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Conformity Assessment of Lead Aprons Used in Conventional Radiology: A Multi-Centre Survey in Togo

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Abstract

Aim: Lead aprons are used to protect against scattered radiation from the patient during interventional procedures and certain special conventional radiological examinations. Given the importance of the role lead aprons are supposed to play in radiation protection, we propose to assess their conformity in medical imaging departments in public and religious hospitals in Togo. **Materials and method:** A multi-centre survey conducted from 26 November to 06 December 2021 in the radiology departments of public and religious health facilities in Togo. All aprons in use were included. The evaluation criteria were physical (visual), quantitative (radiographic) and qualitative (dosimetric). **Results:** We had registred 43 aprons among wich 27 (62.79%) leaded aprons were labelled non-compliant and 16 (37.21%) were labelled compliant. Of the aprons judged to be non-compliant, 70.37% were more than 10 years old and 96.30% showed defects on the radiographic images. The most common defects were vampire marks (18.64%), multiple folds (16.96%), cracks (16.96%), multiple cracks (15.25%), tears (8.47%), absence of lead (5.08%), holes (3.39%) and lead corrosion (1.69%). Defective aprons (62.96%) had at least two defects. The defects were of thoraco-abdomino-pelvic (74.07%), thoracic (14.82%) and abdomino-pelvic (11.11%) topography. For indirect exposure at 50 and 70 kilovolts, all the aprons had an attenuation factor greater than 90%. After dosimetric measurement, 13.95% of aprons had attenuation factors below 90% for indirect exposure at 100 kilovolts. **Conclusion:** The compliance of the leaded decks is trifactorial (physical, radiographic and dosimetric). However, there is no significant difference in X-ray attenuation capacity between defective and normal decks.

Keywords

Lead Apron, Compliance, Radiation Protection, Radiology, Togo

1. Introduction

Ionizing radiation is widely used in medical practice for both diagnostic and therapeutic perposes. However, they are not devoid of adverse health effects on exposed operators [1]. Thas's why lead aprons are used to protect against scattered radiation from the patient during interventional procedures and certain special conventional radiological examinations. They are supposed to reduce the radiation dose received by around 90% (85% - 99%), depending on the energy of the scattered X-rays and the thickness of the lead equivalent [2]. They represent a genuine means of individual protection against ionising radiation. During use, lead aprons can deteriorate and no longer provide adequate protection. They can develop defects if they are used over a long period of time, especially when their lifespan has been exceeded [3]. If left unchecked, defective lead aprons can, over time, contribute significantly to the increase in dose received by the wearer. A routine annual check is therefore recommended to assess the conformity of leaded aprons [4]. Studies carried out in Nigeria and Turkey have shown that some aprons may develop defects during use, rendering them non-compliant and potentially exposing staff to radiation [5] [6].

In Togo, no study of the reliability of leaded aprons has been carried out. The aim of this study was to assess the compliance of aprons used in medical imaging departments in public and religious hospitals in Togo.

2. Materials and Methods

This was a multi-centre survey from 26 November to 06 December 2021, in the radiology departments of public and religious health facilities in Togo. It consisted of a quantitative and qualitative analysis of all labelled lead aprons in use.

The equipment used was a conventional X-ray table (with a 140 kVp generator equipped with an electronic control panel for the precision of the technical parameters and an image development chain), a 35 cm × 43 cm cassette containing a film for X-raying the aprons, a white wooden frame measuring 40 cm × 40 cm × 25 cm with a support surface for the electronic dosimeter, a POLIMASTER type PM1610 electronic dosimeter (S/N 134793), a 5-litre container filled with water to simulate a phantom, a COCHIN coxometer-type graduated ruler, a metal film marking letter, a negatoscope for reading the X-ray films and a marker pen.

We noted how the lead aprons were stored, as well as their state of cleanliness and physical defects. We then noted their thickness in lead equivalents, the model, the length of time they had been in use or the date they were put into service, the number of personnel using the apron and the frequency of use. An identifying number was then assigned to each deck.

