlation coefficient r	P-value	Correlation coefficient r	P-value
50	-0.211	0.585	0.289	0.451
60	-0.340	0.371	0.239	0.536
70	-0.601	0.087	0.601	0.087
80	-0.769	0.015**	0.757	0.018**
90	-0.295	0.442	0.297	0.437
100	-0.425	0.254	0.422	0.258
110	-0.186	0.631	0.139	0.722
120	-0.246	0.523	0.598	0.089

As also seen from Table 3, the correlation between KVp and absorbed dose is positive at all KVps. In the case also, the correlation is strong at 70KVp but non-significant (r = 0.601; P = 0. 087) but strong and significant at 80KVp (r = 0. 757; P = 0. 018).

The transmission efficiency of the lead apron showed non-significant but strong and positive correlation with the KVp at 70, 80, 90 and 120KVps and strong non-significant negative correlation at 100KVp (Table 5).

Table 4.Relationship between KVp and the transmission efficiency of the lead aprons

Aprons /KVp	50	60	70	80	90	100	110	120
A = 0 .35mmPb								
Incidence	4.826	6.841	7.214	7.364	7.360	7.381	7.401	7.298
Transmitted	0.049	0.277	0.662	3.268	5.034	6. 384	6.841	7.152
% Efficiency	1.11	4.05	9.18	44.40	68.40	86.49	92.43	98.000
B = 0 .35mmPb								
Incidence	4.847	6.799	7.318	7.381	7.339	7.318	7.339	7.235
Transmitted	0.000	0.064	0.558	3.060	4.639	6.820	6.861	7.048
% Efficiency	0.00	0.94	7.63	41.46	63.00	93.19	93.49	97.420
C = 0 .25mmPb								
Incidence	4.447	6.657	7.298	7.337	7.422	7.553	7.443	7.526
Transmitted	0.028	0.610	1.057	3.767	5.553	6.555	6.684	7.381
% Efficiency	0.63	9.16	14.480	51.34	74.82	86.79	89.80	98.07
D = 0 .35mmPb								
Incidence	4.514	7.048	7.214	7.422	7.464	7.360	7.339	7.318
Transmitted	0.007	0.197	0.371	0.423	1.267	5.217	6.446	6.529
% Efficiency	0.16	3.80	5.14	5.70	16.98	70.88	87.83	89.22
E = 0 .35mmPb								
Incidence	4.847	6.820	7.381	7.422	7.401	7.464	7.360	7.339
Transmitted	0.122	0.703	0.952	1.004	4.619	5.304	6.571	6.903
% Efficiency	2.52	10.31	12.90	13.53	62.41	71.06	89.28	94.06
F = 0 .35mmPb								
Incidence	5.574	6.944	7.339	7.443	7.382	7.464	7.298	7.298
Transmitted	0.007	0.059	0.308	0.438	1.090	3.321	4.176	5.304
% Efficiency	0.13	0.85	4.20	5.89	14.77	44.49	57.22	72.68
G = 0 .35mmPb								
Incidence	4.921	6.799	7.069	7.422	7.443	7.381	7.256	7.339
Transmitted	0.024	0.106	0.402	0.719	4.722	5.802	6.882	7.173
% Efficiency	0.49	1.56	5.69	9.69	63.44	78.61	94.82	97.74
H = 0 .35mmPb								
Incidence	5.304	6.820	7.298	7.318	7.381	7.401	7.251	7.214
Transmitted	0.001	0.132	0.305	0.633	3.974	5.304	6.550	6.799
% Efficiency	0.19	1.94	4.18	8.65	53.84	71.67	90.33	94.25
I = 0 .35mmPb								
Incidence	4.535	6.716	7.256	7.360	7.381	7.401	7.339	7.235
Transmitted	0.005	0.056	0.208	0.845	3.393	5.947	6.674	6.924
% Efficiency	0.11	0.83	2.87	11.48	45.97	80.35	90.94	95.70

Table 4 shows that only aprons F, H and I can afford to protect the wearer for KVps of 50-70 while aprons C and E are effective for 50KVp energy only. Aprons A, B and G are efficient for 50-60KVp.

Table 5. Correlation between transmission efficiency of the lead aprons and Kvp

Kvp	Correlation coefficient, **r**	P-value
50	-0.376	0.754
60	0.103	0.578
70	0.738	0.472
80	0.684	0.521
90	0.552	0.628
100	0.039	0.975
110	-0.693	0.935
120	0.616	0.512

On radiography some of the aprons were seen to have defects such as tears, cracks and holes which could not be detected by visual inspection or palpation (Figs 1, 3a & b). Fig. 2 shows normal apron.

