Quality Assurance
of X-Ray Protection Clothing at the University Hospital Basel

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Introduction

It is required that for each X-ray unit there are enough X-ray protection clothing and patient covers available and they must be employed sensibly [1] (Note: for what follow we will subsume the patient covers under the term clothing). The protection effect depends on the lead equivalence of the material and the energy of the radiation. It also depends strongly on the condition of the material involved. To evaluate the safety of protective clothing we have been performing regular and standardized quality checks at the University Hospital Basel since 2003. The results demonstrate that about 20% of all tested clothing show defects of the protective layers. The total number of pieces of protective clothing checked has grown from about 200 in 2002 to more than 400 as of today. All protective clothing is prone to such defects irrespective of age and type of material used.

Material and Methods

We set up a two-stage method by defining two distinctly different methods for testing the material, which are performed consecutively:

1. combining visual inspection and palpation
2. using a fluoroscopy unit

According to our judgment as critical positions we established well defined spots for testing on the different pieces of clothing (like e.g. vests, skirts, surgical aprons, patient covers). These spots are emphasized as crosshairs and numbered yellow circles in Figure 1. Additionally the seams are considered as mandatory test points. By clearly defining the test positions on the clothing the development of an incipient defect can be traced from one to the next testing cycle.

Figure 1: Types of X-Ray protective clothing and locations of mandatory testing spots

Visual inspection and palpation

Figure 2: Testing X-Ray protection clothing by visual inspection and palpation

The considered piece of protective clothing is spread out on a flat surface and is checked visually for defects. It is then also examined for breaks, tears and discontinuities by palpating with the hands. This way defects not directly visible from the outside can be detected "manually". The questionable positions are marked as suspicious spots for further verification.

Test using a fluoroscopy unit

Figure 3: Testing X-Ray protection clothing using a fluoroscopy unit

The suspicious locations and the predefined testing spots are X-rayed under fluoroscopy. If fluoroscopy shows locations of increased transparency or even holes and tears, the defects are captured with an X-ray, the locations are clearly marked on the outer fabric cover of the tested object and the results are archived.

The following parameters are suggested for the test procedure:

- use remote controllable fluoroscopy unit
- don't use automatic dose rate control
- do not exceed 70 kV
- use maximum focus-film or focus-detector distance
- select large focus
- recommended field size is 20 cm x 20 cm
- center points of interest with light field (if available)
- use short fluoroscopy time (e.g. not more than 0.3 min), only exception: tracking seams

Classification of defects

The defects are classified according to the following scheme with reference to their potential consequences and they require the stated action:

Insignificant (I)	- defect does not significantly harm protection - small defects on outer fabric cover - defect on protective layer at one irrelevant location - action: "keep an eye on it"
Tolerable and under Observation (T)	- defects could evolve into severe problem - mayor defects on outer fabric cover - defects on protective layers at several irrelevant locations - action: perform 2nd check the same year
Severe (S)	- protection no longer ensured - destruction of outer fabric cover - mayor defects on protective layers at relevant locations - action: withdraw immediately or get it repaired

As the case may be the object under consideration is observed (I), inspected a 2nd time the same year (T) or withdrawn from use right away (S).

Results

Since the year 2003 we have been performing regular quality checks at the University Hospital Basel on our X-Ray protection clothing. Figure 4 gives an overview of the number of different types of equipment in existence starting in the year 2006 until 2009.