The quantitative assessment consisted of making radiographic images of the apron on the radiology table by placing a cassette directly under the apron, with a focal spot-to-film distance of exactly 100 cm and a beam collimation of 35 cm × 43 cm. The exposure parameters were 60 kV and 50 mAs, modified as necessary according to the nature of the development bath in the radiology department concerned. Two regions were generally radiographed (thoracic and abdomino-pelvic), supplemented if necessary by radiographs focusing on other areas where there was a strong suspicion of defects. **Figure 1** shows the lead apron radiography technique.

The resulting films are examined through a light box for defects of various kinds.

We then carried out a dosimetric assessment, subjecting the aprons to a dosimetric test to calculate their attenuation factor. We measured the dose from direct exposure and the dose from indirect exposure (scattered radiation). In the direct exposure method, we fixed the tube at 100 cm with a collimation of 20 cm × 20 cm, with the electronic dosimeter placed at the centre of the beam. With the load set at 100 mAs, we measured exposures at 50 kV, 70 kV and 100 kV. Then, without modifying the existing system, we placed the apron on the wooden support, which was itself positioned so that the beam was at its centre with the dosimeter. The same measurements were taken with the different exposures. **Figure 2** illustrates the dose measurement techniques used to calculate the attenuation factor for the lead apron with direct exposure.

In the measurement method with indirect exposures, with the focus-film distance and beam collimation fixed, the filled 5-litre drum was placed on the table and centred in the beam. The wooden support was placed laterally so that there was a distance of 30 cm between the centre of the beam and the line joining the two lower corners of the wooden support. The apron was placed on the support and the dosimeter placed in the middle of the small board in the median axis of the beam. **Figure 3** illustrates the dose measurement techniques used to calculate the attenuation factor for the lead apron with indirect exposure.

The measurements were made using the same exposure parameters with and without the leaded apron. The various measurements thus obtained enabled us to calculate the attenuation factor of the deck at each kilovoltage according to the formula below [7]:

$$\text{Attenuationfactor} = 1 - \left(\frac{\text{Dose with apron}}{\text{Dose without apron}}\right) \times 100$$

We have therefore established as non-compliance criteria any apron that:

- physically showed tears, loose stitching and a faulty restraint system.
- had at least one defect in the internal structure of the deck.

Figure 1. X-ray technique for leaded deck.

Figure 2. Dose measurement techniques for calculating the lead apron attenuation factor: direct exposure.

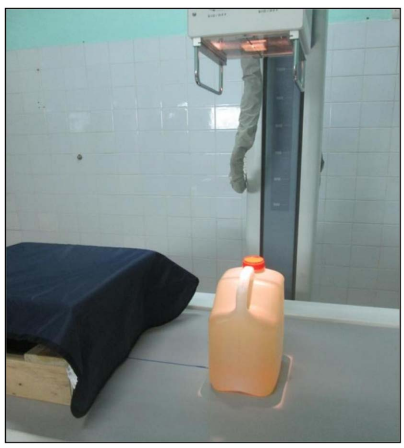

Figure 3. Dose measurement techniques for calculating the lead apron attenuation factor: Indirect exposure (scattered x-rays).

- after the dosimetric measurement had an attenuation factor for indirect exposure of less than 90%.

Statistical analysis was carried out using SSPS (*Statistical Package for the Social Sciences*) software under Windows, version 16.0.

All tests were performed at a 5% significance level.