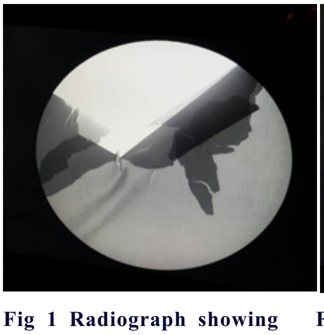


Fig 1 Radiograph showing Cracks on lead aprons

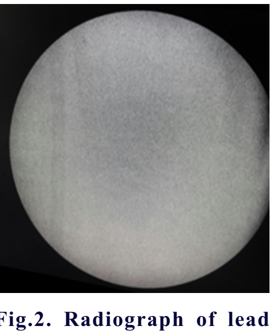
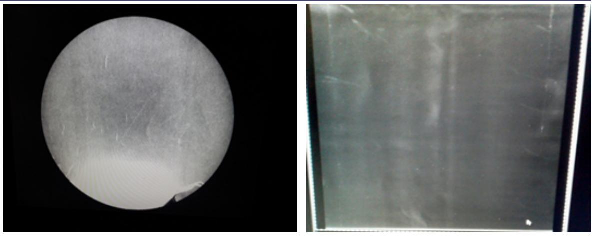


Fig.2. Radiograph of lead apron without defect



a **b**

Fig. 3a &b. Radiographs showing holes on lead aprons

DISCUSSION

A very important aspect of the responsibility of a radiographer in the discharge of his/her duty in the care of the patient is the radiation protection of the patient, public and self. Among the methods of achieving effective radiation protection is the use of distance, time and shielding. One of the methods of providing shielding is the use of lead aprons. For effective protection, the lead aprons in use have to be integrally normal and properly applied. For the lead aprons to maintain their integrity and perform their protective functions well, they have to be taken proper care of. The detection of the integrity of the lead apron can only be made through proper routine quality assurance tests. The result from our study showed that up to 55.6 % of the lead aprons studied were defective which is similar to the result obtained by Oyar and Kislaliglu (2012) , where 68.2%) were defective. Like our findings, cracks were the major defect accounting for 60% of the defects. The presence of cracks is a pointer to careless handling of the lead aprons and should be of concern especially when the study centre is one of the tertiary hospitals in the country with referrals from different places and therefore expected to be the centre of excellence in radiation protection practices.

Our study also revealed that visual inspection and physical palpation are not effective methods of assessing the integrity of lead aprons. In this study, visual inspection and physical palpation gave a false positive ratio of 77.78% which the use of radiation showed to be wrong. The presence of cracks and holes may explain the high transmission of radiation obtained in this study. This is contrary to the result obtained by Christodoulou *et al* (2003) which showed that transmission of radiation (including backscatter) through pure lead is less than through lead equivalent aprons at 70-100kVp. Our study showed that only aprons F, H and I can afford to protect the wearer for KVps of 50-70 while aprons C and E are effective for 50KVp energy only. Aprons A, B and G are efficient for 50-60KVp. Looking at that results it will be observed the more aprons are of the Mediphot make, model 4447001082. This finding agrees with the work of Hiroshige et al (2013) that the X-ray transmission rates of protective aprons differ among manufacturers, despite having the same lead-equivalent thicknesses. This study also noted that lead apron C with lead equivalent of 0.25mmPb was efficient for 50KVp even though it is of the Mediphot make, model 4447001082, thus also agreeing with Hiroshige et al (2013) that the effectiveness of lead apron depends on the thickness of the lead apron and the energy of the x-ray beam used. Apron E is of the Ward ray Promise model with lead equivalent of 0.35mmPb but was only effective for 50KVp x-ray energy unlike other Ward ray promise 0.35mmPb aprons which are effective for 50-60KVp energy. Possible the apron E could be the one with very large tear /crack (fig. 1). It was also discovered through observation during our study that the aprons were all dirty and rumpled with "lack of care written on their faces" Lack of proper was therefore the major cause of defect on the aprons. It will be noted that except for the investigation of the extremities, majority of radiological procedures are carried out using 80KVp and above. The implication from our study is that even when staff or carers helping during such examinations are wearing the lead aprons, they are not being protected. Another point emerging from this study is that radiology centre should put into consideration the KVps when making purchase of lead protective aprons. This is important because in our study, both visual inspection/palpation and qualitative assessment by the use of x-rays showed that 4 of the aprons to be in good order, that is to say that they have structural integrity. With their structure intact, if they were really good, they would have had protection for KVps higher than 70KVp.

CONCLUSION:

We evaluated the protective efficiency of 9 protective lead aprons being used in a radiology department of a tertiary health institution in

Nigeria using physical inspection and radiological evaluation. Our results showed that 4 of the 9 lead aprons were judged to be structurally intact. Only 3 can give protection against scatter radiations for x-rays generated at 50-70KVp and none could protect the wearer against scatter from x-rays generated above 70KVp. The major defects observed were tear/cracks and holes which are indicative of improper care of the aprons. Attention should be paid to the purchase of the right apron suitable for the KVps in use. This is because none of the aprons used in the radiology unit of the hospital offer protection when KVPs above 70 is used for a radiology investigation. Regular and proper quality assurance is important in the department and other radiology units. The first step towards this is to ensure that the lead aprons are tested for radiation protection efficiency before purchase. This will ensure that the right aprons are purchased according to the KVps being in used in the department.

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CONFLICT OT INTEREST
Author declare no conflict of interest in the work.

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