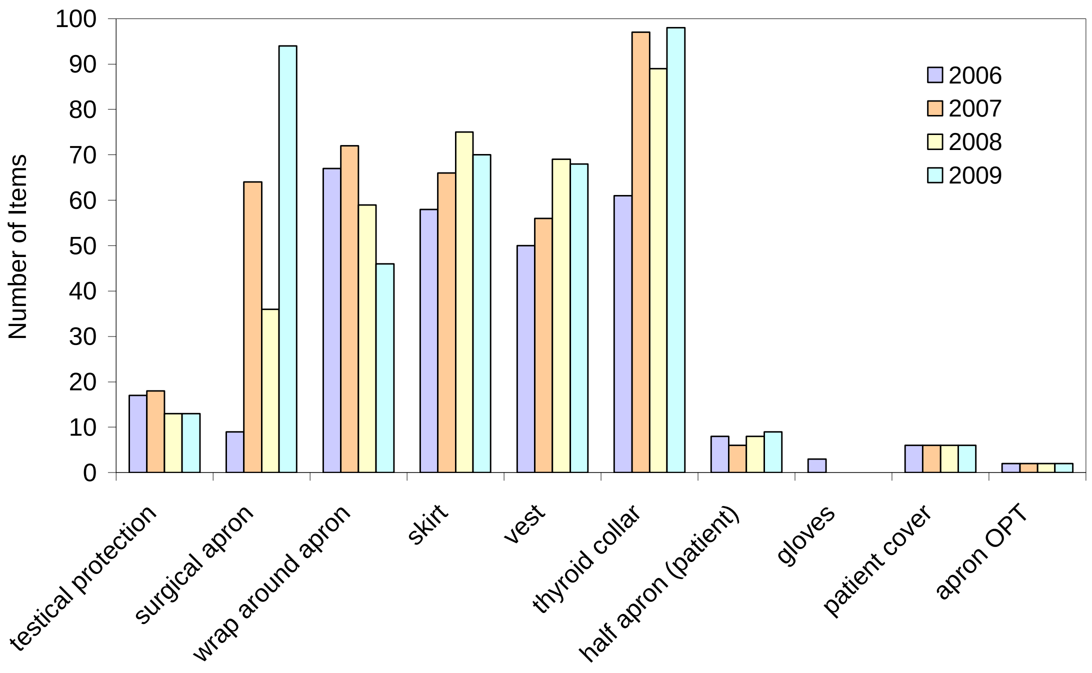


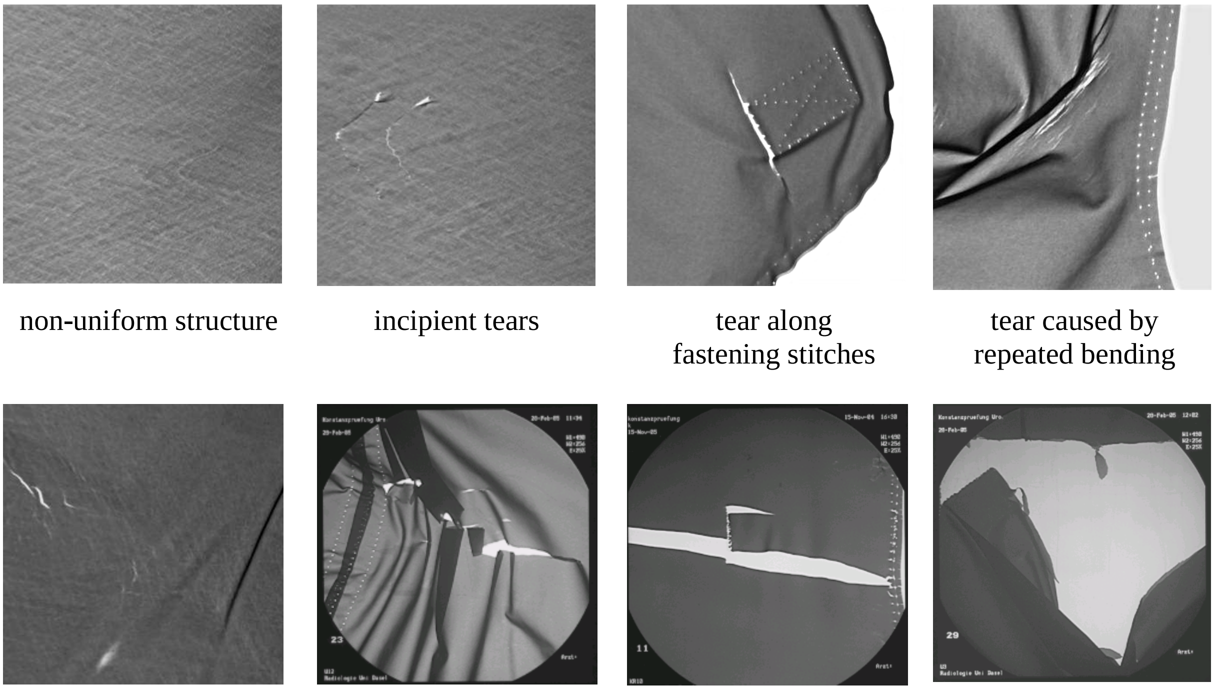
Figure 4: The different types of X-Ray protection clothing at the University Hospital Basel and their number in use for the years 2006 through 2009

The tendency towards larger numbers of tested equipment is shown in Table 1 together with the absolute and relative numbers of detected defects. According to our results about 20% of the tested items (401 in total for the year 2009) show defects (from insignificant to severe), where wrap around aprons, skirts and vests are affected most.