3. Results

This study recorded 43 leaded aprons, of which 90.70% were of the demi-chasuble type, 4.65% of the chasuble type and 4.65% of the jacket type. Leaded aprons 0.5 mm Eq Pb thick accounted for 51.16% (n = 22), those 0.35 mm Eq Pb thick for 25.58% (n = 11) and those 0.25 mm Eq Pb thick for 23.26% (n = 10). Of all the aprons in our sample, 34.88% (n = 15) lasted less than 5 years, 16.28% (n = 7) between 5 and 10 years, and 48.84% (n = 21) more than 10 years. Lead aprons intended for mixed use, *i.e.* used by radiology department staff and patients, accounted for 79.07% (n = 34), those used solely by staff accounted for 13.95% (n = 6) and those intended solely for patients accounted for 6.98% (n = 3). Lead aprons were arranged randomly in 46.51% (n = 20) of cases, folded in 16.28% (n = 7) of cases and spread out in 4.65% (n = 2) of cases. They were placed on suitable supports and hangers in 32.56% (n = 14) of cases. In 83.72% (n = 36) of cases, the lead aprons were normal, while 16.28% (n = 7) showed physical defects. Analysis of the X-ray images of the leaded aprons showed that 37.21% (n = 16) of the aprons were normal with no defects in their internal structure and 62.79% (n = 27) were defective or abnormal with defects in their internal structure. Considering the radiographically defective aprons, the topography of the defects was either thoracic (14.82%, n = 4), abdomino-pelvic (11.11%, n = 3) or thoraco-abdominopelvic (74.07%, n = 20). Defects were fissures (32.21%), vampire marks (18.64%) and folds (16.96%). Figure 4 shows a 0.50mm lead equivalent chasuble apron with multiple creases associated with cracks and tears.

The dosimetric analysis revealed that, at 50 kV, all the lead aprons had attenuation factors greater than 95%. At 70 kV, all leaded aprons had attenuation factors greater than 90%. We noted that 83.72% (n = 36) had attenuation factors greater than 95% and 6.98% (n = 3) had an attenuation factor between 90 and 95%. At 100 KV, 13.95% (n = 6) had attenuation factors below 90%, including 2.33% (n = 1) with an attenuation factor below 80%. It was noted that 86.05% (n = 37) of leaded aprons had attenuation factors greater than 90%, of which 37.21% (n = 16) had attenuation factors between 90 and 95% and 48.83% (n = 21) had attenuation factors greater than 95%. Based on the various physical, radiographic and dosimetric rejection criteria, 27 (62.79%) of the lead aprons were non-compliant and 16 (37.21%) were compliant. Table 1 shows the distribution of non-compliant lead aprons according to the different types of rejection criteria.

Table 2 and Table 3 show, respectively, the distribution of defective leaded aprons according to the length of use in years and the distribution of non-compliant leaded aprons according to their state of storage.

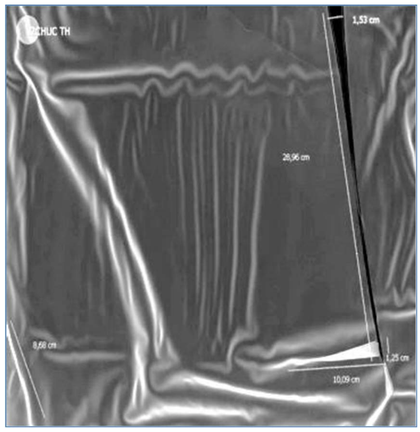

Figure 4. Chasuble apron with 0.50 mm lead equivalent: multiple folds associated with cracks and tears.

Table 1. Distribution of non-compliant leaded aprons according to the different types of rejection criteria.

	0.25 mm Eq Pb		0.35 mm EqPb		0.50 mm Eq Pb		Total	
	n	%	n	%	N	%	n	%
Rx*	6	22.22	4	14.81	10	37.04	20	74.08
Rx + dosimetry	1	3.70	2	7.41	1	3.70	4	14.81
Phys** + Rx + dosimetry	1	3.70	1	3.70	-	-	2	7.41
Phys** + dosimetry	-	-	1	3.70	-	-	1	3.70
Total	**8**	**29.63**	**8**	**29.63**	**11**	**40.74**	**27**	**100.00**

*: radiographic; **: physical.

Table 2. Distribution of defective lead aprons by length of use (in years).

	Effective	Non-compliant	Proportion (%)
]1 - 5]	15	2	7.41
]5 - 10]	7	7	25.93
]10 - 15]	6	4	14.81
]15 - 20]	9	8	29.63
]20 or more [	6	6	22.22
Total	**43**	**27**	**100.00**

Table 3. Distribution of non-compliant leaded aprons by state of storage.

	Effective	Non-compliant	Proportion (%)
Randomly arranged	20	16	59.25
Placed on a suitable surface	14	6	22.21
Folded	7	4	14.84
Spread	2	1	3.70
Total	**43**	**27**	**100.00**

4. Discussion

Our study involved 43 leaded aprons. This sample is representative in view of the samples from similar studies. The study by Ukpong *et al.* [5] involved 22 leaded aprons. The study by Ryu Sung *et al.* [8] involved 71 leaded aprons and 27 thyroid protectors. In Turkey, the study by Oyar *et al.* [6] involved 85 leaded aprons.

Of the decks, 76.74% with a lead equivalent thickness of at least 0.35mm complied with standards NF C 74-100 and C EI61-331-3. Lead-coated aprons and gloves must be at least 0.35mm thick in lead equivalent [9].

Almost half of the leaded aprons (48.84%) in our series had been in use for more than 10 years. The recommended lifespan for leaded aprons is 10 years [10]. In studies by Oyar O *et al.* in Turkey [6] and Ryu Sung J *et al.* in South Korea [8], leaded aprons were used for less than 6 years. On the other hand, Ukpong E. V. *et al.* [5] found in their series aprons that had been in use for more than 40 years. This shows that recommendations NF C 74-100 and C EI61-331-3 are not respected in Africa.

In our series, 16.28% of aprons had physical defects. All the leaded aprons (100%) in the sample from Ryu Sung's study [8] were not defective. This result found in his series would be due to the fact that all the leaded aprons had been in use for less than 6 years.

The study by Oyar *et al.* [6] found 52.90% of decks to be normal, 30.60% worn and 16.50% very worn. Defects in leaded aprons could be linked to a lack of maintenance.

In our series, 53.48% of aprons were dirty. This result is similar to that of d'Oyar *et al.* [6] who found 50.60% of dirty aprons and 23.20% of very dirty aprons [6].

Radiographic analysis, based on a simple reading of the X-ray images, showed that 62.79% of the aprons in our study had defects. These defects were of thoraco-abdominopelvic topography in 74.07% of cases. In the work by Ryu Sung *et al.* [8], defects on the apron were predominantly of medial (51%), low (25%) and thoracic (16%) topography. According to this work [8], the preponderance of defects at waist level is due to the fact that the aprons were used much more in a sitting or walking position, which would lead to much greater mechanical stress on the medial part of the apron, responsible for the formation of defects.

In our study, defects are dominated by cracks (32.21%). This result is similar to that of Ukpong *et al.* [5] and Oyar [6]. On the other hand, in the study by Ryu Sung *et al.* [8], defects were dominated by holes (36%) and cracks (28%).

In the work of Ukpong *et al.* [5], 53% of defects were observed on aprons with between one and five years' service life. Their study also noted that defects existed in aprons between 1 and 20 years old. This study also showed that the defects were linked to the poor quality of the aprons. According to the work of Glaze *et al.* [11], defects can be found on both new decks and those less than five years old. The same observation was made by Ryu Sung *et al.* [8], who found in their work that 42.30% of aprons with 6 years' service life, 8.70% of aprons with 3 years' service life and 12.30% of aprons with 2 years' service life were defective.

In our study, the dosimetric analysis noted that all the aprons were compliant at 50 kV and 70 kV with attenuation factors greater than 90%. At 100 kV, 86% of decks were compliant, with attenuation factors greater than 90%. This means that, despite the presence of defects, the decks retained their attenuation capacity. Oyar *et al.* [6], noted that there was no significant difference in terms of x-ray attenuation between defective leaded decks and normal leaded decks.

5. Conclusion

Lead aprons are a real means of individual protection against ionising radiation during radiological examinations. This study has shown us that if these aprons are of poor quality or used for too long, they can deteriorate and no longer comply with the recommended standards. The compliance of the leaded decks is trifactorial (physical, radiographic and dosimetric). However, there is no significant difference in X-ray attenuation capacity between defective and normal decks. It is therefore essential, in order to comply with the rules of radiation protection, especially for individuals, to analyse these aprons regularly to detect those that are defective and exclude them from use. It is also important to avoid buying poor quality aprons and using them for too long.

Authors' Contribution

All the authors contributed to this work and read and approved the final version of the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest and have received no funding.

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