Year	Number of checked protective items	Number of defective items	Number of defective items [%]
2006	281	81	28.8%
2007	387	90	23.3%
2008	357	84	23.5%
2009	401	74	18.5%

Table 1: Total number and number of detected defects for the X-Ray protection clothing at the University Hospital Basel

As mentioned before we detected a wide variety of defects from virtually undetectable and correspondingly insignificant to really "horrific", where the protection has gone completely. In Figure 5 we give a "picture gallery" of what we have seen.



non-uniform structure | incipient tears | tear along fastening stitches | tear caused by repeated bending

stretched material starts tearing | repeated folding causes tears | crack | hole

Figure 5: The "picture gallery" of defects on the X-Ray protection clothing at the University Hospital Basel

In the last couple of years not only the design and the types of protection clothing have changed but also the materials used. The weight of the clothing with clearly relates to the wearing comfort and the disposal problem for the lead material both gave clear reasons to move toward lead-free material. Consequently basically two types of material are in regular use in our hospital: lead-vinyl and Xenolite® (lead-free material, originally developed by DuPont) [2]. We therefore tried to compare the relative appearance of defects for the two types of material. The items made from Xenolite have been reduced in number by approximately one third over the last years and the remaining Xenolite items now show more than 50% defects. The corresponding number for lead-vinyl is less than 20%. The visual inspections show an increasing number of defects over the inspection period. We also find increasing numbers of defects that can be detected only under fluoroscopy. In some cases we could clearly follow the development of defects in the course of time, i.e. the affected regions became thinner and thinner at the observed regions and tears showed in exactly these locations.

Protective material	2006			2007			2008			2009		
	All	Def.	%	All	Def.	%	All	Def.	%	All	Def.	%
Lead	204	47	23.0	292	61	20.9	312	60	19.2	353	50	14.2
Xenolite	60	18	30.0	51	24	47.1	39	21	53.8	44	24	54.5
unknown	17	16	94.1	44	5	11.4	6	3	50.0	4	-	-
Total	281	81	28.8	387	90	23.3	357	84	23.5	401	74	18.5

Table 2: Number of detected defects for different materials used in X-Ray protection clothing at the University Hospital Basel for the years 2006 through 2009
All = Number of checked protective items
Def. = Number of defective items
% = relative Number of defective items [%]

Discussion

The result of around 20% defects for all X-ray protective items clearly show the necessity for regular quality checks. Although all departments using protective gear are affected, those departments where the equipment is in regular use (angiography, cardiology, urology and surgical disciplines) detect the most defects. Vests, skirts and wrap around aprons are in quite widespread and frequent use and correspondingly show the heaviest wear and tear problems. The number of visual damages to the equipment has increased over the inspection period. The number of defects classified as "Tolerable and under Observation" (T) and/or "Severe" (S) has slightly decreased but we see an increase in the group of problems classified as "Insignificant" (I).

The seams definitely have to be watched very carefully, they often seem to be the origin for tears. The seams appear to be weak points from start since they might coincide with zones of reduced or no protective material and the production process itself might already weaken the pieces of equipment in exactly these locations. It is particularly noteworthy that already relatively new items show regions of increased transparency and irregular thickness.

It is also noticeable that locations with increased radiation transparency more frequently show for the Xenolite material. But we want to emphasize that a statement about the toughness of the protective items comparing lead-free versus lead containing material might be premature. Firstly the number of lead-free objects has been reduced over the last couple of years and secondly the lead-free option has mainly been selected because of its reduced weight at comparable protection level in those departments where frequent and heavy use is standard. Our experience therefore indicates a typical lifetime of two to three years for the lead-free items as compared to a range of five to ten years for lead objects. Irrespective of the protective material used one of the main reasons for the development of defects is the careless handling of the objects what leads to demonstrable tears and breaks.

It can be assumed that the results are not specific for the Basel hospital and a comparison with corresponding results form other hospitals would be desirable. Nevertheless we will continue to perform the necessary quality checks on our x-ray protection clothing at the University Hospital Basel to give proper emphasis to this particular aspect of radiation protection for the patient and the personnel. We think the methods used definitely are a useful tool to detect problems early on and withdraw and replace the protective equipment timely if indicated.

References

[1] Bundesamt für Gesundheit: Schutzmittel für Patienten, Personal und Dritte in der Röntgendiagnostik, Merkblatt R-09-02 vom 29.1.2003

[2] Finnerty M, Brennan PC. Protective aprons in imaging departments: manufacturer stated lead equivalence values require validation. EUR Radiol 2005; 15: 1477-1484